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LISTS OF SPECIES

Angiosperms, Los Tuxtlas Biosphere Reserve, Veracruz, Mexico

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Abstract: The Los Tuxtlas Reserve has been heavily deforested and fragmented since the 1970's. Although the flora of Los Tuxtlas has been described previously, most floristic lists come from the large forest reserve of the Los Tuxtlas field station. Here we present a check list of Angiosperms recorded in 45 rainforest fragments (< 1 to 266 ha) located in three landscapes with different levels of deforestation. We sampled all trees, shrubs, lianas, palms and herbs with diameter at breast height (dbh) Ā 2.5 cm within ten 50 m x 2 m plots per fragment. We recorded 9,435 plants belonging to 73 families and 372 species. Fabaceae, Rubiaceae, and Moraceae were best represented. Eight species are classified as Endangered by the Mexican government, and five are human-introduced species. We conclude that the conservation and restoration of all the remaining rainforest fragments are necessary to effectively preserve the plant diversity of this region.

Introduction

Accelerated deforestation and fragmentation of primary forest in tropical regions (Achard et al. 2002) are threatening global biodiversity at an alarming rate (FAO 2006). These two processes modify the spatial pattern of the remaining forest (e.g. reduced patch area, increased patch isolation, and increased proportion of forest edges; Andrén 1994), potentially affecting ecological processes such as pollination, seed dispersal, recruitment, competition, migration, herbivory and extinction (Turner et al. 1996; Benítez-Malvido 1998; Benítez-Malvido et al. 1999; Cordeiro and Howe 2001; Wright and Duber 2001; Chacoff et al. 2004; Aguirre and Dirzo 2008). As a consequence, habitat fragmentation can not only decrease the number of plant species, but also lead to significant changes in composition and vegetation structure (Turner et al. 1996; Laurance et al. 1998; Hill and Curran 2003; Arroyo-Rodríguez and Mandujano 2006; Chazdon et al. 2007; Santos et al. 2008; Arroyo-Rodríguez et al. 2009; Dirzo et al. 2009).

In Mexico deforestation has led to the loss of approximately 90 % of the tropical rainforest (Flores-Villela and Gerez 1994), particularly affecting the Los Tuxtlas Biosphere Reserve (Dirzo and García 1992; Guevara et al. 2004). This region represents the northern limit of tropical rainforest distribution in the Neotropics (Dirzo and Miranda 1991), and 95 % of the original rainforest here has already disappeared (Castillo-Campos and Laborde 2004; Guevara et al. 2004). While several studies have analyzed the plant communities in this region (e.g. Bongers et al. 1988; Ibarra-Manríquez et al. 1995; 1996a; b; 1997a; b), most were carried out in the large forest reserve (700 ha) of the Los Tuxtlas biological field station of the National Autonomous University of Mexico (UNAM), with little attention being paid to the changes in plant communities that arise from deforestation and forest fragmentation (but see Arroyo-Rodríguez and Mandujano 2006; Arroyo-Rodríguez et al. 2009; Dirzo et al. 2009).

To contribute to the understanding of how the loss and fragmentation of the rainforest affect the vegetation in Los Tuxtlas, and to assess the potential conservation value of forest fragments, we sampled vegetation in 45 rainforest fragments

(< 1 to 266 ha) located in three landscapes with different levels of deforestation (24 %, 11 % and 4 % of remaining forest cover; Arroyo-Rodríguez et al. 2007; 2009). Here we present a species list of all the plants recorded in the study landscapes and suggest some conservation priorities.

Materials and Methods

Study Site

The Los Tuxtlas region is located in the southeast of the state of Veracruz, Mexico (18°8' - 18°45' N, 94°37' - 95°22' W; Figure 1). The climate is warm and humid, with a mean annual temperature of 25 ºC, and annual rainfall between 3,000 and 4,600 mm. This region covers an area of 155,122 ha, with elevation ranging from 0 to 1,780 m above sea level (a.s.l.). Los Tuxtlas was decreed a Biosphere Reserve in 1998 owing to its exceptional biodiversity (CONABIO 2000). The original dominant vegetation type (below 700 m a.s.l.) was tropical rainforest, but the reserve was heavily deforested and fragmented between 1972 and 1993, and the remaining rainforest is surrounded by a matrix of pastures and croplands (Castillo-Campos and Laborde 2004; Guevara et al. 2004; Figure 2).

We selected three landscape fragmentation units (Figure 1) considering that: (1) they represent a gradient of rainforest deforestation; (2) they are all situated between 0 and 400 m a.s.l. (to avoid changes in vegetation associated with altitude; see Castillo-Campos and Laborde 2004); and (3) they each occupy a similar area (ca. 5,000 ha). Elsewhere we have presented a full description of the methods used to digitize the landscapes, and detailed the differences in spatial attributes between landscapes (Arroyo-Rodríguez et al. 2007; 2009). Only a brief overview is given here. The three landscapes have been highly deforested, but there were notable differences in the degree of deforestation. The landscape with the lowest deforestation level (LDL) covered 5,356 ha, 24 % of which was rainforest distributed among 75 patches ranging from 0.5 to 700 ha; the landscape with intermediate deforestation level (IDL) covered 4,965 ha, 11 % of which was rainforest distributed among 88 patches ranging from 0.5 to 76 ha; and the landscape with the highest deforestation level (HDL) covered 5,046 ha, 4 % of which was rainforest distributed among 46 patches ranging from 0.5 to 68 ha.

