UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN

FACULTAD DE CIENCIAS FORESTALES

ESTRUCTURA, COMPOSICIÓN Y DIVERSIDAD DE UN BOSQUE DE GALERÍA CON DIFERENTES REGÍMENES DE AGUA.

POR:

ING. MARÍA DE FATIMA AMARÁN RUIZ

Como requisito parcial para obtener el grado de

MAESTRÍA EN CIENCIAS FORESTALES

Julio de 2020

ESTRUCTURA, COMPOSICIÓN Y DIVERSIDAD DE UN BOSQUE DE GALERÍA CON DIFERENTES REGÍMENES DE AGUA.

Aprobación de Tesis

Director de Tesis: Dr. Eduardo Alanís Rodríguez

Asesor: Dr. Eduardo Treviño Garza

Asesor: Dr. Marco Aurelio González Tagle

Asesor externo: Dr. José Manuel Mata Balderas

Julio de 2020

AGRADECIMIENTOS

Primeramente, agradecer al Consejo Nacional de Ciencia y Tecnología (CONACYT) por la ayuda económica brindada y hacer posible la realización del presente proyecto presentado en esta memoria de tesis.

A la Facultad de Ciencias Forestales de la Universidad Autónoma de Nuevo León, institución que me ofreció la oportunidad, para realizar mis estudios de Maestría y de la cual siempre he recibido apoyo.

Al personal administrativo de la Facultad de Ciencias Forestales por su tiempo y disponibilidad.

A todo mi comité de tesis por la atención, dedicación y ayuda durante este proceso, en especial al Dr. Eduardo Alanís Rodríguez.

A mi familia y amigos por el apoyo y comprensión.

DEDICATORIA

A mis padres y hermanos.

RESUMEN 7
ABSTRACT 7
1. CAPÍTULO I 8
1 GENERALIDADES 8
1.1 Introducción general 8
1.2 Justificación 10
1.3 Hipótesis 11
1.3.1 Hipótesis del Capítulo 1: 11
1.3.2 Hipótesis del Capítulo 2: 11
1.4 Objetivos 11
1.4.1 Objetivo General. 11
1.4.2 Objetivos Específicos. 11
2. CAPÍTULO II 12
2 EFFECT OF WATER REGIME IN THE STRUCTURE, COMPOSITION AND DIVERSITY OF THE WOODY SPECIES OF THE GALLERY FOREST IN THE METROPOLITAN AREA OF MONTERREY, MEXICO 12
2.1 Abstract 12
2.2 Resumo 13
2.3 Introduction 14
2.4 Materials and methods 15
2.4.1 Study area 15
2.4.2 Sampling methods 17
2.5 Results 20
2.6 Discussion 26
3. CAPÍTULO III 28

3 VERTICAL STRUCTURE OF THE SANTA CATARINA RIVER GALLERY FOREST IN THE METROPOLITAN AREA OF MONTERREY IN DIFFERENT WATER REGIMES 28
3.1 Abstract........ 28
3.2 Introduction........ 28
3.3 Materials and methods........ 30
3.3.1 Study area........ 30
3.3.2 Sampling methods........ 31
3.3.3 Data analysis........ 31
3.4 Results........ 33
3.5 Discussion 38
4. CAPÍTULO IV 42
4 CONCLUSIONES........ 42
5 BIBLIOGRAFÍA........ 43

LISTA DE FIGURAS

Figure 1. Location of the study area. 16
Figure 2. Sorensen coefficient, Similarity index between the conditions evaluated 25
Figure 3. Means and typical error of A) Shannon index, B) Abundance, C) Margaleaf index and D) Dominance of plant communities in all three conditions. Condition I (permanent), Condition II (semi-permanent), Condition III (temporary). The (a and b) indicate different levels of significance (p <0.05). 25
Figure 4. Study area.. 30
Figure 5. Heights by stratum 32
Figure 6. Graphic representation of the Jaccard similarity coefficient for the upper stratum of conditions.. 35
Figure 7. Graphic representation of the Jaccard similarity coefficient for the middle stratum of conditions. 36
Figure 8. Graphic representation of the Jaccard similarity coefficient for the lower stratum of conditions... 36

LISTA DE CUADROS

Table 1. Abundance, dominance, frequency and Importance Value Index of the species in all three conditions. 21
Table 2. List of species by stratum. 33
Table 3. Values of index in the condition and stratum 36

RESUMEN

En esta investigación se generó información referente a la diversidad, composición y estructura vertical y horizontal de la vegetación del río Santa Catarina. El capítulo 1 se refiere a la introducción general, conceptos básicos utilizados, generalidades del área de estudio, así como la justificación, diseño y conceptualización de la investigación. En el capítulo 2 se describen y determinan los índices de diversidad, composición y estructura horizontal para cada condición evaluada. Para el capítulo 3 se describe la estructura horizontal de la vegetación en cada condición a través de los índices de estratificación por altura. Mientras que el capítulo 4 recoge las conclusiones finales de la investigación, así como los resultados más importantes.

ABSTRACT

In this investigation, information was generated regarding the diversity, composition and vertical and horizontal structure of the vegetation of the Santa Catarina river. Chapter 1 refers to the general introduction, basic concepts used, generalities of the study area, as well as the justification, design and conceptualization of the research. Chapter 2 describes and determines the diversity, composition and horizontal structure indices for each evaluated condition. For Chapter 3 the horizontal structure of the vegetation in each condition is described through the stratification indices by height. While Chapter 4 collects the final conclusions of the investigation, as well as the most important results.

1. CAPÍTULO I

1 GENERALIDADES

1.1 Introducción general

El paisaje y el ecosistema son dos elementos integrales que dependen el uno del otro como componentes ecológicos (Odum y Barret, 2006). La estructura de un ecosistema se define por el tipo, número, ordenamiento espacial y temporal de los elementos que lo constituyen, y gracias a la evaluación de esos elementos por medio de análisis estructurales, se puede dar un concepto de manejo forestal del ecosistema evaluado. Existen diversos índices para la caracterización de la estructura de un ecosistema, que permiten la reproducción de condiciones bajo situaciones determinadas en el tiempo (Aguirre y Jímenez, 1998., citado por Suárez *et al*., 2017). Índices como el de Pretzsch, el cual es una modificación del índice de Shannon, permiten obtener una identificación más precisa de los rodales a partir de la evaluación de la estructura vertical de los bosques, teniendo en cuenta variables como el diámetro, altura media, área basal, volumen, edad y densidad, entre otras (Aguirre y Jiménez, 1998). Estos tipos de índices se complementan ya que en un paisaje convergen percepciones, identificaciones y representaciones del habitante o los habitantes que se pueden traducir en una valoración social desde el punto de vista ecológico (Íñiguez-Ayón *et al.,* 2015). Esa valoración conjunta ecológica-social se conoce como un enfoque integral, el cual comprende un conjunto de aspectos que son generados a través de los ecosistemas, que de no ser ejecutados traen consecuencias en los usos, actividades y ocupación antrópica de ecosistemas como los de galería (Rodríguez y Reyes, 2008).

El término zona o vegetación riparia designa la región de transición y de interacciones entre los medios terrestre y acuático. Esta zona se caracteriza por una flora y una fauna cuya composición está fuertemente determinada por la

intensidad luminosa, el contenido en agua y la granulometría del suelo. Los bosques de galería o riparios, juegan un papel particularmente importante, retienen parte del nitrógeno y el fósforo transportados por la escorrentía, desde los cultivos hasta los cursos de agua. La creación de corredores vegetales a lo largo de los ríos es uno de los medios que permiten restaurar la calidad de las aguas superficiales. Además de la retención de los elementos mencionados, las bandas de vegetación de ribera sombrean el agua y reducen su temperatura durante los días calurosos, estabilizan las orillas, reducen los riesgos de erosión y ofrecen un hábitat a muchas especies vegetales y animales. Los ríos que atraviesan los bosques están rodeados por una vegetación riparia, que controla la temperatura y la luminosidad del agua, aumenta la estabilidad de las orillas y proporciona cantidades importantes de detritos vegetales (madera muerta y hojas muertas) los cuales reducen la velocidad de la corriente, frenan las crecidas y crean zonas de calma favorables a la instalación de muchas especies animales.
La vegetación inmediatamente adyacente a los arroyos o a lo largo de los bordes de los lagos y charcos, se caracteriza por especies vegetales y formas de vida que difieren de aquéllas de los bosques circundantes. La composición de los árboles riparios depende de la elevación, y típicamente consta de árboles deciduos de los géneros *Populus, Quercus, Salíx, Taxodium, Platanus,* generalmente.

El marcado contraste entre la vegetación riparia y la de las tierras altas, produce una diversidad estructural y las características del borde realzan su utilidad para la fauna silvestre. La diversidad de la vegetación también tiene un componente vertical bien marcado; desde la superficie del agua hasta la parte superior del dosel, se encuentran diversas capas distintivas de vegetación. La diversidad riparia es realzada, además, por diferencias en el hábitat a todo lo largo de los escurrimientos. Más allá de ser diversos y únicos, los bosques riparios tienen otro rasgo que los hace importantes: con frecuencia son excepcionalmente fértiles y productivos.

1.2 Justificación

El Río Santa Catarina nace en la Sierra Madre Oriental dentro del Parque Nacional Cumbres de Monterrey, cerca de San José de las Boquillas en Santiago, Nuevo León, a más de 2,200 metros sobre el nivel del mar (MSNM), recogiendo las aguas de 32 cañones. Presenta un cause sinuoso con una pendiente que tiene una inclinación promedio de 10 metros por kilómetros. La ciudad de Monterrey tiene poco más de 500 msnm, por lo cual en las venidas de agua el río presenta corrientes peligrosas.

