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Patterns of diversity, endemism and conservation: an example with Mexican species of Ternstroemiaceae Mirb. ex DC. (Tricolpates: Ericales)

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Abstract. The Ternstroemiaceae is a family of vascular plants with many taxonomic problems, basically in the delimitation of some of its species. Little is known about its world distribution and about the real state of conservation of its species. An analysis of the distribution patterns of the Mexican species was undertaken to provide information about the present status of species and possible conservation areas. Also, an analysis of the species richness, endemism centres, extension and location of the areas occupied by these species with a 1:50 000 chart index was made. Finally, we propose some of the species of this family to be included in the IUCN Red List of Threatened Species and in the next Mexican 'Norma Oficial Mexicana 059'.

Introduction

Nearly half of the world vascular plant species are highly restricted, and the areas where they occur have been drastically impoverished in the last decades. As a result of this, many of them are considered as threatened and many will become extinct in the mediate future. Brooks et al. (2002) considered that many megadiverse areas, like Mesoamerica (comprising southern Mexico, particularly the states of Campeche, Chiapas, Guerrero, Michoacán, Oaxaca, Quintana Roo, Tabasco, Veracruz, and Yucatán) will lose most of their species in the near future. In past decades, an emphasis on locating centres of endemism and species richness has been renewed to propose conservation strategies (Linder 2001).

As Peterson et al. (2000) noted, the Mexican system of natural protected areas is an old one and was developed considering different motives, like scenic beauty, recreational use, and historical importance, among others, so many areas important for biodiversity conservation are not included. More recently in Mexico, selection of protected natural areas has been based on the presence or absence of organisms with biological meaning, that is, some species that are included in some risk category in the Mexican official publication named 'Norma Oficial Mexicana 059' ('NOM-059', Secretaría del Medio Ambiente y Recursos Naturales 2002). Notwithstanding, selection of the species for inclusion in the NOM has been subjective, because this selection is essentially undertaken through a risk evaluation method (MER), that is the main criterion used, which is based in a subjective measure of the geographic range of these taxa in Mexico, considering four categories: (1) very restricted (distribution less than 5% of the Mexican territory); (2) restricted (between 5 and 15% of the Mexican territory); (3) less restricted or broad distribution (more than 15%, but less than 40% of the Mexican territory); and (4) broadest distribution to very broad (more than 40% of the Mexican territory) (Secretaría del Medio Ambiente y Recursos Naturales 2002). In many cases, little is known about the accurate size of the distribution areas of these species. This geographic range represents one of the four points considered by the MER, along with the habitat status with respect to the natural development of the taxon, the biological vulnerability intrinsic to the taxon, and impact of the human activity on the taxon.

A more objective way to determine the size of the geographic range of the species may be to use a standard and minimal area unit that is easily recognisable; in our case, we thought that a better option was to use the chart index on a scale 1:50,000 formulated by the inventory of geographic information by the 'Instituto Nacional de Estadística, Geografía e Informática' (INEGI 1992). This index makes reference to published maps on a scale 1:50,000, a system based on 2313 grids of $15' \times 20'$ (at a spatial resolution of approximately 27.75 km $\times$ 36.75 km), and shows real sections of the Mexican territory, so the circumscription of the areas with greater species richness and/or that contain certain species or taxa with biological meaning, is easily located for the country and can be easily and objectively quantificated (Figure 1).

Species of the Ternstroemiaceae (Tricolpates: Ericales *sensu* Judd et al. 2002) are shrubs or trees of small to large size, with a wide distribution in the tropics and subtropics; some of the genera exclusively inhabit eastern Asia (*Adinandra*, *Anneslea*, *Archboldiodendron*, *Eurya*, *Euryodendron*), Africa (*Balthasaria* and *Visnea*), America (*Freziera* and *Symplococarpon*), or two (*Cleyera*) or more continents. *Ternstroemia* has the widest distribution range (Asia, Africa, America and Australia). In the Neotropics many of the species are found, mostly in northern South America. They are frequent in temperate montane conditions, mainly in cloud forests and humid oak forests, especially at 1000–2700 m. The disjunct distribution of some genera is of special interest in historical biogeography; notwithstanding, some genera are highly restricted to some areas of the world (Luna and Contreras-Medina 2000). The two former authors have been working in the systematics, chemistry, and embryology of Mexican Ternstroemiaceae since long ago, and our researches are based on the examination of a large amount of Mexican and Central American specimens. As a result of our interest in the family, we have been contributing with the treatment of this taxon in local floras, that is, Flora de Guerrero (Luna and Alcántara 2002) and Flora de Veracruz (in preparation).

Traditionally, Ternstroemiaceae have been included in the Theaceae Mirb., but by morphological (Luna 1997), molecular (Soltis et al. 2000; Prince and Parks 2001; Anderberg et al. 2002; Judd et al. 2002, among others), and embryological evidence (Tsou 1995, 1997), they are considered not to conform to a monophyletic group. Only four genera are found in Mexico: *Cleyera*, *Freziera*, *Symplococarpon*, and *Ternstroemia*, including approximately 15 species (Table 1), with many

