Areas of endemism of Cactaceae and the effectiveness of the protected area network in the Chihuahuan Desert

Héctor M. Hernández and Carlos Gómez-Hinostrosa

Abstract We used distribution data of 121 cactus species endemic to the Chihuahuan Desert to test the effectiveness of the region's protected area network. The analysis of species distribution using a 30′ latitude × 30′ longitude grid facilitated the identification and categorization of areas of endemism. We found a low degree of coincidence between protected areas and the areas of cactus endemism, and only 63.6% of the 121 species occur in protected areas. A complementarity analysis showed that 10 of the protected areas contain the 77 species that occur in protected areas. The four top priority areas protect 65 (84.4%) of these 77 species The 44 unprotected species are mainly micro-endemic and taxonomically distinctive taxa widely scattered in the region. The complementarity analysis applied to these species showed that all of them can be contained in a minimum of 24 grid squares, representing 32.9% of the total area occupied. Their strong spatial dispersion, along with their narrow endemism, is a major conservation challenge. We conclude that the current protected area network is insufficient to protect the rich assemblage of cacti endemic to the Chihuahuan Desert. Conservation efforts in this region should be enhanced by increasing the effectiveness of the already existing protected areas and by the creation of additional protected areas, specifically micro-reserves, to provide refuge for the unprotected species.

Keywords Biodiversity conservation, Cactaceae, complementarity, endemism, gap species, Mexico

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Introduction

The environmental conditions of arid zones, especially the low availability of water, have stimulated plant speciation and the evolution of unusual life forms, and a high proportion of the species of such areas are endemic, particularly in warm deserts (Cowling et al., 1999; Burke, 2004; Riemann & Ezcurra, 2005). Endemic species have a high conservation priority because they are exclusive to a region and are often geographically restricted and ecologically infrequent. Plant communities in some desert areas are thus irreplaceable (Pressey, 1999).

An example of such an area is the Chihuahuan Desert. With an estimated 3,500 plant species (Henrickson & Johnston, 2004) and a high degree of plant and animal endemism (Johnston, 1977; Minckley, 1977; Pinkava, 1984), the region is one of the most diverse deserts. The Cactaceae is the most emblematic plant group of this region (Hernández & Gómez-Hinostrosa, 2005) and some areas within it have the highest number, globally, of cactus species per unit area (Hernández et al., 2001). The region has a total of 329 native cactus species in 39 genera, with 43 and 70% generic and species endemism, respectively (Hernández et al., 2004).

The Cactaceae is a highly threatened plant family and the IUCN Global Cactus Assessment (2010), currently in progress, is confirming that c. 33% of the species are threatened. The principal factor affecting the conservation status of Mexican cacti is habitat deterioration as the result of a diversity of factors, including agricultural development, goat husbandry, mining and road construction. However, the collection of individual plants for ornamentals, which affects the rarest and most threatened species, is also a major threat (Hernández & Gómez-Hinostrosa, 2005). Although Mexican law prohibits collection of threatened species of flora and fauna, there is evidence that cactus plants and seeds are still being collected illegally (Robbins & Bárcenas, 2003).

Protected areas are considered the most effective instrument for in situ biodiversity conservation, with > 100,000 such areas worldwide covering > 12% of the Earth's land surface (Chape et al., 2008). However, protected areas do not always achieve their objective of protecting biodiversity. Many are not enforced and/or are not effectively managed, and are affected by poaching, habitat loss and fragmentation. Frequently they are inadequately designed and do not coincide with high priorities such as areas of high habitat diversity, species richness and/or endemism (Margules & Pressey, 2000; Ervin, 2003; Rodrigues et al., 2004).

Here we use the endemic Cactaceae of the Chihuahuan Desert as biodiversity surrogates. We analysed the species' distributions to answer four questions regarding the effectiveness of the region's protected areas: (1) What is the degree of coincidence between the richest areas of endemism and

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protected areas? (2) What percentage of the species and their populations are in protected areas? (3) What is the relative importance of each of the protected areas for conserving these species? (4) Where are the major gaps in the conservation of these species?

