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BIODIVERSITY RESEARCH

Track analysis and conservation priorities in the cloud forests of Hidalgo, Mexico

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Abstract. A track analysis based on the distributional patterns of 967 species of vascular plant taxa (gymnosperms, angiosperms and pteridophytes) was performed to assess conservation priorities for cloud forests in the state of Hidalgo, Mexico, ranged in the municipalities of Chapulhuacán, Eloxochitlán, Molocotlán, Pisaflores, Tenango de Doria, Tlahuelompa and Tlanchinol, as well as five floristically equivalent areas in the states of Veracruz (Teocelo and Helechales), Tamaulipas (Gómez Farías), Morelos-México (Ocuilan) and Oaxaca (Huautla de Jiménez). In order to detect generalized tracks we employed a new parsimony method, where clades (considered equivalent to generalized tracks) are defined forbidding homoplasy and acting like a compatibility algorithm. Several generalized tracks were found connecting these areas. Cloud forests of Chapulhuacán were connected according to three different generalized tracks and thus have a higher value, qualifying as a priority area for the conservation of cloud forests in the state of Hidalgo.

Key words. Cloud forests, conservation, Mexico, planning, tracks.

INTRODUCTION

Mexican cloud forests (*bosques mesófilos de montaña*, *sensu* Rzedowski, 1978, 1996), situated between 600 and 3000 m of elevation (Luna *et al.*, 1988), exhibit a highly fragmented distributional pattern that is increased by the heavy deforestation and agricultural exploitation rate (Luna *et al.*, 1989, 1994; Dirzo, 1992). Historically, this distributional pattern has determined that each of the forest patches has a different floristic composition, making them particularly interesting from a biogeographic viewpoint (Luna *et al.*, 1994; Vázquez-García, 1995).

The state of Hidalgo ranks third among the Mexican states in the extent of cloud forest habitats (Ortega & Castillo, 1996). These forests occur at elevations of 750–2400 m in the municipalities of Tlanchinol, Tenango de Doria, Chapulhuacán, Eloxochitlán, Zacualtipán, Molango, Xochicoatlán, Pisaflores, San Bartolo Tutotepec, Agua Blanca, Calnali, La Misión and Tepehuacán de Guerrero. They harbour an extraordinary mixture of threatened plant and animal species that are poorly known by the conservation community. The FCME Herbarium contains a collection of 5500 vascular plant specimens from Mexican cloud forests, the majority of which is identified to the specific level. A preliminary floristic list of the cloud forests of Hidalgo includes 967 species, assigned to 496 genera and 145 families (Table 1).

Panbiogeography is a biogeographical approach that attempts to reintroduce and re-emphasize the importance of the spatial or geographical dimension of biodiversity for the understanding

Table 1 Abundance of plant vascular taxa in the cloud forests of Hidalgo

Family	%	Species number
Asteraceae	11.06	107
Solanaceae	4.65	45
Fabaceae	4.55	44
Orchidaceae	4.14	40
Poaceae	3.10	30
Rubiaceae	2.99	29
Labiatae	2.58	25
Euphorbiaceae	2.38	23
Fagaceae	2.27	22
Melastomataceae	2.27	22
Rosaceae	2.17	21
Polypodiaceae	2.17	21
Aspleniaceae	2.06	20
Other families	53.5	518

of evolutionary patterns and processes (Craw *et al.*, 1999). While phylogenetic analyses are applied widely in comparative biology, the spatial component of evolution is usually neglected in understanding the historical structure of biotic systems. Some authors have proposed the application of panbiogeographic or track methods to identify priority areas for biodiversity conservation (Morrone & Crisci, 1992; Grehan, 1993; Morrone & Espinosa, 1998; Morrone, 1999). These methods require mapping localities of different taxa and connecting them with line graphs (individual tracks), according to their minimal geographical proximity. Summary tracks resulting from the geographical coincidence of different individual tracks are considered generalized tracks, that indicate the pre-existence of ancestral biotas that were fragmented in the past due to tectonic and/or climates changes. Areas where two or more generalized tracks intersect are named nodes, and represent the spatial and temporal interrelationships of different biotic and geological components (Morrone & Crisci, 1995). These nodes would be particularly important for the purposes of conservation because they contain biotic elements from different origins – thus qualifying as 'hot spots' – and allow us to protect areas taking into account not only the number of species, but the degree of difference between the biotas overlapping on them (Morrone & Crisci, 1992; Craw *et al.*, 1999).

