

EFFECTIVE DIVERSITY AND IMPORTANCE OF HERBACEOUS PLANTS ALONG RURAL ROADSIDES IN CERVANTES Y LOZADA, VERACRUZ, MEXICO

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ABSTRACT

Rural roadsides represent an important alternative for biodiversity conservation. The objective of this study was to estimate the effective diversity and ecological importance in two herbaceous communities along rural roadsides. Twenty quadrats with an area of 1 m² were systematically established across two 50-m transects. Data on richness, abundance, and plant coverage were obtained. Forty-two species were recorded, comprising 18 families, with Asteraceae being the most abundant (28.57 %). The estimated effective diversity for both transects was greater than 15 effective species, which may be equal to a quarter of the effective diversity of a cloud forest, four times greater than that of an edge of agricultural land, and comparable to that of an edge of a tropical evergreen forest. The importance value index indicated that *Cenchrus ciliaris* and *Syagrus romanzoffiana* for transect one and *Sida rhombifolia* and *Aldama dentata* for transect two are the species most likely to determine the composition, structure, and functioning of the two plant communities studied. Estimates of these indices allow more useful comparisons with similar studies and facilitate the visualization of the species that probably determine the existence of these ecological systems. This study is expected to eventually provide scientific knowledge in the ecological and environmental fields, which will allow the implementation of effective and viable conservation strategies for ecosystems present in rural roadsides.

Keywords: richness, plant structure, diversity, flora.

INTRODUCTION

Anthropized landscapes, especially ruderal and weed vegetation, are present on the edges of rural roads and agricultural crops, respectively. They function as important

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reservoirs of biodiversity, providing multiple ecological and environmental services (Herrera *et al.*, 2017; Real-Luna *et al.*, 2021). In some cases, they behave as biological corridors connecting natural areas through agricultural fields and/or rural roads (Albrecht *et al.*, 2016; Yvoz *et al.*, 2021). However, the lack of historical interest in studying this type of plant communities is emphasized (Vite *et al.*, 2014). Nevertheless, the current global problem generated by the so-called pollinator crisis has brought into focus the potential importance of this kind of ecological system.

On the other hand, attempts to characterize, elucidate, and understand the composition, structure, and general functioning of biotic communities have been made using the so-called richness, diversity, equitability, similarity, and importance value indices. According to Begon *et al.* (1996), the macroscopic parameter that can best characterize a community is “diversity,” understood as a mathematical index with two basic components: richness (S), which is the number (abundance) of species, and evenness (called also equitability), which is defined as the degree to which the component species of the community in question are similar in terms of their abundances.

For this study, the vision of Moreno and Rodríguez (2011) was followed. These authors postulate that the understanding of the concept of “diversity” has never been fully adapted to the biological-ecological field because the statistical algorithms that attempt to estimate it are adaptations imported from other fields of knowledge (information theory, etc.), so that their scales are difficult to understand and compare due to their non-linear mathematical natures. Additionally, some of these algorithms are very sensitive to the high relative abundances found in some of the species sampled.

One of the most frequently used alternatives to solve this problem has been the estimation of the number of “effective species” (García-Morales *et al.*, 2011). These are understood as those that are truly represented in a community, which, as a whole, are known as “effective diversity” or “true diversity.” This concept is formally defined as the maximum possible number of species that could coexist in a community if they all had the same abundance (Hill, 1973; Jost, 2006; Moreno and Rodríguez, 2011; Moreno *et al.*, 2011; Tuomisto, 2010, 2011). Its values can be visualized as quantifiable and comparable units, which are intuitively more manageable and applicable. The latter is fundamental in proposals for the preservation, conservation, and management of biological species and their levels of ecological organization (Moreno *et al.*, 2011). An extensive review of fictional and real examples of the problematic use of traditional diversity indicators is presented by Jost and González-Oreja (2012).

In order to have a more complete characterization of these communities, in this study, the importance value index (IVI) was used, which is defined as an indicator of the relative ecological importance of the species in the community assemblage to which they are part of (Matteucci and Colma, 1982; Soler *et al.*, 2012). Its value is calculated as the sum of the relative values of density, frequency, and dominance for each species considered. This index was selected for its ability to clearly explain the ecological significance of each species. Its division into the three categories that compose it may also be of interest for results interpretation (Matteucci and Colma, 1982).

