*Biodiversity and Conservation* **9**: 403–418, 2000.


# Diversity, geographical distribution, and conservation of Cactaceae in the Mier y Noriega region, Mexico

CARLOS GÓMEZ-HINOSTROSA and HÉCTOR M. HERNÁNDEZ*
*Departamento de Botánica, Instituto de Biología, UNAM, Apartado Postal 70-233, 04510 Mexico, DF;*
**Author for correspondence (fax:(525) 616-2326; e-mail: hmhm@servidor.unam.mx)*

Received 2 December 1998; accepted in revised form 23 July 1999

**Abstract.** We carried out an inventory of the cactus species occurring in the Mier y Noriega region. The study was conducted in a square-shaped area of approximately 2845 km$^2$, located in the southeastern segment of the Chihuahuan Desert region, between $23°00'-23°30'$ lat. N and $100°00'-100°30'$ long. W, including parts of the states of Nuevo León, Tamaulipas, and San Luis Potosí, Mexico. In order to know the cactus diversity, we developed an intensive method of botanical collecting; a total of 80 sites were sampled. With 54 species recorded, of which 28 were new area records and 14 new state records, the Mier y Noriega region is considered moderately rich in cactus species. Cactus diversity is distributed unevenly in the area, and the greatest species concentration occurs in its southwestern portion. The analysis of geographical distribution of individual species showed that the highest proportion (82%) are endemic to the Chihuahuan Desert Region, six of them having extremely narrow distributions. In addition, 19 species are considered endangered. With the aid of a complementarity analysis, we propose a strategy for the optimal conservation of the species and their habitats.

**Key words:** cactus diversity and conservation, Chihuahuan Desert, distribution, endemism, Mexico

## Introduction

More than half of the Mexican territory is arid or semi-arid. In these regions, plants have undergone a deep evolutionary process resulting in a wide variety of specialized life forms and a relatively rich flora (Rzedowski 1991). The Cactaceae is one of the more diagnostic plant families in the Mexican arid lands. According to the most recent taxonomic framework (Hunt 1992), Mexico includes 48 genera and about 570 species. In previous papers (Hernández and Godínez 1994; Hernández and Bárcenas 1995, 1996) it was suggested that the Chihuahuan Desert Region is the main center of distribution of Mexican cacti. Secondary centers are in the Sonoran Desert (Sonora, Baja California and Baja California Sur), in the Tehuacán and Cuicatlán Valleys (Puebla and Oaxaca), in the Mixtec Region (Puebla and Oaxaca), in the southern extreme of the Tehuantepec Isthmus (Oaxaca), and in the Balsas Basin (Guerrero and Michoacán).

The Cactaceae family in Mexico is outstanding for its high rate of endemicity. It has been estimated (Hernández and Godínez 1994) that 73% of the genera and 78%

of the species are endemic to this country. In addition, one third of the total number of species are considered endangered. In fact, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 1990) includes the whole family in its Appendix 2 and a considerable number of cactus species (ca. 64 spp.) are listed in Appendix 1. Moreover, the International Union for Conservation of Nature includes in the Red List of Threatened Plants (Walker and Gillett 1998) 286 species of Mexican cacti, and Mexico's conservation agency, Secretaría del Medio Ambiente, Recursos Naturales y Pesca includes 257 species in its Norma Oficial Mexicana 059 (SEDESOL 1994).

Hernández and Bárcenas (1995) studied the distribution patterns of endangered cacti in the Chihuahuan Desert Region. In that study the region was divided into 30-minute latitude × 30-minute longitude grid squares and species richness was calculated for each area unit. The primary sources of information were a Database of Cactus Collections from North and Central America (Hernández et al. 1993) and an extensive plan of fieldwork throughout the region. The results of that study showed that the grid squares with the highest number of species were aggregate in areas of moderate altitude, towards the eastern and southeastern segments of this desert region, primarily where northern San Luis Potosí and the southern fragments of Coahuila, Nuevo León and Tamaulipas come together. This is the region which Hernández and Bárcenas (1995) suggested as the most important nucleus of endangered cactus species in Mexico. Within this area, the richest grid squares in endangered species, named according to the largest or best known town, were the Huizache, Mier y Noriega, Doctor Arroyo, Matehuala, and Cuatro Ciénegas grid squares. Despite the clear importance of these area units for conservation, it is unfortunate that they are still very poorly known in terms of their cactus diversity and distribution.

Consequently, it is imperative to conduct botanical investigations in these areas, in order to improve our understanding of the family. In this paper we report the results of a research project aimed at learning the diversity and several biogeographical parameters of the Cactaceae in the Mier y Noriega grid square. In addition, we make a proposal based upon a complementarity analysis (Hernández and Bárcenas 1996), for the optimal conservation of the species and their habitats.

## Study area

The studied area is a square-shaped polygon of approximately 2845 km$^2$, located within the Chihuahuan Desert Region (Henrickson and Straw 1976), where the states of San Luis Potosí, Nuevo León, and Tamaulipas come together. It is limited by parallels 23°00′ N – 23°30′ N and meridians 100°00′ W – 100°30′ W (Figure 1). The physiography, geology, climate, and vegetation of the area were thoroughly described by Gómez-Hinostrosa (1998), and only a few general details are outlined here.

