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Floristic survey of flowering plants in a tropical coastal ecosystem in Veracruz, Mexico

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Abstract: Mexico is a megadiverse country and Veracruz is one of the states with the highest floristic diversity. The reserve of La Mancha in central coastal Veracruz comprises several vegetation types. In this site we conducted for a year, monthly surveys of flowering or fruiting plants in six vegetation types, considering the frequency of occurrence of different species. We found a total of 147 species (131 genera and 63 families). The families most represented were Asteraceae, Fabaceae and Verbenaceae. In addition, we found nine species that had not been reported in previous floristic studies. The highest taxonomic richness was observed in the tropical deciduous flood forest with wetland (59 species), while the highest diversity was found in tropical deciduous forest (SDI = 0.9562). We also found that the most similar vegetation types based on the composition and frequency of species were, coastal dune scrub, tropical deciduous forest and pioneer dune vegetation. The dominant plant biological form in La Mancha were herbs (40.41 %) followed by shrubs (23.97 %), vines-lianas (18.49 %) and trees (17.12 %). This study is the first to consider the frequency-occurrence of flowering and fruiting plants in La Mancha, covering six vegetation types through one year. The more relevant results of this study show the diversity of plants in different environments using the frequency of each species based on reproductive events. This information could be useful in future researches that evaluate plant-animal interactions, like pollination and seed dispersal.
Key words: floristic, flowering plants, fruiting plants, La Mancha, Veracruz.

Resumen: México es considerado un país megadiverso y Veracruz es uno de los estados con mayor diversidad florística del país. La reserva de La Mancha en la costa central de Veracruz alberga varios tipos de vegetación. En este sitio realizamos durante un año censos mensuales de la vegetación en floración o fructificación en seis tipos de vegetación, considerando la frecuencia de aparición de las diferentes especies de plantas. Encontramos en total 147 especies (131 géneros y 63 familias). Las familias mejor representadas fueron Asteraceae, Fabaceae y Verbenaceae. Además de nueve especies que no habían sido reportadas en estudios florísticos previos. La mayor riqueza taxonómica se observó en la selva baja inundable y el humedal (59 especies), mientras que, la mayor diversidad se encontró en la selva baja caducifolia (SDI = 0.9562). Además encontramos que los tipos vegetación más similares con base a la composición y frecuencia de especies son el matorral de dunas costeras, la selva baja caducifolia y la vegetación pionera de dunas. La forma biológica predominante en La Mancha fueron las hierbas (40.41 %), seguida por arbustos (23.97 %), bejucos-lianas (18.49 %) y árboles (17.12 %). Este trabajo es el primero que analiza la frecuencia-ocurrencia de plantas con flor y/o fruto en La Mancha, abarcando seis tipos de vegetación. Los resultados más destacados muestran la diversidad de plantas en diferentes ambientes utilizando la frecuencia de cada especie durante sus eventos reproductivos. Esta información puede ser útil en futuras investigaciones sobre interacciones planta-animal, como polinización y dispersión de semillas.
Palabras clave: florística, La Mancha, plantas en floración, plantas en fructificación, Veracruz.

Mexico is known to be megadiverse country because it comprises approximately 10 % of all existent species in the world (Mittermeier *et al*., 1997; Ceballos, 2007; Sarukhán *et al*., 2012; Espinosa-Jiménez *et al*., 2014). This high diversity is due to topography and complex geological structure, and the confluence of Nearctic and Neotropical regions favoring thus, a high variety of climates, soils, fauna and vegetation types, ranging from evergreen tropical forest to arid ecosystems (Miranda and Hernández, 1963; Neyra-González and Durand-Smith, 1998; González-Medrano, 2003; Rzedowski, 2006; Espinosa-Jiménez *et al*., 2014). These characteristics results in high flora diversity, estimat-

ed in 36,000 plant species for Mexico (Neyra-González and Durand-Smith, 1998), concentrated in Chiapas, Oaxaca and Veracruz mainly; further, the arid ecosystems comprise a great proportion of endemic species (Rzedowski, 1991; 1993).

In Mexico, Veracruz State is the third place in floristic richness with 7,855 taxa only below of Chiapas and Oaxaca (Rzedowski, 1991; 1993; Castillo-Campos *et al*., 2011); such richness is distributed in 19 vegetation types (Miranda and Hernández, 1963). La Mancha reserve is located in the central coast of Veracruz, where several vegetation types are represented (Castillo-Campos and Travieso-Bello, 2006). In this area several floristic surveys has been developed focused on biodiversity, ecological and management aspects. Many of this studies are related on characterization of biological forms, or on inventories on particular vegetation associations (Moreno-Casasola *et al*., 1982; García-Franco, 1996; Castillo and Moreno-Casasola, 1998; Castillo-Campos and Medina-Abreo, 2005; Moreno-Casasola and Travieso-Bello, 2006; Peralta-Peláez and Moreno-Casasola, 2009; Moreno-Casasola *et al*., 2010; Infante-Mata *et al*., 2011); other studies, are more exhaustive vegetation compendia on coastal area (Novelo-Retana, 1978; Castillo-Campos and Travieso-Bello, 2006).

Coastal vegetation in La Mancha is the result of an interphase between the sea and land, where their ecological processes are linked (Fragoso, 1995) to configure complex ecosystems; it is particularly interesting because it is so far known the only site in México that house tropical sub-deciduous and tropical dry forest occurring over coastal sand dunes (Castillo-Campos, 2006). Also due to dune formation, sand movement, dune erosion and marked seasonal abiotic changes (Moreno-Casasola, 1982; Moreno-Casasola and Travieso-Bello, 2006; Rico-Gray *et al*., 2012; Sánchez-Galván *et al*., 2012), thus generating an local ecological scenario where a great diversity of biological processes can be developed, such as pollination, seed dispersal, recruitment, competition, migration and herbivory (Turner *et al*., 1996; Benítez-Malvido, 1998; Benítez-Malvido *et al*., 1999; Cordeiro and Howe, 2001; Wright and Duber, 2001; Chacoff *et al*., 2004).

