REVISTA BIO CIENCIAS
http://revistabiociencias.uan.edu.mx
https://doi.org/10.15741/revbio.12.e1825

ISSN 2007-3380

Original article /Artículo original

Structure and diversity of the gallery forest of the Natural Park La Estanzuela, Nuevo Leon, Mexico

Estructura y diversidad del bosque de galería del Parque Natural La Estanzuela, Nuevo León, México

Alanís-Rodríguez, E.[1], *Montiel-Rojas, A. P.*[1], *Molina-Guerra, V. M.*[1,2], *García-García, S. A.*[3], *Mora-Olivo, A.*[4*]

[1]*Facultad de Ciencias Forestales. Universidad Autónoma de Nuevo León. Carretera Nacional, km 145. C.P. 67700, Linares, Nuevo León, México.*
[2] *Departamento de Investigación. RENAC, S.A. de CV. Perlitas 127, Col. Las Glorias, C.P. 67710, Linares, Nuevo León, México.*
[3] *Facultad de Ciencias Agrícolas y Forestales. Universidad Autónoma de Chihuahua. Km 2.5 Carretera Delicias-Rosales. C.P. 33000, Delicias, Chihuahua, México.*
[4] *Facultad de Ingeniería y Ciencias / Instituto de Ecología Aplicada. Universidad Autónoma de Tamaulipas. División del Golfo 356. C.P. 87019, Ciudad Victoria, Tamaulipas, México.*

ABSTRACT

We evaluated the structure and diversity of the gallery forest in La Estanzuela Natural Park in Monterrey, Nuevo Leon, Mexico, was evaluated. Eight rectangular sampling sites of 200 m^2 (20 x 10 m) were systematically established at 250 m intervals along the two kilometers of the river bank. Variables of abundance, dominance, frequency and importance value were calculated, as well as the Margalef indices, Shannon entropy and Shannon's true diversity index. 15 species (ten native and five introduced) belonging to 15 genera and 14 families of vascular plants were recorded. The species that presented the highest value of the importance value index were *Quercus polymorpha*, *Populus alba,* and *Croton fruticulosus.* The indices used indicated the richness and diversity of *a* mature gallery forest, in addition to the graphs of diameter and height classes indicating a mature community in an active state of regeneration.

KEY WORDS: Richness, diametric classes, native species, woody flora, riparian plants.

Please cite this article as/Como citar este artículo: Alanís-Rodríguez, E., Montiel-Rojas, A. P., Molina-Guerra, V. M., García-García, S. A., Mora-Olivo, A. (2025). Structure and diversity of the gallery forest of the Natural Park La Estanzuela, Nuevo Leon, Mexico. *Revista Bio Ciencias*, 12, e1825. https://doi.org/10.15741/revbio.12.e1825

Article Info/Información del artículo
Received/Recibido: October 31th 2024.
Accepted/Aceptado: May 13h 2025.
Available on line/Publicado: May 21th 2025.

***Corresponding Author:**

Arturo Mora-Olivo. Facultad de Ingeniería y Ciencias / Instituto de Ecología Aplicada. Universidad Autónoma de Tamaulipas. División del Golfo 356. C.P. 87019, Ciudad Victoria, Tamaulipas, México. Teléfono (834) 308 5222.
E-mail: amorao@docentes.uat.edu.mx

Revista Bio ciencias
ISSN 2007-3380

RESUMEN

Se evaluó la estructura y diversidad del bosque de galería en el Parque Natural La Estanzuela, en Monterrey, Nuevo León, México. Se establecieron de manera sistemática ocho sitios de muestreo rectangulares de 200 m^2 (20 x 10 m) con una distancia de 250 m a lo largo de los dos kilómetros de la ribera del río. Se calcularon variables de abundancia, dominancia, frecuencia y valor de importancia y los índices de Margalef, entropía de Shannon y el índice de diversidad verdadera de Shannon. Se registraron 15 especies (diez nativas y cinco introducidas) pertenecientes a 15 géneros y 14 familias de plantas vasculares. Las especies que presentaron el mayor valor del índice de valor de importancia fueron *Quercus polymorpha*, *Populus alba* y *Croton fruticulosus*. Los índices empleados indicaron una riqueza y diversidad de un bosque de galería maduro, aunado a los gráficos de clases de diamétricas y de altura indican una comunidad madura en estado activo de regeneración.

PALABRAS CLAVE: Riqueza, clases diamétricas, especies nativas, flora leñosa, plantas riparias.

Introduction

Plant communities that thrive along rivers and other bodies of water are called gallery forests or riparian vegetation (Rzedowski, 2006). Although they are made up of herbaceous plants, it is shrubs and trees that characterize the vegetation cover typical of the edges of water currents (Aguilar-Luna *et al*., 2018). These forests are the habitat of numerous animal and plant species that are adapted to live in an ecotone between the aquatic ecosystems of rivers and the surrounding terrestrial ecosystems (Seaman & Schulze, 2010). Among the ecosystem services offered by these communities, their value stands out as biological corridors that ensure the survival of wildlife, they serve as natural barriers to regulate the flow of water avoiding floods, and they also provide large amounts of nutrients to the subsoil (Riis *et al*., 2020). Likewise, these communities are useful to the inhabitants by having edible, medicinal, or wood species (Rajbongshi & Das, 2024).

Although gallery forests can be found in high or low areas alike, it is in the high mountains where they initially emerge and have a better state of conservation (Ajonina *et al*., 2020). For this reason, the mountainous portions of Mexico include a large number of gallery forests along its rivers and streams (Lot *et al*., 2015). In the case of the Sierra Madre Oriental, there is a good representation of these forests, although in some cases, they have suffered the impact of

Revista Bio ciencias
ISSN 2007-3380

anthropogenic activities such as deforestation, pollution and the introduction of exotic species (Rosete-Vergés *et al*., 2014).

For this reason, public policies have been implemented aimed at the protection of gallery forests and other plant communities, as is the case in the state of Nuevo León, where the Cumbres de Monterrey National Park is located (CONANP, 2006). On the eastern slope of this protected natural area is also located the “La Estanzuela” Natural Park, which is a state reserve located 20 km south of the metropolitan area of Monterrey. Currently, the main and permanent stream of “La Estanzuela” allows the development of extensive gallery forests, which, together with natural waterfalls, are an attraction for national and foreign tourists (PVS, 2022).

Unfortunately, the construction of residential areas and other anthropogenic actions are putting increasing pressure on the forests that grow in this and other natural parks in Nuevo León (Rubio, 2019). For this reason, it is necessary to carry out floristic and ecological studies in these areas, which support and contribute to the conservation of this natural heritage. Although some floristic and ecological studies have been carried out on gallery forests in the metropolitan area of Monterrey, such as those of the Santa Catarina and La Silla rivers (Mata-Balderas *et al.*, 2020, 2022), the La Estanzuela area in particular lacks this type of work. Until now, the only background that exists on the specific subject is the brief mention of gallery communities in the La Estanzuela canyon when the Natural History of the Cumbres de Monterrey Natural Park was published (Cantú *et al*., 2013). In this sense, this work aimed to evaluate the structure and diversity of the gallery forest in the “La Estanzuela” Natural Park, in addition to knowing the origin of the species (native or introduced).

Material and methods

Study area

The study was carried out in the gallery forest of the “La Estanzuela” Natural Park, which is located along the El Calabozo stream within the Cumbres de Monterrey National Park, south of the Monterrey municipality (Northeast Mexico). The El Calabozo stream is a tributary of the La Silla River that is part of the Río Bravo-San Juan Basin and the Río Bravo Hydrological Region (INEGI, 1986). The coordinates of the location of the starting site are 25º 31’ 56.11” N, 100º 16’ 13.46” W and those of the site where the analysis was carried out are 25º 31’ 55.05” N, 100º 16’37.25” W with altitudes that vary between 710 m.a.s.l and 920 m.a.s.l. (Figure 1). The climate is semi-warm subhumid with summer rains (INEGI, 2017), with an average rainfall of 1,034.2 mm (CONAGUA, 2016).