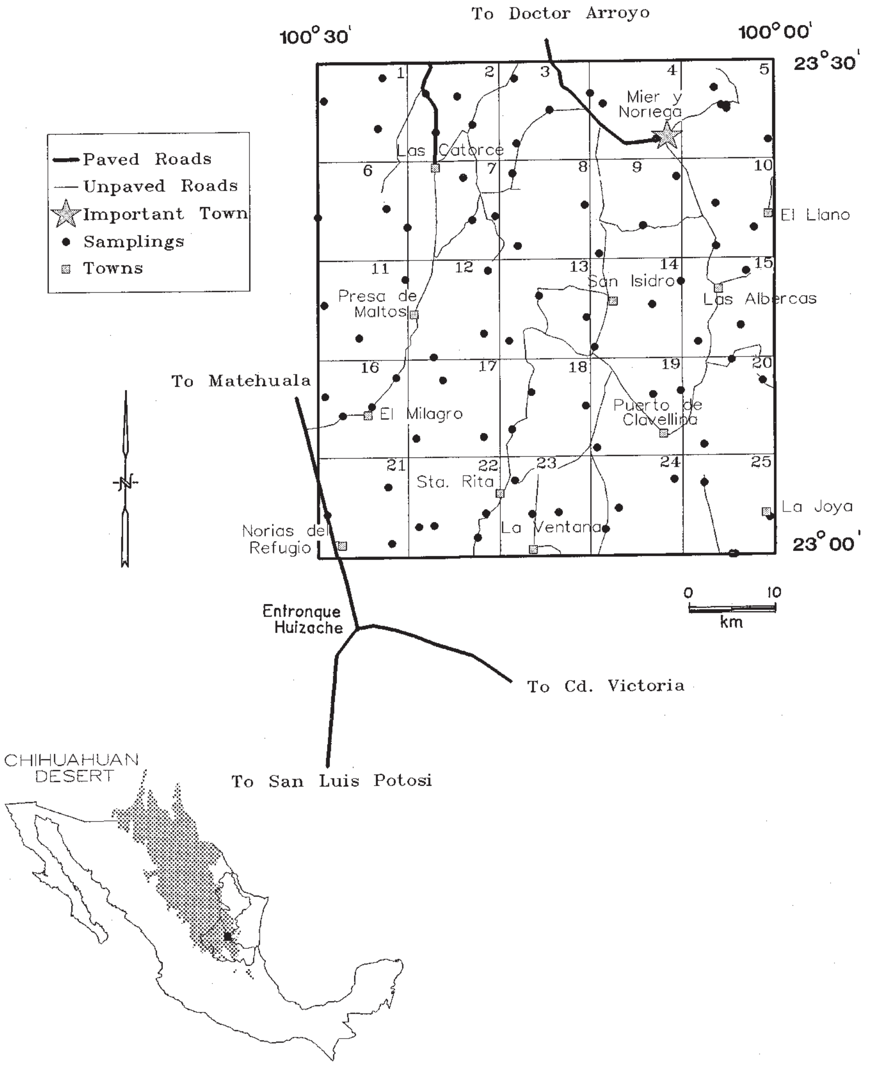


*Figure 1.* Location of the Mier y Noriega grid square. Solid dots indicate sampled localities.

The area is part of the Mexican Plateau physiographic province; however, its extensive valleys, whose altitudes range from 1200 to 1600 m, are dissected by several branches of the Sierra Madre Oriental, most of which have a north–south orientation. The most prominent of these is a complex formed by several smaller mountain ranges known as El Tizu, La Peña, and Las Narices, with maximum altitudes reaching 2490 m. Geologically, the Mier y Noriega area is primarily constituted by Upper Cretaceous limestone and by recent alluvial deposits, the latter covering the lowland valleys and the lower slopes of the mountain valleys. The dominant climate type is arid, semi-hot ($BS_0$) following García's (1988) classification. Mean annual precipitation, which varies from about 300 mm in the valleys to slightly above 500 at higher elevations, is mostly concentrated in the summer. The mean annual temperature is 20 °C.

The area is predominantly covered by xerophytic scrub, usually known as Chihuahuan Desert scrub. Typically, a microphyllous scrub of *Larrea divaricata*, *Prosopis juliflora*, *Flourensia* sp., *Celtis* sp., *Opuntia* spp., *Yucca* spp., etc. dominates the valley bottoms and the lower parts of the alluvial fans. In contrast, a rosetophyllous scrub of *Agave lecheguilla*, *A. striata*, *Hechtia glomerata*, *Opuntia stenopetala*, *Euphorbia antisyphilitica*, *Jatropha dioica*, *Yucca* spp., *Dasylirion* spp., *Nolina* sp., *Fouquieria splendens*, *Karwinskia mollis*, etc. develops on the slopes at higher altitudes (Rzedowski 1956). In addition, at the highest elevations small patches of other vegetation types, such as chaparral, juniper, oak, and pine woodlands, exist in the area.

## Methods

### *Fieldwork*

In order to follow a systematic strategy for sampling, the Mier y Noriega grid square was subdivided into 25 sub-squares measuring each six minutes latitude by six minutes longitude. In each sub-square, an average of three localities were intensively and extensively sampled for cactus species (Figure 1). The selection of the sites was determined by the presence of well preserved, natural vegetation. Highly disturbed sites were avoided.

Eighty sites were sampled and georeferenced using GPS technology. A total of 1283 cactus specimens were incorporated into the National Herbarium of Mexico (MEXU) and the information added to the Database of Cactus Collections from North and Central America (Hernández et al. 1993). This database, which currently contains over 20,000 records, was the source of information for this study.

### *Index of Geographical Expansion*

In order to obtain a quantitative measure of their range size, we calculated an Index of Geographical Expansion (IGE) for each of the cactus species found in the area. To reach this goal, we divided the Mexican Republic into 30-minute latitude by 30-minute longitude grid squares. A total of 3734 records from the database were used to determine the presence or absence of the species in each grid square. This same information was used to generate the distribution maps, employing the geographical information system CAMRIS (The Computer Assisted Resource Inventory System, Ecological Consulting, Inc.). The species of *Opuntia* and *Stenocactus* were excluded from this analysis, as knowledge of their geographical distribution is incomplete.

The IGE was calculated according to the formula IGE = Ss/Sm, where Ss is the number of grid squares from which the species has been recorded and Sm the number of grid squares occupied by the species with the most extensive geographical range. *Myrtillocactus geometrizans* and *Mammillaria heyderi*, both recorded in 40 grid squares, turned out to be the species with the widest distribution range, and consequently were used as reference for the calculation of the index. Thus, highly restricted species such as *Turbinicarpus subterraneus*, which has only been recorded in two grid squares, has an IGE = 0.05. In contrast, *Echinocactus platyacanthus*, which is distributed in 31 grid squares, primarily in the Chihuahuan Desert Region, has an IGE = 0.78. It is important to emphasize that the IGE's were calculated considering the whole distribution range of the species.

*Analysis of complementarity*

The complementarity principle has been used to define priorities to optimize the conservation of biodiversity in specific areas (Humphries et al. 1991; Williams et al. 1991; Pressey et al. 1993; Hernández and Bárcenas 1996). The principle is based upon the identification of a first priority area, which is defined by having the highest number of species. The additional areas are ordered as second, third priority, etc., according to their contribution of additional species not found in the areas of higher priority.

The 25 sub-squares dividing the Mier y Noriega grid square were analyzed by using this method. The complementarity values were calculated according to the formula CV = RC $\times$ 100/CO, where CV is the percentage of complementarity, RC the residual complement, and CO the complement. The complement is defined as the total number of species in the Mier y Noriega grid square (CO = 54 species), whereas the residual complement is the number of species not present in the first priority sub-square or in sub-squares with higher priorities.

