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Ecological interaction between *Artibeus jamaicensis* and *Microdesmia arborea* in a deciduous forest of central México

Interacción ecológica entre *Artibeus jamaicensis* y *Microdesmia arborea* en un bosque caducifolio del centro de México

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Seed dispersal is essential for many plant species, so they can colonize new sites. Among dispersers, fruit bats have been considered essential for ecosystem functioning. Although the role of bats as seed dispersers has been widely proved, many of the mutualistic interactions between plants and frugivorous bats are still unknown and little direct evidence of seed dispersal has been provided. As part of continuous monitoring conducted in the Sierra de Huautla Biosphere Reserve, we found a small colony of *Artibeus jamaicensis* resting in a cave near a series of crops used by local people to grow food. Inside the cave, we found many growing cotyledons of *Microdesmia arborea*, just below the resting places used by the bats. These cotyledons germinated from the seeds of the fruits on which the individuals of *A. jamaicensis* fed. To our knowledge, this is the first record reporting the association between *A. jamaicensis* and *M. arborea*. The growing cotyledons we found demonstrate the importance of *A. jamaicensis* for the dispersal and germination of certain plant species, even in unfavorable conditions like inside a cave. According to Mexican legislation, *M. arborea* is listed as threatened. So, the seed dispersal by bats may be vital for conserving this plant species. Seed dispersal is of great significance in an environment surrounded by crops, where forest regeneration may play a critical role in maintaining natural vegetation.

Key words: Chrysobalanaceae; deciduous forest; seed dispersal; Sierra de Huautla.

La dispersión de semillas es esencial para una gran cantidad de plantas, de manera que estas puedan colonizar nuevos sitios. Entre los dispersores, los murciélagos frugívoros han sido considerados esenciales para el funcionamiento del ecosistema. Aunque el papel de los murciélagos como dispersores de semillas ha sido ampliamente probado, muchas de las interacciones mutualistas entre las plantas y los murciélagos frugívoros aún se desconocen y se ha proporcionado poca evidencia directa de la dispersión de semillas. Como parte de un monitoreo continuo que hemos realizado en la Reserva de la Biosfera Sierra de Huautla, encontramos una pequeña colonia de *Artibeus jamaicensis* descansando en una cueva cerca de una serie de cultivos utilizados por la población local para producir alimento. En el interior de la cueva encontramos una gran cantidad de cotiledones de *Microdesmia arborea* (Chrysobalanaceae) en crecimiento, justo debajo de los lugares de descanso utilizados por los murciélagos. Estos cotiledones germinaron a partir de las semillas de los frutos de los que se alimentaron los individuos de *A. jamaicensis*. Hasta donde sabemos, este es el primer registro que reporta la asociación entre *A. jamaicensis* y *M. arborea*. Los cotiledones en crecimiento que encontramos demuestran la importancia de *A. jamaicensis* para la dispersión y germinación de ciertas especies de plantas, incluso en condiciones desfavorables como el interior de cuevas. De acuerdo con la legislación mexicana, *M. arborea* se encuentra catalogada como amenazada, por lo que la dispersión de sus semillas por parte de los murciélagos puede ser de vital importancia para su conservación. La dispersión de semillas tiene una gran importancia en un ambiente rodeado de cultivos, donde la regeneración forestal debe desempeñar un papel fundamental en el mantenimiento de la vegetación natural.

Palabras clave: Bosque caducifolio; Chrysobalanaceae; dispersión de semillas; Sierra de Huautla.