El río Santa Catarina, hizo posible el establecimiento de Monterrey y su zona metropolitana y generó un sistema económico basado en la agricultura y la ganadería. En el 2008 fue declarado Área Natural Protegida Estatal, en categoría de parque urbano", bajo la denominación de "parque lineal" el cauce del Río Santa Catarina, localizado en los municipios de Monterrey, San Pedro Garza García, Guadalupe, Juárez y Santa Catarina.

En julio de 2010, el Huracán Alex provocó graves inundaciones, deslaves y daños en hogares, puentes, vialidades y demás infraestructura. Las avenidas Constitución e Ignacio Morones Prieto; que corren junto al río, tuvieron que ser rediseñadas y reconstruidas. El parque lineal del 2008 desapareció por completo junto con otras instalaciones deportivas que habían sido construidas alrededor del río. Después de 2010 no se han vuelto a construir instalaciones deportivas o comerciales en el lecho del río, lo que ha permitido que el ecosistema se recupere.

Con el estudio se pretende generar información útil para una mejor comprensión de los procesos ecológicos y del comportamiento de la flora y fauna asociada al río y a los asentamientos poblacionales aledaños. Además de generar herramientas para los decisores en materia ambiental; siendo un punto de referencia para posteriores investigaciones en el área o referentes al tema, debido a la importancia ecológica y económica que presenta el río, y, a todos los intereses y presiones sociopolíticas a los que se encuentra sometido.

1.3 Hipótesis

1.3.1 Hipótesis del Capítulo 1:

La estructura, composición y diversidad de las especies leñosas de la vegetación riparia está determinada por la permanencia de las aguas en el mismo.

1.3.2 Hipótesis del Capítulo 2:

La estructura vertical de las especies leñosas de la vegetación riparia está determinada por la permanencia de las aguas en el mismo.

1.4 Objetivos

1.4.1 Objetivo General.

Describir la variación de estructura, composición y diversidad de las especies leñosas en diferentes tipos de curso de agua en el Área Metropolitana de Monterrey.

1.4.2 Objetivos Específicos.

- Estimar los índices de estructura de la vegetación.
- Estimar los índices de diversidad de la vegetación.
- Describir la estructura vertical y horizontal de la vegetación.

2. CAPÍTULO II

2 EFFECT OF WATER REGIME IN THE STRUCTURE, COMPOSITION AND DIVERSITY OF THE WOODY SPECIES OF THE GALLERY FOREST IN THE METROPOLITAN AREA OF MONTERREY, MEXICO

2.1 Abstract

Gallery forests are presented as lush communities in relation to their surroundings. They develop on the banks of rivers, streams and braided rivers, forming a narrow strip that often functions as wildlife corridors by communicating isolated plant communities. For the evaluation of the area, 3 water regimes were determined, (permanent, semi-permanent and temporary), then 42 sites of 1,000 m^2 were established, 200 meters apart from each other. Which all trees and shrubs with DBH ≥ 5 cm, were measured and identified. The importance value index (IVI), Shannon-Weaver heterogeneity index (H ') and Sørensen similarity index (ISS) were calculated. The results showed significant differences for ($p <$ 0.05) between the evaluated conditions. Registered species were distributed into 32 species, 29 genera and 16 families. The most important species in the sites was *Salix nigra*, which stood out both for its diameter, height and coverage and for its dominance, frequency and density. The low diversity of vegetation makes an anthropic effect evident. Therefore, it is necessary to develop tools with techniques to develop and implement management activities aimed at conserving, restoring and minimizing possible negative impacts.

Keywords: gallery forests, water regimes, vegetation diversity.

2.2 Resumo

As florestas das galerias são apresentadas como comunidades exuberantes em relação aos seus arredores. Eles se desenvolvem nas margens dos rios, canais e canais, formando uma faixa estreita que geralmente funciona como corredores da vida selvagem, comunicando comunidades vegetais isoladas. Para a avaliação da área, foram determinados 3 regimes hídricos (permanentes, semi permanentes e temporários) e, em seguida, foram estabelecidos 42 locais de 1000 m^2, separados por 200 m. Em que todas as árvores e arbustos com DAP ≥ 5 cm foram medidos e identificados; e o índice de valor de importância (IVI), índice de heterogeneidade de Shannon-Weaver (H ') e índice de similaridade de Sørensen (ISS) foram calculados. Os resultados mostram diferenças significativas para ($p \leq 0{,}05$) entre as condições avaliadas. As espécies registradas foram agrupadas em 16 famílias, 29 gêneros e 32 espécies. As espécies mais importantes nos locais foram *Salix nigra*, que se destacou tanto por seu diâmetro, altura e cobertura quanto por sua dominância, frequência e densidade. A baixa diversidade de vegetação torna evidente um efeito antrópico. Portanto, é necessário o desenvolvimento de ferramentas com fundamentos técnicos para desenvolver e implementar atividades de gerenciamento destinadas a conservar, restaurar e minimizar possíveis impactos negativos na área.

Palavras chaves: florestas de galeria, regimes de água, diversidade de vegetação.

2.3 Introduction

Gallery forests are plant formations that are characterized by their connection to the banks of a river or equivalent hydrological entity (Santiago *et al.*, 2014). These are complex and fragile forest communities, which play a fundamental role in ecological, hydrological and biodiversity terms for river conservation (Meli *et al*., 2017). In rivers, species distribution patterns are related to microtopography and edaphic variables (J. C. Cortés and Islebe, 2005) while altitudinal gradients are associated with changes in riverine vegetation characteristics, which include their diversity, as well as their structural and functional properties (Ward *et al.*, 2002; Acosta *et al.,* 2008).

Currently, the evaluation of the structure and condition of gallery forests require detailed information on the richness, abundance, ecological diversity of trees and undergrowth vegetation in order to generate management strategies that ensure the provision of environmental services (Eskelson *et al.,* 2013; Santiago *et al*., 2014). However, rivers and plant communities that develop on their banks have been under intense historical pressure due to the varied human activities, which has led to their transformation since ancient times (Richardson *et al.,* 2007). The long-term investigation of the ecological characteristics, as well as the state or degree of conservation of this type of forest, can provide the technical foundations to implement management activities aimed at conserving, restoring and minimizing possible negative impacts (Camacho *et al*., 2006).

Three categories of water regime have been considered: permanent, semi-permanent river, and temporary streams. We assume that the diversity and dynamics of the woody plants of the gallery forests are related to the water regime, as well as other factors such as the size of the canal width and the phytogeographic position. Considering, substantial changes in vegetation can occur without changing the average annual flow, since it is especially sensitive to changes in minimum and maximum flows, and in many cases, hydrological changes cause changes in the composition of the community of riparian plants, as well as the senescence of woody communities (NAIMAN and OLDEN., 2010). Therefore, our objective was to describe the effect of the water regime on the structure, composition and diversity of the woody species from the gallery forest of the Santa Catarina river, in the Monterrey metropolitan area.

2.4 Materials and methods

2.4.1 Study area

The study was carried out in the segment of Santa Catarina river belonging to the metropolitan area of Monterrey (Figure 1). Covering the municipalities of Monterrey, San Pedro Garza Garcia, Guadalupe, Juárez and Santa Catarina. In 2008, Santa Catarina River channel was declared “State Protected Natural Area, in the category of urban park”, under the name of “linear park” (León, 2008).

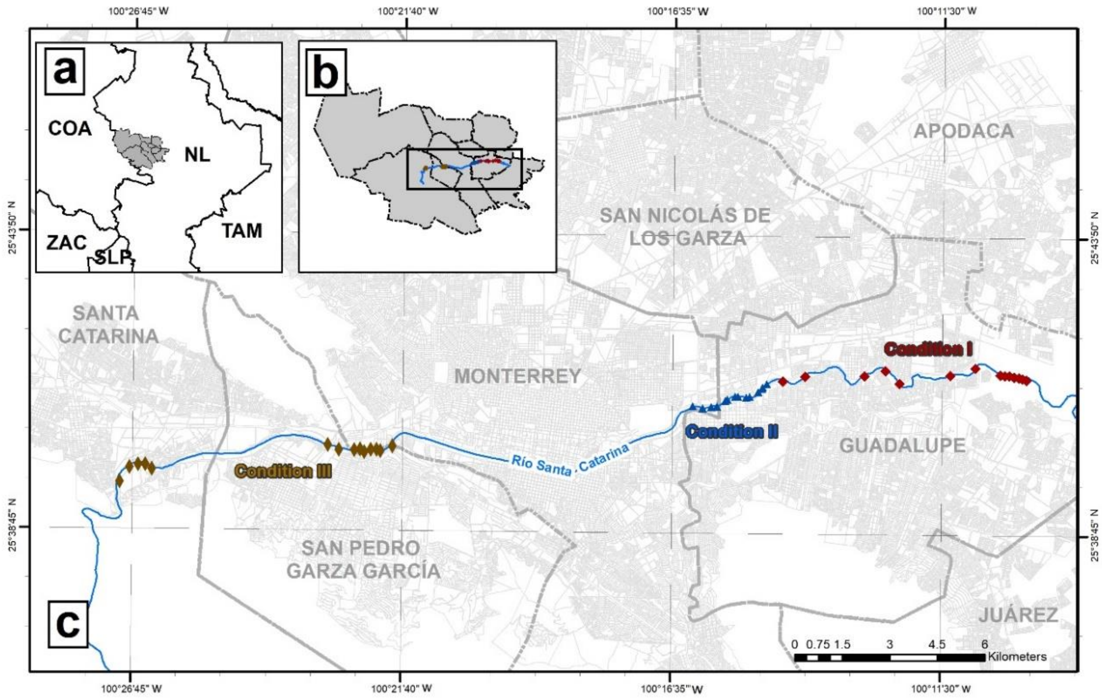

***Figure 1**. Location of the study area.*

The Santa Catarina River is located between 25° 31′ 44″ N and 99° 54′ 3″ W, runs first from south to north; and then, from southeast to northwest, crossing a long and narrow canyon between the foothills of the so-called Sierra del Toro or Taray, and some villages in the municipality of Santa Catarina. Its length is 158.4 km, and its basin area is 1,804 km^2.