## Results and discussion

*Diversity*

A total of 54 species of Cactaceae were recorded in the Mier y Noriega grid square (Appendix 1). Figure 2 shows the cumulative number of species recorded in the course of the 80 samplings. The fact that the curve becomes nearly asymptotic suggests that the collecting method was highly effective, and that the number of species recorded corresponds with those actually occurring in the area.

According to the database, at the beginning of the study only 26 cactus species were known to occur in the area, and 28 new area and 14 new state records resulted from fieldwork. Moreover, in addition to the 10 endangered species reported by

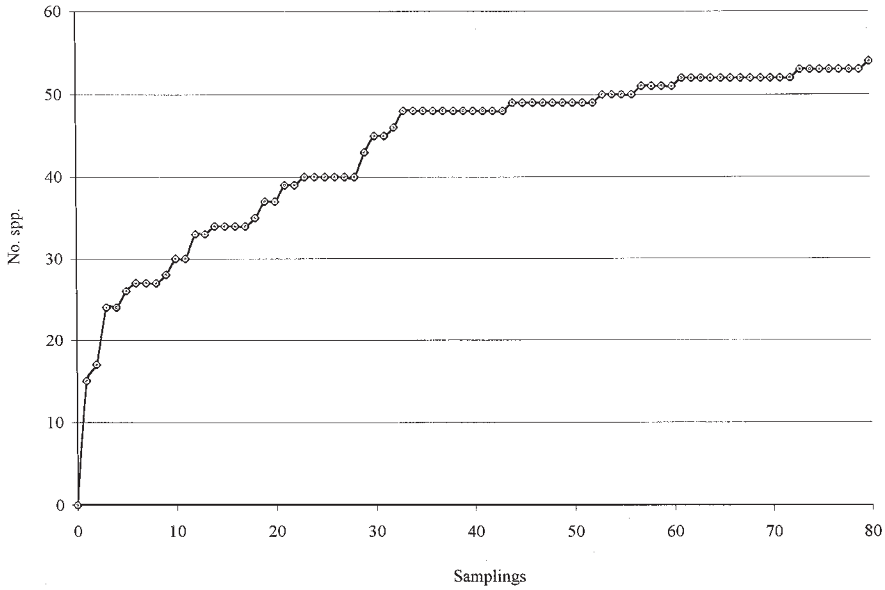


*Figure 2.* Curve of species accumulation. Samplings are ordered chronologically.

Hernández and Bárcenas (1995) to the Mier y Noriega grid square, nine additional ones were detected in the course of this study. Appendix 1 lists the species found in the area; the endangered species, as well as the new area and state records are indicated. Cultivated species (e.g., *Opuntia* spp., *Pachycereus marginatus*, etc.) were excluded from the list. It is important to mention that in this paper we are using the term 'endangered' in a generic sense, so that in Appendix 1 we adopted, with a few modifications, the opinions established in the most accepted lists of endangered species (CITES 1990; SEDESOL 1994; Walker and Gillett 1998). A thorough analysis of the conservation status of the Cactaceae living in the southern portion of the Chihuahuan Desert will be published in the near future; in this assessment, data (e.g., regional frequency and local abundance) from Mier y Noriega and several other nearby regions will be integrated.

In Figure 3 we compare the species richness found in the Mier y Noriega grid square with that of several other relatively well known areas. It is interesting to notice that if we take into account only the regions of comparable size, Mier y Noriega has a richer assemblage of cactus species than Mapimí (30 spp.; Cornet 1985; Ruiz de Esparza 1988), San Luis de la Paz (33 spp.; Bárcenas 1999), La Paila (44 spp.; Villarreal 1994), Cuatro Ciénegas (48 spp.; Pinkava 1984), etc. It is surpassed only by Xichú (56 spp.; Bárcenas 1999) and Huizache (74 spp.; Hernández et al., unpub.). The Tehuacán Valley has the highest number of species (76 spp.; Arias et al. 1997); however, its area (10,000 km$^2$) is more than three times larger than either Mier y Noriega, Xichú, or Huizache (Figure 3). Also, the Mier y Noriega grid square has a

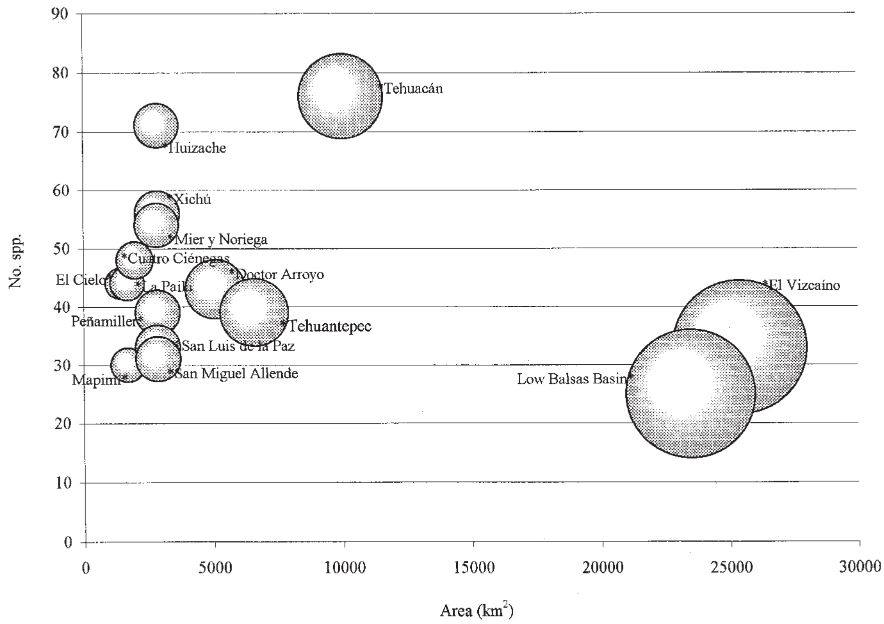


*Figure 3.* Species richness of Cactaceae in several Mexican regions. The diameter of the spheres is proportional to the region's area size.

considerable higher number of cactus species than much larger areas such as the Low Balsas Basin (25 spp.; Castillo et al. 1983) or El Vizcaíno (33 spp.; León et al. 1995).

*Local distribution pattern*

Figure 4 shows the differences in species richness among the 25 sub-squares dividing the Mier y Noriega grid square. The maximum concentration of species occurs in the southwestern segment of the grid square, particularly in sub-squares 17 and 22. Additional areas with a relatively high number of species correspond to sub-squares 3,11,12, 16, 20, and 25. The remaining sub-squares have between 20 and 25 cactus species, and no areas of really low species richness occur in Mier y Noriega.

