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Comparison of Eight Remnant Tamaulipan Biotic Province Plant Communities in the Lower Rio Grande Valley Using Multivariate Analyses [Comparación de Ocho Comunidades Vegetales Remanentes de la Provincia Biótica Tamaulipeca el Valle del Río Grande Usando Análisis Multivariada]

Raziel I. Flores
The University of Texas Rio Grande Valley

COMPARISON OF EIGHT REMNANT TAMAULIPAN BIOTIC PROVINCE PLANT COMMUNITIES IN THE LOWER RÍO GRANDE VALLEY USING MULTIVARIATE ANALYSIS

A Thesis

by

RAZIEL I. FLORES

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COMMITTEE MEMBERS

Dr. Andrew McDonald
Chair of Committee

Dr. Timothy Brush
Committee Member

Dr. Alejandro Fierro Cabo
Committee Member

Dr. Christopher Gabler
Committee Member

August 2019

ABSTRACT

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The Tamaulipan Biotic Province falls within a biogeographic ecotone between temperate North America, the neotropics and the Chihuahuan Desert, and has consequently been defined as "Tamaulipan brushlands." No quantitative, comparative study has ever been undertaken on the many and varied plant communities that occur in the region. This study compares eight remnant, primary plant communities to test the null hypothesis that they comprise a single definable vegetation type. Four 50 x 10 m belt-transects were established at each site and woody plants taller than 1 m were recorded to determine species frequency, density, stratification and dominance. Community diversity was calculated using Shannon-Weiner and Simpson indexes. Permutational multiple analysis of variance (PerMANOVA) and Nonmetric Multidimensional Scaling (NMS) examined the relationship between plant community composition and compared their degrees of similarity. Results indicate all eight sites maintain distinct plant communities.

DEDICATION

This thesis is dedicated to all my friends and family, which are too numerous to mention but all appreciated nonetheless. A special dedication to my parents Jose and Rosalinda for their unconditional love and support. And to the plants and living world for their infinite awe-inspiring capabilities that keep us occupied with something to study.

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CHAPTER I

INTRODUCTION

South Texas is widely acclaimed for its productive agricultural lands and, in more recent years, for its hastening urban development along an international border. Biodiversity in the region has also been gaining attention in recent years, as is reflected by the number of environmentally oriented publications from 1988-2014, totaling 388 (Leslie, 2016). These publications focus solely on the southernmost counties of Texas (Cameron, Hidalgo, Starr, and Willacy), referred to collectively as the Lower Río Grande Valley (LRGV), where the regional biota reaches a pinnacle in biological diversity.

South Texas occupies a climatic transition zone between temperate North America, the Chihuahuan Desert, and neotropics (Lonard and Judd, 1993). This transition, along with variation in soil formation and water availability, supports the convergence of more than 1200 plant species to comprise a biogeographic province that is restricted to South Texas and northeast México (Saghatelyan, 2017). Yet the thorny, uninviting character of vegetation and the scanty scientific scrutiny afforded the region in the recent past limit our broader ecological perspectives on the zone. Regional maps usually lump all of South Texas into a singular vegetation type, often stopping at political boundaries on account of poor baseline ecological information.

Detailed ecological studies are needed to better understand the biological history and conservation options for the future in the context of rapid ecological transformations that have occurred since European colonization and subsequent socio-economic developments. It is estimated that about 300 new introductions of exotic plants species have become established in Texas in a thirty-year period following 1970 (Turner, 2003), with anticipation of new introductions that will no doubt continue to alter the native flora. Without a proper understanding of their impacts on naturally occurring biotic communities that are now highly disturbed and/or in threat of extirpation, social and economic decisions that will impact the welfare of human societies and the future of native biotas will be made on the basis of imprecise guesswork. This investigation intends to improve our basic understanding of plant community diversity in the LRGV to serve the interests of both biologists and land use planners in both urban and rural settings.

Area of interest

This research focuses on the plant communities in the southern tip of Texas known as the Lower Río Grande Valley (LRGV). This area represents a minor portion of the South Texas and northeastern México vegetative area but serves as a relevant model to better understand the biogeography of a transition zone between temperate, desert, and tropical biotas of North America.

Although the region’s geographical and plant community diversity is poorly documented and inconsistently described, the biogeographical limits of South Texas as a whole have been consistently recognized and referenced. On a continental scale, Dice (1943) employs the concept of “biotic provinces” to divide North America into major biogeographic units. He defined a biotic province as a continuous geographic area that can be characterized by peculiarities of vegetation type, ecological climax, flora, fauna, climate, physiography, and soil. His classification of biotic provinces was mainly based on vegetation since he believed that the vegetation offers the most satisfactory basis for distinguishing major ecological communities. In this classification of North American biotic provinces, a large portion of the Mexican states of Tamaulipas and Nuevo León, in addition to the southern tip of Texas, was characterized as the "Tamaulipan Biotic Province." Blair (1950) revised and edited the Texas boundaries delineated by Dice (1943) by extending the Tamaulipan biotic province to encompass a broader region that ranges from the Balcones fault line south of San Antonio, Texas southward into the northern Mexican border states of Coahuila, Nuevo Leon, and Tamaulipas as the "Tamaulipan Biotic Province" (figure 1.1). The revised and popular classification of Texas biotic provinces by Blair (1950) continues to be referenced.

A map of Texan vegetation zones of by Gould (1963) agrees with Blair's (1950) concepts and includes more specific delineations within the United States portion of the province. In Gould's view, the area of south Texas is referred to as "South Texas plains," as it retains the northern boundary as the Balcones fault line but justifiably excludes the eastern-most areas that border the gulf coast. He re-classifies those as "Gulf Prairies and Marshes." Gould's perspective was adopted by Correll and Johnston (1970) in their seminal *Manual of the Vascular Plants of Texas*. Correll and Johnston (1970) refer to the aforementioned area as "Río Grande Plains." A more recent map of "natural regions of Texas" used by Poole, et al. (2007) employs yet another interpretation of South Texas plant communities, which uses the same northern boundary of the Balcones fault to delineate an area they refer to as "South Texas brush country." This map reference also excludes the eastern most areas that border the coast and classifies those as "gulf coast marshes and prairies." Moreover, this map isolates an area just north of the LRGV as "coastal sand plains," also known as the "eolian sand sheet." The sand sheet is situated within the climatic zone of the larger Tamaulipan Biotic Province map but is "defined by a sheet of eolian sand blown inland from the shoreline of the Gulf of Mexico during Holocene times (Poole, et al., 2007).” These distinctive soils support a vegetation type that is observably different from the rest of South Texas, although it does share many plant species in common with adjacent areas, as well as climatic features. Its borders are not clearly outlined because the effects of the inland blown sand vary considerably throughout this region.

There has been much confusion in referencing literature because of the use of political boundaries referenced interchangeably with ecological boundaries. Some maps exclude vegetation types that clearly extend into México and vice versa, despite their inherent similarities (Dice, 1943; Blair, 1950; Johnston, 1963; Jahrsdoerfer and Leslie, 1988). Obviously, ecological divisions have no bearing whatsoever on political divisions. This study will therefore refer to the area that includes South Texas and northeastern México as the Tamaulipan Biotic Province, but will also recognize the vegetative differences between plant communities among the gulf-plain prairies and eolian sand sheet.

Subdivisions of a biotic province are referred to as biotic districts and are distinguished by weaker ecological associations. An ecological association is defined as “a relatively stable assemblage of plants and animals regardless of the stage of ecological succession (Blair, 1950).” Although there was no attempt to map out the districts of the Tamaulipan Biotic Province by Blair (1950), the southernmost counties of Texas that cover the former delta region of the Río Grande watershed were described as having vegetation “more luxuriant” and believed to represent a separate biotic district from the rest of the Tamaulipan province. This area is referred to as the “Matamoran District,” named after the large regional city of Matamoros, México. No attempt was made to mark the district limits in México although it is presumed that sections of the Matamoran District would extend into the floodplain south of the Río Grande. The area known as the Matamoran district overlaps with the four southernmost counties of Texas

(Cameron, Willacy, Hidalgo, and Starr), which are also called the LRGV. Although the LRGV is also referred to as "South Texas," the reference is somewhat imprecise, insofar as the concept of South Texas can refer to the four southernmost counties of Texas or a much broader area from south of the Balcones fault to the border. For this reason, some authors recognize the distinction of the LRGV by referring to it as "Deep South Texas" (Richardson and King, 2011). All references to South Texas in this study will refer to the Tamaulipan Biotic Province excluding México.

The LRGV has been subjected to more ecological and floristic research than other sectors of the Tamaulipan Biotic Province on account of research activities of two academic institutions in the region: The University of Texas Brownsville and the University of Texas-Pan American, which were merged to form the University of Texas Río Grande Valley (UTRGV) in 2015. Additionally, the majority of state and federal wildlife tracts are located in this area along the Río Grande, where economic and national defense interests are focused.

The LRGV is not a true valley and has often been referred to as a delta and floodplain. (Jahrsdoerfer and Leslie, 1988). But only a portion of the area from the four counties encompasses the river's shrunken delta, so it is incorrect to refer to the LRGV collectively as a delta. The portion of the LRGV made up of delta is roughly all of Cameron County, the southern half of Willacy County and the southern portions of Hidalgo County that narrows before the trend westward or upriver (Hathcock et al., 2014). References to the LRGV by some investigations have been used interchangeably and imprecisely with the Río Grande delta, which sometimes refers to the entire delta or only the northern half of the delta. This has caused confusion if one is trying to determine population densities or range distributions of species and references made may have used the land vocabulary incorrectly and inconsistently. This study will use the term LRGV or Deep South Texas to denote the southernmost counties of Texas and the Río Grande delta will refer to the geographical limits of the entire delta (as defined above).

Our data was collected solely in the LRGV but with the recognition that they are relevant to the larger Tamaulipan Biotic Province, as known from scientific reports and supplemental literature. Many of the communities mapped out in this study are represented in the Tamaulipan Biotic Province outside the LRGV but some of the communities surveyed may reach their northern limits in the LRGV and are therefore not found in the northern extremes of the Tamaulipan Biotic Province.

History of land use

The first recorded descriptions of the Río Grande delta were undertaken in 1519 when a ship led by Alonso Alvarez de Pineda was exploring the Gulf of Mexico and landed near the mouth of the Río Grande. Explorations were conducted 6 leagues (approximately 29 km) along the river where 40 small Indian settlements called Rancherías were recorded (Salinas, 1990). Several follow-up expeditions were made in attempt to colonize the territory of the Río Grande delta, which would remain in its natural conditions for the next two-hundred years. Documents from these expeditions tell us little about the existing indigenous culture and landscape sustained considerable population density at around 15,000 nomadic hunters and gatherers near the mouth of the Río Grande and surrounding portions of the delta (Salinas, 1990).

A later expedition was led by José de Escandón in 1745 to scout out land for colonization, which resulted in the establishments of two townships, Camargo and Reynosa, in 1747. The earliest settlements along the Río Grande were upriver in the western parts of the LRGV and most were on the present Mexican side, where there was good livestock forage and safety from the floods. By the year 1750, Camargo had a population of 456 and Reynosa of 223.

Camargo was a flourishing settlement recording 5,272 horse and mules, 932 cattle, 27,935 [sheep and] goats and irrigation systems were under construction (Salinas, 1990; Best 2004). Ranches were established on the present-day U.S.A side, even though Reynosa and other cities were on the present-day Mexican side.

The over-grazing of livestock is known to alter plant communities by the cattle's avoidance of unpalatable species that eventually replaced the more appetizing and nutritious forbs. In this area, woody plant species are favored, many of which are armed with thorns, over grasses, which are preferred by cattle. Plant cover is also frequently diminished with over-grazing and exposes the soil to erosion (Rzedowski, 1978). The encroachment of woody plant communities in the Tamaualipan biotic province was probably slight in the 18th century but increased in the mid-1800's to the end of that century (Inglis, 1964), later experiencing an acceleration of expansion after the introduction of barbed wire in 1874. As a consequence, open rangeland was diminished and sustained less desirable pasturage on account of continuous over-grazing (Rappole et al., 1986; Best 2004). Barbed wire fencing and prolonged drought caused the sheep population to drop from 1.6 million in the 1800s (Lehman, 1967; Best, 2004) to 110,000 by 1910, indicating that native grasslands for grazing were severely depleted (Best, 2004).

Two additional factors accelerated the development of the LRGV: transportation and irrigation systems. In 1904, the railroad connected the LRGV with the Houston market and attracted developers that would transform it into a productive agricultural exporter (Brannstrom and Neuman, 2009). Irrigation systems soon followed and by 1910, there were at least 20 irrigation companies along the Río Grande in Hidalgo and Cameron counties (Knight, 2009).

The creation of several new irrigation districts during the 1920s inspired a second agricultural boom based in large part for large-scale citrus plantations (Knight, 2009).

Agricultural developments occurred mainly in the eastern and southern parts of the LRGV where the delta provides fertile soils and year-round growing opportunities (Jahrsdoerfer and Leslie, 1988; Tremblay et al., 2005). Human population increased rapidly, rising from 85,861 in 1920 to 176,452 in 1930 (Brush, 2005). In the 1930's, extensive mechanized brush control developed through phases by use of steel cables, heavy chains, large rolling choppers, root plows, and chemical growth and stimulants and poisons. The impacts proved devastating to native terrain.

In response to growing interests in agricultural and economic development, the first significant vegetation survey of the LRGV was conducted in the 1930s (Clover, 1937). Prior to this study, knowledge of the vegetation was poor and came from botanical collections, mainly from Jean Louis Berlandier, who made the first extensive biological collections in Texas (Geiser, 1948). Unique plant communities were identified in Clover (1937) and defined in part on the basis of various soil types, edaphic factors and geologic formations. This survey fulfilled an important role as the first useful characterization of the vegetation types and their distributions in the1930s. However, Clover's efforts broadly covered 7840 km^2 of land which had already been altered to a great extent.

Most of the information gathered since the 1930s has been collected to document ongoing changes in vegetation of the region. However, biologists have differing views as to what has changed since this relatively late starting point, as the fabric of life had already sustained wholesale changes on account of intensive agricultural practices over two centuries. From the mid-1930s to 1983, net loss of the native woodland cover of Cameron County was estimated at 91% with approximately 75% of the original vegetation being replaced by agriculture (Tremblay et al., 2005). Less clearance occurred in drier and hillier portions of the western LRGV where irrigation was less feasible. In these areas, ranching is the main use of land. More than 95% of the extensive brushlands and coastal grasslands and 98% of mature riparian woodlands have been negatively affected or lost due to anthropogenic causes (Leslie, 2016).

Several authors have described the conversion of South Texas grasslands into woodlands. Johnston (1963) described remnant grasslands from the Tamaulipan biota, including sites in South Texas and northeast Tamaulipas. He compares highly grazed and minimally grazed grasslands to describe how vegetation has shifted in some grassland communities. Archer et al. (1988) also documented changes in vegetation by using aerial photography from 1941, 1960, and 1983 to document the conversion of grassland to woodland in a research station near Alice, Texas. Hanselka (1980) describes how lack of combustible grass-fuel from overgrazing and rancher's suppression of fires cut off the cycle of natural wild fires which had historically kept woody vegetation in check and maintained savannahs. These and other studies provide circumstantial evidence that South Texas vegetation has been altered considerably by increasing the dominance of woody vegetation over grasslands.

The LRGV experienced a third economic boom beginning in 1942. Before WWII, small farms on tracts of 20-100 acres predominated. In the 1950's agriculture shifted to large business enterprises, ostensibly increasing demand for water control and supply. In April of 1954, Falcon Dam was the first of a series of dams to be completed for the purpose of water conservation, irrigation, power, flood control and recreation (Knight, 2009). The Anzalduas Dam and Retamal Dam were subsequently built as diversion dams to divert water for irrigation and serve as flood control agents. They were completed in 1960 and 1975, respectively (International Boundary and Water Commission, https://www.ibwc.gov/mission_operations/diversion_dams.html). There are also about 270 mi (435 km) of levees on the U.S side of the border, with about 100 mi (161 km) along the river and the remainder along inter floodways (Knight, 2009). Levee construction contributed to other existing brush eradication programs, which by the 1950's had reached levels that had wildlife managers concerned about their effects on wild game (Inglis, 1964).

Historically, the river would change its minimum flow of 1100 ft^3 (31 m^3) to 36,000 – 40,000 ft^3 (1,019 – 1,133 m^3) per second. The elevation could rapidly rise 45 ft. (14 m) above its normal levels and flooding would change the course of the river over a matter of days (Knight, 2009). Today, the Río Grande flow is modified by dams and flood control measures to a shallow, slow moving trickle of except when water is released for agriculture. These developments have also impacted the biological integrity of the region, but in ways that are often difficult to quantify and qualify.

The LRGV has steadily increased in population with population bursts occurring in later in the 20th century and the early 21st century. From the 1960s to 1980s, the population grew from about 4000,000 to nearly 700,000 people and since then has doubled to over 1,300,000 people in 2013 (Leslie, 2016). Population estimates predict that the LRGV will have over 3 million people by 2050 (Stubbs et al., 2003). While agriculture in the LRGV continues unabated, the economy has begun to shift from agrarian interests to one based on services and international trade (Leslie, 2016). This is reflected in the conversion of agriculture fields and rangelands to expansive urban landscapes, buildings and roads, which further isolate and compromise native plant communities (U.S. National Agriculture Statistics Service, 2012; Leslie, 2016).

Plant communities

Despite the long history of study and classification of plant communities, there is still debate and no clear and discrete definition of a plant community. From a practical standpoint, plant communities are often loosely defined on the basis of plant species assemblages that grow in a defined area, the boundaries of which are defined by direct or indirect influences of biotic and abiotic factors (Ornduff, 2003; González-Medrano, 2004; Hakkenberg et al., 2017). Since plant communities comprise more than 80% of the Earth's terrestrial habitats, the study and understanding of plant community diversity and distributions is essential for scientific discourse on conservation and land-use actions and programs. Plant communities comprise the most fundamental and operational units of contemporary ecosystems that define the character and distribution of natural history in South Texas and form the basis of habitat for many animals.

There are multiple unavoidable factors that determine the basis of plant community classification and these often create confusion and disagreements regarding competing classification systems. The inconsistent use of observational and analytical methods, the haphazard adoption of names for the same or similar vegetation types, the poorly defined delimitations of natural ranges of plant communities, and the mix of different subjective systems of classification and nomenclature (González-Medrano, 2004), often based on anecdotal evidence and subjective preferences, continue to challenge consensus among plant ecologists. Several different approaches have been used when classifying the vegetation of the LRGV and its environs, some of which are summarized in table 4.1.

Early and typically more general classifications of vegetation were based on the physiognomy of plant communities, which refers to the physical appearance of vegetation (De Cáceres, 2015; Fosenberg, 1961, Gonzalez-Medrano, 2004), as defined by the structure and growth forms of plants.

A 'province' is different from a vegetation type since it is characterized by ecologic associations of organisms within a geographic location. The classification of "Tamaulipan Biotic Province" has set regional biotic boundaries that are consistently referenced. However, the predominant vegetation type of the Tamaulipan Biotic Province is described as "thorny brush," where a few species of plants account for the bulk of plant cover and give the province a characteristic aspect (Blair, 1950). This implies that there is a single, uniform vegetation throughout the South Texas and northwest México.

Several authors have referred to the vegetation of South Texas as “South Texas plains.” This reference is now popular among authors that are range specialists (Inglis, 1964) since it denotes an open grassland region where range managers operate. This seems to be the most common reference to the region based on Texas vegetation maps (i.e., not limited to the ones in table 4.1).

The term “plains” creates additional confusion since its meaning can also vary. Texas Parks and Wildlife (TPWD) use vegetation maps that call the region “South Texas Plains,” but employ the term “brush country” when referring to region’s unique plant cover. The ambiguous term “brush” is used to denote a vegetation dominated by mixed woody shrubs and trees. Other synonyms to brush used by various authors include shrublands or thorn-scrub. In this sense, the term ‘plain’ more appropriately describes a flat lowland than a vegetation type. Alternatively, Crosswhite (1980) refers to the region as “South Texas Plains” while the vegetation is described as “Tamaulipan brushland consisting of chaparral, mesquital, and sacatal (grassland) elements.” One also encounters the use of the term “chaparral” to describe vegetation from the LRGV, specifically a shrubland dominated by shrubs with the common names chaparro (*Ziziphus obtusifolia*), chaparro amargosa/o (*Castela texana*) and chaparro prieto (*Vachellia rigidula*), mainly the latter (Clover, 1937; Crosswhite, 1980). This nomenclature is at variance, however, with a more widely accepted definition of chaparral in northwest Mexico as a biome dominated by evergreen shrubs of Mediterranean climate, which bears little relationship to the thorny vegetation of the gulf coastal plains.

In an effort to divide the country into biographical units for wildlife conservation, Leopold (1950) constructed a map with vegetation zones of México and classified the Mexican portion of the Tamaulipan Biotic Province as a "mesquite-grassland." Mesquite is a characteristic thorny, woody plant that shares dominance with other shrubs and a ground cover of grasses. Rzedowski (1978) provides another interpretation of vegetation types of México and calls the Mexican portion of the Tamaulipan Biotic Province 'xerophytic shrublands'. Rzedowski's maps includes nine additional types of vegetation in Mexico along with some minor and unique types of plant communities. Contemporaneously, González-Medrano (1972) studied the vegetation of northeast México in an attempt to better understand the plant communities of the region, their floristic composition, floristic relations with other similar zones, and the limits of ecological variation among dominant species. In this study five types of vegetation were identified: coastal dune vegetation, halophytic associations, thorn shrubland, short thorn-forest, and tall unarmed shrubland.

The study of Clover (1937) provides a localized classification of vegetation from the LRGV. This classification includes physiognomy of plant communities but also includes an alternate approach that is based on the dominant or co-dominant species. Examples of this nomenclature are "mesquital-nopalera" based on the widespread co-dominance of honey mesquite trees with arborescent prickly pear cacti (*Prosopis glandulosa* and *Opuntia engelmannii*, respectively). She also identifies a "sacahuistal" vegetation based on the dominance of the coastal salt marsh grass, sacahuista (*Spartina spartinae* (Trin.) Merr.), and recognizes a 'huisachal' with respect to resaca communities, which are dominated by huisache (*Vachellia farnesiana*). Clover's dominant species approach to vegetation classification tends to ignore significant components of plant communities but can be a convenient and effective for quick and basic classification schemes.

Some approaches to classification rank vegetation into hierarchically into units with the more refined units based on floristic composition. The Blaun-Blaunquet methodology is the most well-known floristics approach to plant community classification but various modifications have been implemented by ecologists. This school of community classification is informed by species composition, the presence of 'diagnostic species' and their consistent associates (De Cáceres, 2015; Westhoff and Van Der Maarel, 1978). McLendon (1991) describes the vegetation of South Texas, excluding coastal saline zones, and identifies ten vegetation associations comprising 29 plant communities. These include two grassland, two woodland, and six shrubland (four xeric and two mesic) associations.

Jahrsdoerfer (1988) describes the vegetation of the region as Tamaulipan brushlands and describes the plant cover as dense with thorny shrubs as the climax vegetation. In this study, 11 biotic communities were delineated and described in the "Matamoran District" as priority areas for land acquisition by the USFWS. This approach did not follow a formal classification and nomenclature system of plant communities but have been incorrectly cited as distinct plant communities. These communities were descriptive and were intended to highlight plant diversity and habitat variation (Leslie, 2016).

To seek some order in all the options and criteria that have been employed in vegetation classification, attempts have been made to standardize the nomenclature of plant communities by use of a ranking system proposed by the International Vegetation Classification (IVC). This system uses a hierarchy of eight levels. The upper three levels are predominately based on physiognomy, the middle three levels are predominately based on floristics and physiognomy, and the lower two levels are predominately based on floristics (Faber-Langendoen, et al., 2012). IVC is continuously expanding and refining its database and is becoming a popular tool for classification efforts.

The IVC system was used to identify the 38 terrestrial plant communities in the LRGV using GIS technology (Hatchcock, et al., 2012; Leslie, 2016). This report provides more detailed data on plant community variation but again, this large number of plant communities are described anecdotally on the basis of subjectively chosen dominant species, many of which are equally dominant across several of the 38 plant community types identified.

Modern approaches of using remote-sensing technology, satellite, and geographic information systems (GIS) have facilitated advancements in our understanding plant community distinctions and distributions. We have a general understanding of soil and floral components that define one another, but community structure distinctions in terms of relative abundance and dominance of diagnostic taxa is still lacking for this unknown and complex facet of natural history in South Texas.

Objectives

This study quantitatively describes the vegetational components of the Tamaulipan Biotic Province through the multivariate comparative analysis of eight remnant woody plant communities in Deep South Texas, which appeared to represent examples of typical, relatively undisturbed plant communities. Species composition, frequency, height, area cover, and interspecific organization in space were observed and measured using standard belt transect methods. Ecological characteristics such as habitat requirements of characteristic plants are provided along with growth habits and descriptions of vegetative structure.

Due to the broad scope of the vegetation surveys and the highly fragmented remnants of vegetation available at this point in modern history, not all major plant communities are characterized; but a broad assemblage of stable climax plant communities that occupy distinct substrates and hydrological regimes are compared and contrasted. Scientific literature is also used to supplement the investigation's detailed observations in order to more comprehensively describe the diverse vegetation and distribution of plant communities in the Tamaulipan Biotic Province.

This study tested the null hypothesis that that there is a single vegetation type in the Tamaulipan Biotic Province. Since this hypothesis was rejected, future studies will test the alternate hypothesis that the distinction of plant communities is related to abiotic factors such as temperature, soil types, precipitation, and water availability.

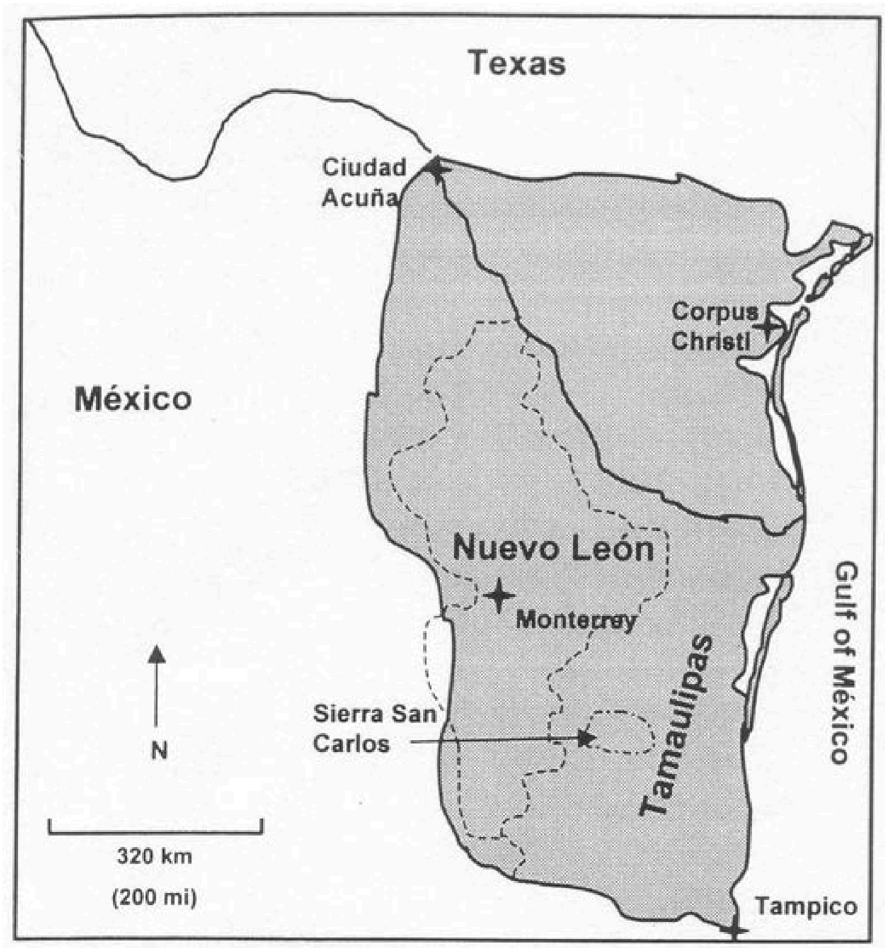

Figure 1.1: Map of the Tamaulipan Biotic Province (shaded area) of Texas and Mexico (Judd, 2002). Note that areas stippled with lines and dots circumscribe to mountain ranges that sustain vegetation types that are absent in the Tamaulipan Biotic Province.

