STRUCTURE AND DIVERSITY OF *Larrea tridentata* (DC.) Coville, MICROPHYLLUS DESERT SCRUB IN NORTHEAST MEXICO

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SUMMARY

Microphyllous desert scrub communities cover about 19.5×10⁶ha and are the most common and widely distributed vegetation in arid areas of Mexico. Larrea tridentata *(DC.) Coville, an evergreen creosote bush or* chaparral *that can survive in extreme drought conditions, due mainly to its allelopathic substances and secondary metabolites, is typically found as the dominant species in this community. The aim of this study was to evaluate the structure and diversity of a microphyllous scrub community dominated by* L. tridentata *in Northeastern Mexico. To determine the composition, diversity and structure of a community consisting of trees, shrubs and succulents, 10 circular sample sites, each of 500m², were established. Within each circular site, square-shaped sampling sites of 1.0m² were established in order to evaluate herbaceous vegetation. The plant species were idetified and the diameters of each individual crown measured. Margalef (D_{Mg}) and Shannon-Weiner (H') indices were calculated to determine the richness and diversity of species, respectively. Forty species, 33 genera and 12 families of vascular plants were registered. Families with the most species were Cactaceae (13), Fabaceae (8) and Asteraceae (5). The* L. tridentata *microphyllous scrub community has a high species richness compared to other xerophilous scrub communities in Northeastern Mexico. The distribution of species abundance was adjusted to the Pareto model, due to the abundance or rare species that characterizes stressful environments.*

Introduction

Scrublands are the most common and widely distributed vegetation communities in arid areas of Mexico (Rzedowski, 1978). Despite the unfavorable conditions of the desert areas, there is a wide diversity of succulent species that hold great ecological relevance such as the case of cacti that are often considered endemic or are endangered (Hernández *et al.,* 2008). These plants are distributed in different communities, forming mosaics according to the conditions of the terrain and the climate (Huerta-Martínez and García-Moya, 2004). Particularly, the microphyllous scrub community covers an area of 19.5×10^6ha in the lower portions of mountain slopes and especially in flatlands with alluvial soils (Granado-Sánchez *et al*., 2011). Typically, the dominant species in this vegetation type is *Larrea tridentata* (DC.) Coville (creosote bush), an aromatic shrub of 1-2 m in height with numerous flexuous stems. Unlike other species of shrubs that are morphologically and physiologically adapted to arid conditions, like succulents, which have spines, indumentum or falling leaves, *L. tridentata* is a defenseless evergreen species that has been able to survive in extreme drought conditions by making use of other attributes (Hamerlynck *et al*., 2000). The presence of allelopathic substances and secondary metabolites has played an important role in helping this bush to thrive and occupy large areas in scrublands and displace other species that are typical of these ecosystems (Mabry *et al*., 1977; Rundel *et al*., 1994).

The scrubland distribution of *L. tridentata* extends from the Southwestern United States to Central Mexico, and it is mostly distributed in Northern and Central Mexico (Granados *et al*., 2011). Despite its significant representation in Mexico and the threat to this community from anthropogenic impacts such as overgrazing, only a few studies have been generated on communities of *L. tridentata* (Mora-Donjuán *et al*., 2014). The floristic and ecological studies on xeric scrubs that have taken place in recent years in Northern Mexico, particularly in the state of Nuevo Leon, have focused on the study of Tamaulipan thornscrub, submontane scrub and rosetophilous desert scrub (Reid *et al*., 1990; Pompa-García *et al*., 2017; Rascón *et al*., 2017). *L. tridentata* microphyllous desert scrub has been little studied in Northeas-

KEYWORDS / Chihuahuan Desert / Diversity / Index / *Larrea tridentata* / Margalef Index / Mexico / Shannon /

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ESTRUCTURA Y DIVERSIDAD DE UN MATORRAL DESÉRTICO MICRÓFILO DE *Larrea tridentata* (DC.) Coville EN EL NORESTE DE MÉXICO

