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Distributional patterns and conservation of species of Asteraceae (asters etc.) endemic to eastern Mexico: a panbiogeographical approach

Abstract Biogeographical patterns of distribution of 74 species of Asteraceae that inhabit mainly the temperate forests of eastern Mexico were studied using track analysis. Five generalized tracks were identified and conservation areas proposed based on degree of complexity of floristic patterns (Luna *et al.*, 1999) and biotic richness. The northern part of the Sierra Madre Oriental harbours a high concentration of narrowly restricted species. In this area there are four track nodes that coincide with the Mexican priority terrestrial regions (RTPs) proposed by the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) and with previously identified areas of importance for bird conservation (AICAs). Two more nodes are found in the central and southern part of the Sierra. With the gathered information, we propose particular selected species of Asteraceae to be included in the Mexican areas of endangered species (NOM).

Key words Asteraceae, distributional pattern, Mexico, Sierra Madre Oriental, panbiogeography, conservation

Introduction

The goal here is to analyse the distributional pattern of the species of Asteraceae which are endemic to the temperate forests of the Sierra Madre Oriental, and to make a panbiogeographical track analysis of them. Using the nodes derived from the analysis, we propose conservation areas that are based on complexity of floristic patterns (Luna *et al.*, 1999) and biotic richness. Finally, based on the results of this work, we use a correlation analysis to test whether this family of flowering plants is useful as a model for detecting areas of conservation.

Mexico contains a great diversity of topography and climate, because of its complex geology. The montane systems are an example of this, and have substantially influenced biological diversity, because they can have a variety of different effects, for example as barriers for dispersal for many species, as ecological islands where speciation phenomena have taken place increasing the biodiversity (Rzedowski, 1991*a*), or as biological corridors for some species (Halffter, 1987; Luna *et al.*, 1999).

The Sierra Madre Oriental (Fig. 1) is the second largest montane system in Mexico (Tamayo, 1998) with a longitude range of 1350 km, width of 150 km, and varied altitudinal ranges. Average altitudes are 1500 to 2000 m, but in some

places they can reach 3000 m (Lugo-Hupb, 1990). It is located in the northeastern part of Mexico, and runs northwest to southeast. This montane system begins in the Sierra del Burro, close to the Bravo River in the state of Tamaulipas, and ends in the Cofre de Perote in the state of Veracruz, where it connects with the Transmexican Volcanic Belt. This montane system includes part of the Mexican states of Coahuila, Durango, Guanajuato, Hidalgo, Nuevo León, Puebla, Querétaro, San Luis Potosí, Tamaulipas, Veracruz and Zacatecas (Tamayo, 1998). This montane chain has a complex geological history, and contains mainly Mesozoic and Cenozoic rocks.

The Sierra Madre Oriental is one of the biologically most important montane Mexican systems. It includes ecosystems rich in species as the cloud forest, which in this region has the most continuous distribution in the country. Other important vegetation types represented in this area are conifer forests, oak forests, xerophytic scrubs, tropical deciduous forests, tropical rain forests and grasslands, among others (Rzedowski, 1978).

A conspicuous floristic component in the Sierra Madre Oriental is the presence of various species of Asteraceae Dumort. (= Compositae Giseke), a family of flowering plants that is diverse in Mexico (Villaseñor, 1991). Villaseñor (2003) established that the family in mexico, with a cosmopolitan distribution, comprises 361 genera and 3021 species. This is the most diverse flowering plant family in Mexico (Villaseñor, 2003), and many of its members are strongly associated with

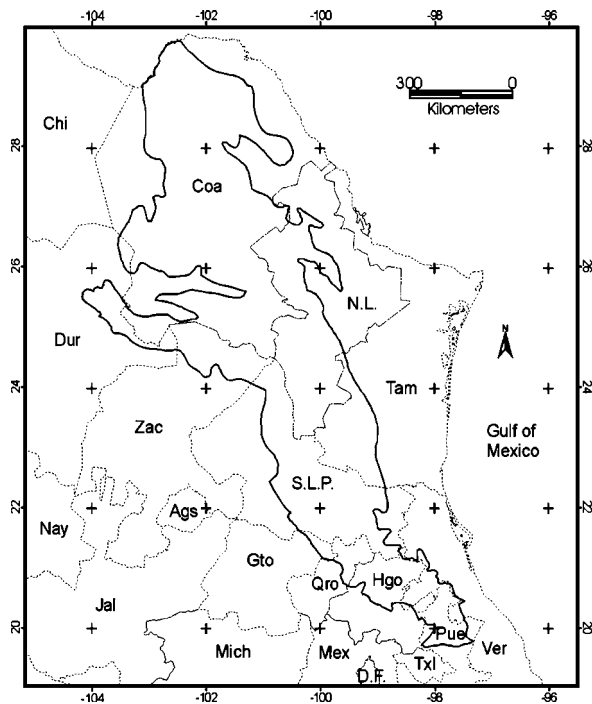*Corresponding author. Email: ilv@hp.fciencias.unam.mx

Figure 1 Distribution of the Sierra Madre Oriental in Mexico. Black lines represent the limits of the physiographic province; grey lines represent the state limits. Ags = Aguascalientes; Chi = Chihuahua; Coa = Coahuila; D.F. = Distrito Federal; Dur = Durango; Gto = Guanajuato; Hgo = Hidalgo; Jal = Jalisco; Mex = México; Mich = Michoacán; Nay = Nayarit; N.L. = Nuevo León; Pue = Puebla; Qro = Querétaro; S.L.P. = San Luis Potosí; Tam = Tamaulipas; Txl = Tlaxcala; Ver = Veracruz; Zac = Zacatecas.

montane systems (Cabrera-Rodríguez & Villaseñor, 1987; Rzedowski, 1996). The endemism for this family in Mexico has been calculated as 119 genera and 1300 species (Villaseñor, 1990). This author stated that 13 genera of Asteraceae represented in the Sierra Madre Oriental are endemic to Mexico, four of them restricted to this province, mainly to the cloud forest and xeric areas, where this family of vascular plants is characteristically predominant. He also estimated that in the Sierra about 769 species occur (approximately 25% of the Mexican species of Asteraceae), 365 of them endemic to Mexico.