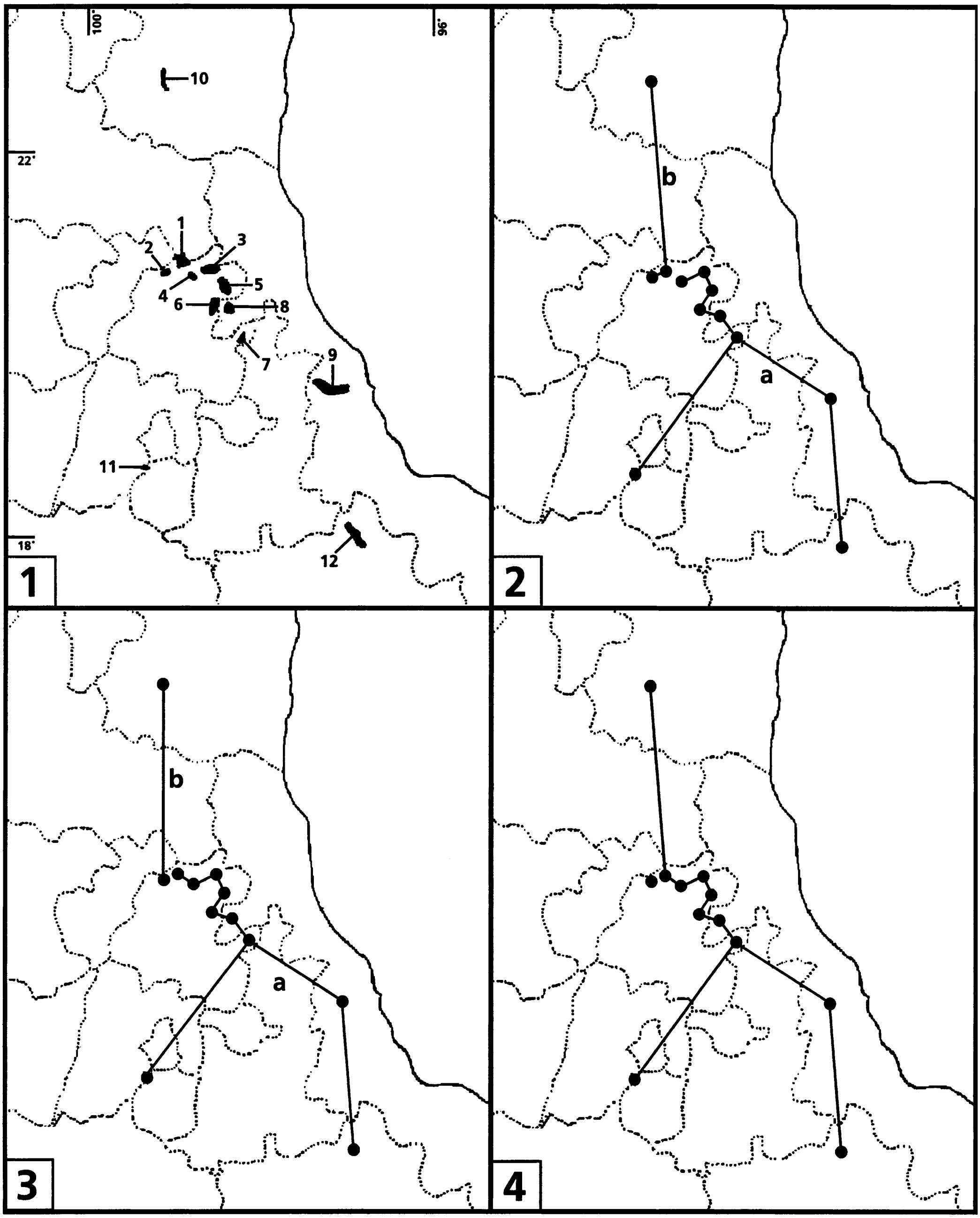
Our aim is to apply a track analysis to the vascular plant species inhabiting the cloud forests of Hidalgo and some floristically equivalent areas to establish conservation priorities for these areas.

