

# Diurnal pollination network of “Cuabales de Cajálbana”, a serpentine shrubwood in western Cuba

## Red diurna de polinización de “Cuabales de Cajálbana”, un matorral xeromorfo sobre serpentina de Cuba occidental

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### INTRODUCTION

Pollination, the transfer of pollen from anthers to stigmas of flowers, is a key process in the life cycle of angiosperms (Faegri & van der Pijl 1978). Approximately 87.5 % of flowering plants depends on pollinating animals for successful pollination and reproduction (Ollerton & al. 2011). Insects are the main group that has closely coevolved with flowering plants for this purpose (Olesen & al. 2007).

Pollination as an ecological process is best studied at the community level with the pollination network analysis (Bascompte & Jordano 2007). Pollination networks are one kind of mutualistic network formed by interactions between all pollinators and plants in a community (Jordano 1987). The network approach is useful for understanding some community phenomena such as interspecific competition (Lara-Romero & al. 2016), facilitation (Feisinger 1987), temporal change (Petanidou & al. 2008), extinction cascades (Elle & al. 2012) and spatiotemporal variation (Petanidou & al. 2008, Freitas & al. 2015).

Variation of pollination networks results from changes in the composition of pollinators and plants, or the structure of the network (Cuartas-Hernández & Medel 2015). Temporal changes are caused by changes in the phenology of plants and variation in abundance of pollinator species between seasons (Olesen & al. 2008). The spatial variation of pollination networks is influenced by several factors including: the richness of pollinators and plants, the foraging area of pollinators, the spatial extension of populations of plants and pollinators and the heterogeneity of landscape (García & al. 2009). Although pollination networks are studied as spatiotemporal snapshots, they are dynamic entities (Olesen & al. 2011a).

Cuba is the largest island of the Caribbean and hosts a high percentage of its biodiversity (Mancina & al. 2017). Specifically, this island harbors the highest diversity and endemism of the flora in the region (González-Torres & al. 2016) and exhibits

a great variety of vegetation (Borhidi 1996). A wide variety of forests, thickets, herbaceous communities, complexes of vegetation and secondary vegetation have been described for the Cuban archipelago (Capote & Berazaín 1984, Borhidi 1996). The distribution of these vegetation types is closely related to geologic, edaphic, geographic and climatic factors (González 2014); however, the edaphic conditions are the most important factor determining the variability of the vegetation and the richness of the flora (Borhidi 1996). The highest number of plant endemism in Cuba is found in areas with ultramafic soils (Samek 1973, Borhidi 1996).

The ultramafic materials are dominated by peridotite, which is composed of olivine and pyroxene, or by serpentinite, which is composed of serpentine. All ultramafic materials have high concentrations of magnesium (18-4% Mg, or 30-40% MgO) and iron (6-9% Fe), very low concentrations of calcium (1-4% Ca) (Alexander 2004) and a significant amount of heavy metals such as nickel (Ni), cobalt (Co) and chrome (Cr) (Brooks 1987, Proctor 1999). These extreme soil features determine the principal feature of ultramafic vegetation, which include a low productivity, distinct physiognomy, predominance of xerophytic species, and a high diversity of ecotypes and endemic species (Brooks 1987).

The serpentine regions in Cuba occupy the 7% of the island's surface (Borhidi 1996). The 15% of the Cuban endemic flora grows on serpentine outcrops (Borhidi 1996, Berazaín 1997) which support two distinct vegetation types, “cuabales” and “charrascales” (Capote & Berazaín 1984). These are described as a dry lowland xeromorph serpentine shrubwoods and a semiarid montane serpentine shrubwoods, respectively, according to the classification of Cuban vegetation (Borhidi 1996).

The interaction network of these ecosystems could be influenced by the small size of flowers and high plant endemism (Berazaín 2001). However, no previous study exists about pollination

at the community level in Cuban serpentine ecosystems. The aim of this study is to describe the pollination network of “Cuabales de Cajálbana” (22° 80' 36" N, 83° 45' 00" W), a serpentine habitat of approximately 170 km<sup>2</sup> that belongs to the protected area “Mil Cumbres” in La Palma, Pinar del Río, in western Cuba. The study was performed between June and July 2018. This habitat is a thorny xeromorph serpentine shrubwoods, according to Capote & Berazaín (1984).