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RESUMEN

Las comunidades de matorral desértico micrófilo comprenden cerca de 19,5'10^{6}ha y son la vegetación más común y ampliamente distribuida en zonas áridas de México. En estas comunidades la especie típicamente dominante es Larrea tridentata *(DC.) Coville ('chaparral'), un arbusto resinoso siempreverde capaz de sobrevivir en condiciones de extrema sequía debido sobre todo a su contenido de sustancias alelopáticas y metabolitos secundarios. El objetivo del estudio fue evaluar la estructura y diversidad de una comunidad de matorral micrófilo dominado por* L. tridentata *en el noreste de México. A fin de determinar la composición, diversidad y estructura de una comunidad contentiva de árboles, matorrales y plantas suculentas, se establecieron 10 sitios de muestreo circulares de 500m^2. Dentro de cada sitio circular se establecieron sitios cuadrangulares de 1m^2 para evaluar la vegetación herbácea. Las especies vegetales fueron identificadas y se midió el diámetro de cada corona. Los índices de Margalef (D_{Mg}) y de Shannon-Weiner (H') fueron calculados para determinar la riqueza y la diversidad de especies, respectivamente. Se registraron 40 especies, 33 géneros y 12 familias. Las familias con más especies fueron Cactaceae (13), Fabaceae (8) and Asteraceae (5). La comunidad de matorral micrófilo de* L. tridentata *en el noreste de México tiene una riqueza de especies alta en comparación a otras comunidades de matorral xerófilo en la región. La distribución de la abundancia de especies se ajustó al modelo de Pareto, dada la abundancia de especies raras que caracterizan los ambientes extremos.*

ESTRUTURA E DIVERSIDADE DE UM MATAGAL DESÉRTICO MICRÓFILO DE *Larrea tridentata* (DC.) Coville NO NORDESTE DE MÉXICO

José Manuel Mata-Balderas, Eduardo Javier Treviño-Garza, Eduardo Alanís-Rodríguez, Alejandro Collantes Chávez-Costa, Ernesto A. Rubio-Camacho, Arturo Mora-Olivo e José Guadalupe Martínez-Ávalos

RESUMO

As comunidades de matagal desértico micrófilo compreendem cerca de 19,5'10^{6}ha e são a vegetação mais comum e amplamente distribuída em áreas áridas de México. Nestas comunidades a espécie tipicamente dominante é Larrea tridentata *(DC.) Coville ('chaparral'), um arbusto resinoso sempre verde capaz de sobreviver em condições de seca extrema devido sobretudo a seu conteúdo de substâncias alelopáticas e metabólitos secundários. O objetivo do estudo foi avaliar a estrutura e diversidade de uma comunidade de matagal micrófilo dominado por* L. tridentata *no nordeste do* México. Com o fim de determinar *a composição, diversidade e estrutura de uma comunidade contentiva de árvores, matagais e plantas suculentas, se estabeleceram 10* áreas *de amostragem circulares de 500m^2. Dentro de cada* área *circular se estabeleceram parcelas quadrangulares de 1m^2 para avaliar a vegetação herbácea. As espécies vegetais foram identificadas e se mediu o diâmetro de cada corona. Os índices de Margalef (D_{Mg}) e de Shannon-Weiner (H') foram calculados para determinar a riqueza e a diversidade de espécies, respectivamente. Registraram-se 40 espécies, 33 gêneros e 12 famílias. As famílias com mais espécies foram Cactaceae (13), Fabaceae (8) e Asteraceae (5). A comunidade de matagal micrófilo de* L. tridentata *no nordeste do México tem uma riqueza de espécies alta em comparação a outras comunidades de matagal xerófilo na região. A distribuição da abundância de espécies se ajustou ao modelo de Pareto, devido à abundancia de espécies raras que caracterizam os ambientes extremos.*

tern Mexico, the work of Mora-Donjuán *et al.* (2014) being one of the few papers published. In order to contribute to the knowledge of this community, the aim of this study was to determine the composition, diversity and structure of a thicket of the *Larrea tridentata* mycrophyllus desert scrub in one of the most well-preserved areas of Northeastern Mexico.