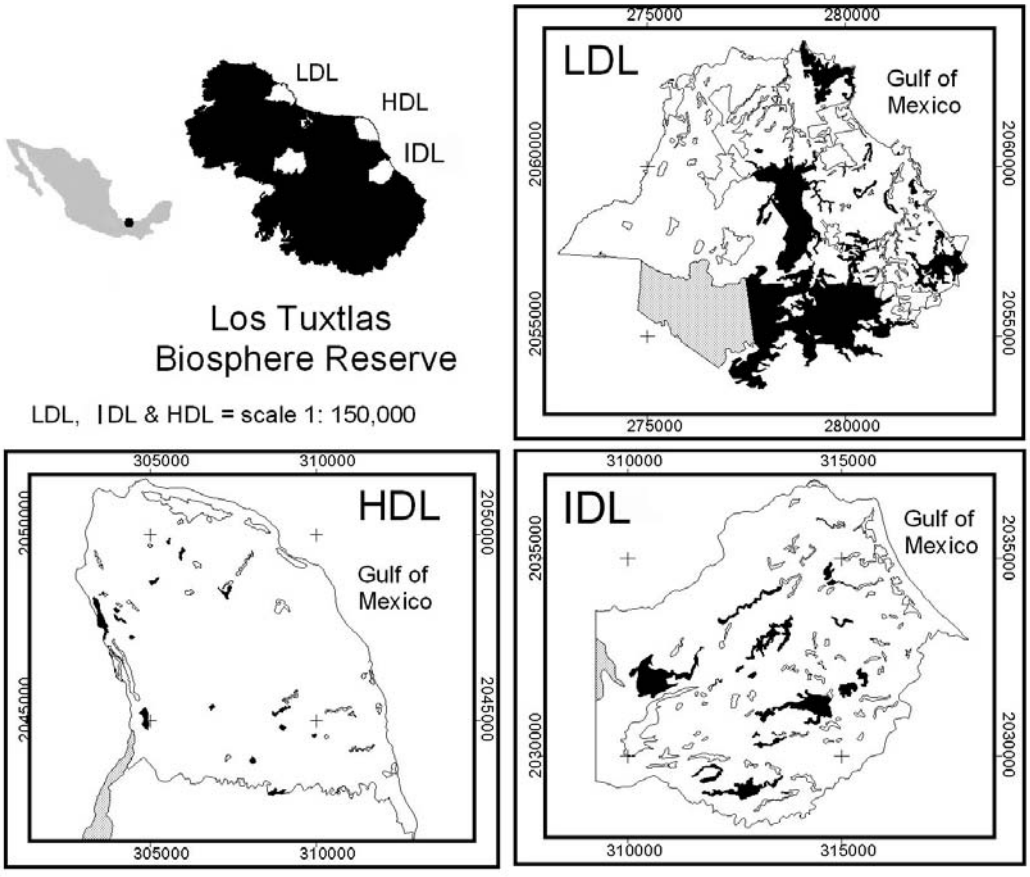

Figure 1. Location of the three landscapes studied in the Los Tuxtlas Biosphere Reserve, southeastern Veracruz, Mexico. Black polygons represent studied patches (LDL, lowest level of deforestation, 24 % of remaining forest cover; IDL, intermediate deforestation level, 11 %; HDL, highest deforestation level, 4 %).

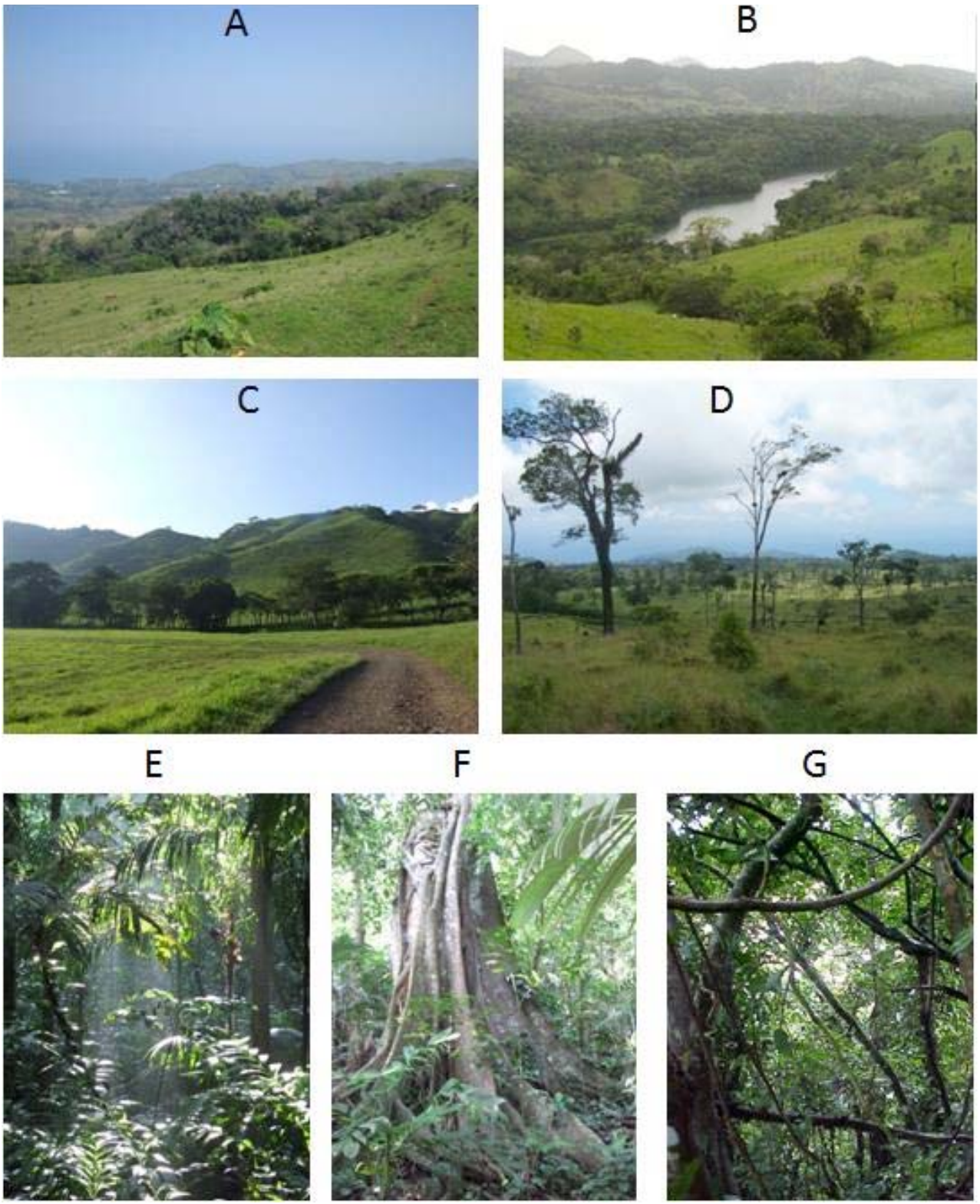

Figure 2. The remaining rainforest fragments in Los Tuxtlas (A-B) are surrounded by a matrix of pastures and croplands, where isolated trees and live fences (i.e. several strands of barbed wire held up by a line of trees) are very common (C-D). Vegetation within forest fragments is highly variable in composition and structure (E-G), with larger fragments dominated by large trees, with a closed canopy (E-F), and smaller fragments dominated by a higher density of smaller trees (G).

Data Collection
Vegetation was sampled in 45 randomly selected rainforest fragments (15 per landscape) using the Gentry (1982) protocol. Within each fragment we randomly located ten 50 m x 2 m plots. All trees, shrubs, lianas, palms and herbs with dbh Ā 2.5 cm were recorded. Lianas were measured at the base, not at dbh (Gentry 1982). Species not identified in the field were collected for identification in the MEXU (Institute of Biology, UNAM, Mexico City) and XAL (Institute of Ecology A.C., Xalapa, Veracruz) herbaria (see further details in Arroyo-Rodríguez and Mandujano 2006; Arroyo-Rodríguez et al. 2007; 2009).

