Alberto González-Zamora, Isolda Luna Vega, José Luis Villaseñor & Carlos Alberto Ruiz-Jiménez
1Departamento de Biología Evolutiva, Facultad de Ciencias, UNAM, México
2Instituto de Biología, UNAM, México

submitted February 2005
accepted March 2006

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, 1991a), 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
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, 1996). The endemism for this family in Mexico was calculated as 119 genera and 1300 species (Villaseñor, 1996). The endemism for this family in Mexico was calculated as 119 genera and 1300 species(148,192),(949,842). 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, 1991b), 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

![Figure 1](image-url) 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.
**Tribe** | **Species**
--- | ---
_Cardueae_ | _Cirsium bicentenariale_ Rzed.
_Lactuceae_ | _Hieracium beamanii_ B.L. Turner, _Pinaropappus pattersonii_ B.L. Turner
_Mutisieae_ | _Acoptostegia graciilis_ L. Cabrera, _Acurtia hintoniorum_ B.L. Turner, _Acurtia potosina_ L. Cabrera, _Chaptalia estribensis_ G.L. Nesom, _Chaptalia lyrafolia_ Burkart, _Chaptalia madrensis_ G. L. Nesom

**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_S147720006002192 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 (REMB), 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_S147720006002192 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
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 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
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 zimapanaica*, *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*, *Greemaniliea resinosa*, *Hymenopappus hintoniorum*, *Hymenoxys insignis*, *H. pinetorum*, *Koanophyllum reyrobinsonii*, *Packera hintoniorum*, *P. monereyana*, *Perymenium tamaulipense*, *Senecio platypus*, *Stevia coahuilensis* and *S. potosina*.

3. Pánano 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: *Acoruria hintoniorum*, *Cristinia lozanoana*, *Koanophyllum hintoniorum*, *Loxothysanthes 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: *Archibacharlis venturana*, *Ageratina quertaroana*, *Chaptalia estribensis*, *Cirsium bicentenariale*, *Grindelia inuloides* var. *latamplexa*, *Hieracium beamanii*, *Roldana metepucus*, *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...
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.

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.

### Table 2

<table>
<thead>
<tr>
<th>NODES</th>
<th>RTPs</th>
<th>AICAs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saltillo</td>
<td>Tokio</td>
<td>Pradera de Tokio</td>
</tr>
<tr>
<td>Monterrey</td>
<td>El Potosí-Cumbres de Monterrey</td>
<td>Sierra de Arteaga</td>
</tr>
<tr>
<td>San Antonio Peña Nevada</td>
<td>Tokio-Puerto</td>
<td>San Antonio Peña</td>
</tr>
<tr>
<td>Tamaulipas-Nuevo León</td>
<td>Valle de Jaumave, El Cielo</td>
<td>Nevada</td>
</tr>
<tr>
<td>Pánuco</td>
<td>Cuetzalan</td>
<td>El Cielo (in part)</td>
</tr>
<tr>
<td>Cuetzalan</td>
<td>Cuetzalan</td>
<td>Cuetzalan</td>
</tr>
</tbody>
</table>

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.