The waters that it carries are regularly due to runoff from the underground swamps, to the thaws of the Arteaga mountain range, to the humidity that the different ecosystems capture and to the water tables that sprout springs that feed the river which collects the rain from 32 canyons or mountain chain accesses that make up the mountain part that belongs to the Santa Catarina river.

2.4.2 Sampling methods

The study was conducted in the period from October 2018 to May 2019. 42 sites were establish built in general along the river, divided into 14 sites by condition, these being determined by the existing water regime, condition 1 (permanent), condition 2 (semi-permanent), condition 3 (temporary). The number of optimal sites for sampling was determined by species accumulation curves, obtained in the *Estimates Software V9.0*. for each of the conditions independently. The plots were established in a rectangular form of 50 m x 20 m (1,000 m^2), with spacing between 100 meters and 200 meters from a random point.

Data analysis

An inventory was made and the identification of the existing vegetation in the different strata (shrub and tree) woody species were recorded. The species nomenclature followed the International Index of Plant Names (www.ipni.org). The variables to be measured were taken in those individuals with (DBH) ≥ 5cm: the number of individuals by species, the height and the diameter at 1.30 m of each individual was also recorded. The species were grouped by gender and family.

The abundance of each species was calculated, according to the number of individuals; its dominance, depending on the tree canopy cover; and its frequency, based on its existence in the sampling sites.

$$A_i = {N_i}/{S}$$

$$AR_i = \left({A_i}/{> Ai_{i=1 \ldots n}} \right) x\ 100$$

Where A_i is the absolute abundance, AR_i is the relative abundance of the species $_i$ is in respect of the total abundance, N_i is the number of individuals of the species $_i$, and S the sampling area (ha).

Relative dominance was assessed by:

$$D = {}^{Ab_i}/_{S(Ha)}$$

$$DR_i = \left({}^{D_i}/_{\sum_{i=1..n} D_i}\right)$$

Where D_i is the absolute dominance, DR_i is the relative dominance of the species $_i$ with respect of the total abundance, Ab_i is the cup area of the species $_i$, and S the sampling area (ha).

The relative frequency was obtained by the following equation:

$$F_i = {}^{P_i}/_{NS}$$

$$FR_i = \left({}^{F_i}/_{> F_i}\right) x\ 100$$

Where F_i is the absolute frequency, FR_i is the relative frequency of species $_i$ with respect to total abundance, P_i is the number of sites where species $_i$ is present, and NS total number of sampling sites (ha).

The results were used to calculate a taxon-weighted value, called Importance Value Index (IVI), (Müeller & Ellenberg, 1974; Mostacedo and Fredericksen, 2000; Magurran, 2004).

$$IVI = \frac{AR_i + DR_i + FR_i}{3}$$

For the basal area and cup area occupied by the species, the formula of (Bettinger, 2009) was used:

$$Basal\ area\ (G) = \left(\frac{\pi}{4}\right) xD^2 1.30$$

To estimate species richness, the Margalef index (D_{Mg}) was used

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

Alpha diversity was estimated using the Shannon-Weaver (H´) index (Shannon, 1948; Magurran, 2004).

$$H' = -\sum_{i=1}^{s} p_i \times ln(p_i)$$

$$p_i = \frac{n_i}{N}$$

After verifying the statistical assumptions of normality, homoscedasticity and independence among the observations, one factor (plant community) Analysis of Variance (ANOVA) was carried out at four levels determined by the type of water regime (permanent, semi-permanent and temporary) between the ecological parameters of abundance and coverage and Margalef index and Shannon index ($P \leq 0,05$). As a Post Hoc test the Tukey HSD test was used.

For the beta diversity the Sorensen index was used:

$$Is = \frac{2 * C}{A + B} * 100$$

This index potentially varies between 0 and 1, and a value close to 1 indicates greater similarity between patches, and therefore low β diversity (Oumarou *et al*., 2011). The similarity ratio is quite sensitive to differences in sample size.

2.5 Results

1,536 individuals were registered distributed in 16 families, 29 genera and 32 species. The *Fabaceae* family recorded the highest abundance with 12 species, followed by the *Asparagaceae* family that presented 4 species.

Abundance: The species that presented the highest abundance was the *Salix nigra* species with 114 N/ha, which represents 26.32% of the total abundance of condition I. The two species that follow it are *Leucaena leucocephala* ssp*. glabrata* and *Fraxinus americana*, with 16.61% and 12.66% respectively. For condition II, *Salix nigra* obtained the highest abundance of 95 N/ha, which represents 26.12% of the total abundance of the condition, followed by the species *Leucaena leucocephala ssp. glabrata* and *Arundo donax* with 22.22% and 16.37% respectively. In the case of condition III, the species of *Baccharis salicifolia* presented greater abundance with 94 N/ha, representing 31.73% of the total followed by *Leucaena leucocephala ssp. glabrata* and *Populus mexicana* with 25.72% and 12.26% in this order.

Dominance: The most dominant species was *Salix nigra* for condition I (1,439.59 m^2/ha) and for condition II (1,056.83 m^2/ha), while in condition III the most dominant was *Leucaena leucocephala ssp. glabrata* (489.51 m^2/ha).

Importance Value Index (IVI): The species with the highest value for condition I were *Salix nigra* (26.80%), *Leucaena leucocephala spp glabrata* (12.43%), *Fraxinus americana* (9.95%) and *Populus mexicana* (8.37%). For condition II, the species with the highest ecological weight were *Salix nigra* (26.25%), *Leucaena leucocephala spp glabrata* (14.40%), *Arundo donax* (10.86%), *Fraxinus americana* (8.59%). In condition III the weight was sustained in *Leucaena leucocephala spp glabrata* (27.55%), *Baccharis salicifolia* (16.59%), *Populus mexicana* (15.98%) and *Fraxinus americana* (9.51%) (Table 1).

***Table 1**. Abundance, dominance, frequency and Importance Value Index of the species in all three conditions.*

Condition I

Species	Abundance		Dominance		Frecuence		
	N ha^{-1}	%	m^2 ha^{-1}	%	N/sites	%	IVI
Salix nigra	114.29	26.32	1439.59	53.15	14	13.21	26.80
Leucaena leucocephala ssp. glabrata	72.14	16.61	457.69	16.90	12	11.32	12.43
Fraxinus americana	55.00	12.66	209.56	7.74	10	9.43	9.95
Baccharis salicifolia	20.00	4.61	203.48	7.51	10	9.43	8.37
Ricinus communis	35.00	8.06	23.78	0.88	7	6.60	8.34
Populus mexicana	41.43	9.54	197.41	7.29	5	4.72	4.42
Vachellia farnesiana	0.71	0.16	28.15	1.04	6	5.66	3.84
Parkinsonia aculeata	7.14	1.64	10.20	0.38	4	3.77	2.69
Leucophyllum frutescens	17.14	3.95	15.11	0.56	4	3.77	2.29
Tecoma stans	0.71	0.16	20.64	0.76	3	2.83	2.27
Celtis laevigata	13.57	3.13	16.98	0.39	3	2.83	1.80
Arundo donax	1.43	0.33	10.64	0.63	3	2.83	1.73
Ehretia anacua	6.43	1.48	17.02	0.63	3	2.83	1.65
Caesalpinia mexicana	4.29	0.99	6.05	0.22	3	2.83	1.59
Prosopis glandulosa var. Torreyaba	6.43	1.48	18.08	0.34	2	1.89	1.57
Vachellia rigidula	5.00	1.15	7.11	0.26	2	1.89	1.54

Nicotiana glauca	4.29	0.99	4.30	0.67	2	1.89	1.35
Pithecellobium dulce	9.29	2.14	9.14	0.16	2	1.89	1.21
Opuntia engelmanni	4.29	0.99	3.64	0.00	1	0.94	1.05
Platanus occidentalis (rzedowski)	3.57	0.82	0.13	0.13	2	1.89	0.81
Celtis pallida	0.71	0.16	3.15	0.12	1	0.94	0.73
Agave americana	0.71	0.16	3.51	0.00	1	0.94	0.68
Agave lechuguilla	3.57	0.82	1.44	0.00	1	0.94	0.64
Sapindus saponaria	2.14	0.49	0.81	0.03	1	0.94	0.59
Melia azederach	2.86	0.66	0.68	0.13	1	0.94	0.57
Yucca filifera	0.71	0.16	0.02	0.00	1	0.94	0.38
Acanthocereus tetragonus	0.71	0.16	0.02	0.03	1	0.94	0.37
Pluchea carolinensis	0.71	0.16	0.02	0.05	1	0.94	0.37
Subtotal	434.29	100	2708.35	100			
Condition II							
Salix nigra	95.71	26.12	1056.83	49.68	13	19.12	26.25
Leucaena leucocephala ssp. glabrata	81.43	22.22	415.02	19.51	11	16.18	14.40
Fraxinus americana	60.00	16.37	203.95	9.59	11	16.18	10.86
Arundo donax	48.57	13.26	125.80	5.91	7	10.29	8.59
Ricinus communis	26.43	7.21	73.23	3.44	7	10.29	7.99
Baccharis salicifolia	7.14	1.95	137.57	6.47	7	10.29	7.32