Vegetation analysis

In April 2021, eight rectangular sampling sites of 200 m^2 (20 x 10 m) were systematically established with a distance of 250 m along the two kilometers of the stream bank of the La Estanzuela Natural Park (Figure 1). The sites were established on both sides in parallel according

Revista Bio ciencias
ISSN 2007-3380

to the direction of the stream bed, which flows from south to north (Canizales Velázquez *et al.*, 2010; Cantú *et al.*, 2013; Canizales-Velazquez *et al.*, 2021). At each site, all individuals with a normal diameter (ND) ($_{1.30}$ m) ≥ 5.0 cm were measured to obtain the vertical and horizontal structure of the woody vegetation. The dasometric variables evaluated were total height (h), normal diameter (d $_{1.30}$ m), and crown diameter (d $_{crown}$), which was measured in two directions: in the section of the greatest projection of the crown and in the direction perpendicular to it (Alanís-Rodríguez *et al.*, 2020a). To identify the plants, samples were taken, herborized and compared with specimens from the FCF and UAT herbariums with the help of specialists. To verify the correct nomenclature of the species, the Tropicos® platform was used (Tropicos, 2024). Subsequently, each species was investigated for its common name, biological form and geographical origin (native or introduced), the latter through electronic platforms such as Plants of the World Online (POWO, 2024) or Enciclovida (CONABIO, 2024) and the review of lists of native and exotic plants for Mexico (Villaseñor & Espinosa-Garcia, 2004; Villaseñor, 2016).

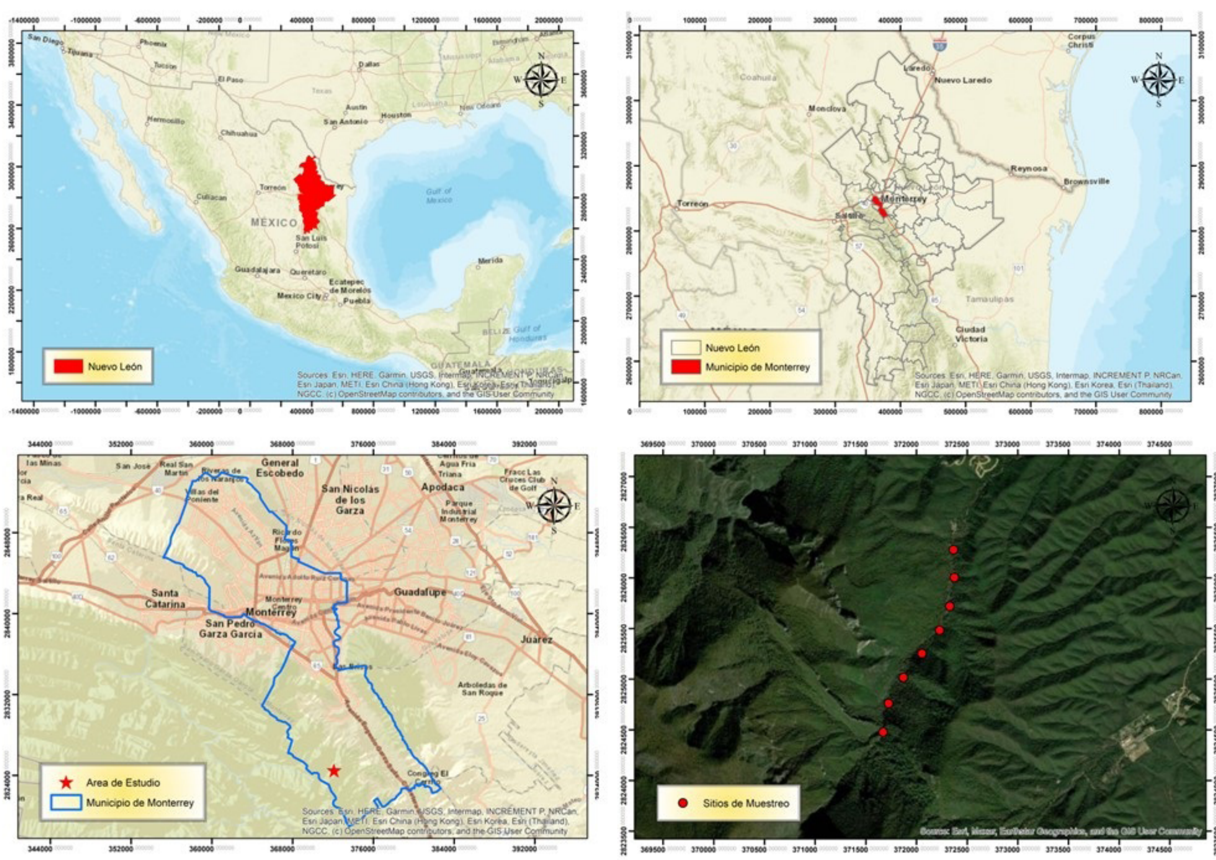

Figure 1. Location of the study area and sampling sites in the Monterrey municipality, Nuevo León.

Revista Bio ciencias ISSN 2007-3380

Information analysis

To evaluate the structure of the species, abundance was determined according to the number of individuals, their dominance based on their canopy area and the frequency of their presence at the sampling sites (Alanís-Rodríguez *et al.*, 2020a). The relative values of these parameters were used to calculate the Importance Value Index (*IVI)*, which acquires percentage values on a scale of 0 to 100 (Alanís-Rodríguez *et al.*, 2020a). The richness and diversity were estimated with the Margalef index (D_{Mg}), the Shannon entropy index (H´) and the number of effective species of order 1 (q=1), also known as the Shannon true diversity index (^1D) (Magurran, 2004; Jost, 2006). Formulas used to estimate the ecological parameters and diversity indices are shown in Table 1.

Table 1. Formulas used to estimate species ecological indicators and diversity indices.

Formula	Where:
$A_i = \frac{N_i}{S}$ $AR_i = \left[A_i / \sum_{i=1}^{n} A_i\right] x\, 100$	A_i = absolute abundance AR_i = relative abundance per species *Neither* = number of individuals of species i *S* = sampling area (ha)
$D_i = \frac{G_i}{S}$ $DR_i = \left[D_i / \sum_{i=1}^{n} D_i\right] x\, 100$	D_i = absolute dominance DR_i = relative dominance of species i with respect to total dominance G_i = basal area of species i *S* = surface area (ha).
$F_i = \frac{P_i}{NS}$ $FR_i = \left[F_i / \sum_{i=1}^{n} F_i\right] x\, 100$	F_i = absolute frequency FR_i = relative frequency of species i with respect to the total frequency P_i = number of sites where species i is present *NS* = the total number of sampling sites.
$IVI = \frac{\sum_{i=1}^{n}(AR_i, DR_i, FR_i)}{3}$	*IVI* = importance value index AR_i = relative abundance per species with respect to total density DR_i = relative dominance of species i with respect to total dominance FR_i = relative frequency of species i with respect to the total frequency
$H' = -\sum_{i=1}^{S} p_i * ln(p_i)$ $p_i = n_i / N$	*H* ‘ = Shannon-Weiner index *S* = number of species present *N* = total number of individuals *neither* = number of individuals of the species ln = natural logarithm

Revista Bio ciencias
ISSN 2007-3380

Continuation

Table 1. Formulas used to estimate species ecological indicators and diversity indices.