Asteraceae have been used as indicators of biodiversity (Rzedowski, 1991*b*), because there is adequate taxonomic knowledge, it is a group of plants that are easy to sample, it has all types of growth form representatives, and it is found over a wide range of habitats and ecosystems (Villaseñor *et al.*, 1998). Also, this family of plants proportionally has the highest number of species in the Sierra Madre Oriental, in comparison with other plant families, as we ascertain later in this paper.

Dispersalist biogeographic studies of Mexican taxa (Martin & Harrell, 1957) have been recently contrasted with vicariant explanations, mainly from vicariance biogeography (i.e. Liebherr, 1991; Marshall & Liebherr, 2000). Nevertheless, the lack of phylogenetic studies of a large number of Mexican species has impeded a more general application of vicariant methods. As an alternative, panbiogeographic (track) methods (Croizat, 1958), which do not strictly depend on cladograms

for the studied groups, can yield results that reflect congruent distributional hypothesis of different taxa (Morrone, 2001). Track methods emphasize the importance of the geographical dimension of biodiversity for the comprehension of evolutionary patterns and processes (Craw *et al.*, 1999). In this way, the spatial component of evolution is decisive in understanding the historical structure of biotic systems. Track methods require the mapping of localities of different taxa, and connecting them with line plots (individual tracks) according to their minimal geographical proximity. If a set of individual tracks are congruent, the combined tracks constitute a generalized track, which is interpreted as evidence of the pre-existence of an ancestral biota that was fragmented in the past due to geographic or climatic changes. Areas where two or more generalized tracks connect or intersect constitute nodes, which represent biological and geologically complex areas.

Recently, historical biogeography methods have been used to propose and design natural reserves, based on the limits determined by areas containing endemic taxa. With these methods it is possible to define biogeographic units, with different limits to those of the political frontiers (Grehan, 1989; Morrone & Crisci, 1992; Espinosa & Morrone, 1998).

Nodes are important for conservation purposes, because they contain biotic elements of two or more floras or faunas. As Heads (2004) argued recently, they represent sites of vicariance related to different kinds of geological and climatic events occurring in the same locality. In this way, nodes can be seen or distinguished as sites characterized by both high diversity and endemism, so they can be compared with 'hotspots' (Myers, 1988, Myers *et al.*, 2000; Morrone & Crisci, 1992; Grehan, 1993; Craw *et al.*, 1999; Contreras-Medina *et al.*, 2001; Heads, 2004), rather than based on number of species alone. Notwithstanding that Mexico is considered as an area of diversification for the family Asteraceae, it is important to propose a conservation plan of its species, because relict taxa occur in some areas (Villaseñor, 1991; Turner & Nesom, 1998; Villaseñor *et al.*, 1998). The detection of areas with a great number of species with restricted distribution and with a complex biogeographic history is essential for maintaining their diversity.

Methods

We selected 74 species of Asteraceae that belong to nine different tribes (*sensu* Bremer, 1994), mostly endemic to the temperate forests of the Sierra Madre Oriental, although some of them extend slightly into adjacent areas. The selected species did not have synonymy problems, and are included in 35 genera (Table 1).

Distributional data of the species involved were gathered from the following herbaria: Herbario Nacional de México, Universidad Nacional Autónoma de México (MEXU), Herbario de la Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional (ENCB), Herbario de la Facultad de Ciencias, Universidad Nacional Autónoma de México (FCME), Herbario-Hortorio del Colegio de Posgraduados (CHAPA), Herbario de la División de Ciencias Forestales de la Universidad Autónoma Chapingo (CHAP), Herbario del Instituto de Ecología, Centro Regional del Bajío (IEB), and