In this area previous studies has been developed only for a few specific plant species, also studies at community level are scarce, and the available studies are centered on reproductive biology (Rico-Gray and Castro, 1996; García-Franco and Rico-Gray, 1997a; 1997b; Arceo-Gómez *et al*., 2012), ant-plant interactions (Rico-Gray *et al*., 1998; Torres-Hernández *et al*., 2000; Cuautle and Rico-Gray, 2003), diversity of ants by vegetation types (Rojas *et al*., 2014), floral visitors richness (González-Vanegas, 2011; Rodríguez-Morales *et al*., 2013), and frugivory by birds (Ortiz-Pulido, 1997). In addition, community-level studies have been developed for extrafloral-nectary bearing plants (Rico-Gray, 1993; Díaz-Castelazo *et al*., 2004; Rico-Gray *et al*., 2012), pollination networks (Hernández-Yáñez et al., 2013), and also studies on phenology (Castillo and Carabias, 1982; Mehltreter, 2006).

Despite the wide range of studies that have been conducted in La Mancha there are not investigations with a focus at the level of the plant community and further considering reproductive effort. Based on this background we did the characterization of flowering and fruiting plants, and show how is the intensity of these phenological stages over a year, including different vegetation types inside La Mancha. The objectives of this study were: (a) make a floristic characterization of the plant flowering and fruiting species in six vegetation types, (b) determine the biological forms of flowering plants, and (c) evaluate the reproductive offer (occurrence-frequency) in these vegetation types.

Materials and methods

Study area. Field work was carried out at Centro de Investigaciones Costeras La Mancha (CICOLMA) located on the coast of Veracruz, Mexico (96°24'48"W, 19°40'33"N and 96°22'25"W, 19°31'49"N). The CICOLMA is a natural reserve area managed by Instituto de Ecología, A.C. (INECOL) and comprises an area of 83.29 ha, which includes several native vegetation types (including wetlands and dune vegetation), transformed forest/agricultural sites, experimental areas and a field station (Moreno-Casasola and Monroy, 2006). The CICOLMA was declared as Ramsar site in 2004 and the protection of natural resources and wildlife is given to INECOL by Mexican federal regulatory organisms in the matter, framed by intergovernmental treaty "The Ramsar Convention on Wetlands" (Secretaría de la Convención de Ramsar, 2013).

The main vegetation types in La Mancha are tropical sub-deciduous forest on two soil types based on mineralogical and physicochemical analyses (Dubroeucq *et al*., 1992; Geissert and Dubroeucq, 1995), tropical deciduous forest, sand dune scrub, mangrove forest, freshwater marsh and tropical deciduous flood forest (Miranda and Hernández, 1963; Rico-Gray 1993; Castillo-Campos and Travieso-Bello, 2006). The climate is warm sub-humid, and the annual precipitation average is 1,300 mm, 78 % of the total annual precipitation occurs during the rainy season, the mean annual temperature is 25 °C (Moreno-Casasola *et al*., 1982; Kellman, 1990; Kellman and Roulet, 1990; Kavanagh and Kellman, 1992; Kellman and Delfosse, 1993; Rico-Gray, 1993; Díaz-Castelazo *et al*., 2004), 18 °C in coldest month and > 22 °C on warmest month (Travieso-Bello and Campos, 2006). The study site is markedly seasonal (Rico-Gray and Oliveira, 2007; Díaz-Castelazo *et al*., 2010) with three distinctively different seasons, the dry season (February-May), the rainy season (June–September), the winter cold front season ("nortes", October-January). In this area, 837 plant species have been recorded, 50 % of which are herba-

ceous plants and the rest are shrubs, trees and vines-lianas (Castillo-Campos and Travieso-Bello, 2006).

The study was carried out at six different vegetation types: (1) coastal dune scrub (CDS), (2) pioneer dune vegetation (PDV), 3) tropical sub-deciduous forest in young soil (TSF-1), (4) tropical sub-deciduous forest in old soil (TSF-2), (5) tropical deciduous forest (TDF), and (6) tropical deciduous flood forest with wetland (TDF-W). For the present study, we unified the *Gymnanthes* forest with tropical sub-deciduous forest, and savanna with tropical deciduous forest, both in one vegetation type (Figure 1).

Sampling design. In each site we established one transect with 20 permanent points separated approximately 20 m each other (Figure 1). Based on each permanent point, we established round plots with five meters in radius from centered fixed point like Franco-Gaona *et al*. (1998). In each round plot we recorded all plant species in flowering and/or fruiting stages. With the species recorded by point, we calculated the presence and the occurrence frequency by species for each point.

The samplings were made monthly in all vegetation types to record all possible flowering or fruiting plants that were distributed in the area. For each plant species we recorded the vegetation type, biological forms and presence in each point, in order to obtain frequency of occurrence. In tropical sub-deciduous forest in young and old soil, tropical deciduous forest, and tropical deciduous flood forest with wetland (Figure 2), only plants under canopy were considered; thus, those species above canopy were discarded.

