

Candy Barrel Cactus (*Echinocactus platyacanthus* Link & Otto): A Traditional Plant Resource in Mexico Subject to Uncontrolled Extraction and Browsing¹

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Candy Barrel Cactus (*Echinocactus platyacanthus* Link & Otto [C Mex.]): A Traditional Plant Resource in Mexico Subject to Uncontrolled Extraction and Browsing. The candy barrel cactus (*Echinocactus platyacanthus*) is an endemic of the Chihuahuan Desert in México that is used as an ornamental plant, for fodder, and for human consumption. The uncontrolled use of this species has resulted in its being put under special legal protection. Although now illegal to harvest, many candy barrel cacti continue being destroyed in situ by both gathering and livestock grazing. This study describes the uses of this species and the characteristics of its natural population in central Mexico. In order to estimate density, percentage of damaged cactus, and height of candy barrel cactus, censuses were carried in stands of 2,500 m². The anthropogenic disturbance in each site was estimated by an environmental disturbance index (DI). Results show that the state of Hidalgo has the best conserved population (mean density=1,111 ind/ha, stratus height=137 cm, and only 2% of the total cacti injured). Populations in Puebla represent an intermediate state of conservation, while Querétaro has populations with the lowest density (435 ind/ha), the shorter height (62 cm), the highest foraging (18%), and the greatest DI (71.30). We recommend that conservation strategies for this species be implemented immediately, and that areas be established that exclude livestock and prevent extraction by humans.

La biznaga dulce (*Echinocactus platyacanthus* Link & Otto [C Mex.]): Un recurso vegetal de México sujeto a extracción no controlada y forrajeo. La biznaga dulce (*Echinocactus platyacanthus*) es una biznaga endémica del desierto de Chihuahuense en México, la cual es usada como planta ornamental, forrajera y para el consumo humano. Debido a su uso la legislación mexicana la ha designado como especie sujeta a protección especial. A pesar de que la extracción es ilícita, muchas biznagas continúan siendo destruidas in situ por colectas y por forrajeo del ganado. Este estudio describe el uso de la especie, así como las características de su población en el centro de México. Con la finalidad de estimar la densidad, el porcentaje de plantas dañadas y la altura del estrato de las biznagas, se realizaron censos en parcelas de 2,500 m². El disturbio antropogénico fue estimado a través de un índice de disturbio (DI) en cada sitio. Los resultados muestran que el estado de Hidalgo tiene la población mejor conservada (promedio de densidad=1,111 ind/ha, una altura del estrato=137 cm y con tan solo el 2% de las biznagas dañadas). Las poblaciones en Puebla representan un estado intermedio de conservación, mientras que las poblaciones de Querétaro presentan las densidades más bajas (435 ind/ha), las menores alturas (62 cm), un forrajeo más elevado (18%) y los mayores DI (71.30). Se recomienda la inmediata implementación de estrategias de conservación para la especie, como el establecimiento de áreas de exclusión para evitar tanto la extracción humana como el forrajeo.

Key Words: *Echinocactus platyacanthus*, candy barrel cactus, conservation biology, environmental disturbance index, México, non-timber forest products.

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Introduction

The candy barrel cactus (*E. platyacanthus* Link & Otto [C Mex.]) is endemic to México and is used as fodder for farm animals and food for humans. Its main use is in the preparation of the traditional candy known as *acitrón* (Bravo-Hollis and Sánchez-Mejorada 1991a, b; Del Castillo and Trujillo 1991). Over a large part of its distribution it is also used as fodder for goats and donkeys, and in some places is collected for ornamental usage. This resource has been used since prehistoric times, as revealed by the discovery of remains of the woolly tissue of the plant dating back to 6,500 years B.C.E. in the caves of Tehuacán (Smith 1967). Del Castillo and Trujillo (1991) and Bravo-Hollis and Sánchez-Mejorada (1991b) indicate that the indumentum or apical "wool" of this cactus was used by indigenous peoples as stuffing for cushions and for weaving various fabrics. The Aztecs called this plant species *teocomitl* or *huitznáhuac* (Bravo-Hollis and Sánchez-Mejorada 1978). The word *teocomitl* comes from *teo* (divine) and *comitl* (pot). The *teocomitl* was also used as an altar for human sacrifice, as depicted in the iconography of the Nutall Codex. The word *huitznáhuac*, also used to name this plant species, comes from *huitzi* (spine), and *náhuac* (surrounded by), i.e., "surrounded by spines." In the 16th century the word *huitznáhuac* was written as *vitzanauac*, from which the word was castilianised by the Spaniards as *biznaga*, familiar to them as an Arabian name used for a Mediterranean plant. In addition, the spines of this plant were used by Aztecs in self-mutilation to puncture ears, finger tips, arms, legs, nose, and tongue (Bravo-Hollis and Scheinvar 1999).