Although our knowledge about the climatic and other ecological patterns in Mier y Noriega is scarce and fragmentary, there appears to be a correlation between high species richness and low precipitation. The southwestern portion of the grid square, which holds the richest species assemblage, coincides with the area of lowest precipitation (Figure 4). In contrast, sub-squares 5 and 9, containing the lowest number of species, receive the maximum precipitation of the area.

*Index of Geographical Expansion*

The degree of geographical expansion of particular species has been used, together with several other geographical and ecological parameters, to assess their degree of

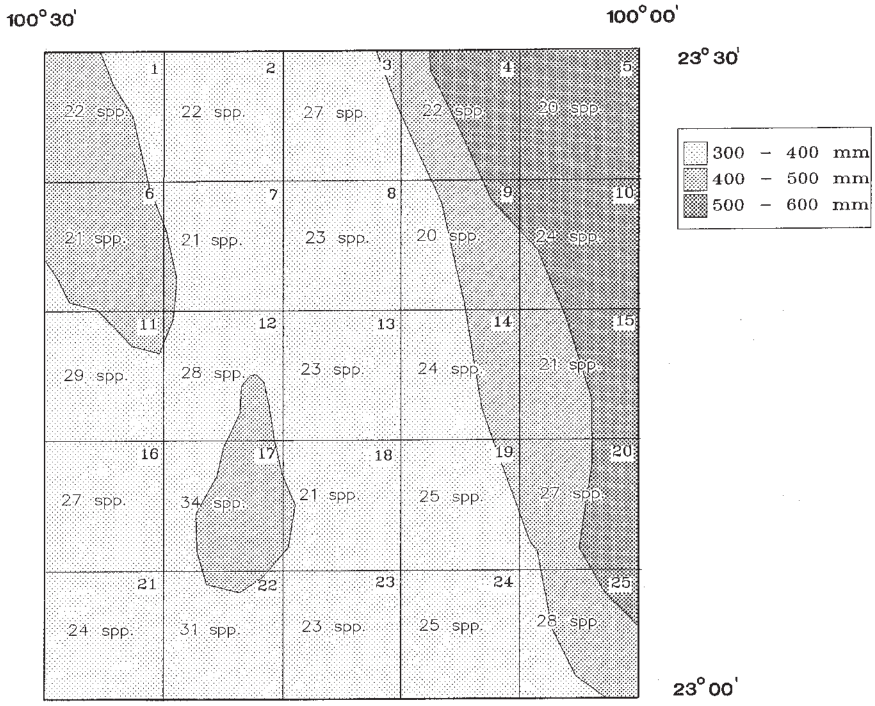


*Figure 4.* Patterns of cactus species richness and precipitation in the Mier y Noriega grid square. Precipitation data from INEGI (1988).

vulnerability. In fact, it is usually assumed that rare species, those with very limited geographical ranges, are by definition more vulnerable than widely distributed ones (Rabinowitz 1981; Gaston 1994; Hernández and Godínez 1994; Hernández and Bárcenas 1996). This is the reason why rare species have a greater likelihood of extinction, and consequently usually are linked to conservation considerations (Gaston 1994).

As shown in Figure 5, IGE values of the Cactaceae of Mier y Noriega, which were calculated for the totality of their distribution range (species of *Opuntia* and *Stenocactus* excluded), exhibited a continuous gradient, ranging from 0.05 to 1. In order to set a limit between widely distributed and geographically narrow species, we arbitrarily used the median value of the IGE's ($M = 0.43$; see Figure 5). Thus, of the 39 species analyzed, 20 (51.3%) have restricted distributions, which means that they occur in 17 or fewer grid squares, out of a maximum of 40. Six species (*Mammillaria surculosa*, *Coryphantha pulleineana*, *C. odorata*, *Turbinicarpus viereckii*, *T. subterraneus*, and *Echinocereus waldeisii*) are remarkable for having extremely low IGE values (IGE = 0.05–0.08). Each of these six narrowly endemic species has only been recorded in two or three grid squares.

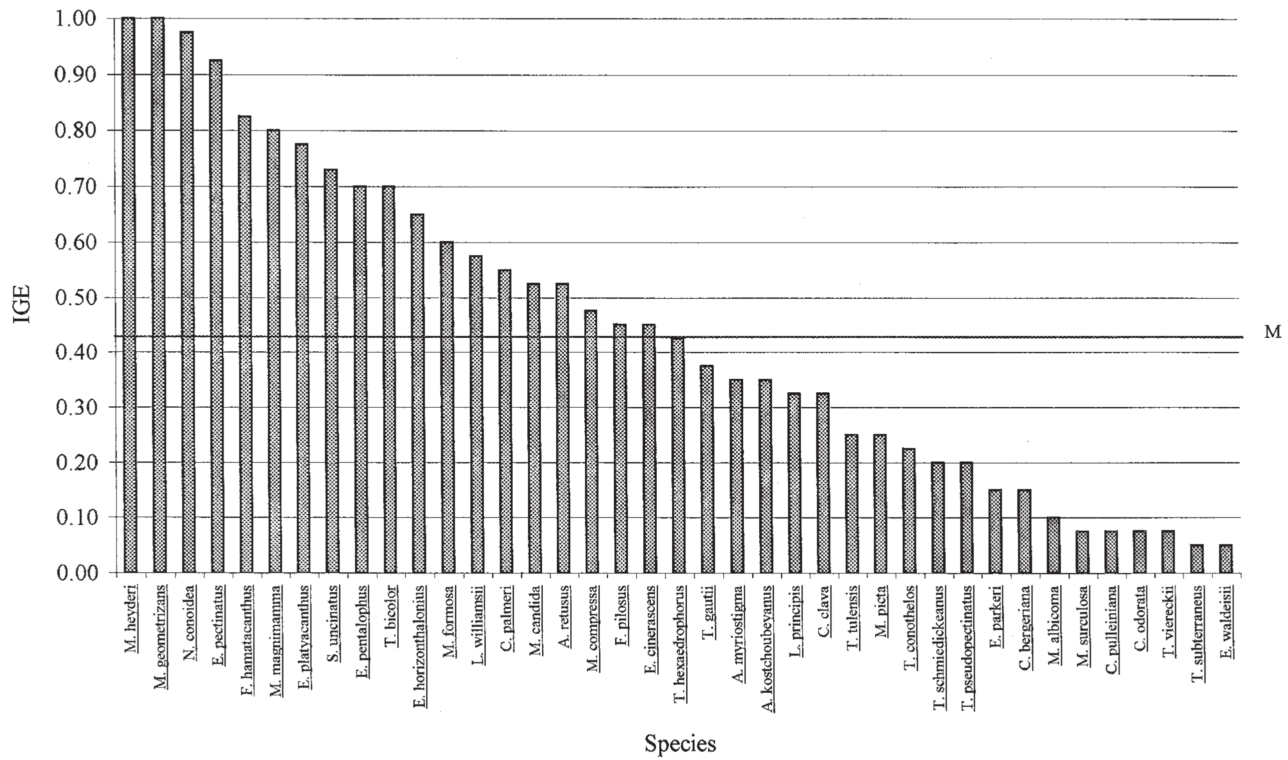


*Figure 5.* Index of Geographical Expansion values of the Cactaceae in the Mier y Noriega grid square. [Median value $(M) = 0.43$].