Tribe	Species
Astereae	*Archibaccharis venturana* G.L. Nesom, *Astranthium beamanii* DeJong, *Erigeron cieloensis* G.L. Nesom, *Erigeron potosinus* Standl., *Erigeron scoparioides* G.L. Nesom, *Grindelia greenmanii* Steyerm., *Grindelia inuloides* Willd. var. *latamplexa* G.L. Nesom, *Solidago hintoniorum* G.L. Nesom
Cardueae	*Cirsium bicentenariale* Rzed.
Eupatorieae	*Ageratina nesomii* B.L. Turner, *Ageratina potosina* B.L. Turner, *Ageratina queretaroana* B.L. Turner, *Ageratina viejoana* B.L. Turner, *Ageratina zapalinama* B.L. Turner, *Bartlettina tamaulipanum* (B.L. Turner) R.M. King et H. Rob., *Critonia lozanoana* (B.L. Rob.) R.M. King et H. Rob., *Flyriella leonensis* (B.L. Rob.) R.M. King et H. Rob., *Flyriella stanfordii* R.M. King et H. Rob., *Koanophyllon galeana* (B.L. Turner) B.L. Turner, *Koanophyllon hintoniorum* B. L. Turner, *Koanophyllon reyrobinsonii* B.L. Turner, *Stevia coahuilensis* Soejima et Yahara, *Stevia hintoniorum* B.L. Turner, *Stevia potosina* Soejima, Yahara et K. Watanabe, *Stevia viejoana* Soejima, Yahara et K. Watanabe
Gnaphalieae	*Gnaphalium ehrenbergianum* Sch.Bip. ex Klatt, *Gnaphalium hintoniorum* G.L. Nesom
Helenieae	*Chrysactinia truncata* S. Watson, *Hymenopappus hintoniorum* B.L. Turner, *Hymenoxys insignis* (A. Gray ex S. Watson) Cockerell, *Hymenoxys pinetorum* (Standl.) Bierner, *Loxothysanus pedunculatus* Rydb., *Porophyllum filiforme* Rydb., *Tagetes muelleri* S. F. Blake
Heliantheae	*Flourensia monticola* M.O. Dillon, *Greenmaniella resinosa* (S. Watson) W.M. Sharp, *Perymenium tamaulipense* B.L. Turner, *Rumfordia exauriculata* B.L. Turner, *Sabazia elata* (Canne) B.L. Turner, *Tetrachyron grayi* (Klatt) Wussow et Urbatsch, *Tetrachyron websteri* (Wussow et Urbatsch) B.L. Turner, *Thelesperma muelleri* (Sherff) Melchert, *Verbesina coahuilensis* A. Gray ex S. Watson var. *coahuilensis*, *Verbesina coahuilensis* A. Gray ex S. Watson var. *viridior*, B.L. Rob. et Greenm., *Verbesina coulteri* A. Gray, *Verbesina daviesiae* B.L. Turner, *Verbesina hidalgoana* B.L. Turner, *Verbesina richardsonii* B.L. Turner, *Verbesina zaragosana* B.L. Turner, *Viguiera nesomii* B.L. Turner
Lactuceae	*Hieracium beamanii* B.L. Turner, *Pinaropappus pattersonii* B.L. Turner
Mutisieae	*Acourtia gracilis* L. Cabrera, *Acourtia hintoniorum* B.L. Turner, *Acourtia potosina* L. Cabrera, *Chaptalia estribensis* G.L. Nesom, *Chaptalia lyratifolia* Burkart, *Chaptalia madrensis* G. L. Nesom
Senecioneae	*Packera hintoniorum* (B.L. Turner) C. Jeffrey, *Packera montereyana* (S. Watson) C. Jeffrey, *Packera zimapanica* (Hemsl.) C.C. Freeman et T.M. Barkley, *Psacalium peltatum* Cass. var. *adenophorum* S.F. Blake, *Robinsonecio porphyresthes* (T.M. Barkley) T.M. Barkley et Janovec, *Roldana metepecus* (B.L. Turner) C. Jeffrey, *Roldana neogibsonii* (B.L. Turner) B.L. Turner, *Roldana nesomiorum* (B.L. Turner) C. Jeffrey, *Senecio carnerensis* Greenm., *Senecio claryae* B.L. Turner, *Senecio lithophilus* Greenm., *Senecio madrensis* A. Gray, *Senecio pattersonii* B.L. Turner, *Senecio platypus* Greenm., *Senecio richardsonii* B.L. Turner, *Senecio viejoanus* B.L. Turner

Table 1 Species of Asteraceae endemic to temperate forests of the Sierra Madre Oriental. A list of voucher specimens is available as an electronic appendix on the *Cambridge Journals* website at Cambridge Journals Online on: http://www.journals.cup.org/abstract_S1477200006002192 and a hard copy deposited in the journal archive at the Natural History Museum, London.

Herbario Nacional Forestal (INIF). We also considered the databases from the University of Texas Herbarium (TEX), the New York Botanical Garden (NY), the Missouri Botanical Garden (MO), the Gray Herbarium (GH) and Herbario del Instituto de Ecología, Xalapa (XAL), all of them available through the Red Mundial de Información sobre Biodiversidad (REMIB), housed at the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) (http://www. conabio.com. mx). A list of voucher specimens is available as an electronic appendix on the *Cambridge Journals* website at Cambridge Journals Online on: http://www.journals.cup.org/abstract_S1477200006002192 and a hard copy deposited in the journal archive at the Natural History Museum, London.

From this information, we generated a database of selected species. All of the localities of these species were geocoded (full latitude and longitude details), based on topographic charts of the Instituto Nacional de Estadística, Geografía e Informática (INEGI) scale 1:50,000 (issued as quadrangle sheets, 15′ latitude by 20′ longitude) available for the area, and on data from Ortiz (2004). Incomplete information and incongruent herbarium specimens were eliminated, resulting in a final database composed of 783 different localities (available through request from the corresponding author).

For track analysis (Craw *et al*., 1999) we used the collection localities of each species, represented by points on the maps of each taxon, and then we drew individual tracks. For each taxon, the localities within a track were united by the line of minimum distance between each point (a minimum spanning tree). All the individual track maps were printed and then superimposed on each other to define several generalized tracks (Craw *et al*., 1999). We then identified baselines, i.e. geographical, climatic or geological features that spatially match a generalized track. In this sense, ocean basins are the most common and conspicuous geographic features to have been used as baselines because, through their plate tectonic
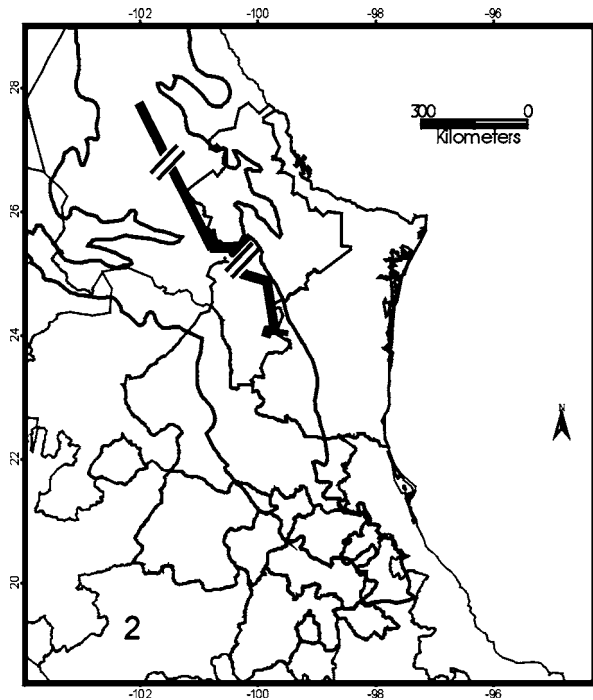
Figure 2 Northern Sierra Madre Oriental generalized track. Double bar breaks signify baselines.
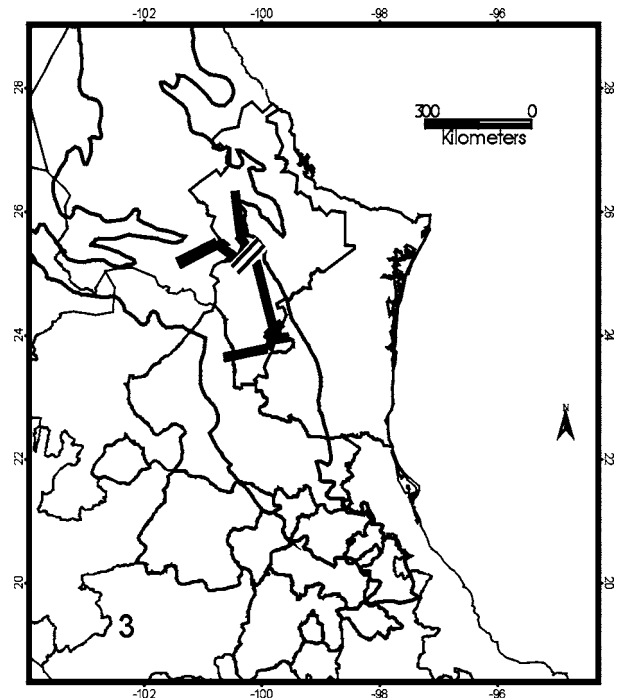