Botanical sampling and identification. We collected two or more samples of each species in order to carry out the botanical identification. The determination of our botanical

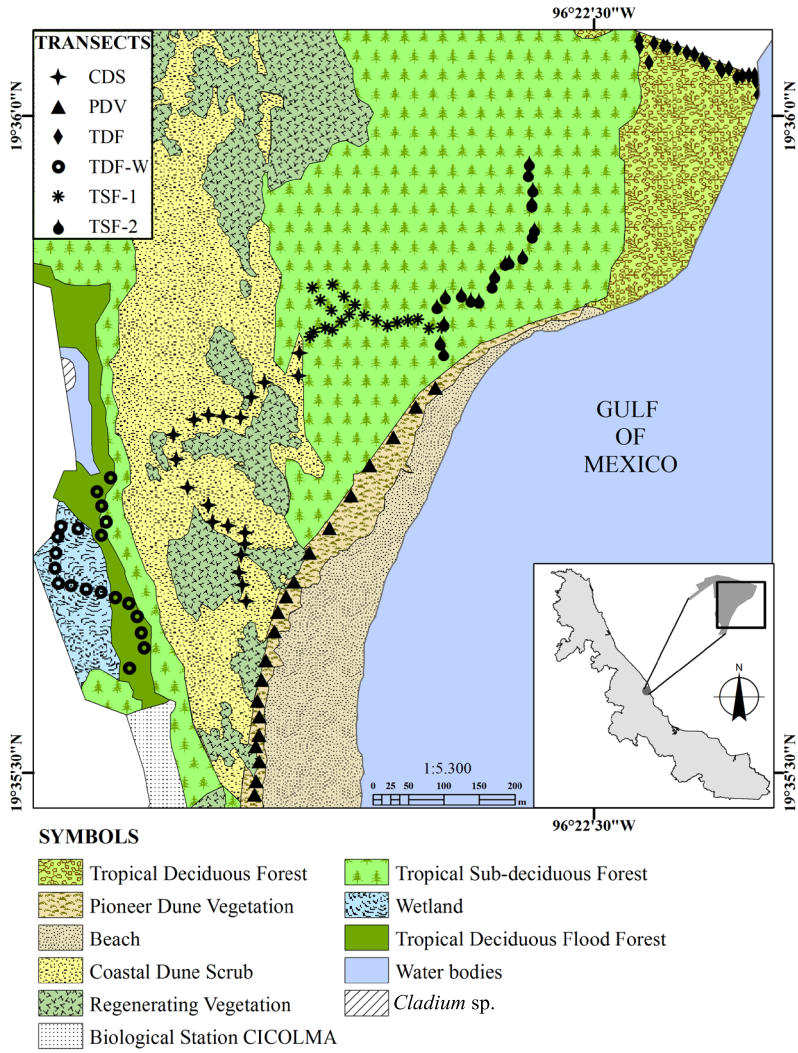

Figure 1. Location of the study area in La Mancha reserve; each symbol corresponds to sites where census was developing in the different vegetation types. (Map was actualized by Elisa Zaragoza-Quintana from Moreno-Casasola and Monroy, 2006, based on Google Earth images [June, 2012] and field observations).

Figure 2. Landscapes showing the different vegetation types where data were collected. (A) coastal dune shrub, (B) pioneer dune vegetation, (C) tropical sub-deciduous forest in young soil, (D) tropical sub-deciduous forest in old soil, (E) tropical deciduous forest, and (F) tropical deciduous flood forest with wetland.

samples was performed by comparing them with specimens deposited in the herbarium XAL, also with the aid of taxonomic keys and field guides of the plant species of the area, as well as personally consulting with botanical specialists. The used nomenclature was according to The International Plant Names Index.

Richness estimates in sampled vegetation types. Floristic richness was expressed as the number of species present in each transect. Also, with the identity of species in the six transects we elaborated a matrix with frequency of occurrence to calculate the Simpson Dominance Index which ranges from 0 to 1, where 0 means no dominance and 1

means species dominance within the community (D), larger index values meaning lower diversity (Simpson, 1949;1960). With D estimates, we obtained, in order to establish habitat plant diversity, the Simpson´s Diversity Index (SDI = 1 - D) with software PAST 2.01 (Hammer *et al.*, 2001), this index ranges 0 to 1 (being most diverse the values close to 1, and less diverse values close to 0). Also, we grouped the vegetation types with Jaccard Similarity Cluster Analysis to determine which vegetation types were most similar. Finally, we use EstimateS software (Colwell, 2013) to calculate the Chao-Jaccard Similarity Index from frequency of incidence (Chao *et al*., 2005); this is an accurate estimator because it considers species abundance or frequency of incidence.