Study area

The c. 533,600 km^2 (Hernández et al., 2010) Chihuahuan Desert is the largest area containing xeric ecosystems in North America. The region extends from the central

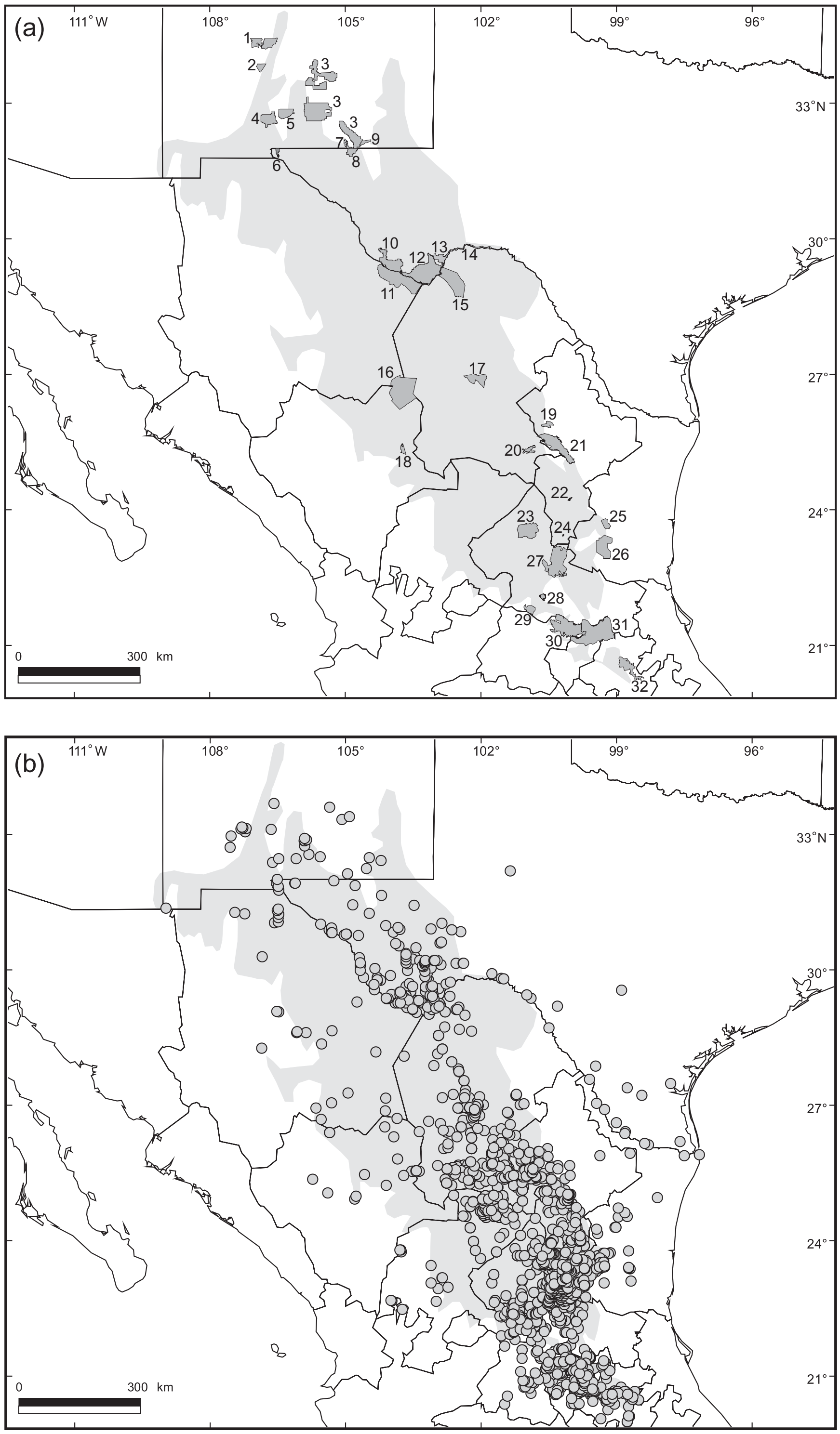

Fig. 1 (a) The 32 protected areas in the Chihuahuan Desert (area shaded light grey); the numbering is approximately north–south (see Table 1 for the names of the areas). (b) Distribution of endemic cactus species in the Chihuahuan Desert; each dot represents the locality of one to several species.

Mexico states of Guanajuato, Querétaro and Hidalgo to southern Texas, New Mexico, and a small part of Arizona, and is bordered by the Sierra Madre Occidental and the Sierra Madre Oriental (Fig. 1a). The ecological and climatic characteristics of this region have been described elsewhere (Shreve, 1942; Johnston, 1977; Schmidt, 1979; Medellín-Leal, 1982; Henrickson & Johnston, 1986; Hernández & Gómez-Hinostrosa, 2005; Hernández, 2006). Thirty-two protected areas cover c. 37,547 km^2 of this desert (7% of the total area; Fig. 1a, Table 1).