Formula	Where:
$D_{Mg} = \frac{S-1}{\ln(N)}$	D_{Mg} = Margalef index S = number of species present N = total number of individuals *ln* = natural logarithm
${}^1D = exp(H')$	${}^1D$ = Shannon's true diversity index H' = Shannon-Weiner index

To describe and analyze the structure of the plant community, diameter and height class distribution graphs were created. These graphs allow identifying patterns of individual size distribution. In addition, trend lines were established to evaluate the relationships, using the r^2 value as an indicator of fit (Alanís-Rodríguez *et al*., 2020a). All analyses were performed manually using the Excel spreadsheet program and based on the formulas described above (Alanís-Rodríguez *et al*., 2020a).

Results

Fifteen species belonging to 15 genera and 14 families of vascular plants were recorded. The family with the largest number of species was Oleaceae, with two species. Other families represented were Boraginaceae, Euphorbiaceae, Fabaceae, Fagaceae, Juglandaceae, Lauraceae, Meliaceae, Pittosporaceae, Platanaceae, Rhamnaceae, Rutaceae, Salicaceae, and Ulmaceae. According to their biological form, three were shrubs, and twelve were trees (Appendix 1). According to their geographic origin, ten were native (including three endemic species from Mexico), and five were introduced.

Table 2 shows the descriptive values of the abundance, dominance, frequency, and importance value index of the species. The absolute abundance of the plant community was 355 N ha $^{-1}$ (individuals per hectare), and the species that presented the highest value was *Quercus polymorpha* Schltdl. & Cham. with 92 N ha $^{-1}$, representing 26.06 % of the total abundance, followed by *Populus alba* L. and *Croton fruticulosus* Torr. with 16.9 % and 16.2 %, respectively, the remaining 12 species make up the missing 40.84 % of the total. The crown area and basal area were 14,980.4 m ^{2} ha $^{-1}$ and 27.99 m ^{2} ha $^{-1,}$ respectively.

The species with the highest crown area value was *Q. polymorpha* with 30.08 % of the total vegetation cover, followed by *P. alba* with 29.62 %, then *Platanus rzedowskii* Nixon & J. M.Poole with 16.21 %, the remaining 12 species representing 24.07 %. Regarding the basal area, the species with the highest value was *P. alba* with 45.45 %, followed by *Q. polymorpha* with 31.70 % and *P. rzedowskii* with 12.69 % respectively, the remaining 12 represented 10.16 % of the plant community.

According to frequency, two species were recorded in more than half of the sampling sites, which were *Q. polymorpha* and *C. fruticulosus.* Four species were recorded at two sampling sites, and six species were recorded at only one sampling site.

P. alba was the species that presented the highest volume value ($m^2 ha^{-1}$), followed by *Q. polymorpha* and *P. rzedowski.* In contrast, the species that had smaller volumes (below 0.04 m^2 ha^{-1}) were *Colubrina greggii* S. Watson, *Ulmus serotina* Sarg. and *Melia azedarach* L.

The species that presented the highest importance value index were *Q. polymorpha* with 23.74 %, followed by *P. alba* and *C. fruticulosus* with 18.65 % and 12.21 %, respectively. These species represent 54.61 % of the plant community. The species with the lowest value (below = .04) were *M. azedarach* and *U. serotina* with 1.57 % and 1.51 %, respectively. The 10 native species represented 68.67 % of *IVI* and the introduced species 31.33 %.

Table 2. Descriptive values of the abundance, dominance, frequency, and importance value index (IVI) of the species recorded in the study area of the gallery forest of the "La Estanzuela" Natural Park.

Species	Abundance		Dominance				Frequency		Volume	*IVI*
			Cup area		Basal area					
	Absolute N ha^{-1}	Relative	$m^2 ha^{-1}$	Relative	$m^2 ha^{-1}$	Relative	Sites	Relative	$m^2 ha^{-1}$	
Quercus polymorpha	92.50	26.06	4506.69	30.08	8.88	31.70	7	18.42	79.21	23.74
**Populus alba*	60.00	16.90	4437.89	29.62	12.72	45.45	4	10.53	101.04	18.65
Croton fruticulosus	57.50	16.20	1084.83	7.24	0.99	3.53	6	15.79	5.80	12.22
Platanus rzedowskii	30.00	8.45	2429.00	16.21	3.55	12.69	2	5.26	32.19	10.11
Juglans mollis	25.00	7.04	455.44	3.04	0.23	0.80	5	13.16	1.11	7.13
**Ligustrum lucidum*	32.50	9.15	375.78	2.51	0.68	2.43	2	5.26	2.66	5.77
Fraxinus berlandieriana	10.00	2.82	844.18	5.64	0.54	1.91	2	5.26	5.38	4.70
**Citrus x aurantium*	12.50	3.52	136.44	0.91	0.05	0.19	2	5.26	0.19	3.36
Ehretia anacua	7.50	2.11	239.86	1.60	0.17	0.62	2	5.26	0.72	3.12
Aiouea pachypoda	10.00	2.82	138.44	0.92	0.09	0.32	1	2.63	0.36	2.50
** Pittosporum tobira*	5.00	1.41	102.74	0.69	0.07	0.24	1	2.63	0.27	1.96
Cercis canadensis	5.00	1.41	66.05	0.44	0.01	0.04	1	2.63	0.04	1.87
Colubrina greggii	2.50	0.70	115.21	0.77	0.01	0.03	1	2.63	0.03	1.75
**Melia azedarach*	2.50	0.70	38.97	0.26	0.01	0.02	1	2.63	0.02	1.58
Ulmus serotina	2.50	0.70	8.91	0.06	0.01	0.03	1	2.63	0.03	1.51
Addition	355	100	14980	100	28.00	100	38	100	229.04	100

*Species with an asterisk are introduced. Species are ordered in descending order of *IVI value.*

Revista Bio ciencias
ISSN 2007-3380

The diameter class graph shows that the highest absolute abundance was recorded in individuals less than 10 cm in normal diameter, with 163 N ha $^{-1}$, then observing a negative exponential trend in the abundance of individuals as their diameter increases, with the categories from 70 cm onwards showing the lowest abundance, with values lower than 5 N ha $^{-1}$ (Figure 2).

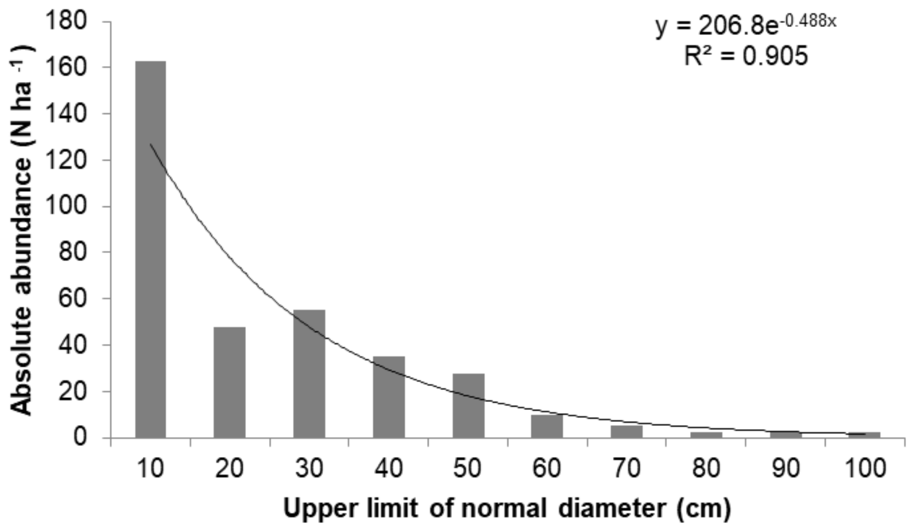

Figure 2. Distribution of diameter classes for the vegetation of the gallery forest of La Estanzuela Natural Park.

The height class graph also showed a negative exponential trend as the height of the individuals increased. The class with an upper limit of 7 m was the dominant one with 123 N ha $^{-1}$. 61.97 % of the trees were in the first two categories, that is, they were less than 11 m tall. The largest trees (category 23.01-27.00 m) had a density of 13 N ha $^{-1}$ (Figure 3).