Populus mexicana	0.71	0.19	81.64	3.84	4	5.88	6.46
Parkinsonia aculeata	1.43	0.39	22.86	1.07	2	2.94	5.56
Dalea scandens var. paucifolia	39.29	10.72	2.52	0.12	2	2.94	5.21
Platanus occidentalis (rzedowski)	0.71	0.19	5.74	0.27	1	1.47	3.59
Pithecellobium dulce	0.71	0.19	1.44	0.02	1	1.47	2.03
Pluchea carolinensis	3.57	0.97	0.45	0.07	1	1.47	1.17
Vachellia farnesiana	0.71	0.19	0.36	0.02	1	1.47	0.56
Subtotal	366.42	100	2127.41	100	68	100	
Condition III							
Leucaena leucocephala ssp. glabrata	76.43	25.72	489.51	42.26	11	14.67	27.55
Baccharis salicifolia	94.29	31.73	54.67	4.72	10	13.33	16.59
Populus mexicana	36.43	12.26	305.32	26.36	7	9.33	15.98
Fraxinus americana	22.14	7.45	105.04	9.07	9	12.00	9.51
Ricinus communis	27.14	9.13	35.13	3.03	5	6.67	6.28
Parkinsonia aculeata	7.14	2.40	22.21	7.11	7	9.33	4.55
Salix nigra	6.43	2.16	82.36	1.92	3	4.00	4.42
Platanus occidentalis (rzedowski)	4.29	1.44	19.34	0.42	3	4.00	2.37
Vachellia farnesiana	3.57	1.20	4.70	0.41	4	5.33	2.31
Washingtonia filifera	2.14	0.72	4.89	1.67	3	4.00	1.71
Sapindus saponaria	5.00	1.68	8.84	0.21	2	2.67	1.70

Prosopis glandulosa var. Torreyaba	2.14	0.72	2.42	0.76	3	4.00	1.64
Dalea scandens var. paucifolia	2.86	0.96	1.82	0.16	2	2.67	1.26
Melia azederach	3.57	1.20	13.58	1.17	1	1.33	1.24
Ipomoea carnea	0.71	0.24	3.51	0.06	1	1.33	0.63
Pluchea carolinensis	0.71	0.24	2.24	0.19	1	1.33	0.59
Ehretia anacua	0.71	0.24	1.26	0.30	1	1.33	0.56
Caesalpinia mexicana	0.71	0.24	0.81	0.07	1	1.33	0.55
Eysenhardtia texana	0.71	0.24	0.68	0.11	1	1.33	0.54
Subtotal	297.14	100	1158.31	100			

The dendrogram of the plant communities depending on the water conditions evaluated (Figure 2) shows in a general way that the communities have a similarity of more than 50%. The first group (Condition I) has a 60% similarity with the other group. The second group (Condition II and III) has a 68% similarity between them.

The values of the Shannon, Margalef, Dominance and Abundance index show significant differences between the conditions evaluated ($p < 0.05$) (Figure 3).

The diversity according to the Simpson index (D´) ranges between 0.135 ± 0.002 and 0.198 ± 0.006. The Shannon index (H´) records a range of values of 1.87 ± 0.708 and 2.41 ± 0.710 for the conditions evaluated.

In the case of Margalef index, the values are between 1.47 ± 0.18 and 1.77 ± 0.22. For Abundance is between 297.14 ± 6.12 and 434.29 ± 4.97, while

Dominance in terms of cup coverage ranges are between 1158.31 ± 28.89 and 2708.34 ± 53.29.

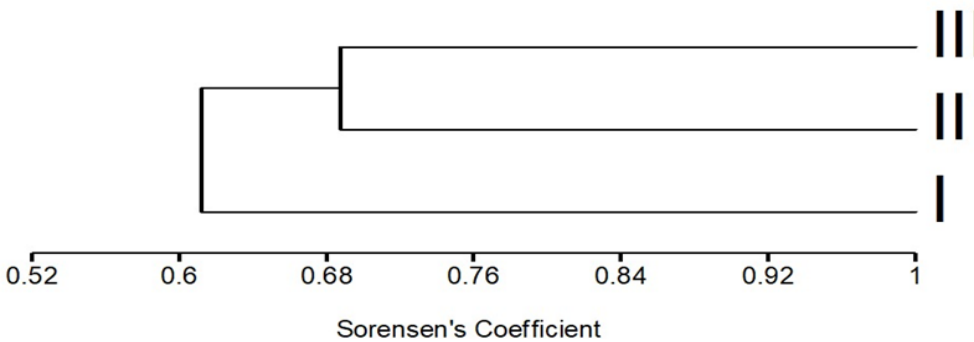

Figure 2. *Sorensen coefficient, Similarity index between the conditions evaluated*

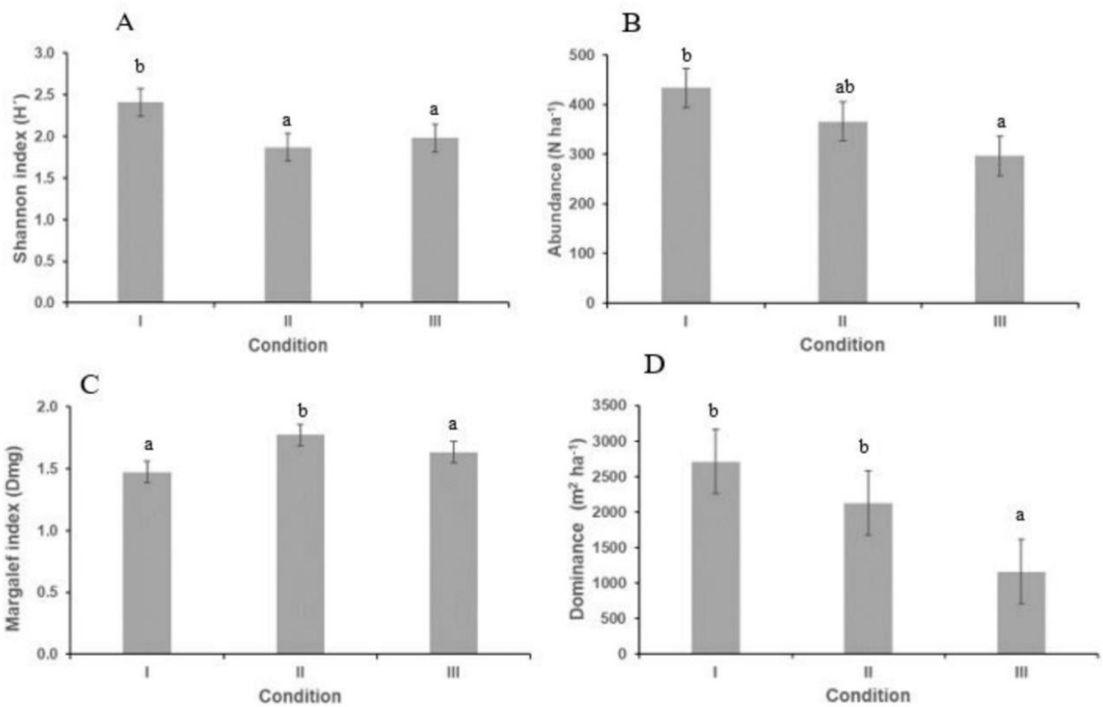

Figure 3*. Means and typical error of A) Shannon index, B) Abundance, C) Margaleaf index and D) Dominance of plant communities in all three conditions. Condition I (permanent), Condition II*

(semi-permanent), Condition III (temporary). The (a and b) indicate different levels of significance (p <0.05).

2.6 Discussion

The sampled area was 4.2 ha (42 sites), with a total wealth of 32 species. The percentage coverage values behave for condition I in 19.34, for condition II 15.19, and for condition III 8.27.

In the case of diversity according to the Simpson index (D´) it presents 0.135, 0.179 and 0.198 for condition I, II, III respectively. The Shannon index (H´) behaved between the values 2.41, and 1.87 for the conditions evaluated.

There are few works carried out in Mexico on the structure of the gallery forest, so it is difficult to compare the results obtained with other investigations due to the differences in the methods used in sampling. In this regard, the values of wealth and diversity obtained in the study are similar to those reported by (Santiago e*t al.,* 2014) for the Sierra de Quila, and coincide with those reported by (Treviño *et al*., 2001) for the south-central region of Nuevo León.

Similarly (Treviño *et al*., 2001) for the Cabezones and Ramos rivers and (Sánchez, 1986) for the Pilón river, recorded pure or codominance patches of *Taxodium, Salix, Populus, Platanus* and *Fraxinus* genera, coinciding with the registered genera in the study, however, the most common throughout gallery forests is that there is no clear dominance for any species.

The Leguminosae family is the most representative because it is one of the most diverse in the world, and because it is widely distributed in tropical regions (Camacho *et al*., 2006).

Vachellia farnesiana and *Leucaena leucocephala* are observed throughout the studied surface, in places invariably close to human settlements.

Baccharis salicifolia, Prosopis glandulosa and *Arundo donax*, are species described for gallery forest communities by (Rzedowski, 1978), or riparian subperennial trees by (Lot, 1990).

The abundance values correspond mostly to those described for the temperate forest plant community, described by (Graciano *et al.,* 2017).

For all conditions, the value obtained for diversity H 'was very low for the tree vegetation of the gallery forest of the Santa Catarina River, if the index for tropical forests is taken as a reference, between 3.85 and 5.85 (Knight, 1975). Coinciding with the data recorded for the gallery forest of the Sierra de Quila, Jalisco (Santiago *et* al., 2014) with values from 1.8 to 2.6.

Seasonal variations in discharge and wet areas create environmental conditions that challenge even the most tolerant species. Almost every year, most riparian plants are subject to flooding, erosion, abrasion and drought (Oumarou *et al*., 2011). Consequently, diversity varies considerably in space and time.

Then, the low number of species along the river could be explained by the low number of species with large diameters, which allow plants to adapt to extreme conditions; drought in the dry season and flood in the wet season.

In fact, the riverside forests of semi-permanent rivers are highly adapted to the flood pulse. Along permanent rivers, despite the high variation, there is always water that provides moisture for the trees (Oumarou *et al*., 2011).

