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) ≥ 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; Benitez-Malvido 1998; Benitez-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 °C, 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](image_url). 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 ≥ 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-Rodriguez and Mandujano 2006; Arroyo-Rodriguez 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; H anski 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 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 species.
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   | 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  | 17    |
|                  | 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   | 1     |
|                  | Xylopia frutescens Aubl.              | Tree | 4   |     | 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   | 1     |
|                  | Tabernaemontana alba Mill.            | Tree | 42  | 20  | 6   | 78    |
|                  | 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   | 1     |
|                  | Aristolochia ovalifolia Duch.         | Liana| 1   |     | 1   | 1     |
| Asteraceae       | Eupatorium galeottii B. L. Rob*       | Shrub| 45  | 117 | 14  | 176   |
|                  | Eupatorium quadrangular DC.           | Shrub| 1   |     | 1   | 1     |
|                  | Mikania aromatica Oerst.              | Liana| 1   |     | 1   | 1     |
|                  | Neurolaena lobata (L.) Cass.          | Herb | 2   |     | 2   | 2     |

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| Family               | Species                                      | LF  | LDL | IDL | HDL | Total |
|---------------------|----------------------------------------------|-----|-----|-----|-----|-------|
| Tuxtla pittieri      | (Greenm.) Villaseñor and Strother            |     |     |     |     |       |
| Vernonio deppeana   | Less.                                         |     |     |     |     |       |
| Vernonio patens     | Kunth                                         |     |     |     |     |       |
| Bignoniaceae        | Amphitecna tuxtlensis A. H. Gentry           | Tree| 4   | 8   | 1   | 13    |
| Anemopaegna         | chrysanthum Dugand                           | Liana| 1   |     |     | 1     |
| Arrabidae 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  | (Schldl.) A. H. Gentry                      | Liana| 2   |     |     | 2     |
| Paragonia pyramidata| (Rich.) Bureau                                | Liana| 6   |     |     | 6     |
| Sitzophyllum        | riparium (Kunth) Sandwith                    | Liana| 1   |     |     | 1     |
| Tabebuia rosea      | (Bertol.) A. DC. *                          | Tree| 3   |     |     | 3     |
| Bignonaceae         | Bernouillia flammea Oliv.*                   | Tree| 7   |     |     | 7     |
| Cetba pentandra     | (L.) Gaertn.*                                | Tree| 3   | 1   | 12  | 16    |
| Pachira aquatica    | Aublet                                       | Tree| 9   |     |     | 9     |
| Quararibia funebris | (La Llave) Vischer*                          | Tree| 10  |     |     | 10    |
| Quararibia yuncker  | 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 lundell| 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     |
| Caricaceae          | Carica papaya L.                             | Tree| 7   |     |     | 7     |
| Caricae             | Carica tapia L.                              | Tree| 3   | 3   | 6    |       |
| Capparaceae         | Carica dodecandra DC.                        | Tree| 10  |     |     | 10    |
| Cecropiaceae        | Cecropia obtusifolia Bertol.*                | Tree| 50  | 45  | 17  | 112   |
| Coussapoa purpussi  | Standl.                                      | Tree| 2   |     |     | 2     |
| Celastraceae        | Crossopetalum parvisflorum (Hemsl.) Lundell  | Shrub| 2   |     |     | 2     |
| Perrottetia longisty| is 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.)| Tree| 5   | 35  | 3   | 43    |
| Rheedia edulis      | (Seem.) Planch. and Triana*                 | Tree| 17  | 50  | 4   | 71    |
| Visnia 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         | Connarans schulensis 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        | Tetragyna 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  | Schldl. and Cham.*                           | Tree| 1   |     |     | 1     |
| Alchornea latifolia | Sw.*                                        | Tree| 5   | 56  | 16  | 77    |
## Lists of Species