Table 1.1: References to vegetation of the Tamaulipan Biotic Province

Reference	**Nomenclature**	**Area of study**	**Notes**
Blair (1950)	Tamaulipan Biotic Province	Texas	
Gould (1663) Correll and Johnston (1970) Hatch et al. (1990)	South Texas Plains	Texas	“Rio Grande Plains” in Correl and Johnston (1970)
TPWD	South Texas plains-Brush country	Texas	
Crosswhite (1980)	Tamaulipan brushland	South Texas	
Leopold (1950)	Mesquite-grassland	Mexico	
Rzedowski (1978)	Xerophytic shrublands	Mexico	
Gonzalez-Medrano (1972)	(1) Thorn shrubland (2) Short perennial thorn forest (3) tall unarmed shrubland	NE Tamaulipas	Also included coastal vegetation types
Clover (1937)	Mesquital-nopalera, mesquital-chaparral, mesquital-zacatal, and others	LRGV	Other community types were identified in this study.
McLendon (1991)	Mentions the dominant vegetation to be shrublands- “the brush country.”	South Texas	Described 29 communities of which shrublands are the most commonly associated vegetation type of South Texas.
Leslie (2016)	“Matrix of vegetation”	LRGV	38 terrestrial communities
Jahrsdoerfer & Leslie (1988)	Tamaulipan brushlands	LRGV	11 biotic communities

CHAPTER II

METHODS

Site selection

Sites were selected in the using geologic and physiographic characteristics of soils to represent a diversity of habitat types. Locating sites that represent various soils and biological communities were a challenge due to limited site availability. In some cases, the limited site availability made selection straightforward since they are the last remnant communities known that can adequately represent native vegetation. Eventual selections of plant communities were based on the lack of major anthropogenic land use or native habitat integrity. Although the eight remnant communities chosen for the study do not represent every possible type of vegetation in the LRGV, the number and diversity of plant communities targeted covers a broad spectrum of plant communities in Deep South Texas that are adapted to the full gamut of climatic and edaphic possibilities for a broad perspective on the Tamaulipan Biotic Province.

Sites were selected with the aid of USFWS resources. Five of the sites surveyed include reserves managed by USFWS that are avowed contain intact biological communities. In addition, other sites were surveyed that contained unique communities that are not included on USFWS lands. These include sites on a private ranch, municipal property, and one privately owned property of the nonprofit Gorgas Science Foundation. Although the sites selected are some of the more pristine accessible sites, all landscapes of South Texas have been disturbed or intentionally altered to varying degrees. Historical land uses, which may influence community structure, is provided in chapter III: Study Sites.

Belt-transect parameters

Two 50 m x 20 m plots were established at each site. Each plot was separated into a side A and a side B, and each of these was treated as an individual belt-transect, amounting to four 50 m x 10 m transects (figures 3.1 & 3.2). The only exception to this approach involved the La Posada site in Brownsville, TX (figure 2.3), where the survey area follows a dry resaca in an urban setting (i.e., with considerable 'edge effect' of disturbance). For this community, plot dimensions of 100 m x 10 m were used to follow the Resaca terraces along a straight and narrow line. In sum, a total of 500 m^2 were surveyed per transect and 2,000 m^2 per site, amounting to 16,000 m^2 for the eight study sites.

Although transects A and B border one another as a subsection within a plot, the spatial proximity of this approach is justified under the premise that no two vegetation samples are exactly alike, whether in space or time, even if they are next to each other and have equivalent habitats (Gonzalez-Medrano, 2004). In addition, each transect was large enough to be considered its own measurable unit in space. In general, sample sizes are typically between 50 and 400 m^2 for shrublands and forests (Dengler, 2017) or between 200 and 500 m^2 in forests of temperate zones (Mueller-Dombois & Ellenberg, 1974). In either case, the uniform transect size of 500 m^2 used in this study substantially satisfy the minimum size requirements (see below).

Reconnaissance of 1-2 field day visits for each survey site were conducted to determine plot and transect locations. Sampling strategies aim to capture variability of study sites while minimizing within-plot heterogeneity (Mueller-Dombois & Ellenberg, 1974; Dengler, 2017). For this reason, locations were chosen using preferential sampling methods to collect data to optimize the representation of the entire plant community across ecological space (De Cáceres et al., 2015). All plant communities exhibit some variation in vegetation structure, so the two plots made at each site were chosen to complement each other to represent a substantial portion of the entire plant community. They were established a considerable distance from each other but there was not a minimum distance between plots because variability in vegetation is preferred over a statistical inference across geographic space (Dengler, 2017) and some sites had a reduced amount of appropriate surveyable area. To get a reliable sample representation and reduce bias, some of the following considerations were followed:

- Truly Random points on a site map were not used because there was a high chance that the area chosen at random might include disturbed vegetation that would not adequately represent native, climax communities, the main focus of this investigation. Stratified-random or even preferential placement of plots are preferable in phytosociological sampling (Dengler, 2017).
- Areas where there were major signs of disturbance were immediately disqualified. Signs of disturbance included, but were not limited to, the presence of invasive species, primarily exotic African grasses, an abundance of pioneer species, road clearings, and plant community effects due to clearing.
- Habitat cover should be uniform within a plot (Mueller Dombois & Ellenberg, 1974) so abrupt vegetation changes and anomalies were avoided such as those caused by a dip or spike in elevation. Small abrupt habitat changes are natural in plant communities, however, the idea here is to sample the dominant community composition and structure.

- Plant cover should be homogeneous within a plot so it should not show large openings nor be dominated by one species in one half of the sample area and by a second species in the other half (Mueller-Dombois & Ellenberg, 1974).
- All transect locations were positioned such that transect boundaries were at least a few meters away from disturbed edges.
- To reduce bias towards feasibility of transect data collection, areas of dense and almost impenetrable vegetation were selected if the researcher believed it was an adequate representation of the entire community. In most, if not all previous local descriptions of vegetation, open areas and paths of least resistance have likely been favored.
- The presence of mature trees, dead tree stumps that seemed to be weathering for several years, and a native herbaceous understory were deemed as signs of old growth.

Data collection

Each data point represents the location of each woody species ≥1 m in height on a transect (determined by taking two measurements, one horizontal along the tape and one perpendicular distance away from the tape), measure of a plant's height, and canopy cover. A 50 m measuring tape was placed from the starting point and fixed in place (Figure 3.1). Two 10 m ropes marked at 0.1 m intervals were placed perpendicular to the 50 m transect line, allowing detailed measurement of plant distances from the 50 m transect line. These ropes were spaced 2 m away from each other and shifted along the transect line as measurements were taken. Once the 50 m transect line measurements were complete, data-gathering was concluded for plot side A or transect 1; then the ropes were placed on the opposite side of the transect line and the process was repeated to measure a complementary plot side B or transect 2 (figure 3.2).

The height of each plant was measured using a 7.5 m extendable measuring pole. For plant species that exceeded the pole length, height was calculated using a clinometer to get the angle from the height of the canopy standing 10 m away from the trunk. The same extendable measuring pole was used to measure canopy diameter and canopy cover was calculated. All transects were completed by the lead researcher but some measurements were taken from research assistants. In order to maintain measurement consistency, all assistants completed field training and their measurements were compared with the lead researcher's before collecting data. The time spent laying out ropes and collecting data varies depending on the structure of the vegetation. It is estimated that an average of 50 hours was spent to complete each plot with two researchers at a time, which amounts to 1600 hours of labor. When including initial reconnaissance field visits, specimen collection, and identification of unknown species, approximately 1800 hours of labor were required.

Identification of plant species was accomplished by using primarily the field guides of Richardson & King (2011) and Richardson (1995). Voucher specimens were collected for all species recorded in data calculations, which are housed at Pan American University Herbarium. For plants that were not readily identifiable to the species level, voucher specimens were compared with herbarium specimens from UTRGV herbarium until a satisfactory identification was made.

Plant Nomenclature

Plant nomenclature follows the most current names at time of publication from The PLANTS Database (USDA, NRCS, 2019). All plants that were represented as a data point in transect measurements are found in Appendix 1. For all other plants mentioned, authorship is introduced in text.

Calculations

Transect sizes are uniform for better community comparison because vegetation analysis can be sensitive to transect size (Dengler, 2017) The transects in this study exceeded the minimum recommended requirements. Area cover and frequency of occurrence are used to calculate both relative cover (dominance, in part) and relative frequency, as well as the percent of area cover at different heights (degree of stratification). The percent of area cover is determined by taking the sum plant cover divided by the transect area of 500 m^2. If the sum of plant cover at various strata exhibit a continuous canopy, > 100% can be reached. Relative percent cover is calculated by dividing the species cover by the entire plant cover for the transect. The collective species cover for this calculation is equal to 100%.

Community species diversity indices based on species richness and evenness are compared using Shannon-Weiner and Simpson indices. Shannon-Weiner diversity quantifies the entropy of a sample while Simpson diversity is based on the probability that two individuals taken at random from the dataset of interest represent the same species.

Multivariate statistical methods were utilized to compare the overall community structure and species composition across all sites. We used nonmetric multidimensional scaling (NMS) ordinations utilizing Bray-Curtis dissimilarity methods to quantify and illustrate community level differences (with all species considered simultaneously) among study sites. We used the 'cca' function in the 'vegan' package in R Statistical Software to model differences in plant community composition based on the categorical site designations, with each transect representing one sample, thus each site had four multivariate data points. We then used permutational multiple analysis of covariance (PerMANCOVA) to test whether the observed relationships between community composition and the categorical site designations were statistically significant. The same modeling and analyses procedures were performed a second time using species abundance values instead of cover. In this way, we tested the null hypothesis that that there is a single distinctive vegetation type in the LRGV. All statistical analyses and modeling were performed using R version 3.4 (R Core Team 2013; R Foundation for Statistical Computing, Vienna, Austria).

Additionally, virtual graphs of each transect were created. Species were represented by an individual color. The size of the colored points represents the canopy size and the placement of the points represent the location that individual plants are located on the transect. These graphs provide a visual perspective on the density of the plant communities surveyed, but because of the overlapping points, it is difficult to distinguish individual species and their distribution. Some species of interest were isolated on separate graphs to more clearly see their representation and distribution between transects.

Classification approach of this study

Many techniques used for classification of plant communities are based out of Europe or are designed to classify vegetation with a global standard in mind. While this is valuable and necessary, the aim of this study is regional and based on a single biotic province. Therefore, by reducing the number of factors considered in distinguishing vegetation on a global level, the classification and nomenclatural schemes are simplified in this study.

When summarizing various classification approaches physiognomy, structure, and floristics seem to be the traits that are most commonly applied. In this study: 1) physiognomy-structure-function 2) floristics and 3) habitat characteristics are used. There is a distinction made between physiognomy, structure, and function. Physiognomy is the general appearance, especially external appearance. Community structure refers to the arrangement in space of the components of vegetation. Function includes the features that suggest adaptations to environmental situations (Fosberg, 1961). Physiognomy, although separate, partly results from structure and function. These terms have also been used inconsistently between different authors. In this study, these traits were combined because there is an overlap in their significance and their conflation reduces them to a single trait that provides a general description of vegetation without requiring prior knowledge about the floristics nor physiography. Floristics are based on the dominant or characteristic species that represent the community. Habitat characteristics are included because there is sufficient information available on a small scale that give us an idea of the association of the communities and their environment. These are determined by comparing study sites to climate, physiographic, soil, and ecological maps.

The criteria below are used for physiognomy-structure-function in this study and are modified from Gonzalez-Medrano (2004). The structural criteria of stratum cover is added to provide a vertical representation of the dominant layers of canopy cover. Phenology is given least priority in this study because data collection was not year-round for any single community but will be noted when possible.

1. Vegetation type based on the dominant presence of trees, shrubs, or herbs.
    a. Forest
    b. Shrubland
    c. Prairie
2. Function
    a. Evergreen (75-100% of dominant species conserve leaves year-round)
    b. Sub-evergreen (25-50% of species deciduous)
    c. Sub-deciduous (50-75% of species deciduous)

    d. Deciduous (more than 75% of species deciduous)

3. Size of life forms
    a. Tall
        i. Trees: 30 m or more
        ii. Shrubs: 2-4 m.
    b. Medium
        i. Tree: 15-30 m
        ii. Shrub: 1-2 m
    c. Short
        i. Tree: 4-15 m
        ii. Shrub: 1 m or less
4. General characteristics of leaves and stems
    a. Texture
    b. Size
    c. Armed (thorny, spines)
    d. Etc.
5. Overall cover
    a. Very compact (more than 200%)
    b. Compact or continuous (100-200%)
    c. Open or discontinuous (50-90%)
    d. Scattered (5-50%)
6. Stratum cover
    a. Stratum I (1.0 – 1.9 m)

b. Stratum II (2.0 – 4.9 m)

c. Stratum III (5.0 – 9.9 m)

d. Stratum IV (10.0 m +)

For this study vegetation is only separated into two hierarchical ranks, associations and formations. The PerMANOVA statistical calculations distinguish communities at the refined association level based on floristics. Once communities are distinguished at the association level, they are placed into a formation level also known as vegetation type, which is defined primarily on the physiognomic character of dominant species that reflect environmental conditions (Faber-Langendoen, 2012).

At the formation level, this study will incorporate the vegetation types from the classic work of Rzedowski (1978). In his study, ten distinct types of vegetation are described and mapped out, with reference to various minor types. Variation of plant communities within each of these vegetation types across Mexico's complex landscapes reveals the discrete and indiscrete plant community features that can blur the lines of distinction. Since all of our study areas include plant community types that extend into Mexico, our biota falls within the boundaries Rzedowski's (1991) seminal concept of 'Megamexico': i.e., the collective biogeographic range of native Mexican organisms that naturally beyond the country's political boundaries.

Figure 2.1: 50 m transect tape extended going away from transect starting point. Visible on forest ground in the center of photo.

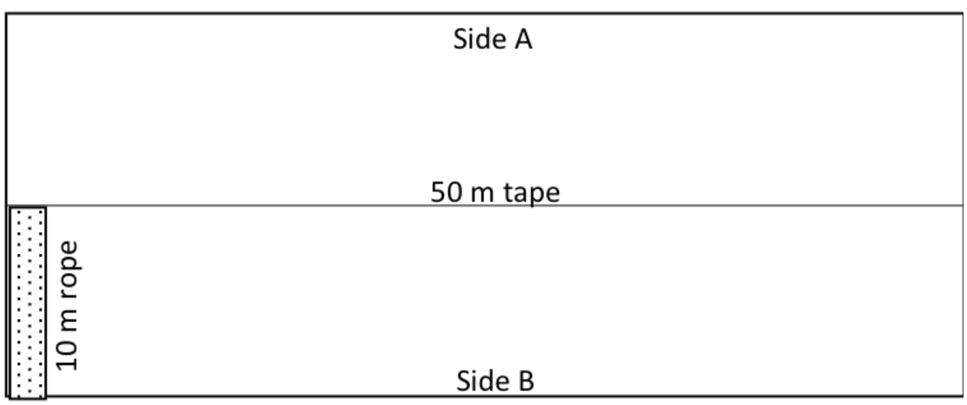

Figure 2.2: Plot diagram with transect 1 (side A) and transect 2 (side B), 50 m tape to measure tape point, two 10 m ropes to measure tape distance in 2 m intervals.

CHAPTER III

STUDY SITES

Climate

Biologists consider climate to be a principal factor in determining the character and distribution of plant communities (Holdridge, 1947). There have been many proposed climate maps but the traditional Köppen-Geisler climate classification system of 1961 remains a global standard (Nascimento et al. 2016 and Kottek, M. et al., 2006). Many subsequent updates have been proposed to the Koppen-Geisler system, such as Peel et al. (2007), which provides fine resolution.

The majority of the Tamaulipan Biotic Province and the section of the province used in this study (LRGV) falls under two closely related climates separated primarily on the basis of a precipitation gradient: hot semi-arid climate (BSh) (B=arid, S=steppe, h=hot) and humid subtropical climate (Cfa) (C=temperate, f=humid year-round, a=hot summer (Kottek, et al., 2006) (Figures 3.1 and 3.2). The BSh climate extends along the west side of the province and reaches the Gulf of Mexico south of the United States-Mexico border. The study sites that fall under this climate classification include Los Olmos (LOOL), La Puerta (LAPU), Yturria Brush (YTBR), and Cactus Flats (CAFL). The Cfa climate covers the eastern borders of the Tamaulipan Biotic Province before transitioning into a BSh climate south of the Río Grande border. The Cfa and BSh climates divide the LRGV roughly around the Hidalgo and Cameron

County line. Study sites that fall under Cfa climate are Thompson Road (THRO), Laguna Atascosa (LAAT), La Posada (LAPO), and Sabal Palm (SAPA).

Average rainfall in Brownsville, TX (eastern edge of the LRGV) is 69 cm while the western edge of the LRGV near Río Grande City averages around 57. In both of these cities, there is more than twice as much average rainfall during the six months from May to October than from November to April. These seasonal fluctuations follow a tropical climatic system that is determined primarily by water rather than temperature cycles (Davis, 1942). Both growth and flowering growth and flowering phenology is governed by day length but not without the impact of precipitation, which during times of drought can arrest normal phenological cycles.

Altitude is not a major influence on the vegetation in Deep South Texas although local topography and drainage can have significant influences. The altitude approaches sea level near the coast and increases gradually toward the west by approximately 1 m per 1 km. Thus, the majority of the LRGV exhibits a sparing range of 0-53 m in altitude.

Vegetation that develops and persists in areas where climate is the primary determinant is referred to as zonal vegetation. Usually these are large areas that overlap on climate maps. On the other hand, azonal vegetation is influenced additionally by soil characteristics, the chemistry of geologic substrates and their inherent water retention capacities. The distance between the survey sites spans 150 km and each is impacted to varying degrees by the two related climatic zones. Hence, we expect observable gradual shifts in vegetation along the east-west climate corridor (figure 3.3). And because of the relatively close proximity between study sites that have near identical climate patterns, we can also observe the influence of soil and geologic substrate on plant communities.

For azonal vegetation influences, we compare the study sites with physiographic maps of

Hatchcock (2014) (figure 3.4) and give a brief description of their soil formation and the site land use history below.

Study Sites

Los Olmos

Los Olmos is a tract managed by the USFWS north of Río Grande City in Starr County. This site contains "ramaderos" – i.e., ephemeral washes that channel flash-flood waters from surrounding xeric environments (Clover, 1937) – which drain into the nearby Los Olmos Creek. The importance of ramaderos to wildlife has been recognized and inspired the initial acquisition of over 1000 acres of this landscape in 1991 to protect threatened ramadero plant communities. Subsequent land acquisitions have expanded the preserve to 800+ hectares (2000+ acres).

This site is located in the western part of the Bordas Cuesta physiographic zone and was formed during the Pliocene Epoch. The Bordas Cuesta is an asymmetric ridge having a short, steep escarpment on one side and a long, gentle slope that dips eastward. Los Olmos is located on the steep escarpment known as the Bordas Escarpment (figures 3.3 - 3.6). This area is adjacent to and influenced by the Oakville formations of the Miocene and composed of mixtures of gravel cemented with calcium carbonate, limestone, sandstone, and a modest amount of clay (Wynd, 1944; Hathcock et al., 2014).

Los Olmos tract was a formerly employed as ranchland for cattle grazing, hunting, and oil extraction. Several strips of land were cleared for oil extraction, electrical poles, and roads and created edges, but such disturbances are localized. The main disturbance was due to former years of cattle grazing. Dense shrublands were probably not affected too much because of lack of grazing material but areas with well-drained soils and grasslands were likely altered.

Vegetation at Los Olmos is highly variable with several xeric shrub communities beyond the ramaderos. Many areas of the site cannot be reached by vehicle. The first plot location was set up at a high-end slope of a caliche hill. The soils of caliche hills are shallow, varying from 0-10 centimeters deep, and have low moisture holding capacities (McLendon, 1991). The second transect location was set up at slightly lower elevation where a thin layer of sand covers the surface. In this area, sand and sandstone is degraded into a dark red sand, with gravel comprised of quartz coated with red iron oxide (Wynd, 1944).

La Puerta

La Puerta is an approximately 1600-hectare (4000-acre) tract of the USFWS tract in southeast Starr County with a unique plant community dominated by a citrus family shrub known as the *barreta* tree (*Helietta parviflora*) (figure 3.7). Accordingly, Clover (1937) nominated this vegetation type as a 'barretal.' Barretales have been identified as the only native plant community in the United States that is dominated by a member of the Citrus family. (Jahrsdoerfer & Leslie, 1988), but this claim ignores vegetation with dominant stands of the rutaceous colima plant (*Zanthxylum fagara*) and highly restricted populations of the limoncillo tree (*Esenbeckia berlandieri* Baill.) in the LRGV.

This site is also located in the Bordas Cuesta physiographic zone but is not part of the Bordas Escarpment geological feature, such as the Los Olmos site. Shorter rolling hills of calcareous soils can still be found locally. Former use of this site can be traced to a Native American era based on artifacts. More recently, the site was a cattle ranch before its purchase by the USFWS in 1990. The site still maintains active oil wells.

The vegetation of La Puerta is complex and comprised of a diversity of short-woodland associations. The northern half of the reserve was formerly dedicated to intense grazing after the removal of woody vegetation. In these areas, sandier and well-drained soils occur and likely provided a variety of desirable forage plants for cattle. These areas are now dominated, however, by honey mesquite (*Prosopis glandulosa*), the now widespread and exotic grass, buffelgrass (*Pennisetum ciliare* Link), and shrublands that represent various stages of plant succession. Some areas also have signs of recent fire and highly damaged vegetation with a preponderance of the invasive African buffelgrass. This leaves a relatively small yet suitable survey area of short rolling hills where vegetation has not been evidently affected by grazing, fire, nor has been impacted by heavy machinery.

Yturria Brush

Yturria Brush is an approximately 700+ hectare (1800-acre) site that is located in southwest Hidalgo County near Sullivan City and managed by USFWS. Yturria is located in the Bordas Cuesta physiographic zone and borders the Lissie-gravel geological zone. Lissie gravel differs from regional substrates on account of its larger proportion of unconsolidated gravel and smaller proportion of limestone, mixed with a little sand and thin beds of caliche. The rocky substrate weathers in time to dark gray or black loamy soils (figure 3.8) (Wynd, 1944)

Vegetation at Yturria Brush sustains a continuous shrubland that covers most of the southern portions of the tract (figure 3.9). Vehicles have limited access and so large extents of this preserve were not observed. Plot 1 had some signs of *Pennisetum ciliare* so it is probably in a late stage of regeneration after moderate impacts of cattle in the past. Plot 2 had no signs of disturbance and the vegetation was observably taller and denser.

Cactus Flats

The Cactus Flats tract is a private ranch located slightly northeast from the center of Hidalgo County, near Hargill, TX. This property is located in the Bordas Cuesta physiographic zone and its soils originated during the Pliocene epoch. The plain of southern Texas is slightly elevated and tilted from the west, forming a peneplain that slopes minimally to the east. Constant erosion and ground water transport of materials toward the gulf coast has caused a thinning of the western Bordas Cuesta boundary. These coarse gravels were conserved in the western end of the LRGV and which can be observed at other study sites, such as Los Olmos and La Puerta. Finer sediments were transported eastward and eventually merge with marine deposits. Wind-blown sand from the Holocene forms a thin top layer that covers the soil (Wynd, 1944).

Jahrsdoerfer & Leslie (1988) highlight the area where the Cactus Flats site is located as having unique "wooded potholes and basins," and thus natural ponds that are inhabited by aquatic plants and animals. Ephemeral ponds are still observable near the study site amidst plowed fields. The vegetation of the cactus flats study area is a dense thorn forest within which occasional light gaps allow entry of sunlight and the growth of a variety of understory shrubs (figure 3.10).

The history of the site traces back as a portion of the "Las Mesteñas" land grant (Ponce, 1996). The land was grazed in the early 1900s and after the 1950s, cattle were removed, with infrequent leasing for deer hunting. The section of the ranch where the transect sites are located has never been cleared or intensely used but a vast eastern side of the tract was cleared for agriculture and left to regenerate since the 1950s. This ranch is of particular interest because of its various stages of succession, where intensely farmed and grazed lands border pioneer, mid-successional and climax forests.

Thompson Road

The Thompson road site is a 12-hectare (30-acre) biological oasis surrounded by conventional agriculture. Despite its small area size, the tract supports a species-rich and intact plant community. The dense and continuous canopy insulates some vegetation from the hot sun and also prohibits the establishment of invasive species. Vegetation at this site falls within Jahrsdoerfer's (1988) concept of an 'upland delta thorn forest', as characterized by dominant woody thorny trees and tightly situated thorny shrubs (figure 3.11).

Disturbance at the site seems relatively low but there are patches that show signs of human use from small clearings and human rubbish. Transect plot locations were placed at the north and south sides of the tract.

Laguna Atascosa Loma

Laguna Atascosa National Wildlife Refuge is a 36359-hectare (89,845-acre) USFW refuge bordering the Laguna Madre, mainly in Cameron County and extending into the southeast corner of Willacy County (Leslie, 2016). The reserve represents one of the largest remaining units of original coastal vegetation in the South Texas (Fleetwood, 1973). Robust and widespread native plant cover supports a waterfowl refuge in the Central Flyway of North America that is best known for harboring populations of the endangered species northern aplomado falcon (*Falco femoralis septentrionalis*) and northern ocelots (*Leopardus pardalis albescens*) (Leslie, 2016).

Laguna Atascosa harbors a diversity of aquatic and marine habitats that include, sand dune prairies, clay dunes, sea grass meadows, tidal flats, and fresh and brackish water wetlands (Leslie, 2016). The refuge is in the Río Grande Delta physiographic zone (figures 3.3 and 3.4). The soil is composed of Beaumont clays and of the recent deposits of alluvial loam from the Holocene epoch (Hathcock, 2014). Many of the plant communities at Laguna Atascosa are herbaceous and tolerate alkaline, saline and sandy soils, but woody vegetation is best developed on shallow clay, sinuous uplifts to 5 m tall known locally as 'lomas.' Lomas form shallow, meandering terraces throughout the tidal flats and marshes of the zone (Leslie, 2016). These provide critical corridors for the shelter and dispersal of northern ocelots.

A loma on the western side of the Laguna Madre was chosen to represent loma plant communities in the region (figure 3.12). Loma communities can vary considerably on these formations with respect to species composition, however, this depends on their height, proximity to the laguna, proximity to fresh water, and relative amounts of disturbance. After disturbance and invasion of exotic grasses, they seem unable to undergo plant succession. No invasive species or evident signs of disturbance were noted with the exception of a maintained caliche road toward the edge of the loma.

La Posada

The La Posada site is a strip of land owned by the municipality of Brownsville and parallels a street by the same name. This site is part of the recent delta physiographic zone, occurring around 1 km from the Río Grande. The soils are alluvial and used to flood seasonally as an extension of Resaca de la Palma before flood control measures were put in place (Eugene Fernandez, personal communication).

The La Posada site is dominated by a monumental stand of Montezuma Cypress trees (*Taxodium mucronatum*): a southern species of conifer of the redwood family (Taxodiaceae) that ranges discontinuously from Guatemala through México and into the Río Grande and a few of its tributaries (Wiggins, 1935; Veblen, 1977). It was proposed in the mid-1800s (Emory, 1857) that *Taxodium* trees are emigrants from the Salado River, which deposits into the Río Grande, since the trees are found downstream from the confluence (Emory, 1857). The urban *T. mucronatum* grove is the largest of only two known remaining natural populations of the Monteuma cypress in the LRGV and in the United States.

As an urban forest, this site has withstood perpetual disturbance and human impacts over the course of time, yet most of the trees that line the resaca are old, climax trees that maintain of a relatively stable forest community (figure 3.13) with equally old associated trees. The irrigation district has recently dredged soil and along the old resaca channel and altered the topography. In addition, there is some encroachment of invasive species but not the standard African grass exotics that now dominate the LRGV. Despite the heavy impact of disturbance on this site and the lack of flood cycles, this site was surveyed as the last remnant forest of its kind in the South Texas.

Sabal Palm Sanctuary

The Sabal Palm Sanctuary site is a 557-acre nature preserve managed by the Gorgas Science Foundation. This site borders the Río Grande and is a part of the Río Grande Delta physiographic zone with recent Holocene alluvial soils. The tract's close proximity to the river-rendered it susceptible to extreme floods and the fluctuation of the delta's water regime (Diamond, 1998), although flooding has been essentially prevented since the completion of Falcon Dam in 1953.