Results and Discussion
In total, we recorded 9,435 plants belonging to 73 families and 372 species (Table 1). We identified 88.4 % (n = 329) of the species and 98.8 % of the stems sampled. Of the 329 identified species, 320 were dicotyledonous and 9 monocotyledonous (i.e. families Arecaceae, Heliconiaceae, and Smilacaceae) (Table 1). The 320 identified dicotyledonous species represent ca. 51 % of the dicotyledonous species reported for the Los Tuxtlas biology field station (627 spp.; Ibarra-Manríquez et al. 1995; 1996a; b), and ca. 17 % of all the plant species (including epiphytes) reported for the Los Tuxtlas Biosphere Reserve (1,873 spp.; Castillo-Campos and Laborde 2004). As two well-known ecological theories predict (island biogeography theory and metapopulation theory: MacArthur and Wilson 1967; Hanski 1999) we found that the number of species was higher in the landscape with lowest deforestation level (LDL = 253 species), than in the other two landscapes (IDL = 160 species; HDL = 180 species) (Table 1).

The families with the highest number of species were Fabaceae (31 species), Rubiaceae (19), and Moraceae (19), together representing 21 % of all the identified species (Table 1). These are also the best represented families in the Los Tuxtlas biological field station (Bongers et al. 1988; Ibarra-Manríquez et al. 1997a). In general, the most common species were *Astrocaryum mexicanum* (Arecaceae), *Siparuna andina* (Monimiaceae), *Croton schiedeanus* (Euphorbiaceae), *Vochysia guatemalensis* (Vochysiaceae) and *Stemmadenia donnell-smithii* (Apocynaceae) (together representing ca. 19 % of all stems) (Table 1). All these species (except *A. mexicanum*) are light-demanding; a functional group that is common in forest gaps and close to forest edges (Benítez-Malvido 1998). As the majority of the study fragments were small (60 % < 5 ha), and therefore, highly affected by edge effects (e.g. increases in light, temperature and wind intensity; Saunders et al. 1991), we expected light-demanding species to be relatively dominant in terms of abundance of stems. However, as we have previously reported, most of the identified species are old-growth forest species (Arroyo-Rodríguez et al. 2009).

Eight of the 372 species sampled (2.2 %) are classified as Endangered by the Mexican government (*Calophyllum brasiliense*, *Chamaedorea alternans*, *Geonoma oxycarpa*, *Mortoniodendron guatemalense*, *Spondias radlkoferi*, *Talauma mexicana*, *Tetrorchidium rotundatum* and *Vatairea lundellii*; SEMARNAT 2002). In the LDL, we found 82 stems of 7 of these species, in the IDL 119 stems of 5 species, and in the HDL only 35 stems of 5 species. Furthermore, of the 148 plant species reported as useful for commerce (i.e. timber, fuelwood, ornamental, artwork, and others) in the Los Tuxtlas rainforest (not including epiphytes; Ibarra-Manríquez et al. 1997b), 113 species (76 %) were sampled in our study fragments (Table 1). These species made up 34 % of all identified species, and 52 % of all identified stems. Of the 249 species identified in the LDL, 95 (38 %) were useful species. Of the 145 species identified in the IDL, 63 (44 %) were useful species, and of the 154 species identified in the HDL, 65 (42 %) were useful species.

Although evidence indicates that fragmentation may favor the invasion of exotic plant species in forest fragments (Turner et al. 1996; Dislich and Pivello 2002), in our sample most of the species (369 species, 99 %) were native to the region, and only five (1 %) were human-introduced species (*Citrus* sp., *Coffea arabica*, *Psidium guajava*, *Theobroma cacao*, and *Manguifera indica*) representing only 0.4 % of the stems sampled (Table 1). This finding is similar to that reported by Dirzo et al. (2009) in the same region, and could be caused by, on the one hand, a relatively short amount of isolation time for the fragments (Turner et al. 1996; Santos et al. 2008), and, on the other hand, the lack of environmental conditions for the natural dispersion, establishment and development of these cultivated species.

In conclusion, our results demonstrate that forest fragments may serve as reservoirs of diverse native plant communities, including endangered

and economically important plant species. In spite of the small size of most of the fragments, in a previous paper we demonstrated that the smallest fragments present a similar species density to the biggest fragments, and also that the species turnover (beta diversity) among fragments and landscapes is very high (Arroyo-Rodríguez et al. 2009). Therefore, and in accordance with Dirzo et al. (2009), we believe that the conservation and restoration of all of the remaining forest fragments is necessary in order to effectively preserve the plant biodiversity in Los Tuxtlas region.

Table 1. Check list of the Angiosperms sampled in 45 rainforest fragments located in Los Tuxtlas, Veracruz, Mexico. Plant nomenclature was used according to the Missouri Botanical Garden nomenclatural update database (Anonymous 2009). The life form (LF) and stem abundances in each fragmented landscape (LDL = lowest deforestation level; IDL = intermediate deforestation level; HDL = highest deforestation level) are also indicated. Species marked with an asterisk (*) are native species reported by Ibarra-Manríquez et al. (1997b) as useful for commerce (i.e. timber, fuel wood, ornamental, artwork, and others).