To sample interactions we used five transects (500 x 15 m) between 08:00 and 13:00 hours, which coincides with the peaks of diurnal pollinator activity (Knop & al. 2017). In each transect, we recorded all interactions observed and collected specimens of plants or insects for further identification. Plants species were identified *in situ* or a sample of them were recollected for a further identification in the Herbarium “Johannes Bisse” of the National Botanical Garden of Cuba (HAJB, Thiers 2020). Pollinators were deposited in the collections of the Faculty of Biology, University of Havana. All flower-visiting animals were considered as “pollinators”, although not all actually pollinate (Traveset & al. 2016). We considered the visiting frequency as an estimate of pollination, and an interaction was defined as the touch between an animal and the sexual parts (gineceum or androceum) of a flower.

The nestedness in the network was measured with *WNODF* index (Weighted Nestedness based on Overlap and Decreasing Fill), which is a modification of the *NODF* index

(Almeida-Neto & al. 2008) that incorporates information on the strength of interactions (Almeida-Neto & Ulrich 2011). The metric *Q* was used to assess modularity, which is the number of species groups strongly linked between them and less linked with the rest of the species of the network (Dupont & Olesen 2009). This statistic was obtained by *QuanBiMo* algorithm (Quantitative Bipartite Modularity Algorithm) proposed by Dormann & Strauss (2014). All analyses were performed in the bipartite package of *R* (R Core Team 2018).

We found a network composed by 17 plant species (Table I), 30 pollinators (Table II) and 187 interactions between them (Figure 1). The species that established the majority of interactions were the plant *Phyllanthus orbicularis* (95 interactions) and the bee *Apis mellifera* (133 interactions). Specifically, *A. mellifera* established 81 interactions with *P. orbicularis*, which represents 43 % of all the interactions recorded. These species represent the network hubs, which are species highly connected to other species in the community. *P. orbicularis* was pollinated by 11 pollinator species and *A. mellifera* pollinated seven out of the 17 plants reported.

The bee *Apis mellifera* is a widespread invasive species present in almost all ecosystems of the island. It is highly generalist, abundant, aggressive and has large foraging periods (Goulson 2003). *Apis mellifera* occupies a central position in the thicket formation studied and in other communities in Brazil (Santos & al. 2012).

**TABLE I**  
**Plant species recorded in the pollination network of “Cuabales de Cajálbana”, Pinar del Río, Cuba**

**TABLA I**  
**Especies de plantas registradas en la red de polinización de “Cuabales de Cajálbana”, Pinar del Río, Cuba**

Family	Species
<i>Apocynaceae</i>	<i>Angadenia berteroi</i> (A. DC.) Miers <i>Neobrcea valenzuelana</i> (A. Rich.) Urb.
<i>Asteraceae</i>	<i>Koanophyllon grisebachianum</i> (Alain) R. M. King & H. Rob. <i>Lescaillea equisetiformis</i> Griseb.
<i>Boraginaceae</i>	<i>Bouyeria pauciflora</i> O. E. Schulz
<i>Erythroxylaceae</i>	<i>Erythroxylum minutifolium</i> Griseb.
<i>Fabaceae</i>	<i>Clitoria falcata</i> Lam.
<i>Malpighiaceae</i>	<i>Stigmaphyllon sagraum</i> A. Juss.
<i>Malvaceae</i>	<i>Melochia spicata</i> (L.) Fryxell
<i>Phyllanthaceae</i>	<i>Phyllanthus orbicularis</i> Kunth <i>Phyllanthus x pallidus</i> C. Wright ex Griseb.
<i>Polygonaceae</i>	<i>Coccoloba armata</i> C. Wright ex Griseb.
<i>Rubiaceae</i>	<i>Exostema ixoroides</i> (Hook. F.) T. McDowell <i>Phyllomelia coronata</i> Griseb. <i>Psychotria revoluta</i> DC. <i>Rondeletia odorata</i> Jacq. <i>Mitracarpus linearifolius</i> A. Rich.