Sabal Palm sanctuary is characterized by the dominance of a native fan palm, the Texas palmetto (*Sabal mexicana*) (figure 3.14). This habitat was described by explorers of early settlement as an area of "luxuriant tropical growth." The distribution of the *S. mexicana* as a dominant or subdominant in the LRGV is now reduced but a number of palm populations can still be found scattered throughout the delta. One such area southwest of Brownsville has the largest populations of *S. mexicana* in the U.S while other remnant communities are usually found along resacas channels. *Sabal mexicana* has a similar distribution on the Mexican side of the Río Grande with the densest growth near the southernmost bend of the river and becoming more infrequent moving further from that area (Davis, 1942). This species extends both along the Pacific and Gulf Coasts as far south as Nicaragua (BONAP, 2014).

Due to clearing operations, restricted *Sabal mexicana* habitats continue to decrease in size and number. The best representation of *S. mexicana* habitat is the Sabal Palm Sanctuary, even though a mere 20 acres is old growth *S. mexicana* habitat remains intact. This area suffers substantial edge effects and the encroachment of invasive species. By necessity, transects in the palmetto grove were established close in proximity.

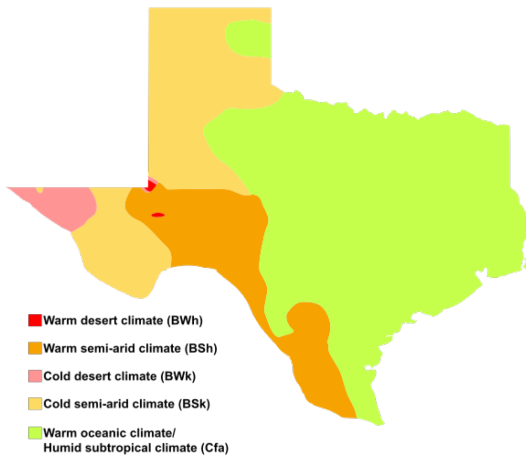

Figure 3.1: Texas map of Köppen classification.

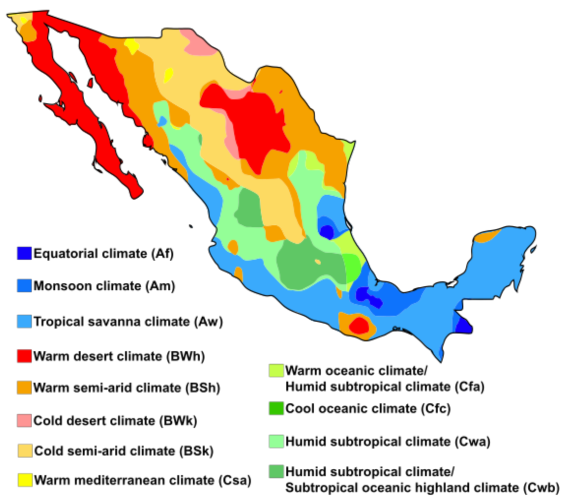

Figure 3.2: Mexico map of Köppen classificaion. Tamaulipan Biotic Province climate represented in NE corner.

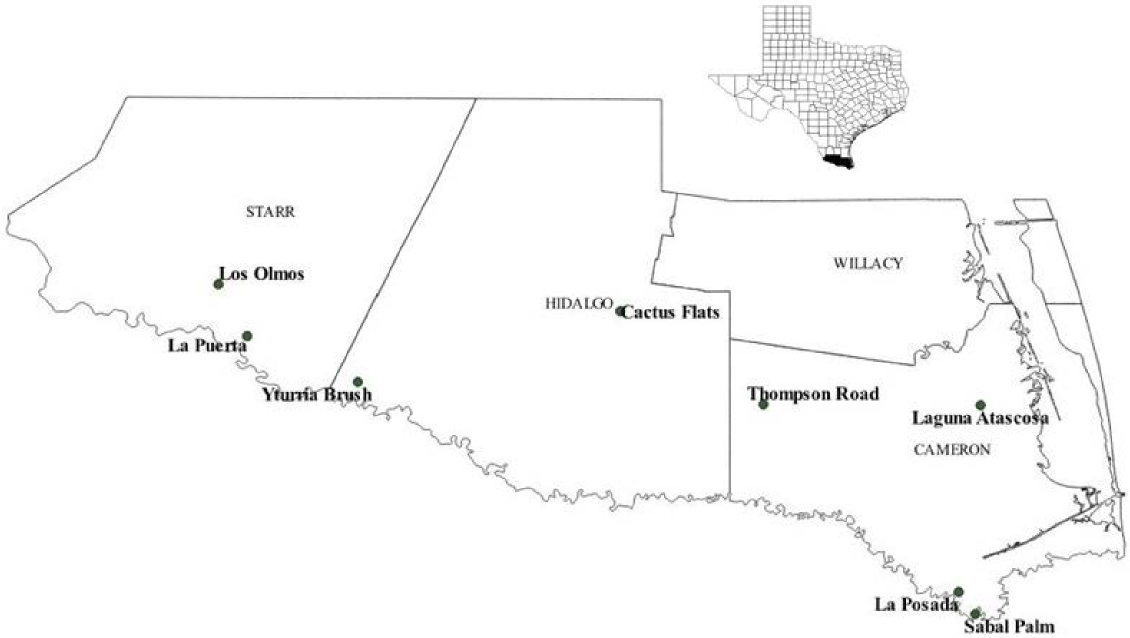

Figure 3.3: Map of the LRGV with study site locations.

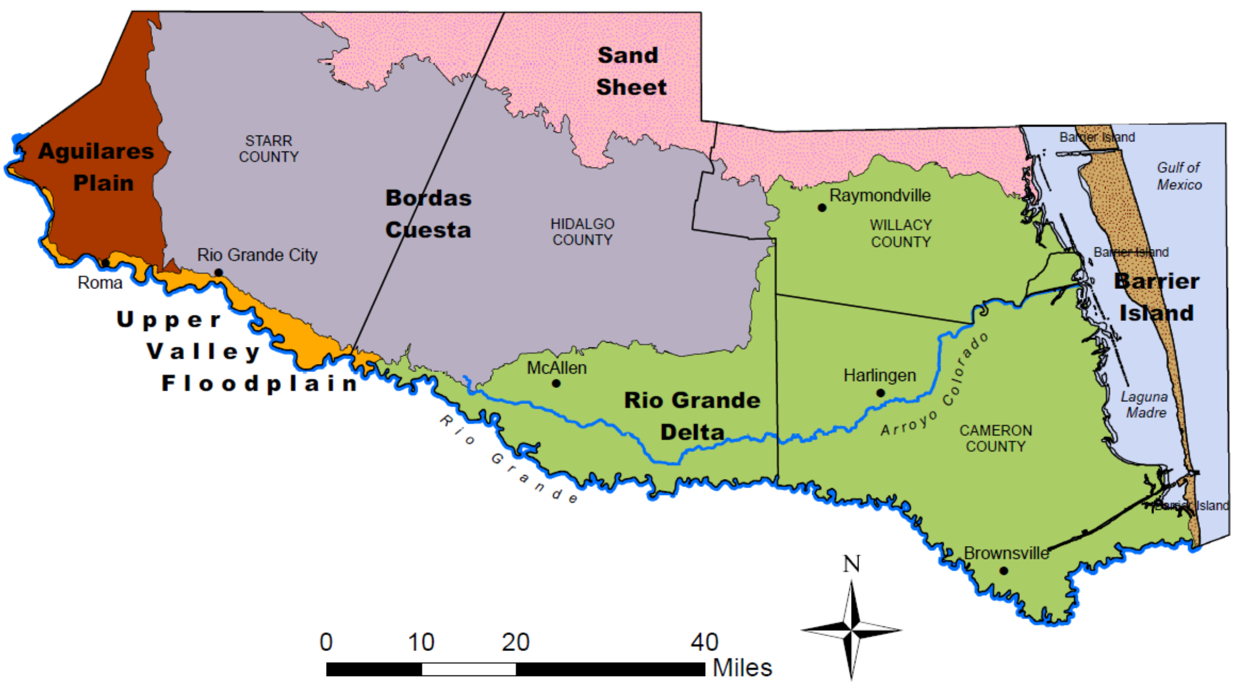

Figure 3.4: Map of physiographic zones of the LRGV (Hathcock et al., 2014).

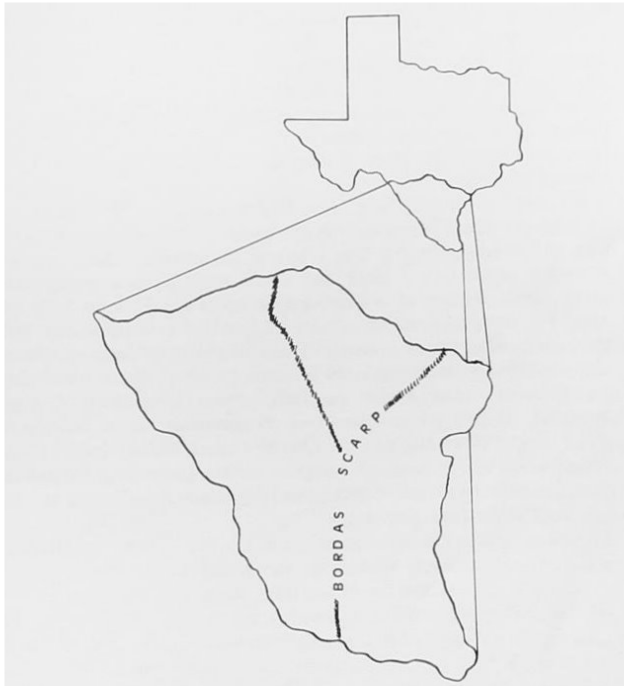

Figure 3.5: Map of Bordas Escarpment in South Texas (McLendon, 1991).

Figure 3.6: Los Olmos study site located on the Bordas escarpment.

Figure 3.7: Plant community near La Puerta dominated by barreta (*Hellieta parvifolia)*, which stands out due to their greater height in the background and cenizo (*Leucophyllum frutescens*) with its ashy hue.

Figure 3.8: Exposed substrate of unconsolidated gravel and caliche near the Yturria Brush site.

Figure 3.9: Yturria Brush shrubland community.

Figure 3.10: Upland thorn forest plant community at Cactus Flats.

Figure 3.11: Delta thorn forest plant community at Thompson Road.

Figure 3.12: A unique loma at Laguna Atascosa NWR

Figure 3.13: Montezuma cypress (*Taxodium mucronatum)* roots lining the edge of a former resaca at La Posada site.

Figure 3.14: Sabal palm forest at Sabal Palm Sanctuary.

CHAPTER IV

RESULTS

A total of 10,043 plants woody plants from 84 species were recorded in eight geographically isolated study sites in South Texas. A small portion of these species were common to every site while other species were restricted to one site. For example, *Forestiera angustifolia* and *Guaiacum angustifolium* were encountered in varying frequencies at all eight sites, while *Abutilon hypoleuca* was restricted to the Sabal Palm Sanctuary and *Parthenium incanum* to short thickets at the Los Olmos site. Most species were found in a subset of the eight survey sites, but with varying degrees of representation in terms of frequency and dominance. Appendix 2 provides a complete presence and absence list of species at each site.

Diversity Indices

Diversity indices varied across study sites (table 4.1). For calculations of both the Shannon-Weiner diversity index and Simpson diversity index, study sites were ranked in relative diversity and can ordered from the relatively highest to lowest diversity: i.e., Yturria Brush, Sabal Palm Sanctuary, La Posada, La Puerta, Thompson road, Cactus Flats, Los Olmos, and Laguna Atascosa loma. Typical values in Shannon-Weiner diversity are between 1.5 and 3.5. The range between Yturria Brush (2.769) and the loma at Laguna Atascosa (1.210) is 1.559. Simpson's index is a similarity index that ranges from 0-1, where 1 represents complete evenness of species abundance. The range between Yturria Brush (.924) and the loma at Laguna Atascosa (.478) is 0.446. These diversity index values use a scale that do not reflect true diversity, such that a sample with a Shannon-Weiner diversity of 3 is not twice as diverse as one with 1.5. However, the values from these diversity indices quantify community biodiversity based on species richness and relative abundances and both approaches at quantifying diversity complement one another's findings.

PerMANOVA

The null hypothesis that there is a single definable vegetation type in the Tamaulipan Biotic Province was tested using PerMANOVA test. This test compared the relationship between plant community composition and study siets by determining whether the centroids (average dissimilarities) of communities are equivalent for all study sites. This analysis includes individual transects or plots as observations for site data and utilizes marginal (Type III) sums of squares and the canonical correspondence analysis (cca) function with 10,000 permutations. Type III sums of squares tests for the presence of a main effect in terms of interactions and other main effects and is used in the presence of significant interactions (Mangiafico, 2015). Canonical ordination associates two or more data sets in the ordination process to test statistical hypotheses about the significance of these relationships and is useful for ecological interpretation of species assemblages.

Four separate PerMANOVA tests were conducted using different parameters to test the null hypothesis. Community composition was based on species area coverage (dominance) or relative abundance (frequency) and sites were separated into transects (4 observations per site) or plots (two observations per site). The baseline analyses chosen to test the null hypothesis used dominance and transects (table 4.2a). The results from this analysis indicated a p-value <0.0001, denoting the rejection of the null hypothesis with strong statistical significance. The analysis using dominance and plots (table 4.2b) had a much lower-F statistic due to the difference in degrees of freedom, however, this analysis also rejected the null hypothesis with strong statistical significance.

The results from the analyses using frequency and transects (appendix 3a) as well as frequency and plots (appendix 3b) coincided with those that had the same degrees of freedom from the previous two analysis and also rejected the null hypothesis with strong statistical significance. Thus, the four PerMANOVA performed using different parameters all rejected the null hypothesis with strong statistical significance. This indicates that plant community composition varies between all surveyed sites and that the Tamaulipan Biotic Province is not defined by a single vegetation type.

Nonmetric Multidimensional Scaling

Nonmetric Multidimensional Scaling (NMS) is an ordination technique used to visualize the level of dissimilarity or similarity of a dataset based on a nonlinear distance matrix (Everitt and Hothorn, 2011). Since the null hypothesis is rejected using the PerMANOVA tests, NMS is used to find which plant communities differ from one another and compare the degree of similarity across study sites. Filled ellipses denote the 95% confidence interval for a given site and reflect the "average" community composition at each site. Unfilled ellipses are minimum bounding ellipses drawn to contain all observations (transects or plots) within a category (site).

This multivariate representation considers community composition and graphs both species and observations (transects or plots) using Bray-Curtis dissimilarity methods. The Bray-Curtis dissimilarity statistic quantifies the compositional dissimilarity between sites based on species abundance and log transforms abundance to account for their order of magnitude (Borcard, et al., 2011). Observations are represented by points and the spread of points within an ellipse reflects the degree of variability across that community; ellipses that encompass smaller space represent communities that have less variability from one observation to the next. Conversely, separation of ellipses within the ordination is a quantitative assessment of similarity so that closer ellipses are more similar and farther ellipses represent less similar plant communities. Since NMS is not an intrinsic value technique, graphs may be arbitrarily rotated, or inverted left-right or top-bottom (Borcard, et al., 2011), but the spread along each axis and relative positions therein are what provide meaning.

Species are charted by the first three letters of the genus and first three letters of the species (i.e, Ade vas = *Adelia vaseyi*). A full list of species names can be found in Appendix 1. The proximity between species on the MNS graph represents the strength of their associations: i.e., how likely those species are observed together in similar abundances. The proximity of species to observation points can be interpreted as associations between those species and observation points, meaning the species closest to a point were those most likely to be observed there. Species within a site's 95% confidence interval were most strongly associated with that site or perhaps only found there. When species are graphed near a site's confidence interval but outside it in a direction away from the other sites, this often denotes that the species was only found there, but not in every transect or plot. If the species is equidistant between two sites, it is probably equally likely to be found at either site. Species in the center of the NMS graph are either found across various sites in similar abundances.

Four separate NMS ordinations were conducted following the same parameters from the PerMANOVA analyses, which used community composition based on species area converge (dominance) or relative abundance (frequency) and sites separated into transects (four observations per site) or plots (two observations per site). The baseline ordination also used the parameters of dominance and transects (figure 4.1a). The main interpretation of these results is that all sites had distinctive communities that are significantly different from the rest. Some plant communities were more similar than others; for example, La Puerta was more similar to Los Olmos and Yturria Brush and less similar to Cactus Flats and Thompson Road. The La Puerta site demonstrates much less similarity to communities at La Posada, Sabal Palm and Laguna Atascosa, which are closer to the coast, and receive relatively higher amounts of precipitation. Likewise, the community at La Posada was is most similar to those of Sabal Palm and Thompson road.

The NMS ordination that compares community structure using frequency and transects (figure 4.1b) demonstrates a near identical configuration as the aforementioned one using dominance and transects. This shows that there is consistency in interpretation of plant communities regardless of whether the parameters of dominance and frequency are used. Minimum bounding ellipses are usually much larger than their 95% confidence interval counterpart but in these NMS ordinations they were almost the same size. This is because there are only four observations per site but this does not influence the results substantially because there is still significant separation between all eight communities. The community at Cactus Flats had all four transects points near each other on the ordination graph, which resulted in a representation with the smallest ellipse. This means the degree of variability between transects is relatively low. In contrast, the ellipse at Los Olmos is larger, representing higher variability between transects. The Ellipses at La Posada and Sabal Palm are long and narrow, meaning that there is similarity within the transects of a plot but variability between plots.

The additional ordinations compared community composition using dominance and plots (appendix 4a) and frequency and plots (appendix 4b). These ordinations do not provide shapes because the plots only have two observations per site and they group sites into lines instead of ellipses. These ordinations are not as useful but again demonstrate again the consistency interpreting the four NMS ordinations using the different parameters of dominance and transects, frequency and transects, dominance and plots, and frequency and plots. Interestingly, the spread of plant communities from observations in the NMS ordination is nearly identical to their geographical location shown in the map of the LRGV with study site locations (figure 2.3).

Another way to display the similarity and differences of plant community transects in a visual reference is by the virtual representation of plant species found at each site in its corresponding spatial location (figure 4.2). Stratification of canopies is not considered here because of the virtual two-dimensional representation and the overlapping of species make it difficult to distinguish the community species composition. However, this figure provides a visual representation of dominance and variation between transects at study sites. From this figure, for example, we can observe the almost solid cover of *Amyris madrensis* at Laguna Atascosa, which may account for its low diversity indices as well as the random and evenly arranged species composition of Yturria Brush and its higher diversity indices. Structural values of canopy cover at various strata, average transect area cover values and average transect percent cover at various strata are provided in table 4.3.

Table 4.1: Shannon-Weiner diversity indices (top) and Simpson diversity indices (bottom) per site.

Shannon-Wiener Diversity Indices

	Lool	Lapu	Ytur	Cafl	Thrd	Laat	Lapo	Sapa
Plot 1 Transect 1	1.997	2.239	2.920	2.024	1.982	1.299	2.500	2.355
Plot 1 Transect 2	1.785	2.148	2.862	2.109	2.004	0.964	2.539	2.679
Plot 1 Average	1.927	2.217	3.003	2.099	2.025	1.146	2.598	2.566
Plot 2 Transect 1	1.568	2.154	2.598	1.726	1.900	1.201	2.238	2.540
Plot 2 Transect 2	1.314	2.154	2.584	1.879	1.902	1.339	2.635	2.632
Plot 2 Average	1.462	2.214	2.648	1.832	1.932	1.313	2.596	2.628
Total Average	**1.675**	**2.188**	**2.769**	**1.945**	**1.957**	**1.210**	**2.518**	**2.567**

Simpson Diversity indices

	Lool	Lapu	Ytur	Cafl	Thrd	Laat	Lapo	Sapa
Plot 1 Transect 1	0.782	0.844	0.937	0.806	0.783	0.538	0.903	0.87
Plot 1 Transect 2	0.74	0.835	0.942	0.816	0.807	0.394	0.901	0.912
Plot 1 Average	0.776	0.839	0.941	0.809	0.796	0.464	0.905	0.891
Plot 2 Transect 1	0.737	0.861	0.906	0.722	0.804	0.49	0.836	0.903
Plot 2 Transect 2	0.672	0.833	0.91	0.783	0.794	0.492	0.903	0.919
Plot 2 Average	0.705	0.861	0.909	0.755	0.807	0.493	0.881	0.913
Total Average	**0.735**	**0.846**	**0.924**	**0.782**	**0.799**	**0.478**	**0.888**	**0.901**

Table 4.2a: PerMANOVA results examining the relationships between plant community composition based on area coverage (dominance) values by species and transects.

Factor	d.f.	Chi^2	F_{24}	*P*	
Site	7	3.267	7.284	**<0.0001**	*******
Residual	24	1.538			

Table 4.2b: PerMANOVA results examining the relationships between plant community composition based on abundance (frequency) values for each species and transects.

Factor	d.f.	Chi^2	F_{24}	*P*	
Site	7	3.376	7.567	**<0.0001**	*******
Residual	24	1.530			

Legend- d.f: degrees of freedom; Chi^2: Chi^2 test statistic; F24: F statistic with denominator degrees of freedom; P: P-value, with stars denoting statistical significance (*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$).

Table 4.3a: Plant community average area cover per stratum.

		Area cover average (m)			
Site	**Stratum I**	**Stratum II**	**Stratum III**	**Stratum IV**	**Total**
LOOL	177.90	140.91	0.00	0.00	**318.81**
LAPU	110.81	192.50	0.00	0.00	**303.31**
YTBR	125.08	226.59	33.31	0.00	**384.98**
CAFL	224.51	409.70	60.05	0.00	**693.13**
THRD	165.93	629.98	204.17	0.00	**1000.08**
LAAT	57.73	656.37	41.55	0.00	**755.65**
LAPO	16.73	129.50	328.82	269.58	**744.63**
SAPA	182.47	658.22	1106.74	658.21	**651.41**

Table 4.3b: Plant community average percent area cover per stratum.

		Area cover average (%)			
Site	**Stratum I**	**Stratum II**	**Stratum III**	**Stratum IV**	**Total**
LOOL	35.58%	28.18%	0.00%	0.00%	**63.76%**
LAPU	22.16%	38.50%	0.00%	0.00%	**60.66%**
YTBR	25.02%	45.32%	6.66%	0.00%	**77.00%**
CAFL	44.90%	81.94%	12.01%	0.00%	**138.63%**
THRD	33.19%	126.00%	40.84%	0.00%	**200.02%**
LAAT	11.55%	131.27%	8.31%	0.00%	**151.13%**
LAPO	3.35%	25.90%	65.77%	53.92%	**148.93%**
SAPA	9.12%	32.91%	55.34%	32.91%	**130.28%**

*Stratum I (1.0-1.9 m), Stratum 2 (2.0-4.9 m), Stratum 3 (5.0-9.9 m), Stratum 4 (10.0 m +)

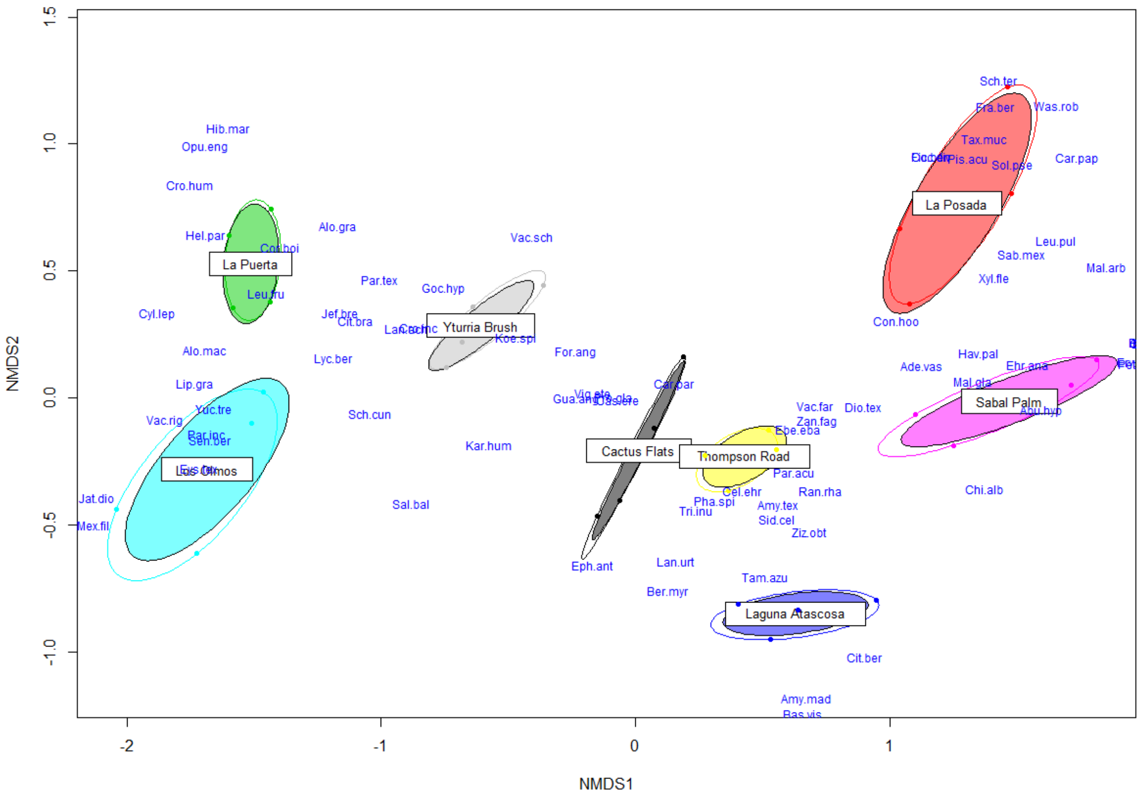

Figure 4.1a: NMS ordination based on species area cover (dominance) using 4 transects per site.

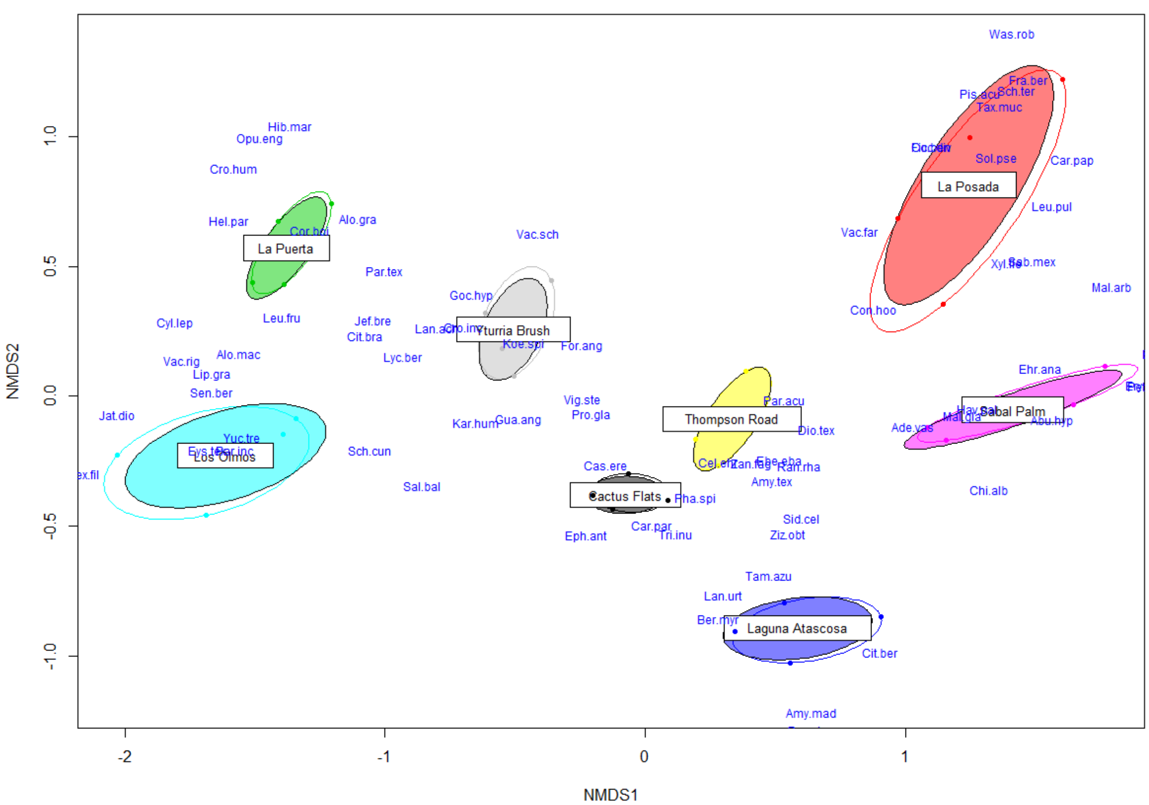

Figure 4.1b: NMS ordination based on species abundance (frequency) using 4 transects per site.

