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Distribution and population patterns of the threatened palm *Brahea aculeata* in a tropical dry forest in Sonora, Mexico

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ABSTRACT

The use of non-timber forest products (NTFPs) has great potential for the conservation of natural resources and rural development. Palms are important NTFPs, providing numerous products, including leaves. The harvest of palm leaves rarely results in the immediate death of individuals and can be considered one example of the sustainable use of forest resources. However, in most cases basic ecological information, such as distribution and abundance of the species is unknown, as is information on the ecological implications of human impacts, such as leaf harvest and livestock grazing. In the tropical dry forests of northwest Mexico, leaves from the threatened palm *Brahea aculeata* are harvested for roofing material and represent an important NTFP. In this study, we assessed the distribution and abundance patterns of this species across 52 plots in the tropical dry forest of Sierra de Álamos-Rio Cuchujaqui Reserve (SARCR) in Sonora, Mexico. We also evaluated patterns of leaf harvest and cattle browse intensity on palm populations. We found that *B. aculeata* density is highly variable across the landscape with a mean (±SE) of $121.7 \pm 36.3\ ha^{-1}$. Results indicate that *B. aculeata* is primarily distributed near to arroyos and rivers. The highest densities were found in sites with low incidence radiation (<0.06 MJ cm^{-2}) and narrow stream width of arroyos/rivers (<9.5 m). Palm abundance also varied within the plots, and *B. aculeata* attained its highest densities near to the arroyo edge (first 20 m from the edge), perhaps indicating a microhabitat effect on palm demography. Overall, fewer than 6% of the stems were seedlings. Leaf harvesting and browsing appear to affect demographic vital rates of the species; specifically we found a significant effect of harvesting and browsing activity on the proportion of reproductive active adults. Thus, low levels of seedlings in the populations may be the result of reduced fruit production by adults and higher mortality rates of seedlings due to livestock herbivory. Result from interviews with land owners also indicated that past land use, especially along arroyos might also have important impacts on the observed distribution, low densities and absence of recruitment in some areas. We believe current distribution and abundance of NTFP, such as *B. aculeata* at SARCR may be a result of combined effects of environmental factors and human impacts. Results from this study will be used to develop appropriate conservation, management and restoration plans of *B. aculeata* in the area.

1. Introduction

Thought to have low impacts on plant populations and ecological communities, the extraction of non-timber forest products (NTFPs) has been suggested as a good ecological and economic option for sustainable development. The extraction of NTFP can contribute to the livelihood and welfare of people living in or near to forests and is thought to be less ecologically destructive. Therefore, the use of NTFP has great potential in the conservation of natural resources and rural development, particularly in and around protected areas, where other development/land use activities are often constrained (Zuidema, 2000; Arnold and Perez, 2001).

Palms exemplify NTFPs potential as they represent a very important botanical family throughout the tropics and subtropics, providing food, building material, medicines, fibers, oils and more for subsistence, commercial and cultural uses (Joyal, 1996a; Henderson et al., 1997). Palm leaf harvesting rarely results in the immediate death of individual palms and has been considered a great opportunity for sustainable use of forest resources (Oyama and Mendoza, 1990; Endress et al., 2004; Zuidema et al., 2007). However, only in certain cases harvesting has been evaluated and for many species we lack information on the ecological impacts of harvesting and whether extraction is sustainable. The effects of harvesting on palms depend on the intensity, frequency and dura-

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tion of harvesting. Thus, single or few removals of leaves had no negative effect and even increases in growth and leaf and fruit production has been reported (Oyama and Mendoza, 1990; Anten and Ackerly, 2001). However, over time, this can change as effects accumulate and as demonstrated in several studies, the sustained harvest may have important effects in the demographic vital rates and in the population growth rate (Endress et al., 2006; Martinez-Ramos et al., 2009). For many palm species used as NFTP, basic information such as distribution, abundance and their conservation status is unknown even in areas where their populations are exploited (Ticktin, 2004).

Often, NTFP have been extracted without management plans based on ecological data. For example, the palms *Geonoma macrostachya*, *Euterpe edulis* and *Mauritia flexuosa* have been exploited for leaves, stems and fruits, and resulted in negative impacts on harvested populations (dos Reis et al., 2000; Zuidema, 2000; Svenning and Macia, 2002; Zuidema et al., 2007; Holm et al., 2008). As a consequence, these practices have diminished their populations and their long-term conservation is compromised.

We believe that one of the prerequisites for implementing sustainable harvest management programs, especially for species that are suspected to be declining in abundance or are threatened by anthropogenic activity, is an understanding of their distribution, abundance, conservation status, and response to harvest. This information is particularly essential for *Brahea aculeata*, as this palm species represents one of the more important non-timber forest products in the Northwest Mexico tropical dry forest. Furthermore, due to over-exploitation, habitat conversion and its restricted range, it is considered a threatened species and it is listed in the Mexican and IUCN Red List (Quero, 1998; Felger et al., 2001; SEMARNAT, 2002).