Figure 3 Nuevo León generalized track. Double bar breaks signify baselines.

origins, they traditionally provide potential explanations of global-scale distributional patterns. In this work, baselines were chosen on a regional intra-continental scale from geologic, climatic and physiographic data of the Sierra Madre Oriental. However, on this scale, baselines are more difficult to identify, because disjunct distributions of organisms are less evident than transoceanic disjunctions.

In the areas of convergence or intersection among two or more generalized tracks, we recognized nodes, and then we compared the node location with priority areas for conservation in the Sierra Madre Oriental determined by CONABIO (Arriaga *et al.*, 2000), areas of importance for bird conservation (AICAs) (Benítez *et al.*, 1999), and other biogeographic works for different groups of organisms (Álvarez & Morrone, 2004; Escalante, 2003).

Results and discussion

Track analysis
We drew 55 individual tracks for the 74 species of Asteraceae (19 species were omitted because they are known from a single locality). Of these individual tracks 41 are found in the northern part of the Sierra, and are included in three different generalized tracks. Nine of the 55 individual tracks are found in the southern part of the Sierra and three individual tracks run northwest to southeast throughout the Sierra.

The congruence of the individual tracks of the species of Asteraceae allowed us to recognize five generalized tracks in the Sierra Madre Oriental (Figs 2–6); the individual tracks of two species (*Erigeron cieloensis* and *Senecio claryae*) were
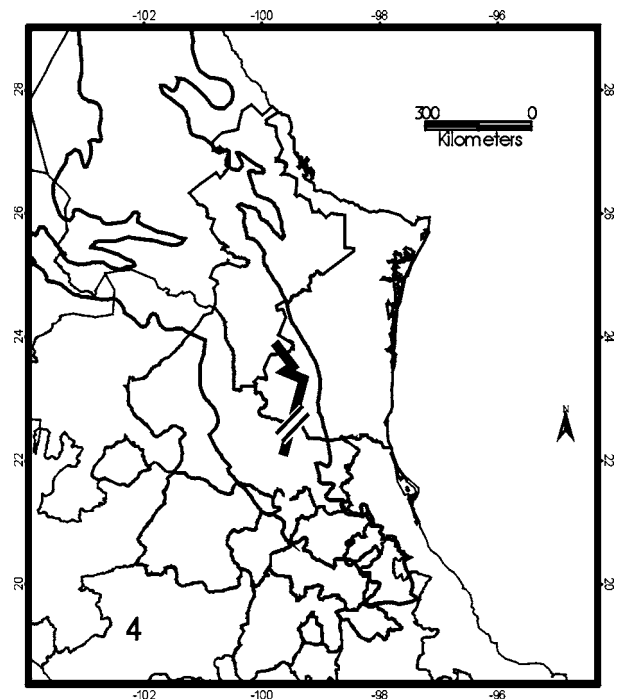

Figure 4 Pánuco basin generalized track. Double bar breaks signify baselines.