Based on the above, the objective of this study was to estimate the effective diversity and IVI of the component species of two herbaceous communities found on rural roadsides in the town of Cervantes y Lozada, in the municipality of Córdoba, Veracruz, Mexico, as an alternative to highlight the real and potential importance of these kinds of ecological systems.

MATERIALS AND METHODS

Description of the study area

The study was conducted in the rural town of Cervantes y Lozada, Córdoba, Veracruz, Mexico, which is located at the geographical coordinates 18° 57' 14.4" N and 96° 55' 35.04" W, at an altitude of 1214 m (Figure 1). It has a semi-warm humid climate with abundant rainfall in summer, with temperatures between 18–24 °C and precipitation between 1900–2100 mm (Gobierno del Estado de Veracruz, 2021).

There are two types of vegetation in the area, according to the Rzedowski (1978) classification: cloud forest (deciduous forest or medium or low evergreen forest, according to Miranda and Hernández-Xolocotzi, 1963), and tropical evergreen forest (or medium sub-evergreen forest), in addition to a transition strip and patches of secondary vegetation.

Sampling method

Two transects (T1 and T2) were established, each 50 m long and 1 m wide (50 m²). These were located on the northwestern and southeastern edges of the Cervantes y Lozada locality, in order to cover the environmental heterogeneity present in the rural roadsides of the study site (Figura 2).

In each transect, 10 quadrats of 1 x 1 m (1 m²) were established, with a separation of at least 3 m between them. In these areas, the species present, their abundance, and coverage were recorded and, when possible, taxonomically determined. According to Matteucci and Colma (1992), coverage is often used with species that grow vegetatively, such as grasses, where density is very difficult to estimate. This was the main reason why this variable was selected to estimate the relative dominances of these species in this study. In any case, for the estimation of abundances and densities, the growth in the form of "macollo" was considered in some of the species reported in this work, thus taking care not to count a single one as several "individuals." All the photographic record was made with a camera (Canon EOS Rebel T6).

Finally, botanical collections were made of all the individuals sampled, except those species that were not flowering during sampling, which were collected later for their correct taxonomic determination, which was carried out by using dichotomous keys and comparisons with herbarium specimens. The collections were deposited at the CPC herbarium of the Postgraduate College Campus Córdoba and the CORU herbarium of the Faculty of Biological and Agricultural Sciences, Orizaba-Córdoba Area of the Universidad Veracruzana.