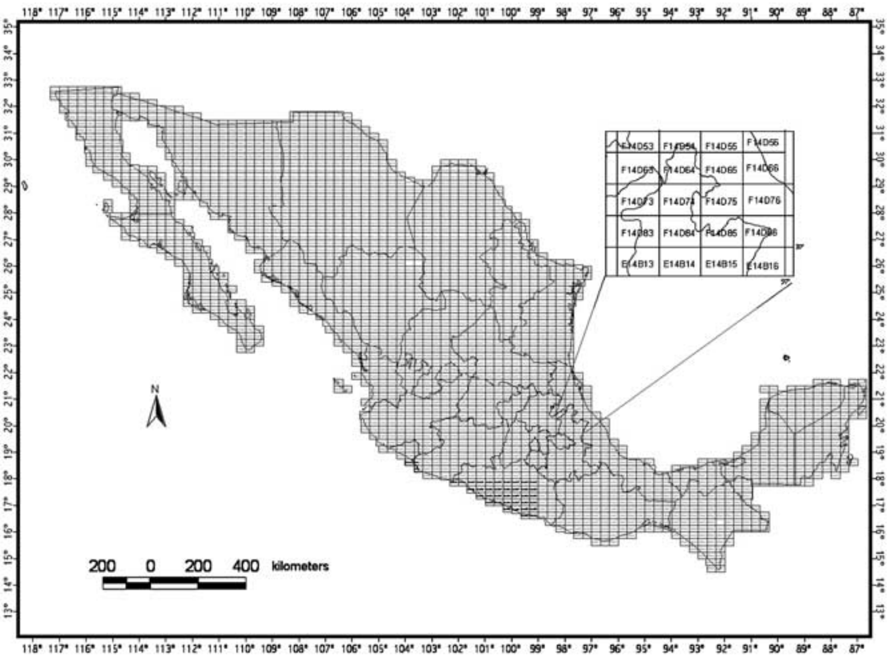

Figure 1. Units of analysis used in this work.

Table 1. Genera and species of Ternstroemiaceae that inhabit Mexico.

Genera	Species	Distribution range
Cleyera Thunb.	*Cleyera cernua* (Tul.) Kobuski	Mexico
	C. integrifolia (Benth.) Choisy	Mexico
	C. theaeoides (Sw.) Choisy	Mexico to Panama
	C. velutina B.M. Barthol.	Mexico
Freziera Willd.	*Freziera candicans* Tul.	Mexico to northern South America
	F. guatemalensis (Donn. Sm.) Kobuski	Mexico to Honduras
Symplococarpon Airy Shaw	*Symplococarpon purpusii* (Brandegee) Kobuski	Mexico to Colombia
Ternstroemia Mutis ex L.f.	*Ternstroemia dentisepala* B.M. Barthol.	Mexico
	T. huasteca B.M. Barthol.	Mexico
	T. lineata ssp. *chalicophila* (Loes.) B.M. Barthol.	Mexico, Honduras
	T. lineata DC. ssp. *lineata*	Mexico
	T. oocarpa (Rose) Melch.	Mexico
	T. seemannii Triana et Planch.*	Mexico to Panama
	T. sylvatica Schltdl. et Cham.	Mexico
	T. tepezapote Schltdl. et Cham.	Mexico to Panama

T. seemannii is possibly a synonym of *T. tepezapote*, as Pool (2001) has suggested recently.

taxonomic problems, mainly in the delimitation of its species, especially in *Ternstroemia*. For this family of vascular plants, as many in Mexico and the world, there are problems with the identification of its taxa and consequently there is a total lack of knowledge about the distribution range of its species, so its conservation status has been ignored by the official world and Mexican conservancy agencies. Only one Mexican species, *Cleyera cernua*, has been considered as a threatened species by the world conservation monitoring centre, particularly by Weitzman, and has been included in the IUCN Red List of Threatened Species (IUCN 2002), in the category and criteria data deficient (DD), which suggests that more fieldwork is necessary to confirm the distribution of this rare species.

The insular and fragmented distribution of some genera and species of Ternstroemiaceae deserves special attention in historical biogeography, because there are congruent distributional areas of other monophyletic plant and animal taxa inhabiting the same geographic region, allowing us to identify areas of endemism (Harold and Mooi 1994). An area of endemism is recognised from the overlap of the areas of distribution of two or more endemic taxa (Espinosa and Llorente 1993); these areas represent the basis for studies in vicariance biogeography. Endemic taxa are those restricted to a specific area, so they represent the exclusive and intrinsic biodiversity of a region; since the endemism areas contain taxa that are not represented anywhere else, these sites can be considered as irreplaceable and with a high priority for conservation (Cavieres et al. 2002).

The goal of this work is to determine the Mexican areas with greater species richness in the Ternstroemiaceae and to evaluate and locate the centres of endemism of the group, and with this information, to propose some areas for conservation of Mexican species. This family of flowering plants is suitable for our work, because many of its elements inhabit the Mexican temperate and humid forests, so in many cases they have a vicarious distribution in the different patches of cloud forests. Notwithstanding, some of the species (i.e., *Cleyera cernua* and *Ternstroemia dentisepala*) are presumably highly restricted to specific localities in Mexico.

Methods

Distributional data of Ternstroemiaceae genera and Mexican species were obtained from collections from the following herbaria: Instituto de Biología, Universidad Nacional Autónoma de México (MEXU), Instituto Politécnico Nacional (ENCB), Instituto de Ecología in Xalapa city (XAL), Facultad de Ciencias, Universidad Nacional Autónoma de México (FCME), New York Botanical Garden (NY), Missouri Botanical Garden (MO), Royal Gardens of Kew (K); and the following databases: Tropicos (Missouri Botanical Garden) and NYBG (New York Botanical Garden). With the information obtained, we conformed a database with 1363 records, that corresponds to 811 unique localities.