not considered because they do not belong to any of the generalized tracks found. Three generalized tracks are located in the northern part of the Sierra, mainly in the states of Coahuila and Nuevo León in the Saltillo-Monterrey area, and connecting with the southern municipalities of the state of Nuevo León, suggesting a close relationship between these areas. This area belongs to the Parras and La Popa geological
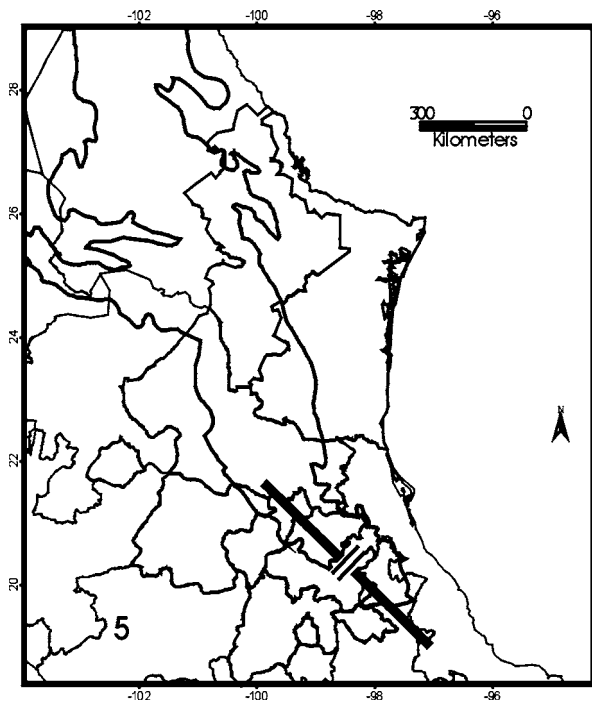
Figure 5 Southern Sierra Madre Oriental generalized track. Double bar breaks signify baselines.
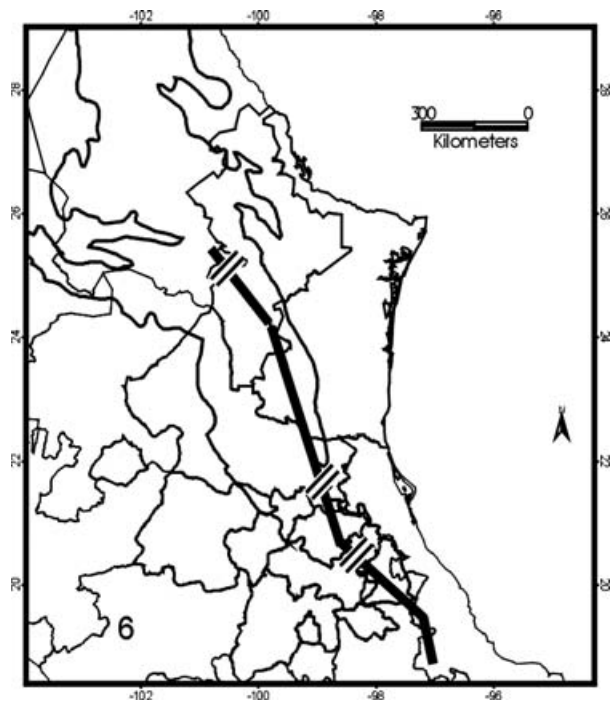

Figure 6 Sierra Madre Oriental generalized track. Double bar breaks signify baselines.

formations, which were subjected to different faulting and folding events during the Laramide Orogeny of the Cretaceous period (Fischer & Jackson, 1999). A fourth generalized track is located in the southern part of the Sierra following the distribution of the temperate forests of the states of Hidalgo, Querétaro, Veracruz, Puebla and southern San Luis Potosí. The fifth and last generalized track runs northwest to southeast throughout the Sierra. The generalized tracks are defined as follows:

1. Northern Sierra Madre Oriental generalized track (Fig. 2). This track is the longest one and is located at the northern part of the Sierra; it runs throughout the central part of the state of Coahuila and Nuevo León and extends close to the border of the state of Tamaulipas. It is defined by the individual tracks of 16 species: *Ageratina potosina*, *Astranthium beamanii*, *Chrysactinia truncata*, *Flourensia monticola*, *Flyriella stanfordii*, *Grindelia greenmanii*, *Packera zimapanica*, *Porophyllum filiforme*, *Psacalium peltatum* var. *adenophorum*, *Rumfordia exauriculata*, *Senecio carnerensis*, *S. madrensis*, *Solidago hintoniorum*, *Stevia hintoniorum*, *Verbesina coahuilensis* var. *coahuilensis* and *V. daviesiae*.

2. Nuevo León generalized track (Fig. 3). This track also crosses the northern part of the Sierra Madre Oriental. It is found mainly in the central part of the state of Nuevo León and branches in the Saltillo area. It is defined by the individual tracks of the following 15 species: *Ageratina nesomii*, *Erigeron potosinus*, *Flyriella leonensis*, *Gnaphalium hintoniorum*, *Greenmaniella resinosa*, *Hymenopappus hintoniorum*, *Hymenoxys insignis*, *H. pinetorum*, *Koanophyllon reyrobinsonii*, *Packera hintoniorum*,

P. montereyana, *Perymenium tamaulipense*, *Senecio platypus*, *Stevia coahuilensis* and *S. potosina*.

3. Pánuco basin generalized track (Fig. 4). This track crosses the south east part the state of Nuevo León and the western part of the state of Tamaulipas, reaching the north east part of San Luis Potosí. It is defined by the individual tracks of ten species: *Acourtia hintoniorum*, *Critonia lozanoana*, *Koanophyllon hintoniorum*, *Loxothysanus pedunculatus*, *Roldana nesomiorum*, *Senecio lithophilus*, *S. richardsonii*, *S. viejoanus*, *Tetrachyron grayi* and *T. websteri*.

4. Southern Sierra Madre Oriental generalized track (Fig. 5). This track runs throughout the southeast part of the state of San Luis Potosí, crosses the states of Querétaro, Hidalgo and northeast part of the state of Puebla, and extends to the central part of Veracruz. This track connects one of the largest distribution areas of the current temperate forest in the Sierra. It is defined by the individual tracks of nine species: *Archibaccharis venturana*, *Ageratina queretaroana*, *Chaptalia estribensis*, *Cirsium bicentenariale*, *Grindelia inuloides* var. *latamplexa*, *Hieracium beamanii*, *Roldana metepecus*, *R. neogibsonii* and *Verbesina coulteri*.

5. Sierra Madre Oriental generalized track (Fig. 6). This track runs throughout the Sierra Madre Oriental, in a northwest-southeast direction. This track is the largest one and is defined by the individual tracks of three species: *Chaptalia lyratifolia*, *C. madrensis* and *Gnaphalium ehrenbergianum*.