Contrasting with the cases mentioned above, 48.7% of the species (19 spp.) are widely distributed (Figure 5). The most extreme examples are *Myrtillocactus geometrizans* (IGE = 1), *Mammillaria heyderi* (IGE = 1), *Neolloydia conoidea* (IGE = 0.98), *Echinocereus pectinatus* (IGE = 0.93), and *Ferocactus hamatacanthus* (IGE = 0.83), which are followed by several other relatively common species (*Mammillaria magnimamma*, *Echinocactus platyacanthus*, *Sclerocactus uncinatus*, *Echinocereus pentalophus, Thelocactus bicolor*, etc.). All of these species have IGE values ranging from 0.7 to 1. In other words, each of them occupies a range from 28 to 40 grid squares, primarily in the Chihuahuan Desert.

*Endemism*

Excluding again the species of *Opuntia* and *Stenocactus*, of which we lack dependable information, 82% of the species (32 spp.) are essentially endemic to the Chihuahuan Desert Region. Included among these, there are species of *Ariocarpus, Astrophytum*, *Leuchtenbergia*, *Neolloydia*, *Thelocactus,* and *Turbinicarpus*, all of which are genera endemic to this region. Six species (*Mammillaria surculosa*, *Coryphantha pulleineana*, *C. odorata*, *Turbinicarpus viereckii*, *T. subterraneus*, and *Echinocereus waldeisii*) are stenoendemic, the last two species having the most restricted distribution (Figure 6).

In contrast, 18% of the species (7 spp.) expand their distribution range beyond the confines of the Chihuahuan Desert: *Coryphantha clava*, *Echinocactus platyacanthus*, *Echinocereus cinerascens*, *E. pectinatus*, *Mammillaria heyderi*, *M. magnimamma* y *Myrtillocactus geometrizans* (Figure 6). All of these species center their range within the Chihuahuan Desert, but also occur outside the limits of this region. For instance, *E. platyacanthus* (Figure 6e) is distributed primarily in the southern half of the Chihuahuan Desert, but it is relatively common in the Tehuacán Valley, south of the Trans-volcanic Belt; a similar pattern is displayed by *M. geometrizans*, but this species extends its range further south and west into Oaxaca and Jalisco (Figure 6f). *Mammillaria heyderi* and *Echinocereus pectinatus* (Figure 6g and h) also center their distribution in the Chihuahuan Desert, but several populations of these species have been recorded west of this region, along the Sierra Madre Occidental and in presumably disjunct populations in the Pacific slope, in Sonora; the former species is also common in Tamaulipas, east of the eastern boundary of the Chihuahuan Desert.

*Complementarity analysis*

According to the complementarity analysis, sub-square 17 is the first priority, as it has the highest number of species (34 spp.), representing 63% of the Cactaceae of the whole Mier y Noriega grid square (Table 1). The second priority is sub-square 10, as it contains six species not present in sub-square 17, corresponding to a complementarity value (CV) of 11.1%. With three additional species, not present in the