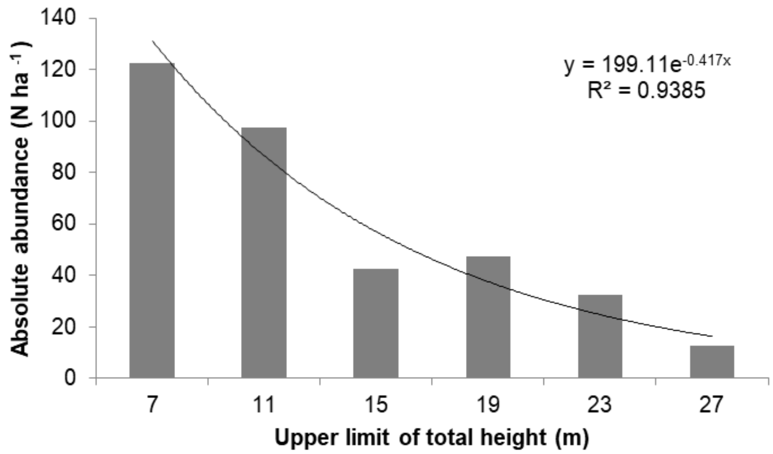

Figure 3. Distribution of height classes for the vegetation of the gallery forest of La Estanzuela Natural Park.

The evaluated plant community presented a Margalef diversity index (D_{Mg}) of 2.82, a Shannon entropy index (H') of 2.18, and a Shannon true diversity index (1 ^1D) of 8.84.

Discussion

According to the results, the family with the greatest preeminence in the area was Oleaceae, which can be understood by the presence of two species (*Fraxinus berlandieriana* and *Ligustrum lucidum* WT Aiton) that preferentially inhabit along water streams or have a wide tolerance to humidity (Brixner Dreyer *et al*., 2019; Alanís-Rodríguez *et al*., 2020b). Although the rest of the families only had one species, some are also characteristic of riparian vegetation or gallery forests such as Juglandaceae, Platanaceae, and Salicaceae (Rzedowski, 2006).

It has been pointed out that genera such as *Platanus, Populus, Fraxinus, Salix,* and *Taxodium* are typical of gallery forests in Mexico (Enríquez-Peña and Suzán-Azpiri, 2011); however, in the present study only the first three were recorded. And in fact, *Populus* was the most representative after *Quercus* in this work, both genera are typical of gallery forests or Mexican temperate forests at higher altitudes (Holguín-Estrada *et al*., 2021; Vega-Mares *et al., 2020). The Quercus* genus is not usually common in the gallery forests of Nuevo León, but due to the altitude at which the study area is located, it can become part of these ecosystems (Rzedowski, 2006). In addition, Nuevo León is the second state with the highest number of species of this genus (Valencia-A., 2004).

The species richness recorded in this work is considered acceptable, considering that only eight sites were sampled in 250 m of the stream bank and that other nearby gallery forests had lower

Revista Bio ciencias ISSN 2007-3380

values. This was the case of two studies carried out on the Ramos River in Allende, Nuevo León, where 12 and 15 sites were sampled, obtaining seven and nine species, respectively (Canizales Velázquez *et al.*, 2010; Alanís-Rodríguez *et al.*, 2020b). However, the number of species was equal (15) to that recorded by Holguín-Estrada *et al.* (2021) in two of their three intervals evaluated in a gallery forest in Guachochi, Chihuahua. On the other hand, it is also pertinent to mention that other studies in this type of forest have recorded a greater number of species as reported by Canizales-Velázquez *et al.* (2021) found 21 species in an urban gallery forest in Linares, Nuevo León. Mata-Balderas *et al.* (2020) mention the existence of 18 and 60 species in two strata of riparian vegetation of the Santa Catarina River in Nuevo León.

The recorded native species include three species with a distribution restricted to the borders of Mexico: *Aiouea pachypoda* (small avocado), *Juglans mollis* (Mexican walnut), and *Platanus rzedowskii* (Rzedowski's sycamore) (Villaseñor, 2016; CONABIO, 2024; POWO, 2024). The first of these (small avocado) had a wide distribution in the country, occupying different types of vegetation; however, the change in land use has restricted it to protected microenvironments, as occurs in the study area (van der Werff, 1997). *J. mollis* is an endemic tree from the northeast and center of Mexico, where it grows mainly in oak forests (Pérez-Calix, 2001). *P. rzedowskii* is a species restricted to the streams and rivers of Nuevo León, Tamaulipas, and northern San Luis Potosí, which is frequently cultivated as an ornamental in northern Mexico (Nixon & Poole, 2003).

It is interesting to note that, although the majority of species (66.67 %) are native, a significant contingent (33.33 %) is introduced: *Citrus x aurantium* L. *Ligustrum lucidum, Melia azedarach, Pittosporum tobira* (Thunb.) W.T. Aiton and *Populus alba* (Annex 1). These plants, mainly of Asian origin, are cultivated or ornamental plants in many parts of the world and eventually escape by invading wetlands and other ecosystems (Weber, 2003; Villaseñor & Espinosa-García, 2004; Henderson, 2007; Fernandez *et al.*, 2020). Several of the mentioned species have been reported in both natural and urban forests of Nuevo León and in gallery forests in central Mexico (Alanís, 2005; Galicia, 2011; Alanís *et al.*, 2014; Sánchez-Castillo *et al.*, 2017; Aguilar-Luna *et al.*, 2018; Canizales-Velázquez *et al.*, 2021). However, the registration of these species in a protected natural area such as the Cumbres de Monterrey National Park where only the presence of *Ligustrum lucidum* had been reported since 2011 (Estrada Arellano *et al.*, 2018), is an important fact that must be considered as a threat to the conservation of the native flora of the region. And this is relevant considering that the dynamics of the species respond to the anthropic presence, as other similar studies have shown (Arechiga *et al*., 2022).

The total density in the area (355 N ha $^{-1}$) was similar to that recorded by Canizales-Velázquez *et al.* (2021), who estimated 464 N ha $^{-1}$ for a gallery forest in Linares, Nuevo León. These two areas have in common that they are very close to urban areas; possibly, this influences the low density of the species. Other authors have reported higher density values in gallery forests far from urban centers, from 820 N ha $^{-1}$ in a gallery forest of the Xaltatempa River, Puebla (Aguilar-Luna *et al.*, 2018) to 2187 N ha $^{-1}$ in a gallery forest in Allende, Nuevo León (Alanís-Rodríguez *et al.*, 2020b).

Some gallery forests in Nuevo León are characterized by having *Taxodium mucronatum* as the most abundant species. Ten. (Canizales Velázquez *et al.*, 2010; Alanís-Rodríguez *et al.*, 2020b; Canizales-Velázquez *et al.*, 2021), in the present study it was *Quercus polymorpha* followed by *Populus alba;* in other gallery forests in Mexico species such as *Salix nigra* are abundant Marshall (Mata-Balderas *et al.*, 2020), *Platanus mexicana* Moric. (Aguilar-Luna *et al.*, 2018) or *Alnus acuminata* Kunth (Santiago-Pérez *et al.*, 2014) as the most abundant. A possible explanation for why *T. mucronatum* was not distributed in the evaluated area is the altitude, since in the state of Nuevo León this species is distributed in an altitudinal range less than 700 msnm; however, in other investigations in central Mexico it has been reported at higher altitudes, from 1020 to 2060 msnm (Enríquez-Peña and Suzán-Azpiri, 2011; Correa-Díaz *et al*., 2018; Rivera-Hernández *et al* ., 2019; Villanueva-Díaz *et al* ., 2020).

