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Assessing the importance of multiple threats to an endangered globose cactus in Mexico: Cattle grazing, looting and climate change

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ABSTRACT

Cacti are a priority for conservation because their slow recovery rates and high habitat specificity make their populations particularly susceptible to looters who raid their populations, anthropogenic disturbance and climate change (CC). Identifying the most damaging threat is critical to the direction and efficiency of conservation efforts. We analyzed the impacts of looting, disturbance and CC on the geographically rare globose cactus *Coryphantha werdermannii* in Coahuila, Northern Mexico. We collected evidence on looting and estimated the impacts of seed and adult plant extraction through demographic models. We compared 10 sites differing in disturbance intensity and analyzed the effect on plant density, size structure and reproduction. The potential distribution of *C. werdermannii* under current conditions and future CC was assessed through ecological niche modeling. We found that looting is mostly confined to seeds, which have little impact on population growth and therefore not responsible for population decline. As in many globose cacti, the density of *C. werdermannii* populations increased with disturbance, likely because cattle grazing increases recruitment rates. Contrastingly, even the most optimistic CC scenarios suggest a 90% reduction in the potential distribution area by 2050, indicating that *C. werdermannii* is an endangered species most threatened by CC. We suggest that relocation programs and the maintenance of livestock levels appropriate for this species (moderate-high) may effectively counteract or delay the effects of CC. Our results suggest that current efforts are devoted to relatively minor threats, while CC is neglected, and highlight the importance of formal assessments of multiple threats.

1. Introduction

Cacti are considered a priority for conservation. They are the 13th most at risk flowering-plant family, with more species classified as endangered or critically endangered on the IUCN's Red List (IUCN, 2010), and the second with more taxa listed as threatened by the Mexican government (SEMARNAT, 2002). The whole family is included on Appendix II of CITES (CITES, 2010). Three anthropic factors have been considered to underlie this high degree of threat: anthropogenic disturbance, climate change and looting (Anderson et al., 1994; Bárcenas-Luna, 2003; Godínez-Álvarez et al., 2003; Hernández and Godínez-Álvarez, 1994; Martorell and Peters, 2005; Oldfield, 1997; Téllez-Valdés and Dávila-Aranda, 2003; Ureta et al., 2012).

Cacti are thought to be highly vulnerable to anthropogenic disturbance. Low growth rates and rare recruitment events suggest that the replacement of individuals killed by disturbance may be extremely slow (Godínez-Álvarez et al., 2003; Hernández and Godínez-Álvarez, 1994). They also depend on nurse plants during establishment (Flores and Jurado, 2003; Franco and Nobel, 1989; Valiente-Banuet et al., 1991; Valiente-Banuet and Ezcurra, 1991), making vegetation clearing a threat to their survival. Many cacti are endemic to extremely small areas, so land use change may wipe out whole species (Godínez-Álvarez et al., 2003; Hernández and Godínez-Álvarez, 1994; Oldfield, 1997).

Little is known about the potential impacts of climate change (CC) on cacti. In the only assessment available, Téllez-Valdés and Dávila-Aranda (2003) suggest that CC might threaten several species by reducing their potential distribution area (PDA). Furthermore, the Chihuahuan desert, home to the largest cactus diversity in the world (Hernández and Bárcenas, 1995; Hernández and Gómez-Hinostrosa, 2011), is expected to be one of the regions most affected by CC worldwide (Solomon et al., 2007).

Looting is frequently singled out as the most important threat to some cacti (Godínez-Álvarez et al., 2003; Martínez-Peralta and Mandujano, 2009; Muro-Pérez et al., 2011; Oldfield, 1997;

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Robbins, 2003). This is especially important for the rarest species that are the most prized items in a collection. We lack robust data on the magnitude of the problem due to weak surveillance and opacity of the government agencies in charge of cactus protection. However, some 2000 individual plants from approximately 300 different species of Chihuahuan desert cacti are seized from looters each year (Bárcenas-Luna, 2003; Martínez-Peralta and Mandujano, 2009).

Thus far, we lack data on the relative importance of anthropogenic disturbance, CC and looting as determinants of the conservation status of cacti. Determining which factors are the greatest threats is critical for establishing appropriate policies (*e.g.*, establishing cattle-free reserves, translocation of populations to climatically appropriate areas or enforcing laws against looting). Furthermore, because most cacti occur in developing countries with limited resources, conservation efforts need to be prioritized.

In this paper, we assess the effects of anthropogenic disturbance, CC and looting on the globose species *Coryphantha werdermannii*. This species is endemic to a relatively small area in the Chihuahuan desert, and is representative of Mexican cacti in terms of threats and legal status. Our specific aims are to (1) assess the current conservation status of *C. werdermannii* and its biological vulnerability, (2) determine the effects of chronic anthropogenic disturbance on *C. werdermannii* populations, (3) analyze the impact of CC on the potential distribution of *C. werdermannii* and (4) estimate the magnitude of looting and its effects on the viability of this species.