MATERIALS AND METHODS

Data from 967 species of vascular plants (gymnosperms, angiosperms and pteridophytes) were obtained from published floristic surveys (de Ballesteros, 1986; Luna *et al.*, 1988, 1989, 1994; Puig, 1989; Ruiz, 1995; Alcántara & Luna, 1997; Mayorga *et al.*, 1998) and unpublished sources (Luna & Alcántara, in preparation). The complete list is available through e-mail upon request to the first author (ilv@hp.fciencias.unam.mx). The list was checked carefully to assess the plant diversity and detect synonyms to avoid possible mistakes, by consulting the relevant literature or communication with specialists.

The units of analysis were seven cloud forest patches from Hidalgo (Fig. 1); we excluded from the analysis some minor and very disturbed patches. In addition, we selected five 'external' localities from the states of Veracruz, Tamaulipas, Oaxaca, Morelos and México, based on their geographical proximity and because they represent this vegetation type in the Sierra Madre Oriental and the Mexican Transvolcanic belt.

Taxa were coded for their absence (0) or presence (1) in each area in the data matrix. In order to detect generalized tracks we employed a new parsimony method that we propose here. Clades (considered equivalent to generalized tracks) are defined forbidding homoplasy and acting like a compatibility algorithm. The cladistic analysis was carried out with the heuristic search option in PAUP Version 4 (Swofford, 1999), setting Goloboff fit criterion (Goloboff, 1993) to $k = 0$. Cladograms were rooted with an hypothetical area coded zero for all taxa. An iterative procedure was followed where, each time a cladogram was obtained, the species defining the clades (synapomorphies) were deleted and a new run undertaken, thus allowing alternate clades to be found. The cladograms obtained in each run were converted into generalized tracks, by joining together by their minimal geographical distance the areas included in the same clade. For examples of the species defining the tracks see Table 2.



Figs 1–4 Fig. 1, maps of Mexico showing the cloud forests analysed in the study. Hidalgo: 1 = Chapulhuacán; 2 = Pisaflores; 3 = Tlanchinol; 4 = Eloxochitlán; 5 = Molocotlán; 6 = Tlahuelompa; 7 = Tenango de Doria. Veracruz: 8 = Helechales; 9 = Teocelo. Tamaulipas: 10 = Gómez Farías. Morelos-México: 11 = Ocuilan. Oaxaca: 12 = Huautla de Jiménez. Figs 2–4, generalized tracks obtained in the study.