The basal area (27.99 m^2 ha^{-1}) was smaller than that documented in various gallery forests. For example, Holguín-Estrada *et al.* (2021) estimated a basal area of 29.4 and 38.3 m^2 ha^{-1} for two of three altitudinal intervals evaluated; while Canizales Velázquez *et al.* (2010) reported a total of 109.76, 146.12 and 104.74 m^2 ha^{-1} for three areas with different degrees of disturbance; Aguilar-Luna *et al.* (2018) reported 235.72 m^2 ha^{-1} in a gallery forest of the Xaltatempa River in the Puebla state. The recorded basal area is more similar to that of a temperate forest in Nuevo León, as estimated by González Cubas *et al.*, (2018) in three of four evaluated sites of forest with predominance of *Abies vejarii* Martínez, or as estimated by Buendía-Rodríguez *et al.* (2019) in a temperate *Pinus* - *Quercus* forest.

The canopy cover (14,980.4 m^2 ha^{-1}) was greater than that reported in other gallery forests. Sampayo-Maldonado *et al.* (2021) report 6,184.44 m^2 ha^{-1} for a gallery forest in the Fuerte River, in Sinaloa. There are few studies on the structure of gallery forests where the canopy cover is determined. López -Hernández *et al.* (2017) determined a canopy cover of 8,463 m^2 ha^{-1} in a temperate forest in Puebla. The canopy covers in this study indicated that there is 100 % vegetation cover and canopy overlap, which indicates a good state of conservation of the plant community.

It is worrying that the highest value of wood volume was from an introduced species (*P. alba)*, which has escaped from cultivated areas, invading mainly river courses both in Mexico and in other regions of the world (Pasiecznik, 2008). The fact that the second place in volume was occupied by a native plant (Q. *polymorpha)* shows that the disturbance of the area has not reached higher levels of alteration.

According to the importance value index, *Q. polymorpha* was the species with the greatest ecological weight, obtaining 23.74 %, and *P. alba* 18.65 %. Other gallery forests in Nuevo León report *T. mucronatum* as the species of greatest importance for three disturbance conditions in Allende, Nuevo León (Canizales Velázquez *et al.*, 2010); meanwhile Treviño-Garza *et al.* (2001) mention *Platanus occidentalis* L. and *T. mucronatum* as the most relevant species in two rivers in the municipality of Linares and the metropolitan area of Monterrey, Nuevo León. Other gallery forests in Mexico mention *A. acuminata* as the most important species in Quila, Jalisco (Santiago-Pérez *et al., 2014);* on the other hand, *Populus mexicana* was documented in Sinaloa Wesm. ex

Revista Bio ciencias ISSN 2007-3380

DC. as the most significant species for a forest of this type (Sampayo-Maldonado *et al.*, 2021). One explanation for the high importance value of *Q. polymorpha* in this study is its high presence in temperate forests of Nuevo León (Valencia-A., 2004). Alanís-Rodríguez *et al.* (2011) recorded *Q. polymorpha* as the species with the highest *IVI* value (23.7 %) in a temperate ecosystem of the Chipinque Ecological Park, in a location close to this study.

The richness in the study area (D_{Mg} = 2.82), according to the Margalef index (D_{Mg}) can be defined as intermediate, since the index considers high richness when values greater than five are obtained and when they are less than two it is determined as low richness (Margalef, 1972). Sampayo-Maldonado *et al*. (2021) report a lower richness (D_{Mg} = 1.61) in a gallery forest of the Fuerte River in Sinaloa; Holguín-Estrada *et al*., (2021) reached a higher richness for two altitudinal intervals (D_{Mg} = 3.10 and D_{Mg} = 3.30) and the third was lower (D_{Mg} = 1.52) than the one determined here. Gallery forests evaluated in Nuevo León such as Canizales-Velázquez *et al*., (2021) mention a greater richness (D_{Mg} = 3.87) and Canizales Velázquez *et al.* (2010), mention lower values (D_{Mg} = 0.44, 0.76 and 0.50) for three areas in Nuevo León; Alanís-Rodríguez *et al*. (2020b) for their part obtained a lower index (D_{Mg} = 1.52) in a forest in Allende, Nuevo León. These values indicate that gallery forests in Mexico register low to intermediate values of the Margalef index. This study shows an intermediate value, possibly due to the presence of species typical of gallery forests and others from the oak forest (*Quercus)*.

The diversity in the study area (H*'* = 2.18 and ^1D = 8.84) according to the Shannon entropy index (H*'*) and the Shannon true diversity index (^1D) is considered to be of a medium-low level since Shannon index values less than two are taken as low and greater than three are considered high (Shannon, 1948). These results were contrasted with other investigations that used the Shannon diversity index with natural logarithm and the Shannon true diversity index (D*)* was estimated, such as Santiago-Pérez *et al.* (2014), who report a lower diversity (H*'* = 2.06 and ^1D =7.84) in a gallery forest in Quila, Jalisco; Holguín-Estrada *et al.* (2021) who report lower richness for three altitudinal intervals in a gallery forest in Guachochi, Chihuahua (Interval 1 H' = 1.56 and ^1D = 4.75; Interval 2 H' = 1.75 and ^1D = 5.75 and Interval 3 H' = 1.19 and ^1D = 3.28). They were also compared with gallery forests close to that of this study, such as the one assessed by Canizales-Velázquez *et al.* (2021), who point out a greater diversity (H*'* = 2.35 and ^1D = 10.48) than that obtained here for a forest in Linares, Nuevo León. For their part, Canizales Velázquez *et al.* (2010) mention lower values (H*'* = 0.74 and ^1D = 2.09; H' = 0.47 and ^1D = 1.59 and H' = 0.18 and ^1D = 1.19) in three areas with different degrees of disturbance in Montemorelos, Nuevo León and Alanís-Rodríguez *et al.* (2020b) obtained a lower value (H*'* = 0.58 and ^1D = 1.78) in a forest in Allende, Nuevo León. Like the Margalef index, the values of the Shannon index indicate that gallery forests in Mexico register low to intermediate values and that this study shows an intermediate value due to the presence of species typical of gallery forests and others from the oak forest (Quercus*)*.

The diameter distribution showed a negative trend in the form of an inverted "J", which indicates that there is a greater number of young trees and, to a lesser extent the presence of individuals in larger diameter categories, which suggests favorable regeneration and a mature growing system (Lähde *et al.*, 2022). This behavior has been identified in different types of mature forests; Canizales-Velázquez *et al.* (2021) and Sampayo-Maldonado *et al.* (2021) have described

Revista Bio ciencias ISSN 2007-3380

this type of distribution for gallery forests in the states of Nuevo León and Sinaloa. On the other hand, Ramírez Santiago *et al.* (2019) mention it for mixed forests in the Sierra Juárez of Oaxaca, Martínez-Calderón *et al.* (2021) report this same distribution in temperate forests of Aguascalientes, while Rendón-Pérez *et al.* (2021) indicate greater abundance in the smaller diameter categories in areas with a predominance of *Pinus in* the Hidalgo state. Manzanilla Quijada *et al.* (2020) determined a decrease in individuals as diameter classes increase in size for two of their four sites evaluated in temperate forests of Nuevo León. Some authors attribute this particularity to the dominance of shade-loving species (Encina-Domínguez *et al.*, 2008) or they are classified as regenerating and growing forests with sufficient trees in the smaller diameter categories to replace mature trees that die (Méndez Osorio *et al.*, 2018).

The height classes of the species showed the same trend as those of diameter: the higher the height, the lower the number of individuals. This coincides with various corresponding works in different types of mature forests. Sampayo-Maldonado *et al.* (2021) documented it for a gallery forest of the Fuerte River in Sinaloa, Canizales-Velázquez *et al.* (2021) also report that the taller the trees, the lower their abundance in a forest in Linares, Nuevo León; Quintero-Gradilla *et al.* (2019) report most individuals in their first two height classes in a *Pinus douglasiana forest.* Martínez in the Sierra de Manantlán Biosphere Reserve in the state of Jalisco. For their part, Rendón-Pérez *et al.* (2021) showed this trend for a *Pinus* forest in the state of Hidalgo, where the first two classes, 5 and 10 cm, had the highest abundance. Finally, Hernández-Álvarez *et al.* (2021) also identified a greater abundance in lower height classes for four out of five *Abies religiosa localities.* (Kunth) Schltdl. & Cham. in the State of Hidalgo.