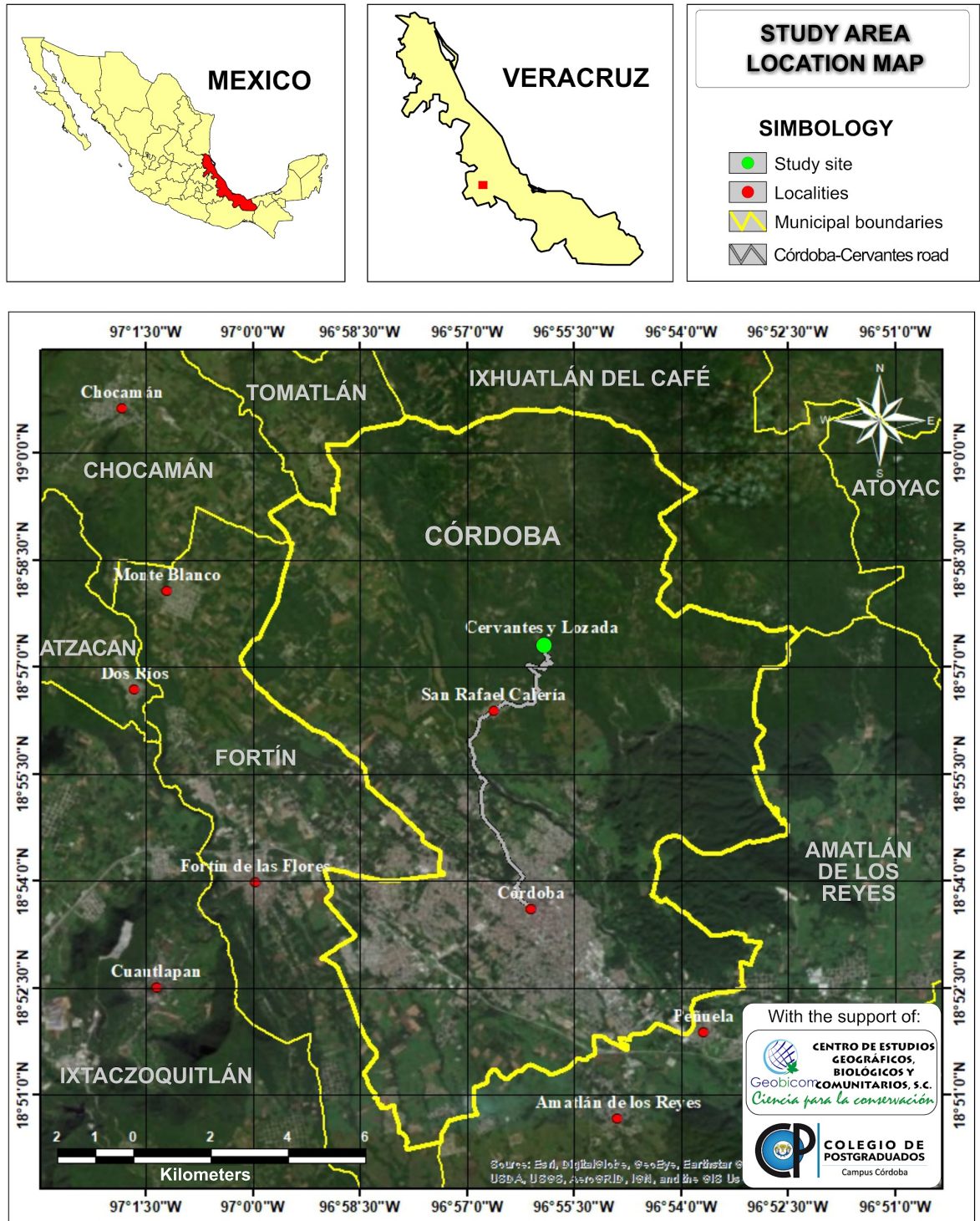


Figure 1. Location of Cervantes y Lozada, in the municipality of Córdoba, Veracruz, Mexico. Elaborated from Google Earth images.