Materials and Methods

Location and site description

The study was conducted within a *Larrea tridentara* (DC.) Coville microphyllous desert scrub community located in the city of Garcia, state of Nuevo Leon, Northeastern Mexico, at 25º49'01''North and 100º36' 45''W, at an elevation of 740 masl (Figure 1). The climate is dry semiwarm BSh according to the Köppen Climate Classification. The average annual temperature is 18-22ºC and the hottest months are July and August. The representative soil type in the study area is Haplic Xerosol.

Vegetation sampling

In September 2014, parameters of the *Larrea tridentata* microphyllus desert scrub community

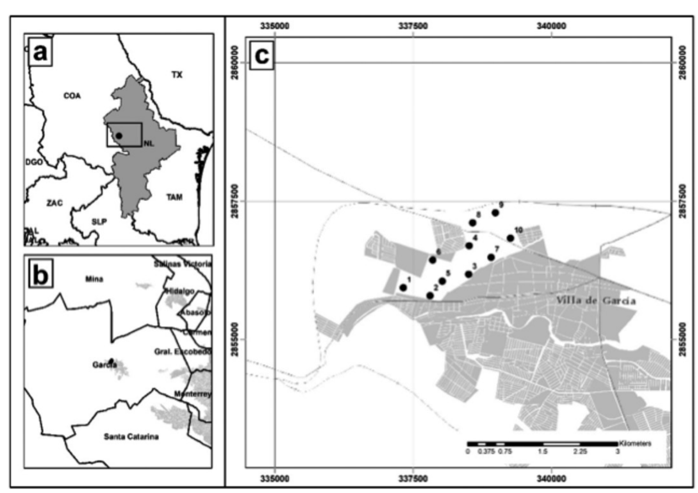

Figure 1. Location of the study area. a: Northeastern Mexico and Southeastern United States; b: the municipality of Garcia, Nuevo Leon; c: the spatial location of the sampling sites.

nity were determined at ten randomly located circular plots of 500m^2. Two levels of stratification were followed: tree, shrub and succulent components were analyzed in the circular area, while the herbaceous vegetation was studied in a 1m^2 square-shaped site established within each circular plot. Following this experimental design, a census of all trees, shrubs, succulents and grasses was conducted, measuring coverage, height and diameter for all individuals, except for the diameter in herbaceous and succulent vegetation, due to the lack of a woody stem. The coverage was measured as the area of ground occupied by plants within the circular and quadrat plots, and was calculated as the average of the north-south and east-west measure of the crown (for trees and shrubs) or of the individual and clump (for succulents and herbaceous).

Data analysis

To estimate the species richness index of Margalef (1958; D_{Mg}) and the species diversity index of Shannon-Weiner (Shannon y Weaver, 1949), the following equations were used:

$$D_{Mg} = \frac{(S-1)}{\ln(N)}$$

$$H' = -\sum_{i=1}^{s} p_i \times \ln(p_i); \quad p_i = n_i / N$$

where S: number of species present, N: total number of individuals, and n_i: number of individuals of species i.

Species abundance (AR_i) was determined according to the total number of individuals per species, dominance (DR_i) was based on the average crown cover (horizontal ground projection from the aerial section), and frequency (FR_i) was based on the species presence within each sampling site. Relative values of these variables were used to obtain the Importance Value Index (IVI), which represents a weighted value of the level of taxon representativeness expressed as percentage on a scale of 0 to 100 (Müeller and Ellenberg, 1974) defined by the following equation (Whittaker, 1972):

$$IVI = \sum_{n}^{i=1} \frac{(AR_i, DR_i, FR_i)}{3}$$

The distribution of species abundance is described by using three models: the Pareto model, the Poisson model of normal lognormal series and the Neutral Model of Alonso and Mackane (Alonso and McKane, 2004). The three models were fitted according to the maximum likelihood method, using the R software (R Core Team, 2016), via the R Studio interface (R Studio, version 0.99) and the Species Abundance Distributions (SADs package, version 0.2.4.). The model selection was conducted by visual and statistical methods, via the following steps: 1) the predicted behavior of the data was evaluated by graphically observing the similarity or difference of the distribution of data against the theoretical distribution; 2) a comparison was undertaken of models selected by the Akaike Information Criterion (AIC), which takes into account the statistical adjustment and complexity. When two models are compared with this statistical selection method, the best model is chosen based on the lower value in the AIC and the delta AIC (dAIC) in comparing models based on the outcome of AIC, minus the minimum AIC. If dAIC<2 there is no difference between the models (Kindt and Coe, 2005).