3. CAPÍTULO III

3 VERTICAL STRUCTURE OF THE SANTA CATARINA RIVER GALLERY FOREST IN THE METROPOLITAN AREA OF MONTERREY IN DIFFERENT WATER REGIMES

3.1 Abstract

Gallery forests are fragile ecosystems, prone to disturbances mainly induced by human action. The modifications caused to this type of vegetation and its environment are constant, in most cases they give little importance to the ecological and environmental consequences that they entail. In the study, the vertical structure of the gallery forest belonging to the Santa Catarina river was described, in different water regimes. For the evaluation of the area, 3 water regimes were determined, (permanent, semi-permanent and temporary), then 42 sites of 1,000 m^2 were established. With the information obtained, the vertical structure was analyzed using the Pretzsch Index, the abundance (N ha^{-1}), the mean, minimum, maximum values and coefficient of variation of the height and normal diameter were estimated. and coverage, as well as diversity based on the Shannon-Wiener Index (H´) and the Margalef Index (DMg). 31 species were registered. The family with the highest representation was Fabaceae. With the Pretzsch A Index it was specified that the largest number of individuals meets in stratum III (Low). There are only 2 species represented in all the strata, and which are also those that make up stratum I (upper) in each condition. generally indicating low diversity in the upper strata, unlike stratum III (low), which has a large number of species. The vegetation studied generally has low diversity, but with a high ecological value.

3.2 Introduction

Riparian vegetation’s vary widely in their physical characteristics, expressed through natural history strategies and succession patterns (Arcos, 2005). Particular characteristics such as the ability to withstand temporary floods and quickly invade exposed areas define them as the most complex ecological ecosystems of the biosphere and the most important to maintain the vitality of the landscape and its rivers within the river basins (Treviño *et al.,* 2001).

They are distinguished from temperate forests by being relatively higher, of higher density, greater amount of biomass and being structurally more complex with a greater number of evergreen species (Suárez *et al.,* 2017). In Mexico the dominant species of these ecosystems are of the genera *Platanus, Populus, Salix, Astianthus, Bambusa, Inga, Pachira, Carya, Ficus, Hace, Alnus, Fraxinus* and *Taxodium* (Enriquez & Suzan, 2011). The gallery vegetation presents a high structural and physiognomic variety represented by a line that extends on both banks of the river, forming narrow strips conducive to the communication of isolated plant communities (Suárez *et al.,* 2017).

The vertical structure of the forest is determined by the distribution of different tree species that make up an ecosystem and occupy defined sites in response to microclimatic factors, environmental gradients or natural or man-made disturbance (Remmert, 1991; Ramos *et al.,* 2017). Each ecosystem has a unique spatial stratification and heterogeneity, given by the vertical and horizontal structure of the taxa that integrate it (Dajoz, 2002; Ramos *et al.,* 2017). An important aspect for understanding the dynamics of ecosystems is to characterize tree diversity at different stages of succession (EA Rubio Camacho, 2014).

There are several indexes for the characterization of the structure of an ecosystem, which allow the reproduction of conditions under certain situations over time (Suárez *et al.,* 2017). The Pretzsch index which uses different height zones for the detection of changes in tree diversity in the different strata of the forest, providing basic information on the dynamics of the ecosystem (Pretzsch & Kassier, 2009, 2011) (EA Rubio Camacho, 2014).

The objective of the study is to determine the vertical structure of the gallery forest of the Santa Catarina River in different water regimes. This will allow us to know if changes in water regimes influence the distribution of vegetation in the different strata and the presence of species that indicate the successive stages of the forest.

3.3 Materials and methods

3.3.1 Study area

The study was carried out in the segment of Santa Catarina River belonging to the metropolitan area of Monterrey (Figure 4). Covering the municipalities of Monterrey, San Pedro Garza García, Guadalupe, Juárez and Santa Catarina. In 2008, Santa Catarina River channel was declared "State Protected Natural Area, in the category of urban park", under the name of "linear park" (León, 2008).

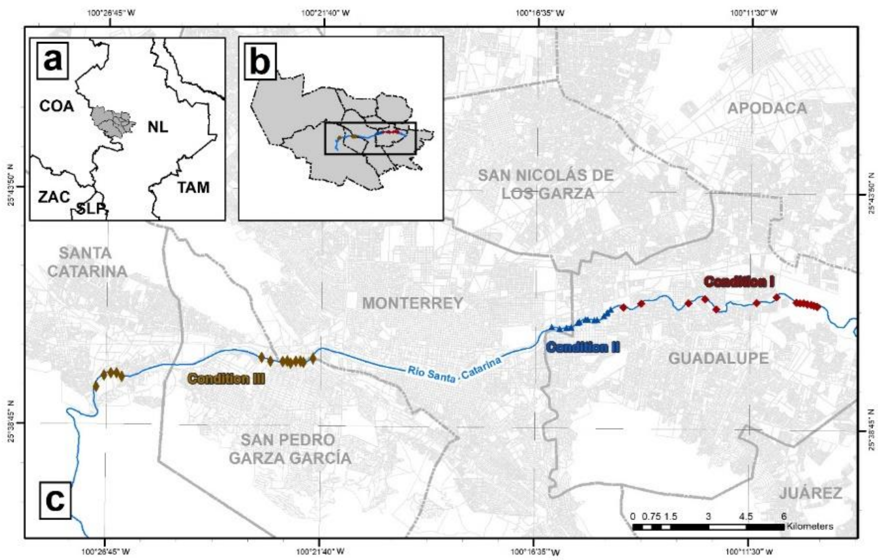

***Figure 4**. Study area*

The Santa Catarina River is located between 25° 31′ 44″ N and 99° 54′ 3″ W, runs first from south to north; and then, from southeast to northwest, crossing a long and narrow canyon between the foothills of the so-called Sierra del Toro or Taray, and some villages in the municipality of Santa Catarina. Its length is 158.4 km, and its basin area is 1,804 km^2.

The waters that it carries are regularly due to runoff from the underground swamps, to the thaws of the Arteaga mountain range, to the humidity that the different ecosystems capture and to the water tables that sprout springs that feed the river which collects the rain from 32 canyons or mountain chain accesses that make up the mountain part that belongs to Santa Catarina rivers.

3.3.2 Sampling methods

42 sites were established in general along the river, divided into 14 sites by condition, these being determined by the existing water regime, condition 1 (permanent), condition 2 (semi-permanent), condition 3 (temporary) (Figure 1). The number of optimal sites for sampling was determined by species accumulation curves, obtained in the *Estimates Software V9.0*. for each of the conditions independently. The plots were established in a rectangular form (1,000 m^2), with spacing between 100 meters and 200 meters from a random point.

3.3.3 Data analysis

An inventory was made and the identification of the existing vegetation in the different strata (shrub and tree) woody species was recorded. The species *Arundo donax* was also considered for this study, since it had a high abundance in the sites, sometimes forming reeds, and its height was similar to that of woody species. The species nomenclature followed the International Index of Plant Names (www.ipni.org). The variables to be measured were taken in those individuals with (DBH) ≥ 5cm: the number of individuals by species, the height and the diameter at 1.30 m of each individual was also recorded. The species were grouped by gender and family.

For the basal area and cup area occupied by the species, the formula of (Bettinger, 2009, 2017) was used:

$$Basal\ area\ (G) = \left(\frac{\pi}{4}\right) x D^2 1.30$$

Pretzsch Index A

The A index is a modification of the Shannon index (Pretzsch & Kassier, 2009, 2011), in which three strata are represented according to the maximum height recorded. Stratum I comprise heights with a range of 80 to 100%, where the highest tree constitutes 100%, and from which the proportions of subsequent trees are defined; Stratum II comprises heights with 50 to 80% of the total recorded height, and Stratum III ranges from 0 to 50% (Pretzsch and Kassier, 2011) (Figure 5).

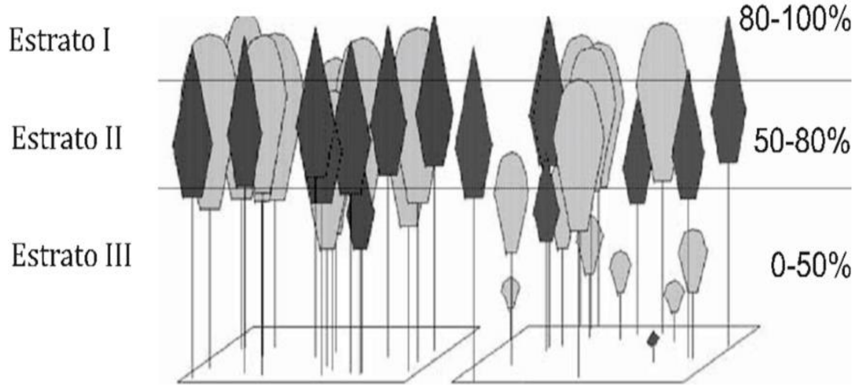

***Figure 5**. Heights by stratum*

Figure taken from (Pretzsch & Kassier, 2009, 2011)

The A_{max} is derived from the index *A*, which corresponds to the maximum value of *A*, given by the number of species and height zones; and the A_{rel}, which is the standardization in percent of the *A* index.

$$A = -\sum_{i=1}^{s}\sum_{j=1}^{z} op_{ij} * lnp_{ij}$$

$$A_{max} = ln(S * Z)$$

$$A_{rel} = \left({}^{A}/_{A_{max}}\right)$$

Where: A = Vertical distribution index, S = Number of species present, Z = Number of height zones, P*ij* = Percentage of species in each zone $P_{ij} = \frac{n_{ij}}{N}$.

To estimate species richness, the Margalef index (D_{Mg}) was used

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

Alpha diversity was estimated using the Shannon-Weaver (H´) index (Shannon, 1948); (Magurran, 2004).

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

The results were subjected to an analysis of variance (P≤0.05) and a comparison of means through the Tukey test (P≤0.05).