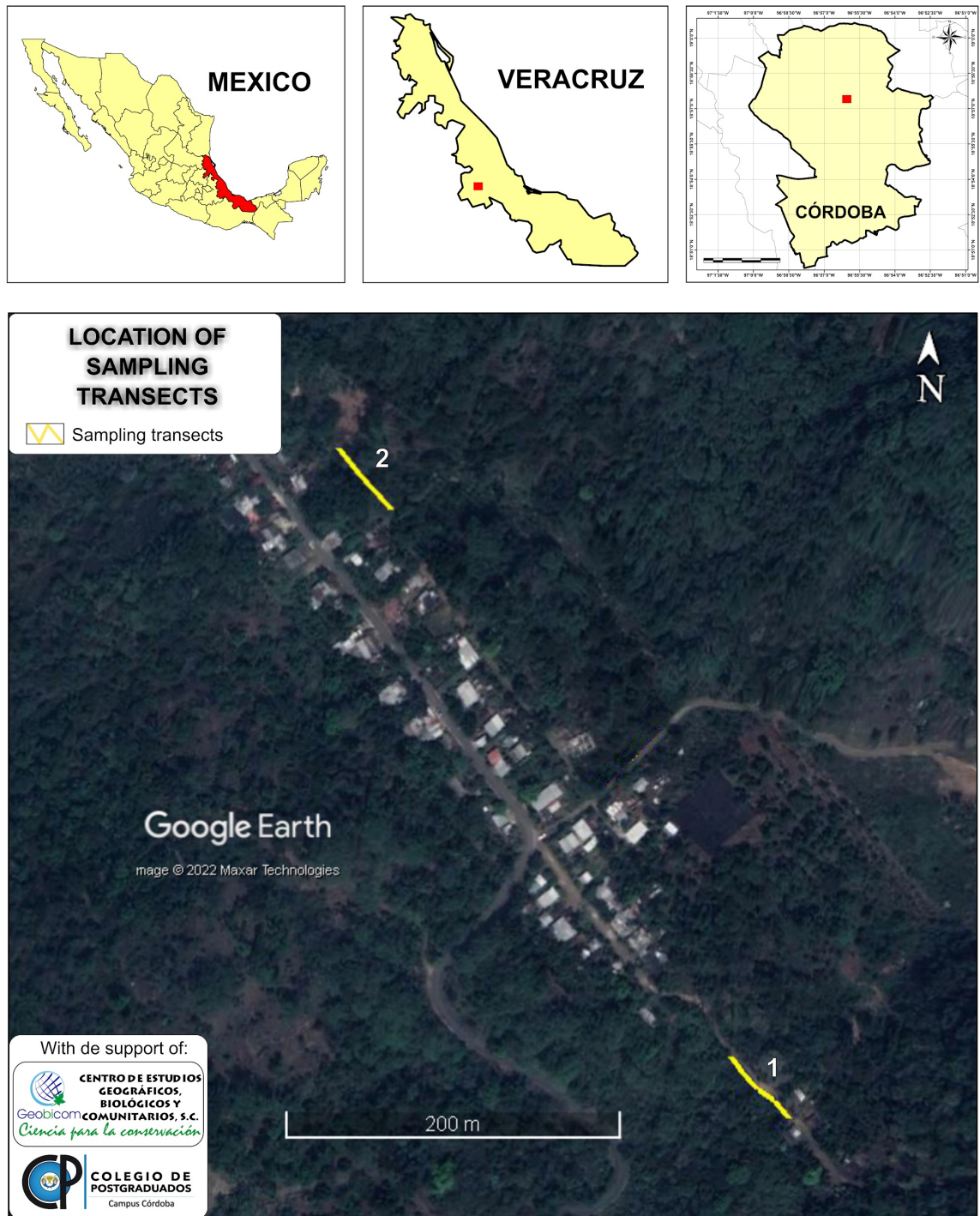


Figure 2. Geographical location of the vegetation sampling transects in Cervantes y Lozada, in the municipality of Córdoba, Veracruz, Mexico. Transect 1) start: $18^{\circ} 57' 10.3''$ N, $96^{\circ} 55' 48.1''$ W, altitude 1178 m; end: $18^{\circ} 57' 11.3''$ N, $96^{\circ} 55' 48.9''$ W, altitude 1174 m. Transect 2) start: $18^{\circ} 57' 21.5''$ N, $96^{\circ} 55' 56.8''$ W, altitude 1214 m; end: $18^{\circ} 57' 22.6''$ N, $96^{\circ} 55' 57.6''$ W, altitude 1219 m. Elaborated from Google Earth images.

Estimation of the effective diversity

The number of effective species was obtained with the formula:

$$qD = \frac{1}{\sum_{i=1}^S P_i^q}$$

This index is no other than Simpson's Dominance Index, that is, the inverse of Simpson's Diversity Index, where: qD is the effective diversity, P_i is the relative abundance (proportional abundance) of the i th species, S is the number of species, and q is the order of diversity that defines the sensitivity of the index to the relative abundances of the species. In this study, the estimation of two values of effective diversity are considered: (a) zero order (${}_0D = S$), whose value is simply referred to as Richness (S) and is insensitive to the proportional abundance of the species found, and (b) effective diversity of order 1 (${}_1D$), where all species are considered with a weight exactly proportional to their abundance in the studied community) (Hill, 1973; Jost, 2006, 2010; Tuomisto, 2010, 2011; Moreno *et al.*, 2011).

Estimation of the importance value index

This index is defined in terms of which species contribute the most to the composition, structure, and functioning of a plant community (Alvis-Gordo, 2009; López-Hernández *et al.*, 2017; Díaz-Vazquez *et al.*, 2018; Rendón-Pérez *et al.*, 2021). This value is obtained as the sum of the relative frequency (F_r = number of sampling units where the species in question appears in proportion to the total number of sampling units), the relative density (D_r = number of individuals of the species in question in proportion to the total number of individuals per species sampled), and the relative dominance (Dom_r), in terms of a quantifiable characteristic in the individuals per species sampled in proportion to the total value of this variable, which is measured in all individuals per species sampled (e.g., diameter at breast height, basal area, height, and vegetation cover). Relative dominance in this case was estimated from the total vegetation coverage recorded for each of the species sampled (Campo and Duval, 2014).

$$F_r = \left(\frac{\text{Frecuency of the } i\text{-th species}}{\text{Frecuency of all sampled species}} \right) \cdot 100$$

$$D_r = \left(\frac{\text{Individuals number of the } i\text{-th species}}{\text{Total number of sampled individuals}} \right) \cdot 100$$

$$Dom_r = \left(\frac{\text{Dominance of the } i\text{-th species}}{\text{Dominance of all sampled species}} \right) \cdot 100$$

Sampling effort analysis

Observed diversity usually has lower values than expected diversity (Moreno *et al.*, 2011). To ensure that the sampling efforts were adequate to record all potential species present in the study site, the Chao, Jackknife, and abundance coverage estimator (ACE) mathematical models were used (Escalante-Espinosa, 2003). The EstimateS software (Colwell, 2013) was used to calculate these metrics.