These localities were superimposed, using the software ArcView version 3.2 (ESRI 2000), on digital maps of Mexico with scale 1:1,000,000 produced by the Comisión Nacional para el Uso y Conocimiento de la Biodiversidad (CONABIO

1998). The Mexican territory was divided using a grid system, based on the chart index (scale 1:50,000) of the Instituto Nacional de Estadística, Geografía e Informática (INEGI 1992), and formulated in digital format by CONABIO (1999). Each map (chart) has a key-name, that was used to recognise each of our units of analysis (Figure 1).

Using the software ArcView version 3.2a, we intersected the maps of localities of the species and genera of Ternstroemiaceae with the grid system scale 1:50,000, including first all the species and genera to obtain the richness of each grid, and second, using only the species with restricted distribution to Mexico, to obtain the areas with high concentration of endemic species to the country (centres of endemism).

In order to obtain an approximation of the geographic range of all Mexican species of Ternstroemiaceae, based on MER criteria in relation to geographic distribution, we calculated the percentage of the geographic range of these taxa based on the total number of charts (2313) with scale 1:50,000, that cover the Mexican territory; thus we counted the number of charts where each taxon is present and divided this number by the total number of charts.

An endemism measure (corrected weighted endemism) was calculated following Linder (2001) and Crisp et al. (2001), that consists in dividing the weighted endemism index by the total count of species in the grid; in the weighted endemism, each species is weighted by the inverse of its range, so a single-grid endemic has the maximum weight of 1, a species occurring in four grids has a weight of 0.25, and a species occurring in 50 grids has a weight of 0.02. To obtain the value of each grid, these weights are summed for all species occurring in that grid; thus grids with many range-restricted species must show a much higher total score than grids with few range-restricted taxa (Linder 2001). Unfortunately, this index is correlated with species richness (Crisp et al. 2001), but this problem was solved dividing the index data obtained from the weighted endemism by the total number of species in that grid, so the result obtained is scarcely correlated with species richness (Crisp et al. 2001).

Finally, we selected those areas with more species richness and/or more concentration of endemic species to Mexico and drew them on the map of Mexican protected areas system of SEMARNAT (electronic page), and on the map of Mexican priority regions for conservation of CONABIO (electronic page), to find out if the areas occupied by these species have some type of special protection.

Results

The 15 species of Ternstroemiaceae included in this work are listed in Table 1. Species are distributed mainly in the Mesoamerican Mountain region (Sierra Madre Occidental, Sierra Madre Oriental, Serranías Meridionales, and Serranías Transístmicas floristic provinces of Rzedowski 1978), that is characterised by its mountain temperate humid conditions, principally in cloud forest, oak and pine forests (Figure 2). Notwithstanding, we find records in other sites with other vegetation types and different climates.

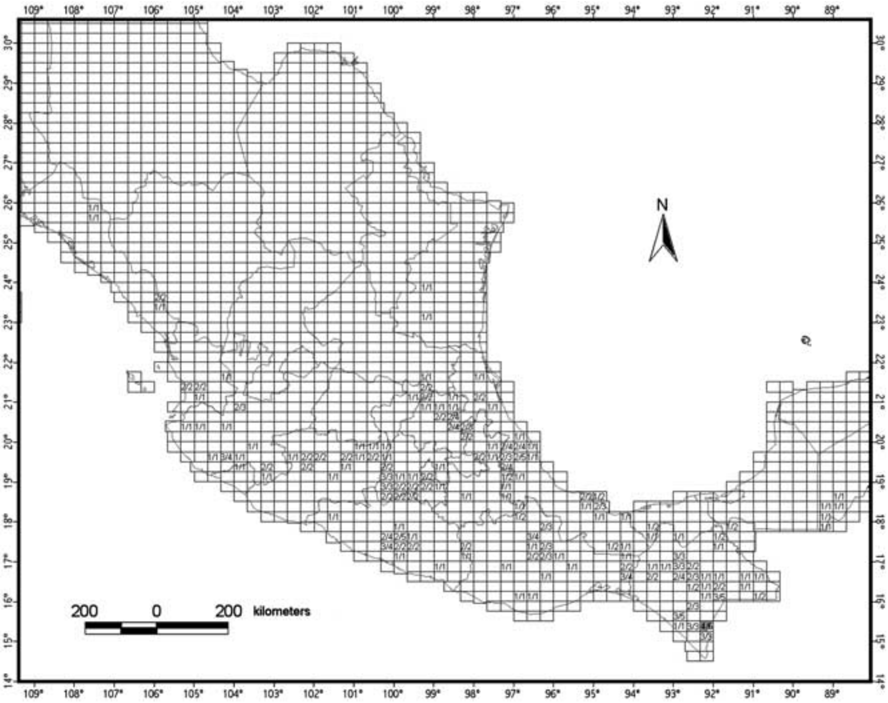

Figure 2. Genera and species richness of Ternstroemiaceae in Mexico.

The number of species and genera by grid represents the richness of each chart (map); Figure 2 shows that the richest area at generic (four genera) and species level (six species) is located in southern Mexico, in the state of Chiapas, at the boundary with Guatemala (chart D15B33, Motozintla, Chiapas). In this area all the genera of the family that inhabit Mexico are represented. The charts (maps) with more than two species are enlisted in Table 2. Only one species (*C. cernua*) was recorded in a single chart, whereas *Ternstroemia lineata* ssp. *lineata* was recorded in 50 charts (Table 3).