To compare species composition between strata, the Sorensen index for similarity was calculated (Mostacedo, 2000) using MVSP program. This index potentially varies between 0 and 1, and a value close to 1 indicates greater similarity between patches, and therefore low β diversity (Oumarou, 2011). The similarity ratio is quite sensitive to differences in sample size.

3.4 Results

In general, 1535 individuals were registered, grouped into 31 species, 28 genera and 15 families. Of these, 4 species are introduced and 27 natives. The family with the highest number of species was *Fabaceae* with 7 species, and the gender with the highest representation was *Leucaena* follow by *Salix* and *Baccharis* According to the lifestyle 16 species are trees and 17 are shrub (Table 2).

***Table 2**. List of species by stratum.*

Family	Gender	Species	Strata	Nature state	Lifestyle
Arecaceae	*Washingtonia*	*filifera*	*3*	X	Tr
Asparagaceae	*Agave*	*americana*	*3*	N	Sh
		lechuguilla	*3*	N	Sh
	Yucca	*filifera*	*3*	N	Tr
Asteraceae	*Baccharis*	*salicifolia*	*3*	N	Sh
	Pluchea	*carolinensis*	*3*	N	Sh
Boraginaceae	*Ehretia*	*anacua*	*3*	N	Tr
Cactaceae	*Acanthocereus*	*tetragonus*	*3*	N	Sh
	Opuntia	*engelmannii*	*3*	N	Sh
Euphorbiaceae	*Caesalpinia*	*mexicana*	*3*	N	Tr

	Celtis	*laevigata*	*3*	N	Tr
		pallida	*3*	N	Tr
	Dalea	*scandens var. paucifolia*	*3*	N	Sh
	Eysenhardtia	*texana*	*3*	N	Sh
	Ricinus	*communis*	*3*	X	Sh
Fabaceae	*Leucaena*	*leucocephala subsp. glabrata*	*1,2,3*	N	Tr
	Parkinsonia	*aculeata*	*3*	N	Tr
	Pithecellobium	*dulce*	*3*	N	Tr
	Prosopis	*glandulosa var. Torreyana*	*3*	N	Tr
	Tecoma	*stans*	*3*	N	Sh
	Vachellia	*farnesiana*	*3*	N	Tr
		rigidula	*3*	N	Tr
Meliaceae	*Melia*	*azederach*	*3*	X	Sh
Oleaceae	*Fraxinus*	*americana*	*3*	N	Sh
Platanaceae	*Platanus*	*occidentalis (rzedowski)*	*3*	N	Tr
Poaceae	*Arundo*	*donax*	*3*	X	Sh
Salicaceae	*Populus*	*mexicana*	*2,3*	N	Tr
	Salix	*nigra*	*1,2,3*	N	Tr
Sapindaceae	*Sapindus*	*saponaria*	*3*	N	Tr
Scrophulariaceae	*Leucophyllum*	*frutescens*	*3*	N	Tr

Solanaceae	*Nicotiana*	*glauca*	*3*	X	Sh

Native (N), Exotic (X), Tree (Tr), Shrub (Sh)

The riparian plant community is made up of very few very abundant species, and the rest of the species are practically rare. The taxa with the highest abundance in all the strata were *Leucaena leucocephala* subsp. *glabrata* and *Salix nigra*, this indicates that the plant community presents incorporation of individuals from the lower stratum (III) to the upper strata.

If the three vegetation conditions are grouped, the upper stratum (I) is dominated by *Leucaena leucocephala* subsp. *glabrata* and *Salix nigra*, with a maximum height of 14 m and an ecological value of 30 % and 69 % respectively.

This level (I) constitutes 1.05% of the total of individuals. The Jaccard´s similarity index (Figure 6) shows a 100% similarity for condition 2 and 3, while this group differs 33.3% from condition 1.

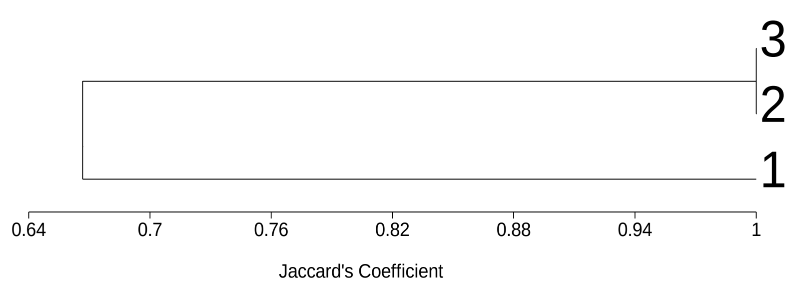

Figure 6*. Graphic representation of the Jaccard similarity coefficient for the upper stratum of conditions.*

The middle stratum (II) presents three species, *Salix nigra*, *Leucaena leucocephala* subsp. glabrata and *Populus mexicana*; with a maximum height of 11 m and ecological values of 76.6, 12.8 and 10.6% respectively. 3.65% of individuals are represented (Figure 7).

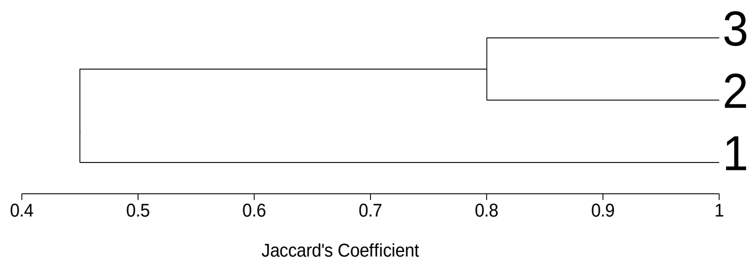

Figure 7. *Graphic representation of the Jaccard similarity coefficient for the middle stratum of conditions.*

The lower stratum (III) is made up of 32 species, being *Salix nigra, Leucaena leucocephala* susp. *glabrata*, *Fraxinus americana* and *Baccharis salicifolia* those with the highest ecological value. A maximum height of 7 m is presented for this level and 95.3% of all individuals are contained in it (Figure 8).

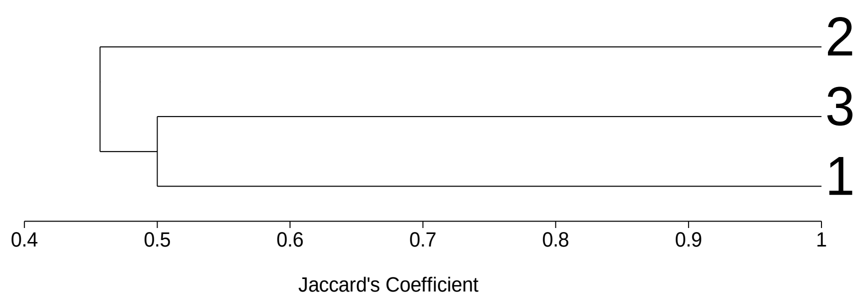

Figure 8*. Graphic representation of the Jaccard similarity coefficient for the lower stratum of conditions*

The Margalef index shows low values in almost all the strata, since values less than 2.00 are considered to be of low diversity (Alanís *et al.,* 2018). Not being the case of the lower stratum of the conditions 1 and 3 that show values higher than 2 but lower than 5, so they indicate a medium diversity (Table 3).

Table 3. *Values of index in the condition and stratum*

Condition	Stratum	Abundance (N/ha)	Coverage (m^2/ha)	Indices	
				Shannon (*H'*)	Margalef (*Dmg*)
	1	6	163.8	0.56	0.48

1	2	25	604.6	0.36	0.28
	3	404	1939.9	2.48	4.26
	1	7	187.1	0.64	0.87
2	2	54	53.6	0.53	0.69
	3	306	1140.0	1.89	1.98
	1	16	225.5	0.57	0.64
3	2	25	215.8	1.23	1.13
	3	256	717.0	1.89	3.06

The Shannon entropy index is one of the most widely used variables for estimating species diversity. Acquires values close to zero when plant communities are made up of few species. Therefore, our community presents a diversity of low species (Table 3).

Vertical distribution index.

Condition 1. A total of 608 individuals, belonging to 28 species, were registered. The result of the A index is 2.62 with an A_{max} of 4.43 and an A_{rel} of 59.18%. This indicates that the distribution of the species in the high strata is at 40.81% of the maximum dimensional differentiation, which occurs when the total number of individuals is equally distributed between strata and species, that is, it is not uniform in terms of heights.

Condition 2. A total of 513 individuals were registered, represented in 13 species. The A index is 1.8 with an A_{max} of 3.7 and an A_{rel} of 49.2%, which indicates an average structural diversity in the high strata, since A_{rel} values close to 100% implies that all species are equally distributed in the three strata of height.

Condition 3. A total of 416 individuals were registered, grouped into 19 species. The values obtained were an A of 2.29 with an A_{max} of 4.0 and an A_{rel} of 56.7%, which indicates that the area presents medium uniformity, in terms of height diversity.

The A, A_{max} and A_{rel} values of the three conditions correspond to those of a regenerated forest after a disturbance.

3.5 Discussion

In the Pretzsch stratification some differences are observed regarding the dynamics of the vegetation in the studied conditions. However, all the strata in the 3 evaluated conditions were dominated by the same species, *Salix nigra* and *Leucaena leucocephala* subsp. g*labrata*. Some authors have already reported the presence of introduced species in riparian plant communities (Burton et al., 2005; Pennington et al., 2010; Alanís, et al., 2020).

Salix nigra coincides with that reported by (Treviño *et al.,* 2001), for the Cabezones river, who identifies as an outstanding species in this plant community. Being also reported by (Íñiguez *et al.,* 2015), in an evaluation of the Tamazula river, Culiacán. *Salix nigra* has been widely evaluated and is frequently associated with gallery vegetation where floods are less frequent (Stover *et al.,* 2018). This specie is typical of riparian environments or waterlogged soils; it has a colonizing character which has favored it to establish itself in much of the world, either naturally or by naturalization. It presents pioneering species strategies and due to its heliophilic nature they are able to colonize open spaces, which is why it is usually present in the first phases of ecological succession, mainly forming the first line in riparian ecosystems.