In spite of its historical and current importance, there are few studies of the population dynamics of this species. Jiménez-Sierra (2008) and Jiménez-Sierra et al. (2007) provided data on the population growth as evaluated using transition matrices for six populations over three years of observation in the state of Puebla. The finite rates of population growth (λ) recorded ranged from 0.9285 to 1.0005, with average $\lambda = 0.98$. For the state of Hidalgo, the finite rates of population growth of a population in Texcatepec was 1.02 (Xochipa 2006). This population has been isolated for the past two decades and therefore has not suffered damage from foraging or loss of individuals by removal. The elasticity matrices for both studies indicate that the

permanence of the adults has the highest impact on the λ values. This results from the very slow growth of this species, in spite of the fact that the plants grow up 1 or 2 cm/year (Jiménez-Sierra, pers. obs.), and that it is the large individuals that contribute the largest number of seeds.

THE SPECIES

Echinocactus platyacanthus is a barrel cactus, endemic to México, and characteristic of the Chihuahuan Desert. It is known as the barrel cactus (*biznaga*), candy barrel cactus (*biznaga dulce*), giant barrel cactus (*biznaga gigante*), or donkey barrel cactus (*biznaga burra*). It occurs between 18° N and 25° N latitudes, and 97° W and 102° W longitudes (Trujillo 1984) in the Mexican states of Coahuila, Guanajuato, Hidalgo, Nuevo León, Oaxaca, Puebla, Querétaro, San Luis Potosí, Tamaulipas, and Zacatecas (Fig. 3). The stem is light or dark green, with thick, hard ribs. There are large, thick spines in its areoles. This cactus is an important element of the landscape as it reaches heights up to 2 m and diameters up to 90 cm. Its apex is sunken and circular or elliptical in shape with abundant wool (Fig. 1). The flowers are diurnal, ca. 6 cm in diameter and bright yellow in color. Fruit is yellowish, dry, long (around 7 cm), and covered with wool and hair. The seeds are black and about 2.5 mm long (Bravo-Hollis and Sánchez-Mejorada 1991a; Jiménez-Sierra and Reyes 2000). Its growth is monopodial, but when its apical meristem is damaged, the stem branches. Each branch is a replicate of the original plant and produces new reproductive structures (Fig. 2).

CONSERVATION STATUS

This species is considered threatened (Hernández and Godínez 1994; Hunt 1992). The Official Mexican Ecological Regulation (NOM-0590-ECOL-2001) (SEMARNAT 2002) lists *E. platyacanthus* as a species under special protection because, although it has a wide distribution, its population densities are relatively low due to anthropogenic impacts. The International Union for Conservation of Nature and Natural Resources (IUCN 2004) classified the candy barrel cactus as a vulnerable species, although it was not included in the 2004 IUCN list (IUCN 2004).

The goals of this study are 1) to determine how people use *E. platyacanthus*, 2) to evaluate some



Fig. 1. *Echinocactus platyacanthus* with monopodial growth at the Cecilia site, showing one flower and mature fruits.

characteristics (density and the height of the stratum) of natural populations that sporadically are subject to illegal exploitation, and 3) to estimate the anthropogenic disturbance of its habitats. We anticipate a correlation between habitat disturbance and the status of *E. platyacanthus* populations (density, height, and percentage of damaged plants). If this correlation exists, then the index could be a good estimator of the state of the wild population of *E. platyacanthus*.