Table 2 Generalized tracks and examples of species defining them

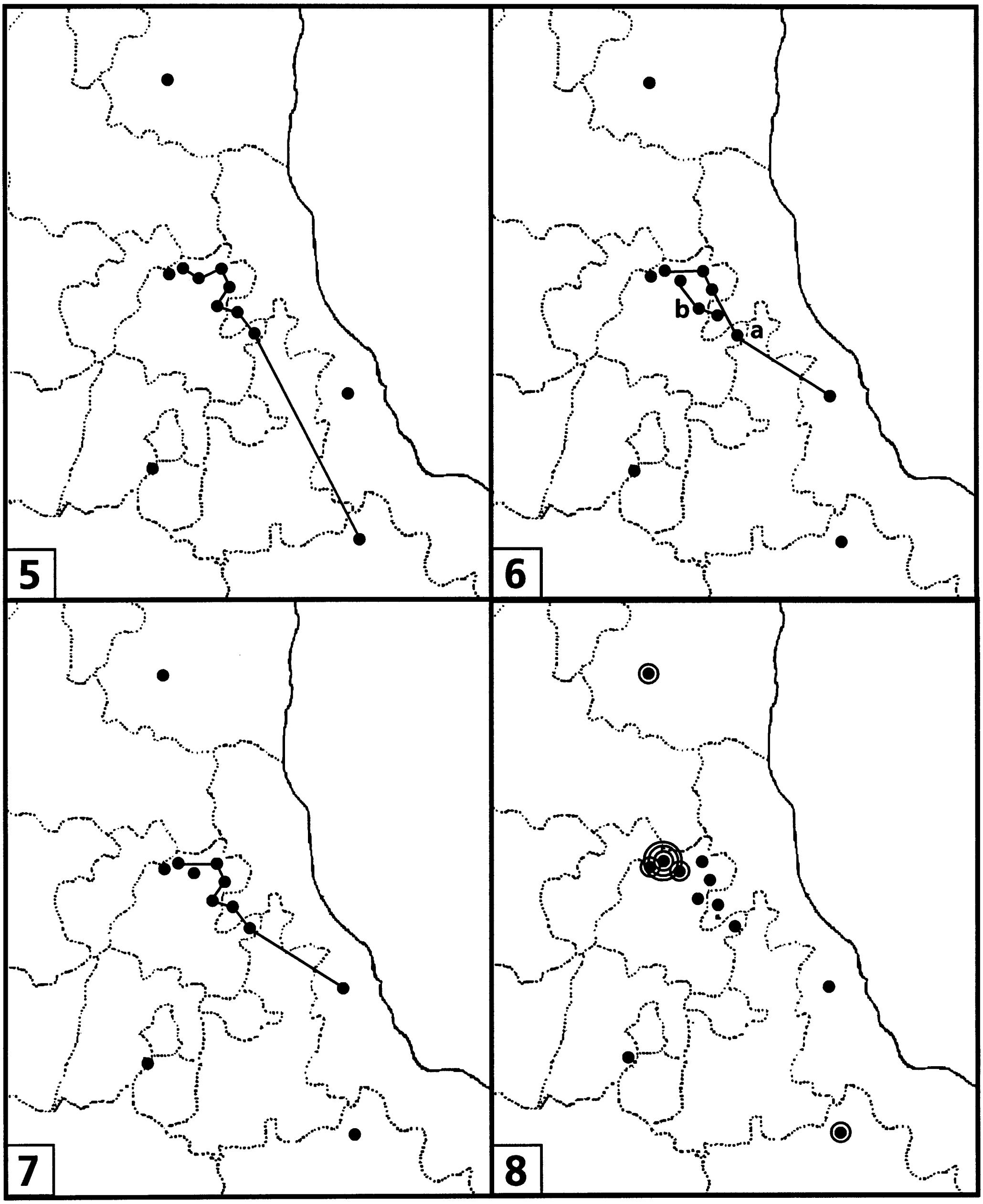
Track	Total of species involved	Examples
2a	70	*Clethra mexicana* A.DC.
		Ageratina ligustrina (DC.) R.M. King et H.Rob.
2b	10	*Quercus rysophylla* Weath.
		Guazuma ulmifolia Wedd.
3a	42	*Oreopanax xalapensis* (Kunth) Decne. et Planch.
3b	2	*Euphorbia heterophylla* L.
		Celtis iguanaea (Jacq.) Sarg.
4	40	*Sambucus mexicana* C. Presl ex DC.
		Carpinus caroliniana Walter (except to Huautla)
5	19	*Solanum appendiculatum* Dunal
6a	15	*Smilax mollis* Humb. et Bonpl. ex Willd.
		Palicourea padifolia (Willd. ex Roem. et Schult.) C.M. Taylor
6b	5	*Aporocactus flagriformis* (Zucc.) Lem.
7	26	*Fleischmannia pycnocephala* (Less.) R.M. King et H. Rob.
		Campyloneurum angustifolium (Sw.) Fée