Conclusions

According to the obtained data , the following conclusions are highlighted: (1) the evaluated plant community presents a richness and diversity of a mature gallery forest, (2) the graphs of diameter and height classes indicate a mature community in an active state of regeneration, (3) the species with the highest value of the importance value index were *Quercus polymorpha, Populus alba,* and *Croton fruticulosus*. The research generated quantitative information of a gallery forest adjacent to the metropolitan area of Monterrey, Mexico, which is threatened by the naturalized presence of exotic species that can displace the native flora of a wetland in a protected natural area. Future work on the interaction of native and introduced species would provide relevant data for the conservation of gallery forests in northeastern Mexico.

Authors' contribution

Conceptualization of the work, EAR; development of the methodology, APMR, VMMG; experimental validation, SAGG, QS; analysis of results, EAR, VMMG; data management, EAR, AMO; writing and preparation of the manuscript, VMMG, SAGG; writing, review and editing, VMMG, AMO, APMR; project administrator, VMMG.

All authors of this manuscript have read and accepted the published version of the manuscript.

Financing

This research was funded by own funds.

Acknowledgements

We would like to thank the Nuevo Leon Parks and Wildlife Service for the facilities provided to carry out the research. We also thank the personnel involved in the field activities, especially Mr. Guadalupe Pérez Malacara and the staff of RENAC, SA de CV and the Research Network on Ecology and Restoration of Forest Ecosystems (RIEREF).

Conflicts of interest

The authors encourage that they do not have any conflicts of interest.

References

Aguilar-Luna, J., Loeza-Corte, J. M., García-Villanueva, E., & Hernández-Fernández, L. A. (2018). Estructura y diversidad de la vegetación arbórea del bosque de galería del río Xaltatempa, Puebla, México. *Madera y Bosques*, 24 (3). https://doi.org/10.21829/myb.2018.2431616

Ajonina, G. N., Temgoua, L. F., Itagah, M. C., Lyonga, N. M., Etame, P., & Forkam, D. C. (2020). Floristic diversity and stand structural analysis of gallery forests in Ajei highland watershed community forest, North West Cameroon: Implications for forest conservation and management. International *Journal of Biodiversity and Conservation*, 12(3), 185-201. https://doi.org/10.5897/IJBC2020.1411

Alanís, G. J. (2005). El arbolado urbano en el área metropolitana de Monterrey. *Ciencia UANL*, 8(1), 20-32. https://www.redalyc.org/pdf/402/40280104.pdf

Alanís, E., Jiménez J., Mora-Olivo, A., Canizalez, P. A., & Rocha, L. (2014). Estructura y composición del arbolado urbano de un campus universitario del noreste de México. *Revista Iberoamericana de Ciencias*, 1(7), 93–101. http://www.reibci.org/publicados/2014/diciembre/0700111.pdf

Alanís-Rodríguez, E., Mora-Olivo, A., & Marroquín-de la Fuente, J. S. (2020a). Muestreo ecológico de la vegetación. Editorial Universitaria de la Universidad Autónoma de Nuevo León. https://www.researchgate.net/publication/343137042_Muestreo_Ecologico_de_la_vegetacion

Alanís-Rodríguez, E., Rubio-Camacho, E. A., Canizales-Velázquez, P. A., Mora-Olivo, A., Pequeño-Ledezma, M. Á., & Buendía-Rodríguez, E. (2020b). Estructura y diversidad de un bosque de galería en el noreste de México. *Revista Mexicana de Ciencias Forestales*, 11(58), 134–153. https://doi.org/10.29298/rmcf.v11i58.591

Alanís-Rodríguez, E., Jiménez-Pérez, J., Valdecantos-Dema, A., Pando-Moreno, M., Aguirre-Calderón, O. A., & Treviño-Garza, E. J. (2011). Caracterización de regeneración leñosa post-incendio de un ecosistema templado del Parque Ecológico Chipinque, México. *Revista Chapingo Serie Ciencias Forestales y del Ambiente*, 17(1), 31–39. http://dx.doi.org/10.5154/r.rchscfa.2010.05.032

Arechiga, J., Esquivel, T., Camacho, A., Delgado-Rodríguez, M. R., Vargas-González, P., & Quijas, S. (2022). Diversidad florística y estructural de la vegetación riparia a lo largo de un gradiente urbano-natural del río Pitillal, Jalisco, México. *Revista U.D.C.A Actualidad & Divulgación Científica*, 25, 1-14. http://doi.org/10.31910/rudca.v25.nSupl.1.2022.2196

Brixner Dreyer, J. B., Higuchi, P.& Silva, A. C.(2019). *Ligustrum lucidum* W.T. Aiton (broad-leaf privet) demonstrates climatic niche shifts during global-scale invasion. *Scientific Reports*, 9, 30813. https://www.nature.com/articles/s41598-019-40531-8

Buendía-Rodríguez, E., Treviño-Garza, E. J., Alanís-Rodríguez, E., Aguirre-Calderón, O. A., & González-Tagle, M. A. (2019). Estructura de un ecosistema forestal y su relación con el contenido de carbono en el noreste de México. *Revista Mexicana de Ciencias Forestales*, 10(54), 3–25. https://doi.org/10.29298/rmcf.v10i54.149

Canizales-Velázquez, P. A., Alanís-Rodríguez, E., García-García, S. A., Holguín-Estrada, V. A., & Chávez-Costa, A. C. (2021). Estructura y diversidad arbórea de un bosque de galería urbano en el río Camachito, noreste de México. *Polibotánica*, 51, 91–105. https://doi.org/10.18387/polibotanica.51.6

Canizales Velázquez, P. A., Alanís Flores, G. J., Favela Lara, S., Torres Morales, M., Alanís Rodríguez, E., Jiménez Pérez, J., & Padilla Rangel, H. (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. https://www.redalyc.org/pdf/402/40211897009.pdf

Cantú, C., Rovalo, M., Marmolejo, J., Ortiz, S., & Seriñá, F. (2013). Historia Natural del Parque Natural Cumbres de Monterrey. Universidad Autónoma de Nuevo León. Comisión Nacional de Áreas Naturales Protegidas. Pronatura Noreste A.C. Consejo de Flora y Fauna Silvestre de Nuevo León.

CONABIO [Comisión Nacional para el Conocimiento y Uso de la Biodiversidad]. (2024, septiembre, 20). Enciclovida. https://enciclovida.mx/

CONAGUA [Comisión Nacional del Agua]. (2016). Registro Mensual de Precipitación Pluvial en mm de Nuevo León. https://smn.conagua.gob.mx/es/climatologia/pronostico-climatico/precipitacion-form

CONANP [Comisión Nacional de Áreas Naturales Protegidas]. (2006). Programa de Conservación y Manejo Parque Nacional Cumbres de Monterrey. México, D.F. 179. https://www.conanp.gob.mx/anp/consulta/PCM-20DIC06.pdf

Correa-Díaz, A., Gómez-Guerrero, A., Villanueva-Díaz, J., Silva, L. C., Horwath, W. R., Castruita-Esparza, L. U., Martínez-Trinidad, T., & Suárez-Espinosa, J. (2018). Respuesta fisiológica de *Taxodium mucronatum* Ten. a los incrementos atmosféricos de CO_2 y temperatura del último siglo. *Agrociencia*, 52(1), 129–149. https://agrociencia-colpos.org/