RESULTS AND DISCUSSION

Species richness

In both transects, 384 individuals were recorded, corresponding to 42 species comprised in 18 families. The Asteraceae family was the best represented in terms of number of species (28.6 %), followed by the Acanthaceae family (11.9 %). Of the species, 88.1 % were native and 11.9 % were exotic; 28.6 % of the species were shared by both transects (Table 1).

Table 1. Botanical families and species recorded in systematic sampling in two transects along rural roadsides in Cervantes y Lozada, Veracruz, Mexico.

Family	Species	Transect	%*	Status
Acanthaceae	** <i>Ruellia blechum</i> L.	1, 2	11.90	Native
	<i>Dicliptera sexangularis</i> (L.) Juss.	2		Native
	<i>Hypoestes phyllostachya</i> Baker	2		Exotic
	** <i>Odontonema callistachyum</i> (Schltdl. & Cham.) Kuntze	2		Native
	** <i>Thunbergia alata</i> Bojer ex Sims	1, 2		Exotic
Amaranthaceae	<i>Amaranthus hybridus</i> L.	1	9.52	Native
	** <i>Chamissoa altissima</i> Kunth	2		Native
	** <i>Gomphrena serrata</i> L.	2		Native
	<i>Iresine diffusa</i> Humb. & Bonpl. ex Willd.	2		Native
Apiaceae	<i>Cyclospermum leptophyllum</i> (Pers.) Sprague ex Britton & P. Wilson	2	4.76	Native
	<i>Eryngium foetidum</i> L.	1		Native
Araceae	<i>Syngonium neglectum</i> Schott.	1	2.38	Native
Arecaceae	** <i>Syagrus romanzoffiana</i> (Cham.) Glassman	1	2.38	Exotic
Asteraceae	** <i>Aldama dentata</i> La Llave	1, 2		Native
	** <i>Bidens alba</i> DC.	1, 2		Native
	** <i>Calyptocarpus wendlandii</i> Sch. Bip.	1, 2		Native
	** <i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.	1		Native
	** <i>Erigeron canadensis</i> L.	2		Native
	<i>Gamochaeta americana</i> (Mill.) Wedd.	1		Native
	** <i>Melampodium divaricatum</i> DC.	1, 2		Native
	** <i>Melanthera nivea</i> (L.) Small	2		Native

Table 1. Continue.

Family	Species	Transect	%*	Status
	** <i>Parthenium hysterophorus</i> L.	1, 2		Native
	** <i>Heliopsis buphthalmoides</i> Dunal	1	28.57	Native
	** <i>Tithonia diversifolia</i> (Hemsl.) A. Gray	1		Native
	** <i>Vernonanthura patens</i> (Kunth) H. Rob.	1		Native
Cyperaceae	<i>Cyperus hermaphroditus</i> (Jacq.) Standl.	2	4.76	Native
	<i>Fimbristylis dichotoma</i> (L.) Vahl	1		Exotic
Fabaceae	** <i>Desmodium orbiculare</i> Schltld.	1	2.38	Native
Lamiaceae	** <i>Salvia lasiocephala</i> Hook. & Arn.	2	2.38	Native
Linaceae	<i>Linum orizabae</i> Planch.	1	2.38	Native
Malvaceae	** <i>Anoda cristata</i> (L.) Schltld.	2	7.14	Native
	<i>Sida rhombifolia</i> L.	1, 2		Native
	** <i>Triumfetta semitriloba</i> Jacq.	1, 2		Native
Melastomataceae	** <i>Miconia xalapensis</i> (Bonpl.) M. Gómez	1	2.38	Native
Myrtaceae	** <i>Eugenia capuli</i> (Schltld. & Cham.) Hook. & Arn.	1	2.38	Native
Poaceae	<i>Cenchrus ciliaris</i> L.	1	7.14	Exotic
	<i>Oplismenus hirtellus</i> (L.) P. Beauv.	1, 2		Native
	<i>Cenchrus clandestinus</i> (Hochst. ex Chiov.) Morrone	1, 2		Native
Polypodiaceae	<i>Phlebodium aureum</i> J. Sm.	1	2.38	Native
Rubiaceae	<i>Galianthe brasiliensis</i> (Spreng.) E.L. Cabral & Bacigalupo	1	2.38	Native
Solanaceae	** <i>Cestrum nocturnum</i> L.	1	2.38	Native
Verbenaceae	<i>Stachytarpheta jamaicensis</i> (L.) Vahl	1, 2	2.38	Native
	Total		100	