2. Methods

2.1. Study site and species

C. werdermannii is a solitary, globose cactus reaching 8–15 cm tall and 6–8 cm in diameter; seedling size is about 2 mm. Areoles surrounding the apex produce four dark spines once the reproductive stage is reached (Fig. 1). Flowering and fruiting occurs mostly in May and June, although further reproduction may be observed as late as September. *C. werdermannii* is endemic to the Cuatro Ciénegas region (Coahuila, Mexico), one of the most biodiverse cactus hotspots worldwide (Bravo-Holis, 1978; Hernández and Bárcenas, 1995). *C. werdermannii* is listed as endangered by Mexican law (SEMARNAT, 2002) and on Appendix I of CITES (CITES, 2010) because it is thought to experience intense looting (Lüthy, 2001), but has not yet been assessed for the IUCN Red List.

C. werdermannii grows in topographically complex regions, with steep sierras and wide bajadas. The climate has extreme temperatures and precipitation that vary with season and elevation. At the lowest elevation (740–1200 m a.s.l.) the mean temperature is 21.2 °C, with a maximum in June of 34.8 °C and a minimum in January of 4.8 °C (mean of daily). The total annual precipitation is 252.5 mm, with a minimum in March of 5.5 mm and a maximum in September of 38.8 mm.

C. werdermannii grows in a microphyllous-succulent scrub. Naturally occurring vegetation provides food to livestock, which is the most important source of anthropogenic disturbance in the region: the county of Cuatro Ciénegas raises cattle on 92% of its land, and only 6% of the land has relatively intact plant cover (INEGI 2001, 2002). In addition, the extraction of candelilla (*Euphorbia antisyphilitica*) wax is common in the area, meaning a continuous movement of people, mules and trucks, as well as the removal of plant biomass (Martínez-Ballesté and Mandujano, 2013). Events of livestock grazing and candelilla harvest are of relatively low intensity, but are frequent and recurring, classifying them as chronic anthropogenic disturbances (CAD). However, CAD does not cause sudden land use change but rather a gradual degradation (Martorell and Peters, 2005; Singh, 1998). A mosaic of patches in different phases of deterioration occurs in the region, but the most affected areas have nearly no vegetation.

2.2. Conservation status

To assess the conservation status of *C. werdermannii* we used IUCN (2001) criteria, which require data on species distribution, number of populations and population sizes. Thus, in June 2005 we explored a large region looking for extant populations. We located 10 *C. werdermannii* populations in the area, which were delimited by a polygon joining the most distant plants found (see Martorell and Peters, 2009 for details). To estimate plant density, we randomly placed between 3 and 15 (depending on the population's area) 50 × 6 m transects in each site. Because large individuals (>5 cm) are relatively scarce and thus were unlikely to be properly represented in the sample if only a few transects were chosen, in small (<1 ha) populations we included all individuals >5 cm in a census. However, this method was inaccurate for counting small (1–5 cm) individuals. For this reason we still used transects that were thoroughly revised to sample such plants. In large (>1 ha) sites, we relied completely on transect data, which in this case included all individuals with diameters >1 cm. Plants <1 cm in diameter are difficult to find and their numbers cannot be estimated without considerable error, and were therefore excluded from the analyses. We also recorded the number of reproductive structures (flowers, buds and fruits) and the sizes of all individuals. Population sizes were obtained by extrapolation of transect data to the whole polygon area. In small populations,

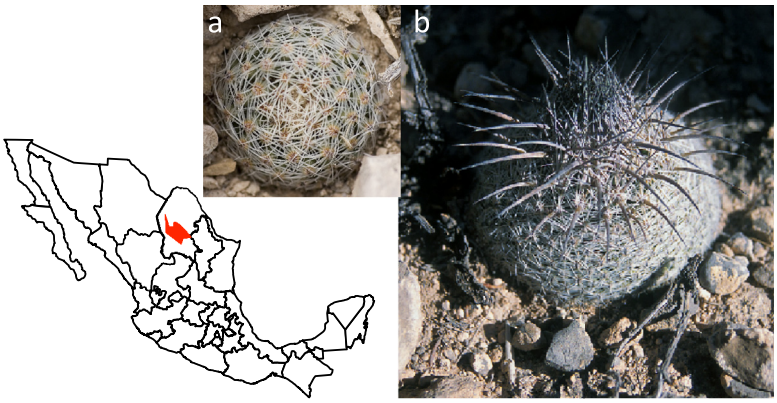

Fig. 1. Potential distribution area of *Coryphantha werdermannii* with (a) a juvenile ca. 3 cm in diameter and (b) adult plant with dark, central spines near the apex. The spot in the map corresponds to the distribution area of *C. werdermannii*.