Family	Species	LF	LDL	IDL	HDL	Total
Actinidiaceae	*Saurauia scabrida* Hemsl.	Tree		19		19
	Saurauia sp.	Tree		22		22
	Saurauia yasicae Loes.	Tree	15	21	7	43
Amaranthaceae	*Iresine arbuscula* Uline et W. L. Bray	Tree	1		1	2
Anacardiaceae	*Mangifera indica* L.	Tree			3	3
	Mosquitoxylum jamaicense Krug and Urb.	Tree		43		43
	Spondias mombin L.*	Tree	3	22	9	34
	Spondias radlkoferi Donn. Sm.*	Tree	33	16	22	71
	Tapirira mexicana Marchand	Tree	2	163	6	171
Annonaceae	*Cymbopetalum baillonii* R. E. Fr.	Tree	41	45	49	135
	Cymbopetalum penduliflorum (Dunal) Baill.	Tree		2		2
	Desmopsis trunciflora var. *glabra* G.E. Schatz	Tree	10			10
	Guamia sp.	Tree	2		20	22
	Guatteria amplifolia Triana and Planch.	Tree			8	8
	Malmea depressa (Baill.) R. E. Fr.	Tree	2			2
	Rollinia mucosa Baill.*	Tree	27	23	95	145
	Tridimeris hahniana Baill.	Tree	1			1
	Xylopia frutescens Aubl.	Tree		4		4
Apocynaceae	*Aspidosperma megalocarpon* Müll. Arg.*	Tree	5			5
	Forsteronia viridescens S. F. Blake	Liana	15			15
	Stemmadenia donnell-smithii (Rose) Woodson	Tree	29	44	178	251
	Stemmadenia galeottiana (A. Rich.) Miers*	Tree	1			1
	Tabernaemontana alba Mill.	Tree	42	20	6	68
	Tabernaemontana arborea Rose	Tree	7	36	38	81
Aquifoliaceae	*Ilex quercetorum* I.M. Johnst.*	Tree	1	13	7	21
	Ilex valerioi Standl.*	Tree	5		11	16
Araliaceae	*Dendropanax arboreus* (L.) Decne. and Planch.*	Tree	53	65	74	192
	Oreopanax obtusifolius L. O. Williams	Tree			6	6
Arecaceae	*Astrocaryum mexicanum* Liebm.*	Palm	216	233	90	539
	Bactris mexicana Mart.	Palm	25	9	16	50
	Chamaedorea alternans H. Wendl.*	Palm	13			13
	Chamaedorea tepejilote Liebm. ex Mart.*	Palm	23	1	41	65
	Desmoncus ferox Bartlett*	Palm	4			4
	Geonoma oxycarpa Mart	Palm	3			3
Aristolochiaceae	*Aristolochia grandifolia* Salisb.	Liana	1			1
	Aristolochia ovalifolia Duch.	Liana			1	1
Asteraceae	*Eupatorium galeotti* B. L. Rob*	Shrub	45	117	14	176
	Eupatorium quadrangulare DC.	Shrub			1	1
	Mikania aromatica Oerst.	Liana	1			1
	Neurolaena lobata (L.) Cass.	Herb	2			2

Family	Species	LF	LDL	IDL	HDL	Total
	Tuxtla pittieri (Greenm.) Villaseñor and Strother	Liana	4			4
	Vernonia deppeana Less.	Shrub			1	1
	Vernonia patens Kunth	Shrub	1			1
Bignoniaceae	*Amphitecna tuxtlensis* A. H. Gentry	Tree	4	8	1	13
	Anemopaegma chrysanthum Dugand	Liana	1			1
	Arrabidaea verrucosa (Standl.) A. H. Gentry	Liana	5			5
	Callichlamys latifolia (Rich.) K. Schum.	Liana	2			2
	Mansoa hymenaea (DC.) A. H. Gentry	Liana	3	25		28
	Mansoa verrucifera (Schltdl.) A. H. Gentry	Liana	2			2
	Paragonia pyramidata (Rich.) Bureau	Liana	6			6
	Stizophyllum riparium (Kunth) Sandwith	Liana	1			1
	Tabebuia rosea (Bertol.) A. DC.*	Tree			3	3
Bombacaceae	*Bernoullia flammea* Oliv.*	Tree			7	7
	Ceiba pentandra (L.) Gaertn.*	Tree	3	1	12	16
	Pachira aquatica Aublet	Tree	9			9
	Quararibea funebris (La Llave) Vischer*	Tree	10			10
	Quararibea yunckeri Standl.	Tree	2			2
Boraginaceae	*Cordia alliodora* (Ruiz and Pav.) Oken*	Tree	17	3	29	49
	Cordia dodecandra DC.	Tree		10		10
	Cordia megalantha S. F. Blake*	Tree	3	4	17	24
	Cordia stellifera I. M. Johnst.*	Tree	5			5
	Cordia stenoclada I. M. Johnst.	Shrub	18		6	24
	Rochefortia lundelli Camp*	Tree	6			6
Burseraceae	*Bursera simaruba* (L.) Sarg.*	Tree	36	62	36	134
Capparaceae	*Capparis baduca* L.	Tree	14			14
	Capparis mollicella Standl.	Tree	3			3
	Crataeva tapia L.	Tree	7			7
Caricaceae	*Carica papaya* L.	Tree	3		3	6
	Jacaratia dolichaula (Donn. Sm.) Woodson	Tree	2			2
Cecropiaceae	*Cecropia obtusifolia* Bertol.*	Tree	50	45	17	112
	Coussapoa purpusii Standl.	Tree	2			2
Celastraceae	*Crossopetalum parviflorum* (Hemsl.) Lundell	Shrub	2			2
	Perrottetia longistylis Rose	Tree	1			1
	Wimmeria bartletti Lundell	Tree	1	6	1	8
Chrysobalanaceae	*Couepia polyandra* (Kunth) Rose*	Tree	1	13		14
	Hirtella triandra (Standl.) Prance*	Tree		71	14	85
Clethraceae	*Clethra macrophylla* M. Martens and Galeotti*	Tree			4	4
Clusiaceae	*Calophyllum brasiliense* var. *rekoi* (Standl.) Standl.*	Tree	5	35	3	43
	Rheedia edulis (Seem.) Planch. and Triana*	Tree	17	50	4	71
	Vismia baccifera (L.) Triana and Planch.	Tree		2		2
Cochlospermaceae	*Cochlospermum vitifolium* (Milld.) Spreng.	Tree		16		16
Combretaceae	*Combretum laxum* Jacq.	Liana	2			2
	Terminalia amazonia (J. F. Gmel) Exell	Tree		45		45
Connaraceae	*Connarus schultesii* Standl.	Liana	4			4
Convolvulaceae	*Ipomoea batatas* (L.) Lam.	Liana	2			2
	Ipomoea philomega (Vell.)House	Liana	3		1	4
Cyclanthaceae	*Carludovica gracilis* Liebm. ex. Matuda	Herb		7	2	9
Dilleniaceae	*Tetracera volubilis* L.	Liana	1	12		13
Ebenaceae	*Diospyros digyna* Jacq.*	Tree	6			6
Elaeocarpaceae	*Sloanea medusula* K. Schum. and Pittier*	Tree		34		34
Erythroxylaceae	*Erythroxylum panamense* Turcz.	Tree	2			2
Euphorbiaceae	*Acalypha diversifolia* Jacq.*	Shrub	21	10	14	45
	Adelia barbinervis Schltdl. and Cham.*	Tree	1			1
	Alchornea latifolia Sw.*	Tree	5	56	16	77