*Percentage of species per family; **species registered as melliferous (Rivera-Hernández *et al.*, 2024).

Reliability of the sampling effort

When using species abundance data as in the present study, the best non-parametric indicators of the sampling effort are Chao 1 and ACE (Moreno *et al.*, 2011). For this reason, and based on these indicators, species accumulation curves were made (Figure 3). The results justify the sampling area used to represent the alpha diversity of species in each of the selected transects. The estimators of total species richness show that similar values of representativeness were obtained in the two transects (Table 2).

Effective diversity Analysis

The Cervantes y Lozada locality is immersed in the so-called High Mountain Region of Veracruz. According to Rivera-Hernández *et al.* (2019) and Vargas-Rueda *et al.* (2020), the cloud forest is one of the ecosystems that once dominated the region, but its existence is currently limited to reduced patches in inaccessible sites. Vargas-Rueda *et al.* (2020) carried out systematic sampling in conserved cloud forests near the

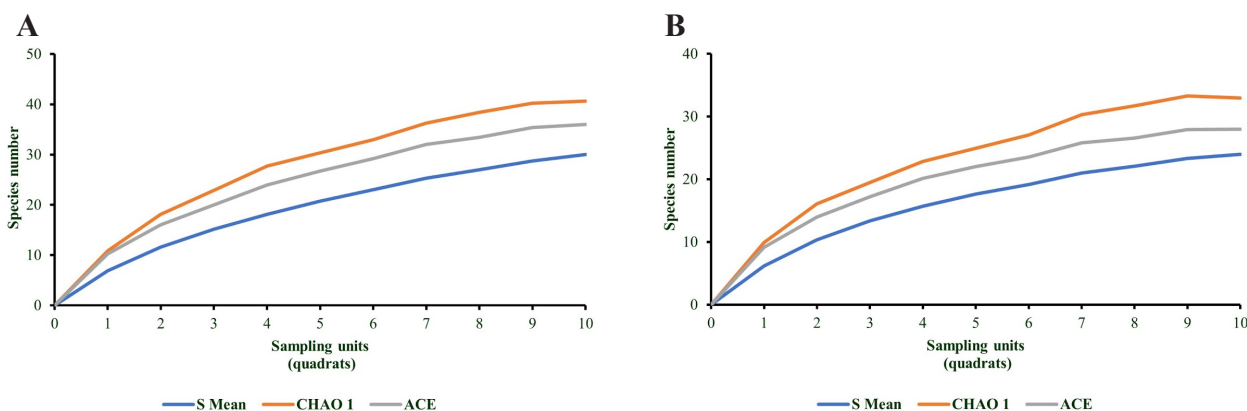


Figure 3. Accumulation curves (by rarefaction) of species of herbaceous plant communities in roadsides at Cervantes y Lozada in the municipality of Córdoba, Veracruz, Mexico. A: transect 1 (Chao 1: 73.84 %, abundance coverage estimator (ACE): 83.13 % of the potential richness explained); B: transect 2 (Chao 1: 72.84 %, ACE: 85.87 % of the potential richness explained). S mean is the estimator whose asymptotic curve is very similar to that produced by the original observed data; in general, it is comparable to S obs (species number observed) (Villareal *et al.*, 2006).

Table 2. Species richness estimators used in this study and their percentage representativeness values.