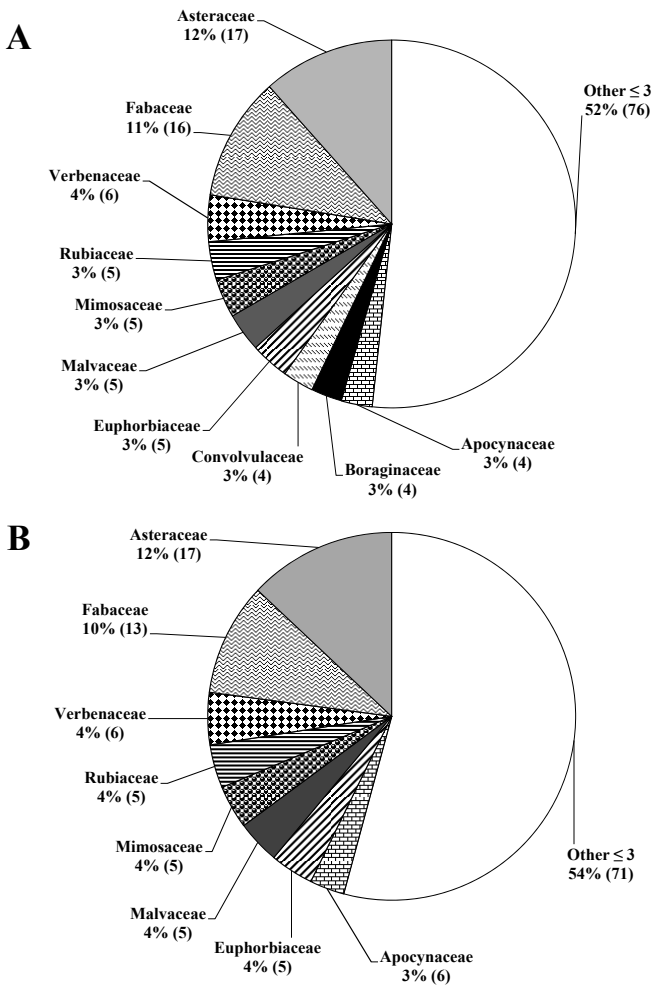

Figure 3. Taxonomic representativeness of flowering or fruiting plants in La Mancha. A) Percent of species by family, Fabaceae and Asteraceae comprised 12 % of all species, while 52 % correspond to taxa with less (or equal) to three species per family. B) Number of genera by family. We observe the same tendency with Fabaceae and Asteraceae comprising the major number of genera (22 %), while 54 % correspond to genera with less (or equal) to two genera per family. In parentheses is show the number of species and genera respectively.

Results

Floristic richness estimates in each vegetation type. From March 2013 to May 2014 we obtained 3,564 records of plants in flowering or fruiting stage, belonging to 63 families, 131 genera, and 147 species (Table 1). Asteraceae showed the largest number of genera and species (17 and 17 respectively), followed by Fabaceae (16 species) and Verbenaceae both with six species and six genera (Figure 3A, B). These three families comprise 27 % of all observed species, while the other families only had five or less species. Among the flowering and/or fruiting plant species at our sampling points, we found interesting species from a conservationist perspective, such as the threatened wetland tree species *Conocarpus erectus* (according to Mexican conservation regulation NOM-059-SEMARNAT-2010 [SEMARNAT, 2010]), and *Chamaecrista chamaecristoides* (Caesalpinaceae) and *Palafoxia lindenii* (Asteraceae) both as endemic species (according to Martínez and Moreno-Casasola, 1998; Álvarez-Molina *et al*., 2013). In addition it is important to note that nine species not have been cited previously for this study area: *Neurolaena lobata* (Asteraceae), *Tillandsia utriculata* (Bromeliaceae), *Capparidastrum frondosum* (Capparaceae), *Crossopetalum gaumeri* (Celastraceae), *Calliandra eriophylla* (Mimosaceae), *Desmodium scorpiurus* (Fabaceae), *Lonchocarpus fuscopurpureus* (Fabaceae), *Vigna adenantha* (Fabaceae), and *Trichocentrum luridum* (Orchidaceae).

On the other hand, in terms of vegetation types, we found the highest taxonomic richness in tropical deciduous flood forest with wetland (59), followed by coastal dune scrub with 50 species, pioneer dune vegetation (47 species), and tropical deciduous forest (41 species). Considering families, Fabaceae had the highest contribution at tropical deciduous flood forest with wetland and coastal dune scrub. In the tropical deciduous forest the highest contribution is given by Asteraceae and Fabaceae, whereas Asteraceae was a mainly important family at pioneer dune vegetation. The species diversity index showed that the tropical deciduous forest was the most diverse (SDI = 0.9562), followed by pioneer dune vegetation (SDI = 0.9437), coastal dune scrub (SDI = 0.9377), tropical deciduous flood forest with wetland (SDI = 0.9036), tropical sub-deciduous forest in old soil (SDI = 0.8677), and tropical sub-deciduous forest in young soil (SDI = 0.6254). The analysis of Jaccard Similarity formed three different clusters, the first group consisting of coastal dune scrub (CDS), tropical deciduous forest (TDF) and pioneer dune vegetation (PDV), where both the deciduous tropical forest (TDF), and pioneer dune vegetation (PDV) had the highest values of Chao-Jaccard similarity with coastal dune scrub (CDS). In turn, the second group was formed of two subtypes of tropical subdeciduous forest, while the tropical deciduous flood forest with wetland formed a separate cluster non-similar to any other vegetation type (Table 2, Figure 4).

Table 1. Plant species, biological forms and the flowering or fruiting total occurrence frequency recorded in six vegetation types inside to La Mancha, reserve. CDS = coastal dune scrub, PDV = pioneer dune vegetation, TSF-1 = tropical sub-deciduous forest in young soil, TSF-2 = tropical sub-deciduous forest in old soil, TDF = tropical deciduous forest, and TDF-W = tropical deciduous flood forest with wetland. (*) denoted the new reported species and (X) presence in vegetation types. The used nomenclature and scientific authorities was according to The International Plant Names Index.