Family	Species	LF	LDL	IDL	HDL	Total
	Cnidoscolus multilobus (Pax) I. M. Johnst.	Shrub	1		2	3
	Croton glabellus L.	Shrub		35	13	48
	Croton pyramidalis Donn. Sm.*	Shrub	34		13	47
	Croton schiedeanus Schltdl.*	Tree	108	150	84	342
	Manihot sp.	Shrub		2		2
	Omphalea oleifera Hemsl.	Tree	46		6	52
	Sapium lateriflorum Hemsl.	Tree			16	16
	Sapium nitidum (Monach.) Lundell	Tree	31	17	18	66
	Tetrorchidium rotundatum Standl.*	Tree	17	17	7	41
Fabaceae	*Acacia cornigera* (L.) Willd.	Tree	28	12	38	78
	Acacia hayesii Benth.	Liana	1			1
	Acacia mayana Lundell	Tree	5			5
	Albizia purpusii Britton and Rose	Tree			13	13
	Albizia tomentosa (Micheli) Standl.	Tree	2		1	3
	Cojoba arborea (L.) Britton and Rose*	Tree	1			1
	Cynometra retusa Britton and Rose*	Tree	4	20		24
	Dalbergia glomerata Hemsl.*	Tree	13			13
	Dialium guianense (Aubl.) Sandwith*	Tree		50	2	52
	Dussia mexicana (Standl.) Harms*	Tree	3	10	2	15
	Erythrina folkersii Krukoff and Moldenke*	Tree	8	1	10	19
	Gliricidia sepium (Jacq.) Kunth ex Walp.	Tree	1			1
	Inga acrocephala Steud.	Tree	4	5	15	24
	Inga paterno Harms*	Tree	8			8
	Inga pavoniana G. Don	Tree	3	7	47	57
	Inga quaternata Poepp.	Tree	2	54	15	71
	Inga semialata (Vell.) Mart.	Tree			10	10
	Inga sinacae M. Sousa and G. Ibarra Manriquez	Tree		9		9
	Lonchocarpus cruentus Lundell*	Tree	17	8	12	37
	Lonchocarpus guatemalensis Benth.*	Tree	18	2	8	28
	Machaerium cobanense Donn. Sm.	Liana	6			6
	Machaerium floribundum Benth	Liana	2	57	4	63
	Ormosia panamensis Benth. ex Seem.*	Tree			2	2
	Ormosia sp.	Tree		8		8
	Pithecellobium hymenaeifolium (Humb. and Bonpl. ex Willd.) Benth.	Tree	3	5		8
	Platymiscium pinnatum (Jacq.) Dugand*	Tree	2		20	22
	Pterocarpus rohrii Vahl*	Tree	25			25
	Senna multijuga (Rich.) H. S. Irwin and Barneby*	Tree	1	1	7	9
	Senna papillosa (Britton and Rose) H. S. Irwin and Barneby	Shrub	3		1	4
	Swartzia guatemalensis (Donn. Sm.) Pittier	Tree	9			9
	Vatairea lundellii (Standl.) Killip ex Record*	Tree	7	27	1	35
Flacourtiaceae	*Casearia* sp.	Tree		15		15
	Casearia sylvestris Sw. subsp. *Sylvestris*	Tree	6	130	14	150
	Lunania mexicana Brandegee*	Shrub	1		174	175
	Pleuranthodendron lindenii (Turcz.) Sleumer*	Tree	42			42
	Xylosma flexuosa (Kunth) Hemsl.	Tree	1			1
	Zuelania guidonia (Sw.) Britton and Millsp.	Tree		1		1
Heliconiaceae	*Heliconia* sp.*	Herb		6		6
	Heliconia uxpanapensis C. Gut. Baez*	Herb	1	14		15
Hernandiaceae	*Sparattanthelium amazonum* Mart.	Liana	2			2
Hippocrataceae	*Hippocratea celastroides* Kunth	Liana			3	3
	Salacia megistophylla Standl.	Liana	6			6
Icacinaceae	*Calatola laevigata* Standl.	Tree	2			2
	Mappia racemosa Jacq.	Tree	2			2
Lacistemaceae	*Lacistema aggregatum* (P. J. Bergius) Rusby	Tree		23	5	28

Family	Species	LF	LDL	IDL	HDL	Total
Lauraceae	*Licaria velutina* van der Werff*	Tree	2			2
	Nectandra ambigens (S. F. Blake) C. K. Allen*	Tree	8	6	16	30
	Nectandra cuspidata Nees	Tree			13	13
	Nectandra hihua Lundell*	Tree	2	1		3
	Nectandra lundellii C. K. Allen*	Tree	20	11		31
	Nectandra reticulata (Ruiz and Pav.) Mez	Tree	1			1
	Nectandra rubriflora (Mez) C. K. Allen	Tree		6	2	8
	Nectandra salicifolia (Kunth) Nees	Tree	18	32	19	69
	Nectandra sp.	Tree	2	3		5
	Ocotea dendrodaphne Mez	Tree	14	43		57
	Ocotea rubriflora Mez.	Tree			18	18
	Ocotea uxpanapana T. Wendt and van der Werff*	Tree	13			13
	Persea americana Mill.	Tree	1		3	4
	Persea schiedeana Nees*	Tree			2	2
Loganiaceae	*Strychnos tabascana* Sprague and Sandwith	Liana	2			2
Magnoliaceae	*Talauma mexicana* (DC.) G. Don*	Tree		24	2	26
Malpighiaceae	*Bunchosia lindeniana* A. Juss.	Tree	4			4
	Byrsonima crassifolia (L.) Kunth	Tree		3	3	6
	Heteropterys laurifolia (L.) A. Juss.	Liana	1			1
	Hiraea fagifolia (DC.) A. Juss.	Liana	2			2
	Mascagnia vacciniifolia Nied.	Liana	1			1
	Stigmaphyllon lindenianum A. Juss.	Liana	1			1
	Tetrapterys glabrifolia (Griseb.) Small	Liana	5			5
Malvaceae	*Hampea nutricia* Fryxell	Tree	40		74	114
	Robinsonella mirandae Gómez Pompa	Tree	19	10	16	45
Marcgraviaceae	*Marcgravia mexicana* Gilg	Liana		5		5
	Ruyschia enervia Lundell	Liana	3			3
Melastomataceae	*Conostegia xalapensis* (Bonpl.) D. Don ex DC.	Shrub	3	3		6
	Miconia argentea (Sw.) DC.	Tree		38	4	42
	Miconia dodecandra Cogn	Tree		1		1
	Miconia fulvostellata L. O. Williams	Shrub		38	2	40
	Miconia glaberrima (Schltdl.) Naudin	Tree		4	10	14
	Miconia sp.	Tree		3		3
	Miconia trinervia (Sw.) D. Don ex Loudon	Tree		47	8	55
Meliaceae	*Cedrela odorata* L.*	Tree	2	6	2	10
	Guarea excelsa Kunth	Tree			9	9
	Guarea glabra Vahl var. *bijuga* (DC.) Pennington*	Tree	18	33		51
	Guarea glabra Vahl var. *glabra* Penn.*	Tree	21	12	3	36
	Guarea grandifolia DC.*	Tree	9	18	38	65
	Guarea sp.	Tree			11	11
	Trichilia breviflora S. F. Blake and Standl.	Tree	25	1	12	38
	Trichilia havanensis Jacq.*	Tree	1			1
	Trichilia martiana C. DC.*	Tree	11			11
	Trichilia moschata Sw.*	Tree	1			1
Menispermaceae	*Abuta panamensis* (Standl.) Krukoff and Barneby	Liana	1		4	5
	Disciphania calocarpa Standl.	Liana	1			1
	Hyperbaena mexicana Miers	Tree	2			2
Monimiaceae	*Mollinedia viridiflora* Tul.	Tree	7			7
	Siparuna andina (Tul.) A. DC.*	Tree	85	260	44	389
Moraceae	*Brosimum alicastrum* Sw.*	Tree	25	23	17	65
	Brosimum lactescens (S. Moore) C. C. Berg	Tree		31		31
	Castilla elastica Sessé ex Cerv.	Tree	4			4
	Clarisia biflora subsp. *mexicana* (Liebm.) W. C. Burger	Tree	2		21	23
	Ficus colubrinae Standl.	Tree	3		3	6