Methods

Species distribution information was obtained from herbarium specimens (ENCB, MEXU, and Herbario Metropolitano Ramón Riva y Nava

Esparza) and from the literature. In order to understand how the artisanal production of *acitrón* affects the species, interviews were carried out with two families. Other families interviewed refused to provide any information because the use of this plant constitutes an illegal activity. In order to obtain information about plant extraction in wild populations, six people in each nearby town were interviewed. Local markets were visited at Puebla, Tehuacán, Querétaro, and Pachuca, in addition to the main market in México City (*Central de Abastos*, the Central Wholesale Food Market), where six stall-keepers were interviewed to estimate the amount of *acitrón* sold.



Fig. 2. Branched *Echinocactus platyacanthus* at Cecilia site, showing new branches emerging from damaged branches (November 1997).

In order to estimate the density of natural populations, censuses of the species were carried out using plots of 2,500 m² in three populations at Hidalgo, six at Puebla, and three at Querétaro States. The localization, area covered by the population, and vegetation type were recorded (Table 1), as well as the number of plants, mean height of the candy barrel cactus, and number of damaged plants.

To evaluate the chronic anthropogenic environmental deterioration of the sites, the Disturbance Index (DI), as described by Peters and Martorell (2000) and Martorell and Peters (2005 and 2009), was estimated. We used two orthogonal, 50-m transects in each site. This index is based on the instantaneous and objective evaluation of different parameters that can be classified into three main

groups: a) livestock, which takes into account the presence of small (goats) and large (cattle, donkeys, and horses) grazers, plant browsing, the presence of livestock trails, and soil compaction; b) human activities, including the evaluation of cut plants, the presence of human pathways, nearness of towns, and nuclei of human activity, in addition to changes in soil use and evidence of fires; and c) habitat deterioration, including soil erosion, the presence of islands of vegetation, and the area of completely modified land. This index has been applied to different communities of xerophilous scrub in the Tehuacán-Cuicatlán region. Values for this index range from close to zero for well-conserved sites to almost 100 for extremely disturbed sites (Martorell and Peters 2009). Statistical analyses were carried out in order to

TABLE 1. CHARACTERISTICS OF THE STUDY SITES: LOCATION, ALTITUDE, AREA OF THE POPULATION, AND VEGETATION TYPE (*SENSU* RZEDOWSKI 1978).

	Sites	Latitude Longitude	Altitude (masl)	Area (km ²)	Vegetation Type (Dominant Species)
Hidalgo	Buenavista 1	20°28'59" N 98°41'06.8" W	1,352	5	Crassicaullous scrub (<i>Cephalocereus senilis</i> Pfeiff.)
	Buenavista 2	20°28'59.9" N 97°39'05.05" W	1,360	4	Crassicaullous scrub (<i>Cephalocereus senilis</i>)
	Santuario	20°35'19.1" N 98°45'52.8" W	1,294	1	Crassicaullous scrub (<i>Cephalocereus senilis</i> , <i>Turbincarpus horripilus</i> [Lem.] Vác. John & Riha)
Puebla	Roberto	18°24'53.4" N 97°25'24.6" W	1,720	1	Rosetophyllous scrub (<i>Hechtia podantha</i> Mez)
	Mauricio	18°23'03.6" N 97°26'38.4" W	1,640	3	Crassicaullous scrub (<i>Cephalocereus columna-trajani</i> [Karw.] K. Schum.)
	Jardín	18°20'54.5" N 97°26'06.9" W	1,700	4	Crassicaullous scrub (<i>Cephalocereus columna-trajani</i>)
	Cecilia	18°14'55.8" N 97°36'36.6" W	1,600	4	Crassicaullous scrub (<i>Neobuxbaumia macrocephala</i> [F.A.C. Weber ex K. Schum.] E.Y. Dawson)
	Cielo	18°19'17.6" N 97°33'30.1" W	1,770	5	Thorn scrub (<i>Yucca periculosa</i> Baker)
	A. el Burro	18°19'11.4" N 97°33'33.0" W	1,650	2	Crassicaullous scrub (<i>Neobuxbaumia tetetzo</i> [F.A.C. Weber ex K. Schum.] Backeb.)
Querétaro	Casas Viejas	20°55'18.7" N 99°54'27.5" W	1,599	5	Crassicaullous scrub (<i>Fouquieria splendens</i> Engelm. in Wilm, <i>Cylindropuntia leptocaulis</i> [DC.] F.M. Knuth)
	Tolimán	20°25'02.05"N 99° 56' 15.5" W	1,602	1.5	(<i>Fouquieria splendens</i> , <i>Cylindropuntia leptocaulis</i>)
	Don Lucas	20°53'07.5" N 99° 56' 48.5" W	1,627	3	Thorn scrub (<i>Mammillaria parkinsonii</i> Ehrenb., <i>M. compressa</i> DC., <i>Thelocactus leucacanthus</i> [Zucc. ex Pfeiff.])