These three models were chosen because they can be used to describe the species abundance distribution, with some differences. The Pareto distribution follows a power law distribution and is commonly used to make inferences about the distributions in community assemblages: in plant ecology, for example, this power law distribution could be used to explain the assumption of a high presence of pioneer plants and low presence of late successional ones, due to the implicit ‘costs’ to the ecosystem of setting the necessary conditions for these plants to invade. The neutral model is Hubel’s metacommunity zero-sum multinomial distribution, with the density approximation form Alonso and McKane (2004). In the case of the Poison lognormal distribution, the species abundance distributions follow a lognormal density function with independent random variables (Prado and Dantas, 2014).

Results

A total of 40 species belonging to 33 genera and 12 families of vascular plants were recorded (Table I). The families with the

TABLE I
LIST OF THE SCRUB FLORA COMPRISING THE *Larrea tridentata* SCRUB IN THE MUNICIPALITY OF GARCÍA, NUEVO LEON, MEXICO

Agavaceae
Agave lechuguilla Torr.
Asteraceae
Acourtia nana (A. Gray) Reveal & R.M. King
Calyptocarpus vialis Less.
Parthenium hysterophorus L.
Parthenium incanum Kunth
Pectis papposa Harv. & A. Gray
Thymophylla pentachaeta (DC.) Small
Viguiera stenoloba S.F. Blake
Zinnia acerosa (DC.) A. Gray
Boraginaceae
Cordia boissieri A. DC.
Tiquilia canescens (A. DC.) A.T. Richardson
Cactaceae
Coryphantha neglecta L. Bremer
Coryphantha salinensis (Poselger) Dicht & A. Lüthy
Cylindropuntia imbricata (Haw.) F.M. Knuth
Cylindropuntia leptocaulis (DC.) F.M. Knuth
Echinocactus horizonthalonius Lem.
Echinocactus texensis Hopffer
Echinocereus enneacanthus Engelm.
Echinocereus poselgeri Lem.
Mammillaria heyderi Muehlenpf.
Opuntia engelmannii Salm-Dyck
Opuntia microdasys (Lehm.) Pfeiff.
Sclerocactus scheeri (Salm-Dyck) N.P. Taylor
Thelocactus bicolor (Galeotti ex Pfeiff.) Britton & Rose
Euphorbiaceae
Jatropha dioica Sessé
Fabaceae
Acacia rigidula Benth.
Dalea lasiathera A. Gray
Mimosa texana (A. Gray) Small
Prosopis glandulosa Torr.
Senna lindheimeriana (Scheele) H.S. Irwin & Barneby
Rhamnaceae
Karwinskia humboldtiana (Schult.) Zucc.
Koeberliniaceae
Koeberlinia spinosa Zucc.
Scrophulariaceae
Leucophyllum frutescens (Berland.) I.M. Johnst.
Solanaceae
Nicotiana glauca Graham
Nicotiana trigonophylla Dunal
Solanum elaeagnifolium Cav.
Ulmaceae
Celtis pallida Torr.
Ziziphus obtusifolia (Hook. ex Torr. & A. Gray) A. Gray
Zygophyllaceae
Larrea tridentata (DC.) Coville
Porlieria angustifolia (Engelm.) A. Gray

most species were Cactaceae (13), Asteraceae (8) Fabaceae (5) and Solanaceae (3); these families accounted together for 72% of the species recorded in the study.