Encina-Domínguez, J. A., Encina-Domínguez, F. J., Mata-Rocha, E., & Valdes-Reyna, J. (2008). Aspectos estructurales, composición florística y caracterización ecológica del bosque de oyamel de la sierra de Zapalinamé, Coahuila, México. *Boletín de la Sociedad Botánica de México*, 83, 13–24. https://doi.org/https://doi.org/10.17129/botsci.1785

Enríquez-Peña, E. G., & Suzán-Azpiri, H. (2011). Estructura poblacional de *Taxodium mucronatum* en condiciones contrastantes de perturbación en el estado de Querétaro,

Revista Bio ciencias ISSN 2007-3380

México. *Revista Mexicana de Biodiversidad*, 82(1), 153–167. http://dx.doi.org/10.22201/ib.20078706e.2011.1.380

Estrada Arellano, J. R., Cardoza Martínez, G. F., Sánchez Salas, J. (2018). Plantas exóticas invasoras presentes en las áreas naturales protegidas (ANP) de México y su impacto en la biodiversidad. *Ciencia UANL*, 21(89), 49-57. https://cienciauanl.uanl.mx/ojs/index.php/revista/article/view/42

Fernandez, R. D., Ceballos, S. J., Aragón, R. Malizia, A., Montti, L., Whitworth-Hulse, J. I., Castro-Díez, P. & Grau, H. R. (2020). A Global review of *Ligustrum lucidum* (OLEACEAE) invasion. *The Botanical Review*, 86, 93–118. https://doi.org/10.1007/s12229-020-09228-w

Galicia, N. F. (2011). Estructura arbórea y composición de la vegetación del río Magdalena, en la delegación Coyoacán, México, D.F. [Tesis de licenciatura, Universidad Nacional Autónoma de México]. https://repositorio.unam.mx/contenidos/133985

González Cubas, R., Treviño Garza, E. J., González Tagle, M. A., Duque Montoya, Á., & Gómez Cárdenas, M. (2018). Diversidad y estructura arbórea en un bosque de *Abies vejarii* Martínez en el sur del estado de Nuevo León. *Revista Mexicana de Ciencias Forestales*, 9(45), 36–65. https://doi.org/10.29298/rmcf.v9i45.142

Henderson, L. (2007). Invasive, naturalized and casual alien plants in southern Africa: a summary based on the Southern African Plant Invaders Atlas (SAPIA) *Bothalia* 37(2), 215-248 https://doi.org/10.4102/abc.v37i2.322

Hernández-Álvarez, A. G., Reyes-Ortiz, J. L., Villanueva-Díaz, J., & Sánchez-González, A. (2021). Variación en la estructura del bosque de *Abies religiosa* (Pinaceae), en diferentes condiciones de manejo y disturbio. *Acta Botanica Mexicana*, (128). https://doi.org/10.21829/abm128.2021.1752

Holguín-Estrada, V. A., Alanís-Rodríguez, E., Aguirre-Calderón, O.A., Yerena-Yamallel, J. I., & Pequeño-Ledezma, M. Á. (2021). Estructura y composición florística de un bosque de galería en un gradiente altitudinal en el noroeste de México. *Madera y Bosques*, 27(2). https://doi.org/10.21829/myb.2021.2722123

Instituto Nacional de Estadística, Geografía e Informática [INEGI]. (1986). Síntesis Geográfica del Estado de Nuevo León. Instituto Nacional de Estadística, Geografía e Informática. Secretaría de Programación y Presupuesto, México, D.F. https://www.inegi.org.mx/contenidos/productos/prod_serv/contenidos/espanol/bvinegi/productos/historicos/2104/702825220747/702825220747_1.pdf

Instituto Nacional de Estadística, Geografía e Informática [INEGI]. (2017). Anuario estadístico y geográfico de Nuevo León 2017. México. https://www.datatur.sectur.gob.mx/ITxEF_Docs/NL_ANUARIO_PDF.pdf

Jost, L. (2006). Entropy and diversity. *Oikos*, 113(2), 363–375. https://doi.org/10.1111/j.2006.0030-1299.14714.x

Lähde, T. E., Eskelinen, T., & Väänänen, A. (2022). Growth and diversity effects of silvicultural alternatives on an old-growth forest in Finland. *Forestry*, 75(4), 395–400. https://doi.org/doi:10.1093/forestry/75.4.395

López-Hernández, J. A., Aguirre-Calderón, Ó. A., Alanís-Rodríguez, E., Monarrez-Gonzalez, J. C., González-Tagle, M. A., & Jiménez-Pérez, J. (2016). Composición y diversidad de especies forestales en bosques templados de Puebla, México. *Madera y Bosques*, 23(1), 39–51, 201. https://doi.org/10.21829/myb.2017.2311518

Lot, A., Zepeda, C., & Mora, A. (2015). Vegetación acuática y subacuática de México. In: Lot, A. (Coord.). Catálogo de la flora y vegetación de los humedales mexicanos. (pp. 27-104). Universidad Nacional Autónoma de México. https://www.researchgate.net/publication/328729465_Catalogo_de_la_flora_y_vegetacion_de_los_humedales_mexicanos

Magurran, A. E. (2004). Measuring biological diversity blackwell science. Biological diversity: frontiers in measurement and assessment. Oxford, 105. https://www.wiley.com/en-us/Measuring+Biological+Diversity-p-9781118687925

Manzanilla Quijada, G. E., Mata Balderas, J. M., Treviño Garza, E. J., Aguirre Calderón, Ó. A., Alanís Rodríguez, E., & Yerena Yamallel, J. I. (2020). Diversidad, estructura y composición florística de bosques templados del sur de Nuevo León. *Revista Mexicana de Ciencias Forestales*, 11(61), 94–123. https://doi.org/10.29298/rmcf.v11i61.703

Margalef, R. (1972). Homage to Evelyn Hutchinson, or why there is an upper limit to diversity. *Transactions of the Connecticut Academy of Arts and Sciences*, 44, 211–235. https://books.google.com.mx/books/about/Homage_to_Evelyn_Hutchinson_Or_why_There.html?id=rl4BogEACAAJ&redir_esc=y

Martínez-Calderón, V. M., Sosa-Ramírez, J., Siqueiros-Delgado, M. E., & Díaz-Núñez, V. (2021). Composición, diversidad y estructura de especies leñosas en los bosques templados de Monte Grande, Sierra Fría, Aguascalientes, México. *Acta Botanica Mexicana*, (128). https://doi.org/10.21829/abm128.2021.1829

Mata-Balderas, J. M., Hernández-Cárdenas, S. E., Alanís-Rodríguez, E., & Mora-Olivo, A. (2020). Riqueza, composición y abundancia de especies en una comunidad vegetal ribereña en el río Santa Catarina, Monterrey, Nuevo León. *CienciaUAT*, 14(2), 6–20. https://doi.org/10.29059/cienciauat.v14i2.1248

Mata-Balderas, J. M., Alanís-Rodríguez, E., Mora-Olivo, A., Collantes-Chávez-Costa, A. (2022). Woody plant community structure and composition of an urban riparian forest in Monterrey metropolitan area, Northeast Mexico. *The Journal of the Torrey Botanical Society*, 149(3), 210-218. https://doi.org/10.3159/TORREY-D-21-00030.1

Méndez Osorio, C., Mora Donjuan, C. A., Alanís Rodríguez, E., Jiménez Pérez, J., Aguirre Calderón, O. A., Treviño Garza, E. J., & Pequeño Ledezma, M. A. (2018). Fitodiversidad y estructura de un bosque de pino-encino en la Sierra Madre del Sur, México. *Revista Mexicana de Ciencias Forestales*, 9(50), 35–53. https://doi.org/10.29298/rmcf.v9i50.236

Nixon, K. & Poole, J. M. (2003). Revision of the Mexican and Guatemalan Species of *Platanus* (Platanaceae). *Lundellia*, 6, 103-137. https://doi.org/10.25224/1097-993X-6.1.4