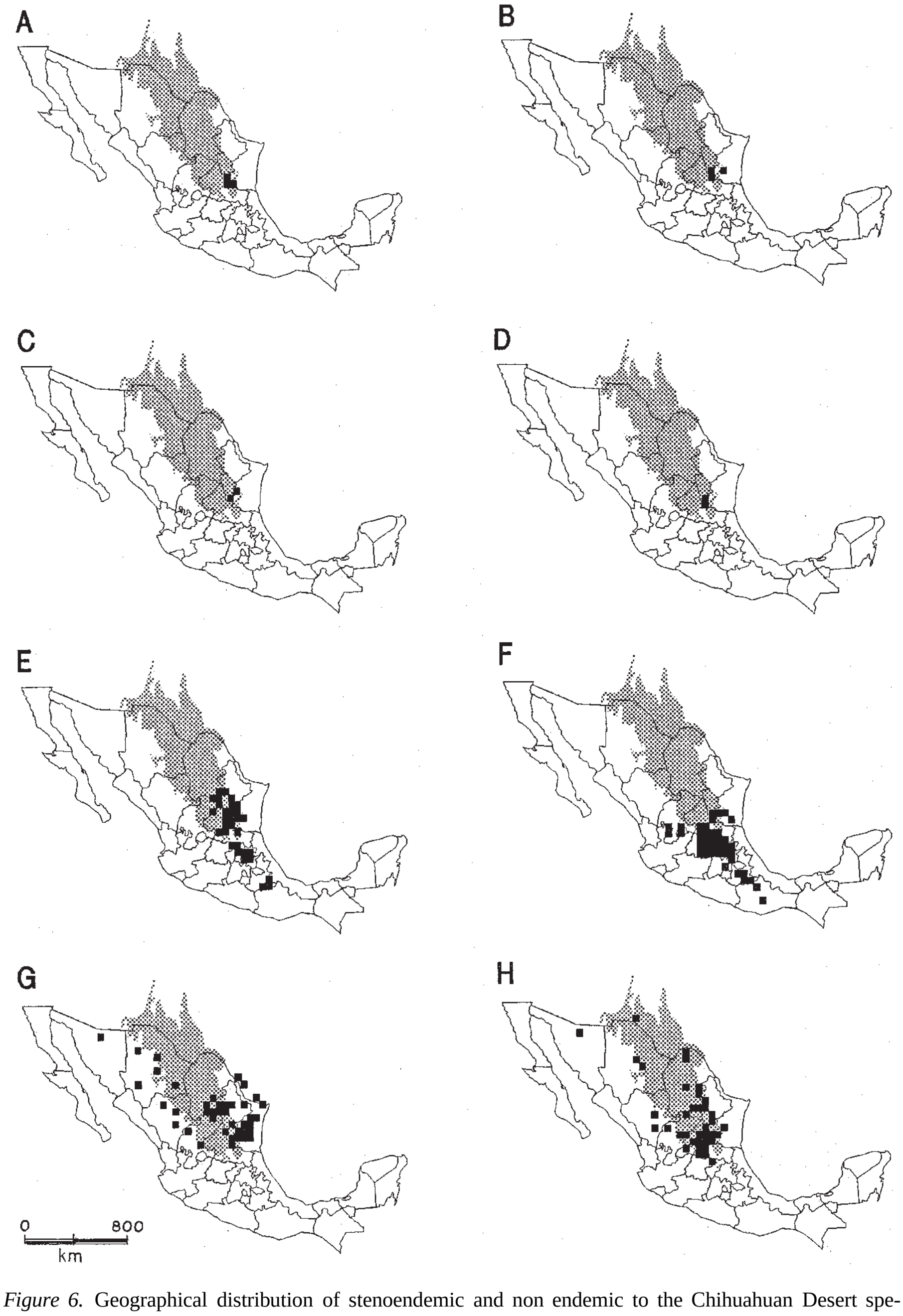


*Figure 6.* Geographical distribution of stenoendemic and non endemic to the Chihuahuan Desert species indicated by the solid squares; the shaded area corresponds to the Chihuahuan Desert region. (A) *Mammillaria surculosa* and *Coryphantha pulleineana*, (B) *Turbinicarpus viereckii*, (C) *T. subterraneus*, (D) *Echinocereus waldeisii*, (E) *Echinocactus platyacanthus*, (F) *Myrtillocactus geometrizans*, (G) *Mammillaria heyderi*, and (H) *Echinocereus pectinatus*.

*Table 1.* Complementarity among the subsquares in the Mier y Noriega grid square.

| Priority | Sub-square | No. of unique species | Complementarity value (%) |
|---|---|---|---|
| All species | | | |
| First | 17 | 34 | 63 |
| Second | 10 | 6 | 11.1 |
| Third | 25 | 3 | 5.5 |
| Fourth | 2 | 2 | 3.8 |
| Fourth | 16 | 2 | 3.8 |
| Fourth | 21 | 2 | 3.8 |
| Fifth | 5 | 1 | 1.8 |
| Fifth | 6 | 1 | 1.8 |
| Fifth | 7 | 1 | 1.8 |
| Fifth | 11 | 1 | 1.8 |
| Fifth | 23 | 1 | 1.8 |
| Endangered species | | | |
| First | 17 | 10 | 52.6 |
| Second | 25 | 2 | 10.5 |
| Third | 11 | 1 | 5.3 |
| Third | 23 | 1 | 5.3 |
| Third | 20 | 1 | 5.3 |
| Third | 2 | 1 | 5.3 |
| Third | 7 | 1 | 5.3 |
| Third | 16 | 1 | 5.3 |
| Third | 21 | 1 | 5.3 |

priorly considered areas (sub-squares 17 and 10), sub-square 25 came out to be the third priority (CV = 5.5%). Sub-squares 2, 16, and 21 are fourth priority with a CV = 3.8%, and finally sub-squares 5, 6, 7, 11, and 23 are fifth priority, as they have the lowest complementarity value (CV = 1.8%). The remaining sub-squares (1, 3, 4, 8, 9, 12, 13, 14, 15, 18, 19, 20, 22, and 24) do not add additional species (CV = 0%).

If the same analysis is conducted considering only the endangered species, the results are similar, although some differences are observed (Table 1). With 10 endangered species and a very high complementarity value (CV = 52.6%), sub-square 17 is again first priority. Subsequently, sub-square 25 is second priority, with two unique species and a CV of 10.5%. The remaining endangered species are distributed in seven third priority sub-squares (2, 7, 11, 16, 20, 21, and 23), each of which has one additional species and a CV of 5.3%. The remaining sixteen sub-squares have complementarity values of 0%.

Considering these analyses some interesting conclusions can be drawn (see Table 1): the 54 cactus species recorded from the Mier y Noriega region are contained in 11 of the 25 sub-squares dividing the area; the conservation of these 11 sub-squares, which represent 44% of the studied area (1251.8 $km^2$), would optimize the protection of the totality of the species. On the other hand, the conservation of the three sub-squares with the highest CV (sub-squares 17, 10 and 25), would guarantee the survival of 79.6% of the species, but only of 13 endangered species.

Alternatively, if we want to privilege the conservation of all the species considered endangered (19 spp.), conservation actions would have to be taken in nine sub-squares (Table 1 and Figure 7), which constitute 36% (1024.2 $km^2$) of the studied area. However, this would result in the conservation of 94% of the totality of the species (51 spp.). Thus, in this case, three species (*Coryphantha clava*, *Opuntia tomentosa*, and *O*. sp.) would be missed. The first two extend their ranges far away from the studied area, whereas the last one probably is an undescribed species endemic to the region.

The patterns of geographical distribution of cacti in the Chihuahuan Desert, as in virtually all Mexican arid and semi-arid lands, still are poorly known, although certain patterns are being unraveled. We need to generate more data from other areas within the Chihuahuan Desert, using the methods developed in this study. This would allow us to gain a better understanding on the biogeography of this plant family, and consequently envisage scientifically based strategies for its optimal conservation. Similarly, we need comparable data from other plant and animal taxa in order to test the biogeographical consistency among groups, and thus improve our knowledge of