determine the relations between DI and population variables.

Results

SPECIES DISTRIBUTION

The distribution of *E. platyacanthus* by states and municipalities (Arguelles et al. 1991; Arias et al. 1997; Bravo-Hollis and Sánchez-Mejorada 1991b; Sánchez-Mejorada 1978; Scheinvar 2004) is shown in Fig. 3. The sites mentioned in the literature have been strongly affected by the growth of towns and changes in land use as many areas have been opened to agriculture (Bravo-Hollis and Sánchez-Mejorada 1991b;

Del Castillo and Trujillo 1991; Jiménez-Sierra 2008; Scheinvar 2004).

ACITRÓN PRODUCTION

Acitrón is a crystallized or candied sweet that is handcrafted using the pulp of the stem of the candy barrel cactus. It is sold as a treat in town fairs all over México (Bravo-Hollis and Sánchez-Mejorada 1991b; Del Castillo and Trujillo 1991; Jiménez-Sierra and Torres-Orozco 2003). Acitrón is also an important ingredient in many Mexican and international dishes. It is used in the preparation of sweet tamales, hot fruit punch, the ring-shaped sweet bread prepared for the celebration of the

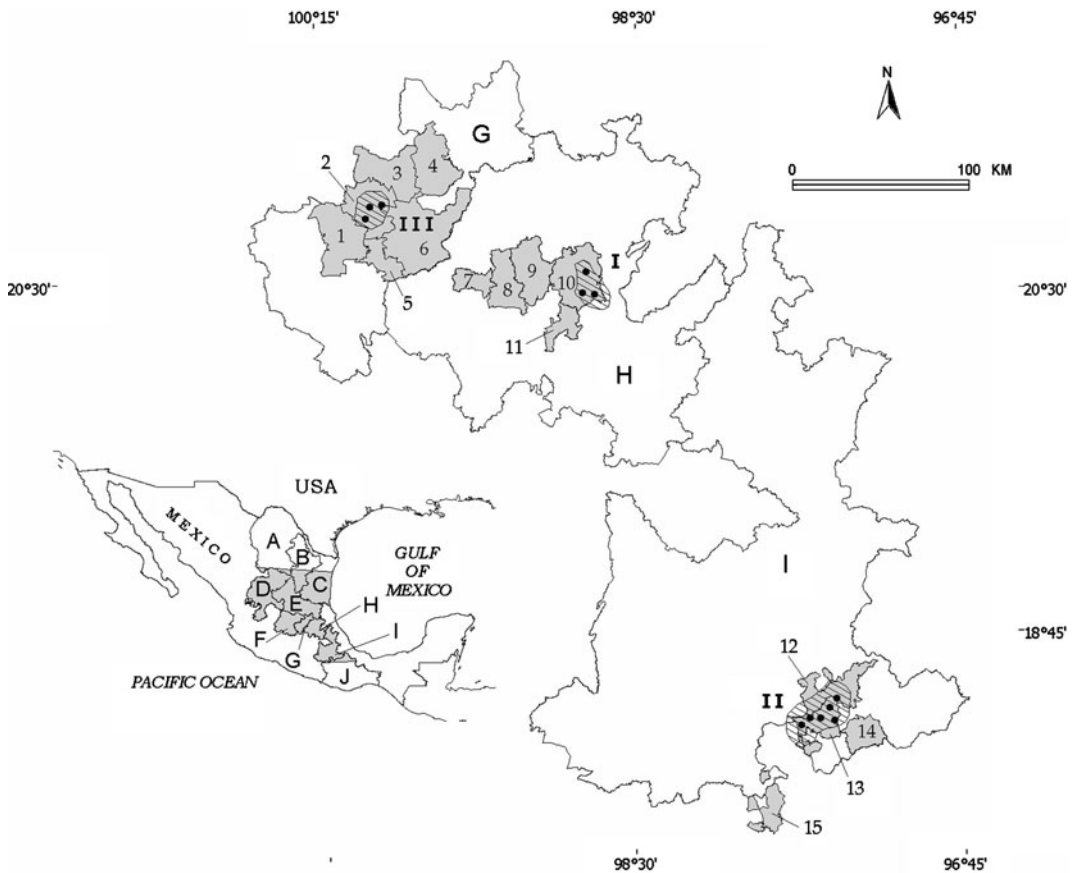


Fig. 3. Distribution map for *Echinocactus platyacanthus*, a species endemic to México, and the study sites. States where the species is present: A) Coahuila, B) Nuevo León, C) Tamaulipas, D) Zacatecas, E) San Luis Potosí, F) Guanajuato, G) Querétaro, H) Hidalgo, I) Puebla, and J) Oaxaca. Municipalities: 1) Colón, 2) Tolimán, 3) Peña Miller, 4) Pinal de Amoles, 5) Ezequiel Montes, 6) Cadereyta de Montes, 7) Tasquillo, 8) Ixmiquilpan, 9) Cardonal, 10) Metztlán, 11) Actopan, 12) Tehuacán, 13) Zapotitlán, 14) Miahuatlán, and 15) Huajuapán de León. Lines and circles indicate localities studied in: I) Hidalgo, II) Puebla, and III) Querétaro.

three wise men, chilies in cream and walnut sauce, and in a regional Christmas salad. In México it is used in confectionary and baking, as in the Mexican version of the Christmas fruit cake. *Acitrón* is prepared at home following family recipes that have been handed down for generations. The pulp from the stem is separated from the roots and the ribs, and then cut into 20–40 cm wide chunks. These are left to soak in copper pots in