In the mountains of southern Sonora, Mexico, leaves of *B. aculeata* are harvested for thatching roofs. *B. aculeata* and another palm, *Sabal uresana*, whose leaves are used to make baskets and other handicrafts represent the two most important NTFP in the area (Joyal, 1996a,b), but harvest pressure is intense and may be negatively affecting palm populations. In addition, the use of unplanned silvopastoral systems in the region, where livestock graze throughout the forest, has resulted in overgrazed areas, and the evergreen nature of *B. aculeata*, uncommon for trees in the tropical dry forest, seems to lead to intense browsing on *B. aculeata* during the long dry season (8 months with monthly rainfall <100 mm) (Borchert et al., 2004; Vasquez-Leon and Liverman, 2004).

Within the Sierra de Álamos-Rio Cuchujaqui Reserve (SARCR), *B. aculeata* is patchily distributed and its abundance varies throughout the area. For palms in humid environments, previous research has demonstrated that distributions of palms are strongly influenced by microhabitat heterogeneity, especially topography and edaphic factors (Clark and Clark, 1995; Svenning, 1999; Svenning et al., 2009). For dry forest and arid environments, microhabitat heterogeneity has also been documented as one of the more important factors influencing plant populations and communities as a result of limitations imposed by lack of water and high temperatures (Arriaga et al., 1993). Therefore, we hypothesize that the distribution and abundance of *B. aculeata* is shaped by microhabitat. Moreover, palms may respond to harvest, browse or other disturbance events differently under different microhabitat conditions. This ecological information is critical not only to determine the main environmental factors affecting its distribution, but it will also help inform management plans. The study of microhabitat can help identify those areas with higher densities where extraction can occur and areas requiring protection and/or restoration (Lopez-Toledo et al., 2011).

In this study, we collected basic ecological data to inform the conservation and sustainable use of *B. aculeata*. We assessed the distribution and abundance patterns of this species in the tropical dry forest of Sierra de Álamos-Rio Cuchujaqui Reserve (SARCR) in Northwest Mexico and evaluated the factors affecting its distribution and abundance. Additionally, we estimated the harvest and browse impacts on palm populations across the landscape. Results from this study will be used to better understand the factors affecting *B. aculeata* abundance, distribution and stage structure and develop appropriate conservation, management and restoration plans.

2. Materials and methods

2.1. Study site

The study was conducted in the Sierra de Álamos-Rio Cuchujaqui Reserve, a 92,890 ha protected area in the northern Mexican state of Sonora (Fig. A of Appendix). SARCR is part of Mexico's network of natural protected areas and is also recognized by the UNESCO Man and the Biosphere Program (UNESCO). While the Reserve is a federally recognized protected area, nearly 60% of the land remains private property. Elevations range from 300 to 1600 m asl and gives rise to a vegetation gradient ranging from tropical deciduous to pine-oak forest. Nearby meteorological stations indicate annual rainfall in the area is highly variable with a mean of 650 mm and 190 and 1120 mm as the lowest and highest records between 1940 and 2005. The 8-month dry season (November to June) is very pronounced, receiving only 25–35% of the total annual rainfall, and many intermittent rivers and arroyos dry out during this time. Mean annual temperature is 21–22 °C with 10 °C and 41 °C as minimum and maximum temperatures. Our study was focused within the upper watershed of the Cuchujaqui River, focusing on five properties part of Rancho Ecológico Monte Mojino (REMM) and one private property. REMM is owned and managed by Nature and Culture International (NCI). As part of its mission, NCI has acquired land within SARCR to conduct conservation, applied research and community development (Fig. A of Appendix).

2.2. Study species

B. aculeata (Brandegee) H.E. Moore (basionym of *Erythea aculeata* Brandegee) is a solitary-trunk palm with hermaphrodite reproduction. It has flabellate leaves with palmate lamina and large inflorescences (100–150 cm length). *B. aculeata* is an endemic palm species native to northern Mexican states of Sonora, Sinaloa, Chihuahua and Durango. It has a patchy distribution and can be found in a range of habitats, from sunny mountains slopes, to shadier areas along arroyos and canyon bottoms in tropical dry forest and lower oak and pine-oak woodlands among 300–1500 m asl. In the tropical dry forest of SARCR, *B. aculeata* grows up to 10 m in height and 25 cm in diameter (Quero, 2000; Felger et al., 2001). *B. aculeata* is listed in the IUCN Red List as "Vulnerable" (A1c) and as "Endangered" in the Mexican Red List (Quero, 1998; Felger et al., 2001; SEMARNAT, 2002).

2.3. Management of B. aculeata

In the area of SARCR, leaf harvest is intense as leaves are harvested and used for thatching roofs and many other products both locally and in the tourist resorts along the coast of Sonora (Joyal, 1996a). Depending on the quality of the roof 10,000–20,000 leaves are required to thatch a 20 m × 20 m roof. Spear leaves are also harvested as part of the thatching process (they are used to tie the leaves to the roof) and also used in the construction of some handicrafts. In the region, some property owners sell between 20,000 and 100,000 leaves every year. For harvesting, the *palmilleros* (people harvesting leaves) use a machete for short palms and a hook for