Tree, shrub and succulent stratus

The tree, shrub and succulent components present a D_{Mg}= 4.09, and an H'= 1.75. Also, this stratus has a species richness of 29 species (S), a density of 1,858 individuals/ha and a total crown cover of 1622.39m^2·ha^{-1}. The most important species (Table II) were *Larrea tridentata, Jatropha dioica* Sessé, *Cylindropuntia leptocaulis* (DC.) F.M. Knuth, *Parthenium incanum* Kunth, *Opuntia microdasys* (Lehm.) Pfeiff and *Ziziphus obtusifolia* (Hook. ex Torr. & A. Gray) A. Gray. Together, these species accounted for 75.73% of the IVI of the community. Furthermore, 48.27% of the species presented values of IVI<1.0%. *Mammillaria heyderi* Muehlenpf., *Coryphantha salinensis* (Poselger) Dicht & A. Lüthy and *Coryphantha neglecta* L. Bremer recorded the lowest IVI values (0.38%).

The analysis of the distribution pattern of species abundance showed that the best visual adjustment (Figure 2) and statistics (Table III) were obtained with the Pareto model, followed by the Poisson model of logarithmic series, and finally by the neutral model.

TABLE II
STRUCTURAL PARAMETERS OF SPECIES TAKING THE FORM OF TREE, SHRUB AND SUCCULENT GROWTH REGISTERED AT THE SITES OF 500 m^2 AREAS

Species	Abundance		Dominance		Frequency		IVI
	N/ha	%	m^2/ha	%	Sites	%	
Larrea tridentata (DC.) Coville	1040	55.97	854.30	52.66	10	9.26	39.30
Jatropha dioica Sessé	204	10.98	201.26	12.41	10	9.26	10.88
Cylindropuntia leptocaulis (DC.) F.M. Knuth	144	7.75	182.90	11.27	10	9.26	9.43
Parthenium incanum Kunth	114	6.14	75.29	4.64	7	6.48	5.75
Opuntia microdasys (Lehm.) Pfeiff.	82	4.41	75.54	4.66	8	7.41	5.49
Ziziphus obtusifolia (Hook. Ex Torr. & A. Gray)	56	3.01	68.46	4.22	8	7.41	4.88
Prosopis glandulosa Torr.	16	0.86	34.81	2.15	6	5.56	2.85
Acacia rigidula Benth.	4	0.22	3.80	0.23	7	6.48	2.31
Koeberlinia spinosa Zucc.	20	1.08	10.39	0.64	5	4.63	2.12
Echinocactus horizonthalonius Lem.	42	2.26	1.71	0.11	4	3.70	2.02
Opuntia engelmannii Salm-Dyck	14	0.75	7.89	0.49	5	4.63	1.96
Sclerocactus scheeri (Salm-Dyck) N.P. Taylor	12	0.65	0.04	0.00	5	4.63	1.76
Echinocereus enneacanthus Engelm.	8	0.43	1.71	0.11	4	3.70	1.41
Agave lechuguilla Torr.	36	1.94	18.10	1.12	1	0.93	1.33
Cylindropuntia imbricata (Haw.) F.M. Knuth	4	0.22	34.21	2.11	1	0.93	1.08
Echinocactus texensis Hopffer	14	0.75	0.37	0.02	2	1.85	0.88
Celtis pallida Torr.	4	0.22	19.64	1.21	1	0.93	0.78
Echinocereus poselgeri Lem.	6	0.32	0.85	0.05	2	1.85	0.74
Thelocactus bicolor Britton & Rose	6	0.32	0.02	0.00	2	1.85	0.73
Nicotiana glauca Graham	2	0.11	7.60	0.47	1	0.93	0.50
Karwinskia humboldtiana S. Watson	2	0.11	6.93	0.43	1	0.93	0.49
Mimosa texana Small	2	0.11	6.28	0.39	1	0.93	0.47
Viguiera stenoloba S.F. Blake	4	0.22	4.52	0.28	1	0.93	0.47
Leucophyllum frutescens I.M. Johnst.	2	0.11	3.30	0.20	1	0.93	0.41
Porlieria angustifolia A. Gray	4	0.22	1.54	0.09	1	0.93	0.41
Cordia boissieri A. DC.	4	0.22	0.79	0.05	1	0.93	0.40
Coryphantha neglecta L. Bremer	4	0.22	0.08	0.00	1	0.93	0.38
Mammillaria heyderi Muehlenpf.	4	0.22	0.06	0.00	1	0.93	0.38
Coryphantha salinensis (Poselg.) Dicht & A. Lüthy	4	0.22	0.01	0.00	1	0.93	0.38
Total	1858	100.00	1.622.39	100.00		100.00	100.00