RESULTS AND DISCUSSION

Analysis of the original data matrix (Table 1) yielded a single most parsimonious cladogram (1796 steps, CI = 0.54, RI = 0.41). The two main clades in the cladogram (a and b) were mapped as generalized tracks (Fig. 2). The second analysis was performed deleting the species defining tracks a and b, and yielded a single most parsimonious cladogram (1671 steps, CI = 0.53, RI = 0.36). The two main clades in the cladogram (a and b) were mapped as generalized tracks (Fig. 3). The third analysis was performed deleting the species defining the previous tracks, and yielded a single most parsimonious cladogram (1596 steps, CI = 0.53, RI = 0.34). The largest clade in the cladogram was mapped as a generalized track (Fig. 4), leaving one isolated locality (Pisaflores). The fourth analysis yielded a single most parsimonious cladogram (1528 steps, CI = 0.53, RI = 0.32), where only one clade is recognized and mapped as a generalized track (Fig. 5), leaving four isolated localities (Gómez Farías, Pisaflores, Teocelo and Ocuilan). The fifth analysis was performed deleting the species defining the previous tracks, and yielded a single most parsimonious cladogram (1460 steps, CI = 0.54, RI = 0.34). The two main clades in the cladogram (a and b) were mapped as generalized tracks (Fig. 6), leaving four isolated localities (Huautla, Ocuilan, Gómez Farías and Pisaflores). The sixth analysis was performed deleting the species defining the previous tracks, and yielded a single most parsimonious cladogram (1460 steps, CI = 0.52, RI = 0.29), where only one clade was mapped as a generalized track (Fig. 7), leaving five isolated localities (Huautla, Ocuilan, Eloxochitlán, Gómez Farías and Pisaflores).

Comparing the different generalized tracks obtained, we found that Chapulhuacán is a panbiogeographic node according to three different connections between generalized tracks; and Huautla de Jiménez, Gómez Farías, Eloxochitlán and Pisaflores are panbiogeographic nodes according to one connection between generalized tracks (Fig. 8). For this reason, Chapulhuacán turned out to be the most important area for conservation because it has different biotic affinities, so it should have the first priority when protecting the cloud forests of Hidalgo. It is interesting to note that Chapulhuacán harbours a relict population of *Magnolia dealbata*, which is also present in one locality of Veracruz and another in Querétaro.

Even though the cloud forests of Hidalgo hold high numbers of endemic species (e.g. *Bouvardia martinezii*, *Carya palmeri*, *Ceratozamia mexicana*, *Cyathea mexicana*, *Dalbergia palo-escrito*, *Deppea hernandezii*, *D. microphylla*, *Elaphoglossum obscurum*, *Juglans mollis*, *Magnolia schiedeana*, *M. dealbata* and *Tibouchina galeottiana*), as well as species with highly restricted distributional



Figs 5–8 Figs 5–7, generalized tracks obtained in the study. Fig. 8, localities surrounded by circles with their diameters proportional to the number of nodes; Chapulhuacán, with three concentric circles, has the higher value; Huautla de Jiménez, Gómez Farías, Eloxochitlán, and Pisaflores, with one circle, follow it.

patterns in Mexico (e.g. *Fagus mexicana*, *Illicium floridanum*, *Nyssa sylvatica* and *Schizandra glabra*), there are no protected areas including this habitat. None of the cloud forests of Hidalgo is currently under official protection (Challenger, 1998). If protected areas are planned in a future for the cloud forests of Hidalgo, Chapulhuacán should be considered as a priority area, because it includes species from different ancestral biotas. A belt of endemic species can be detected in the Huasteca region, which includes Tlanchinol, Eloxochitlán, Molocotlán, Tlahuelompa, Helechales and Tenango de Doria, that agrees with the proposal of the Comisión Nacional para el Estudio y Uso de la Biodiversidad (Conabio), that the regions 'Cañones y Afluentes del Pánuco' and 'Tlanchinol', where these areas are localized, should be considered as a priority for conservation based on their species richness, endemicity and habitat fragility. Williams & Humphries (1994), however, have argued convincingly that endemicity is a measure of distribution range and does not constitute an appropriate surrogate for measuring biodiversity.

From the perspective of biodiversity conservation, biogeography can (and should) play a key role (Morrone & Espinosa, 1998). Instead of the species-richness criterion, which considers that all species are equivalent, track methods measure the distinctiveness among biotas, weighting those areas with representatives of different ancestral biotas. In addition there are other analyses, e.g. phylogenetic indices or complementarity, that would help elucidate this problem (Morrone & Crisci, 1992; Morrone, 1999). The track approach allows conservationists to integrate distributional data efficiently, which could be a complement to the other methods. Furthermore, implementation of biogeographic atlases (Morrone & Espinosa, 1998) can help to develop in the population an understanding of the interrelationship between biology, geology, history and conservation. The biodiversity crisis is far from being a simple matter, and different approaches should be applied and tested in order to allow its appropriate conservation.

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