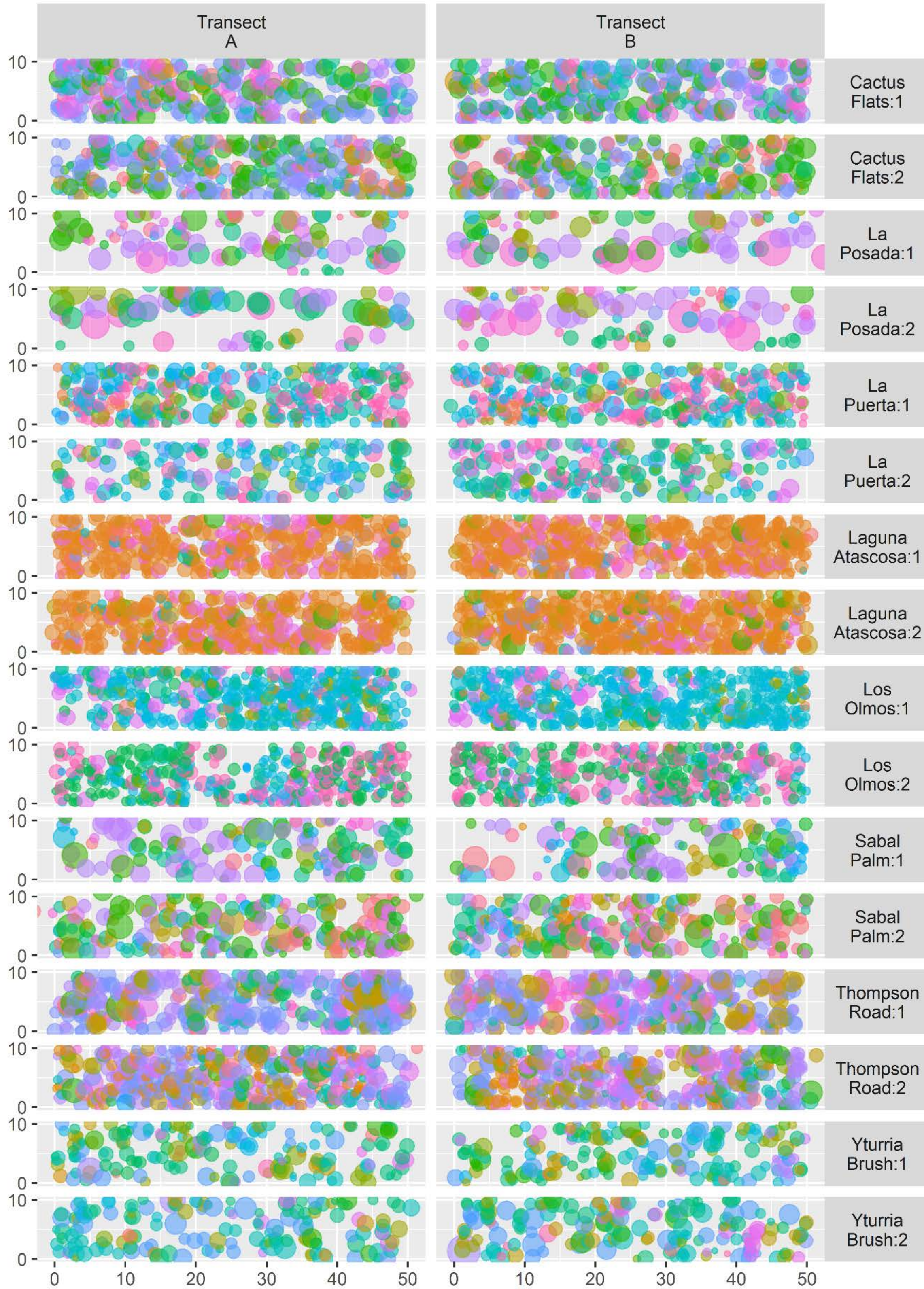

Figure 4.2a: Virtual representation of species across transects

Figure 4.2B: Species representation color legend

CHAPTER V

DISCUSSION

The LRGV is located in the center of the Tamaulipan Biotic Province and is acclaimed for biological interest. Despite this, plant communities are loosely defined and often circumscribed on the basis of observable dominant species and without any sense of degrees of relatedness between each other. This study improves our available ecological understanding with a detailed quantitative comparison of eight remnant plant communities in the LRGV. Given the rejection of the null hypothesis, it is concluded that the vegetation composition of the LRGV is composed of distinct plant communities. The results of this study expose ecological characteristics that have implications for future research and conservation.

The diversity of communities in the Tamaulipan Biotic Province may be influenced by the relatively flat topography of the region which has allowed an ecotone of migration routes. The floral components of the region have particularly high colonization of desert flora extending from west and neotopical flora (Lonard and Judd, 1993; Saghatelyan, 2017) that follows a migration route along the coast and reaches a fundamental niche at the Río Grande Delta. The eight plant communities in this study are all unique and distinct from one another and are classified into various types of vegetation, three of which can be categorized into xeric shrublands, three into thorn forests, one subaquatic gallery forest, and one palm forest (table 5.4). Other types of vegetation that were not part of this study are also represented in the Tamaulipan Biotic Province, such as the prairies of deep sandy soil.

Descriptions of Plant Communities

Descriptions of plant communities are provided using criteria from chapter II: Methods. Communities were then placed into one of the vegetation types adopted by Rzedowski (1978) (Table 5.4). Additional ecological characteristics and distribution of communities are provided. A complete list of species abundance values per plot can be found in appendix 5 and species area cover, area percent covers, and relative percent covers (as determined by the calculations section in chapter II: Methods) per plot can be found in appendices 6 and 6.

Los Olmos

The plant community surveyed at the Los Olmos site is a subdeciduous shrubland on calcareous soils dominated by *Senegalia-Lippia-Leucophyllum* (plot 1) and *Vachellia-Eysenhardtia* (plot 2). This plant community fits under the vegetation type ‘xeric shrubland’ from Rzedowski’s (1978) classification of vegetation types, and it forms a discontinuous canopy that covers approximately 64% of the terrain, although this area coverage would be higher if species that were <1 m in height were included. Shrubs of medium stature (1.0-1.9 m) cover 36% (56% relative cover) of the site and tall-statured shrubs (2.0-4.9 m) cover 28% (44% relative cover) of the site. No plants measured above 5 m in height. The community contains compact shrubs but is open enough to allow human passage by maneuvering around shrubs and using deer or other animal trails through the thickets, which are usually lined with short native grasses

Most of the plants in this community seem to have features that are associated with arid environments. Plants such as *Leucophyllum frutescens* and *Parthenium incanum* exhibit silver-pubescent leaves to block out excess solar radiation. Other plants, such as *Helietta parvifolia*, *Schaefferia cuneifolia*, and *Jatopha dioica* exhibit a thick cuticle or have thick or succulent stems and blades, as is the case for *Yucca treculeana*, *Jatropha dioica*, *Cylindropuntia leptocaulis* and

Lycium berlandieri. Another aspect of this community is that about half of the plants are deciduous. Most of these plants will drop their leaves as a stress response during the hottest and driest period of the year although many of these species will retain their leaves in more favorable years. The data collection for this community was conducted during a drought of the months of June and July and several species had partially or fully lost their leaves, such as *Eysenhardtia texana*, *Lycium berlandieri*, *Salvia ballotiflora*, *Ziziphus obtusifolia*, *Forestiera angustifolia* and *Cylindropuntia leptocaulis* (as expected for most cacti species). Plants such as *Prosopis glandulosa*, *Jathropa dioica*, and *Parthenium incanum* lose their leaves during the short days of the year (coldest time of year=temperate weather) so there is a degree of seasonality of different species dropping their leaves at different times.

A visit to this site was made after the data collection period during the month of February. During this month the otherwise near bare ground (with the exception of strips of short grass species) was a carpet of densely-packed populations of several annual herbs, including *Gilia incisa* (Benth.) J.M. Porter, *Hedeoma drummondii* Benth., *Nama spp.*, *Galium sp*., *Lithospermum matamorense* DC., among others. Peaks in phenology can spike quickly and also be short lived in this type of community.

Dominant species in plot one includes *Senegalia berlandieri* followed by *Lippia graveolens* and *Leucophyllum frutescens. Senegalia berlandieri* (n= 52) and occupies 13% of area cover (20% relative cover). This species is typically the largest shrub of the community. Although small in size, the abundance of *Lippia* and *Leucophyllum* make them the significant components of the community that cover a modest space. *Lippia* (n=428) occupied 11% of area cover (17% relative cover) while *Leucophyllum* (n=378) had an average area cover of 0.28 m^2 an average height of 1.38 m, amounting to 10% area cover (16% relative cover).

The reduced stature recorded for *Leucophyllum* is apparently due to the porous and therefore dry substrate and dry conditions, as this species can grow several times larger in wetter soils. Individual plants of *Leucophyllum* grew so close together at this site that in many instances it was difficult to distinguish individuals apart from one another. The tallest species was *Prosopis glandulosa*, which, not unlike *Leucophyllum*, grows primarily as a shrub in this community due to low water availability. *Prosopis* was encountered five times and had an average area cover of 4.6 m and an average height of 3.4 m, representing only 2.3% of area cover (3.6% relative cover). Given that this is the tallest plant species and its foliage density is sparse, this community provides minimal shade.

Dominant species of plot two were *Vachellia rigidula and Eysenhardtia texana*. *Vachellia* (n=241) occupied 32% area cover (51% relative cover), while *Eysenhardtia* (n=360) occupied 17% area cover (27% relative cover). This plot showed signs of previous grazing on account of with the abundance of *Eysenhardtia*, a pioneer species. The tract is now left fallow and demonstrates various stages of plant succession.

Subdeciduous shrubland communities of calcareous soils can be found along the Bordas Escarpment. There is high variation in plant dominance, depending on the depth of soil. In areas where there are outcrops of calcium carbonate, it is common to find communities dominated by *Leucophyllum,* sometimes referred to as "cenizales" (Crosswhite, 1980), such as the *Senegalia-Lippia-Leucophyllum* association found in plot one. These have been observed in the Tamaulipan Biotic Province north of the LRGV in counties at least into Live Oak County and southward in the state of Tamaulipas often mixed with the characteristic species, *Yucca filifera* Chabaud. Due to extensive grazing, similar community structure of plot two can be found across rangelands of the Tamaulipan Biotic Province.

La Puerta

The plant community surveyed at La Puerta is a tall shrubland on calcareous soils. The vegetation is defined by a tall element with dark green canopies, *Helietta parvifolia* and dominated by *Vachellia* and mixed shrubs in plot one and by *Helietta* and mixed shrubs in plot two. This plant community fits under the vegetation type 'xeric shrubland' and exhibits a discontinuous canopy that covers approximately 61% of the site. The community is dominated by tall shrubs between 1.9-4.9 m amounting to 39% area cover (63% relative cover) and by similar shrubs between 1.0-1.9 m that occupy 22% of area cover (37% relative cover). No vegetation was measured above 5 m. Some areas have dense canopies but the vegetation cover is discontinuous enough to allow human passage. The understory of this community has bare ground in many areas but several species characteristic to calcareous soils type can be found including *Dalea pogonathera* A. Gray, *Krameria ramosissima* (A. Gray) S. Watson, *Turnera diffusa* Willd. Ex Schult., *Acalypha radians* Torr., *Thamnosma texana* (A. Gray) Torr. and the endangered *Manihot walkerae* Croizat, and several graminoids.

Dominant species in plot one includes *Vachellia rigidula* (n= 235), which occupies 17% of area cover (26% relative cover), and in association with *Opuntia engelmanni*, which occupies 11% area cover (16% relative cover). Localized sites with dense stands of *Opuntia* are often avoided by larger mammals but provide excellent cover for small mammal and bird nesting and forage for various wildlife species such as eastern cottontails (*Sylvilagus floridanus*) and the threatened Texas tortoise (*Gopherus berlandieri*). *Cordia boissieri* covers 7% of the site (11% relative cover). *Helietta parvifolia* is the characteristic climax species of this community and occupies the higher strata of the canopies (ca. 3.4 m). In this plot it was a subdominant species (n=30) and occupies about 9% plant cover (13% relative cover).

Dominant species of plot two were *Helietta parvifolia* (n=109) and accounts for 12% area cover (22% relative cover), while *Senegalia berlandieri* (n=51) occupies 9% area cover (16% relative cover) and *Vachellia rigidula* (n=57) had about 8% area cover (14% relative cover). These shrubs along with *Parkinsonia texana* and *Cordia boissieri* formed the bulk of the canopy with an average height between 2-2.5 m. At a lower stratum near 1 m *Lippia gravelons* was frequently encountered as was *Croton humilis*, which was under-represented in both plots on account of its short stature (<1 m).

Tall shrubby communities on calcareous soils characterized by the dominance of *Helietta parvifolia* can be found on southern portions of the Bordas Escarpment. This community type is rare in the United States and restricted to a few areas of Starr County. It persists more commonly in Tamaulipas where it can also be found on hilltops of rocky substrates.

Yturria Brush

The plant community surveyed at Yturria Brush was a thorn-scrub on thin eolian soils dominated by a mixture of varying shrubs. Although there were no clear dominant plant species, some that share co-doiminance include *Parkinsonia texana*, *Koeberlinia spinosa*, *Ebenopsis ebano*, *Prosopis glandulosa*, and *Gochnatia hypoleuca*.

This plant community fits under the vegetation type “xeric shrubland” and is distinguished by its thorny vegetation and discontinuous canopy that covers around 77% area cover, although this calculation would be higher if species <1 m in height were included. This community has two main woody strata, the shorter of which (stratum I, from 1.0-1.9 m) accounts for 25% of area cover (32% relative cover) and the taller stratum (II from 2.0-4.9 m) attains 45% area cover (59% relative cover). Stratum III (from 5.0-9.9 m) attains 7% area cover (9% relative cover), this on account of three large, isolated mesquite trees. The density and stature of the vegetation changes apparently under different soil conditions. Soil with deeper sand and more aeration tend to engender a more open and smaller statured, herbaceous vegetation. Among these members of the community are included *Melampodium cinereum* DC., *Menodora heterophylla* Moric. Ex DC., *Palafoxia texana* DC., *Justicia pilosella* (Nees) Hilsenb., *Nama hispidum* A. Gray, *Hibiscus martianus*, *Thymophylla sp*., *Erogrostis sp*., and *Aristida sp*. Areas with denser soils sustain a denser and taller shrub layer, resulting in continuous cover and minimal herbaceous cover. This is especially apparent in plot of this study, where the canopy cover reached 107%.

This vegetation includes a mixture of different shrub species whose frequency and area cover fluctuates continuously throughout the landscape. The complex mixtures of co-dominant shrubs are what gives the Yturria Brush site the highest diversity values from the eight communities surveyed. This diversity is also reflected in the structure and growth habits of various shrubs. Some species are deciduous (i.e. *Parkinsonia texana* and *Prosopis glandulosa*) but there is little leaf litter since most species produce small leaves or leaflets. *Cordia Boissieri* and *Ebenopsis ebano* produce the most shade and leaf litter and create cooler microclimates for other organisms in the understory. Mature *Ebenopsis* individuals grow to approximately 4 m and emerge as one of the taller species. Their dense foliage and thorny branches make for desirable nesting sites for birds.

Dominant species of plot one includes *Parkinsonia texana* (n=28), which accounts for 12% area cover (20% relative cover), in association with *Cordia boissieri* (n=18, 7% area cover, 12% relative cover) and *Ebenopsis ebano* (n=14, 7% area cover, 12% relative cover). This plot had a discontinuous canopy where a forb and graminoid dominated understory is develops during wet seasons. Conversely, dominant species of plot two include *Parkinsonia texana* (n=56), amounting to 26% area cover (28% relative cover), few *Prosopis glandulosa* trees (n=2) that reach 11% area cover (11% relative cover), *Koeberlinia spinosa* (n=37, 15 % area cover, 16% relative cover) and *Gochnatia hypoleuca* (n=45, 8% area cover, 9% relative cover). This plot had patches of discontinuous cover and other patches where shrubs comprise dense stands. This habitat was often utilized by small mammals such as pack rats, which utilize the thorns to build their nests. This community and in particular this plot had an abundance of various lichens that live on both living and deceased branches. These lichens possibly favor some shrubs, such as *Castela erecta* (figure 5.3). The codominance of *Gochnatia hypoleuca* was also observed to be an important nectar source that attracts various insects in the Fall season, when most other species are lacking flowers.

Thornscrub of thin eolian soils dominated by mixed shrub species are widespread communities found throughout the majority of the Tamaulipan Biotic Province. These communities vary in density where they transition from dense shrublands to savannah grasslands and vary in species composition and dominance. The Tamaulipan Biotic Province represents a transition zone. Some species that comprise these communities reach their range limits and are replaced by other species. This is observed in species such as *Citharexylum brachyanthum* which is absent in the northern and eastern areas of the Tamaulipan Botic Province, while other species such as *Mahonia trifoliolata* (Moric.) Fedde are found in thornscrub of thin eolian soil communities of the province, but only outside of the LRGV (Turner et al., 2003). Many other species are found throughout thornscrub of thin eolian soil communities such *Prosopis glandulosa* and *Celtis ehrenbergiana*, the former found with dominance correlated to amount of disturbance. This was found in the climax vegetation of the Yturria Brush transects, which had only a few large *P. glandulosa* trees and otherwise can form near monocultural stands in disturbed soils.

Cactus Flats

The plant community surveyed at Cactus Flats is a short thorn-forest on thin eolian soils dominated by *Ebenopsis ebano* and *Phaulothamnus spinescens*. The community is justifiably identified locally as a 'thorn-forest' but exhibits subtle difference in comparison to other thorn forest types in the LRGV that used to gradually transition to other types of vegetation, as has been observed in Mexico (Rzedowski, 2006). The community at Cactus Flats can just as well be classified as a shrubland since most species are shrubs and the shrub layer is very dense. Only three tree species regularly reached above 4 m in height: *Ebenopsis ebano*, *Prosopis glandulosa*, and *Sideroxylon celastrinum*. Of these, *Ebenopsis* is the most prominent and at this study site its trucks branched at the base in a shrub-like manner. Forty-five *Ebenopsis* trees <4 m tall cover 147 m^2 in plot one, while 42 individuals >4 m tall cover $291\ m^2$. Plot two had 81 *Ebenopsis* trees <4 m tall cover $173\ m^2$ while 61 trees >m tall covered $396\ m^2$. Since most *Ebenopsis* area cover exceeded 4 m in height, the zone suggests the aspect of 'thorn-forest' than a thicket.

This short-thorn forest community has a continuous canopy with 139% cover. Stratum I (1.0-1.9 m) had 45% area cover (32% relative cover); stratum II (2.0-4.9) amounted to 82% area cover (59% relative cover) and stratum III (5.0-9.9 m) reached 12% area cover (9% relative cover). Consequently, the forest's midstory accounts for the bulk of the cover. Ground cover with herbaceous species is sparse underneath the dense canopy of *Ebenopsis*.

The dominant species in plot one are *Ebenopsis ebano* (n=87), amounting to 44% area cover (30% relative cover), with *Phaulothamnus spinescens* (n=257), amounting to 38% area cover (26% relative cover). These two species alone account for 56% of the relative cover at this plot. Another subdominant species in the tree layers is *Sideroxylon celastrinum*, accounting for 11% area cover (7% relative cover), along with other subdominant shrub species, such as *Guaiacum angustifolium* (14% area cover, 9% relative cover) and *Tamaulipa azurea* (10% area cover, 7% relative cover).

Dominant species in plot two include *Ebenopsis ebano* (n=142), amounting to 57% area cover (43% relative cover) and *Phaulothamnus spinescens* (n=255), commanding around 29% area cover (22% relative cover). These two species alone account for 65% of the relative cover in this plot. Another significant tree species is *Prosopis glandulosa*, which occupies 13% area cover (10% relative cover) and is the most dominant species in strata III (5.0-9.9 m), amounting to 55% relative cover in that stratum. Other subdominant shrub species include *Zanthoxylum fagara* (11% area cover, 9% relative cover), *Celtis ehrenbergiana* (9% area cover, 6% relative cover), and *Guaiacum angustifolium* (7% area cover, 5% relative cover). Surprisingly, *Zanthoxylum* was present 80 times in plot two and absent in plot one despite their close proximity of these plots. This supports the notion that no two plots of land are exactly the same in time or space.

The short thorn-forest of thin eolian soils dominated by *Ebenopsis ebano* and *Phaulothamnus spinescens* is located in the northeastern Hidalgo County before transitioning into unique plant communities on deeper sands further north. The surrounding natural vegetation is composed of mixed shrublands and wooded potholes. The vegetation from the community surveyed deviates from the surrounding vegetation and may be a unique community from the area. This community type could have been more locally extensive before the introduction of livestock to the area.

Thompson road

The plant community surveyed at Thompson road forms a dense thorn-forest on delta (alluvial) loams dominated by *Celtis ehrenbergiana* and *Phaulothamnus spinescens* (plot one) and mixed thorny species (plot two). This stratified forest to 10 m tall is very dense and averages 200% area cover (plot one with 234% and plot 2 with 166%). The dense canopies lower understory temperatures and raises the humidity, which reduces water stress and allows some plant species to survive extreme drought and cold wind in the winter. Large mammals cannot readily navigate the dense plant cover except when using select trails, but small and agile mammals ostensibly seek out this vegetation for protective cover.

The tallest species is honey mesquite, which often exceeds the continuous canopy but is infrequent and can be absent for long stretches. Beneath *Prosopis* canopies there is a discontinuous tree layer in shared by *Ebenopsis ebano* and *Sideroxylon celastrinum*, thereby endowing the vegetation with dark green midstory. Most lateral branches of *Ebenopsis* trees arise from trunks around 1.9 m from the ground. This growth habit contrasts those at Cactus Flats, where *Ebenopsis* trees branch profusely from the base of the trunk as shrubs. Shrubs are the most dominant life form in both plots. Of these, *Phaulothamnus spinescens* forms dense round stands mixed with *Randia rhagocarpa*, which forms a more open canopy, and *Celtis ehrenbergiana*, which intertwines through the understory and forms patches of dense impenetrable vegetation. Several understory species compete where reduced light filters through, such as *Amyris texana* and *Tamaulipa azurea*, these usually reaching mature growth to 1.5 m. The rare plant species *Justicia runyonii* (Oerst.) Hemsl. can form a ground cover at this site, otherwise there is minimal herbaceous growth in the understory.

The dominant species in plot one are *Celtis ehrenbergiana* (n=98), accounting for 60% of area cover (26% relative cover) and *Phaulothamnus spinescens* (n=284) for 59% area cover

(25% relative cover). These and other shrub species, such as *Randia rhagocarpa,* make strata II (2.0-4.9 m) the dominant strata with 143% area cover (61% relative strata cover). As for trees, *Prosopis glandulosa* makes up 29% area cover (12% relative cover), *Sideroxylon celastrinum* 27% area cover (12% relative cover), and *Ebenopsis ebano* 16% area cover (7% relative cover).

The dominant shrub of plot two is *Phaulothamnus spinescens* (n=228), comprising 33% area cover (20% relative cover). Other subdominant shrubs include *Celtis ehrenbergiana*, occupying 24% area cover (14% relative cover), *Randia rhagocarpa* (20% area cover, 12% relative cover), and *Amyris texana* (10% area cover, 6% relative cover). The dominant tree of this plot is *Sideroxylon celastrinum* (n=57), amounting to 32% area cover (19% relative cover). Other subdominant trees include *Ebenopsis ebano* (21% area cover, 13% relative cover) and *Condalia hookeri* (10% area cover 6% relative cover).

In the Tamaulipan Biotic Province there are various types of thorn forests, one of which occupies areas with less than 700 mm of annual rainfall, such as the community described as very compact thorn forest of delta soils and can be found throughout the Río Grande delta and in pockets of Tamaulipas and Nuevo Leon. Another type is found in southeastern Tamaulipan Biotic Province where annual rainfall exceeds 700 mm, such as the Soto La Marina, Tamaulipas area. These forests have a higher representation of epiphytes, vines and understory herbs that grow rapidly during the rainy season (González-Medrano, 1972). These forests transition into tropical deciduous and subdeciduous forests and in some cases are thought could be the result of disturbance of tropical deciduous forests (Puig, 1974 in Rzedowski, 2006). Disturbance to thorn forests often give rise to thorn shrublands, with altered species compositions, especially in areas where vegetation was historically influenced by a river or water source and now cut off from that source. In low areas or soils that remain hydrated, at least seasonally, the woody species

Vachellia farnesiana, *Parkinsonia aculeata*, *Leucaena leucocephala*, *L. pulverulenta*, and *Baccharis neglecta* usually dominate, the latter species often becoming dominant after agricultural disturbance. The understory is dominated by the invasive Guinea grass (*Urochloa maxima* (Jacq.) R Webster).

Laguna Atascosa

The plant community surveyed at Laguna Atascosa is a short thorn-forest on clay lomas (clay-loam rises) dominated by *Amyris madrensis*. Although this species is not armed with thorns, the other subdominant species are often armed. This forest community is characterized by the dominance of *Amyris madrensis*. On this particular loma, *A. madrensis* trees tend to branch near the base, but produce several minor trunks that reach up to 5 m in height (but usually shorter, figure 5.4). At the Cactus Flats site, *A. madrensis* grows more like a typical shrub, branching profusely at the base.

Like the other thorn forest communities surveyed in this study, this community has evergreen foliage and the dominant cover occurs in stratum II (2.0-4.9 m), with an average area cover of 131% (relative cover of 89%). The canopy density of an individual *Amyris madrensis* is sparse but when grouped together the trees form a dense dark canopy and poorly vegetated understory. Herbaceous species in the community include *Justicia turneri* Hilsenb. and *Tragia glanduligera* Pax & K. Hoffm. In stratum I (1.0-1.9 m), *Tamaulipa azurea* fills sporadic light gaps. Unlike other thorn forests communities, this community lacked diversity and dominance of leguminous species, save for *Ebenopsis ebano*.

The dominant species of plot one is *Amyris madrensis* (n=629), comprising 107% area cover (73% relative cover) and comprising a near-monoculture of this shrubby member of the citrus family. Other subdominant species include *Sideroxylon celastrinum* (17% area cover, 11% relative cover) and *Ebenopsis ebano* (8% area cover, 6% relative cover).

The dominant species of plot two is *Amyris madrensis* (n=769), which reaches 82% area cover (53% relative cover). Other subdominant species include *Celtis ehrenbergiana* (24% area cover, 16% relative cover), *Sideroxylon celastrinum* (22% area cover, 14% relative cover), and *Ebenopsis ebano* (11% area cover, 7% relative cover). This plot differed from plot one by a slight increase of area cover from *S. celastrinum* and *E. ebano* and a significant increase in cover from *C. ehrenbergiana*. *Celtis ehrengergiana* was encountered only once in plot one, covering 1.77 m^2, but was encountered 41 times in plot two covering 244.11 m^2. This species defines a significant character of this community as its branches weave through foliage and to create a dense, thorny vegetation.

The frequency of *A. madrensis* also increased from 629 observations in plot one to 769 in plot two, although the area cover decreased by 244m^2 in the latter. This is reflected by the higher representation of *A. madrensis* in stratum I (1.0-1.9 m) of plot two, which suggests that there are younger trees that are competing for resources. This plot also supported the highest population of ticks from any other plot in the study.

Short thorn forest of clay lomas dominated by *Amyris madrensis* represents an anomalous community in the Tamaulipan Biotic province. Every loma supports a unique community but, for unknown reasons, there are no other known lomas that are dominated by *A. madrensis*. It is worth noting the absence of *Prosopis glandulosa* in these plots since this tree is found in all major soil types from the Tamaulipan biota, including the relatively saline soils that border this loma. If this loma was heavily disturbed at any point we would expect to have a presence of *P. glandulosa*. Further study on is necessary to determine why *A. madrensis* is so abundant on this loma, along with a broader survey of clay lomas are necessary to better understand coastal land ecology and critical habitats the endangered northern ocelot (*Leopardus pardalis*), which use lomas for cover, to den and disperse.