Based on MER criteria in relation to geographic range, all species of Ternstroemiaceae present a very restricted distribution (less than 5% of the Mexican territory), which means that all taxa inhabit less than 115 charts with scale 1:50,000.

When we superimposed the localities of the species with restricted distribution on the grid system, we obtained the centres of endemism of the Ternstroemiaceae; Figure 3 shows only the grids that contain two or more species. The grids with a high number of endemic species are E14C26 (La Primavera) and E14C27 (Chichihualco), both in the state of Guerrero, with four species; other grids with more than two species are listed in Table 4. We found also species with very restricted distribution areas (Figure 4); four species are distributed in less than 10 grids (Table 3).

Table 2. Charts with more than two species of Ternstroemiaceae.

Chart	Number of genera	Number of species
D15B33 (Motozintla, Chiapas)	4	6
D15B21 (Samuel León Brindis, Chiapas)	3	5
E15D84 (El Triunfo, Chiapas)	3	5
E13B23 (El Chante, Jalisco)	3	4
E14C36 (El Paraíso, Guerrero)	3	4
E14D28 (San Juan Quiotepec, Oaxaca)	3	4
E15C66 (Benito Juárez, Oaxaca-Chiapas)	3	4
E15D51 (Bochil, Chiapas)	3	4
D15B32 (Escuintla, Chiapas)	3	3
D15B43 (Pavincul, Chiapas)	3	3
E14A56 (Tejupilco de Hidalgo, México)	3	3
E14A46 (Valle de Bravo, México)	3	3
E15D41(Jitotol de Zaragoza, Chiapas)	3	3
E14B27 (Xalapa, Veracruz)	2	5
E14C27 (Chichihualco, Guerrero)	2	5
E14B16 (Altotonga, Puebla-Veracruz)	2	4
E14B17 (Misantla, Veracruz)	2	4
E14B36 (Xico, Puebla-Veracruz)	2	4
E14C26 (La Primavera, Guerrero)	2	4
F14D62 (Zacualtipán, Hidalgo-Veracruz)	2	4
F14D72 (Carbonera Jacales, Hidalgo-Veracruz)	2	4
E15D61 (Acala, Chiapas)	2	4
D15B12 (Rizo de Oro, Chiapas)	2	3
E14B26 (Perote, Veracruz)	2	3
E14D19 (Valle Nacional, Oaxaca)	2	3
E14D49 (Santa María Tlahuitoltepec, Oaxaca)	2	3
E15A74 (San Juan Volador, Veracruz)	2	3
E15D62 (San Cristóbal de las Casas, Chiapas)	2	3
F13D54 (Tequila, Jalisco)	2	3
F14D73 (Pahuatlán de Valle, Hidalgo-Puebla)	2	3

Table 3. Species of Ternstroemiaceae restricted to Mexico, and number of grids where they appear.

Species	Number of grids
Ternstroemia dentisepala	5
T. huasteca	9
T. lineata ssp. *lineata*	50
T. oocarpa	23
T. sylvatica	28
Cleyera integrifolia	41
C. velutina	6
C. cernua	1

The measure of endemism that considered the values obtained by weighted endemism (Table 5) in general resembles the pattern of species richness (see Table 2). The chart identified by both indices as the high-score was E14D19 (Valle

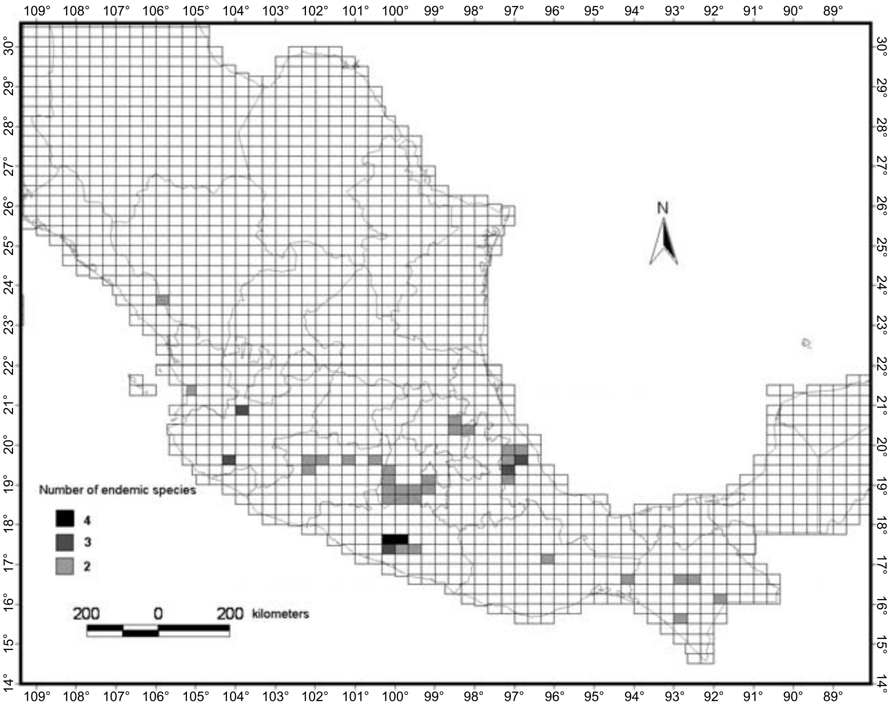

Figure 3. Endemism centres based on the distribution of Ternstroemiaceae.