Family	Species	LF	LDL	IDL	HDL	Total
	Ficus eugeniaefolia (Liebm.) Hemsl.	Tree	2		1	3
	Ficus insipida Willd.*	Tree	2			2
	Ficus lundellii Standl.	Tree			3	3
	Ficus pertusa L. f.	Tree	1			1
	Ficus perforata L.	Tree	3	3	2	8
	Ficus petenensis Lundell*	Tree	7	1	4	12
	Ficus rzedowskii Carvajal ex Sosa and Gómez Pompa	Tree			1	1
	Ficus sp.	Tree			2	2
	Ficus tecolutensis (Liebm.) Miq.	Tree	3	6		9
	Ficus trigonata L.	Tree	1			1
	Ficus yoponensis Desv.*	Tree	9	17	7	33
	Poulsenia armata (Miq.) Standl.*	Tree	44	26	36	106
	Pseudolmedia oxyphyllaria Donn. Sm.*	Tree	40	121	38	199
	Trophis mexicana (Liebm) Bureau	Tree	75	9	7	91
Myristicaceae	*Virola guatemalensis* (Hemsl.) Warb.*	Tree	2			2
Myrsinaceae	*Icacorea compressa* (Kunth) Standl.*	Shrub	2			2
	Parathesis conzattii (S. F. Blake) Lundell	Tree			40	40
	Parathesis lenticellata Lundell	Tree	2	20	2	24
	Parathesis psychotrioides Lundell*	Tree	2			2
Myrtaceae	*Calyptranthes chytraculia* var. *americana* McVaugh	Tree		29		29
	Calyptranthes lindeniana O. Berg.	Shrub			1	1
	Eugenia acapulcensis Steud.*	Tree	3		2	5
	Eugenia aeruginea DC.*	Tree	1	72	12	85
	Eugenia capuli (Schltdl. and Cham.) Hook. and Arn.*	Shrub	5	3		8
	Eugenia colipensis O. Berg*	Tree	1			1
	Eugenia inirebensis P. E. Sánchez*	Tree	8			8
	Eugenia mexicana Steud.*	Tree	6	5	1	12
	Eugenia sp.	Tree		23	1	24
	Pimenta dioica (L.) Merr.*	Tree	4	2		6
	Psidium guajava L.	Tree			1	1
	Psidium sartorianum (O. Berg) Nied	Tree		16		16
Nyctaginaceae	*Neea psychotrioides* Donn. Sm.	Tree	6			6
	Pisonia aculeata L. var *aculeata*	Liana	1		14	15
Ochnaceae	*Ouratea tuerckheimii* Donn. Sm.	Shrub	1			1
Passifloraceae	*Passiflora ambigua* Hemsl.*	Liana		4		4
	Passiflora cookii Killip	Liana	1			1
Piperaceae	*Piper aequale* Vahl	Tree	12	1		13
	Piper amalago L.	Tree	8	1	1	10
	Piper auritum Kunth*	Shrub	1		1	2
	Piper hispidum Sw.	Shrub	15		9	24
	Piper sp.	Tree			12	12
	Piper lapathifolium (Kunth) Steud.	Shrub	3			3
	Piper sanctum (Miq.) Schltdl. ex C. DC.	Tree	45	19	48	112
Polygonaceae	*Coccoloba hondurensis* Lundell	Tree	13		6	19
	Coccoloba matudae Lundell*	Tree	4	19	6	29
Rhamnaceae	*Gouania lupuloides* (L.) Urb.	Liana	2			2
Rubiaceae	*Alibertia edulis* (Rich.) A. Rich. ex DC.	Tree		8		8
	Chione mexicana Standl.*	Tree		7		7
	Coffea arabica L.	Shrub	19			19
	Faramea occidentalis (L.) A. Rich.	Tree	24	78	19	121
	Genipa americana L.*	Tree	1			1
	Hamelia longipes Standl.*	Shrub	25		1	26
	Hamelia patens Jacq.	Shrub	1			1
	Posoqueria latifolia (Rudge) Roem. and Schult.	Tree	22			22