La Posada

The plant community surveyed at La Posada is a gallery forest of the banks of a resaca (oxbow lake) formed primarily by large *Taxodium mucronatum* trees that intermingle with *Ebenopsis* and *Sabal* in plot one and primarily *Sabal* in plot two. This plant community fits under the vegetation type "aquatic and subaquatic." More specifically, it is a subcategory of vegetation called "gallery forest," connoting an arborescent corridor along more or less perennial streams in an area that is otherwise more devoid of trees. These forests serve as corridors of biodiversity that support more life forms than surrounding areas and are important roosting areas for migrating birds. The high amounts of leaf litter and moist soil conditions support healthy reptile populations such as those of the Central American indigo snake (*Drymarchon melanurus)*, Texas coral snake (*Micrurus tener*) four-lined skink (*Eumeces tetragrammus*), and green anole (*Anolis carolinensis*).

This community has a continuous, highly stratified vegetation with a tall canopy measured at 149% cover. The dominant strata are III and IV, where stratum III covers an average of 66% and stratum IV covers an average of 54%. Stratum IV is dominated by *Taxodium mucronatum*, most individuals of which reach above 15 m in height. Strata I and II are dominated by immature trees and shrubs; Stratum I, amounting to only 3% area cover and strata II to 26%. The epiphytes *Tillandsia baileyi* Rose ex Small and *T. recurvata* (L.) L. as well as tall vines (*Nekemias arboreus*, *Cocculos diversifolius*, *Mikania scandens* (L. Willd), and *Cissus trifoliata* (L.) L.) festoon many tree canopies and further block out sunlight by their profuse growth, thereby precluding a rich herbaceous understory, which on forest margins is often dominated by *Achyranthes aspera* L. The grape family member, *Cissus trifoliata*, dangles adventitious aerial roots from aerial stems and is beginning to outcompete other native plants (figure 5.5).

The dominant species of plot one is *Taxodium mucronatum* (n=9), which attains 49% area cover (34% relative cover). This species towers above the rest of the vegetation and constitutes 86% of stratum IV. Subdominant species include *Ebenopsis ebano* with an area cover of 37% (26% relative cover) and *Sabal mexicana* with an area cover of 32% (22% relative cover).

The dominant species of plot two is *Taxodium mucronatum* (n=8), which accounts for 42% of area cover (27% relative cover). This giant emergent tree to >20 m constitutes 79% of stratum IV. The subdominant species in this plot is *Sabal mexicana*, which amounts to 33% area cover at lower strata (22% relative cover). There are several successional species in this plot that have not reached full maturity, such as *Fraxinus* berlandieriana, which has a median height of only 3.2 m but is frequent enough to constitute 23% area cover (15% relative cover). Other species of importance in this plot are the hardwoods *Condalia hookeri* (18% area cover, 11% relative cover) and *Ebenopsis ebano* (12% area cover, 8% relative cover).

This plant community is not wholly intact due to continual human disturbance in an urban environment, the presence of several invasive species, as well as a lack of seasonal flooding in the present day, which played a historical role in shaping the species composition and structure of this unique community in the recent past. This site is, however, the last known community dominated by *Taxodium mucronatum* in the LRGV and it provides the best possible window into the LRGV's natural history, during an age which vast sections of the Río Grande and associated resacas of Cameron County were dominated by this charismatic tree. On the Mexican side of the Tamaulipan Biotic Province, gallery forests dominated by *Taxodium mucronatum* are still found along streams and creeks but their composition and abundance can vary considerable and therefore require further study.

Sabal Palm Sanctuary

The plant community surveyed at Sabal Palm Sanctuary is a tropical palm forest on alluvial soils characterized by the fan palm species, *Sabal mexicana*, in association with *Ebenopsis* in plot one and *Ebenopsis* and *Havardia* in plot two. This plant community does not constitute a major vegetation type in South Texas but merits attention for its distinct structure and historical importance. These forests are found in floodplain soils and in some cases their existence can be determined by periodic fire (Rzedowski, 2006). Dried palm fronds create deep leaf litter which is important habitat for wildlife, such as the speckled racer (*Drymobius margaritiferus*), but can also serve as fuel for fires during dry seasons. Apart from the dominant palm trees, this community supports several species with neotropical plant groups, such as *Sabal mexicana*, *Solanum erianthum*, *Xylosma flexuosa*, *Pisonia aculeata*, *Chiococca alba*, *Erythrina herbacea*, *Passiflora filipis* Benth., *Iresine palmeri* (S. Watson) Standl., *Plumbago scandens* L., *Tournefortia volubilis* L., among others. Thus, the floristic and faunistic compositions of these communities supports the long-held view that South Texas is tropical in nature (Davis, 1942). Many species found in thorn forests and shrublands make up part of the composition of palm forests, but they often exhibit the distinction of tall arborescent growth habits.

This community exhibits a mostly continuous canopy cover, averaging 130% cover due to tree stratification. Unlike most other communities from this study, stratum I (1.0-1.9 m) co-dominated by *Chiococca alba* and *Malpighia glabra*, is not a prominent component of the vegetation and averages only 9% cover. Stratum IV is mainly comprised of *Sabal mexicana*, and forms a tall, discontinuous canopy that allows pockets of filtered light in the understory. Individual palm canopies are somewhat restricted, averaging approximately 3.0 m in diameter (7.9 m in area^2). Other species occasionally found in strata IV include *Ebenopsis ebano*, *Havardia pallens*, and *Leucaena pulverulenta*.

The dominant species of plot one is *Sabal mexicana* (n=53), maintains around 51% area cover (41% relative cover), followed by *Ebenopsis ebano* (n=46), which constitutes 30% area cover (24% relative cover). These dominant species are mainly found in the upper strata III and IV which exhibit 42% area cover (34% relative cover) and 55% area cover (45% relative cover), respectively. The lower two strata are relatively open and account for a mere 4% area cover (3% relative cover) for strata I and 22% area cover (18% relative cover) for strata II. This plot is located at slightly lower elevation and is likely part of an inundation period after heavy rains from tropical storms. This could allow the development of higher *Sabal mexicana* frequency and a more open understory from periods of standing water and higher leaf litter content from the dominant species.

The dominant species of plot two is *Ebenopsis ebano* (n=75), which accounts for 48% area cover (35% relative cover). Other subdominant species include *Havardia pallens* (17% area cover, 12% relative canopy) and *Sabal mexicana* (14% area cover, 10% relative canopy). This plot had a lower frequency of *S. mexicana* than plot one and less cover in stratum IV with area 11% cover (8% relative cover). The dominant strata were II and III with 44% area cover (32% relative cover) and 69% area cover (50% relative cover), respectively. Strata I was represented with 14% area cover (10% relative cover). This plot has many thorn forest species and is a transition into thorn forest structure and composition.

Tropical Palm forests of alluvial flood plain soils are now limited throughout the southeast delta of the LRGV along the Río Grande and resaca banks. We encounter the most extensive palm forests on the Texas side of the border, about 10 mi (16 km) southeast of Brownsville, TX. Palmetto palm groves become increasingly scattered to the west, where the furthest natural growth appears to be 29 mi (47 km) from the Gulf of Mexico. The extent of natural palm trees are also encountered sporadically near Harlingen, TX (Davis, 1942), in addition to a disjunct population in the central coast of Texas in Jackson and Victoria Counties of South Texas (Lockett and Read, 1990).

On the Mexican side of the Tamaulipan biota, the densest growth of *S. mexicana* is found on either side of the southernmost bend of the river (Davis, 1942) and they extend widely in sandy soils along the gulf coast (Miranda and Hernandez X, 1963) from Tamaulipas to Chiapas, Mexico (Rzedowski, 2006). In many cases, the distribution of these communities is determined by periodic fire (Rzedowski, 2006). There are however, some zones where communities of *S. mexicana* seem to represent the primary vegetation along the coast and form palm monocultures (i.e., 'palmares'; Rzedowski, 2006).

Additional Plant Communities in Need of Study

There are several other plant communities that are represented in the LRGV and the Tamaulipan Biotic Province in addition to the focal ones compared and described above. This section introduces other plant communities and types of vegetation descriptively through literature review and personal observation. This section is far from introducing all communities but gives a broader perspective of the vegetation that covers area of study.

Prairies

Several authors have depicted all or most of southern Texas as prairies or grasslands.

The extent of grasslands in the Tamaulipan Biotic Province was studied by Johnston (1963), where the main remnant grassland communities during the period of study were grouped into three communities types and include: (1) Kleberg clay prairies, which are coastal prairies on clay soil in Kleberg and Nueces Counties; (2) Ingleside and Kenedy sand prairies- on the Ingleside terrace in the counties surrounding Corpus Christi and the Kenedy prairie representing the eolian plain known as the “sand sheet” and it’s peripheries; and (3) the Loreto grasslands of the Loreto caliche sand plain of Tamaulipas, Mexico. These grouping purposefully excluded sparse woody communities even if they were rich in perennial grasses and grassland communities that had minor area cover.

The range of the sand sheet is not easily discernable but includes most of Kenedy and brooks Counties, parts of Kleberg and Jim Hogg Counties, and extends into the LRGV in northern portions of Starr, Hidalgo, and Willacy Counties (Texas Coastal Sand Sheet Wetlands, https://texaswetlands.org/wetland-types/texas-coastal-sand-sheet-wetlands/). The sand sheet has pure, fine sand which can blow into dunes and its peripheral zones have loamier soils of fine sand, silt, and clay. Not all of its area is covered by prairie but vast sections of it are and the prairie becomes increasingly scattered in the peripheries, where woody vegetation begins to replace it (Johnston, 1963).

The community composition of the sand sheet can vary considerably but the structure of its prairie is typically of a midgrass prairie dominated by *Schizachyrium littorale* (Nash) E.P. Bicknell and is frequently encountered with other grasses such as *Elionurus tripsacoides* Humb. & Bonpl. ex Willd., *Paspalum setaceum* Michx., *Aristida purpurea* Nutt. *Chloris cucullata* Bisch., *Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult., and *Cenchrus spinifex* Cav. Forbs are abundant in the grass understory where several perennial and seasonal forbs thrive, most notably in the Spring (Johnston, 1963, McLendon, 1991, and Andrea Bueno, unpublished data)

Riparian

The riparian vegetation was not represented in this study because of the lack of remnant primary riparian plant communities in the LRGV, of which 98% of their range are estimated to have been negatively affected by or lost to human activity (Leslie, 2016). Santa Ana NWR is considered a tract with prime example of riparian vegetation (Leslie, 2016) although it is believed that no undisturbed old-growth stands as large as an acre remain (Diamond, 1998) and its floodplain forest communities have already been quantitatively documented and mapped out (Vora, 1990).

The most comprehensive study comes from Lonard and Judd (2002), in which riparian vegetation was studied using seven study sites across the LRGV from the mouth of the river to upstream from Roma, TX. This study found sugar hackberry (*Celtis laevigata*) to be the dominant tree species at three of the study sites and the most consistent across riparian communities. Other tree species of importance included *Prosopis glanulosa*, *Ulmus crassifolia* Nutt., *Ehretia anacua*, *Fraxinus berlandieriana*, *Salix nigra*, and *Salix exigua* Nutt. The most important species of the shrub layer were *Celtis ehrengergiana* and *Zanthoxylum fagara*. The ground layer at four of the sites was dominated by the invasive *Urochloa maxima* and one site of the invasive *Pennisetum ciliare* (L.) Link and the other two sites were near the gulf coast and nearly restricted to halophytes. These results demonstrate the lack of pristine remnants of riparian vegetation in the LRGV, which continue to be encroached by invasive species. One of the study sites was the floodplain-bottomland community at Santa Ana NWR where *Urochloa* *maxima* had displaced *Rivina humilis* L. as the dominant ground layer species 12 years after the study conducted by Vora (1990).

Coastal

Coastal communities were not included in this study since coastal vegetation is clearly distinct from inland vegetation and is usually studied separately. The vegetation of the Gulf of Mexico is composed of the facultative coastal vegetation found throughout the continent with higher temperate influence in the northern portions of the gulf and higher tropical influence in the southern of the gulf (Rzedowski, 1978, Lehman, et al., 2005; Richardson and King, 2011).

The influence of wind-blown salt spray, high tides from hurricanes, elevation, and soil composition supports a diversity of plant community types that include salt and brackish tidal marshes, coastal dunes and grasslands, and saline coastal prairies (Leslie, 2016). Plant composition in salt and brackish tidal marshes are directly influenced by the abiotic factors mentioned above, where brackish marshes are typically dominated by *Monanthochloe littoralis* Engel., *Batis maritima* L., *Borrichia frutescens* (L.) DC., and *Spartina spartinae* in decreasing order of importance and salt marshes by *Spartinae spartinae, Monanthochloe littoralis, Borrichis frutescens* and *Sporobolus virginicus* (L.) Kunth (Judd and Lonard, 2002). Coastal dunes are found on barrier islands and include shifting dunes and permanent dunes- where the leeward side is protected from the wind and is typically more vegetated (Clover, 1937 and Leslie, 2016). Coastal prairies occur on level terraces in remnant patches mostly in private land (Leslie, 2016).

Arroyo Brush

Arroyo brush is a local term to denote vegetation growing along the Arroyo Colorado. The Arroyo Colorado is the only permanent stream in the LRGV other than the Río Grande. Its channel begins southwest of Mercedes, TX in eastern Hidalgo County, and proceeds northeast through Cameron County where it drains into the Laguna Madre (Heep and Lester, 2011). Some of the vegetation along the Arroyo supports some of the most intact plant communities in the LRGV (Ken King, personal communication), although currently only a few fragments remain with some of them set purchased for conservation, but continual pressures threaten its vegetation (Mild, 2011; Mild 2017).

The surface sediments along the Arroyo Colorado are mostly of late Pleistocene deposits, as opposed younger Holocene deposits of the Recent Delta that surround it (Brown, 1980; Heep and Lester 2011). The most abundant trees along the Arroyo brush are *Ebenopsis ebano*, *Sideroxylon celastrinum*, and *Adelia vaseyi*. Along some of the ravines, the vegetation is riparian with *Ulmus crassifolia*, *Fraxinus berlandieriana*, *Leucaena pulverulenta*, *Ehretia anacua*, and *Celtis laevigata*. On higher land, the vegetation is shorter and is composed of a community of plants that otherwise more typically dominate the shrublands of the western valley such as: *Vachellia rigidula*, *Castela erecta*, *Leucophyllum frutescens* and a variety of cacti including *Echinocereus berlandieri* (Engelm.) Haage, E. pentalophus (DC.) Lem., Thelocactus setispinus (Engelm.) E.F. Anderson and others. These species are mixed with species characteristic of clay dunes, and others characteristic of mesic woodlands. Other unique elements in the Arroyo brush is the abundance of *Adelia vaseyi* and the presence of the federally endangered *Ayenia limitaris* Cristobal (Poole et al., 2007). The characterization of plant communities along the Arroyo Colorado is worthy of further study.

Augilares Plain

The Augilares Plain is one of the six physiographic zones of the LRGV that area and occurs in the western portion of Starr County north of the Upper Valley Floodplain and west of the Bordas Cuesta and extends northwest to other areas of the Tamaulipan Biotic Province (figure 4.4). The soils are generally a gray sandy loam derived from sandstone, with outcrops of clay and clay with sandstone and caliche. Petrified wood and oyster and other fossils are common there (Hathcock et al., 2014). Most of the Augilares Plain is utilized as private ranches, where disturbance varies from frequently plowed to large tracts of relatively intact climax communities.

Most of the vegetation from the Augilares Plain has been considered a mesquite-grassland with the dominant plants being *Prosopis glandulosa*, *Bouteloua barbata* Lag., and *Aristida purpurea* (Clover, 1937), although this likely considers disturbed communities. Pockets of alkaline soils can be found that support unique plant communities of halophytic plants such as: *Varilla texana* A. Gray, *Hechtia glomerata* (Clover, 1937), *Frankenia jonstonii* Correl, *Coryphantha macromeris* (Engelm.) Lem., *Lenophyllum texanum* (J.G. Sm.) Rose, *Lophophora williamsii* (Lem. Ex Salm-Dyck) J.M Coult. *Atriplex canescens* (Pursh) Nutt., *Atriplex sp*. *Suaeda conferta* (Small) I.M. Johnst., and *Sporobolus airoides* (Torr.) Torr. (Raziel Flores, personal observation). These are mixed with communities of shrubs that often include *Vachellia rigidula*, *Senegalia berlandieri*, *Leucophypllum frutescens*, and *Cordia boissieri* and others.

Focal Species

Despite the differences between the eight communities surveyed, one pattern that they share is that they all had at least one dominant or subdominant legume species. *Ebenopsis ebano* was perhaps the most important tree across the communities surveyed and played a dominant or subdominant role in most communities (figure 6.1). It was the most dominant tree of the Cactus Flats site, where it branched profusely at the base with shrub-like growth, and was a subdominant tree at each of the other sites located within the Río Grande Delta physiographic zone (Thompson road, Laguna Atascosa, La Posada, and Sabal Palm), where *Ebenopsis* grew with a single main trunk in tree-like growth. *Ebenopsis* also played a co-dominant role at the Yturria Brush site, which unlike the other communities previously mentioned, is a shrubland instead of a forest community. The only sites where *Ebenopsis* was not recorded within transect parameters were Los Olmos and La Puerta, which suggests that this species does not compete well in calcareous soils.

At the Los Olmos and La Puerta sites where calcareous soils predominate, *Ebenopsis ebano* is replaced with the legume species *Vachellia rigidula* in importance, which is probably the most common tree/shrub of Starr County and of other areas of South Texas. *Senegalia berlandieri* is also a dominant species in some areas and was subdominant at the Los Olmos site. The most dominant species at the Yturria Brush transects was the legume species *Parkinsonia texana*.

Prosopis glandulosa is perhaps the most iconic species of the region and is ubiquitously found throughout the various soil types, as reflected in the LRGV vegetation map of Clover (1937). *Prosopis*, however, is a successional species that readily colonizes after disturbance or heavy grazing. Although *Prosopis* has been a natural component of Tamaulipan biota vegetation prior to European colonization (Johnston, 1963), the increase in human disturbance and the efficient seed dispersal from cattle grazing has accelerated its spread. *Prosopis* was recorded at Los Olmos, Yturria Brush, Cactus Flats, Thompson road, and La Posada transects, where it was infrequently recorded but had a significantly high area cover. The representation of this species in the stable climax plant communities from this study is likely more consistent with natural vegetation than the representation found in the vegetation map of Clover (1937) or what is seen today.

Other species that played an important role throughout the plant communities surveyed includes *Celtis ehrenbergiana* (figure 6.2). *Celtis* had the highest representation at thorn forest vegetation types, where it forms dense patches of intertwining branches. At the Yturria Brush site *Celtis* exhibits the more typical stunted growth of a xeric shrub. At the calcareous soils transects, *Celtis* was only recorded once at La Puerta and absent at Los Olmos. *Sideroxylon celastrinum* was also recorded in all the study sites except for those of calcareous soils (figure 6.3). It was a subdominant species at Thompson road and Laguna Atascosa. *Phaulothamnus spinescens* was most closely associated with thorn forest plant communities, where it was a dominant shrub. It was also infrequently recorded in plots from La Puerta, Yturria Brush, and Sabal Palm (figure 6.4).

Several community associations of plants were found in this study that were not expected. *Randia rhagocarpa* was found in all of the Río Grande Delta plant communities and played a dominant role at Thompson Road. It can also be infrequently found in xeric shrublands, where it exhibits stunted growth. Since several dominant thorn forest and Río Grande Delta plant species were excluded from the calcareous communities of calcareous soils, they were replaced with typically shorter drought tolerant shrubs. These include *Eysenhardtia texana*, *Leucophyllum frutescens*, and *Lippia graveolens*, which were most closely associated with the Los Olmos, La Puerta, and Yturria Brush sites. *Karwinskia humboldtiana* was found with relatively high abundance across all of the xeric shrubland and thorn forest communities but was not recorded at the La Posada and Sabal Palm sites. This suggests that it does not compete well with taller forests that have higher moisture contents.

Implications for Conservation Initiatives

The natural vegetation of the LRGV has been reduced to remnant isolated community patches. By conservative estimates, the LRGV has suffered human induced habitat degradation in 90-95 percent of woodlands and coastal grasslands and 91-98 percent in riparian zones (Leslie, 2016), which, in large part, have been replaced with exotic invasives as dominant species. The most abundant invasive species include *Urochloa maxima*, *Pennisetum ciliare*, and *Dichanthium annulatum* (Forssk.) Stapf. Other invasive plants that have high degrading impacts include *Chloris gayana* Kunth, *Cynodon dactyon* (L.) Pers., *Dichanthium aristatum* (Poir.) C.E Hubbard, *Bothriochloa ischaemum* (L.) Keng, *Melinis repens* (Willd.) Zizka, and *Sorghum halepense* (L.) Pers. (Best, 2004). The invasion of these species replaced large stands of our landscape with a vegetation that is more indicative of an African savanna than native plant communities.

Due the degradation of the LRGV's native landscape, the community view to conservation implemented by USFWS (Jahrsdoerfer, 1988) is an appropriate approach since it is the scale at which individual populations of species can be identified and grouped to characterize a given area and it is the scale where human activity is centered and where conservation practices and policies can best be applied (González-Medrano, 2004). Many of the plant communities can be considered critically endangered or down to the last remnant patch, such as the *Taxodium* gallery forest at La Posada. Isolated patches serve as a biodiversity sink and identification and conservation of these communities is the most crucial initiative for the survival of all types of wildlife in the area.

Ecological restoration can create corridors between isolated communities and increase gene flow throughout the region. The results from this study can be used to determine the selection of species used in restoration and their relative abundances according to the type of community that is being restored. The structure of communities being restored can also be compared with the structure of intact, remnant communities in this study by monitoring the differences in natural and restored areas, the rate of restoration, and identifying ways to improve restoration efforts. Effective restoration efforts can enhance biodiversity in the area which has potential for economic contributions. Nature tourism in the LRGV is quickly increasing and accounted for a revenue exceeding $300 million in 201l (Leslie, 2016).

This study has compared some of plant communities that are distributed in a mosaic pattern across the region but several others still require further analysis, such as those along the Arroyo Colorado, or a comparison of the coastal lomas. The quantitative description of community structure sets the framework for future ecological studies. Currently one thesis correlated snail diversity using the plant communities from this study (Najev, 2018) with a manuscript submitted for publication (Najev, et al., in review). Other studies can layer different organisms to provide synecology depth; such as the stratification of thorn forests can be correlated with avian abundance and nesting habits. The results of this study intend to be followed up with the correlation of plant communities with the abiotic factors that determine their floral components.

Table 5.1: Study site vegetation classification based on vegetation types from Rzedowski (1978)

Site	**Vegetation Type**
Los Olmos	Xeric shrubland
La Puerta	Xeric shrubland
Ytrurria Brush	Xeric shrubland
Cactus Flats	Thorn forest
Thompson Road	Thorn forest
Laguna Atascosa	Thorn forest
La Posada	Subaquatic woody vegetation: Gallery forest
Sabal Palm	Other: Palm grove

Figure 5.1: Lichens on *Castela erecta*

Figure 5.2: *Amyris madrensis* branching


Figure 5.3: Adventitious aerial roots from *Cissus trifoliata* at La Posada site.

Figure 5.4: Representation of *Ebenopsis ebano* at study site transects.

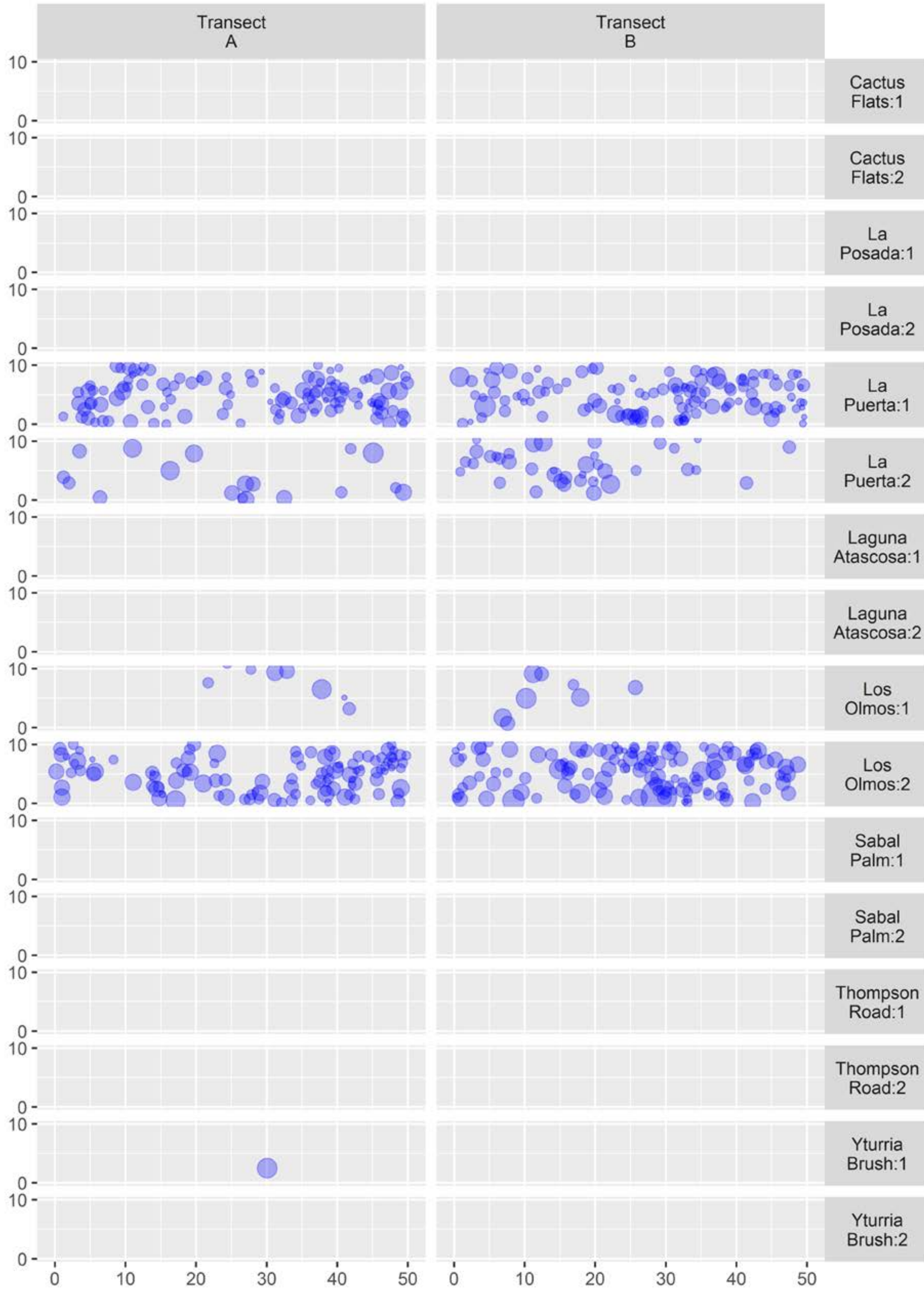

Figure 5.5: Representation of *Vachellia rigidula* at study site transects.