FAMILY	SPECIES	ENVIRONMENT						BIOL. FORM	FREQUENCY
		CDS	PDV	TSF-1	TSF-2	TDF	TDF-W		
Acanthaceae	*Blechum pyramidatum* (Lam.) Urb.						X	Herb	2
Alismataceae	*Sagittaria lancifolia* L.						X	Herb	90
Amaranthaceae	*Achyranthes aspera* L.				X			Herb	2
	Iresine diffusa Humb. & Bonpl. ex Willd.	X	X					Herb	24
Annonaceae	*Annona glabra* L.						X	Tree	3
Apiaceae	*Hydrocotyle bonariensis* Lam.						X	Herb	6
Apocynaceae	*Pentalinon andrieuxii* (Müll.Arg.) B.F.Hansen & Wunderlin					X		Vine	4
	Pinochia peninsularis (Woodson) M.E.Endress & B.F.Hansen					X		Vine	9
	Stemmadenia pubescens Benth.			X				Tree	1
	Tabernaemontana alba Mill.						X	Tree	4
Araceae	*Spathiphyllum cochlearispathum* (Liebm.) Engl.						X	Herb	3
Arecaceae	*Cocos nucifera* L.		X					Tree	11
Asclepiadaceae	*Asclepias curassavica* L.						X	Herb	18
	Metastelma schlechtendalii (Decne.) Standl. & Steyerm.	X	X			X		Vine	49
Asteraceae	*Ageratum corymbosum* Zuccagni ex Pers.		X					Herb	72
	Bidens pilosa L.	X	X			X	X	Herb	230
	Critonia quadrangularis (DC.) R.M.King & H.Rob.				X			Shrub	3
	Cyanthillium cinereum (L.) H.Rob.		X				X	Herb	7
	Chromolaena odorata (L.) R.M.King & H.Rob.		X					Herb	9
	Eclipta prostrata (L.) L.						X	Herb	4
	Erigeron procumbens (Houst. ex Mill.) G.L.Nesom	X	X					Herb	10
	Florestina pedata (Cav.) Cass.	X	X			X		Herb	130
	Melampodium americanum L.		X			X		Herb	36
	Mikania micrantha Kunth						X	Vine	7
	Neurolaena lobata (L.) Cass.R.Br. (*)						X	Shrub	6
	Palafoxia lindenii A.Gray		X					Herb	82
	Pectis saturejoides (Mill.) Sch. Bip.	X	X			X		Herb	70
	Pluchea odorata (L.) Cass.		X					Shrub	4
	Porophyllum punctatum S.F.Blake	X	X					Herb	111
	Tridax procumbens (L.) L.		X					Herb	1
	Trixis inula Crantz	X	X	X				Herb	9
Bignoniaceae	*Tecoma stans* (L.) Kunth	X	X					Shrub	6
Bombacaceae	*Pachira aquatica* Aubl.						X	Tree	12
Boraginaceae	*Cordia spinescens* L.		X				X	Shrub	2
	Cordia polycephala (Lam.) I.M.Johnst.	X						Shrub	3
	Tournefortia hirsutissima L.	X						Herb	3
	Tournefortia volubilis L.						X	Herb	3
Bromeliaceae	*Tillandsia paucifolia* Baker *utriculata* L. (*)	X				X		Herb	1
	Tillandsia paucifolia Baker *utriculata* L. (*)	X				X		Herb	60
Burseraceae	*Bursera fagaroides* (Kunth) Engl.					X		Tree	22
	Bursera simaruba (L.) Sarg.	X		X		X		Tree	29
Cactaceae	*Opuntia stricta* (Haw.) Haw.	X				X		Shrub	133
Caesalpiniaceae	*Caesalpinia bonduc* (L.) Roxb.		X					Shrub	36
	Chamaecrista chamaecristoides Greene	X	X					Shrub	70
Capparaceae	*Capparidastrum frondosum* (Jacq.) Cornejo & Iltis (*)				X			Shrub	3
	Cynophalla flexuosa (L.) J. Presl		X					Shrub	1

Table 1. Continuation.

FAMILY	SPECIES	ENVIRONMENT						BIOL. FORM	FREQUENCY
		CDS	PDV	TSF-1	TSF-2	TDF	TDF-W		
Caricaceae	*Carica papaya* L.						X	Tree	2
Celastraceae	*Crossopetalum gaumeri* (Loes.) Lundell (*)	X		X		X		Shrub	12
	Crossopetalum uragoga Kuntze	X		X	X	X		Shrub	149
	Elaeodendron laneanum A.H. Moore					X		Tree	3
Combretaceae	*Conocarpus erectus* L.		X					Tree	13
	Terminalia catappa L.						X	Tree	1
Commelinaceae	*Commelina erecta* L.	X	X			X		Herb	235
Connaraceae	*Rourea glabra* Kunth				X	X		Vine	10
Convolvulaceae	*Ipomoea aquatica* Forssk.						X	Vine	6
	Ipomoea pes-caprae (L.) Sweet		X					Vine	48
	Ipomoea stolonifera (Cirillo) J.F. Gmel.		X					Vine	78
	Merremia umbellata (L.) Hallier f.						X	Vine	3
Cucurbitaceae	*Melothria pendula* L.	X						Vine	2
	Momordica charantia L.		X					Vine	1
Chrysobalanaceae	*Chrysobalanus icaco* L.	X				X		Tree	38
Ebenaceae	*Diospyros verae-crucis* (Standl.) Standl.	X						Tree	5
Erythroxylaceae	*Erythroxylum havanense* Jacq.					X		Tree	1
Euphorbiaceae	*Adelia barbinervis* Cham. & Schltdl. & Cham.						X	Shrub	1
	Cnidoscolus herbaceus (L.) I.M. Johnst.	X				X		Herb	42
	Croton punctatus Lour.		X					Shrub	20
	Euphorbia heterophylla L.						X	Herb	2
	Manihot aesculifolia (Kunth) Pohl		X			X		Shrub	12
Fabaceae	*Calopogonium caeruleum* (Benth.) C. WrightHemsl.						X	Herb	7
	Canavalia rosea (Sw.) DC.	X	X					Vine	65
	Centrosema virginianum (L.) Benth.	X						Vine	18
	Crotalaria incana L.	X	X					Shrub	101
	Dalbergia brownei (Jacq.) Schinz		X				X	Shrub	46
	Desmodium adscendens (Sw.) DC.						X	Herb	4
	Desmodium scorpiurus (Sw.) Poir. (*)	X	X				X	Herb	4
	Gliricidia sepium (Jacq.) Kunth ex Walp.		X					Tree	5
	Indigofera miniata Ortega	X				X		Herb	6
	Lonchocarpus fuscopurpureus Brandegee (*)					X		Tree	1
	Macroptilium atropurpureum (L.) Urb.	X	X			X		Vine	172
	Rhynchosia americana (Mill.) Metz	X					X	Vine	7
	Rhynchosia minima (L.) DC.						X	Vine	2
	Tephrosia cinerea (L.) Pers.	X				X		Herb	16
	Vigna adenantha (G. Mey.) Maréchal, Mascherpa & Stainier (*)		X					Vine	4
	Vigna vexillata (L.) A. Rich.						X	Vine	7
Flacourtiaceae	*Casearia corymbosa* Kunth	X						shrub	7
Lamiaceae	*Aegiphila deppeana* Steud.	X					X	vine	8
	Callicarpa acuminata Kunth	X						shrub	2
Leguminosae	*Diphysa americana* (Mill.) M. Sousa	X	X					Tree	2
	Mucuna pruriens (L.) DC.						X	Vine	7
Loranthaceae	*Psittacanthus schiedeanus* (Schltdl. & Cham.) Blume	X				X		shrub	8
Malpighiaceae	*Malpighia glabra* L.			X				Shrub	1
Malvaceae	*Anoda cristata* (L.) Schltdl.						X	Herb	7
	Herissantia crispa (L.) Brizicky						X	Herb	1
	Kosteletzkya depressa (L.) O.J. Blanch., Fryxell & D.M. Bates						X	Herb	1
	Malachra capitata (L.) L.						X	Herb	1
	Sida acuta Burm. f.	X					X	Herb	10
Marantaceae	*Thalia geniculata* L.						X	Herb	5