water with lime. The pulp is then boiled in water over a wood fire and left to cool. This activity is repeated several times. During the final boiling, sugar or honey is added, approximately 1.5 kg of sugar per kg of cactus tissue. This mix is then left to harden before being sold or eaten (Roberto Vargas, México City, pers. comm.; Juvencio Durán Pérez, Metztlán, Hgo, pers. comm.). The product can be stored for several months and up to a year if refrigerated.

PLANT EXTRACTION

The preparation of *acitrón* requires the extraction of the entire plant. For this purpose, individuals taller than 50 cm are chosen. Because the quality of the pulp varies between plants, collectors first take a sample of the pulp. Plants with a reddish pulp or with grainy or sandy pulp are not used. There are no reports of whether this type of activity affects the survivorship of sampled plants. In the towns close to the sites where this cactus grows, *acitrón* is usually prepared for local consumption, as is the case in Zapotitlán Salinas. There the sweet is prepared and sold by a single family during November, the month of the town's festival. National commerce depends on the illegal extraction of candy barrel cactus, which is done by local inhabitants. These collectors obtain only USD 0.50–0.60/kg of candy barrel cactus. The lion's share of the profit goes to the intermediaries (producers and merchants) who sell it for seven times more than what they pay for it. There is some evidence of illegal trafficking of this resource when the authorities unexpectedly encounter and confiscate shipments. One such instance occurred when ten tons of candy barrel cactus and other cacti intended for making *acitrón* were confiscated in Ixmiquilpan in June 2004 (SSP 2004). In another example, 326 large candy barrel cacti were confiscated from Tolimán (Hidalgo) (PROFEPA 2008). Because extraction of pulp for the preparation of *acitrón* kills the plant, candy barrel cactus populations have decreased, and extraction is becoming increasingly

difficult. Collectors now focus on populations that are isolated and increasingly distant from towns and villages (an *acitrón* expert, *acitrón* producer pers. comm.; Scheinvar 2004).