Methods

We regarded as endemic those cactus species essentially restricted to the Chihuahuan Desert as delineated by Hernández & Gómez-Hinostrosa (2005). A total of 229 cactus species endemic to this region have been recorded (Hernández et al., 2004). From these we selected a subset of 121 species (Appendix) that are well studied taxonomically and for which the geographical distributions are well documented. The ranges of most of these species are strictly restricted to the Chihuahuan Desert (Hernández & Gómez-Hinostrosa, 2005). However, we also included a few species whose geographical range is centred in the region but that also have a small part ($\leq 5\%$) of their populations outside the region (Fig. 1b). We follow Hunt's (2006) taxonomic nomenclature.

We used 3,786 geo-referenced records from a database of cactus collections for North and Central America developed by HMH and collaborators. The database is a compilation of specimen data of Cactaceae from 35 herbaria in Mexico and several other countries. The number of specimen records per species is 1–219 (Appendix).

To identify areas of endemism we overlaid the records of the 121 species on a map with a 30′ latitude × 30′ longitude grid and ranked the grid squares according to

Table 1 The 32 protected areas in the Chihuahuan Desert (CONANP, 2008; WDPA, 2008; see numbered locations in Fig. 1a).

Protected area	Category*	Location	Area (km^2)	No. of cactus species
1, Sevilleta	NWR	New Mexico	929	0
2, Bosque del Apache	NWR	New Mexico	231	0
3, Lincoln	NF	New Mexico	4,466	1
4, Jornada Experimental Range	EC	New Mexico	784	0
5, White Sands	NM	New Mexico	578	0
6, Franklin Mountains	SP	Texas	97	1
7, Brokeoff Mountains	WSA	New Mexico	124	1
8, Guadalupe Mountains	NP	Texas	349	0
9, Carlsbad Caverns	NP	New Mexico	189	0
10, Big Bend Ranch	SP	Texas	1,134	6
11, Cañón de Santa Elena	APFF	Chihuahua	2,772	5
12, Big Bend	NP	Texas	2,865	8
13, Black Gap	WMA	Texas	404	1
14, Rio Grande	NSR	Texas	388	2
15, Maderas del Carmen	APFF	Coahuila	2,083	4
16, Mapimí	BR	Durango, Chihuahua, Coahuila	3,423	1
17, Cuatro Ciénegas	APFF	Coahuila	843	12
18, Cañón de Fernández	SP	Durango	170	1
19, Sierra El Fraile y San Miguel	SZEC	Nuevo León	235	1
20, Serranía de Zapalinamé	SZEC	Coahuila	257	5
21, Cumbres de Monterrey	NP	Coahuila, Nuevo León	1,773	6
22, Sandía el Grande	SZEC	Nuevo León	19	1
23, Huiricuta	NSS	San Luis Potosí	1,400	7
24, San Elías	SZEC	Nuevo León	6	2
25, Altas Cumbres	SZEC	Tamaulipas	312	3
26, El Cielo	BR	Tamaulipas	1,445	5
27, Real de Guadalcázar	SP	San Luis Potosí	2,570	37
28, Sierra de Álvarez	ZPF	San Luis Potosí	169	1
29, Gogorrón	NP	San Luis Potosí	369	1
30, Sierra Gorda de Guanajuato	BR	Guanajuato	2,368	17
31, Sierra Gorda	BR	Querétaro	3,835	16
32, Barranca de Metztitlán	BR	Hidalgo	960	11
Total			37,547	77

*APFF, Area of Protection of Flora and Fauna; BR, Biosphere Reserve; EC, Experimental Camp; NF, National Forest; NM, National Monument; NP, National Park; NWR, National Wildlife Refuge; NSS, Natural Sacred Site; NSR, Natural Scenic River; SP, State Park; SZEC, Special Zone under Ecological Conservation; WMA, Wildlife Management Area; WSA, Wildlife Study Area; ZPF, Zone of Forest Protection