Nacional, Oaxaca); *C. cernua* is endemic to that grid. Other charts high-scored for both indices are E14C36 (El Paraíso, Guerrero), D15B43 (Pavincul, Chiapas), and F13D31 (Jalisco-Nayarit) (Tables 5 and 6).

Chart E14D69 (Totolapan, Oaxaca) is ranked second by corrected weighted endemism, and chart F13A37 (Copala, Sinaloa-Durango) shows the third-highest level of corrected endemism in this analysis. Charts ranked second to sixth by corrected weighted endemism are supported by one species each (Table 6); the species that are present in these grids are considered range-restricted taxa, because they are only recorded in 4–6 charts (see Table 3). The existence of five charts with a single species among the high-scoring charts can be explained by the low number of taxa analysed in this study. In a strict sense these areas cannot be considered centres of endemism, because an area of endemism is defined by two or more taxa whose distributional range is overlapped (Harold and Mooi 1994); a similar case occurs with chart F13D31 (Jalisco-Nayarit), that does not owe any endemic species (see Table 7).

The proportion of range-restricted taxa in the Ternstroemiaceae is not random across southern Mexico. Range-restricted taxa are concentrated in few localities, while large areas of the country have very few or no range-restricted taxa.

Table 4. Charts (maps) with two or more endemic species.

Chart	Number of endemic species
E14C26 (La Primavera, Guerrero)	4
E14C27 (Chichihualco, en Guerrero)	4
E13B23 (El Chante, Jalisco)	3
E14B27 (Xalapa, Veracruz)	3
E14B36 (Xico, Puebla-Veracruz)	3
E14C36 (El Paraíso, Guerrero)	3
F13D54 (Tequila, Jalisco)	3
D15B21 (Samuel León Brindis, Chiapas)	2
E13B29 (Paracho, Michoacán)	2
E13B39 (Uruapan, Michoacán)	2
E14A21 (Cheran, Michoacán)	2
E14A23 (Morelia, Michoacán)	2
E14A25 (Ciudad Hidalgo, Michoacán)	2
E14A36 (Villa de Allende, México)	2
E14A46 (Valle de Bravo, México)	2
E14A49 (Milpa Alta, Distrito Federal-Morelos)	2
E14A56 (Tejupilco de Hidalgo, México)	2
E14A57 (Ixtapan de la Sal, México)	2
E14A58 (Tenancingo, México-Morelos)	2
E14A59 (Cuernavaca, Morelos)	2
E14A66 (Amatepec, México-Guerrero)	2
E14A67 (Pilcaya, México-Guerrero)	2
E14A68 (Taxco, Guerrero)	2
E14B16 (Altotonga, Puebla-Veracruz)	2
E14B17 (Misantla, Veracruz)	2
E14B26 (Perote, Veracruz)	2
E14B46 (Coscomotepec de Bravo, Veracruz)	2
E14C37 (Jaleacan de Catalán, Guerrero)	2
E14C38 (Mazatlán, Guerrero)	2
E14D49 (Santa María Tlahuitoltepec, Oaxaca)	2
E15C66 (Benito Juárez, Oaxaca-Chiapas)	2
E15D61 (Acala, Chiapas)	2
E15D62 (San Cristóbal de las Casas, Chiapas)	2
E15D84 (El Triunfo, Chiapas)	2
F13A27 (La Ciudad, Durango-Sinaloa)	2
F13C39 (Jalcocotán, Nayarit)	2
F14D62 (Zacualtipán, Hidalgo-Veracruz)	2
F14D72 (Carbonera Jacales, Hidalgo-Veracruz)	2
F14D73 (Pahuatlán de Valle, Hidalgo-Puebla)	2

The congruence among the areas of endemism suggested in this work and the vicarious distributions of other groups of vascular plants (i.e., some species of the *Clethra*, *Magnolia*, *Meliosma*, *Styrax*, and *Symplocos* suggested by Alcántara et al. 2002) support the existence of areas of endemism located mainly in the Serranías Meridionales floristic province, *sensu* Rzedowski (1978).

With this analysis, we detected four different types of important areas to be conserved for this group of plants: (1) areas with more taxonomic richness; in this

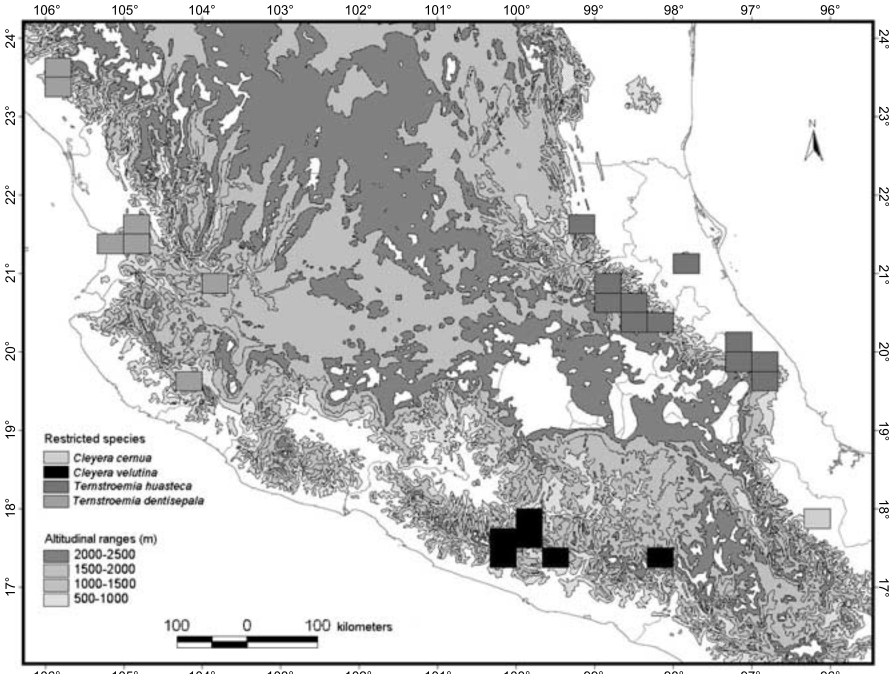

Figure 4. Species of Ternstroemiaceae with very restricted distribution in Mexico.