Family	Species	LF	LDL	IDL	HDL	Total
	Psychotria acuminata Benth.	Tree			4	4
	Psychotria chiapensis Standl.	Tree	72	1		73
	Psychotria flava Oerst. ex Standl.	Tree	14	2		16
	Psychotria galeottiana (M. Martens) C. M. Taylor and Lorence	Tree		1		1
	Psychotria limonensis K. Krause	Shrub	1	50	60	111
	Psychotria papantlensis (Oerst.) Hemsl.	Shrub	1			1
	Psychotria sarapiquensis Standl.	Tree	1			1
	Psychotria simiarum Standl.	Tree	8			8
	Randia pterocarpa Lorence and Dwyer	Shrub	4			4
	Randia retroflexa Lorence and M. Nee	Liana	1		3	4
	Rondeletia galeottii Standl.*	Shrub	23			23
Rutaceae	*Citrus* sp.	Tree	2		8	10
	Zanthoxylum caribaeum Lam.*	Tree	1		8	9
	Zanthoxylum kellermanii P. Wilson*	Tree	14	6	19	39
	Zanthoxylum procerum Donn. Sm.*	Tree		10	6	16
Sapindaceae	*Allophylus camptostachys* Radlk.*	Tree	4			4
	Cupania belizensis Standl.	Tree	3			3
	Cupania glabra Sw.*	Tree	6	18	67	91
	Matayba apetala Radlk	Tree		1		1
	Matayba oppositifolia (A. Rich.) Britton	Tree		14		14
	Paullinia clavigera Schltdl.	Liana	8			8
	Paullinia costata Schltdl. and Cham.	Liana	2			2
	Paullinia fuscescens Kunth	Liana	1			1
	Paullinia venosa Radlk.	Liana	1			1
	Sapindus saponaria L.*	Tree	2			2
	Serjania goniocarpa Radlk.	Liana	1			1
	Serjania mexicana (L.) Willd.	Liana	1	8		9
	Talisia sp.	Tree		12	6	18
Sapotaceae	*Chrysophyllum mexicanum* Brandegee ex Standl.*	Tree			2	2
	Manilkara zapota (L.) P. Royen*	Tree		8	2	10
	Pouteria campechiana (Kunth) Baehni*	Tree	1	25	3	29
	Pouteria durlandii (Standl.) Baehni*	Tree	19	7		26
	Pouteria reticulata (Engl.) Eyma subsp. *reticulata*	Tree	2	41	1	44
	Pouteria rhynchocarpa T. D. Penn.*	Tree	6			6
	Pouteria sapota (Jacq.) H. E. Moore and Stearn*	Tree	4	13	1	18
	Pouteria unilocularis (Donn. Sm.) Baehni	Tree		8		8
	Sideroxylon persimile (Hemsl.) T. D. Penn.*	Tree	1			1
	Sideroxylon portoricense subsp. *minutiflorum* (Pittier) T. D. Penn*	Tree	8			8
Solanaceae	*Cestrum racemosum* Ruiz and Pav.	Tree	10	2	7	19
	Cyphomandra hartwegii (Miers) Walp.	Tree	2		36	38
	Lycianthes heteroclita (Sendtn.) Bitter	Shrub	2			2
	Lycianthes purpusii (Brandegee) Bitter	Liana	5			5
	Solanum aturense Dunal	Liana	1			1
	Solanum rudepannum Dunal	Shrub			4	4
	Solanum schlechtendalianum Walp	Shrub	1		2	3
Smilacaceae	*Smilax domingensis* Willd.	Liana	1			1
Staphyleaceae	*Turpinia occidentalis* subsp. *breviflora* Croat	Tree	5	9	19	33
Sterculiaceae	*Guazuma ulmifolia* Lam.	Tree		1		1
	Theobroma cacao L.	Tree	5			5
Tiliaceae	*Heliocarpus appendiculatus* Turcz.*	Tree	7	2		9
	Heliocarpus donnellsmithii Rose*	Tree	2	16	1	19
	Luehea sp.	Tree		10		10
	Mortoniodendron guatemalense Standl. et Steyerm.	Tree	4			4
	Trichospermum galeottii (Turcz.) Kosterm.*	Tree	10	30		40

Family	Species	LF	LDL	IDL	HDL	Total
Ulmaceae	*Ampelocera hottlei* (Standl.) Standl.*	Tree	1		3	4
	Celtis iguanaea (Jacq.) Sarg.	Liana	3			3
	Trema micrantha (L.) Blume*	Tree			1	1
Urticaceae	*Myriocarpa longipes* Liebm.*	Shrub	148		60	208
	Urera caracasana (Jacq.) Gaudich. ex Griseb.	Shrub	20			20
	Urera elata (Sw.) Griseb	Shrub	49			49
Verbenaceae	*Aegiphila costaricensis* Moldenke	Tree	7			7
	Aegiphila monstrosa Moldenke	Tree	3			3
	Citharexylum affine D. Don	Tree	3			3
	Citharexylum hexangulare Greenm.	Tree	5			5
	Cornutia pyramidata L	Tree			3	3
Violaceae	*Orthion oblanceolatum* Lundell	Tree	117			117
	Rinorea guatemalensis (S. Watson) Bartlett	Shrub	1	143		144
	Rinorea hummelii Sprague	Shrub	6		39	45
Vitaceae	*Cissus gossypiifolia* Standl.	Liana	2	1		3
	Cissus microcarpa Vahl	Liana	2			2
	Cissus sicyoides L.	Liana			1	1
	Vitis tiliifolia Humb. and Bonpl. ex Roem. and Schult.*	Liana		16		16
Vochysiaceae	*Vochysia guatemalensis* Donn. Sm.	Tree	16	227	56	299
	Total stem density (stems/1.5 ha)		2,854	3,953	2,513	9,320

	Morphospecies	LF	LDL	IDL	HDL	Total
	A1	Tree	3			3
	A2	Tree			5	5
	A3	Tree			1	1
	A4	Tree	1			1
	A5	Tree			1	1
	A6	Tree	1			1
	A7	Tree			3	3
	A8	Tree			1	1
	A9	Tree			1	1
	A10	Tree			1	1
	A11	Tree			2	2
	A12	Tree			1	1
	A13	Tree		1		1
	A14	Tree		4		4
	A15	Tree		1		1
	A16	Tree		1		1
	A17	Tree		1		1
	A18	Tree		14		14
	A19	Tree		5		5
	A20	Tree			1	1
	A21	Tree			1	1
	Ar1	Shrub		6		6
	Ar2	Shrub		2		2
	Ar3	Shrub		1		1
	Ar4	Shrub	2			2
	Ar5	Shrub			2	2
	L1	Liana			1	1
	L2	Liana			1	1
	L3	Liana			1	1
	L4	Liana			1	1
	L5	Liana			4	4
	L6	Liana			1	1

Morphospecies	LF	LDL	IDL	HDL	Total
L7	Liana			3	3
L8	Liana			1	1
L9	Liana			1	1
L10	Liana			1	1
L11	Liana		2		2
L12	Liana			1	1
L13	Liana		7		7
L14	Liana		8	3	11
L15	Liana		1	1	2
L16	Liana		13		13
L17	Liana			1	1
Stem density of morphospecies (stems/1.5 ha)		7	67	41	115
Total stem density (stems/1.5 ha)		2,861	4,020	2,554	9,435
Number of species (species/1.5 ha)		253	160	180	374

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Literature Cited

Achard, F., H.D. Eva, H.J. Stibig, P. Mayaux, J. Gallego, T. Richards, and J.P. Malingreau. 2002. Determination of deforestation rates of the world's humid tropical forest. Science 297: 999-1002.

Aguirre, A. and R. Dirzo. 2008. Effects of fragmentation on pollinator abundance and fruit set of an abundant understory palm in a Mexican tropical forest. Biological Conservation 141: 375-384.

Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportion of suitable habitat: a review. Oikos 71: 340-346.

Anonymous. 2009. Electronic Database accessible at http://mobot.org/W3T/search/vast.html. Missouri Botanical Garden, St. Louis, Missouri. Captured on November 2008.

Arroyo-Rodríguez, V., A. Aguirre, J. Benítez-Malvido, and S. Mandujano. 2007. Impact of rain forest fragmentation on a structurally important palm species: *Astrocaryum mexicanum* Liebm. at Los Tuxtlas, Mexico. Biological Conservation 138: 198-206.