In the Sierra Madre Oriental we identified the existence of different geological and climatic events that allowed us to identify several baselines. For example, the northern part of the Sierra has a complex geological history that caused the folding and faulting of the components of this zone, as discussed
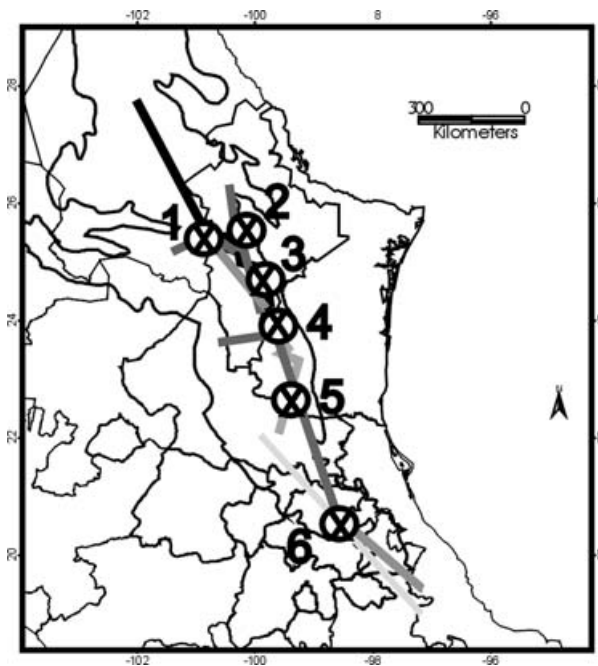
Figure 7 Panbiogeographic nodes in the Sierra Madre Oriental. 1 = Saltillo node; 2 = Monterrey node; 3 = San Antonio Peña Nevada node; 4 = Tamaulipas-Nuevo León node; 5 = Pánuco node; 6 = Cuetzalan node. Shades distinguish different tracks.

recently by Fischer and Jackson (1999). A second baseline, also located in the northern part of the Sierra, and represented by the desert areas of central Coahuila, suggest an explanation for the disjunction of the taxa involved. A third baseline can be identified mainly in connection with climatic changes during the Quaternary that have affected the distribution and composition of the different types of vegetation in the Sierra. Palynological and palaeoenvironmental evidence (Conserva & Byrne, 2002) demonstrate alternation of tropical and temperate climatic periods which caused a reduction of the distributional areas of the temperate forest in the Sierra Madre Oriental, and help to explain their currently fragmented distribution. These areas possibly acted as refuges for the vegetation, as Toledo (1982) suggested earlier for Mesoamerica. The Pánuco river basin is considered as the fourth baseline; this basin is located in the central part of the Sierra and divides this chain into two parts, a northern and a southern component (Smith, 1941; Luna *et al.*, 1999).

At the intersections of the different generalized tracks, we identify six nodes (Fig. 7). Four of them are located in the northern part of the Sierra, one in the border of the states of San Luis Potosí and Tamaulipas and the sixth one in the southern part. These are:

1. Saltillo node. This node is the concurrence of three tracks: the northern Sierra Madre Oriental, Nuevo León and Sierra Madre Oriental generalized tracks.
2. Monterrey node. This node is located in the Monterrey municipality, in the Sierra de Anáhuac. It is defined by the coincidence of the northern Sierra Madre Oriental and Nuevo León generalized tracks.

NODES	RTPs	AICAs
Saltillo	Tokio	Pradera de Tokio
Monterrey	El Potosí-Cumbres de Monterrey	Sierra de Arteaga
San Antonio Peña Nevada	Tokio-Puerto Purificación	San Antonio Peña Nevada
Tamaulipas-Nuevo León	Valle de Jaumave, El Cielo	El Cielo (in part)
Pánuco		El Cielo (in part)
Cuetzalan	Cuetzalan	Cuetzalan

Table 2 Coincidence of panbiogeographic nodes and conservation areas in the Sierra Madre Oriental.
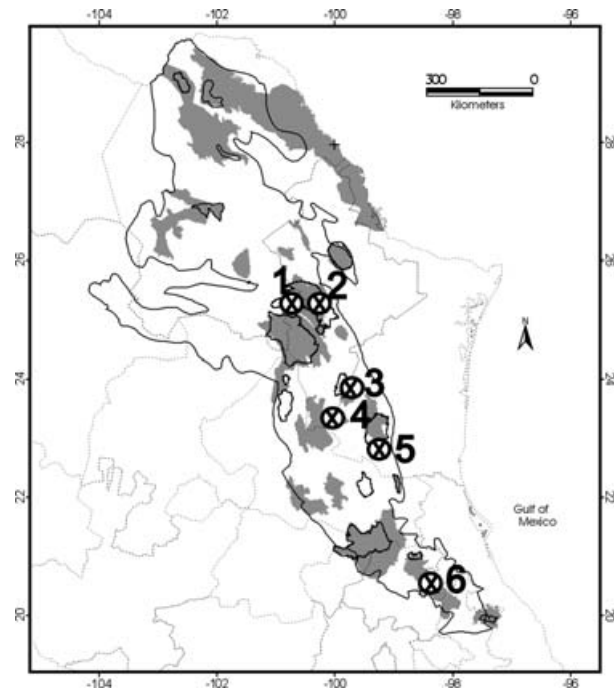

Figure 8 Comparison among panbiogeographic nodes (⊗); priority terrestrial regions (RTPs) ▬ and areas of importance for bird conservation (AICAs) ▭.