On the other hand, the biology of *Leucaena* has not been studied as such (Zárate, 1994); however, some characteristics of the dispersion, reproduction and some biological interrelations are known, which allow us to see, in general, the forms or models of evolution of the taxa that make up the genus. In the case of *Leucaena leucocephala* subsp. *glabrata*, which constitutes an invasive species in these ecosystems, there are no reports in riparian communities in northeast Mexico (Treviño *et al.,* 2001; Canizalez *et al.,* 2010; Alanís *et al*., 2020), only in Santa Catarina River (Mata *et al*., 2020). However, if it has been reported in some riparian ecosystems in southern Mexico (Moreno-Jiménez, 2017).

The species is on the list of the 100 most harmful invasive alien species in the world (Lowe *et al.,* 2004). It is a weed of open habitats, often coastal or riverine, semi-natural, disturbed, degraded habitats and others. It has a local distribution and its populations have known potential to invade and disturb native vegetation (Lowe *et al.,* 2004). Its main characteristic is the rapid capacity for growth and dispersion, in addition to a great reproductive capacity and a wide range of environmental tolerance, making it capable of surviving, establishing itself and reproducing outside its original habitat, competing strongly with local species; being able to transform the structure of ecosystems by direct exclusion of native species through competition for resources, or indirectly by modifying their habitat (Hughes, 1998).

The *Leucaena leucocephala* subsp. *glabrata* it is a heliophytic species, in this study it was registered with greater abundance in all the strata, especially the low (III), indicating that it is still establishing itself. It is possible that after abundant rain events individuals move and create spaces, where they take advantage of this species to germinate and establish themselves (Zárate, 1994). In Mexico, this species in the wild is ruderal. But it is also cultivated often, and it is not always easy to know the origin of a plant (Grether, A, & S., 2006).

Some of the main genera found coincide with those reported by (Enríquez-Peña and Suzán-Azpiri, 2004) for the riparian vegetation of Mexico, also agreeing with the species reported by (Treviño *et al.,* 2001) and (Canizalez *et al.,* 2010). However, they do not coincide with the taxa reported by (Alanís, *et al.,* 2020) in a similar study for this same river, because they evaluated a mature forest. It is important to mention that there are few documented studies regarding this type of plant communities.

Studies have evaluated the consequences on the affectations in the growth of gallery species due to different causes of disturbance of the ecosystem; however, 2 types of causes are highlighted: the direct causes of anthropogenic pressure such as agriculture and livestock, and the indirect causes such as the construction of canals and levees.

The diversity indices evaluated agree with the values reported for riverside communities near urban areas (Burton, 2005). Becoming even higher than those reported by Alanís, *et al.* (2020), Treviño *et al.* (2001) and Canizalez *et al.* (2010) in similar studies comparing disturbed and conserved riparian vegetation in the Northeast of Mexico. Coinciding with the fact that anthropogenic activity has a negative effect on the diversity and abundance of species.

The analysis of similarity of the species composition shows that the lower the height stratum, the greater the dissimilarity between the three conditions. In stratum III, the two groups present values of 50%, which indicates an average similarity, since there are species that occur exclusively in one condition. Otherwise, in the upper stratum (I), conditions 2 and 3 have 100% similarity and this group has a similarity of 67% with 1. This indicates that regardless of the water regime, the species with the highest height and they are similar.

The values of A, A_{max} and A_{rel} indicate the presence of a regenerated forest. These results coincide with those reported by (EA Rubio Camacho, 2014) and (García et al., 2020) in regenerated plant communities after disturbances. Although the measurement scale is temporary, that is, there are no measurements from previous years, the vegetation is a perfect reflection of the conditions or regime of disturbances that occurred.

Only 2 species are shown in all strata for each condition, thus being considered species of continuous vertical distribution (DVC) (Lamprecht, 1990).

With the results of this investigation it is concluded that the water regime does influence the vertical distribution of the species of the Santa Catarina river. The vegetation studied under the different conditions is in the low latizal stage, since a differentiation of the crown began, most of the individuals have a maximum height of 8-15 m, and small diametric dimensions, in addition to being located in strata II and III.

4. CAPÍTULO IV

4 CONCLUSIONES

La información obtenida constituye una base sólida para futuras investigaciones sobre el crecimiento, establecimiento y desarrollo de la vegetación asociada al río Santa Catarina, así como de las vegetaciones riparias del norte de México. Lo cual proporcionará mayores y mejores elementos para la toma de decisiones.

Las hipótesis planteadas en cada capítulo están sustentadas por los resultados obtenidos.

El uso del índice de estratificación de alturas (Pretzch), brinda una visión más detallada de la distribución vertical de las especies que componen la zona de estudio. Con esta información, se podrá analizar parte de la dinámica de la vegetación mediante la determinación de las proporciones y dimensiones por especie. Permitiendo hacer inferencias sobre la competencia interespecífica y estadio sucesional en que se encuentra la vegetación.

Solo se muestran 2 especies en todos los estratos para cada condición (*Leucaena leucocephala* subsp. *glabrata y Salix nigra)*, por lo que se consideran especies de distribución vertical continua (DVC) (Lamprecht, 1990). Mostrando que conforme aumenta la altura de los árboles disminuye la diversidad de especie.

La composición florística se encuentra determinada por la permanencia de las aguas a lo largo del río. Siendo más abundante y con mayor riqueza en aquellas áreas en donde el agua se encuentra de manera permanente o semi permanente.

Predominan las especies nativas, aunque, no las representativas de este tipo de ecosistemas. Tomando fuerza especies pioneras, invasoras y colonizadoras.

5 BIBLIOGRAFÍA

ACOSTA C., MONDRAGÓN ALCIDES., ALVARADO HIPÓLITO. (2008). Contribución de la flora arbórea de un sector del bosque ribereño "Los Letreros", estado Trujillo, Venezuela. *Revista Forestal Venezolana*, (52), 21-31.

Alanís, R. E., Camacho, E. A., Velázquez, P. A., Olivo, A. M., Ledezma, M. Á., & Rodríguez, E. B. (marzo – abril de 2020). Estructura y diversidad de un bosque de galería en el noreste de México. Revista Mexicana de Ciencias Forestales, 11(58). doi:https://doi.org/10.29298/rmcf.v11i58.591

Arcos, T. I. (2005). Efecto del ancho los ecosistemas riparios en la conservación de la calidad del agua y la biodiversidad en la microcuenca del río Sesesmiles, Copán, Honduras. Turrialba, Costa Rica: Tesis MSc. CATIE. doi:https://www.oieau.org/eaudoc/system/files/documents/41/205415/205415_doc.pdf

Bettinger, P. B. (2009, 2017). Forest management and planning. (Segunda Edición ed.). San Diego, Estados Unidos: Academic Press.

Burton, M. L. (2005). Riparian Woody plant diversity and forest structure along an urban-rural gradient. Urban Ecosystems(8), 93-106. doi:10.1007/s11252-005-1421-6

CAMACHO, R. F., TREJO, I. and BONFIL, C. (2006). Estructura y composición de la vegetación ribereña de la barranca del Río Tembembe, Morelos, México. *Boletín de la Sociedad Botánica de México*, (76), 17-31. https://www.academia.edu/670504/Estructura_y_composici%C3%B3n_de_la_vegetaci%C3%B3n_ribere%C3%B1a_de_la_barranca_del_r%C3%ADo_Tembembe_Morelos_M%C3%A9xico

Canizales V., P. A. (2010). Efecto de la actividad turística en la diversidad y estructura del bosque de galería en el noreste de México. Ciencia UANL, 13(1), 55-63. doi:https://dialnet.unirioja.es/descarga/articulo/3110999.pdf

CORTÉS-CASTELÁN, J. C., and ISLEBE, G. A. (2005). Influencia de factores ambientales en la distribución de especies arbóreas en las selvas del sureste de México. *Revista de Biología Tropical*, (53), 115-133. https://www.scielo.sa.cr/scielo.php?script=sci_arttext&pid=S0034-77442005000100012

Dajoz, R. (2002). Tratado de ecología (2 ed.). Madrid, España: Mundi-Prensa. doi:http://www.sidalc.net/cgi-bin/wxis.exe/?IsisScript=FCL.xis&method=post&formato=2&cantidad=1&expresion=mfn=008830

E, A.-R., A, M.-O., & J.S, M. d. (2018). Manual práctico para el muestreo ecológico de la vegetación.