| 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* Schltld.*                      | 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 |
|                            | *Tetrarchidium rotundatum* Standl.*                | Tree | 17 | 17 | 7  | 41 |
| Fabaceae                   | *Acacia cornigera* (L.) Willd.                     | Tree | 28 | 12 | 38 | 78 |
|                            | *Acacia hayesii* Bentham.                          | Liana | 1 | 1  |     |       |
|                            | *Acacia mayana* Lundell                            | Tree | 5  | 5  |     |       |
|                            | *Albizia purpurii* Britton and Rose                | Tree | 13 | 13 |     |       |
|                            | *Albizia tomentosa* (Micheli) Standl.              | Tree | 2  | 1  | 3  |       |
|                            | *Cajoboa arborea* (L.) Britton and Rose*           | Tree | 1  |     | 1  |       |
|                            | *Cynometra retusa* Britton and Rose*               | Tree | 4  | 1  | 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 |
|                            | *Gliciridia 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. Ibara 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 uexpanapensis* C. Gut. Baez*            | Herb | 1  | 14 | 15 |       |
| Hernandiaceae             | *Sparanthanthelium amazonum* Mart.                 | Liana | 2 |     | 2  |       |
| Hippocrataceae            | *Hippocratea celastroides* Kunth                   | Liana | 3 |     | 3  |       |
| Icacinaceae               | *Calatola laevigata* Standl.                       | Tree | 2  |     | 2  |       |
|                            | *Mappia racemosa* Jacq.                            | Tree | 2  |     | 2  |       |
| Lacistemaceae             | *Lacistema aggregatum* (P. J. Bergius) Rusby       | Tree | 23 | 5  | 28 |       |

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### Lists of Species

| Family       | Species                        | LF | LDL | IDL | HDL | Total |
|--------------|--------------------------------|----|-----|-----|-----|-------|
| Lauraceae    | *Licaria velutina* van der Werff* |    |     |     |     |       |
|              | *Nectandra ambigens* (S. F. Blake) C. K. Allen* | Tree | 8   | 6   | 16  | 30    |
|              | *Nectandra cuspidata* Nees      | Tree |     |     |     | 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 uspanapanoa* T. Wendt and van der Werff* | Tree | 13  |     |     | 13    |
|              | *Persea americana* Mill.        | Tree | 1   |     |     | 3     |
|              | *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| *Bunchiosia 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 vaccinifolia* Nied.  | Liana | 1   |     |     | 1     |
|              | *Stigmaphyllon lindenianum* A. Juss. | Liana | 1   |     |     | 1     |
|              | *Tetrapteryx 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   |     | 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* Jaq.*    | 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     |
| 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     |

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| Family             | Species                                              | LF | LDL | IDL | HDL | Total |
|--------------------|------------------------------------------------------|----|-----|-----|-----|-------|
| Myristicaceae      | *Ficus eugeniaefolia* (Liebm.) Hemsl.                | Tree | 2   | 1   | 3   |       |
|                    | *Ficus insipida* Willd.*                              | Tree | 2   |     |     |       |
|                    | *Ficus lundellii* Standl.                             | Tree | 3   |     |     |       |
|                    | *Ficus pertusa* L. f.                                 | Tree | 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   |     |     |       |
| Myrtaceae          | *Ficus tecolutensis* (Liebm.) Miq.                   | Tree | 3   | 6   | 9   |       |
|                    | *Ficus trigonata* L.                                  | Tree | 1   |     |     |       |
|                    | *Ficus yoponensis* Desv.*                             | Tree | 9   | 17  | 7   | 33    |
|                    | *Poulsenia armata* (Miq.) Standl.*                   | Tree | 44  | 26  | 36  | 106   |
|                    | *Pseudolmedia oxyphylaria* Donn. Sm.*                | Tree | 40  | 121 | 38  | 199   |
|                    | *Trophis mexicana* (Liebm.) Bureau                    | Tree | 75  | 9   | 7   | 91    |
| Myrsinaceae        | *Virola guatemalensis* (Hemsl.) Warb.*               | Tree | 2   |     |     |       |
| Myrtaceae          | *Icacorea compressa* (Kunth) Standl.*                | Shrub | 2 |     |     |       |
|                    | *Parathesis conzattii* (S. F. Blake) Lundell          | Tree | 40  |     |     | 40    |
|                    | *Parathesis lentiscella* Lundell                     | Tree | 2   | 20  | 2   | 24    |
|                    | *Parathesis psychotrioides* Lundell*                 | Tree | 2   |     |     |       |
| Myrtaceae          | *Calyxanthus chryaculensis var. americana* McVaugh   | Tree | 29  |     |     | 29    |
|                    | *Calyxanthus lindeniana* O. Berg.                    | Shrub | 1 |     |     | 1     |
|                    | *Eugenia acapulcensis* Steud.*                       | Tree | 3   | 2   |     | 5     |
|                    | *Eugenia aeruginea* DC.*                             | Tree | 1   | 72  | 12  | 85    |
|                    | *Eugenia capuli* (Schldlt. 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    |
|                    | *Psidium guajava* L.                                 | Tree | 4   | 2   |     | 6     |
|                    | *Psidium sartorianum* (O. Berg) Nied                 | Tree | 16  |     |     | 16    |
| Nyctaginaceae      | *Neea psychotrioides* Donn. Sm.                      | Tree | 6   |     |     | 6     |
| Passifloraceae     | *Passiflora ambigua* Hemsli.*                        | 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 |     |     | 2     |
|                    | *Piper hispidum* Sw.                                 | Shrub | 15 | 9   |     | 24    |
|                    | *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  |     | 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 patiens* Jacq.                              | Shrub | 1  |     |     | 1     |
|                    | *Posoqueria latifolia* (Rudge) Roem. and Schult.     | Tree | 22  |     |     | 22    |
### Lists of Species