3. San Antonio Peña Nevada node. This node is defined by the intersection of the northern Sierra Madre Oriental, Nuevo León and Pánuco generalized tracks.
4. Tamaulipas-Nuevo León node. This node is located in the southeastern part of the state of Nuevo León, where it borders with the state of Tamaulipas, and is defined by the concurrence of the northern Sierra Madre Oriental, Nuevo León and Pánuco generalized tracks.
5. Pánuco node. This node is located in the border area of the states of San Luis Potosí and Tamaulipas, and is defined by the intersection of the southern Sierra Madre Oriental and Sierra Madre Oriental generalized tracks.
6. Cuetzalan node. This node is located in the southern part of the Sierra Madre Oriental in the state of Puebla, and is defined by the intersection of the Southern Sierra Madre Oriental and Sierra Madre Oriental generalized tracks.
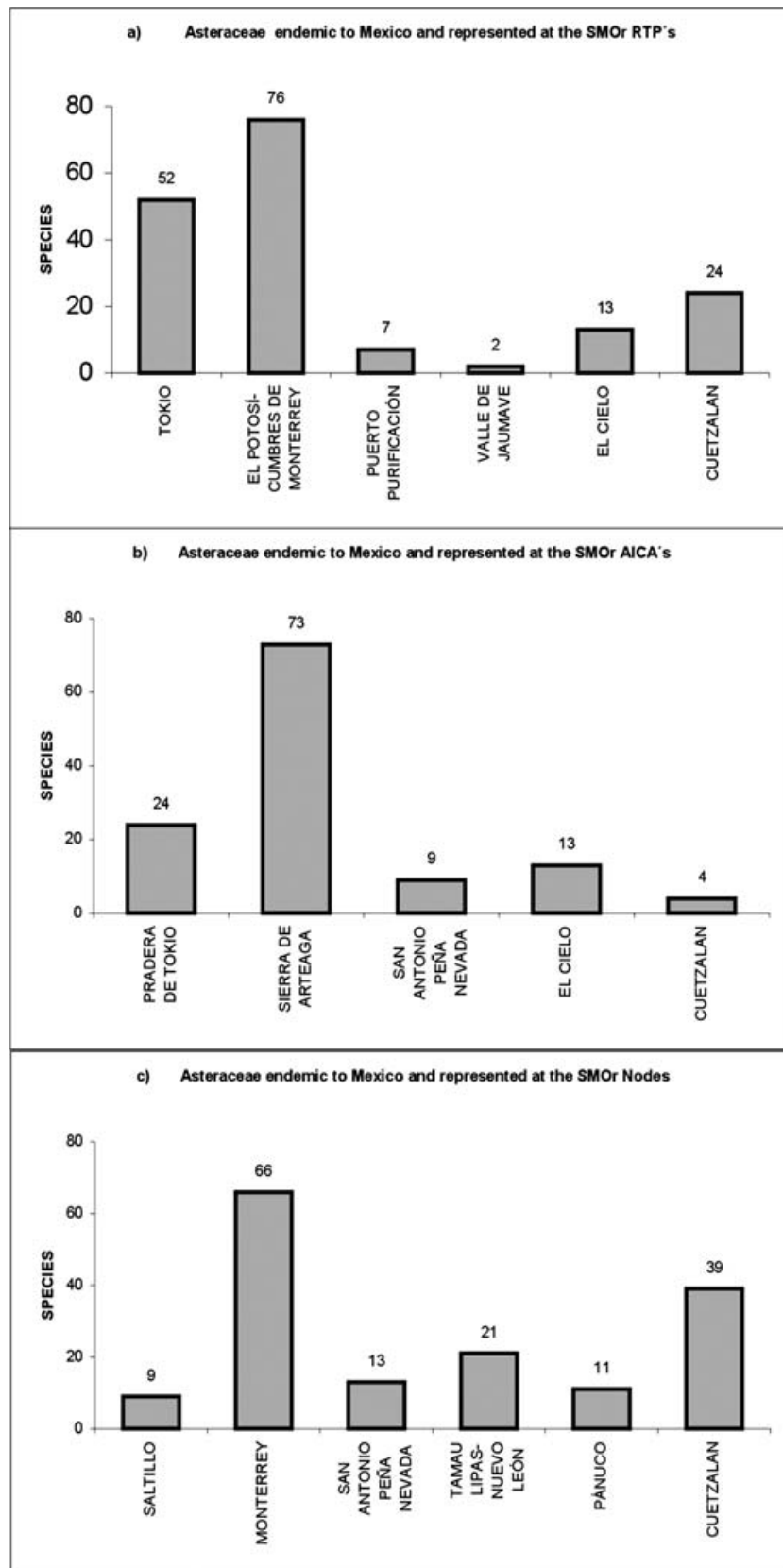
Figure 9 Species of Asteraceae recorded at different sites located at: (a) Mexican priority terrestrial regions (RTPs), (b) Areas of importance for bird conservation (AICAs) and (c) panbiogeographic nodes at the Sierra Madre Oriental.

Floristic lists from the Sierra Madre Oriental	Total number of species of Magnoliophyta	Total number of species of Asteraceae
Sierra de Parras, Coahuila (Rodríguez *et al.*, 1994)	629	14
Saltillo, Coahuila (Villarreal, 2001)	918	194
Santiago, Nuevo León (Valdez, 1981)	296	47
Cerro Potosí, Nuevo Léon (García-Arévalo & González-Elizondo, 1991)	115	22
Sierra San Carlos, Tamaulipas (Briones, 1991)	387	53
Gómez Farías, Tamaulipas (Valiente-Banuet *et al.*, 1995)	248	6
Sierra de Guatemala, Tamaulipas (Johnston *et al.*, 1989)	583	67
General Zaragoza, Nuevo León (Treviño, 1984)	241	40
Landa de Matamoros, Querétaro (Cartujano *et al.*, 2002)	607	70
Sierra Gorda, Querétaro (Arreguín-Sánchez & Fernández, 2004)	1231	156
San Joaquín, Querétaro (Fernández & Colmenero, 1997)	256	51
Tlanchinol, Hidalgo (Luna *et al.*, 1994)	255	31
Barranca de Tolantongo, Hidalgo (Hiriart & González, 1983)	287	28
Tenango de Doria, Hidalgo (Alcántara & Luna, 1997)	379	54
Molocotlán, Hidalgo (Mayorga *et al.*, 1998)	309	32
Eloxochitlán and Tlahuelompa, Hidalgo (Alcántara & Luna, 2001)	333	39
Barranca de Metztitlán, Hidalgo (Villaseñor, unpubl. data)	237	22
Lolotla, Hidalgo (Ponce *et al.*, 2006)	228	11

Table 3 Total number of species of Asteraceae in comparison with the total number of species of Magnoliophyta in selected localities of the Sierra Madre Oriental.