DISTRIBUTION OF ACITRÓN

It is difficult to collect information about the candy barrel cactus pulp business because it is an illegal activity. México City seems to be the principal distributor of the candy. It is assumed that the majority of the *E. platyacanthus* that currently arrives in México City comes from México's northern states, such as Hidalgo, Querétaro, Aguascalientes, San Luis Potosí, and Zacatecas. To avoid legal problems related to the extraction of *E. platyacanthus* and other barrel cacti protected by the Mexican Official Ecological Regulation (NOM-0590-ECOL-2001) (SEMARNAT 2002), only the pulp (without the ribs) is transported to México City in unrefrigerated transport trucks. Once the shipment is received, the *acitrón* is prepared by a small group of producers who are related to the main distributors.

Information provided by the merchants at the Wholesale Food Market in México City indicates that between 800 and 1,000 kg of *acitrón* are sold per day. A candy barrel cactus that is 50 cm tall has a mean weight of 65 kg. If only 25% of its total mass is used (without taking into account either lignified tissue or ribs), an extraction of 25 plants per day would be necessary. That constitutes an extraction of 9,000 individual plants annually. Demand increases from October to February owing to the traditional festivities during which local dishes and delicacies are prepared with *acitrón*. The candy is available all year long in some cities in central México, such as the local markets of San Luis Potosí, Querétaro, Hidalgo, Puebla, and Oaxaca, among others, where stallholders indicated that the candy came from México City. In the Wholesale Food Market of México City, one kilogram of *acitrón* is sold wholesale for USD 3.00–3.50. However, at fairs, local markets, and in candy shops, where small quantities are sold, the price can be as high as USD 8.00 per kg.

STATUS OF WILD POPULATIONS

The locations of the 12 populations investigated in this study (Fig. 3) and their main environmental characteristics are presented in Table 1. They range in altitude from 1,294 to

1,700 m (mean=1,554 m). The vegetation is xerophilous scrub (*sensu* Rzedowski 1978), though there is some variation in the dominant plant species (Table 1). The sites studied in Hidalgo are located in Metztitlán Canyon Biosphere Reserve. In this zone, the candy barrel cactus grows in xerophilous scrub along with the endemic columnar cactus *Cephalocereus senilis* (Haw.) Pfeiff, a species classified as threatened by the Mexican government. In Puebla, the populations we studied inhabit the Tehuacán-Cuicatlán Biosphere Reserve. The sites in Querétaro are in the vicinity of Cadereyta and in the Vizarrón zone, which are close to towns. The areas occupied by the populations, according to field observations, range from 1–5 km² (Table 1).

The populations with the largest plants are found in Hidalgo, where the cacti reach a mean height of 137 cm, followed by those of Puebla at 66 cm, and finally Querétaro at 62 cm (Table 2).

The population density of *E. platyacanthus* varied among sites. The highest mean density was recorded in Hidalgo (1,111 ind/ha), followed by Puebla (598 ind/ha), and finally Querétaro (435 ind/ha; Table 2). The percent of plants damaged per population ranged from 1% (San-

tuario, Hidalgo) to 34.6% (Roberto, Puebla). The mean percentage of plants injured was 2% in Hidalgo, 13.4% in Puebla, and 18.3% in Querétaro (Table 2).

ENVIRONMENTAL DISTURBANCE

Table 2 lists the mean disturbance index (DI) for each site. Values range from a low of DI=20.07 (Roberto, Puebla) to a high of DI=76.25 (Don Lucas, Querétaro). Mean DI was greatest in the state of Querétaro (71.3), followed by Hidalgo (56.18), and finally by Puebla (28.56). We did not find a correlation between population variables (density, percentage of plant damage, or height) and DI, nor did we find a correlation between DI and λ values for the Tehuacán populations (Jiménez-Sierra et al. 2007). For all states, the most important disturbance factor was human activity, followed by habitat deterioration and finally livestock. The impact of human activity is a result of the proximity of settlements and towns, which have tracks or pathways and where land is tilled for agriculture. Environmental deterioration is indicated by the presence of erosion and islands of vegetation surrounded by

TABLE 2. POPULATION DENSITIES, DAMAGED CACTUS (%), HEIGHT OF THE *E. PLATYACANTHUS* STRATUM, AND DISTURBANCE INDEX (DI) (MARTORELL AND PETERS 2009; PETERS AND MARTORELL 2000). SOURCES OF DISTURBANCE BY LIVESTOCK, HUMAN ACTIVITIES, AND ENVIRONMENTAL DETERIORATION.