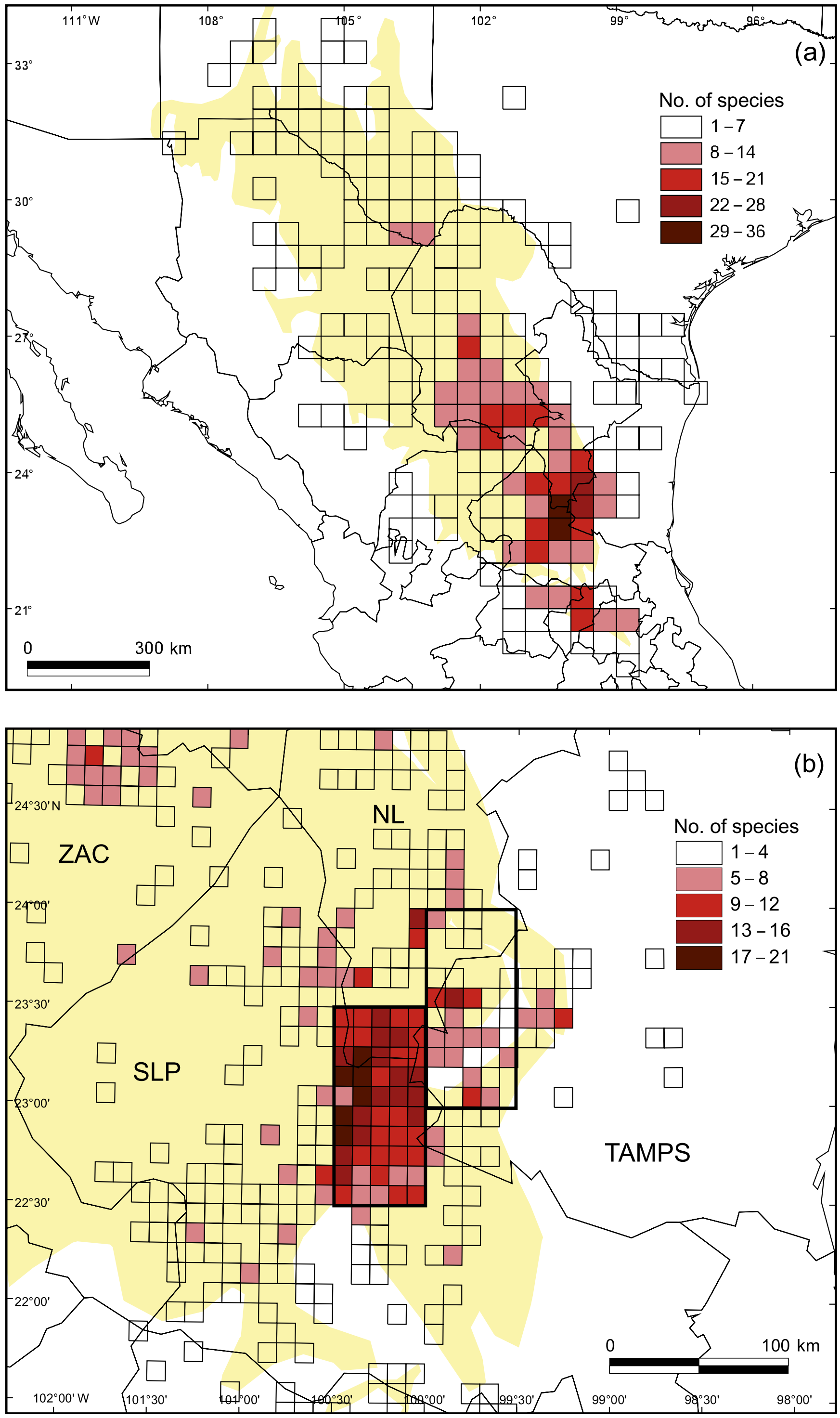

FIG. 2 (a) Pattern of species richness of endemic cacti in the Chihuahuan Desert at a scale of 30′ latitude × 30′ longitude. Grid squares are ranked according to their respective number of species: rank I = 29–36 spp., rank II = 22–28 spp., rank III = 15–21 spp., rank IV = 8–14 spp., rank V = 1–7 spp. (b) Detail of pattern of species richness in the rank I (left pair of 30′ × 30′ grid squares) and rank II (right pair of 30′ × 30′ grid squares) areas of endemism (delimited by thicker line) at a scale of 6′ × 6′. State abbreviations: NL, Nuevo León; SLP, San Luis Potosí; TAMPS, Tamaulipas; ZAC, Zacatecas.

their respective number of species. Areas with ≥ 22 species were further analysed at a scale of $6' \times 6'$. To compare the geographical configuration of the areas of endemism with that of the protected areas, the percentage of the areas of endemism overlapping with protected areas was calculated.

We assessed the efficacy of the protected areas in protecting individual cactus species by overlaying the geo-referenced records on the map of protected areas (Fig. 1). We estimated the degree of protection afforded individual species by calculating the percentage of known localities of each species situated within one or more protected areas. The number of known localities per species was taken from Hernández et al. (2010). Following Hernández et al. (2010) a locality is defined here as a point displayed on a map that is separated from its nearest neighbour by at least 797.9 m, the radius of a 2-km^2 circle. Points located within this radius were considered part of the same locality.

Protected area shape files were obtained from CONANP (2008), Bezaury-Creel et al. (2007) and WDPA (2008). For spatial analyses we used *ArcView v. 3.2* (ESRI, Redlands, USA).