ESKELSON, B. N. I., ANDERSON, P. D., and TEMESGEN, H. (2013). Sampling and modeling riparian forest structure and riparian microclimate. In: Anderson, P. D., K. L. Ronnenberg (eds.). Density management for the 21st century: west side story. USDA Forest Service, Pacific Northwest Research Station. Gen. Tech. Rep. PNW-GTR-880, Portland, OR. USA. https://doi.org/10.2737/PNW-GTR-880

EA Rubio Camacho, M. G. (Año 17 de enero-febrero de 2014). Diversidad y distribución vertical de especies vegetales mediante el índice de Pretzsch. CIENCIA UANL (65). Obtenido de http://eprints.uanl.mx/7024/1/Diversidad-y-distribucion-vertical-de-especies.pdf

Enriquez, P. E., & Suzan, A. H. (2011). Estructura poblacional de Taxodium mucronatum en condiciones contrastantes de perturbación en el estado de Querétaro, México. Enriquez, G., & Suzán, H., 82(1), 153-167. doi:http://www.scielo.org.mx/scielo.php?script=sci_abstract&pid=S1870-34532011000100013&lng=es&nrm=iso

Enríquez-Peña, E. G.-A.-B. (2004). Viabilidad y germinación de semillas de Taxodium mucronatum (Ten.) en el estado de Querétaro, México. Agrociencia, 38(3), 375-381. doi:https://www.colpos.mx/agrocien/Bimestral/2004/may-jun/art-11.pdf

GRACIANO-ÁVILA, G., AGUIRRE-CALDERÓN, O. A., ALANÍS-RODRÍGUEZ, E., & LUJÁN-SOTO, J. E. (2017). Composition, structure and diversity of tree species in a temperate forest in Northwestern Mexico. *Ecosistemas y*

Recursos Agropecuarios, 4(12), 535-542. http://dx.doi.org/10.19136/era.a4n12.1114

Grether, R., A, M.-B., & S., L. M. (2006). Flora del Valle de Tehucán – Cuiatlán. Fascículo 44. Mimmosaseae Tribu Mimoseae. En Flora del Valle de Tehucán – Cuiatlán (julio 2006 ed.). Instituto de Biología, UNAM. Obtenido de http://www.ibiologia.unam.mx/barra/publicaciones/floras_tehuacan/F44.pdf

Hughes, C. E. (1998). Leucaena. A Genetic Resources Handbook. Tropical Forestry Papers(37), 274. Obtenido de https://www.gov.uk/dfid-research-outputs/leucaena-a-genetic-resources-handbook

Íñiguez-Ayón, Y. P.-S. (2015). Ecosistema fluvial urbano: evaluación ecológica y visual del río Tamazula en la ciudad de Culiacán, Sinaloa. Quivera, 17(1), 75-97. doi:https://www.redalyc.org/jatsRepo/401/40140031005/html/index.html

KNIGHT, D. H. (1975). A phytosociological analysis of species-rich tropical forest on Barro Colorado Island, Panamá. *Ecologycal Monographs*, 45(3), 259-284. https://doi.org/10.2307 / 1942424

León, E. l. (2008). Periodico oficial gobierno constitucional del estado libre y soberano de Nuevo León, jueves, 11 de septiembre. Periodico , Monterrey, Nuevo León.

LOT, A. (1990). Forested wetlands of Mexico. In: LUGO, A. E., M. M. BRISON and S. BROWN (eds.). *Forested wetlands of the World*. Vol. 15 Ecosystems of the World. Elsevier. Amsterdam. https://www.worldcat.org/title/forested-wetlands/oclc/18780970

Lowe, S. B., S., B., & M, D.-P. (2004). 100 de las Especies Exóticas Invasoras más dañinas del mundo. Una selección del Global Invasive Species Database. Grupo Especialista de Especies Invasoras (GEEI), un grupo especialista de la Comisión de Supervivencia de Especies (CSE) de la Unión Mundial para la Naturaleza (UICN) Nueva Zelanda. Obtenido de http://www.iucngisd.org/gisd/pdf/100Spanish.pdf

Magurran, A. E. (2004). Measuring Biological Diversity. (U. C. Designs, Ed.) Blackwell Science. Obtenido de https://www2.ib.unicamp.br/profs/thomas/NE002_2011/maio10/Magurran%202004%20c2-4.pdf

Mata, B. J., Eduardo, H. C., Rodríguez, E. A., & Olivo, A. M. (enero - junio de 2020). Riqueza, composición y abundancia de especies en una comunidad vegetal ribereña en el río Santa Catarina, Monterrey, Nuevo León. Ciencia UAT, 14(2), 06-20. doi:10.29059/cienciauat.v14i2.1248

MELI, P., RUIZ, L., AGUILAR, R., RABASA, A., REY, J.M., and CARABIAS, J. B. (2017). Bosques ribereños del trópico húmedo de México: un caso de estudio y aspectos críticos para una restauración exitosa. *Madera y Bosques*, (23), 181-193. DOI: http://dx.doi.org/10.21829/myb.2017.2311118

Mora-Donjuán, C. A.-C.-R.-P.-T.-B.-O. (2014). Composición y diversidad vegetal de un área de matorral desértico micrófilo con historial pecuario en el noreste de México. Polibotánica(38), 53-66. doi:https://www.researchgate.net/publication/269998779_Composicion_y_diversidad_vegetal_de_un_area_de_matorral_desertico_microfilo_con_historial_pecuario_en_el_noreste_de_Mexico

Moreno-Jiménez, V. C.-A.-C.-C.-P. (2017). Relación de vegetación ribereña y propiedades del suelo en un afluente del río Tacotalpa, Tabasco, México. Madera y Bosques, 23(1), 91-109. doi:http://dx.doi.org/10.21829/myb.2017.231510

Mostacedo, B. F. (2000). Manual de métodos básicos de muestreo y análisis en ecología vegetal. Santa Cruz, Bolivia: El País. Obtenido de http://www.bio-nica.info/biblioteca/mostacedo2000ecologiavegetal.pdf

NAIMAN, R. J., and OLDEN J. D. (2010). Incorporating thermal regimes into environmental flow sassessments: modifying dam operations to restore freshwater ecosystem integrity. *Freshwater Biology*, 55, 86-107. Obtenido de https://www.researchgate.net/publication/227679855_Incorporating_Therm al_Regimes_into_Environmental_Flows_Assessments_Modifying_Dam_Operations_to_Restore_Freshwater_Ecosystem_Integrity

Oumarou, S. (22 de 2 de 2011). Woody species composition, diversity and structure of riparian forests of four watercourses types in Burkina Faso. Journal of Forestry Research, 145-158.

Pennington, D. N. (2010). Urbanization and riparian forest woody communities:diversity, composition, and structure within a metropolitan landscape. Biological Conservation, 143(1), 182-194. doi:https://www.sciencedirect.com/science/article/pii/S000632070900439X

Pretzsch, H., & Kassier, H. W. (13 de julio de 2009, 2011). Forest Dynamics, Growth and Yield: From Measurement to Model. Southern Forests: a Journal of Forest Science, 73, 63-65. doi:https://doi.org/10.2989/20702620.2011.574816

Ramos, R. J., Treviño, G. E., Buendía, R. E., Aguirre, C. O., & López, M. J. (septiembre/ octubre de 2017). Productividad y estructura vertical de un bosque templado con incidencia de incendios forestales. Revista mexicana de ciencias forestales, 8(43). doi:http://www.scielo.org.mx/scielo.php?pid=S2007-11322017000500064&script=sci_arttext&tlng=pt#B33

Remmert, H. (1991). The mosaic-cycle concept of ecosystems. Berlin, Germany: Springer Verlag. doi:https://link.springer.com/chapter/10.1007/978-3-642-75650-4_1

RICHARDSON, D. M., HOLMES, P.M., ESLER, K.J., GALATOWITSCH, S. M., STROMBERG, J. C., KIRKMAN, S. P., PYŠEK, P., and HOBBS, R.J. (2007). Riparian vegetation: degradation, alien plant invasions, and restoration prospects. Divers. Distrib., 1(13), 126-139. Obtenido de https://onlinelibrary.wiley.com/doi/full/10.1111/j.1366-9516.2006.00314.x

RUBIO, C. E., TAGLE, M. A., PÉREZ, J. J., RODRÍGUEZ, E. A., & FLORES, D. Y. (Año 17 de enero-febrero de 2014). Diversidad y distribución vertical de especies vegetales mediante el índice de Pretzsch. CIENCIA UANL(65).

Obtenido de http://eprints.uanl.mx/7024/1/Diversidad-y-distribucion-vertical-de-especies.pdf

RZEDOWSKI, J. (1978). *Vegetación de México*. México, D.F.: Ed. Limusa. http://bioteca.biodiversidad.gob.mx/janium/Documentos/7369.pdf

SÁNCHEZ S., R. (1986). Vegetación de galería y sus relaciones hidrogeomorfológicas. *Ingeniería Hidráulica de México*, 70-78. DOI: www.revistatyca.org.mx › ojs › index.php › tyca › articleCms › download

SANTIAGO-PÉREZ, P. A. AYÓN A., ROSAS-ESPINOZA, V.C., RODRÍGUEZ F.A. and TOLEDO S.L. (2014). Estructura del bosque templado de galería en la sierra de Quila, Jalisco. *Revista Mexicana de Ciencias Forestales*, 5(24). http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2007-11322014000400012

Stover, J. K. (2018). Fluvial geomorphology, root distribution, and tensile strength of the invasive giant reed, Arundo donax and its role on stream bank stability in the Santa Clara River, Southern California. Geosciences, 8(8). doi:10.3390/geosciences8080304

Suárez, G. P., Alanís, R. E., & Villarraga, F. L. (2017). EVALUACIÓN ECOLÓGICA DE LA ESTRUCTURA VERTICAL Y VALORACIÓN ECONÓMICA, POR LA PRESTACIÓN DEL SERVICIO DE CAPTURA DE CARBONO, DEL BOSQUE DE GALERÍA ASOCIADO AL RÍO HUALAHUISES (NUEVO LEÓN, MÉXICO). Bogotá D.C.: UNIVERSIDAD DISTRITAL FRANCISCO JOSÉ DE CALDAS. doi:http://repository.udistrital.edu.co/bitstream/11349/5929/6/SuarezGarciaPaulaAlejandra2017.pdf

Treviño, G. E., Cavazos, C. C., & Aguirre, C. O. (2001). Distribución y estructura de los bosques de galería en dos ríos del centro sur de Nuevo León. Madera y Bosques, 1(7), 13-25. doi:https://www.researchgate.net/publication/312253383_Distribucion_y_estructura_de_los_bosques_de_galeria_en_dos_rios_del_centro_sur_de_Nuevo_Leon

WARD, J.V., TOCKNER, K., ARSCOTT, D. B., and CLARET, C. (2002). Riverine landscape diversity. *Freshwater Biology*, (47), 517-539.
https://doi.org/10.1046/j.1365-2427.2002.00893.x

Zárate, P. S. (1994). Revisión del género *Leucaena* en México. Anales del Instituto de Biología serie Botánica, 65(002).