Table 1. Continuation.

FAMILY	SPECIES	ENVIRONMENT						BIOL. FORM	FREQUENCY
		CDS	PDV	TSF-1	TSF-2	TDF	TDF-W		
Mimosaceae	*Acacia cornigera* (L.) Willd.						X	Shrub	8
	Calliandra eriophylla Benth. (*)					X		Shrub	2
	Lysiloma divaricatum (Jacq.) J.F. Macbr. Hook. & B.D.Jacks.					X		Tree	27
	Mimosa tricephala Cham. & Schltdl. & Cham.	X						Shrub	10
	Neptunia plena (L.) Benth.						X	Herb	2
Moraceae	*Brosimum alicastrum* Sw.	X			X			Tree	2
Myrtaceae	*Eugenia acapulcensis* Steud.	X						shrub	12
	Psidium guajava L.						X	tree	3
Nymphaeaceae	*Nymphaea ampla* (Salisb.) DC.						X	herb	7
Onagraceae	*Ludwigia leptocarpa* (Nutt.) H. Hara						X	herb	2
	Ludwigia octovalvis (Jacq.) P.H. Raven		X				X	herb	43
Orchidaceae	*Trichocentrum luridum* (Lindl.) M.W.Chase & N.H.Williams (*)				X			herb	1
Oxalidaceae	*Oxalis frutescens* L.					X		herb	7
Passifloraceae	*Passiflora holosericea* L.	X						vine	2
	Passiflora suberosa L.						X	vine	1
Phytolaccaceae	*Petiveria alliacea* L.			X	X			herb	15
	Rivina humilis L.				X		X	herb	4
Piperaceae	*Piper amalago* L.						X	shrub	3
	Piper nitidum Sw.						X	shrub	17
Polygonaceae	*Coccoloba humboldtii* Meisn.		X			X		tree	19
	Coccoloba liebmannii Lindau				X			tree	1
Pontederiaceae	*Pontederia sagittata* C. Presl						X	herb	82
Rafflesiaceae	*Bdallophytum americanum* (R. Br.) Eichler ex SolmsHarms				X			Herb	1
Ranunculaceae	*Clematis grossa* Benth.						X	vine	2
Rhamnaceae	*Rhamnus humboldtiana* Willd. ex Schult.					X		tree	3
Rubiaceae	*Chiococca coriacea* M. Martens & Galeotti	X	X			X		shrub	65
	Diodia teres Walter					X		herb	8
	Psychotria erythrocarpa Schltdl.			X		X	X	shrub	21
	Randia aculeata L. var. *dasyclada* Steyerm.	X	X			X		shrub	142
	Spermacoce assurgens Ruiz & Pav.						X	herb	1
Sapindaceae	*Cardiospermum halicacabum* L.	X						vine	10
	Paullinia tomentosa Jacq.	X	X			X		vine	22
Scrophulariaceae	*Bacopa monnieri* (L.) Wettst.						X	herb	4
	Russelia sarmentosa Jacq.					X		herb	34
Solanaceae	*Solanum diphyllum* L.						X	shrub	2
	Solanum rudepannum Solanum rudepannum Dunal						X	shrub	1
Sterculiaceae	*Waltheria indica* L.	X	X			X	X	Herb	60
Theophrastaceae	*Jacquinia macrocarpa* Cav.			X	X			tree	9
Tiliaceae	*Muntingia calabura* L.						X	Tree	2
	Triumfetta lappula L.				X			Shrub	2
Turneraceae	*Turnera diffusa* Willd.	X				X		herb	37
	Turnera ulmifolia L.	X	X				X	herb	99
Verbenaceae	*Lantana camara* L.	X	X			X		shrub	79
	Lippia graveolens Kunth					X		herb	4
	Petrea volubilis L.				X			vine	3
	Phyla nodiflora (L.) Greene		X				X	herb	32
	Priva lappulacea (L.) Pers.						X	herb	2
	Tamonea curassavica (L.) Pers.					X		herb	30
Viscaceae	*Phoradendron quadrangulare* (Kunth) Griseb.Trel.	X	X					herb	5
Vitaceae	*Vitis tiliifolia* Humb. & Bonpl. ex Schult.		X				X	vine	4

Table 2. Chao-Jaccard Similarity Index for the six vegetation types. The bold numbers belongs to highest values of similarity.