Table 5. Values of weighted endemism in each high-scored chart.

Chart	Weighted endemism	Number of species
E14D19 (Valle Nacional, Oaxaca)	1.074	3
D15B33 (Motozintla, Chiapas)	0.581	6
E14C36 (El Paraíso, Guerrero)	0.460	4
D15B43 (Pavincul, Chiapas)	0.443	3
D15B21 (Samuel León Brindis, Chiapas)	0.311	5
E13B23 (El Chante, Jalisco)	0.299	4
E14C27 (Chichihualco, Guerrero)	0.285	5
E15C66 (Benito Juárez, Oaxaca-Chiapas)	0.260	4
E15D61 (Acala, Chiapas)	0.256	4
F13D31 (Jalisco, Nayarit)	0.255	2

case, the most important area is Motozintla, in the state of Chiapas (chart D15B133), that contains all the genera of Ternstroemiaceae that inhabit Mexico, and the greatest number of species (six species). This area is located near the Soconusco area, formerly recognised by Toledo (1981) as a refuge place that maintained wet and favourable conditions during the Pleistocene climatic changes, an area that is characteristically rich in species and that contains high endemism;

Table 6. Values of corrected weighted endemism in each high-scored chart.

Chart	Corrected weighted endemism	Number of species
E14D19 (Valle Nacional, Oaxaca)	0.358	3
E14D69 (Totolapan, Oaxaca)	0.250	1
F13A37 (Copala, Sinaloa-Durango)	0.200	1
E14C17 (Tlacotepec, Guerrero)	0.166	1
E15C52 (Guevea, Oaxaca)	0.166	1
E15D73 (Comitán de Domínguez, Chiapas)	0.166	1
D15B43 (Pavincul, Chiapas)	0.147	3
F13D31 (Jalisco, Nayarit)	0.127	2
E14C36 (El Paraíso, Guerrero)	0.115	4
F13C39 (Jalcocotán, Nayarit)	0.112	2

Table 7. Elected criteria in the selection of the areas for the Mexican Ternstroemiaceae (a = taxa endemic to Mexico, b = taxa restricted, c = species richness, d = high-scored endemism indices; **species with very restricted distribution).

Grid	Criteria used	Number of endemic species	Total number of species by grid	Species involved
F13D31	d	1	2	***Ternstroemia dentisepala, Symplococarpon purpusii*
F13D54	a, b	3	3	*Cleyera integrifolia, **Ternstroemia dentisepala, T. lineata* ssp. *lineata*
F14D62	a, b	2	4	*Cleyera theaeoides, **Ternstroemia huasteca, T. sylvatica, T. tepezapote*
F14D72	a, b	2	4	*Cleyera theaeoides, **Ternstroemia huasteca, T. sylvatica, T. tepezapote*
E13B23	a, b	3	4	*Cleyera integrifolia, Symplococarpon purpussii, **Ternstroemia dentisepala, T. lineata* ssp. *lineata*
E14B16	a	2	4	*Cleyera theaeoides, **Ternstroemia huasteca, T. sylvatica, T. tepezapote*
E14B17	a, b	2	4	*Cleyera theaeoides, Ternstroemia lineata ssp. lineata, T. sylvatica, T. tepezapote*
E14B27	a, b, c	3	5	*Cleyera theaeoides, **Ternstroemia huasteca, T. lineata* ssp. *lineata, T. sylvatica, T. tepezapote*
E14B36	a, c	3	4	*Cleyera integrifolia, C. theaeoides, Ternstroemia lineata* ssp. *lineata, T. sylvatica*
E14C26	a, b	4	4	*Cleyera integrifolia, **C. velutina, Ternstroemia lineata* ssp. *lineata, T. sylvatica*

Table 7. (Continued)

Grid	Criteria used	Number of endemic species	Total number of species by grid	Species involved
E14C27	a, b, c	4	5	*Cleyera integrifolia, **C. velutina, Ternstroemia lineata* ssp. *lineata, T. sylvatica, T. tepezapote*
E14C36	a, b	3	4	*Cleyera integrifolia, **C. velutina, Ternstroemia lineata* ssp. *lineata, Freziera candicans*
E14D19	b	1	3	***Cleyera cernua, C. theaeoides, Ternstroemia seemanii*
E14D28	a	1	4	*Cleyera integrifolia, **C. velutina, Ternstroemia lineata* ssp. *lineata, T. tepezapote*
E15C66	a	2	4	*Cleyera theaeoides, C. integrifolia, Ternstroemia oocarpa, Freziera guatemalensis*
E15D61	a	2	4	*Cleyera theaeoides, Ternstroemia lineata* ssp. *chalicophila, T. lineata* ssp. *lineata, T. oocarpa*
E15D84	a, c	2	5	*Cleyera theaeoides, Symplococarpon purpussii, Ternstroemia lineata* ssp. *lineata, T. tepezapote, T. oocarpa*
D15B21	a, c	2	5	*Cleyera theaeoides, Symplococarpon purpussii, Ternstroemia lineata* ssp. *chalicophila, T. lineata* ssp. *lineata, T. oocarpa*
D15B33	a, c	1	6	*Cleyera theaeoides, Freziera candicans, Symplococarpon purpussii, Ternstroemia lineata* ssp. *chalicophila, T. oocarpa, T. tepezapote*
D15B43	d	0	3	*Cleyera theaeoides, Ternstroemia lineata* ssp. *chalicophila, Freziera candicans*