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

<table>
<thead>
<tr>
<th>Location</th>
<th>Total number of species of Asteraceae</th>
<th>Total number of species of Magnoliophyta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sierra de Parras, Coahuila (Rodríguez et al., 1994)</td>
<td>629</td>
<td>14</td>
</tr>
<tr>
<td>Saltillo, Coahuila (Villarreal, 2001)</td>
<td>918</td>
<td>194</td>
</tr>
<tr>
<td>Santiago, Nuevo León (Valdez, 1981)</td>
<td>296</td>
<td>47</td>
</tr>
<tr>
<td>Cerro Potosí, Nuevo León (García-Arévalo &amp; González-Elizondo, 1991)</td>
<td>115</td>
<td>22</td>
</tr>
<tr>
<td>Sierra San Carlos, Tamaulipas (Briones, 1991)</td>
<td>387</td>
<td>53</td>
</tr>
<tr>
<td>Gómez Farias, Tamaulipas (Valiente-Banuet et al., 1995)</td>
<td>248</td>
<td>6</td>
</tr>
<tr>
<td>Sierra de Guatemala, Tamaulipas (Johnston et al., 1989)</td>
<td>583</td>
<td>67</td>
</tr>
<tr>
<td>General Zaragoza, Nuevo León (Treviño, 1984)</td>
<td>241</td>
<td>40</td>
</tr>
<tr>
<td>Landa de Matamoros, Querétaro (Cartujano et al., 2002)</td>
<td>607</td>
<td>70</td>
</tr>
<tr>
<td>Sierra Gorda, Querétaro (Arreguín-Sánchez &amp; Fernández, 2004)</td>
<td>123</td>
<td>156</td>
</tr>
<tr>
<td>San Joaquín, Querétaro (Fernández &amp; Colmenero, 1997)</td>
<td>256</td>
<td>51</td>
</tr>
<tr>
<td>Tlanchinol, Hidalgo (Luna et al., 1994)</td>
<td>255</td>
<td>31</td>
</tr>
<tr>
<td>Barranca de Tolantongo, Hidalgo (Hiriart &amp; González, 1983)</td>
<td>287</td>
<td>28</td>
</tr>
<tr>
<td>Tenango de Doria, Hidalgo (Alcántara &amp; Luna, 1997)</td>
<td>379</td>
<td>54</td>
</tr>
<tr>
<td>Molocotlán, Hidalgo (Mayorga et al., 1998)</td>
<td>309</td>
<td>32</td>
</tr>
<tr>
<td>Eloxochitlán and Tlahuelompa, Hidalgo (Alcántara &amp; Luna, 2001)</td>
<td>333</td>
<td>39</td>
</tr>
<tr>
<td>Barranca de Metztitlán, Hidalgo (Villaseñor, unpubl. data)</td>
<td>237</td>
<td>22</td>
</tr>
<tr>
<td>Lolotla, Hidalgo (Ponce et al., 2006)</td>
<td>228</td>
<td>11</td>
</tr>
</tbody>
</table>

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 scoparioidei, Koanophyllum galeahn, Pinarpappus patternsonii, Robbinsecio porphyresthes, Sabazia elata, Senecio patternsonii, 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).
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 mega-diverse 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 hypotheses that may help to explain the evolution of the eastern Mexican biota.

Acknowledgements

Tania Escalante, David Espinosa, Raúl Contreras, Alfredo Bueno and Othón Alcántara kindly made suggestions to this work. Alfredo Colín helped us with the design of some maps. Financial support from projects PAPIIT IN206202 and FOSEMARNAT-2004–01-311 is appreciated.