A total area of 5000 m^2 was evaluated. The abundance (number of individuals N) and coverage (in m^2) are expressed per ha. IVI: Importance Value Index. The species are sorted in descending order according to their IVI.

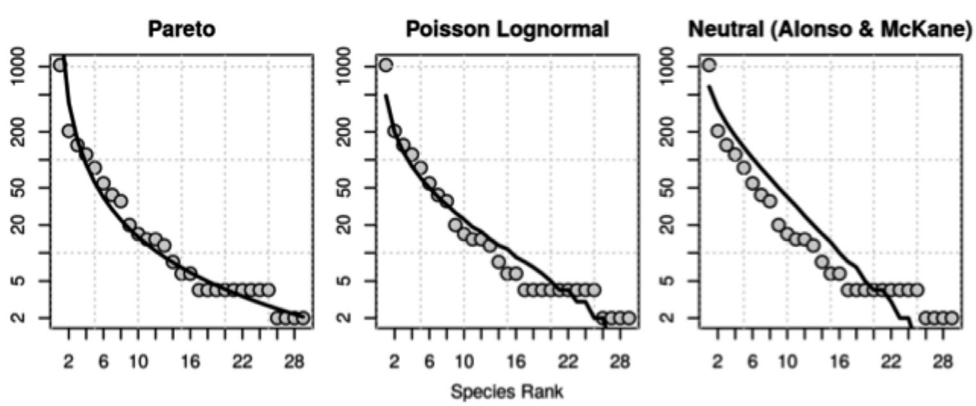

Figure 2. Rank abundance form for the species abundance distributions. From left to right, the first plot is the Pareto model with best fit to the observed data indicating high abundance for few species and low abundance for most species; the second is the Poisson lognormal and the third is the neutral model, both are showing a similar behavior, at the end of the distribution they tend to misfit the data distribution.

Herbaceous stratus

The herbaceous stratus presents a D_{Mg}= 1.36, and an H'= 1.76. Also, this stratus showed a species richness (S) of 11, a density of 153,000 individuals/ha, and a total coverage of 678.13 m^2 ha^{-1}. *Pectis papposa* Harv. & A. Gray, *Solanum elaeagnifolium* Cav., *Senna lindheimeriana* (Scheele) H.S. Irwin & Barneby, *Dalea lasiathera* A. Gray, and *Tiquilia canescens* (A. DC.) A.T. Richardson were the most important species, accounting for 73.37% of the IVI (Table IV). No IVI for herbaceous species was <1%, and *Parthenium hysterophorus* L. had the lowest recorded value of IVI (2.31%).

Discussion

Tree, shrub and succulent stratus

In the current study, values of 4.09 for the Margalef index (D_{Mg}) and of 1.75 for Shannon index (H') were found. Mora-Donjuán *et al.* (2014) and Mata *et al* (2014) reported lower D_{Mg}, values, of 2.29 and 2.59, respectively, and similar H' values, of 1.87 and 1.90, respectively. The tree, shrub, and succulent richness (S) we found in of the *Larrea tridentata* microphyllus desert scrub (29 species) are higher than those recorded by González-Delgado (2016) and Mora-Donjuán *et al.* (2014), in 15 species of trees, shrubs and succulents in a microphyllous desert scrub with a history of livestock-use. Alanís *et al.* (2015) also registered 15 species in a microphyllous desert