(2) areas with more concentration of endemic species; the areas that have such conditions are La Primavera and Chichihualco, both in the state of Guerrero (charts E14C26 and E14C27, respectively), where we can find the major concentration of endemic species (Table 3); (3) areas that include species very restricted to specific localities; the areas that possess those features are Tequila and El Chante, Jalisco (charts F13D54 and F13B23, respectively); Zacualtipán and Carboneras, Hidalgo-Veracruz (charts F14D62, F14D72); Altototonga and Xico, Puebla-Veracruz (charts E1416, E14B36); Xalapa, Veracruz (chart E14B27); La Primavera and Chichihualco, Guerrero (charts E14C26, E14C27); and Valle Nacional and San Juan Quiotepec, Oaxaca (charts E14D19, E14D28); the areas located in Oaxaca are also comprised in the Sierra de Juárez refuge of Toledo (1981) (Table 7); and (4) charts high-scored detected by both indices: E14D19 (Valle Nacional, Oaxaca), D15B43 (Pavincul, Chiapas), E14C36 (El Paraíso, Guerrero), and F13D31 (Jalisco, Nayarit).

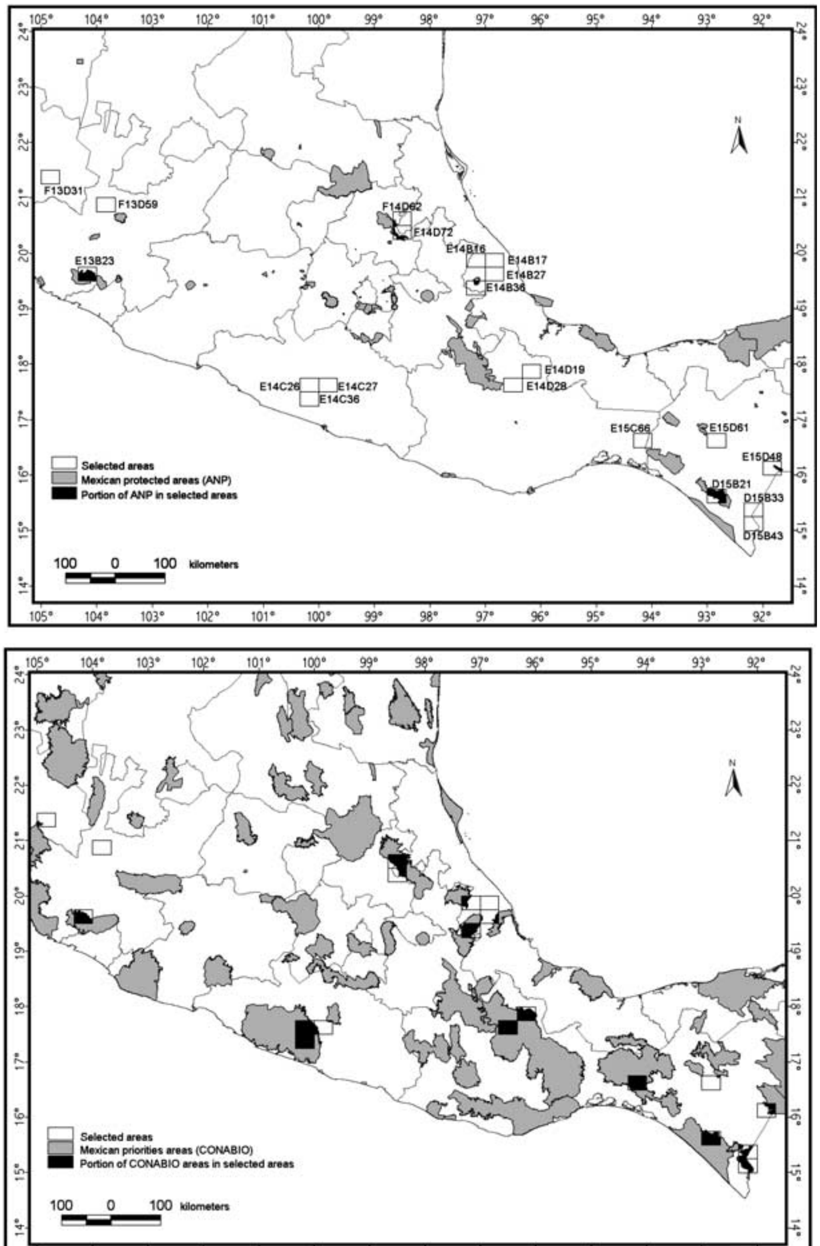

Figure 5. (a) Ternstroemiaceae represented in the Mexican National System of Protected Areas (SEMARNAT 2002); (b) Ternstroemiaceae represented in the Mexican Priority Regions for Conservation (RPT) (CONABIO 2000).

The species better represented in Mexico are *T. lineata* ssp. *lineata, Cleyera integrifolia* and *Ternstroemia sylvatica*.