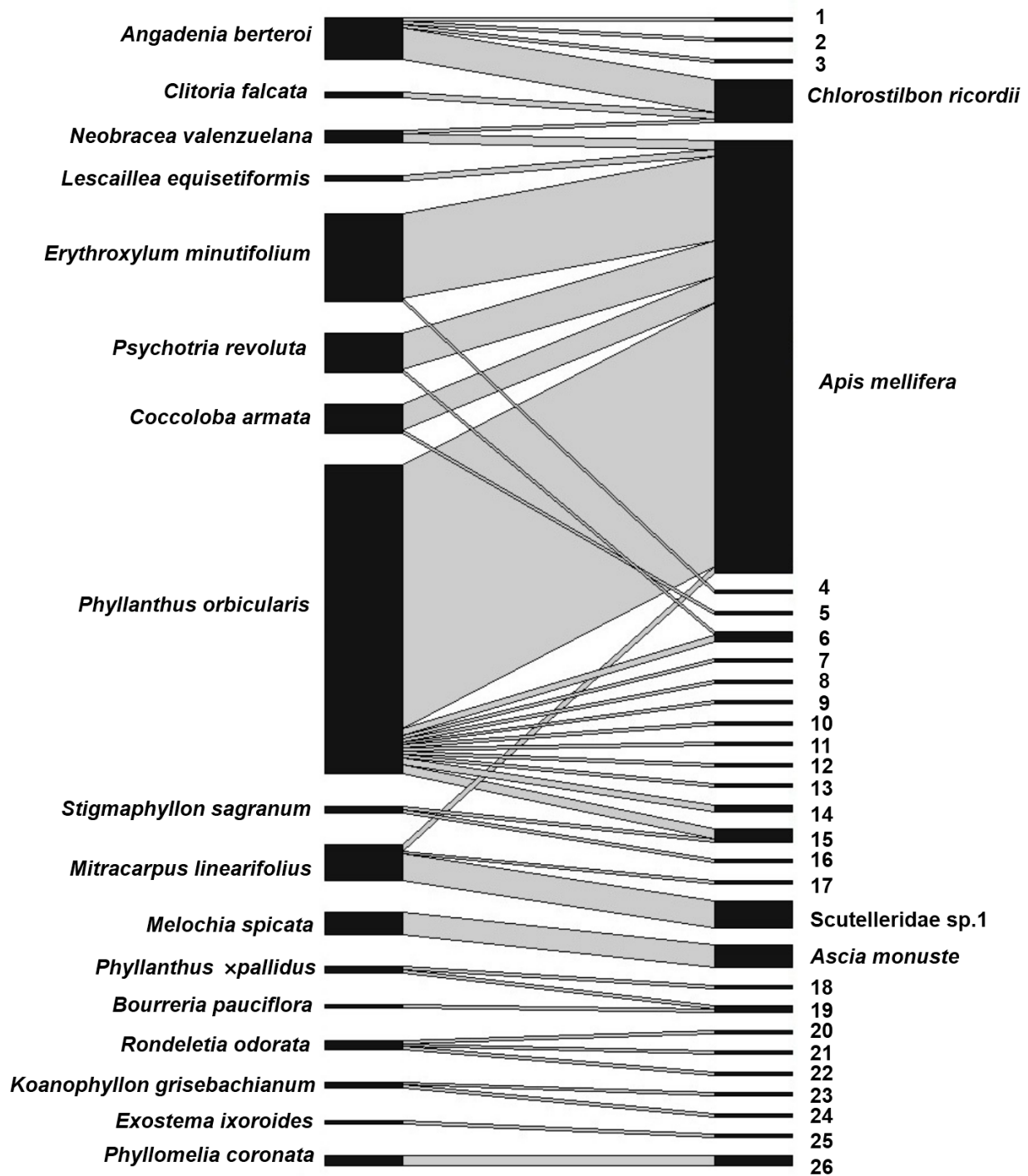
**TABLE II**  
**Pollinator species recorded in the pollination network of “Cuabales de Cajálbana”, Pinar del Río, Cuba**  
**TABLA II**  
**Especies polinizadoras registradas en la red de polinización de “Cuabales de Cajálbana”, Pinar del Río, Cuba**