Seed dispersal by birds and mammals is fundamental for ecosystem functioning and forest regeneration processes (Mello *et al.* 2005; Rocha *et al.* 2018). Many studies have shown that among mammals, fruit-eating bats contribute successfully to seed dispersal and the reforestation and restoration of tropical forests (Brändel *et al.* 2020; Enríquez-Acevedo *et al.* 2020). In the New World, bats of the family Phyllostomidae are the main representatives of seed dispersers among mammals (Dumont 1999; Melo *et al.* 2009; Trevelin *et al.* 2013). Phyllostomid bats disperse ~559 plant species in the neotropical region (Lobova *et al.* 2009). However, many of the mutualistic interactions between plants and frugivorous bats are still unknown. The study and determination of these relationships become essential, especially when the relationship involves species that have been severely affected by human activities (Moran *et al.* 2009).

In the neotropical region, with its 12 species currently described, bats of the genus *Artibeus* are one of the main components of the mammal fauna (Redondo *et al.* 2008; Larsen *et al.* 2013). *Artibeus jamaicensis* is one of the most widespread and ecologically diverse frugivorous

bat species in this genus. It occurs from northern México southward to Central America to northwestern Argentina (Ortega and Arita 2000). Roosting sites used by the species include caves, tree holes, and human-made structures that in some cases are located within its foraging areas (Kunz *et al.* 1983; Handley and Gardner 1991; Kunz and Diaz 1995). Commuting distances between roosting sites and foraging areas have been determined by food availability and can range from 1 to 8 km (Morrison 1978). *Artibeus jamaicensis* is a specialized fig-eater (*Ficus* sp.); however, its diet includes a wide variety of fruits encompassing 44 plant genera (August 1981; Handley and Gardner 1991; Ortega and Castro-Arellano 2001).

The role of *A. jamaicensis* as seed disperser of many plant species has been inferred mainly from scatological evidence (*e.g.*, Andrade *et al.* 2013; Kasso and Balakrishnan 2013; Horsley *et al.* 2015). However, such evidence is indirect and provides partial proof of its effectiveness as seed dispersal. For example, to be an effective disperser, the seeds need to be dispersed in optimal sites for their germination (Schupp *et al.* 2010). In this sense, many bat-plant interactions remain to be determined. Here we present an observation of *A. jamaicensis* presumably feeding on the cacahuananche (*Microdesmia arborea*) and the seed dispersal and germination of this plant species inside a cave located in a tropical dry forest in Central México.

As part of a continuous wildlife monitoring in the Sierra de Huautla Biosphere Reserve, we visited the "Cueva del Toro" cave located in the community of Chimalacatlán in the state of Morelos, in central México (18º 27´43.176" N, 99º 6´ 0.801" W). We conducted a single visit in December 2021. The vegetation surrounding the cave is composed of tropical dry forest with species from the Burseraceae, Bombacaceae, Moraceae and the Chrysobalanaceae families, and an extensive area of crops (Alba-Zúñiga *et al.* 2009; Ebergenyi and León 2015). We recorded the ambient temperature and humidity inside the cave using a temperature-humidity meter (model 971, Fluke Corporation). We found a maternity colony of *A. jamaicensis* roosting inside the cave. We determined at sight the size of the colony and the presence of pregnant females and pups. Underneath roosting sites, we found germinated seeds which were collected (8 seedlings and 3 seeds) for their identification. Seedlings and seeds were measured and weighted. Species identification was done following Rios-García (2018).

Inside the cave, the average ambient temperature was 27.8 ºC, and the relative humidity was 71 %. We observed at least 100 pregnant females and 50 young bats of *A. jamaicensis* and some individuals of the nectar-feeding bat *Glossophaga soricina*. No signs from another mammal or bird were found. We also identified the germinated seeds as *M. arborea* (Chrysobalanaceae; Sothers *et al.* 2016). We found seeds under the roosting area of *A. jamaicensis* of ~16 m^2 (~ ¼ of the total area of the cave), ~ 10 m inside the cave with their respective cotyledons. The etiolated cotyledons had a mean height ± standard deviation of 340 ± 1.2 mm ($n = 8$). Seeds ($n = 3$) measured 19.5 ± 0.6 mm long and 12.2 ± 1.1 mm wide and weighted 1.4 g ± 0.7 gr.