	CDS	PDV	TSF-1	TSF-2	TDF	TDF-W
CDS	1	**0.479**	0.06	0.04	**0.518**	0.036
PDV		1	0.003	0	0.205	0.075
TSF-1			1	**0.444**	0.145	0.013
TSF-2				1	0.081	0.004
TDF					1	0.018
TDF-W						1

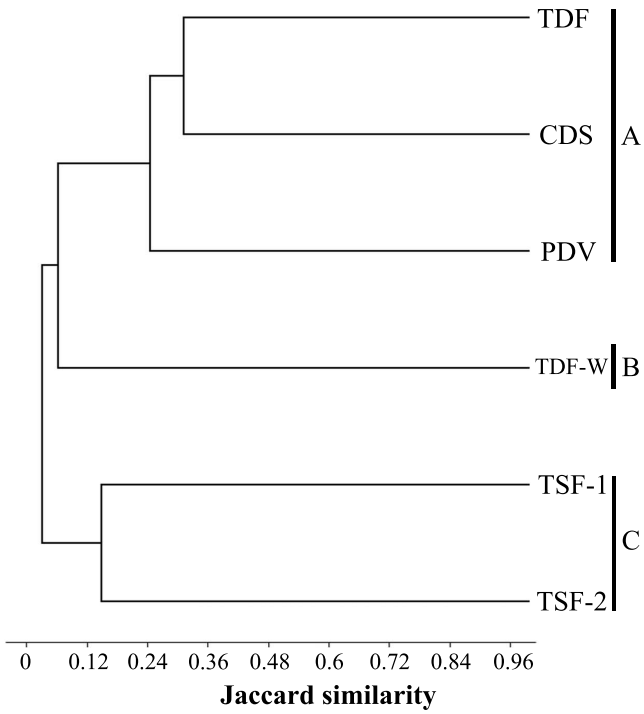

Figure 4. Clustering analyses using Jaccard Similarity Index. TDF = tropical deciduous forest, CDS = coastal dune scrub, PDV = pioneer dune vegetation, TDF-W = tropical deciduous flood forest with wetland, TSF-1 = tropical sub-deciduous forest in young soil, and TSF-2 = tropical sub-deciduous forest in old soil.

Biological forms. Considering the six vegetation types, the herbs contribute with 40.41 % of species, followed by shrubs (23.97 %), vines-lianas (18.49 %), and trees (17.12 %). Moreover, herbs were represented mostly by Asteraceae, whereas shrubs, vines-lianas, and trees were well represented by Fabaceae. On other hand, the herbs were the most represented biological forms followed by shrubs in coastal dune scrub, pioneer dune vegetation, and tropical deciduous forest. Shrubs and herbs were the most important biological form in tropical sub-deciduous forest in old soil. Moreover herbs were highly represented as main plants in the tropical deciduous flood forest with wetland; however, this site showed that vines-lianas were well represented as well.

Flowering and fruiting display. Overall, our results showed that species with the highest frequency of occurrence in these phenological stages were: *Commelina erecta*, *Bidens pilosa*, *Macroptilium atropurpureum*, *Crossopetalum uragoga* (Table 1). On other hand, and some species like *C. erecta*, *B. pilosa*, *Palafoxia lindenii*, *M. atropurpureum*, and *C. uragoga* had a flower display and fruit setting in long periods through year, while, *Randia aculeata* var. *dasyclada*, *Opuntia stricta*, and *Florestina pedata* had a flower display in some months and fruit setting on almost months posterior to flowering.

In addition, the species that had high frequencies also we were recorded in three or four vegetation types, like *Bidens pilosa* and *Crossopetalum uragoga* which occurred in four, followed by *Commelina erecta*, *Macroptilium atropurpureum*, *Randia aculeata* var. *dasyclada*, and *Florestina pedata* in three vegetation types. The other species occurred in less than three vegetation types and had low frequencies (Table 1). We also classified the plant species based on floral symmetry and we observed that plant species with actinomorphic flowers had higher number of species (67 %) than those plants species with zygomorphic (25 %) and asymmetric (8 %) flowers. Asteraceae showed the highest number of actinomorphic species, while Fabaceae, Mimosaceae and Caesalpiniaceae had more zygomorphic and asymmetric flowers species.

Discussion

In this study we recorded 147 plant species, that represent 53.4 % of all families, genera (28.1 %), and species (17.5 %) registered in La Mancha by Castillo-Campos and Travieso-Bello (2006), also this represent 1.85 % of total flora of Veracruz State (Dirzo and Gómez, 1996; Castillo-Campos *et al*., 2011). Inside of Veracruz State the great floristic diversity is distributed in 19 vegetation types (Miranda and Hernández-X., 1963; Castillo-Campos *et al*., 2011). In other areas, like Los Tuxtlas Biosphere Reserve (329,941 ha) have been reported 22 vegetation types, containing 3,356 species and 212 families (Castillo-Campos and Laborde, 2004); in La Sierra Cruz Tetela 569 species were reported that belong to 110 families, which 22 are introduced in crop fields in three vegetation types (Castillo-Campos *et al*., 2003), while at the present study we recorded plant species only in six vegeta-

tion types, inside a very small area (83.29 ha), focusing only at flowering and/or fruiting species, discarding those without reproductive events, thus, our study is a small representation of all the plant diversity at the state scale. Despite this we found nearly half of species recorded in previous studies in the same place that used specific methods for vegetation analyses (Castillo-Campos and Travieso-Bello, 2006).

Other important findings are the nine new species that have not been reported previously in the existent inventories in La Mancha. This is important to be highlighted because new species could be present at these environments, as well as determining if these species are ruderals or potentially become invasive species. On the other hand, species like *Crossopetalum gaumeri*, *Calliandra eriophylla*, and *Lonchocarpus fuscopurpureus* have been registered and accessed as herbarium specimens (XAL-Herbarium), but have not been recorded in floristic studies.