TABLE III
FIT OF THE DISTRIBUTION PATTERNS OF SPECIES ABUNDANCE WITHIN THE STUDY AREA

Model	loglik	AIC	dAIC	GL	Weight
Pareto	-122	245	0.0	1	0.991
Poisson Lognormal	-126	255	10.3	2	0.006
Modelo Neutral	-129	260	15.5	1	0.000

scrub adjacent to a metropolitan area of Monterrey in Northeast Mexico. These low richness values reported by Mora-Donjuán *et al.* (2014) and Alanís *et al.* (2015), compared to the results of the present study, were due to both areas having a history of productive use. This may have altered the structure and composition of the natural plant communities. However, because research that addresses the study of these communities are rare (Pompa-García *et al.* 2017), it is necessary to carry out further studies to know the ranges of variation in their composition and diversity.

In this study, the Cactaceae family has the largest number of species (13), coinciding with the reports by Mora-Donjuán *et al.* (2014) and Alanís *et al.* (2015). These results support the conclusions of other studies that recognize the region as one of the most important areas in terms of cactus diversity. This may be due to the high degree of aridity that occurs in this region of Northeastern Mexico.

In general, the xeric scrub, which is predominated by succulent and semi-succulent plants, include certain species of plant families that are closely linked to arid and semi-arid areas of Mexico, where their centers of origin and diversification occur (Rzedowski, 1978). Among the most frequent are the Cactaceae (Guzmán *et al.*, 2003), Agavaceae (magueys, izotes and sotoles; Gentry, 1998), Fouquieriaceae (ocotillo, Boojum tree, etc.), and Crassulaceae families. Crassulaceae is a botanical family that, despite being primarily African, is cosmopolitan; however, in Mexico it has a very important center for diversification in the genus Echeveria (Meyrán and López, 2003; Thiede and Eggli, 2007; Pilbeam, 2008). Furthermore, all these families have extremely high specific percentages of endemism in this region (Rzedowski, 1978).

The high number of families (12) and genera (24) recorded in this study can probably be attributed to the overall structural complexity of the bushland (Humphries *et al.*, 1995; MacGillivray and Grime, 1995). For example, extremes of abiotic factors such as high and low temperatures, have strong impacts on the establishment of seedlings in these arid environments. The interaction of unpredictable extreme temperatures and the prolonged droughts have been found by others to be determining factors in the structure and function of plant communities in arid zones (Jordan and Nobel 1979; Rundel and Gibson 1996; PockMan and Sperry, 1997; Hamerlynck *et al.*, 2000; Zúñiga-Vásquez *et al.*, 2017). According to Challenger and Soberón (2008), these types of communities, have plant groups with neotropical affinity (37%), are especially rich in endemics, 44% at the genus level growing to 60% at the species level. These types of vegetation are among the most important in Mexico because of their expanse and contribution to the endemic flora of the country. The results of this research show that the species with the highest importance value is Larrea tridentata (IVI= 39.09), which is in accordance with those of other authors (Granados *et al.*, 2011; Pompa-García *et al.*, 2017), who note that it is a species that dominates the landscape with respect to its density (individuals/ha) and its canopy cover (m2·ha-1).

The tree, shrub and succulent plant components combined have a density of 1,858 individuals/ha and a total canopy cover of 1622.39m^2·ha^{-1}. The results for density are similar to those reported by Mora-Donjuán *et al.* (2014), who recorded a density of 1,792 individuals/ha and, although the total canopy cover reported by these authors (2,505m^2·ha^{-1}) was higher than the ones found in our study, both are lower than those reported in other studies. The results recorded by Mata *et al.* (2014), who evaluated a microphyllous desert scrubland community in the Valley of Santa Catarina, West of Nuevo Leon, Mexico, are a density of 2,469 individuals/ha and canopy cover of 3,439m^2·ha^{-1}, which are higher than those recorded in the present study. It is generally seen that this type of community has a low canopy cover (<40% in all cases) and it therefore has a high exposure of the substrate (without canopy cover).