Estimator	Value		Representativeness (%)	
	T1	T2	T1	T2
Richness	30	24		
Chao 1	40.63	32.95	73.84	72.84
Chao 2	41.03	29.21	73.12	82.16
Incidence coverage estimator (ICE)	49.99	34.02	60.01	70.55
Abundance coverage estimator (ACE)	36.01	27.95	83.31	85.87
Bootstrap	35.84	27.99	83.71	85.74
Jack 1	42.6	32.1	70.42	74.77

region and obtained a Shannon index value of 4.20 ($S = 138$), which places this type of ecosystem in ranges of high to very high diversity. The values obtained in the present study with the same index were 2.71 ($S = 30$) and 2.73 ($S = 24$), respectively, for T1 and T2.

Despite the notable disparity in species richness between the conserved cloud forest and the study sites of this research, when using the Shannon diversity index, the difference is 1.5 *decits*, which are the units used by the natural logarithm in the estimation of this indicator (Jost and González-Oreja, 2012). However, when converting the Shannon index into effective diversity indices in both sites, the value of 4.2 for the conserved forest is transformed into 66.49 effective species, and the values of 2.71 and 2.73 are

transformed into 15.07 and 15.35 effective species for T1 and T2, respectively. In this new scale, because of its linear mathematical nature, we can visualize and affirm that about 25 % of the effective diversity reported for a conserved cloud forest is present in these rural roadsides. This was not possible from the results obtained by Shannon's way.

Likewise, based on the analysis of other sites with similar environmental disturbance characteristics (Table 3), it is possible to visualize that the plant communities studied in Cervantes y Lozada can support four times the effective diversity of an edge of agricultural land and can be comparable, in the same context, with vegetation of the edges of medium sub-evergreen forests. This highlights the great importance of these areas as reservoirs of biodiversity.

Table 3. Species richness, Shannon index, and its transformation to effective diversity index in five sites in the states of Veracruz and Oaxaca, Mexico.

Site	Species richness	Shannon index (<i>decits</i>)	Effective diversity index (effective species)
T1 Rural roadside (this study)	30	2.71	15.07
T2 Rural roadside (this study)	24	2.73	15.35
Preserved cloud forest (Veracruz) (Vargas-Rueda <i>et al.</i> , 2020).	138	4.20	66.49
Edge of agricultural land (Oaxaca) (Muñoz-Jiménez <i>et al.</i> , 2019)	10	1.32	3.74
Edge of medium sub evergreen forest (Oaxaca) (Muñoz-Jiménez <i>et al.</i> , 2019)	48	2.99	19.89

It is worth mentioning that opportunistic species can play an important role in the dominant structural and functional arrangement of these secondary plant communities. This study attempts, predominantly, to highlight the great biodiversity that these ecological systems can safeguard and the ease of achieving comparisons with other types of conserved or non-conserved plant communities, using estimates based on the so-called effective diversity.

On the other hand, when this type of data needs to be directed to non-specialists in the subject, this information is valuable due to the use of an easily manageable language, since it is enough to have basic notions of the concept of percentages or, in its absence, that of proportions (e.g., a quarter or an eighth). This, in turn, can facilitate the implementation of appropriate conservation and management measures in community social projects.

Finally, the edges of rural roads and agricultural crops are less exposed to the practices implemented in agricultural lands and become spaces of vital importance for the maintenance of numerous ecological interactions. In particular, the intricate mutualistic network that surely sustains numerous pollinators and flowering plants that survive

in these spaces and that has been ignored until a few years ago is highlighted (Vite *et al.*, 2014). In this study, 57.1 % of the species recorded are melliferous, and about 7.14 % of them produce flowers all year round. Among these species, the following stand out: *Thunbergia alata*, *Aldama dentata*, *Bidens alba*, and *Melampodium divaricatum*.

Importance value analysis

The species with the highest importance values at T1 were *Cenchrus ciliaris* (40) and *Syagrus romanzoffiana* (35). For T2, they were *Sida rhombifolia* (51) and *Aldama dentata* (30) (Figure 4). In this study, vegetation coverage was the variable considered to