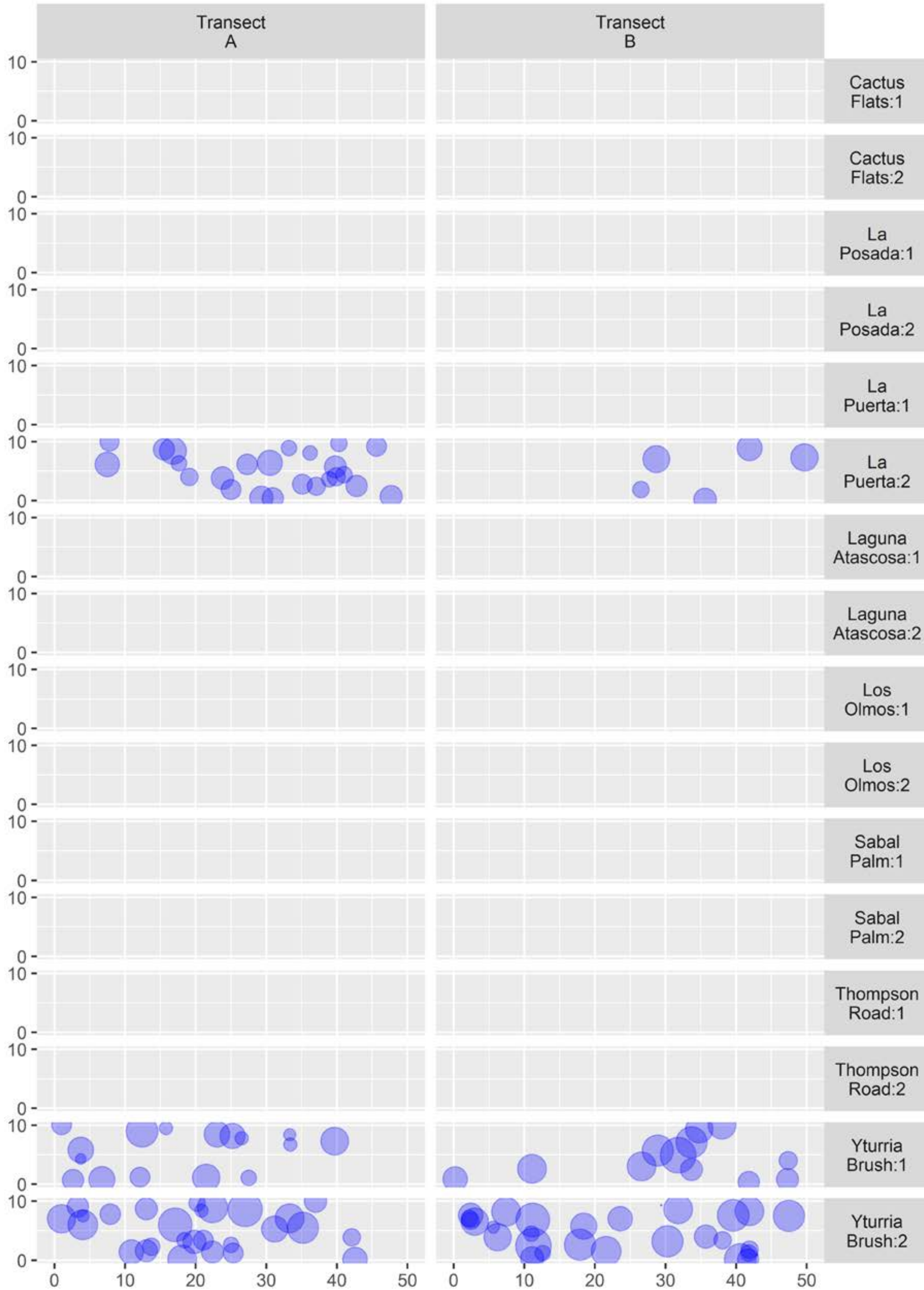

Figure 5.6: Representation of *Parkinsonia texana* at study site transects.

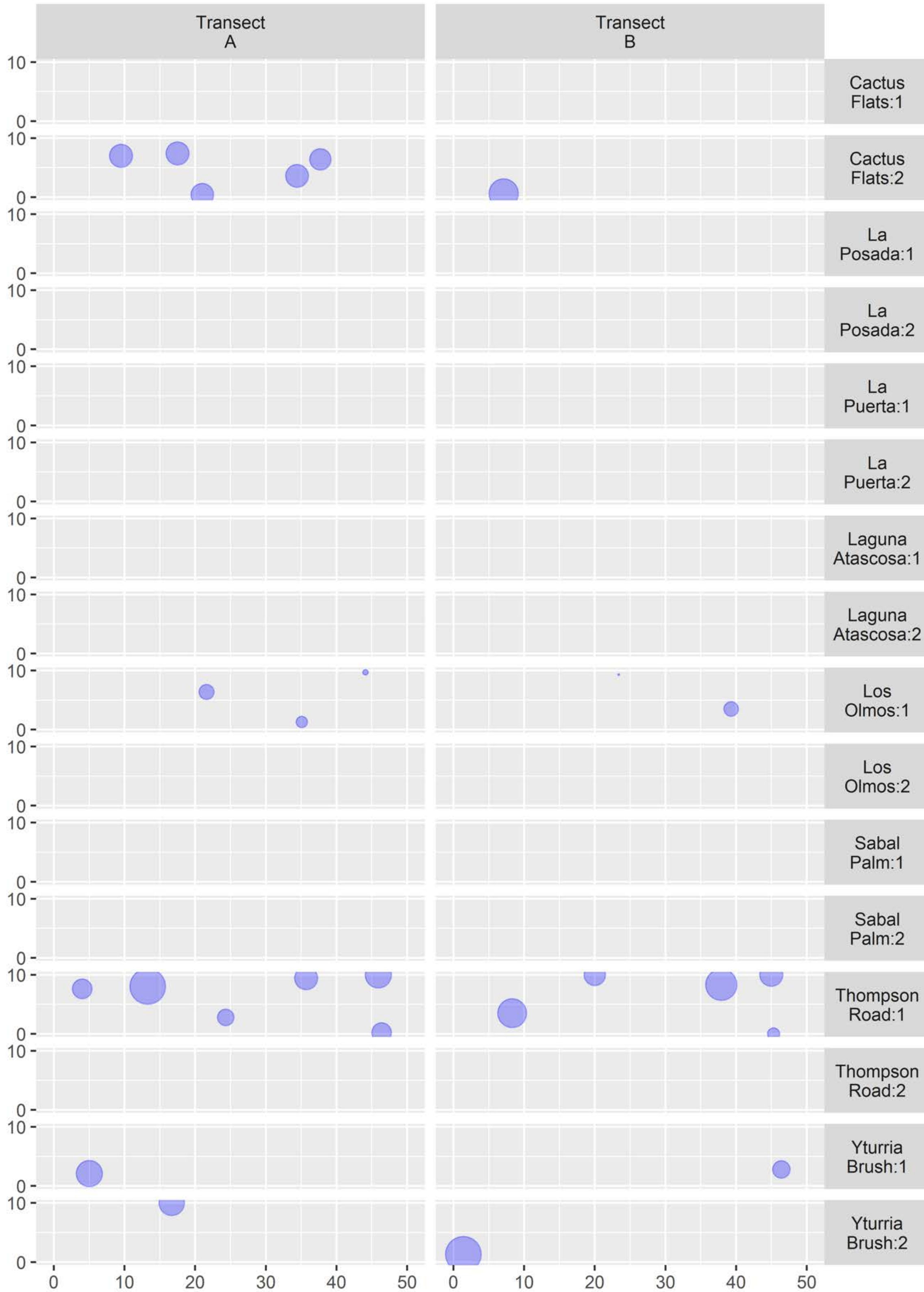

Figure 5.7: Representation of *Prosopis glandulosa* at study site transects.

Figure 5.8: Representation of *Celtis ehrenbergiana* at study site transects.

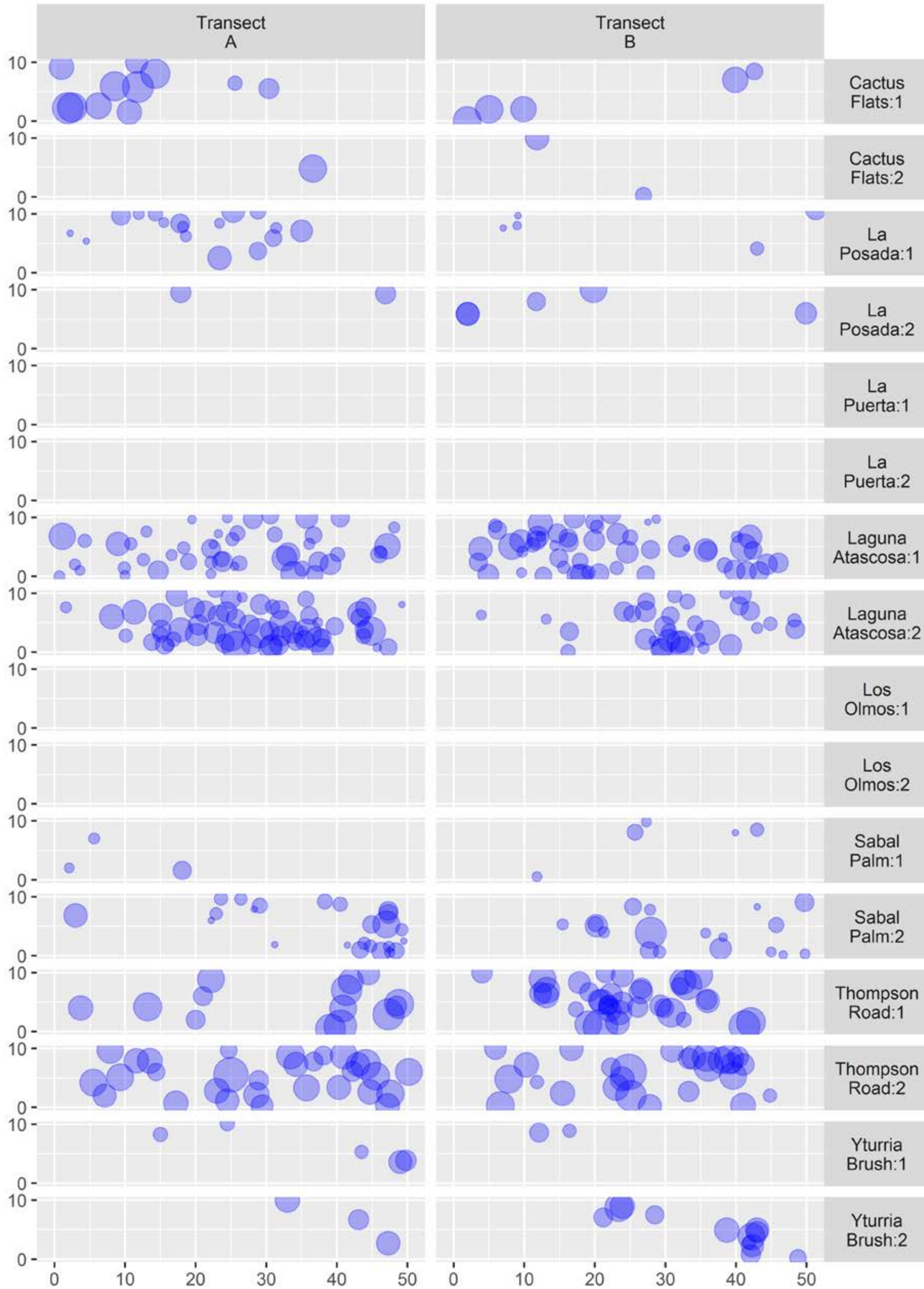

Figure 5.9: Representation of *Sideroxylon celastrinum* at study site transects.

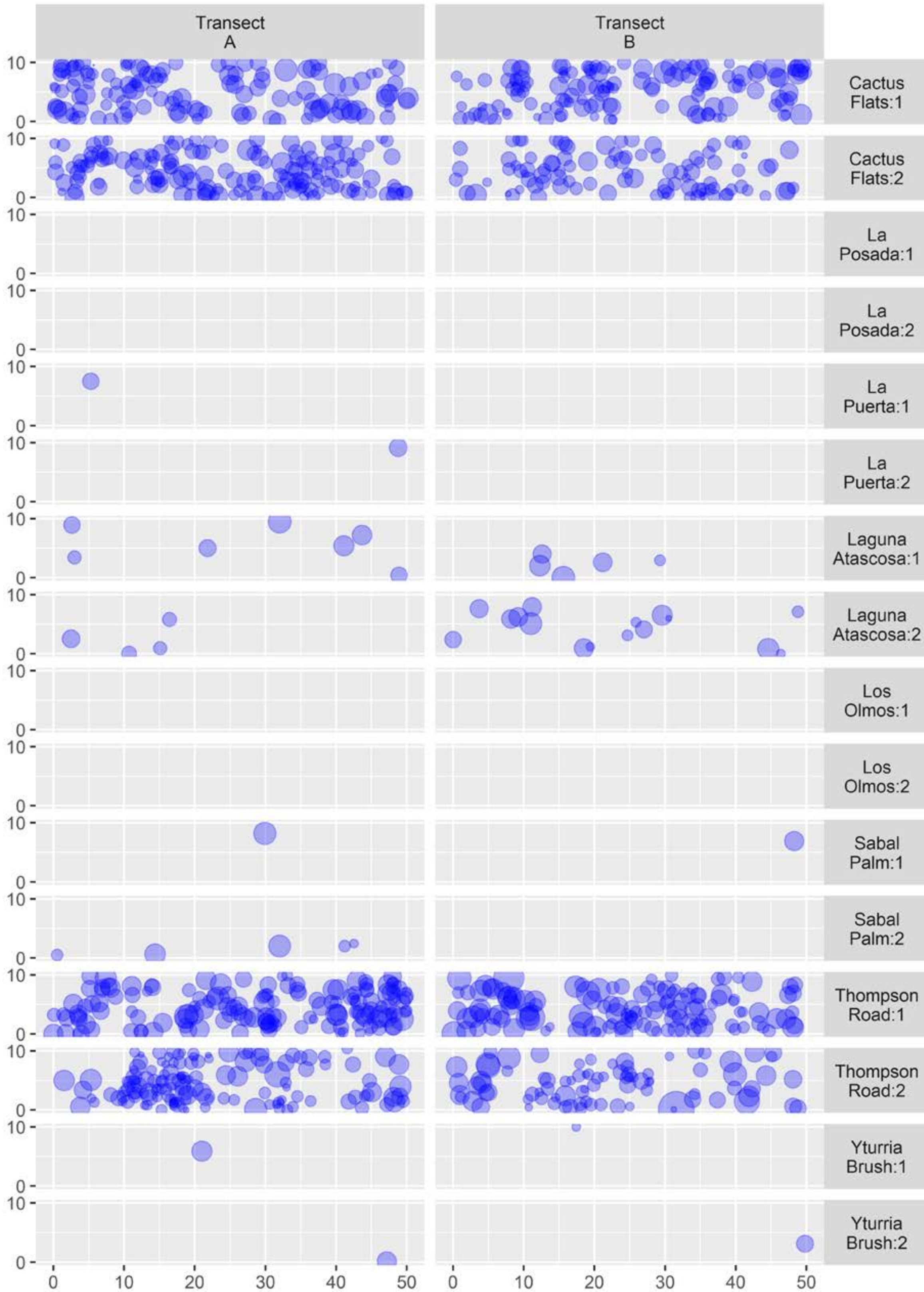

Figure 5.10: Representation of *Phaulothamnus spinecens* at study site transects.

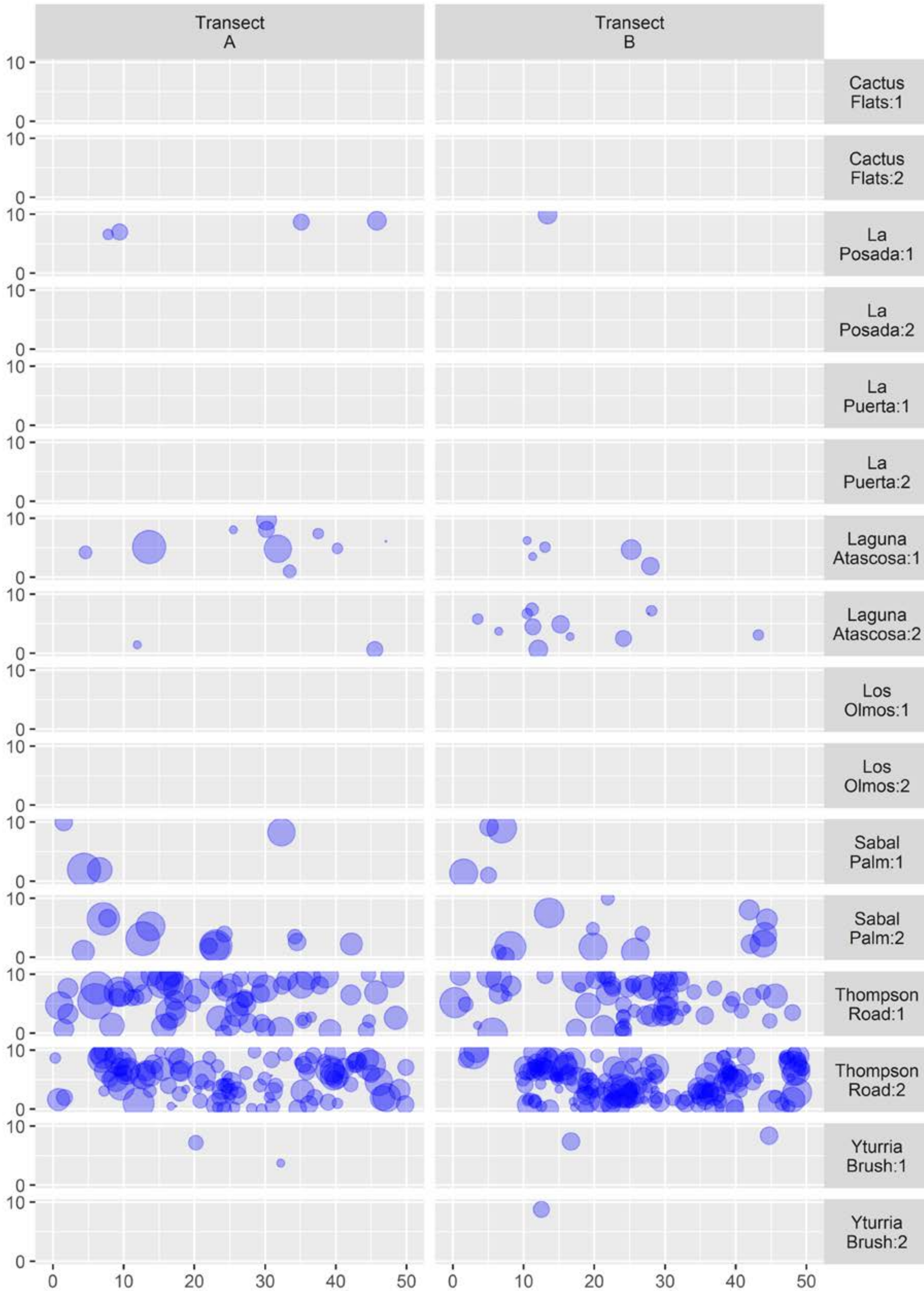

Figure 5.11: Representation of *Randia rhagocarpa* at study site transects.

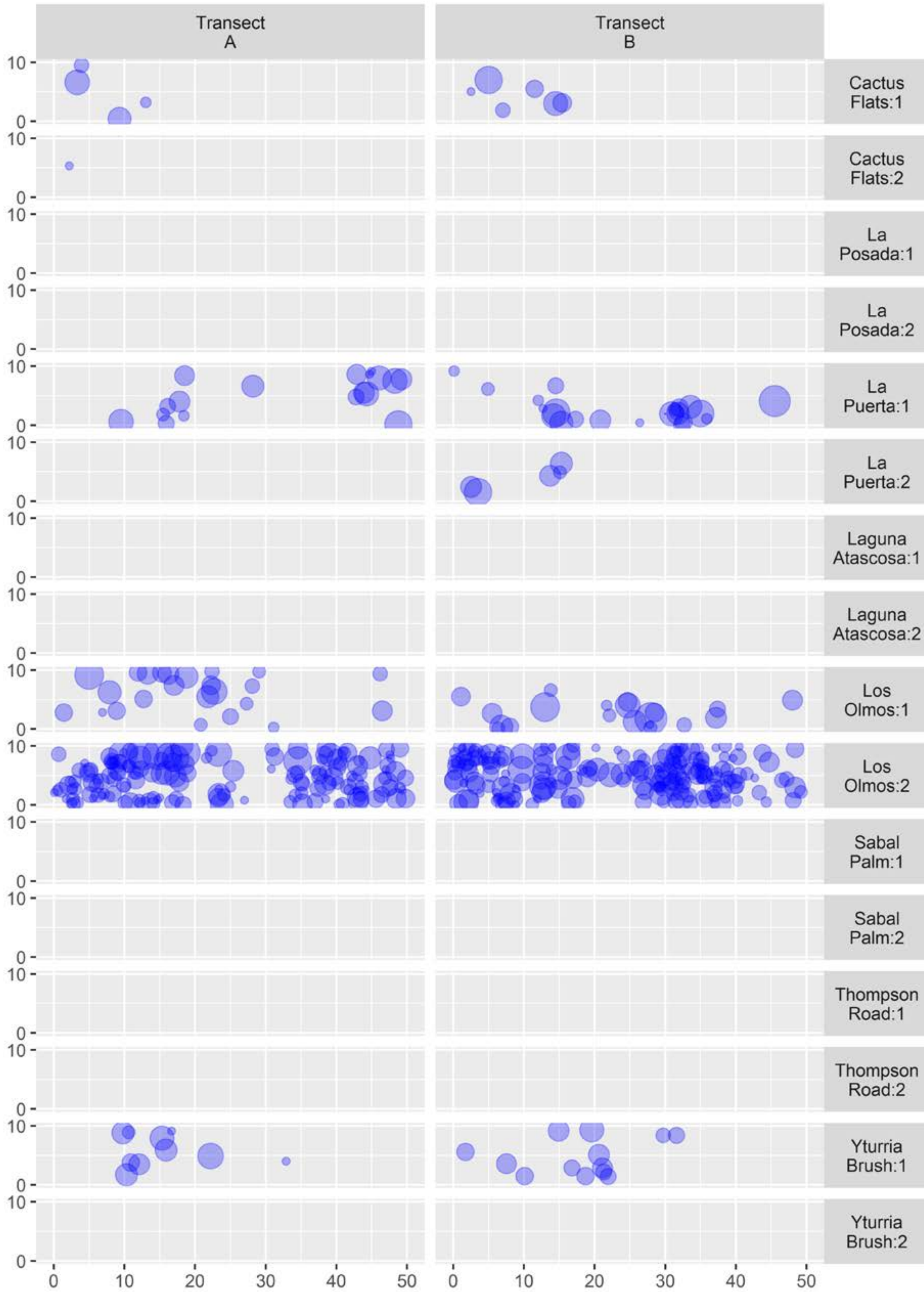

Figure 5.12: Representation of *Eysenhardtia texana* at study site transects.

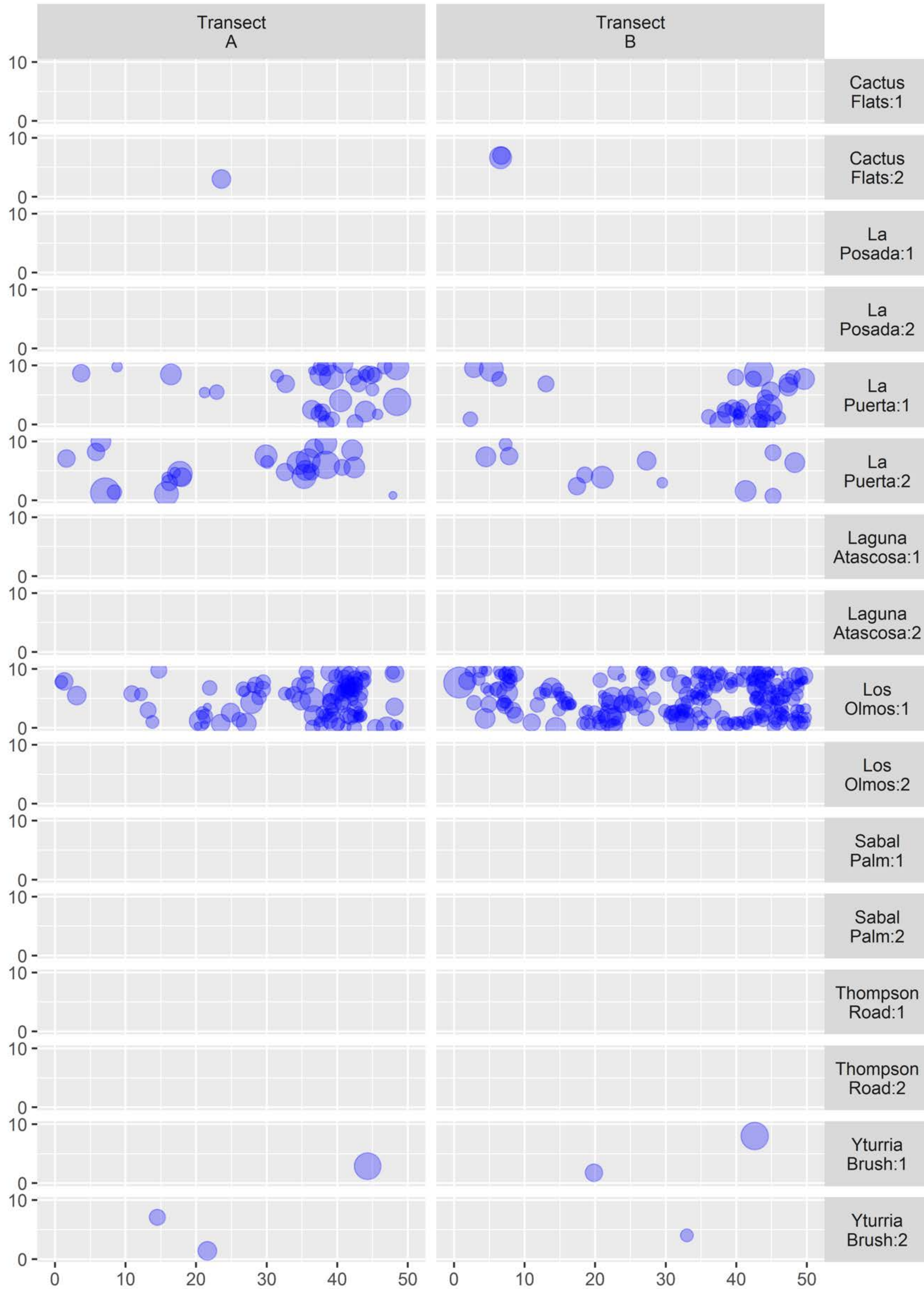

Figure 5.13: Representation of *Leucophyllum frutescens* at study site transects.

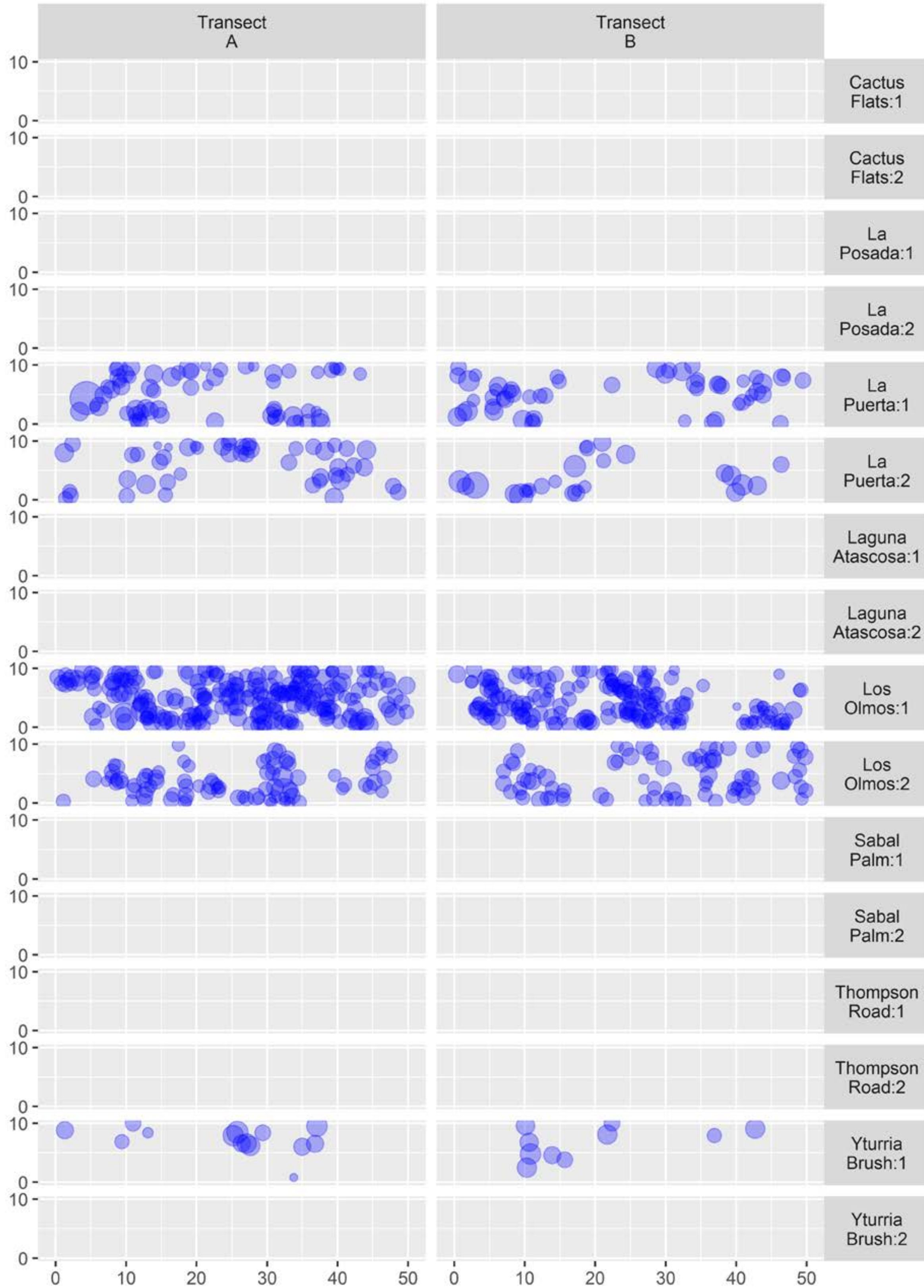

Figure 5.14: Representation of *Lippia graveolens* at study site transects.