Several studies in Veracruz found that the families with largest number of species were Fabaceae and Asteraceae mainly (Castillo and Moreno-Casasola, 1998; Castillo-Campos *et al*., 2003; Castillo-Campos and Travieso-Bello, 2006; Arroyo-Rodríguez *et al*., 2009), and in other studies the second most represented family was Asteraceae (Castillo and Moreno-Casasola, 1998; Castillo-Campos and Travieso-Bello, 2006; Espinosa-Jiménez *et al*., 2014), similarly, our findings showed this pattern. At the present study a concentration of species richness in few families was found: 27 % of all recorded species were comprised in only three families. This pattern is concordant with other floristic studies, *i.e*. in Los Tuxtlas Biosphere Reserve on 45 rainforest fragments 21 % of all identified plant species, were concentrated within only four families (Arroyo-Rodríguez *et al*., 2009); also in coastal dune systems in central Veracruz, more than half species are represented in a small number of families (16 of 91 families) (Castillo and Moreno-Casasola, 1998).

Considering the species richness in different vegetation types and comparing it with the total of species reported for Veracruz (7,855 species) (Castillo-Campos *et al*., 2011), we found that tropical flood deciduous forest with wetland represent 0.75 % of plant species in the state, while coastal dune vegetation (considering pioneer dune vegetation and dune scrub for this research) represent 0.94 %, and for tropical deciduous forest only 0.52 %. Particularly, for wetlands at La Mancha, Infante-Mata *et al*. (2011) reported 12 species while in present study we found 59 species. On other hand, in contrast with the list of Castillo-Campos and Travieso-Bello (2006), our more-local survey the local representation of this survey; the tropical flood deciduous forest with wetland represent 62.1 % of total plant species, coastal dune vegetation represents 35.1 %, and tropical deciduous forest a 9.51 %. Thus, the floristic survey provided at the present study is truly representative of the sampled vegetation types.

Moreover, Castillo-Campos and Travieso-Bello (2006) found that the floristic communities of La Mancha that share a large number of species and have a higher similarity were the coastal dune vegetation, deciduous forest, and tropical sub-deciduous forest. These results were similar to those observed in our study, since the cluster analysis according to the identity and frequency of each species as well as the analysis of Chao-Jaccard, showed higher similarity between coastal dune scrub, tropical deciduous forest, and pioneer dune vegetation. This pattern was also observed for the analysis of floristic diversity associated with extrafloral nectaries in La Mancha, where the vegetation types with highest similarity values (in number of shared species) were coastal dune scrub and pioneer dune vegetation (Diaz-Castelazo *et al*., 2004). The pattern showed at the present study points out that coastal dune scrub, tropical deciduous forest and pioneer dune vegetation in La Mancha, shared a large number of species and similar frequencies, making them more similar to each other.

In general, another important aspect within plant communities is the diversity of biological forms, that, depending of the vegetation type, are represented by trees, shrubs, vines-lianas, and herbs, and in some cases are considered as functional groups (Ribeiro *et al*., 1999). Frequently, herbs represent the main number of species, followed by shrubs, trees and vines-lianas within plant communities (Dirzo and, Gómez, 1996; Castillo-Campos *et al*., 2003; Castillo-Campos *et al*., 2011), and in some studies shrubs, trees, and vines-lianas can change in the order of importance in which they are represented (Castillo-Campos *et al*., 2003; Castillo-Campos and Laborde, 2004; Ponce-Vargas *et al*., 2006; Espinosa-Jiménez *et al*., 2014). Also this pattern was observed in the plant community of La Mancha (Castillo and Moreno-Casasola, 1998; Castillo-Campos and Travieso-Bello, 2006), and similar to observations in our study, herbs were the most importantly represented and only changing the order of trees and vines-lianas. In addition, our results were consistent with reported in the literature for Asteraceae as a family with most contribution to herbs, while Fabaceae, Mimosaceae, and Caesalpiniaceae have an important contribution to the tree, shrub, and vine-liana biological forms, similarly to reports by Espinosa-Jiménez *et al*., (2014). Herbs also were well represented on all vegetation types in this study followed by shrubs, and trees, while vines-lianas were only well represented for the tropical flood forest with wetland, in accordance to Castillo-Campos and Travieso-Bello (2006). Thus, the more representative plant biological form for La Mancha at the present study was herbs and this biological form was mainly represented by Asteraceae, whereas the trees, shrubs, and vines-lianas were comprised in Fabaceae, Mimosaceae, and Caesalpiniaceae.

The frequency, density and abundance of plant species in different environments involving reproductive events (*i.e*. flowering and fruiting) is not common in floristic studies; this information was also lacking for plant communities in La Mancha, where there are no studies considering these

variables in different plant species. Recently Infante-Mata *et al*. (2011) found (using absolute densities) that *Pachira aquatica*, *Ficus insipida* subsp. *insipida*, and *Annona glabra* are the most common species of trees and the vines-lianas *Dalbergia brownei*, *Hippocratea celastroides*, and *Rhabdadenia biflora* in swamp of La Mancha. Our study reported also *P. aquatica*, *A. glabra,* and *D. brownei* in tropical deciduous flood forest with wetland, however, from our perspective of flowering and fruiting plants, these three species showed very low frequencies. On the other hand, we observed that plant species with high frequency of occurrence (as *Bidens pilosa* and *Crossopetalum uragoga*) occurred in four vegetation types, while, *Commelina erecta*, *Macroptilium atropurpureum*, *Randia aculeata* var. *dasyclada*, and *Florestina pedata* occurred in three vegetation types, in accordance to the information of the existing plant checklist (Castillo-Campos and Travieso-Bello, 2006), because these species occur in the same environments in both studies.

In summary, this is the first study that evaluates the frequency-occurrence of plants flowering or fruiting in six vegetation types simultaneously through one year, comprising dry, rainy, and winter cold-front seasons. The relevance and novelty of our study is that it shows the diversity of plant species in different environments, but more importantly is to show the frequency of each species based on reproductive events. This information can be used in future research evaluating ecological and biological processes at community level or in plant-animal interactions, *i.e*. pollination and seed dispersal.

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