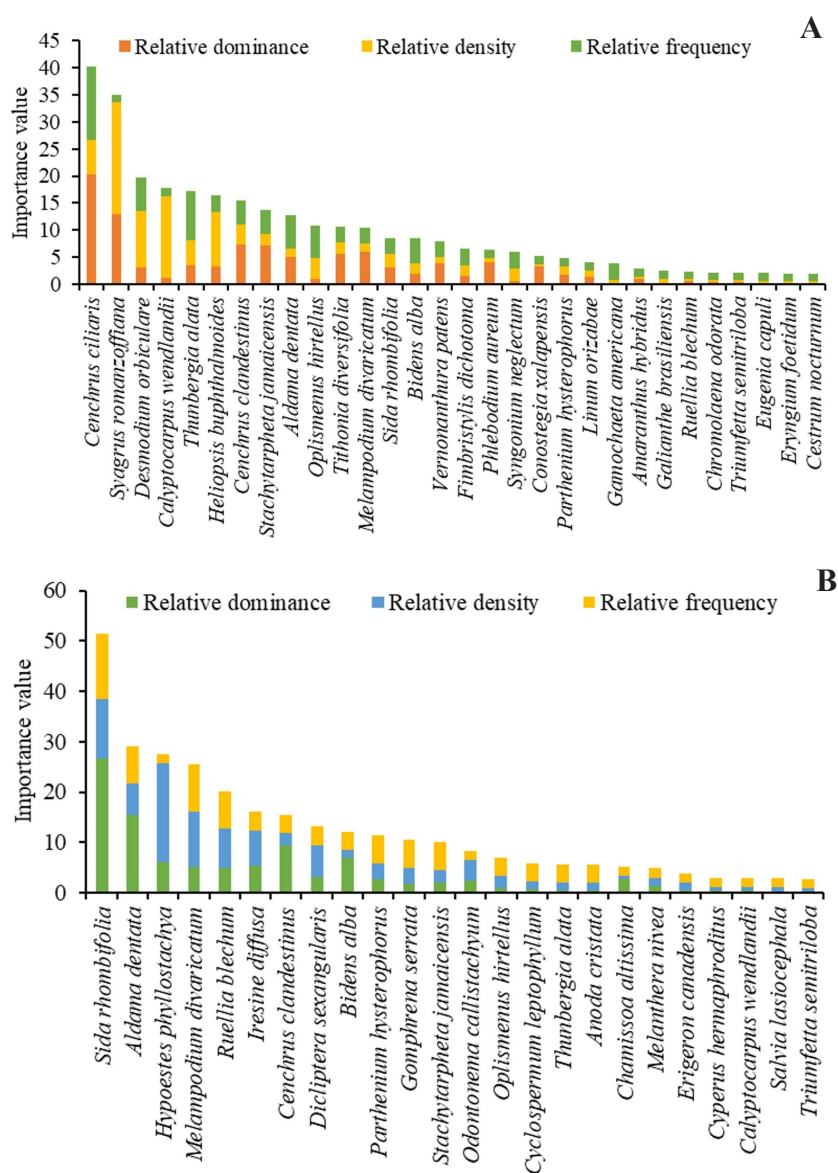


Figure 4. Importance value of plant species present in two roadsides in Cervantes y Lozada, in the municipality of Córdoba, Veracruz, Mexico. A) Transect 1, B) Transect 2

estimate relative dominances per species. In general, the importance values for these four species were 50 % explained by this variable, although the relative frequency of *Cenchrus ciliaris* and *Sida rhombifolia* is also remarkable, as well as the relative density for *Syagrus romanzoffiana*. Two of the four species are of exotic origin, reflecting the potentially high competitiveness of these species.

Because of its multidimensionality, the complexity of ecological systems is a very difficult subject to address; this proposal attempts to clarify it by using the so-called value of importance. In summary, four are the key species that explain the structure, composition, and functioning of the ecosystems studied in this work.

CONCLUSIONS

This study demonstrates the high potential of roadside ecosystems as reservoirs of regional biodiversity when compared to conservation sites and other areas with similar levels of environmental disturbance. The roadside ecosystems sampled were found to support approximately 25 % (15 vs. 66 effective species) of the effective diversity of a conserved cloud forest. Understanding the ecological complexity of roadside ecosystems should be the basis for their valorization, conservation, and management, since in many regions of the world roadsides and agricultural edges are eliminated using herbicides on the understanding that only “weeds” thrive in them.

The use of effective diversity indicators and ecological importance value indices is merely one instance of how to address ecological complexity through composition, structure, and function attributes in conservation and management contexts. It is hoped that this information will serve as a basis for future taxonomic and ecological research proposals on these types of biotic communities and in necessary conservation and management actions that may clarify and revalue the importance of these ecological systems.

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