Pasiecznik, N. (2008). *Populus alba* (silver-leaf poplar). *CABI Compendium*, 43426. https://doi.org/10.1079/cabicompendium.43

Pérez-Calix, E. (2001). Juglandaceae. *Flora del Bajío y de Regiones Adyacentes*, 96: 1-15. http://inecolbajio.inecol.mx/floradelbajio/documentos/fasciculos/ordinarios/Juglandaceae%2096.pdf

Plants of the Worl Online [POWO]. (2024, septiembre, 20). Plants of the Worl Online. Board of Trustees of the Royal Botanic Gardens, Kew. https://powo.science.kew.org/

Parques y Vida Silvestre [PVS]. (2022). Parque Natural “La Estanzuela”. Gobierno de Nuevo León. Monterrey, N.L. https://nl.gob.mx/campanas/parque-natural-la-estanzuela

Quintero-Gradilla, S. D., Jardel-Peláez, E. J., Cuevas-Guzmán, R., García-Oliva, F., & Martínez-

Revista Bio ciencias
ISSN 2007-3380

Yrizar, A. (2019). Cambio postincendio en la estructura y composición del estrato arbóreo y carga de combustibles en un bosque de *Pinus douglasiana* de México. *Madera y Bosques*, 25(3). https://doi.org/10.21829/myb.2019.2531888

Rajbongshi, P., Das, T. (2024). High-value plant resources in riparian areas. In Thangjam Anand Singh, T. A., Sarangi, P. K., & Singh, C. B. High-value plants. (pp. 1-24). Apple Academic Press. https://doi.org/10.1201/9781003457572

Ramírez Santiago, R., Ángeles Pérez, G., Hernández de la Rosa, P., Cetina Alcalá, V. M., Plascencia Escalante, O., & Clark-Tapia, R. (2019). Efectos del aprovechamiento forestal en la estructura, diversidad y dinámica de rodales mixtos en la Sierra Juárez de Oaxaca, México. *Madera y Bosques*, 25(3), 1-12. https://doi.org/10.21829/myb.2019.2531818

Rendón-Pérez, M. A., Hernández-de la Ros, P., Velázquez-Martínez, A., Alcántara-Carbajal, J. L., & Reyes-Hernández V. J. (2021). Composición, diversidad y estructura de un bosque manejado del centro de México. *Madera y Bosques*, 27(1). https://doi.org/10.21829/myb.2021.2712127

Riis, T., Kelly-Quinn, M., Aguiar, F. C., Manolaki, P., Bruno, D., Bejarano, M. D., Clerici, N., Fernandes, M. R., Franco, J. C., Pettit, N., Portela, A. P., Tammeorg, O., Tammeorg, P., Rodríguez-González, P. M., & Dufour S. (2020). Global overview of ecosystem services provided by riparian vegetation. *BioScience*, 70(6), 501–514. https://doi.org/10.1093/biosci/biaa041

Rivera-Hernández, J., Muñoz-Márquez, R. A., Vargas-Rueda, A., Alcántara-Salinas, G., Real-Luna, N., & Sánchez-Páez, R. (2019). Flora, vegetación y paisaje de la región de las altas montañas de Veracruz, México, elementos importantes para el turismo de naturaleza. *Agroproductividad*, 12(12), 1,180-1,375. https://doi.org/10.32854/agrop.vi0.1460

Rosete-Vergés, F. A., Pérez-Damián, J. L., Villalobos-Delgado, M., Navarro-Salas, E. N., Salinas-Chávez, E., & Remond-Noa, R. (2014). El avance de la deforestación en México 1976-2007. *Madera y Bosques*, 20(1), 21-35. https://doi.org/10.21829/myb.2014.201173

Rubio, R. (2019). Impactan Parque La Estanzuela y su agua. Periodismo News. http://periodismonewsmty.com/index.php/2019/05/09/impactan-parque-la-estanzuela-y-su-agua/

Rzedowski, J. (2006). Vegetación de México. 1ra. Edición digital. https://www.biodiversidad.gob.mx/publicaciones/librosDig/pdf/VegetacionMx_Cont.pdf

Sampayo-Maldonado, S., Moreno-Aldaco, J. D., Lara-Ponce, E., & Piña-Ruíz, H. H. (2021). Diversidad y estructura del bosque de galería del río Fuerte, Sinaloa, México. *Ecosistemas y Recursos Agropecuarios*, 8(2). https://doi.org/10.19136/era.a8n2.3046

Sánchez-Castillo, L., Kubota, T., & Cantu-Silva, I. (2017). Influence of root reinforcement of forest species on the slope stability of Sierra Madre Oriental, Mexico. *Journal of the Faculty of Agriculture, Kyushu Uni*, 177–181. https://doi.org/10.5109/1801779

Santiago-Pérez, A. L., Ayón Escobedo, A., Rosas-Espinoza, V. C., Rodríguez Zaragoza, F. A., & Toledo González, S. L. (2014). Estructura del bosque templado de galería en la sierra de Quila, Jalisco. *Revista Mexicana de Ciencias Forestales*, 5(24), 144-159. https://doi.org/10.29298/rmcf.v5i24.326

Seaman, B.S., & Schulze, C. (2010). The importance of gallery forests in the tropical lowlands of Costa Rica for understorey forest birds. *Biological Conservation*, 143(2), 391–398. https://doi.org/10.1016/j.biocon.2009.11.002

Shannon, C. (1948). The mathematical theory of communication. En C. E. Sahnnon; W. Weaver

Revista Bio ciencias
ISSN 2007-3380

(Ed). University of Illinois Press, 134–154. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x
Treviño-Garza, E. J., Cavazos Camacho, C., & Aguirre Calderón, O. A. (2001). Distribución y estructura de los bosques de galería en dos ríos del centro sur de Nuevo León. *Madera y Bosques*, 7(1), 13–25. https://doi.org/10.21829/myb.2001.711315
Tropicos. (2024). Tropicos, org. Missouri Botanical Garden. Missouri Botanical Garden. https://www.tropicos.org/home
Valencia-A., S. (2004). Diversidad del género *Quercus* (Fagaceae) en México. *Botanical Sciences*, 75, 33–53. https://doi.org/10.17129/botsci.1692
Van der Werff, H. (1997). Lauraceae. *Flora del Bajío y de Regiones Adyacentes*, 56: 1-58. http://inecolbajio.inecol.mx/floradelbajio/documentos/fasciculos/ordinarios/Lauraceae%2056.pdf
Vega-Mares, J. H., Rivero-Hernández, O., Martínez-Salvador, M., & Melgoza-Castillo, A. (2020). Análisis de la flora vascular de la Sierra Azul, Chihuahua, México. *Botanical Sciences*, 98(3), 618-652. https://doi.org/https://doi.org/10.17129/botsci.2565
Villanueva-Díaz, J., Stahle, D. W., Therrell, M. D., Beramendi-Orosco, L., Estrada-Ávalos, J., Martínez-Sifuentes, A. R., & Cerano-Paredes, J. (2020). The climatic response of baldcypress (*Taxodium mucronatum* Ten.) in San Luis Potosi, Mexico. *Trees*, 34, 623-635. https://doi.org/10.1007/s00468-019-01944-0
Villaseñor, J. L. (2016). Checklist of the native vascular plants of Mexico. *Revista Mexicana de Biodiversidad*, 87, 559–902. https://doi.org/10.1016/j.rmb.2016.06.017
Villaseñor, J. L., & Espinosa-Garcia, F. J. (2004). The alien flowering plants of Mexico. *Diversity and Distributions*, 10, 113–123. https://doi.org/10.1111/j.1366-9516.2004.00059.x
Weber, E. (2003). Invasive plant species of the world. A reference guide to environmental weeds. CABI publishing, Wallingford, UK.