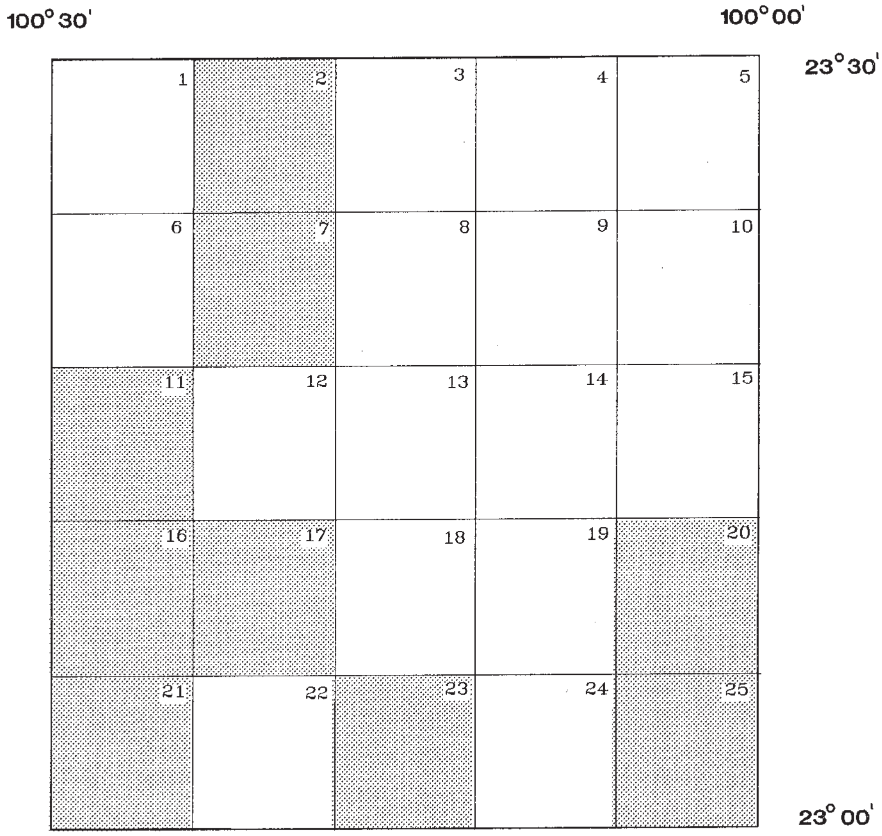


*Figure 7.* Priority areas for the conservation of endangered cacti (shaded areas) based upon complementarity analysis.

this desert. We consider that the information provided in this paper is fundamental to categorize the conservation status of the cactus species. However, much data is still needed about the most critically endangered species, particularly on their population and genetical structure.

## Acknowledgements

We would like to thank Héctor Arita and Fernando Chiang for critically reading the manuscript; Renata Zárate, Miguel Herrera, Santos Martínez, and María Antonieta Casariego for fieldwork assistance; Miriam Ramírez and Alfredo Wong for database management, and especially Rolando Bárcenas for his continuous support throughout the study. This study was carried out under SEMARNAP collecting permit 3540/95 and 5532/97. Project supported by a grant from the National Geographic Society (5577-95).

*Note added in proof*

Fieldwork carried out recently by members of the Sociedad Potosina de Cactología (M. Sotomayor, pers. comm.) has revealed that an additional species (*Ariocarpus agavoides*) exists in the studied area. In addition, we have also found *Echinocereus enneacanthus* in several localities. These two findings have to be added to the species listed in Appendix 1.

## Appendix 1

Cactus species recorded in the Mier y Noriega region; new area and state records are indicated. Endangered species (*) are marked according to CITES (1990), SEDESOL (1994), and Walker and Gillett (1998) with modifications.

| Species | Voucher | New area records | New state records |
|---|---|---|---|
| *Ariocarpus kotschoubeyanus* (Lemaire) Schumann* | Gómez-H. 669 | X | |
| *Ariocarpus retusus* Scheidw* | Gómez-H. 962 | | |
| *Astrophytum myriostigma* Lemaire* | Gómez-H. 807 | X | NL |
| *Coryphantha bergeriana* Boedeker* | Gómez-H. 1105 | X | |
| *Coryphantha clava* (Pfeiffer) Lemaire | Gómez-H. 1244 | | NL |
| *Coryphantha odorata* Boedeker* | Gómez-H. 1288 | X | Tamps, NL |
| *Coryphantha palmeri* Britton & Rose | Gómez-H. 651 | X | |
| *Coryphantha pulleineana* (Backeberg) Glass* | Gómez-H. 1461 | X | |
| *Echinocactus platyacanthus* Link & Otto* | Gómez-H. 953 | | |
| *Echinocactus horizonthalonius* Lemaire | Gómez-H. 258 | X | NL |
| *Echinocereus cinerascens* (DC.) Lemaire | Gómez-H. 278 | X | |
| *Echinocereus parkeri* N.P. Taylor | Gómez-H. 657 | X | |
| *Echinocereus pectinatus* (Scheidw.) Engelm. | Gómez-H. 640 | X | |
| *Echinocereus pentalophus* (DC.) Lemaire | Gómez-H. 473 | X | |

**Appendix 1.** Continued.

| Species | Voucher | New area records | New state records |
|---|---|---|---|
| *Echinocereus waldeisii* Haugg* | Gómez-H. 938 | X | |
| *Ferocactus hamatacanthus* (Muehlenpf.) Britton & Rose | Gómez-H. 907 | X | |
| *Ferocactus pilosus* (Galeotti) Werderm.* | Gómez-H. 333 | | |
| *Leuchtenbergia principis* Hooker* | Gómez-H. 475 | | |
| *Lophophora williamsii* (Lemaire ex Salm-Dyck) Coulter | Gómez-H. 446 | X | |
| *Mammillaria albicoma* Boedeker* | Gómez-H. 509 | X | SLP |
| *Mammillaria candida* Scheidw. | Gómez-H. 1455 | | |
| *Mammillaria compressa* DC. | Gómez-H. 265 | | NL |
| *Mammillaria formosa* Galeotti ex Scheidw. | Gómez-H. 1107 | | |
| *Mammillaria heyderi* Muehlenpfordt | Gómez-H. 455 | | |
| *Mammillaria magnimamma* Haw. | Gómez-H. 740 | | |
| *Mammillaria picta* Meinshausen | Gómez-H. 1347 | | |
| *Mammillaria surculosa* Boedeker* | Gómez-H. 530 | X | |
| *Myrtillocactus geometrizans* (Martius) Console | Gómez-H. 516 | X | |
| *Neolloydia conoidea* (DC.) Britton & Rose | Gómez-H. 112 | | |
| *Opuntia engelmannii* Salm-Dyck | Gómez-H. 507 | | |
| *Opuntia imbricata* Haw. | Gómez-H. 1099 | | |
| *Opuntia kleinieae* DC. | Gómez-H. 1279 | X | Tamps, SLP |
| *Opuntia leptocaulis* DC. | Gómez-H. 1235 | | |
| *Opuntia leucotricha* DC. | Gómez-H. 1076 | X | NL |
| *Opuntia microdasys* (Lehmann) Pfeiffer | Gómez-H. 808 | X | |
| *Opuntia rastrera* Weber | Gómez-H. 1353 | | |
| *Opuntia stenopetala* Engelm. | Gómez-H. 332 | X | |
| *Opuntia streptacantha* Lemaire | Gómez-H. 550 | X | Tamps |
| *Opuntia tomentosa* Salm-Dyck | Gómez-H. 137 | X | NL |
| *Opuntia tunicata* (Lehmann) Link & Otto | Gómez-H. 1008 | | |
| *Opuntia vilis* Rose | Gómez-H. 444 | X | SLP |
| *Opuntia* sp. (hybrid) | Gómez-H. 478 a | X | |
| *Opuntia* sp. | Gómez-H. 1669 | X | |
| *Sclerocactus uncinatus* (Galeotti) N.P. Taylor* | Gómez-H. 1045 | | |
| *Stenocactus* sp. | Gómez-H. 1019 | | |
| *Thelocactus bicolor* (Galeotti) Britton & Rose | Gómez-H. 445 | | |
| *Thelocactus conothelos* (Regel & Klein) Backeb. & Knuth | Gómez-H. 1250 | | |
| *Thelocactus hexaedrophorus* (Lemaire) Britton & Rose | Gómez-H. 978 | | |
| *Thelocactus tulensis* (Poselger) Britton & Rose* | Gómez-H. 68 | | |
| *Turbinicarpus gautii* (Benson) Zimmerman* | Gómez-H. 1230 | X | |
| *Turbinicarpus pseudopectinatus* (Backeberg) Glass & Foster* | Gómez-H. 1000 | | |
| *Turbinicarpus schmiedickeanus* (Boedeker) Buxb. & Backeb.* | Gómez-H. 1625 | | |
| *Turbinicarpus subterraneus* (Backeberg) Zimmerman* | Gómez-H. 315 | X | |
| *Turbinicarpus viereckii* (Glass & Foster) John & Riha* | Gómez-H. 1373 | | SLP |