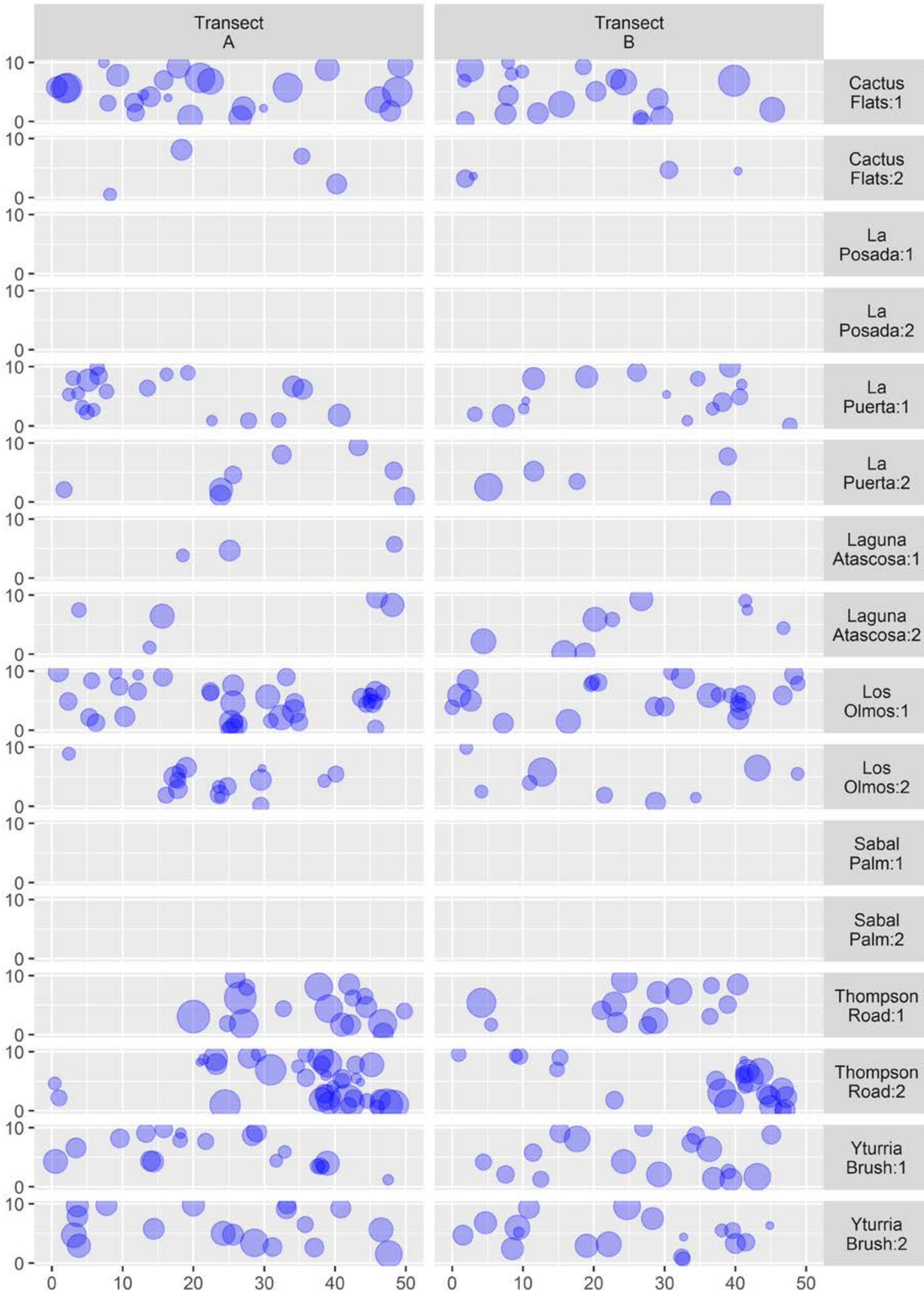

Figure 5.15: Representation of *Karwinskia humboldtiana* at study site transects.

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APPENDIX

Appendix 1: Transect species names with authorship

Abutilon hypoleucum A. Gray
Adelia vaseyi (J.M. Coult.) Pax & K. Hoffm.
Aloysia gratissima (Gillies & Hook.) Troncoso
Aloysia macrostachya (Torr.) Moldenke
Amyris madrensis S. Watson
Amyris texana (Buckley) P. Wilson
Baccharis neglecta Britton
Bastardia viscosa (L.) Kunth
Bernardia myricifolia (Scheele) S. Watson
Carica papaya L.
Carlowrightia parviflora (Buckley) Wassh.
Castela erecta Turp.
Celtis ehrenbergiana (Klotzsch) Liebm.
Celtis laevigata Willd.
Chiococca alba (L.) Hitchc.
Chromolaena odorata (L.) R.M. King & H. Rob.
Citharexylum berlandieri B.L. Rob.
Citharexylum brachyanthum A. Gray
Cocculus diversifolius DC.
Condalia hookeri M.C Johnst.
Cordia boissieri A. DC.
Croton humilis L.
Croton incanus Kunth.
Cylindropuntia leptocaulis (DC.) F.M. Knuth
Diospyros texana Scheele
Ebenopsis ebano Barneby & Grimes
Ehretia anacua (Terán & Berl.) I.M. Johnst.
Ephedra antisyphilitica Berl. ex C.A. Mey.
Erythrina herbacea L.
Eysenhardtia texana Scheele
Ficus benjamina L.
Forestiera angustifolia Torr.
Fraxinus berlandieriana DC.
Gochnatia hypoleuca (DC.) A. Gray
Guaiacum angustifolium Engelm.
Havardia pallens (Benth.) Britton & Rose
Helietta parvifolia (A. Gray ex Hemsl.) Benth.
Hibiscus martianus Zucc.
Jatropha dioica Cerv.
Jefea brevifolia (A. Gray) Strother
Karwinskia humboldtiana (Schult.) Zucc.
Koeberlinia spinosa Zucc.
Lantana achyranthifolia Desf.
Lantana urticoides Hayek
Leucaena pulverulenta (Schltdl.) Benth.
Leucophyllum frutescens (Berl.) I.M. Johnst.
Lippia graveolens Kunth
Lycium berlandieri Dunal
Malpighia glabra L.
Malvaviscus arboreus Dill. ex Cav.
Meximalva filipes (A. Gray) Fryxell
Nekemias arborea (L.) J. Wen & Boggan
Opuntia engelmanni Salm-Dyck ex Engelm.
Parkinsonia aculeata L.
Parkinsonia texana (A. Gray) S. Watson
Parthenium incanum Kunth
Petiveria alliacea L.
Phaulothamnus spinescens A. Gray
Pisonia aculeata L.
Pluchea carolinensis (Jacq.) G. Don
Prosopis glandulosa Torr.
Randia rhagocarpa Standl.
Sabal mexicana Mart.
Salix nigra Marshall
Salvia ballotiflora Benth.
Schaefferia cuneifolia A. Gray
Schinus terebinthifolius Raddi
Senegalia berlandieri Britton & Rose
Sideroxylon celastrinum (Kunth) T.D. Penn.
Solanum erianthum D. Don
Solanum pseudocapsicum L.
Tamaulipa azurea (DC.) R.M. King & H. Rob.
Taxodium mucronatum Ten.
Triadica sebifera (L.) Small
Trixis inula Crantz
Vachellia farnesiana (L.) Wight & Arn.

Vachellia rigidula (Benth.) Seigler & Ebinger
Vachellia schaffneri (S. Watson) Seigler & Ebinger
Viguiera stenoloba S.F. Blake
Washingtonia robusta H. Wendl.
Xylosma flexuosa (Kunth) Hemsl.
Yucca treculeana Carrière
Zanthoxylum fagara (L.) Sarg.
Ziziphus obtusifolia (Hook. ex Torr. & A. Gray) A. Gray

Appendix 2: Presence/Absence values of species per site

	Site							
Species	Lool	Lapu	Ytbr	cafl	Thrd	Laat	Lapo	Sapa
Abutilon hypoleucum	0	0	0	0	0	0	0	1
Adelia vaseyi	0	0	0	0	0	1	1	0
Aloysia gratissima	0	1	1	1	1	0	0	0
Aloysia macrostachya	1	1	0	0	0	0	0	0
Amyris madrensis	0	0	0	1	0	1	0	0
Amyris texana	0	0	1	1	1	1	0	1
Baccharis neglecta	0	0	0	0	0	0	0	1
Bastardia viscosa	0	0	0	0	0	1	0	0
Bernardia myricifolia	0	0	1	1	0	1	0	0
Carica papaya	0	0	0	0	0	0	1	1
Carlowrightia parviflora	0	0	0	1	0	0	0	0
Castela erecta	0	0	1	1	0	0	0	0
Celtis ehrenbergiana	0	1	1	1	1	1	1	1
Celtis laevigata	0	0	0	0	0	0	1	0
Chiococca alba	0	0	0	0	0	1	0	1
Chromolaena odorata	0	0	0	0	0	0	0	1
Citharexylum berlandieri	0	0	0	0	0	0	0	1
Citharexylum brachyanthum	1	1	1	0	0	1	0	0
Cocculus diversifolius	0	0	0	0	0	0	1	0
Condalia hookeri	0	1	0	0	1	1	1	1
Cordia boissieri	0	1	1	0	0	0	0	0
Croton humilis	0	1	0	0	0	0	0	0
Croton incanus	1	0	1	0	0	0	0	0
Cylindropuntia leptocaulis	1	1	0	0	0	0	0	0
Diospyros texana	0	0	1	1	1	0	1	1
Ebenopsis ebano	0	0	1	1	1	1	1	1
Ehretia anacua	0	0	0	0	0	0	1	1
Ephedra antisyphilitica	0	0	0	1	0	0	0	0
Erythrina herbacea	0	0	0	0	0	0	0	1
Eysenhardtia texana	1	1	1	1	0	0	0	0
Ficus benjamina	0	0	0	0	0	0	1	0
Forestiera angustifolia	1	1	1	1	1	1	1	1
Fraxinus berlandieriana	0	0	0	0	0	0	1	0
Gochnatia hypoleuca	0	1	1	0	0	0	0	0
Guaiacum angustifolium	1	1	1	1	1	1	1	1
Havardia pallens	0	0	0	1	1	0	1	1
Helietta parvifolia	1	1	0	0	0	0	0	0

Hibiscus martianus	0	1	0	0	0	0	0	0
Jatropha dioica	1	1	0	0	0	0	0	0
Jefea brevifolia	1	1	1	0	0	0	0	0
Karwinskia humboldtiana	1	1	1	1	1	1	0	0
Koeberlinia spinosa	0	0	1	1	0	0	0	0
Lantana achyranthifolia	0	1	1	0	0	1	0	0
Lantana urticoides	0	0	1	0	1	1	0	0
Leucaena pulverulenta	0	0	0	0	0	0	1	1
Leucophyllum frutescens	1	1	1	1	0	0	0	0
Lippia graveolens	1	1	1	0	0	0	0	0
Lycium berlandieri	1	1	1	1	0	0	1	0
Malpighia glabra	0	0	0	1	1	1	1	1
Malvaviscus arboreus	0	0	0	0	0	0	1	1
Meximalva filipes	1	0	0	0	0	0	0	0
Nekemias arborea	0	0	0	0	0	0	1	0
Opuntia engelmanni	0	1	0	0	0	0	0	0
Parkinsonia aculeata	0	0	0	0	1	0	0	0
Parkinsonia texana	0	1	1	0	0	0	0	0
Parthenium incanum	1	0	0	0	0	0	0	0
Petiveria alliacea	0	0	0	0	0	0	0	1
Phaulothamnus spinescens	0	1	1	1	1	1	0	1
Pisonia aculeata	0	0	0	0	1	0	1	0
Pluchea carolinensis	0	0	0	0	0	0	0	1
Prosopis glandulosa	1	0	1	1	1	0	1	0
Randia rhagocarpa	0	0	1	0	1	1	1	1
Sabal mexicana	0	0	0	0	0	0	1	1
Salix nigra	0	0	0	0	0	0	1	0
Salvia ballotiflora	1	0	1	1	0	0	0	0
Schaefferia cuneifolia	1	0	1	1	0	0	0	0
Schinus terebinthifolius	0	0	0	0	0	0	1	0
Senegalia berlandieri	1	1	0	1	0	0	0	0
Sideroxylon celastrinum	0	0	1	1	1	1	1	1
Solanum erianthum	0	0	0	0	0	0	0	1
Solanum pseudocapsicum	0	0	0	0	0	0	1	0
Tamaulipa azurea	0	0	0	1	1	1	0	1
Taxodium mucronatum	0	0	0	0	0	0	1	0
Triadica sebifera	0	0	0	0	0	0	1	0
Trixis inula	0	0	0	1	1	1	0	0
Vachellia farnesiana	0	0	0	0	1	0	1	0
Vachellia rigidula	1	1	1	0	0	0	0	0
Vachellia schaffneri	0	0	1	0	0	0	0	0
Viguiera stenoloba	0	0	1	1	0	0	0	0

Washingtonia robusta	0	0	0	0	0	0	1	0
Xylosma flexuosa	0	0	0	0	1	0	1	1
Yucca treculeana	1	0	0	0	0	0	0	0
Zanthoxylum fagara	1	0	1	1	1	1	1	1
Ziziphus obtusifolia	1	0	1	1	1	1	1	1

**Presence (1) – absence (0) of species found in site plots*
**Site acronyms are the first two letters of each word*

Appendix 3: Supplemental PerMANOVA results

Appendix 3a: PerMANOVA results examining the relationship between plant community composition (based on canopy coverage values by species) and plots (2 observations per site).

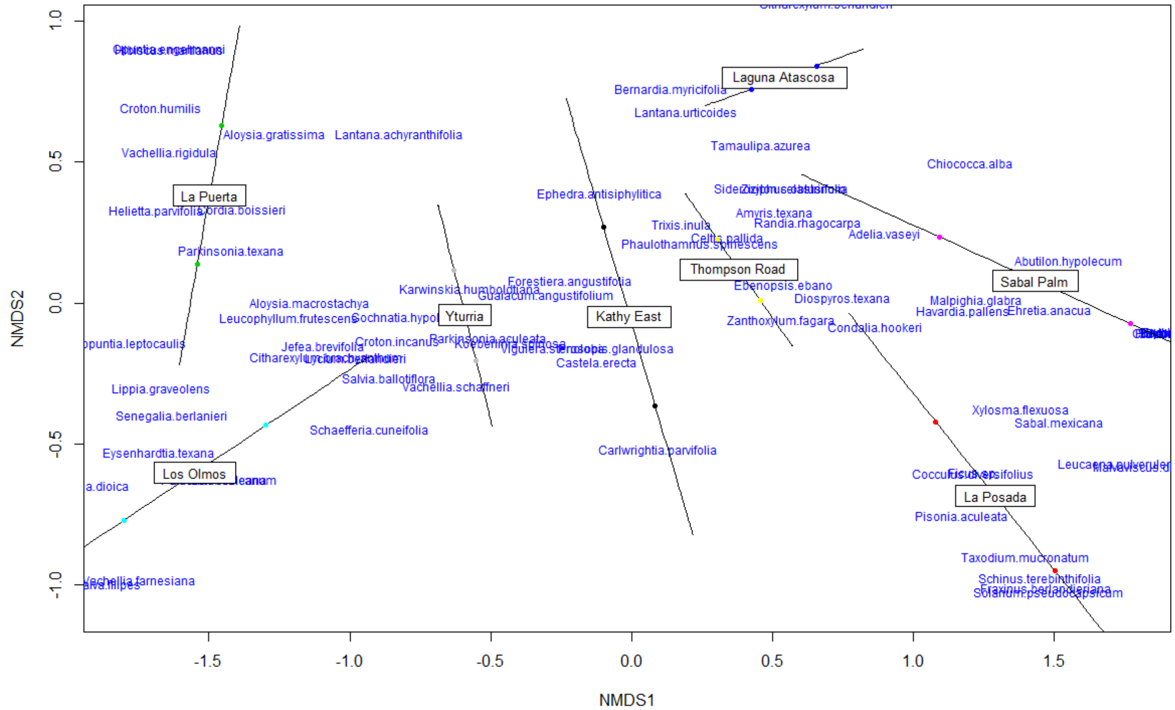
Factor	d.f.	Chi^2	F_8	*P*	
Site	7	3.556	3.527	**<0.0001**	***
Residual	24	1.152			

Appendix 3b: PerMANOVA results examining the relationship between plant community composition (based on abundance values for each species) and transects (2 observations per site).

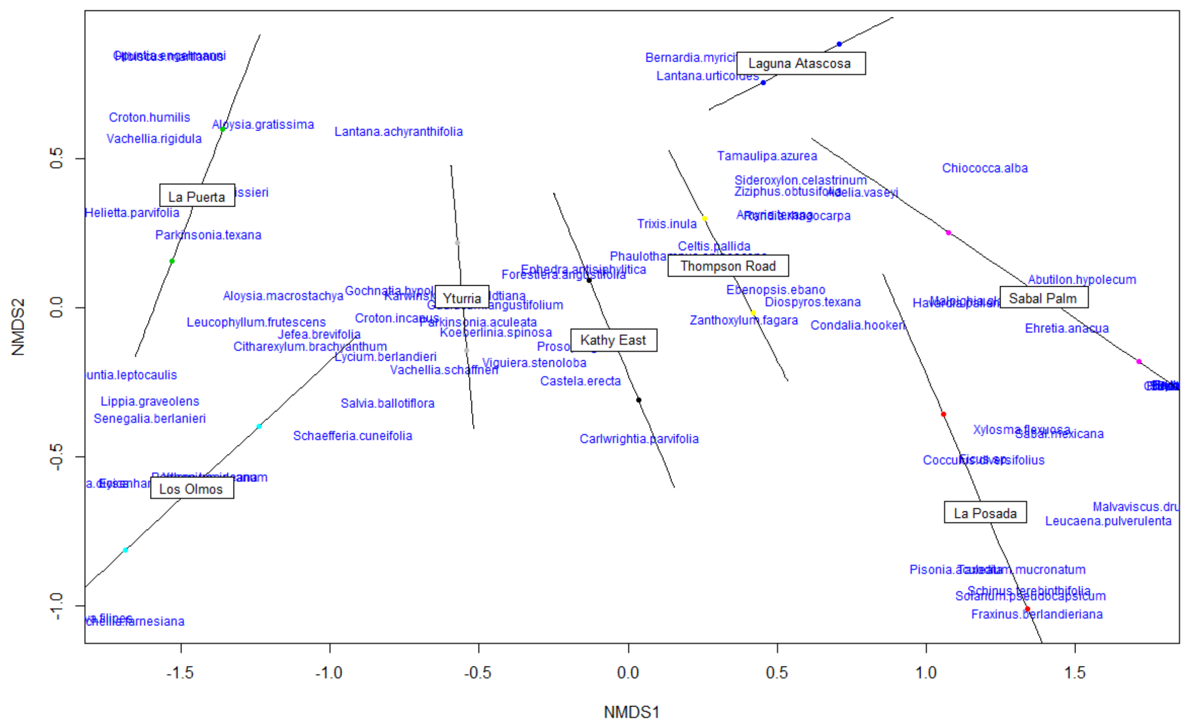
Factor	d.f.	Chi^2	F_8	*P*	
Site	7	3.571	3.209	**<0.0001**	***
Residual	24	1.272			

Legend- d.f.: degrees of freedom; Chi^2: Chi^2 test statistic; F_8: F statistic with denominator degrees of freedom; *P*: *P*-value, with stars denoting statistical significance (*, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$).

Appendix 4: Supplemental NMS ordinations



Appendix 4a: NMS ordination of community data graphed by species coverage (dominance) per plot (2 observations per site)



Appendix 4b: NMS ordination of community data graphed by species abundance (frequency) per plot (2 observations per site)

Appendix 5: Species abundance per site

Appendix 5a: Los Olmos Species abundance

Plot 1

Aloysia macrostachya	16
Citharexylum brachyanthum	78
Croton incanus	1
Eysenhardtia texana	45
Forestiera angustifolia	3
Guaiacum angustifolium	79
Helietta parvifolia	3
Jefea brevifolia	13
Karwinskia humboldtiana	61
Leucophyllum frutescens	378
Lippia graveolens	428
Lycium berlandieri	31
Meximalva filipes	1
Parthenium incanum	2
Prosopis glandulosa	5
Salvia ballotiflora	15
Schaefferia cuneifolia	16
Senegalia berlandieri	52
Vachellia rigidula	16
Yucca treculeana	2
Ziziphus obtusifolia	1
Total	1246

Plot two

Cylindropuntia leptocaulis	15
Eysenhardtia texana	360
Jatropha dioica	12
Karwinskia humboldtiana	25
Lippia graveolens	165
Meximalva filipes	5
Salvia ballotiflora	8
Schaefferia cuneifolia	2
Senegalia berlandieri	22
Vachellia rigidula	241
Zanthoxylum fagara	1
Total	856

Appendix 5b: La Puerta species abundance

Plot one

Aloysia gratissima	52
Aloysia macrostachya	4
Celtis ehrenbergiana	1
Citharexylum brachyanthum	1
Condalia hookeri	1
Cordia boissieri	31
Croton humilis	10
Cylindropuntia leptocaulis	19
Eysenhardtia texana	41
Forestiera angustifolia	10
Guaiacum angustifolium	4
Helietta parvifolia	30
Hibiscus martianus	1
Jatropha dioica	2
Karwinskia humboldtiana	35
Lantana achyranthifolia	5
Leucophyllum frutescens	69
Lippia graveolens	119
Lycium berlandieri	1
Opuntia engelmanni	53
Phaulothamnus spinescens	1
Vachellia rigidula	235
Total	725

Plot two

Citharexylum brachyanthum	2
Cordia boissieri	24
Croton humilis	1
Cylindropuntia leptocaulis	4
Eysenhardtia texana	5
Forestiera angustifolia	10
Gochnatia hypoleuca	1
Guaiacum angustifolium	13
Helietta parvifolia	109
Jatropha dioica	1
Jefea brevifolia	2
Karwinskia humboldtiana	13
Leucophyllum frutescens	38
Lippia graveolens	75
Parkinsonia texana	29
Phaulothamnus spinescens	1
Senegalia berlandieri	51
Vachellia rigidula	57
Total	436

Appendix 5c: Yturria Brush species abundance

Plot one

Aloysia gratissima	3
Amyris texana	1
Bernardia myricifolia	6
Celtis ehrenbergiana	23
Citharexylum brachyanthum	25
Cordia boissieri	18
Croton incanus	6
Diospyros texana	1
Ebenopsis ebano	14
Eysenhardtia texana	23
Forestiera angustifolia	8
Gochnatia hypoleuca	41
Guaiacum angustifolium	22
Jefea brevifolia	12
Karwinskia humboldtiana	36
Koeberlinia spinosa	11
Lantana achyranthifolia	2
Lantana urticoides	15
Leucophyllum frutescens	3
Lippia graveolens	24
Lycium berlandieri	6
Parkinsonia texana	28
Phaulothamnus spinescens	2
Prosopis glandulosa	2
Randia rhagocarpa	4
Salvia ballotiflora	8
Schaefferia cuneifolia	4
Sideroxylon celastrinum	7
Vachellia rigidula	1
Zanthoxylon fagara	1
Ziziphus obtusifolia	1
Total	358

Plot two

Amyris texana	2
Castela erecta	2
Celtis ehrenbergiana	17
Citharexylum brachyanthum	37
Cordia boissieri	3
Croton incanus	3
Ebenopsis ebano	10
Forestiera angustifolia	16
Gochnatia hypoleuca	45
Guaiacum angustifolium	18
Jefea brevifolia	13
Karwinskia humboldtiana	36
Koeberlinia spinosa	37
Lantana achyranthifolia	1
Leucophyllum frutescens	3
Lycium berlandieri	4
Parkinsonia texana	56
Phaulothamnus spinescens	2
Prosopis glandulosa	2
Randia rhagocarpa	1
Salvia ballotiflora	3
Schaefferia cuneifolia	3
Sideroxylon celastrinum	15
Vachellia schaffneri	1
Viguiera stenoloba	4
Zanthoxylon fagara	2
Ziziphus obtusifolia	1
Total	337

Appendix 5d: Cactus Flats species abundance

Plot one

Amyris madrensis	14
Amyris texana	1
Bernardia myricifolia	1
Castela erecta	2
Celtis ehrenbergiana	12
Diospyros texana	4
Ebenopsis ebano	87
Ephedra antisyphilitica	2
Eysenhardtia texana	10
Forestiera angustifolia	8
Guaiacum angustifolium	73
Karwinskia humboldtiana	46
Koeberlinia spinosa	3
Lycium berlandieri	1
Phaulothamnus spinescens	257
Salvia ballotiflora	52
Schaefferia cuneifolia	1
Senegalia berlandieri	3
Sideroxylon celastrinum	16
Tamaulipa azurea	96
Trixis inula	6
Viguiera stenoloba	1
Ziziphus obtusifolia	9
Total	705

Plot two

Aloysia gratissima	1
Carlowrightia parviflora	3
Castela erecta	7
Celtis ehrenbergiana	34
Diospyros texana	3
Ebenopsis ebano	142
Eysenhardtia texana	1
Forestiera angustifolia	1
Guaiacum angustifolium	45
Havardia pallens	2
Karwinskia humboldtiana	8
Koeberlinia spinosa	4
Leucophyllum frutescens	3
Malpighia glabra	1
Phaulothamnus spinescens	255
Prosopis glandulosa	6
Salvia ballotiflora	3
Schaefferia cuneifolia	4
Sideroxylon celastrinum	3
Tamaulipa azurea	11
Trixis inula	1
Viguiera stenoloba	1
Zanthoxylum fagara	80
Ziziphus obtusifolia	2
Total	621

Appendix 5e: Thompson Road species abundance

Plot one

Aloysia gratissima	1
Amyris texana	2
Celtis ehrenbergiana	98
Condalia hookeri	6
Diospyros texana	5
Ebenopsis ebano	6
Forestiera angustifolia	34
Guaiacum angustifolium	2
Havardia pallens	1
Karwinskia humboldtiana	32
Lantana urticoides	10
Phaulothamnus spinescens	284
Prosopis glandulosa	11
Randia rhagocarpa	129
Sideroxylon celastrinum	50
Tamaulipa azurea	33
Trixis inula	5
Zanthoxylon fagara	27
Ziziphus obtusifolia	10
Total	746

Plot two

Amyris texana	199
Celtis ehrenbergiana	40
Condalia hookeri	26
Diospyros texana	2
Ebenopsis ebano	26
Forestiera angustifolia	20
Havardia pallens	2
Karwinskia humboldtiana	59
Malpighia glabra	3
Parkinsonia aculeata	1
Phaulothamnus spinescens	228
Pisonia aculeata	1
Prosopis glandulosa	1
Randia rhagocarpa	276
Sideroxylon celastrinum	57
Tamaulipa azurea	4
Vachellia farnesiana	1
Xylosma flexuosa	1
Zanthoxylum fagara	12
Total	959