The large number of germinated seeds of *M. arborea* we found under the resting places used by *A. jamaicensis* as the only frugivore capable of seed dispersion inside the cave, strongly suggests an ecological interaction between these species. This interaction is an important association of a fruit bat with a plant species categorized as threatened by the Mexican legislation (SEMARNAT 2010). Although it has been suggested that *A. jamaicensis* feeds on fruits produced by plants of the *Microdesmia* genus (Ortega and Castro-Arellano 2001), to our knowledge, this is the first record reporting this specific association. *Microdesmia arborea* is a native American plant species distributed from México to Panamá (Carpio-Malavassi 2003). In México, this plant species has been traditionally used for a variety of purposes which may include household construction, fuel, live fences, and for many medicinal uses (Ríos-García *et al.* 2014, 2017; Ríos-García 2018). However, with an exemption of some protected areas where the species can be relatively safe from human disturbance (López *et al.* 2012), the management and exploitation plans along the territory for this threatened plant species are scarce (Ríos-García *et al.* 2014, 2017). Up to date, there are no reforestation plans in the places where *M. arborea* is extensively used. In these places, the ecosystem services provided by frugivorous bats are crucial to decrease the impact of humans on the ecosystems. This is especially important in tropical dry forests, one of the most threatened ecosystems in México (Trejo and Dirzo 2000; CONANP 2006).

Our observation also highlights the amazing ability of *M. arborea* to germinate and develop cotyledons in unfavorable low-light conditions inside a cave. *Microdesmia arborea* is distributed in sub-deciduous and sub-evergreen forests. The flowering and fruiting occur from October to July (Palacios 2006; Ríos-García *et al.* 2017). Like other species of the family Chrysobalanaceae, *M. arborea* is a secondary succession plant (Finegan 1996) that requires dispersing agents like birds and bats (Horseley *et al.* 2015). The germination of *M. arborea* is hypogeal (*i.e.*, it takes place under the ground), and this species roots preferably in sandy soils (Palacios 2006; Ríos-García 2018). Although the cave presents favorable conditions like the humidity for its germination, we believe that the cotyledons of *M. arborea* should not be successful because of the low-light conditions inside the cave and the strict sunlight requirements of this tropical plant species (Poorter *et al.* 2005). This could be interpreted as if *A. jamaicensis* could not be an effective disperser for *M. arborea* in our study site (Schupp *et al.* 2010). However, the successful germination of *M. arborea* may occur when bats roost in trees immersed in the vegetation or near the crops or while navigating in their foraging areas. Although there is no information on the feeding sites used by *A. jamaicensis* out of their resting places in tropical dry forests, in the humid forests of Costa Rica, this species has been observed using feeding roosts in primary forests and abandoned

plantations. In these sites, bats have been reported depositing seeds of *Ficus insipida* below the places where they fed, contributing to the forest regeneration process (Lopez and Vaughan 2004).

The size of the seeds we found strongly suggests that the dispersal of *M. arborea* is epizoochoric rather than endozoochoric. This means that bats used their resting place to feed at night after transporting the fruit and deposited the seed once they consumed the pulp. In this regard, it has been reported that *A. jamaicensis* is a generalist fruit-eating bat (Gardner 1977) that carries the fruit to feeding roosts that can be located close to the parental tree or several hundred meters away (Fleming and Heithaus 1981). In these places, bats drop the seeds on the ground once they have fed (Bizerril and Raw 1998; Charles-Dominique and Cockle 2001).

In this work, we provide a direct observation of the seed dispersal capacity of the frugivorous bat *A. jamaicensis* living in the tropical dry forest of central México. In this ecosystem, bats may play a fundamental role in habitat regeneration. Seed dispersal is especially important for threatened plant species like *M. arborea* which is distributed in an environment surrounded by crops, where human activities have affected the ecosystem functioning in one of the most vulnerable places on the earth.

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