## References


Arias S, Gama S and Guzmán U (1997) Cactaceae A. L. Juss. Flora del Valle de Tehuacán-Cuicatlán. 14. Instituto de Biología, Universidad Nacional Autónoma de México, Mexico City

Bárcenas RT (1999) Patrones de distribución de cactáceas en el estado de Guanajuato. Tesis de Licenciatura. Facultad de Ciencias, Universidad Nacional Autónoma de México, Mexico City

Castillo O, Blanco M and Toledo C (1983) Estudio de las cactáceas de la cuenca baja del Río Balsas. Universidad Autónoma de Guerrero, Mexico, Chilpancingo

CITES (1990) Appendices l, ll and lll to the Convention. US Fish and Wildlife Service, Washington DC

Cornet A (1985) Las Cactáceas de la Reserva de la Biosfera de Mapimí. Instituto de Ecología A.C., Mexico City

García E (1988) Modificaciones al Sistema de Clasificación Climática de Köppen para adaptarlo a las condiciones de la República Mexicana. Offset Larios, Mexico City

Gaston KJ (1994) Rarity. Chapman & Hall, London

Gómez-Hinostrosa C (1998) Diversidad, distribución y abundancia de cactáceas en la región de Mier y Noriega, México. Tesis de Licenciatura. Facultad de Ciencias, Universidad Nacional Autónoma de México, Mexico City

Henrickson J and Straw RM (1976) A Gazetteer of the Chihuahuan Desert Region. A Supplement to the Chihuahuan Desert Flora. California State University, Los Angeles

Hernández HM, Alvarado V and Ibarra R (1993) Base de datos de colecciones de cactáceas del Norte y Centroamérica. Anales Inst. Biol. Univ. Nac. México 64: 87–94

Hernández HM and Bárcenas RT (1995) Endangered cacti in the Chihuahuan Desert: l. Distribution patterns. Conservation Biol. 9(5): 1176–1188

Hernández HM and Bárcenas RT (1996) Endangered cacti in the Chihuahuan Desert: II. Biogeography and conservation. Conservation Biol. 10(4): 1200–1209

Hernández HM and Godínez H (1994) Contribución al conocimiento de las cactáceas mexicanas amenazadas. Acta Bot. Mex. 26: 33–52

Humphries C, Vane-Wright D and Williams P (1991) Biodiversity reserves: setting new priorities for the conservation of wildlife. Parks 2(2): 34–38

Hunt D (1992) CITES Cactaceae Checklist. Royal Botanic Gardens Kew, Surrey

INEGI (1988) Atlas Nacional del Medio Físico. Instituto Nacional de Estadística, Geografía e Informática, Mexico, Aguascalientes

León JL, Coria R and Cansino J (1995) Reserva de la Biosfera El Vizcaíno, Baja California Sur. Listados Florísticos de México. Instituto de Biología, Universidad Nacional Autónoma de México, Mexico City

SEDESOL (1994) Norma Oficial Mexicana NOM – 059 – ECOL – 1994, que determina las especies de flora y fauna silvestre, terrestres y acuáticas en peligro de extinción, amenazadas, raras y las sujetas a protección especial y que establece especificaciones para su protección. Diario Oficial de la Federación 438: 2–60

Pinkava DJ (1984) Vegetation and flora of the Bolsón of Cuatro Ciénegas region, Coahuila, Mexico: summary, endemism and corrected catalogue. J. Arizona-Nevada Acad. Sci. 19: 23–47

Pressey R, Humphries C, Margules C, Van-Wright R and Williams P (1993) Beyond opportunism: key principles for systematic reserve selection. Trends in Ecology and Evolution 8: 124–128

Rabinowitz D (1981) Seven forms of rarity. In: Synge H (ed) The Biological Aspects of Rare Plant Conservation, pp 205–217. Wiley, New York

Ruiz de Esparza R (1988) Lista de las especies vasculares. In: Montaña C (ed) Estudio Integrado de los Recursos, Vegetación, Suelo y Agua en la Reserva de la Biosfera de Mapimí, pp 225–239. Instituto de Ecología A.C, Mexico City

Rzedowski J (1956) Notas sobre la vegetación del estado de San Luis Potosí. III. Vegetación de la región de Guadalcázar. Anales Inst. Biol. Univ. Nac. México 27: 169–228

Rzedowski J (1991) Diversidad y orígenes de la flora fanerogámica de México. Acta Bot. Mex. 14: 3–21

Villarreal JA (1994) Flora vascular de la Sierra de la Paila, Coahuila, México. Sida 16(1): 109–138

Walker KS and Gillett HJ (eds) (1998) 1997 IUCN Red List of Threatened Plants. Gland and Cambridge: Compiled by the World Conservation Monitoring Center. IUCN – The World Union

Williams P, Humphries C and Vane-Wright R (1991) Measuring biodiversity: taxonomic relatedness for conservation priorities. Austral. Syst. Bot. 4: 665–679