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Bromeliad rain: An opportunity for cloud forest management

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ABSTRACT

Large numbers of epiphytic bromeliads are regularly harvested from the canopy of cloud forests for traditional uses and illegal trade, with detrimental effects on the viability of populations. Since a significant proportion of natural mortality in epiphytes is caused by detachment from the support trees, harvesting of fallen plants represents a potential supply for commercial use that would have no impact on bromeliad population dynamics. We evaluated the potential of four cloud forest sites in southern Mexico to supply epiphytic bromeliads for commercialization. Bromeliad diversity and abundance was determined by sampling eight trees in each forest site and the number of fallen plants from these trees was recorded over three years. To determine the size of the potential harvest from the forest floor, the rate of bromeliad fall, and the species, condition and size of fallen individuals were recorded monthly in 10 plots (10×10 m) at each site over a period of five months. Bromeliad fall rate varied from 26,910 to 92,712 rosettes ha^{-1} y^{-1}. Of these, *ca.* 60% (16,770 to 55,992 rosettes ha^{-1} y^{-1}) of the 18 species identified were in a suitable condition for commercialization. Diversity and abundance in the canopy were positively related to that of the fallen rosettes ($P < 0.05$), indicating that the harvesting rate can be estimated from population densities in the host trees and that the fallen plants could therefore be used to indirectly evaluate the epiphyte community. Assessment revealed that the forest canopy could act as a nursery to supply a constant "rain" of bromeliads with minimum production costs. Even one ha of cloud forest can supply thousands of marketable bromeliads every year. Harvesting of fallen epiphytic bromeliads could add to the diversification of cloud forest management, contribute to the reduction of excessive canopy harvesting pressure and supply plants for forest enrichment programs. The results of this study are discussed in the context of the local stakeholder participation and national conditions.

1. Introduction

Sustainable management of wild plants is of vital importance to the maintenance of forest diversity and to sustain and improve the livelihoods of forest users (CBD, 2000; FAO, 2010). Historically, rural populations in forested areas have been dependent on the collection and use of non-timber forest products (NTFP) for subsistence (FAO, 1995; Shackleton and Pandey, 2013). NTFP also play a central role in local culture, identity, and spiritual practices around the world (Alexiades and Shanley, 2004). Evaluation of NTFP management as a viable strategy for conservation of wild species and social development has yielded complex and contrasting results (Peters et al., 1989; Arnold and Ruiz-Pérez, 2001; Newton et al., 2006; Wadt et al., 2008). The lack of information and appropriate management strategies continues to contribute to over-exploitation of many species, ecosystem impoverishment and, indirectly, to habitat loss through replacement by more profitable land uses (Hall and Bawa, 1993; Putz et al., 2008; Shackleton and Pandey, 2013). Despite international treaties and the prevailing national environmental legislation, illegal trade of wild flora is still common practice in numerous countries (Roe et al., 2002).

Many epiphytic bromeliad species are sold on important international horticultural markets (Flores-Palacios and Valencia-Díaz, 2007; del Castillo et al., 2013) and have been used in traditional ceremonies in Latin America for centuries (Haeckel, 2009; Hornung-Leoni, 2011). Over-extraction of these plants for illegal trade and traditional celebrations is common practice in Mexico and Guatemala (Flores-Palacios and Valencia-Díaz, 2007; Haeckel, 2008; Toledo-Aceves and Wolf, 2008). As a result, various bromeliad species have become locally rare and are now listed as threatened (Hietz et al., 2002; Flores-Palacios and Valencia-Díaz, 2007; Haeckel, 2009; NOM-059-SEMARNAT-2010). Demand for epiphytic bromeliads for the construction of floral arches has recently undergone a significant increase in southern Mexico (Haeckel, 2008). Furthermore, in central Veracruz, illegal harvesting

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of epiphytic bromeliads from the cloud forest for commercial purposes occurs with no right of access (Toledo-Aceves pers. obs.). Overexploitation of the forest canopy exacerbates the loss of tropical montane cloud forest (TMCF) – only 28% of the original TMCF cover of Mexico remained by 2002 (Challenger and Dirzo, 2009) – prompting the need for urgent action towards sustainable forest management strategies. Frequently, there is no real management of cloud forest resources based on a rational assessment of the extent of goods and services that can be provided by appropriate managed forests (Doumengue et al., 1995). In common with other regions, the main causes of TMCF degradation and loss in Mexico are illegal logging and conversion of forest to pastureland (Aubad et al., 2008; Scatena et al., 2010; Toledo-Aceves et al. 2011).

Harvesting of epiphytes from the forest canopy has been proposed as an alternative source of forest-based revenue (Verhoeven and Beckers, 1999; Wolf and Konings, 2001; Hietz et al., 2002). However, a number of studies on epiphytic bromeliad demography in Mexican montane forest indicate trends of decline in the evaluated populations; 10 out of 11 populations analyzed show a tendency towards decline (population growth rate below unity; $\lambda < 1$), even in the absence of harvesting (Winkler et al., 2007; Haeckel, 2009; Mondragón and Ticktin, 2011; Toledo-Aceves et al., 2014). Epiphytes are extremely vulnerable to forest disturbance, fragmentation (Holbrook, 1991; Zhu et al., 2004; Wolf, 2005) and climate change due to their total dependence on established vegetation for completion of the life cycle and high sensitivity to microclimate (Benzing, 1998; Nadkarni and Solano, 2002). Whether climate change, fragmentation, illegal logging and/or forest disturbance are responsible for the tendency of populations to decline, commercial epiphyte harvesting directly from the canopy would be unsustainable in this context. Since the main cause of natural mortality in epiphytes is related to substrate instability, due to periodic windstorms, branch fall, and treefall (Hietz, 1997; Pett-Ridge and Silver, 2002; Winkler et al., 2007), harvesting of these fallen plants may represent a potential supply for commercial use that would not have a significant impact on population dynamics (Mondragón and Ticktin, 2011).