References


FISCHER, M.P. & JACKSON, P.B. 1999. Stratigraphic controls on de-
formation patterns in fault-related folds: a detachment fold ex-
dample from the Sierra Madre Oriental, northeast Mexico. Journal
of Structural Geology 21, 613–633.
GARCÍA-ARÉVALO, A. & GONZÁLEZ-ELIZONDO, S. 1991. Flora y ve-
getación de la cima del Cerro Potosí, Nuevo León, México. Acta
Botanica Mexicana 13, 53–74.
GREHAN, J.R. 1989. Panbiogeography and conservation science in
GREHAN, J.R. 1993. Conservation biogeography and the biodiver-
sity crisis: a global problem in space/time. Biodiversity Letters 1, 134–
140.
HALFFTER, G. 1987. Biogeography of the montane entomofauna of
Mexico and Central America. Annual Review of Entomology 32,
95–114.
1891.
HIRIART, P. & GONZÁLEZ, F. 1983. Vegetación y fitogeografía de la
Barranca de Tolutango, Hidalgo, México. Anales del Instituto de
Biolología, Universidad Nacional Autónoma de México, Serie
Botánica 54, 29–96.
Listado de plantas vasculares conocidas de la Sierra de Guatemala,
Gómez Farías, Tamaulipas, México. Biota 1, 21–53.
LIEBHERR, J.K. 1991. A general area cladogram for montane Mex-
ican biota. Historical Relationships of the Mexican cloud forests:
a preliminary vicariance model applying parsimony analysis of endemi-
city to vascular plant taxa. Journal of Biogeography 26, 1299–
1305.
biogeográficas del bosque mesófilo de montaña del municipio de
Tlanchinol, Hidalgo, México. Anales del Instituto de Biología,
Universidad Nacional Autónoma de México, Serie Botánica 65,
31–62.
Historical relationships of the Mexican cloud forests: a prelimi-
nary vicariance model applying parsimony analysis of endemi-
city to vascular plant taxa. Journal of Biogeography 26, 1299–
1305.
Track analysis and conservation priorities in the cloud forests of
Hidalgo, México. Diversity and Distributions 6, 137–143.
Sierra Madre Oriental. CONABIO, Facultad de Ciencias, UNAM, México.
LIEBHERR, J.K. & LIEBHERR, J.K. 2000. Cladistic biogeography of
the Mexican transition zone. Journal of Biogeography 27, 203–
216.
MARTÍN, P.S. & HARRELL, B.E. 1957. The Pleistocene history of
temperate biotas in Mexico and eastern United States. Ecology 38,
467–480.
mesófilo de montaña de Molocotlán, Molango-Xochicoatlán,
Hidalgo, México. Boletín de la Sociedad Botánica de México 63,
101–119.
MERRONE, J.J. 2001. Homology, biogeography and areas of endem-
ism. Diversity and Distributions 7, 297–300.
y panbiogeográficos en la conservación de la diversi-
The Environmentalist 8,187–208.
MYERS, N., MITTERMEIER, R.A., MITTERMEIER, C.G., DA FONSECA,
priorities. Nature 403, 853–858
RONE, J.J. & ESPINOSA, D., Eds., Biodiversidad de la Sierra Madre
Oriental. CONABIO, Facultad de Ciencias, UNAM, México,
pp. 25–62.
Vegetación del bosque de montaña de Monte Grande, munici-
pio de Lolotla, Hidalgo, México. Revista Mexicana de Biodi-
RZEDOWSKI, J. 1991a. El endemismo en la flora fanerógamica mexi-
icana: una apreciación analítica preliminar. Acta Botánica Mexicana
15, 47–64.
RZEDOWSKI, J. 1991b. Diversidad y orígenes de la flora fanerógamica
RZEDOWSKI, J. 1996. Análisis preliminar de la flora vascular de los
bosques mesófilos de montaña de México. Acta Botánica Mexi-
cana 35, 25–44.
SECRETARÍA DEL MEDIO AMBIENTE Y RECURSOS NATURALES.
ambiental-Especies nativas de México de flora y fauna silvestres:
Categorías de riesgo y especificaciones para su inclusión, ex-
clusión o cambio-Lista de especies en riesgo. México.
SMITH, H.M. 1941. Las provincias bióticas de México según la dis-
tribución geográfica de las lagartijas del género Sceloporus. Anales de la Escuela Nacional de Ciencias Biológicas 10, 103–110.
TOLEDO, V.M. 1982. Pleistocene changes of vegetation in tropical
México. In: FRANCE, G.T., Eds., Biological diversification in the
TREVISÓN, E.J. 1984. Contribución al conocimiento de la vegetación
del municipio de General Zaragoza, Nuevo León, México. Thesis,
Facultad de Ciencias Biológicas, Universidad Autónoma de Nuevo
León, México.
TURNER, B.L. & NESOM, G.L. 1998. Biogeografía, diversidad y
situación de peligro o amenaza de Astereaceae de México. In:
RAMAMOORTHY, T.P., BYE, R., LOT, A. & FA, J., Eds., Diver-
sidad biológica de México: Orígenes y distribución. Instituto de
VALDEZ, J.V. 1981. Contribución al conocimiento de los tipos de ve-
getación, su cartografía y notas florístico-ecológicas del municipio
de Santiago, Nuevo León, México. Thesis. Facultad de Ciencias
Biológicas, Universidad Autónoma de Nuevo León, México.
VÁLENTE-BANUET, A., GONZÁLEZ, F. & PIÑERO, D. 1995. La vegeta-
tación selvática de la región de Gómez Farías, Tamaulipas, México.
Acta Botánica Mexicana 33, 1–36.
cit. Naturalistas de México XXIII. Instituto de Biología, UNAM, México.
de las asteráceas de Coahuila, México. Acta Botánica Mexicana
36, 29–42.
VILLASEÑOR, J.L. 1990. The genera of Asteraceae endemic to Mexico
and adjacent regions. Aliso 12, 685–692.
VILLASEÑOR, J.L. 1991. Las Heliantheae endémicas a México: una
VILLASEÑOR, J.L. 2003. Diversidad y distribución de las Magnolio-
conservation of Asteraceae in Mexico. Conservation Biology
12, 1066–1075.