The complementarity principle has been used to select minimal sets of areas that are complementary in terms of the features of a region, with the aim of maximizing the chances of achieving representative networks of reserves (Humphries et al., 1991; Vane-Wright et al., 1991). The first step is to select a priority choice, which corresponds to the area containing the highest number of species. From this, the remaining areas are ordered according to their contribution of additional species not found in the areas of higher priority. The Real de Guadalcázar State Park was the first priority, and the 31 other protected areas were prioritized according to their complementarity values. The complementarity value was calculated for each protected area as $(AS \times 100)/RC$, where AS is number of unique, additional species not found in the first priority area or in higher priority areas, and RC is the residual complement, calculated as the difference of the complement (the total number of species considered that occur in protected areas; 77 spp.) and the number of species in the first priority area (37 spp.). In addition to the complementarity analysis of the 77 species occurring within protected areas we determined the near minimum area set for the 44 species that occur outside the 32 protected areas using the $30' \times 30'$ grid squares as the units of analysis.

Results

Fig. 2a shows the pattern of species richness at a resolution of $30' \times 30'$. The number of endemic cactus species per grid square was 1–36. We categorized the grid squares according to the number of endemic species present: rank I (29–36), rank II (22–28), rank III (15–21), rank IV (8–14), and rank V (1–7). There are two general areas of endemism of ranks I and II in the south-east (Fig. 2a). There are two grid squares of rank I, the cactus flora of which was recently described (Hernández et al., 2001; Gómez-Hinostrosa & Hernández, 2000): the Huizache and Mier y Noriega grid squares, with 36 and 32 species respectively. Fig. 2b shows the spatial pattern of the rank I and II areas at a finer scale $(6' \times 6')$. The richest areas lie mainly towards the west of the rank I area.

The two grid squares of rank II (Miquihuana and Tula with 27 and 22 species, respectively) lie to the north-east and east of the Mier y Noriega grid square (Fig. 2a). Around the rank I and II areas there is a group of rank III grid squares, some of which are contiguous with the rank I and II squares of endemism, although others are further away, in the Queretaroan arid zone, along the Sierra de Parras, in southern Coahuila and Cuatro Ciénegas.

The two rank I grid squares have a total surface area of 5,674 km^2, 41.1% (2,334 km^2) of which overlaps with the Real de Guadalcázar and San Elías protected areas (Table 2). The two rank II squares are totally unprotected. Table 2 summarizes the degree of protection of the different areas at a scale of $30' \times 30'$.

Fig. 3 shows the number of species in each of the numbered protected areas. Four areas (Real de Guadalcázar, 37 species; Sierra Gorda de Guanajuato, 17; Sierra Gorda, 16; Cuatro Ciénegas, 12) protect, at least in theory, 65 species; i.e. 84.4% of the species occurring in the protected areas and 53.7% of the species in our sample of 121 species. Sixteen of the areas protect 0–1 species in our sample; these areas are mostly located in the north of the region (Figs 1a & 3).

Overall 892 localities (24% of the 3,786 geo-referenced localities) lie within protected areas. For each species the Appendix provides the percentage of localities occurring in protected areas of the total number of localities known (Hernández et al., 2010). Only nine species (7.4%) are fully protected (i.e. 100% of localities in protected areas) and 50% or less of the number of localities of 59 species (48.8%) are protected.

The complementarity analysis (Table 3) shows that 10 of the 32 reserves together shelter all 77 species, of our subset

Table 2 Degree of protection of different areas of cactus endemism at a scale of 30′ latitude × 30′ longitude. Ranks were defined according to the number of species found per grid square: rank I (29–36 spp.), rank II (22–28 spp.), rank III (15–21 spp.), rank IV (8–14 spp.) and rank V (1–7 spp.).

Degree of endemism	No. of grid squares	Total area (km^2)	Area protected, km^2 (% of total)
Rank I	2	5,674	2,334 (41.1)
Rank II	2	5,652	0
Rank III	13	36,684	4,182 (11.4)
Rank IV	28	78,584	9,780 (12.4)
Rank V	92	250,969	16,424 (6.5)