Coincidence between panbiogeographic nodes and conservation areas

When we compared these nodes with the priority terrestrial regions for conservation (RTPs) (Arriaga *et al.*, 2000) proposed by the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) and with the defined areas of importance for bird conservation (AICAs) (Benítez *et al.*, 1999), we noted that all the nodes proposed coincide with these same areas (Table 2 and Fig. 8). In contrast, not one of these nodes is included in the list of Mexican Natural Protected Areas (ANP).

Many of the species studied in this work are narrowly restricted endemics, and are therefore poorly represented in herbaria. Based on our present findings, we suggest a more careful study is needed of the populations of these species, so that they might be included in the Mexican official publication, *Norma Oficial Mexicana NOM 059-ECOL-2001* (Secretaría del Medio Ambiente y Recursos Naturales 2002), which lists Mexican species placed in various risk categories. The following 19 Asteraceae are candidates for consideration: *Acourtia gracilis, A. potosina, Ageratina viejoana, A. zapalinama, Bartlettina tamaulipana, Erigeron scoparioides, Koanophyllon galeana, Pinaropappus pattersonii, Robinsonecio porphyresthes, Sabazia elata, Senecio pattersonii, Stevia viejoana, Tagetes mulleri, Thelesperma muelleri, Verbesina coahuilensis* var. *viridior, V. hidalgoana, V. richardsonii, V. zaragosana* and *Viguiera nesomii*.

Coincidence between these different approaches (panbiogeographic nodes and conservation areas) shows that it is possible, from different methodological viewpoints, to obtain similar results, especially if, as in this case, endemism plays a key role in all of them. In this way, it is possible to detect areas with high diversity values using different biogeographical approaches. Coincidence between these different approaches reinforces the results obtained.

The northern part of the Sierra Madre Oriental with the highest concentration of endemic species of Asteraceae is mainly occupied by the Monterrey node (Figs 8 and 9). We recommend that this area be given conservation priority, due to the fact that it contains a rich vascular plant biota. Another rich area is the Cuetzalan node, in the southern part of the Sierra. The area occupied by this node is noticeably smaller than the Monterrey one, but it harbours a great number of endemic species. The present conclusions are based on the distribution analysis of 561 species of Asteraceae, 310 of which are restricted to Mexico and collected at least once from the Sierra Madre Oriental. From our results, it appears justifiable to make more complete floristic, vegetational and biogeographic studies of these rich and complex areas.

Conclusions

Scientific collections are important data sources to undertake biogeographical analysis. Although such collections obviously do not reflect the real or potential geographical distribution of the species, we emphasize that our results provide the most up to date scenario, based on real distribution records, and are based on most of the national and foreign collections in which these taxa are represented.

More than a half of the species are confined in their distribution to the northern part of the Sierra Madre Oriental, in the border region between Coahuila and Nuevo León states, known as MegaCoahuila (Villarreal *et al.*, 1996).
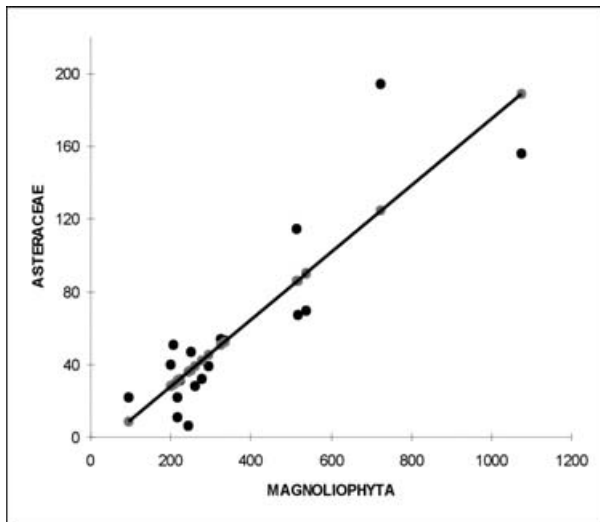
Figure 10 Relation between the total number of species of Asteraceae and the total number of species of Magnoliophyta in the Sierra Madre Oriental ($r = 0.872$, $P < 0.005$). See Table 3 for a list of localities included in the dataset.

The generalized tracks and nodes recognized in this work reflect a complex and common biogeographic history of the species involved and the geological and climatic complexity of the montane eastern part of Mexico. If we overlay our results on the Mexican priority conservation regions (RTPs) (Arriaga *et al.*, 2000) and the areas important for the conservation of birds (AICAs) (Benítez *et al.*, 1999), congruence amongst the nodes is evident. This fact is an interesting one, because the track method has not been commonly applied to identify areas for potential conservation (but see Grehan, 1989; Luna *et al.*, 2000; Álvarez & Morrone 2004). Our results show that track methods are useful tools to determine and characterize megadiverse areas, especially those that contain highly restricted species. This type of study can be used as evidence in support of programmes for preserving complex areas with high species diversity, especially in those cases where species with restricted distributions in fragmented habitats exist, as is the case of the Mexican cloud forests. We suggest that these methods should be included in future conservation programmes, especially because they are cheap and relatively fast to undertake.

Knowledge of the distributional patterns of the species of Asteraceae, as well as the exploration of historical factors that have determined such patterns, provide additional evidence about the composite nature of the biota currently occurring on the Sierra (Luna *et al.*, 1999, 2004). Without doubt, such information has increased and will continue to improve our knowledge to that achieved already with other biological groups. The high correlation that exists between the total number of species of Asteraceae, in relation to the total number of species of Magnoliophyta in the Sierra Madre Oriental, confirms that this family of vascular plants can be considered as a key group in conservation, because it faithfully reflects the biogeographical history of this Mexican floristic province (Table 3 and Fig. 10). This additional evidence may also enable us to propose sounder hy-

potheses that may help to explain the evolution of the eastern Mexican biota.

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