The Pareto distribution was used to model distributions that follow a power law behaviour (Newman, 2005). In the case of plant communities, it could explain the trend of the abundance curve when few species have a high abundance that decreases with the increase of number of species (Prado *et al.*, 2015). In the presence of a large number of rare species, the Pareto model has a good fit (Ulrich *et al.*, 2010). The abundant presence of rare species is characteristic of stressful environments with the possible presence of disturbances (Verberk, 2011), such as the desert, where a relatively high rate of local extinction and immigration are recorded (Ulrich and Ollik, 2004). While local extinction can be random or deterministic (Harrison, 1991), the fit to the Pareto model suggests the latter. This model indicates the presence of pioneer plants and a low presence of late successional ones, due to the implicit 'costs' to the ecosystem on setting the necessary conditions for these plants to invade.

TABLE IV
STRUCTURAL PARAMETERS OF HERBACEOUS SPECIES GROWTH ON 1m^2 SAMPLE SITES

Species	Abundance		Dominance		Frequency		IVI
	N/ha	%	m^2/ha	%	Sites	%	
Pectis papposa Harv. & Gray	76000	49.67	73.12	10.78	9	14.75	25.07
Solanum elaeagnifolium Cav.	9000	5.88	252.29	37.20	6	9.84	17.64
Senna lindheimeriana (Scheele) H.S. Irwin & Barneby	8000	5.23	209.74	30.93	6	9.84	15.33
Dalea lasiathera A. Gray	19000	12.42	23.88	3.52	6	9.84	8.59
Tiquilia canescens (DC. A.T.Richardson	11000	7.19	10.58	1.56	7	11.48	6.74
Nicotiana trigonophylla Dunal	6000	3.92	27.37	4.04	6	9.84	5.93
Acourtia nana (A. Gray) Reveal & R.M.King	9000	51.88	9.66	1.42	6	9.84	5.71
Calyptocarpus vialis Less.	6000	3.92	16.12	2.38	6	9.84	5.38
Thymophylla pentachaeta Small	5000	3.27	8.88	1.31	5	8.20	4.26
Zinnia acerosa A. Gray	3000	1.96	15.08	2.22	3	4.92	3.03
Parthenium hysterophorus L.	1000	0.65	31.42	4.63	1	1.64	2.31
	153000	100.00	678.13	100.00	61	100.00	100.00

The total area evaluated was 100 m^2. The abundance (number of individuals N) and coverage (in m^2) are expressed per ha. IVI: Importance Value Index. The species are sorted in descending order according to their IVI.

Herbaceous vegetation

There is only a small body of literature that evaluates herbaceous communities in xeric scrublands. Most studies are focused on elements such as trees, shrubs and succulents. One of the few studies evaluating the herbaceous communities of *Larrea* was carried out by Morici *et al*. (2006), who evaluated the effect of distance to a water source on the structure of the herbaceous layer when grazed by cattle in arid areas of Argentina. Another study was undertaken by Passera *et al*. (1996), who evaluated the responses of vegetation which was excluded from grazing in a community of *Larrea* in the foothills of Mendoza, Argentina. Evidently, the diversity of herbaceous species is low compared to species of woody character. However, it is noteworthy that almost 50% show indications of disturbance. At least five species are characteristic of these environments: *Solanum elaeagnifolium, Senna lindheimeriana, Nicotiana trigonophylla* Dunal*, Parthenium hysterophorus* and *Calyptocarpus vialis* Less.

Conclusion

According to the analysis in the current study it can be stated that: 1) The community of *L. tridentata* microphyllous desert scrub has a high species richness compared to other xeric scrub communities of Northeastern Mexico, with diversity values being similar to those of other xerophilous bush communities. 2) The distribution of species abundance best fits the Pareto model, with an adjustment that is explained by the abundance of rare species, a condition that characterizes stressful environments. 3) The adjustment of the Pareto model suggests the presence of nonrandom local extinction events that are possibly associated with the ecological strategies of *L. tridentata* (e.g., allelopathy), a species with a high IVI.

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