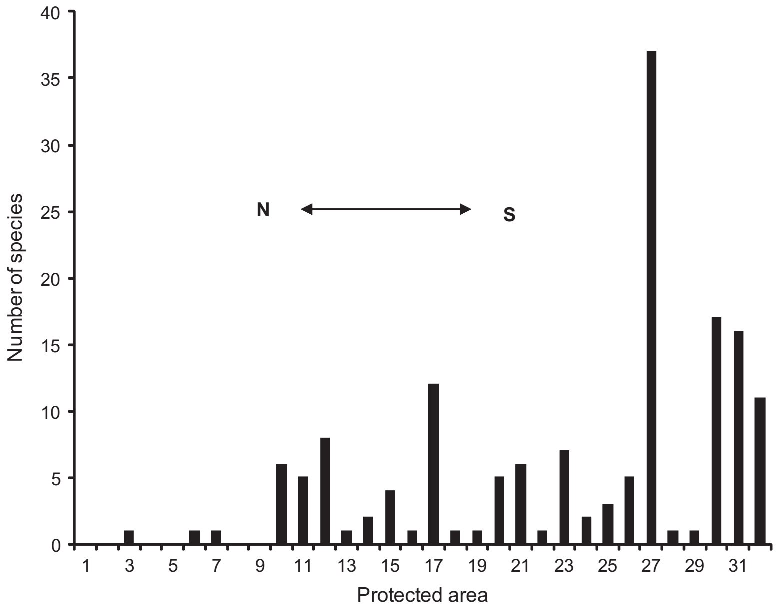

FIG. 3 Number of species of endemic cacti in each numbered protected area. The numbers in the x-axis correspond to the numbered protected areas in Fig. 1a and Table 1.

of 121 species, that occur in protected areas; this is the optimal solution for the conservation of these species. The four top priority areas protect 65 (84.4%) of the species. The complementarity analysis applied to the areas occupied by the 44 species occurring exclusively outside protected areas shows that of the 73 grid squares (a total area of 208,000 km^2) in which these species occur, a minimum of 24 (32.9% of the squares) are necessary to contain all of the species. None of the grid squares contain high numbers of these 44 species, and the difference in number of unique species between the first priority area (5 species) and fifth priority area (1) is small (Table 4, Fig. 4).

Discussion

Although the protected areas of the Chihuahuan Desert cover 7% of the region's area there is a low degree of coincidence with the richest areas of cactus endemism (Table 2). With the exception of the rank I areas of endemism, 41.1% of which are protected by the Real de Guadalcázar State Park and another, smaller protected area, the protection of areas of cactus endemism is low or non-existent. With respect to the protection of individual species, almost two thirds (77 species) are protected but 44, including several of the rarest endemic species, are unprotected. It is not only species of cacti that are endemic to the Chihuahuan Desert. Approximately one-third of the region's plant species are endemic (Johnston, 1977) and there are also high levels of endemism amongst reptiles and freshwater fish (Miller, 1977; Minckley, 1977; Morafka, 1977).

The protected areas of Real de Guadalcázar, Sierra Gorda de Guanajuato, Cuatro Ciénegas and Sierra Gorda are particularly important because of the number of species they protect and for their high complementarity. The 2,570 km^2 Real de Guadalcázar State Park was gazetted to protect the habitat of the 76 cactus species in the area. The Park is the richest centre of cactus diversity globally (Hernández et al., 2001), and has the richest number of threatened (Hernández & Bárcenas, 1995) and endemic cactus species. However, although the Park was gazetted in 1997 several portions of the reserve are under severe pressure. In an assessment of the effectiveness of federal protected areas in Mexico Figueroa & Sánchez-Cordero (2008) found that two protected areas important for the conservation of Chihuahuan Desert Cactaceae, Cuatro Ciénegas and Sierra Gorda, were 'weakly effective' and 'non-effective' respectively, because of high rates of land use and land cover change. The Real de Guadalcázar and Sierra Gorda de Guanajuato were not included in the study because the former is a state reserve under the jurisdiction of the government of San Luis Potosí and the latter was decreed only in 2008.

The 44 cactus species that do not lie within any protected area are some of the most taxonomically distinctive taxa of Mexican Cactaceae: the monotypic genus *Geohintonia* (*G. mexicana*), the two members each of the genera *Aztekium* (*A. hintonii* and *A. ritteri*) and *Pelecyphora* (*P. aselliformis* and *P. strobiliformis*), and one species of *Acharagma* (*A. aguirreanum*), all genera endemic to the Chihuahuan Desert. This group also includes several species belonging to other genera endemic to the Chihuahuan Desert (*Ariocarpus*, *Thelocactus* and *Turbinicarpus*).

The most critical of these species are the 20 that occur in only a single $30' \times 30'$ square (Table 4). Sixteen of the 24 grid squares prioritized by the complementarity analysis contain 1–2 of these narrow endemics. Narrow endemism is a prominent phenomenon amongst Mexican Cactaceae, and many of these microendemics have extremely small

TABLE 3 Results of the complementarity analysis of the 32 protected areas of the Chihuahuan Desert, considering the 77 cactus species that occur in these protected areas (Fig. 1a).