Based on the previous analyses, we selected 20 grids that contain the areas with more species and genera richness and/or with more endemic species and/or with more species with restricted distribution for these groups of plants (Figure 5a, Table 7) and superimposed these 20 resultant areas on the map of the Mexican National System of Protected Areas (ANP) of SEMARNAT (electronic page); with this, we can see that many of them are not included in the Mexican protected areas (Figure 5a). When we drew these areas on the map of the Mexican priority regions for conservation of CONABIO (2000), we noted that many of these areas were included (Figure 5b). Many of these grids are located on the Mesoamerican hotspot of Myers et al. (2000) and in the Mesoamerican node (number 5) of Croizat (1958).

Discussion and conclusions

The results found conducted us to the fundamental question in conservation biology, that is, what do we have to elect for conservation: sites with more species richness or with more concentration of endemic species, in the sense of Myers et al. (2000). We may consider that in some cases many of the important components of biodiversity are not present in areas with species richness, as in this example, due to the fact that many of them can be of wide distribution, and with this they show a great adaptability, so they are not immediately endangered (Thirgood and Heath 1994).

In this work, we suggest a combination of four criteria in the selection of conservation areas for Mexican vascular plants based on Ternstroemiaceae. In this way, the 20 areas chosen are of great importance for this group of plants (Figure 5a), because in these areas are represented the highest species and genera richness, the greater concentration of endemic species, and those species restricted to specific localities, many of them in imminent extinction danger in the short and medium term.

As many authors argued, i.e. Prance (1994), an important fact in the development and implementation of different types of conservation strategies is the identification of areas with species richness. Other authors, like Thirgood and Heath (1994), consider that any strategy that intends to preserve the biodiversity must include the sites in which a high concentration of endemic species is present, mainly those with a very restricted distribution, since the loss of these areas can provoke the extinction of many lineages.

The grid system used in this study is an alternative method to perform a distributional analysis, and it can be helpful to understand the distributional patterns of other groups of Mexican organisms, with similar distributional patterns. This method has the advantage to detect and locate with precision congruent patterns of distribution, and to calculate objectively the size of the area occupied by the taxa in question. With this procedure, other biogeographical and biological criteria, like richness, diversity, and endemism, can be included in an objective way, and with this we can propose conservation areas more rigorously.

In relation to the geographic range of taxa considered in the MER (SEMARNAT 2002), we propose an evaluation of this criterion by the Mexican government, because with this criterion the distribution range of each species is calculated by eye, in the absence of sufficient information and technology to evaluate the geographic range objectively. All the Mexican species of Ternstroemiaceae belong to the category of very restricted geographic distribution (less than 5% of Mexican territory) in the MER.

Finally, with this method it is possible to propose objectively the inclusion in the IUCN Red List of Threatened Species (IUCN 2002) of the following taxa: *Ternstroemia dentisepala, T. huasteca, T. velutina*, and *Cleyera theaeoides* in the EN (endangered) category. It is also urgent to include them in the next version of the Mexican official publication 'Norma Oficial Mexicana 059'. *C. cernua*, that was included in the DD category of the IUCN (2002) Red List, should be changed to the critically endangered (CR) category, since this species is only known from one recollection. This change of status follows the parameters suggested in the (B) (1) criteria of the IUCN Red List Categories and Criteria (1994). Those species with small ranges, especially *C. cernua*, as Brown (1984) affirms, tend to be scarce within their distribution areas, so they have a high possibility of extinction. In addition, narrowly endemic species are by definition rare, and therefore potentially threatened (Crisp et al. 2001). Many of these species are highly restricted to temperate montane forests (cloud forest), a vegetation type that is highly threatened (Luna et al. 1999).

The presence of five charts with a single species among the high scored can be explained by the low number of taxa analysed in this study; as noted by Crisp et al. (2001) one problem with the corrected weighted endemism is that it is sensitive to artifacts of poor sampling.

A remarkable congruence exists between centres of endemism and richness; the same four centres recognised from both indices are E14D19 (Valle Nacional, Oaxaca), D15B43 (Pavincul, Chiapas), E14C36 (El Paraíso, Guerrero), and F13D31 (Jalisco, Nayarit). These two indices place them in a different rank order, so this coincidence lets us suggest these areas for conservation purposes, based on the high values of both indices.

Repeatability of this research should be tested using independent data from different organisms, since areas of endemism are fundamentally the same for a wide range of taxa (Humphries and Parenti 1999; Crisp et al. 2001). In our study, some grids might benefit from a detailed analysis based on other plant groups (*v. gr. Clethra, Magnolia, Cyathea* and *Meliosma*, among others), animals and fungi, namely E14D69 (Totolapan, Oaxaca), F13A37 (Copala, Sinaloa-Durango), E14C17 (Tlacotepec, Guerrero), E15C52 (Guevea, Oaxaca), E15D73 (Comitán de Domínguez, Chiapas), and F13D31 (Jalisco-Nayarit).

In the past decades, there has been a renewed enthusiasm on locating centres of richness or endemism in attempts to optimize conservation strategies (Ceballos and Brown 1995; Linder 2001); in this sense, the indices used in the present analysis let us locate centres of endemism and richness for Ternstroemiaceae in Mexico, from a rigorous numerical analysis of their distributional data.

We consider that the centres of endemism detected in this study have certain value as units in future cladistic biogeography analysis; similar analyses for other plant groups and animals are necessary for a more accurate consideration in this sense.

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