| Family | Species | LF | LDL | IDL | HDL | Total |
|--------|---------|----|-----|-----|-----|-------|
|        | *Psychotria acuminata* Benth. | Tree | 4   | 4   |     | 8     |
|        | *Psychotria chiapensis* Standl. | Tree | 72  | 1   | 73  |       |
|        | *Psychotria flavula* 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 papatantensis* (Oerst.) Hems. | Shrub | 1   |     |     | 1     |
|        | *Psychotria sarapiquensis* Standl. | Tree | 1   |     | 1   |       |
|        | *Psychotria simiarium* 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    |
|        | *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  |       |
|        | *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  |       |
|        | *Paulinia clavigera* Schltdl. | Liana | 8   |     | 8   |       |
|        | *Paulinia costata* Schltdl. and Cham. | Liana | 2   |     | 2   |       |
|        | *Paulinia fuscescens* Kunth | Liana | 1   |     | 1   |       |
|        | *Paulinia 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  |       |
|        | *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 durandii* (Standl.) Baehni* | Tree | 19  | 7   | 26  |       |
|        | *Pouteria reticulata* (Engl.) Eyma subsp. reticulata | Tree | 2   | 41  | 1   | 44    |
|        | *Pouteria rhyynchocarpa* 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* (Hems.) T. D. Penn.* | Tree | 1   |     | 1   |       |
|        | *Sideroxylon portoricense* subsp. minutiflorum (Pittier) T. D. Penn* | Tree | 8   |     | 8   |       |
|        | *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 purpuriae* (Brandegee) Bitter | Liana | 5   |     | 5   |       |
|        | *Solanoa aturense* Dunal | Liana | 1   |     | 1   |       |
|        | *Solanoa rudepannum* Dunal | Shrub | 4   |     | 4   |       |
|        | *Solanum schlechtendalianum* Walp | Shrub | 1   | 2   | 3   |       |
|        | *Smilax domingensis* Willd. | Liana | 1   |     | 1   |       |
|        | *Turpinius occidentalis* subsp. breviflora Croat | Tree | 5   | 9   | 19  | 33    |
|        | *Sterculia* sp. | Tree | 5   |     | 5   |       |
|        | *Theobroma cacao* L. | Tree | 5   |     | 5   |       |
|        | *Heliocarpus appendiculatus* Turecz.* | Tree | 7   | 2   |     | 9     |
|        | *Heliocarpus donnellsmithii* Rose* | Tree | 2   | 16  | 1   | 19    |
|        | *Luehea* sp. | Tree | 10  |     | 10  |       |
|        | *Mortoniiodendron guatemalense* Standl. et Steyerm. | Tree | 4   |     | 4   |       |
|        | *Trichospermum galeottii* (Turecz.) Kosterm.* | Tree | 10  | 30  | 40  |       |

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### Lists of Species

| 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 | 3   |     | 3   |       |
|              | *Cornutia pyramidata* L.                     | Tree | 3   |     | 3   |       |
| Violaceae    | *Orthion oblongifolium* Lundell              | Tree | 117 |     | 117 |       |
|              | *Rinorea guatemalensis* (S. Watson) Bartlett | Shrub | 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   |       |

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# Lists of Species

## Check List

| 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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**Acknowledgements:** The Department of Biodiversity and Animal Ecology at the Institute of Ecology (INECOL, A.C.) and the Secretary of Public Education (SEP) in Mexico provided financial support to VAR, and Fundación BBVA provided financial support to JD. We thank B. Gómez, L. Mendoza, R. Mateo-Gutierrez and their families for their hospitality and invaluable help. M. Peredo-Nava (XAL herbarium) and G. Castillo-Campos provided valuable information for the identification of plant species. We also thank C. Scareli-Santos and an anonymous reviewer for their comments on the final version of this paper.

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