Protected area	Number of unique species	Complementarity value (%)	Priority
27, Real de Guadalcázar	37		1
30, Sierra Gorda de Guanajuato	15	37.5	2
17, Cuatro Ciénegas	9	22.5	3
31, Sierra Gorda	4	10.0	4
32, Barranca de Metztitlán	3	7.5	5
25, Altas Cumbres	3	7.5	5
15, Maderas del Carmen	2	5.0	6
21, Cumbres de Monterrey	2	5.0	6
26, El Cielo	1	2.5	7
28, Sierra de Álvarez	1	2.5	7

distribution ranges. For example, *Mammillaria humboldtii, Mammillaria schwarzii, Opuntia chaffeyi, Thelocactus hastifer, Turbinicarpus ysabelae* and *Turbinicarpus zaragozae* occur in areas of < 6 km^2 (Hernández et al., 2010). The microendemic nature of these species, along with their high taxonomic distinctiveness, is a clear reflection of the high conservation value and high degree of irreplaceability of the areas inhabited by them (May, 1990; Vane-Wright et al., 1991; Pressey, 1999).

The simplest solution to protect the 44 unprotected species would be the creation of additional reserves. The optimal size for any such reserves is, however, difficult to resolve (Primack, 2006; Hunter & Gibbs, 2007, and references therein). In practice, reserve size should be determined following a consideration of the complex combination of biological, political and economic factors that make every situation unique (Hunter & Gibbs, 2007). A large number of reserves would be required to protect the 44 species and extremely small reserves may have several disadvantages: they may not be adequate to support long-term populations and ecosystem processes, they usually cover a narrower range of environmental conditions, and reserves of < 100 ha may not be sufficiently large to encompass the diversity of a region, especially considering that parts of the Chihuahuan Desert have high beta diversity (Goettsch & Hernández, 2006; Hernández et al., 2008).

TABLE 4 Results of the complementarity analysis of the 30′ latitude × 30′ longitude grid squares containing the 44 cactus species that do not occur in protected areas (Fig. 1a). Grid squares are named according to the largest city or town.

Grid square name	Location	No. of species (no. in a single grid square)	Complementarity value (%)	Priority
San Luis Potosí	22°00′–22°30′ N, 100°30′–101°00′ W	5 (2)		1
Miquihuana	23°30′–24°00′ N, 99°30′–100°00′ W	4	10.3	2
Mazapil	24°30′–25°00′ N, 101°30′–102°00′ W	3	7.7	3
Ramos Arizpe	25°30′–26°00′ N, 100°30′–101°00′ W	3 (1)	7.7	3
Galeana	24°30′–25°00′ N, 100°00′–100°30′ W	3 (1)	7.7	3
Tolimán	20°30′–21°00′ N, 99°30′–100°00′ W	3 (2)	7.7	3
Parras	25°00′–25°30′ N, 102°00′–102°30′ W	2 (1)	5.1	4
Guanajuato	21°00′–21°30′ N, 101°00′–101°30′ W	2 (1)	5.1	4
Querétaro	20°30′–21°00′ N, 100°00′–100°30′ W	2 (2)	5.1	4
Tula	23°00′–23°30′ N, 99°30′–100°00′ W	2	5.1	4
Linares	24°30′–25°00′ N, 99°30′–100°00′ W	2 (2)	5.1	4
Estación Mezquite	31°00′–31°30′ N, 106°30′–107°00′ W	1	2.6	5
Coneto de Comonfort	24°30′–25°00′ N, 104°30′–105°00′ W	1 (1)	2.6	5
East Mapimí	26°30′–27°00′ N, 103°00′–103°30′ W	1 (1)	2.6	5
Zacatecas	22°30′–23°00′ N, 102°30′–103°00′ W	1	2.6	5
Cuatro Ciénegas	26°30′–27°00′ N, 102°00′–102°30′ W	1	2.6	5
Cinco de Mayo	25°00′–25°30′ N, 101°30′–102°00′ W	1	2.6	5
San Luis de la Paz	21°00′–21°30′ N, 100°30′–101°00′ W	1 (1)	2.6	5
Matehuala	23°30′–24°00′ N, 100°30′–101°00′ W	1	2.6	5
Xichú	21°00′–21°30′ N, 100°00′–100°30′ W	1 (1)	2.6	5
Cerritos	22°00′–22°30′ N, 100°00′–100°30′ W	1 (1)	2.6	5
Ciudad del Maíz	22°00′–22°30′ N, 99°30′–100°00′ W	1 (1)	2.6	5
Metztitlán	20°30′–21°00′ N, 98°30′–99°00′ W	1 (1)	2.6	5
González	25°30′–26°00′ N, 99°30′–100°00′ W	1 (1)	2.6	5