Arroyo-Rodríguez, V. and S. Mandujano. 2006. The importance of tropical rain forest fragments to the conservation of plant species diversity in Los Tuxtlas, Mexico. Biodiversity and Conservation 15: 4159-4179.

Arroyo-Rodríguez, V., E. Pineda, F. Escobar, and J. Benítez-Malvido. 2009. Value of small patches in the conservation of plant-species diversity in highly fragmented rainforest. Conservation Biology 23: 729-739.

Benítez-Malvido, J. 1998. Impact of forest fragmentation on seedling abundance in a tropical rain forest. Conservation Biology 2: 380-389.

Benítez-Malvido, J., G. García-Guzman, and I.D. Kossmann-Ferraz. 1999. Leaf-fungal incidence and herbivory on tree seedlings in tropical rainforest fragments: an experimental study. Biological Conservation 91: 143-150.

Bongers, F., J. Popma, J. Meave and J. Carabias. 1988. Structure and floristic composition of the lowland rain forest of Los Tuxtlas, Mexico. Vegetatio 74: 55-88.

Castillo-Campos, G. and J. Laborde. 2004. La vegetación; p. 231-265 *In* S. Guevara, J. Laborde, and G. Sánchez-Ríos (ed.). Los Tuxtlas. El paisaje de la sierra. Mexico city: Instituto de Ecología A. C. and European Union.

Chacoff, N.P., J.M. Morales and M.P. Vaquera. 2004. Efectos de la fragmentación sobre la aborción y depredación de semillas en el Chaco Serrano. Biotropica 36: 109-117.

Chazdon, R.L, S.G. Letcher, M. van Breugel, M. Martínez-Ramos, F. Bongers, and B. Finegan. 2007. Rates of change in tree communities of secondary Neotropical forests following major disturbances. Philosophical Transactions of the Royal Society B. 362: 273-289.

CONABIO (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad). 2000. Regiones terrestres prioritarias para la conservación. Mexico city: CONABIO. 609 p.

Cordeiro, N.F. and H.F. Howe. 2001. Low recruitment

of trees dispersed by animals in African forest fragments. Conservation Biology 15: 1733-1741.

Dirzo, R., A. Aguirre, and J.C. López. 2009. Diversidad florística de las selvas húmedas en paisajes antropizados. Investigación ambiental 1: 17-22.

Dirzo, R. and A. Miranda. 1991. El límite boreal de la selva tropical húmeda en el Continente Americano: contracción de la vegetación y solución de una controversia. Interciencia 16: 240-247.

Dirzo, R. and M.C. García. 1992. Rates of deforestation in Los Tuxtlas, a neotropical area in Southeast Mexico. Conservation Biology 6: 84-90.

Dislich, R. and V.R. Pivello. 2002. Tree structure and species composition changes in an urban tropical forest fragment (Saõ Paulo, Brasil) during a five-year interval. Boletim de Botânica da Universidade de São Paulo 20: 1-11.

Flores-Villela, O. and P. Gerez. 1994. Biodiversidad y conservación en México: vertebrados, vegetación y uso del suelo. Mexico city: Ediciones Técnico Científicas SA de CV. 250 p.

FAO (Food and Agriculture Organization of the United Nations). 2006. Global Forest Resources Assessment. Rome: FAO. Forestry Department.

Gentry, A.H. 1982. Patterns of Neotropical plant species diversity. Evolutionary Biology 15: 1-85.

Guevara, S., J. Laborde and G. Sánchez-Ríos. 2004. Los Tuxtlas. El paisaje de la sierra. Mexico city: Instituto de Ecología A. C. and European Union. 287 p.

Hanski, I. 1999. Metapopulation ecology. Oxford: Oxford University Press. 313 p.

Hill, J.L. and P.J. Curran. 2003. Area, shape and isolation of tropical forest fragments: effects on tree species diversity and implications for conservation. Journal of Biogeography 30: 1391-1403.

Ibarra-Manríquez, G. and S. Sinaca-Colín. 1995. Lista florística comentada de la Estación de Biología Tropical "Los Tuxtlas", Veracruz, México. Revista de Biología Tropical 43: 75-115.

Ibarra-Manríquez, G. and S. Sinaca-Colín. 1996a. Estación de Biología Tropical "Los Tuxtlas", Veracruz, México: lista florística comentada (Mimosaceae a Verbenaceae). Revista de Biología Tropical 44: 41-60.

Ibarra-Manríquez, G. and S. Sinaca-Colín. 1996b. Lista florística comentada de plantas de la Estación de Biología Tropical "Los Tuxtlas", Veracruz, México: (Violaceae-Zingiberaceae). Revista de Biología Tropical 44: 427-447.

Ibarra-Manríquez, G., M. Martínez-Ramos, R. Dirzo, and J. Núñez-Farfán. 1997a. La vegetación; p. 61-85 *In* E. González-Soriano, R. Dirzo, and R.C. (ed.). Historia Natural de Los Tuxtlas. Mexico city: UNAM.

Ibarra-Manríquez, G., M. Ricker, G. Angeles, S. Sinaca-Colín, and M.A. Sinaca-Colín. 1997b. Useful plants of the Los Tuxtlas rain forest (Veracruz, Mexico): considerations of their market potential. Economic Botany 51: 362-376.

Laurance, W.F., L.V. Ferreira, J.M. Rankin-de Merona, and S.G. Laurance. 1998. Rain forest fragmentation and the dynamics of Amazonian tree communities. Ecology 79: 2032-2040.

MacArthur, R.H. and E.O. Wilson. 1967. The theory of island biogeography. Princeton: Princeton University Press. 203 p.

Santos, B.A., C.A. Peres, M.A. Oliveira, A. Grillo, C. P. Alves-Costa, and M. Tabarelli. 2008. Drastic erosion in functional attributes of tree assemblages in Atlantic forest fragments of northeastern Brazil. Biological Conservation 141: 249-260.

Saunders, D.A., R.J. Hobbs, and C.R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5: 18-32.

SEMARNAT (Secretaria del Medio Ambiente y Recursos Naturales). 2002. Norma oficial Mexicana NOM-059-SEMARNAT-2001, lista de especies en riesgo. Diario Oficial de la Federación. Mexico city: SEMARNAT.

Turner, I.M., K.S. Chua, J.S. Ong, B.C. Soong, and H.T.W. Tan. 1996. A century of plant species loss from an isolated fragment of lowland tropical rain forest. Conservation Biology 10: 1229-1244.

Wright, S.J. and H.C. Duber. 2001. Poachers and forest fragmentation alter seed dispersal, seed survival, and seedling recruitment in the palm *Attalea butyracea*, with implications for tropical tree diversity. Biotropica 33: 583-595.

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