Site	Density Ind/ha	Damaged Plants (%)	Average Height of <i>E. platyacanthus</i> (Intervals) cm	Disturbance Index (DI)	Disturbance Factors		
					Human Activity (%)	Livestock (%)	Erosion (%)
Hidalgo							
Buenavista 1	2,000	2	150 (5–180)	48.87	62.97	27.85 (g)	9.19
Buenavista 2	1,000	3	150 (5–200)	62.55	48.79	37.58 (g)	13.64
Santuario	333	1	110 (5–150)	57.12	35.63	–	64.37
Mean	1,111	2	137	56.18	49.13	21.81 (g)	29.07
Puebla							
Roberto	276	34.8	60 (7–120)	20.07	59.85	16.67 (g/m)	23.48
Maurilio	564	4.2	65 (4–120)	44.29	27.14	34.85 (g/m)	38.02
Jardín	1,016	16.1	50 (3.5–81)	10.85	63.67	5.28 (g/m)	31.04
Cecilia	516	16.3	75 (4–180)	23.07	45.83	30.81 (g/m)	23.35
Cielo	300	10.7	95 (2.5–105)	32.55	57.12	15.98 (g/m)	26.9
A.el Burro	404	12.9	50 (3–85)	40.59	34.8	12.63 (g/m)	52.57
Mean	598	13.9	66	28.57	48.07	19.37 (g/m)	32.56
Querétaro							
Casas Viejas	333	15	50 (5–120)	63.19	52.48	13.4 (d)	34.11
Tolimán	453	26	90 (5–185)	74.46	48.15	1.16 (d)	50.69
Don Lucas	520	14	45 (10–60)	76.25	46.49	19.32 (d)	34.19
Mean	435	18.3	62	71.3	49.04	11.29 (d)	39.66

Principal forage cattle; g = goats and sheep; g/m = goats and sheep/hurt by machete; d = feral donkeys.

eroded soils. The total estimated impact of livestock in most cases is the least important factor, since this index undervalues the presence of large animals (cattle and donkeys) and assumes that these livestock tend to establish in the best-conserved scrublands. However, the candy barrel cactus populations can be directly affected when they are damaged with machetes or when large livestock like feral donkeys forage directly on them.

Most of the consumption of candy barrel cacti by cattle occurs during the dry season, when fresh foliage of shrubs and herbaceous plants is scarce. Goats and sheep cannot harm adult plants. In the state of Puebla, *E. platyacanthus* was under great foraging pressure until about 40 years ago because, in addition to local livestock, herds of goats from northern Oaxaca were driven up to the outskirts of Tehuacán. A goat slaughterhouse was located there, and the meat was sold in central México. Peak slaughter season for goats was November, and, during the drive northwards through Puebla, it was customary to feed the animals with candy barrel cactus and salt from the local *saltnes* of Zapotitlán. It is said that this resulted in higher-quality meat. With their machetes the shepherds damaged or hit the cacti they encountered along the way so that the animals could eat them (Pedro G. Miranda, Zapotitlán Salinas, pers. comm.) This appears to have been the cause of the notable occurrence of individuals with branches in southern Puebla.

Wild donkeys have learned to remove the spines of the cactus using their hind legs, after which they can bite through to the tender pulp. The situation with foraging donkeys has deteriorated in recent years as there are now wild populations in the states of Hidalgo and Querétaro (Chávez-Martínez et al. 2007). At Tolimán (Querétaro), for example, practically all of the candy barrel cacti taller than 50 cm have been damaged (26% of the population). The probability of survival in these cases depends on the percent of tissue removed and the frequency of the damage. If the apical meristem is damaged and the plant has not lost much biomass, the plant may produce new branches.