Epiphytes in general have been recognized as sensitive indicators of forest disturbance (Wolf, 2005; Larrea and Werner, 2010); however, not all groups respond equally (Barthlott et al., 2001; Larrea and Werner, 2010). In general, epiphytic ferns and orchids are more susceptible than bromeliads to disturbance (Barthlott et al., 2001; Flores-Palacios and García-Franco, 2004; Hietz et al., 2006; Toledo-Aceves et al., 2012). Various bromeliads have been found to increase in abundance and contribute greatly to diversity in disturbed montane forests (Krömer and Gradstein, 2003; Wolf, 2005; Hietz et al., 2006) and in shaded coffee plantations (Toledo-Aceves et al., 2011). Based on these findings, we expected TMCF fragments to present high potential for epiphytic bromeliad management while contributing towards the economic livelihood of rural inhabitants. This study addressed the following specific questions: (1) Are TMCF fragments suitable for epiphyte harvesting from the forest floor? (2) Is the number of fallen plants related to the number of plants in the canopy? (3) Are forest users willing to participate in the sustainable management of epiphytic bromeliads?

2. Methods

2.1. Study area

This study was conducted in the communities of San Antonio Hidalgo (623 ha) and San Andrés Tlalnelhuayocan (1024 ha), located in central Veracruz, Mexico. The TMCF of this region has been severely deforested and degraded and currently exists as remnant fragments (Williams-Linera et al., 2002). Total annual precipitation in this region varies from 1350 to 2200 mm, and mean annual temperature ranges from 12 to 18 °C (Williams-Linera 2002). The two main seasons are the rainy season (June to October) and the dry season (November to May).

To determine the potential for epiphyte harvesting from TMCF, four sites representing a range of sizes and management histories were selected based on epiphyte abundance, accessibility and the commitment of the owners to participation in the project (for individual site descriptions see Table 1). The study site forest fragments were located an average of 1.92 km apart. All sites were immersed within a matrix of forest, pasture, crops (mainly maize) and different successional stages of secondary vegetation. The studied fragments are heterogeneous in terms of structure and composition, probably due to the intrinsically high heterogeneity of TMCF (Hamilton et al., 1995; Williams-Linera 2002; Williams-Linera et al., 2013), as well as the result of past and present interventions. TMCF in the region has been subjected to selective logging for timber, firewood and charcoal production, livestock free-grazing within the forest and NTFP harvesting, among other activities. In the study area, unplanned and illegal selective tree logging has occurred over the last 80 years (Geréz et al., 2012), producing an on-going process of forest degradation. The removal of older trees and local depletion of valuable species are widespread in the watershed (Toledo-Aceves unpubl. data). Cattle had been grazed within parts of the forest fragments in all the sites, producing an impoverished understory. The vegetation structure (tree density, basal area and mean diameter at 1.3 m height (dbh)) was obtained from a separate vegetation study in each site (Toledo-Aceves et al., 2014; Table 1). The dominant trees species at all sites include *Clethra macrophylla* M. Martens & Galeotti, *Liquidambar styraciflua* L., *Quercus delgadoana* S. Valencia, Nixon & L.M. Kelly, *Quercus lancifolia* Schltdl. & Cham. and *Hedyosmum mexicanum* C. Cordem (Toledo-Aceves et al., 2014).

People from outside the communities, with no access rights, illegally harvest the epiphytic bromeliads in the region (Geréz et al., 2012). Targeted trees are stripped of all accessible epiphytes, including orchids, ferns and mosses. This type of harvesting technique is extremely destructive and completely disregards the recovery capacity of the resources involved (Toledo-Aceves pers. obs.). In this particular area, epiphytic bromeliads are not collected for traditional festivities; the only species used in the local communities for the construction of floral arches (*Tillandsia imperialis*) is found in pine-oak forest at higher altitude (Haeckel, 2009).

2.2. Interviews and participatory inventories

To assess local knowledge and the interest of stakeholders in epiphytic bromeliad management, 42 semi-structured interviews were held with the forest owners. These interviews focused on the following aspects related to epiphytic bromeliad biology and management: (1) recognition of bromeliad species, (2) tree and forest conditions where bromeliads grow, (3) abundance, (4) time

Table 1
Tropical montane cloud forest study sites in central Veracruz, Mexico. Dbh = diameter at breast height (mean ± 1 SE).

	Site 1	Site 2	Site 3	Site 4
Size (ha)	1.2	4.1	6.6	9.8
Latitude (N)	19° 30′ 26″	19° 31′ 03″	19° 32′ 16″	19° 30′ 57″
Longitude (W)	96° 59′ 09″	97° 00′ 25″	96° 59′ 57″	96° 59′ 58″
Elevation (m asl)	1460	1660	1660	1580
No. of trees ha^{-1}	533	383	758	625
Mean dbh (cm)	26.7 ± 1.5	29.9 ± 2.7	27.6 ± 1.9	30.8 ± 2.6