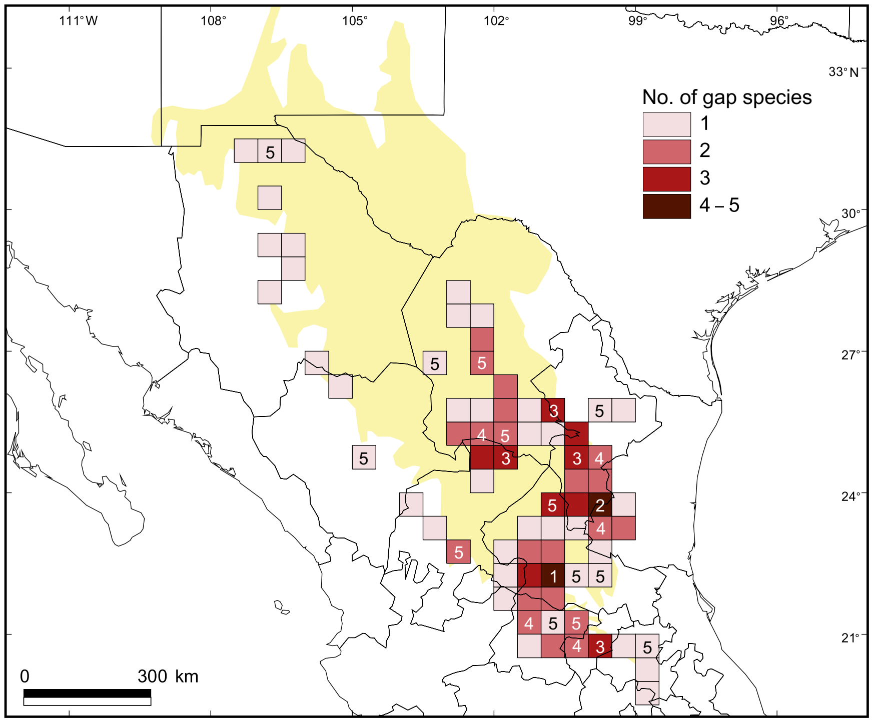

FIG. 4 Density map of unprotected species per half-degree cell. The numbers within some of the grid squares indicate the priority levels based on the results of the complementarity analysis (Table 4).

Nevertheless, despite these and other considerations, several examples demonstrate the practical value, as well as the ecological and genetic viability, of small protected areas for plants (Lesica & Allendorf, 1992; Cowling et al., 2003). In the Valencian region of Spain a network of micro-reserves of 2–20 ha, established since 1994, has proved highly effective for protecting elements of the region's flora (Laguna et al., 2004; Laguna, 2008). The legal framework confers upon these micro-reserves 'permanent status and provides strong protection to plants and substrates while allowing traditional activities compatible with plant conservation' (Laguna et al., 2004). Similar networks have been successfully implemented in Eastern Europe and the Mediterranean region (Laguna et al., 2006; Laguna, 2008), and small-scale conservation approaches have also been used in the Cape Floristic Region of South Africa (Tansley, 1988; Cowling et al., 2003).

Another approach relevant in the context of micro-reserve networks is the Alliance for Zero Extinction (AZE). This joint initiative of 52 biodiversity conservation organizations, which is targeted at geographically restricted and highly threatened species, identifies and safeguards sites in most urgent need of conservation (Ricketts et al., 2005). We estimate that c. 40 cactus species endemic to the Chihuahuan Desert meet the criteria to be regarded as AZE species.

To protect the endemic flora of the Chihuahuan Desert we believe that a small-scale approach to in situ conservation is necessary as a complement to the large, established protected areas. Such small reserves should not be conceived as an alternative to large protected areas but rather both should be perceived as complementary approaches to biodiversity conservation (Tansley, 1988; Cowling et al., 2003; Laguna et al., 2004).

The 7% of the Chihuahuan Desert under legal protection is less than the minimum 10% recommended by international organizations (SCBD, 2002, 2004) and less than the 12% of the warm desert areas protected globally (Chape et al., 2005). To improve the conservation of the Chihuahuan Desert Cactaceae several actions are required: increase the effectiveness of the protected areas, especially those with numerous, unique, taxonomically distinctive species, and create a network of micro-reserves to protect the habitat of the highest possible number of unprotected and threatened species.

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Appendix

The appendix for this article is available online at http://journals.cambridge.org

Biographical sketches

Héctor M. Hernández studies the systematics and biogeography of Mexican Cactaceae, primarily in the Chihuahuan Desert, with the aim of developing tools for their conservation. He is also chairman of the IUCN Cactus and Succulent Plant Specialist Group. Carlos Gómez-Hinostrosa has extensive experience of the taxonomy of the Mexican Cactaceae and is a member of the IUCN Cactus and Succulent Plant Specialist Group.