Discussion

The candy barrel cactus, *Echinocactus platyacanthus*, is an important resource in the xerophilous scrubland of northern and central México. Its use is important to the familiar economies of

the towns. It is part of the region's historical and cultural legacy, as well as being a potential resource for future generations. The extraction of *E. platyacanthus* is illegal, yet *acitrón* is sold and consumed all over México. Many habitats where the species occurs have been modified, and the remaining populations, with generally low mean densities, face serious problems for survival. Two of the populations at Metztlán (Buenavista 1 and 2) have maintained high density because they are far from human establishments. The impact of human activity is observed when the height of the plants is compared; in half of the populations, individuals measure no more than 100 cm, although this species can reach up to 200 cm. This is because large candy barrel cacti are most commonly collected and injured. The percentage of foraged individuals is high in sites where feral donkeys are present, such as Querétaro State, where 18.3% of plants are damaged. The growth of wild donkey populations is alarming because the females reach sexual maturity in only one year and can produce offspring each year.

Environmental disturbance ranges from moderate for Puebla (DI=28.57) to high for Hidalgo (DI=56.18) and severe for Querétaro (DI=71.3). These values do not, however, correlate with the status of the candy barrel cactus, because although the habitats may be seriously altered, the adult cacti can be still intact. However, environmental disturbance in these cases may well be affecting population recruitment, which will likely have an impact on future generations. Populations of *E. platyacanthus* are at risk because, in general, the individuals are destroyed (live foraging or direct removal of individuals), and their environments have often deteriorated, resulting in individuals less than 5 cm tall and a scarcity of seedlings.

The demographic studies carried out in Puebla suggest that the populations are barely achieving equilibrium ($\lambda \approx 1$), and that the removal or destruction of large individuals—as is currently occurring—has a severe negative impact on lambda (Jiménez-Sierra et al. 2007). The continued existence of these populations is in danger because these large individuals are the most prolific seed producers.

To provide for the survival of the species, we make the following recommendations: 1) establish exclusion areas to prevent removal of and damage to these cacti; 2) create germplasm banks; 3) establish greenhouses in the towns surrounding

candy barrel cactus populations; 4) create environmental education and technical support programs to cultivate candy barrel cactus within natural ecosystems; and 5) eradicate the wild donkeys.

Programs of this type need strong community participation and appropriate government support. The reason that this and other barrel cacti have not been established is due to their slow growth rate. The search for alternative strategies, such as commercial cultivation of the species, should start with the inhabitants of these zones, given that they are the ones most affected by the loss of their resources and also the ones who currently receive the least economic benefit. This approach has been suggested in other programs supporting non-timber forest products, like the United Nations Environment Program (UNEP-WCMC), which promotes policies to achieve multiple and sustainable ecosystem use. The establishment of mixed plantations could include 1) agaves like *Agave lechuguilla* Torrey (to obtain fibers), or *A. salmiana* Otto ex Salm-Dyck (to produce pulque or mezcal), or *A. angustifolia* Haw., *Agave scabra* Salm-Dyck, and *A. weberi* Cels ex Poiss., *A. potatorum* Zucc., 2) other plants like *Yucca carnerosana* (Trel.) McKelvey, that produces fibers, or *Euphorbia antisiphilitica* Zucc. or *Pedilanthus macrocarpus* Benth and *Simmondsia chinensis* C.K. Schneid (to obtain waxes and oils), 3) other cactus of economic importance such as *Hylocereus* spp., *Myrtillocactus geometrizans* Console, and *Opuntia* spp., or 4) timber species such as *Prosopis* spp. (mesquite), *Leucena* spp., and *Sena* spp., all of which could serve as nurse plants for the cactus crops.

Conclusions

The use of *E. platyacanthus* requires strategic planning at the local, regional, and national levels. Given the importance of this resource and its current use, it is not possible to completely prohibit either its extraction or its use as forage. It is, however, important to protect the regions where the plant grows in order to guarantee not only its continued availability as a resource, but also its genetic diversity.

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