Appendix 5f: Laguna Atascosa species abundance

Plot one

Amyris madrensis	629
Amyris texana	1
Bastardia viscosa	13
Bernardia myricifolia	2
Celtis ehrenbergiana	1
Chiococca alba	2
Citharexylum berlandieri	8
Condalia hookeri	1
Ebonopsis ebano	10
Guaiacum angustifolium	2
Karwinskia humboldtiana	3
Lantana urticoides	8
Malpighia glabra	2
Phaulothamnus spinescens	12
Randia rhagocarpa	15
Sideroxylon celastrinum	100
Tamaulipa azurea	50
Zanthoxylum fagara	1
Zizphus obtusifolia	13
Total	873

Plot two

Adelia vaseyi	3
Amyris madrensis	769
Amyris texana	43
Bastardia viscosa	18
Bernardia myricifolia	14
Celtis ehrenbergiana	41
Chiococca alba	2
Citharexylum berlandieri	11
Condalia hookeri	1
Ebenopsis ebano	14
Forestiera angustifolia	1
Guaiacum angustifolium	1
Karwinskia humboldtiana	14
Lantana achyranthifolia	1
Lantana urticoides	6
Phaulothamnus spinescens	20
Randia rhagocarpa	14
Sideroxylon celastrinum	94
Tamaulipa azurea	14
Trixis inula	1
Zanthoxylum fagara	5
Ziziphus obtusifolia	5
Total	1092

Appendix 5g: La Posada species abundance

Plot one

Celtis ehrenbergiana	5
Cocculus diversifolius	1
Condalia hookeri	16
Diospyros texana	4
Ebenopsis ebano	26
Ehretia anacua	2
Ficus benjamina	1
Forestiera angustifolia	6
Fraxinus berlandieriana	15
Guaiacum angustifolium	2
Leucaena pulverulenta	5
Lycium berlandieriana	1
Malpighia glabra	6
Randia rhagocarpa	5
Sabal mexicana	37
Schinus terebinthifolia	3
Sideroxylon celastrinum	23
Solanum pseudocapsicum	1
Taxodium mucronatum	9
Xylosma flexuosa	13
Zanthoxylum fagara	3
Ziziphus obtusifolia	3
Total	187

Plot two

Adelia vaseyi	1
Carica papaya	2
Celtis laevigata	5
Celtis ehrenbergiana	2
Condalia hookeri	19
Ebenopsis ebano	6
Forestiera angustifolia	2
Fraxinus berlandieriana	49
Guaiacum angustifolium	1
Havardia pallens	1
Leucaena pulverulenta	4
Malpighia glabra	2
Malvaviscus arboreus	2
Nekemias arborea	2
Pisonia aculeata	7
Prosopis glandulosa	1
Sabal mexicana	35
Salix nigra	3
Schinus terebinthifolius	5
Sideroxylon celastrinum	7
Solanum pseudocapsicum	2
Taxodium mucronatum	8
Triadica sebifera	5
Vachellia farnesiana	1
Washingtonia robusta	1
Xylosma flexuosa	13
Zanthoxylum fagara	4
Ziziphus obtusifolia	1
Total	191

Appendix 5h: Sabal Palm species abundance

Plot one

Abutilon hypoleucum	2
Amyris texana	1
Baccharis neglecta	1
Carica papaya	1
Celtis ehrengergiana	2
Chiococca alba	12
Chromolaena odorata	1
Citharexylum berlandieri	2
Condalia hookeri	1
Diospyros texana	4
Ebenopsis ebano	46
Ehretia anacua	13
Erythrina herbacea	4
Havardia pallens	36
Leucaena pulverulenta	6
Malpighia glabra	27
Malvaviscus arboreus	7
Petiveria alliacea	2
Phaulothamnus spinescens	2
Pluchea carolinensis	1
Randia rhagocarpa	8
Sabal mexicana	53
Sideroxylon celastrinum	8
Solanum erianthum	1
Tamaulipa azurea	4
Xylosma flexuosa	10
Zanthoxylum fagara	6
Total	261

Plot two

Abutilon hypoleucum	2
Amyris texana	9
Celtis ehrenbergiana	15
Chiococca alba	52
Citharexylum berlandieri	2
Condalia hookeri	3
Diospyros texana	9
Ebenopsis ebano	75
Ehretia anacua	7
Forestiera angustifolia	2
Guaiacum angustifolium	3
Havardia pallens	48
Malpighia glabra	29
Phaulothamnus spinescens	5
Randia rhagocarpa	26
Sabal mexicana	29
Sideroxylon celastrinum	43
Tamaulipa azurea	30
Xylosma flexuosa	9
Zanthoxylum fagara	14
Ziziphus obtusifolia	38
Total	450

Appendix 6: Species area cover, area percent cover, and relative percent cover by site.

Appendix 6a-1: Los Olmos, plot one values

species	**area cover**	**% cover**	**relative % cover**
Aloysia macrostachya	5.92	0.59%	0.91%
Citharexylum brachyanthum	42.90	4.29%	6.62%
Croton incanus	0.38	0.04%	0.06%
Eysenhardtia texana	36.58	3.66%	5.64%
Forestiera angustifolia	2.55	0.26%	0.39%
Guaiacum angustifolium	26.70	2.67%	4.12%
Helietta parvifolia	11.89	1.19%	1.83%
Jefea brevifolia	3.35	0.34%	0.52%
Karwinskia humboldtiana	40.30	4.03%	6.21%
Leucophyllum frutescens	104.26	10.43%	16.08%
Lippia graveolens	110.62	11.06%	17.06%
Lycium berlandieri	62.40	6.24%	9.62%
Meximalva filipes	0.20	0.02%	0.03%
Parthenium incanum	0.41	0.04%	0.06%
Prosopis glandulosa	23.01	2.30%	3.55%
Salvia ballotiflora	4.38	0.44%	0.68%
Schaefferia cuneifolia	6.97	0.70%	1.08%
Senegalia berlandieri	127.26	12.73%	19.62%
Vachellia rigidula	33.17	3.32%	5.11%
Yucca treculeana	1.74	0.17%	0.27%
Ziziphus obtusifolia	3.46	0.35%	0.53%
Total	648.46	64.85%	100.00%

Appendix 6a-2: Los Olmos, plot two values

species	**area cover**	**% cover**	**relative % cover**
Cylindropuntia leptocaulis	7.73	0.77%	1.23%
Eysenhardtia texana	170.49	17.05%	27.22%
Jatropha dioica	16.86	1.69%	2.69%
Karwinskia humboldtiana	14.08	1.41%	2.25%
Lippia graveolens	37.94	3.79%	6.06%
Meximalva filipes	0.35	0.04%	0.06%
Salvia ballotiflora	5.21	0.52%	0.83%
Schaefferia cuneifolia	0.58	0.06%	0.09%
Senegalia berlandieri	56.49	5.65%	9.02%
Vachellia rigidula	316.37	31.64%	50.51%
Zanthoxylum fagara	0.28	0.03%	0.05%
Total	626.40	62.64%	100.00%

Appendix 6b-1: La Puerta, plot one values

species	**area cover**	**% cover**	**relative % cover**
Aloysia gratissima	14.82	1.48%	2.24%
Aloysia macrostachya	1.12	0.11%	0.17%
Celtis ehrenbergiana	0.38	0.04%	0.06%
Citharexylum brachyanthum	0.79	0.08%	0.12%
Condalia hookeri	0.95	0.10%	0.14%
Cordia boissieri	72.40	7.24%	10.93%
Croton humilis	4.52	0.45%	0.68%
Cylindropuntia leptocaulis	49.32	4.93%	7.45%
Eysenhardtia texana	36.50	3.65%	5.51%
Forestiera angustifolia	9.61	0.96%	1.45%
Guaiacum angustifolium	3.55	0.35%	0.54%
Helietta parvifolia	85.33	8.53%	12.89%
Hibiscus martianus	0.20	0.02%	0.03%
Jatropha dioica	0.57	0.06%	0.09%
Karwinskia humboldtiana	15.72	1.57%	2.37%
Lantana achyranthifolia	0.93	0.09%	0.14%
Leucophyllum frutescens	38.58	3.86%	5.83%
Lippia graveolens	40.82	4.08%	6.17%
Lycium berlandieri	1.33	0.13%	0.20%
Opuntia engelmanni	108.49	10.85%	16.38%
Phaulothamnus spinescens	1.77	0.18%	0.27%
Vachellia rigidula	174.52	17.45%	26.35%
Total	662.20	66.22%	100.00%

Appendix 6b-2: La Puerta, plot two values

species	**area cover**	**% canopy**	**relative % cover**
Citharexylum brachyanthum	1.23	0.12%	0.22%
Cordia boissieri	91.59	9.16%	16.62%
Croton humilis	0.28	0.03%	0.05%
Cylindropuntia leptocaulis	1.18	0.12%	0.21%
Eysenhardtia texana	5.77	0.58%	1.05%
Forestiera angustifolia	7.46	0.75%	1.35%
Gochnatia hypoleuca	1.54	0.15%	0.28%
Guaiacum angustifolium	15.64	1.56%	2.84%
Helietta parvifolia	122.33	12.23%	22.20%
Jatropha dioica	1.13	0.11%	0.21%
Jefea brevifolia	1.07	0.11%	0.19%
Karwinskia humboldtiana	10.73	1.07%	1.95%
Leucophyllum frutescens	30.96	3.10%	5.62%
Lippia graveolens	26.76	2.68%	4.86%
Parkinsonia texana	67.65	6.76%	12.28%
Phaulothamnus spinescens	2.27	0.23%	0.41%
Senegalia berlandieri	88.24	8.82%	16.01%
Vachellia rigidula	75.23	7.52%	13.65%
Total	551.05	55.11%	100.00%

Appendix 6c-1: Yturria Brush, plot one values

species	area cover	% cover	relative % cover
Aloysia gratissima	1.26	0.13%	0.20%
Amyris texana	0.28	0.03%	0.05%
Bernardia myricifolia	3.87	0.39%	0.63%
Celtis ehrenbergiana	37.48	3.75%	6.08%
Citharexylum brachyanthum	24.61	2.46%	3.99%
Cordia boissieri	72.09	7.21%	11.69%
Croton incanus	2.34	0.23%	0.38%
Diospyros texana	0.79	0.08%	0.13%
Ebenopsis ebano	71.05	7.11%	11.52%
Eysenhardtia texana	17.07	1.71%	2.77%
Forestiera angustifolia	6.50	0.65%	1.05%
Gochnatia hypoleuca	51.60	5.16%	8.36%
Guaiacum angustifolium	26.81	2.68%	4.35%
Jefea brevifolia	4.47	0.45%	0.72%
Karwinskia humboldtiana	27.86	2.79%	4.52%
Koeberlinia spinosa	27.65	2.77%	4.48%
Lantana achyranthifolia	0.16	0.02%	0.03%
Lantana urticoides	8.38	0.84%	1.36%
Leucophyllum frutescens	5.32	0.53%	0.86%
Lippia graveolens	11.04	1.10%	1.79%
Lycium berlandieri	28.05	2.81%	4.55%
Parkinsonia texana	122.59	12.26%	19.87%
Phaulothamnus spinescens	4.00	0.40%	0.65%
Prosopis glandulosa	37.90	3.79%	6.14%
Randia rhagocarpa	1.36	0.14%	0.22%
Salvia ballotiflora	3.57	0.36%	0.58%
Schaefferia cuneifolia	1.28	0.13%	0.21%
Sideroxylon celastrinum	10.39	1.04%	1.68%
Vachellia rigidula	5.31	0.53%	0.86%
Zanthoxylon fagara	1.33	0.13%	0.22%
Ziziphus obtusifolia	0.50	0.05%	0.08%
Total	616.91	61.69%	100.00%

Appendix 6c-2: Yturria Brush, plot two values

species	**area cover**	**% cover**	**relative % cover**
Amyris texana	1.90	0.19%	0.21%
Castela erecta	4.93	0.49%	0.53%
Celtis ehrenbergiana	28.89	2.89%	3.13%
Citharexylum brachyanthum	41.26	4.13%	4.47%
Cordia boissieri	11.42	1.14%	1.24%
Croton incanus	0.60	0.06%	0.07%
Ebenopsis ebano	72.15	7.21%	7.82%
Forestiera angustifolia	17.74	1.77%	1.92%
Gochnatia hypoleuca	84.71	8.47%	9.18%
Guaiacum angustifolium	21.66	2.17%	2.35%
Jefea brevifolia	3.11	0.31%	0.34%
Karwinskia humboldtiana	35.85	3.58%	3.88%
Koeberlinia spinosa	151.61	15.16%	16.43%
Lantana achyranthifolia	0.20	0.02%	0.02%
Leucophyllum frutescens	1.22	0.12%	0.13%
Lycium berlandieri	6.20	0.62%	0.67%
Parkinsonia texana	259.83	25.98%	28.15%
Phaulothamnus spinescens	5.15	0.52%	0.56%
Prosopis glandulosa	104.96	10.50%	11.37%
Randia rhagocarpa	0.38	0.04%	0.04%
Salvia ballotiflora	0.76	0.08%	0.08%
Schaefferia cuneifolia	4.23	0.42%	0.46%
Sideroxylon celastrinum	54.18	5.42%	5.87%
Vachellia schaffneri	4.91	0.49%	0.53%
Viguiera stenoloba	0.99	0.10%	0.11%
Zanthoxylon fagara	3.03	0.30%	0.33%
Ziziphus obtusifolia	1.13	0.11%	0.12%
Total	923.00	92.30%	100.00%

Appendix 6d-1: Cactus Flats, plot one values

species	area cover	% cover	relative % cover
Amyris madrensis	40.82	4.08%	2.83%
Amyris texana	0.50	0.05%	0.03%
Bernardia myricifolia	19.63	1.96%	1.36%
Castela erecta	14.33	1.43%	0.99%
Celtis ehrenbergiana	27.63	2.76%	1.92%
Diospyros texana	11.16	1.12%	0.77%
Ebenopsis ebano	438.11	43.81%	30.41%
Ephedra antisyphilitica	1.45	0.15%	0.10%
Eysenhardtia texana	9.08	0.91%	0.63%
Forestiera angustifolia	5.51	0.55%	0.38%
Guaiacum angustifolium	135.22	13.52%	9.39%
Karwinskia humboldtiana	56.84	5.68%	3.95%
Koeberlinia spinosa	15.11	1.51%	1.05%
Lycium berlandieri	0.50	0.05%	0.03%
Phaulothamnus spinescens	375.81	37.58%	26.08%
Salvia ballotiflora	36.84	3.68%	2.56%
Schaefferia cuneifolia	0.28	0.03%	0.02%
Senegalia berlandieri	17.07	1.71%	1.19%
Sideroxylon celastrinum	106.12	10.61%	7.37%
Tamaulipa azurea	102.08	10.21%	7.09%
Trixis inula	2.51	0.25%	0.17%
Viguiera stenoloba	0.50	0.05%	0.03%
Ziziphus obtusifolia	23.63	2.36%	1.64%
Total	1440.76	144.08%	100.00%

Appendix 6d-2: Cactus Flats, plot two values

species	**area cover**	**% cover**	**relative % cover**
Aloysia gratissima	0.38	0.04%	0.03%
Carlowrightia parviflora	1.27	0.13%	0.10%
Castela erecta	13.52	1.35%	1.01%
Celtis ehrenbergiana	85.07	8.51%	6.39%
Diospyros texana	1.67	0.17%	0.13%
Ebenopsis ebano	569.08	56.91%	42.73%
Eysenhardtia texana	0.07	0.01%	0.01%
Forestiera angustifolia	0.28	0.03%	0.02%
Guaiacum angustifolium	66.55	6.66%	5.00%
Havardia pallens	3.55	0.35%	0.27%
Karwinskia humboldtiana	3.46	0.35%	0.26%
Koeberlinia spinosa	14.72	1.47%	1.11%
Leucophyllum frutescens	2.27	0.23%	0.17%
Malpighia glabra	0.28	0.03%	0.02%
Phaulothamnus spinescens	294.00	29.40%	22.08%
Prosopis glandulosa	132.84	13.28%	9.97%
Salvia ballotiflora	0.68	0.07%	0.05%
Schaefferia cuneifolia	1.59	0.16%	0.12%
Sideroxylon celastrinum	12.65	1.27%	0.95%
Tamaulipa azurea	11.26	1.13%	0.85%
Trixis inula	0.95	0.10%	0.07%
Viguiera stenoloba	0.20	0.02%	0.01%
Zanthoxylum fagara	114.09	11.41%	8.57%
Ziziphus obtusifolia	1.34	0.13%	0.10%
Total	1331.77	133.18%	100.00%

Appendix 6e-1: Thompson Road, plot one values

species	**area cover**	**% cover**	**relative % cover**
Aloysia gratissima	0.95	0.10%	0.04%
Amyris texana	0.41	0.04%	0.02%
Celtis ehrenbergiana	602.33	60.23%	25.78%
Condalia hookeri	34.32	3.43%	1.47%
Diospyros texana	8.24	0.82%	0.35%
Ebenopsis ebano	159.23	15.92%	6.81%
Forestiera angustifolia	44.48	4.45%	1.90%
Guaiacum angustifolium	6.92	0.69%	0.30%
Havardia pallens	6.61	0.66%	0.28%
Karwinskia humboldtiana	44.58	4.46%	1.91%
Lantana urticoides	3.85	0.38%	0.16%
Phaulothamnus spinescens	588.09	58.81%	25.17%
Prosopis glandulosa	289.33	28.93%	12.38%
Randia rhagocarpa	141.80	14.18%	6.07%
Sideroxylon celastrinum	273.04	27.30%	11.69%
Tamaulipa azurea	60.40	6.04%	2.59%
Trixis inula	9.14	0.91%	0.39%
Zanthoxylon fagara	34.16	3.42%	1.46%
Ziziphus obtusifolia	28.81	2.88%	1.23%
Total	2336.70	233.67%	100.00%

Appendix 6e-2: Thompson road, plot two values

species	area cover	% cover	relative % cover
Amyris texana	95.88	9.59%	5.76%
Celtis ehrenbergiana	237.52	23.75%	14.28%
Condalia hookeri	99.23	9.92%	5.96%
Diospyros texana	7.30	0.73%	0.44%
Ebenopsis ebano	214.85	21.48%	12.91%
Forestiera angustifolia	14.54	1.45%	0.87%
Havardia pallens	4.44	0.44%	0.27%
Karwinskia humboldtiana	65.19	6.52%	3.92%
Malpighia glabra	1.48	0.15%	0.09%
Parkinsonia aculeata	6.16	0.62%	0.37%
Phaulothamnus spinescens	327.39	32.74%	19.68%
Pisonia aculeata	6.61	0.66%	0.40%
Prosopis glandulosa	12.57	1.26%	0.76%
Randia rhagocarpa	202.55	20.25%	12.17%
Sideroxylon celastrinum	319.18	31.92%	19.19%
Tamaulipa azurea	0.79	0.08%	0.05%
Vachellia farnesiana	8.04	0.80%	0.48%
Xylosma flexuosa	0.28	0.03%	0.02%
Zanthoxylum fagara	39.67	3.97%	2.38%
Total	1663.638244	166.36%	100.00%

Appendix 6f-1: Laguna Atascosa, plot one values

species	**area cover**	**% cover**	**relative % cover**
Amyris madrensis	1065.83	106.58%	72.60%
Amyris texana	0.13	0.01%	0.01%
Bastardia viscosa	3.93	0.39%	0.27%
Bernardia myricifolia	0.25	0.03%	0.02%
Celtis ehrenbergiana	1.77	0.18%	0.12%
Chiococca alba	1.82	0.18%	0.12%
Citharexylum berlandieri	9.68	0.97%	0.66%
Condalia hookeri	3.80	0.38%	0.26%
Ebonopsis ebano	82.93	8.29%	5.65%
Guaiacum angustifolium	3.50	0.35%	0.24%
Karwinskia humboldtiana	1.53	0.15%	0.10%
Lantana urticoides	2.06	0.21%	0.14%
Malpighia glabra	0.83	0.08%	0.06%
Phaulothamnus spinescens	35.83	3.58%	2.44%
Randia rhagocarpa	11.33	1.13%	0.77%
Sideroxylon celastrinum	165.88	16.59%	11.30%
Tamaulipa azurea	37.48	3.75%	2.55%
Zanthoxylum fagara	1.13	0.11%	0.08%
Zizphus obtusifolia	38.47	3.85%	2.62%
Total	1468.17	146.82%	100.00%

Appendix 6f-2: Laguna Atascosa, plot two values

species	**area cover**	**% cover**	**relative % cover**
Adelia vaseyi	0.99	0.10%	0.06%
Amyris madrensis	821.58	82.16%	52.85%
Amyris texana	13.59	1.36%	0.87%
Bastardia viscosa	11.58	1.16%	0.75%
Bernardia myricifolia	8.91	0.89%	0.57%
Celtis ehrenbergiana	244.11	24.41%	15.70%
Chiococca alba	1.61	0.16%	0.10%
Citharexylum berlandieri	15.28	1.53%	0.98%
Condalia hookeri	5.69	0.57%	0.37%
Ebenopsis ebano	109.09	10.91%	7.02%
Forestiera angustifolia	0.03	0.00%	0.00%
Guaiacum angustifolium	0.79	0.08%	0.05%
Karwinskia humboldtiana	12.28	1.23%	0.79%
Lantana achyranthifolia	0.20	0.02%	0.01%
Lantana urticoides	0.68	0.07%	0.04%
Phaulothamnus spinescens	38.50	3.85%	2.48%
Randia rhagocarpa	3.24	0.32%	0.21%
Sideroxylon celastrinum	215.84	21.58%	13.89%
Tamaulipa Azurea	18.13	1.81%	1.17%
Trixis inula	0.20	0.02%	0.01%
Zanthoxylum fagara	7.60	0.76%	0.49%
Ziziphus obtusifolia	24.51	2.45%	1.58%
Total	1554.42	155.44%	100.00%

Appendix 6g-1: La Posada, plot one values

species	**cover area**	**% cover**	**relative % cover**
Celtis ehrenbergiana	8.40	0.84%	0.58%
Cocculus diversifolius	1.77	0.18%	0.12%
Condalia hookeri	46.97	4.70%	3.27%
Diospyros texana	12.74	1.27%	0.89%
Ebenopsis ebano	371.80	37.18%	25.88%
Ehretia anacua	1.74	0.17%	0.12%
Ficus benjamina	1.77	0.18%	0.12%
Forestiera angustifolia	9.06	0.91%	0.63%
Fraxinus berlandieriana	78.96	7.90%	5.50%
Guaiacum angustifolium	9.05	0.90%	0.63%
Leucaena pulverulenta	11.08	1.11%	0.77%
Lycium berlandieriana	0.07	0.01%	0.00%
Malpighia glabra	6.95	0.70%	0.48%
Randia rhagocarpa	2.17	0.22%	0.15%
Sabal mexicana	319.30	31.93%	22.23%
Schinus terebinthifolia	9.79	0.98%	0.68%
Sideroxylon celastrinum	23.66	2.37%	1.65%
Solanum pseudocapsicum	0.50	0.05%	0.03%
Taxodium mucronatum	484.98	48.50%	33.76%
Xylosma flexuosa	7.36	0.74%	0.51%
Zanthoxylum fagara	13.52	1.35%	0.94%
Ziziphus obtusifolia	14.97	1.50%	1.04%
Total	1436.60	143.66%	100.00%

Appendix 6g-2: La Posada, plot two values

species	**area cover**	**% cover**	**relative % cover**
Adelia vaseyi	1.33	0.13%	0.09%
Carica papaya	3.87	0.39%	0.25%
Celtis laevigata	0.86	0.09%	0.06%
Celtis ehrenbergiana	18.28	1.83%	1.19%
Condalia hookeri	176.56	17.66%	11.45%
Ebenopsis ebano	119.00	11.90%	7.72%
Forestiera angustifolia	0.70	0.07%	0.05%
Fraxinus berlandieriana	234.54	23.45%	15.21%
Guaiacum angustifolium	3.80	0.38%	0.25%
Havardia pallens	52.81	5.28%	3.42%
Leucaena pulverulenta	11.59	1.16%	0.75%
Malpighia glabra	3.22	0.32%	0.21%
Malvaviscus arboreus	1.26	0.13%	0.08%
Nekemias arborea	14.14	1.41%	0.92%
Pisonia aculeata	25.56	2.56%	1.66%
Prosopis glandulosa	3.14	0.31%	0.20%
Sabal mexicana	334.78	33.48%	21.71%
Salix nigra	9.16	0.92%	0.59%
Schinus terebinthifolius	34.73	3.47%	2.25%
Sideroxylon celastrinum	23.59	2.36%	1.53%
Solanum pseudocapsicum	3.09	0.31%	0.20%
Taxodium mucronatum	422.85	42.29%	27.42%
Triadica sebifera	30.21	3.02%	1.96%
Vachellia farnesiana	0.20	0.02%	0.01%
Washingtonia robusta	1.33	0.13%	0.09%
Xylosma flexuosa	4.91	0.49%	0.32%
Zanthoxylum fagara	4.38	0.44%	0.28%
Ziziphus obtusifolia	2.01	0.20%	0.13%
Total	1541.91	154.19%	100.00%

Appendix 6h-1: Sabal Palm, plot one values

species	area cover	% cover	relative % cover
Abutilon hypoleucum	0.98	0.10%	0.08%
Amyris texana	0.50	0.05%	0.04%
Baccharis neglecta	0.07	0.01%	0.01%
Carica papaya	0.64	0.06%	0.05%
Celtis ehrengergiana	2.29	0.23%	0.19%
Chiococca alba	13.07	1.31%	1.06%
Chromolaena odorata	0.50	0.05%	0.04%
Citharexylum berlandieri	1.96	0.20%	0.16%
Condalia hookeri	14.52	1.45%	1.18%
Diospyros texana	50.27	5.03%	4.09%
Ebenopsis ebano	295.44	29.54%	24.03%
Ehretia anacua	13.53	1.35%	1.10%
Erythrina herbacea	1.06	0.11%	0.09%
Havardia pallens	104.62	10.46%	8.51%
Leucaena pulverulenta	73.98	7.40%	6.02%
Malpighia glabra	25.78	2.58%	2.10%
Malvaviscus arboreus	2.70	0.27%	0.22%
Petiveria alliacea	0.57	0.06%	0.05%
Phaulothamnus spinescens	8.87	0.89%	0.72%
Pluchea carolinensis	1.33	0.13%	0.11%
Randia rhagocarpa	17.44	1.74%	1.42%
Sabal mexicana	505.00	50.50%	41.08%
Sideroxylon celastrinum	3.93	0.39%	0.32%
Solanum erianthum	1.54	0.15%	0.13%
Tamaulipa azurea	5.07	0.51%	0.41%
Xylosma flexuosa	5.11	0.51%	0.42%
Zanthoxylum fagara	78.59	7.86%	6.39%
Total	1229.40	122.94%	100.00%

Appendix 6h-2: Sabal Palm, plot two values

species	area cover	% cover	relative % cover
Abutilon hypoleucum	0.88749992	0.09%	0.06%
Amyris texana	5.91404817	0.59%	0.43%
Celtis ehrenbergiana	88.6243288	8.86%	6.44%
Chiococca alba	47.5244429	4.75%	3.45%
Citharexylum berlandieri	0.88749992	0.09%	0.06%
Condalia hookeri	8.80431341	0.88%	0.64%
Diospyros texana	18.5432506	1.85%	1.35%
Ebenopsis ebano	477.655601	47.77%	34.71%
Ehretia anacua	9.65254343	0.97%	0.70%
Forestiera angustifolia	1.02101761	0.10%	0.07%
Guaiacum angustifolium	19.0773214	1.91%	1.39%
Havardia pallens	170.737707	17.07%	12.41%
Malpighia glabra	29.9001081	2.99%	2.17%
Phaulothamnus spinescens	10.6657071	1.07%	0.77%
Randia rhagocarpa	47.1081818	4.71%	3.42%
Sabal mexicana	143.123107	14.31%	10.40%
Sideroxylon celastrinum	52.4488894	5.24%	3.81%
Tamaulipa azurea	19.234401	1.92%	1.40%
Xylosma flexuosa	6.12610567	0.61%	0.45%
Zanthoxylum fagara	76.5213431	7.65%	5.56%
Ziziphus obtusifolia	141.780076	14.18%	10.30%
Total	1376.23749	137.62%	100.00%

BIOGRAPHICAL SKETCH

Raziel I. Flores graduated with a B.S in biology from the University of Texas – Pan American in the Fall of 2013. He has worked as a naturalist at the McAllen Nature Center since 2015 where he has implemented the results of his thesis data for habitat restoration of native plant communities. Raziel has also worked in environmental consulting as a wildlife biologist since 2017. He can be contacted at ravolucionar@gmail.com