Order / Family	Species
Araneae / Thomisidae	Thomisidae sp.1 Thomisidae sp.2
Apodiformes / Trochilidae	<i>Chlorostilbon ricordii</i> (Gervais, 1835)
Coleoptera / Chrysomelidae	Chrysomelidae sp.
Coleoptera / Curculionidae	Curculionidae sp.1 Curculionidae sp.2 Curculionidae sp.3
Diptera	Diptera sp.
Diptera / Bombyliidae	Bombyliidae sp.
Diptera / Syrphidae	Syrphidae sp.
Diptera / Tachinidae	Tachinidae sp.
Hemiptera / Reduviidae	Reduviidae sp.
Hemiptera / Scutelleridae	Scutelleridae sp.1 Scutelleridae sp.2
Hymenoptera / Apidae	<i>Apis mellifera</i> Linnaeus, 1758
Hymenoptera / Formicidae	<i>Camponotus rufipilis</i> Aguayo, 1932 <i>Camponotus planatus</i> Roger, 1863 <i>Camponotus</i> sp. <i>Pseudomyrmex pazosi</i> (Santschi, 1909) <i>Rogeria</i> sp. <i>Zatania gibberosa</i> Roger, 1863
Hymenoptera / Halictidae	<i>Lasioglossum</i> sp.
Hymenoptera / Pompilidae	Pompilidae sp.
Hymenoptera / Sphecidae	<i>Trypoxylon subimpresum</i> F. Smith, 1856
Lepidoptera / Hesperidae	Hesperidae sp.
Lepidoptera / Lycaenidae	<i>Leptotes cassius theonus</i> (Lucas, 1857)
Lepidoptera / Nymphalidae	<i>Marpesia chiron</i> Fabricius, 1775
Lepidoptera / Pieridae	<i>Ascia monuste</i> (Linnaeus, 1764) <i>Eurema</i> sp. <i>Phoebis</i> sp.

This species could have an effect either positive or negative for the community. The negative effect is caused by interspecific competition with native bees or other native pollinators that are displaced and cause a rewiring of interactions (Monte-ro-Castaño & Vilá 2017). This bee species could also have a positive effect because it can replace the pollination service of native pollinators that are already locally extinct or have low abundance (Maruyama & al. 2018). However, with our sampling design we cannot know the real effect of *Apis mellifera* in this ecosystem. The shrub *Phyllanthus orbicularis* is very abundant

in this ecosystem (Leyva & al. 2018) and its flowers produce a large amount of nectar. This causes most interactions to be concentrated on this plant.

Species serving as hubs should receive special conservation priorities (Olesen & al. 2007). In the case of *Apis mellifera*, although it is an invasive species, we propose not to perform any management plan to eradicate it without studying its effect in this protected area. We consider *Phyllanthus orbicularis* and *Erythroxylum minutifolium* as key species for the direct



**Fig. 1.** Pollination network of "Cuabales de Cajálbana", Pinar del Río, Cuba. Plant species are shown in the left column whereas pollinators are shown in the right column. 1: *Camponotus* sp. 2: *Rogeria* sp. 3: *Phoebis* sp. 4: *Marpesia chiron*. 5: Pompilidae sp. 6: *Camponotus rufipilis*. 7: *Eurema* sp. 8: *Hesperiidae* sp. 9: *Leptotes cassius theonus*. 10: *Pseudomyrmex pazosi*. 11: *Reduviidae* sp. 12: *Tachinidae* sp. 13: *Trypoxylon subimpresum*. 14: *Diptera* sp. 15: *Camponotus planatus*. 16: *Lasioglossum* sp. 17: *Bombyliidae* sp. 18: *Chrysomelidae* sp. 19: *Syrphidae* sp. 20: *Scutelleridae* sp. 2. 21: *Curculionidae* sp. 1. 22: *Curculionidae* sp. 2. 23: *Curculionidae* sp. 3. 24: *Thomisidae* sp. 2. 25: *Thomisidae* sp. 1. 26: *Zatania gibberosa*.

**Fig. 1.** Red de polinización de "Cuabales de Cajálbana", Pinar del Río, Cuba. Las especies de plantas se muestran en la columna izquierda mientras que los polinizadores se muestran en a columna derecha. 1: *Camponotus* sp. 2: *Rogeria* sp. 3: *Phoebis* sp. 4: *Marpesia chiron*. 5: *Pompilidae* sp. 6: *Camponotus rufipilis*. 7: *Eurema* sp. 8: *Hesperiidae* sp. 9: *Leptotes cassius theonus*. 10: *Pseudomyrmex pazosi*. 11: *Reduviidae* sp. 12: *Tachinidae* sp. 13: *Trypoxylon subimpresum*. 14: *Diptera* sp. 15: *Camponotus planatus*. 16: *Lasioglossum* sp. 17: *Bombyliidae* sp. 18: *Chrysomelidae* sp. 19: *Syrphidae* sp. 20: *Scutelleridae* sp. 2. 21: *Curculionidae* sp. 1. 22: *Curculionidae* sp. 2. 23: *Curculionidae* sp. 3. 24: *Thomisidae* sp. 2. 25: *Thomisidae* sp. 1. 26: *Zatania gibberosa*.

conservation of insects and indirectly the pollination service of other plants in the community. They can compete with other plants for pollinators, but also could maintain stable pollinator populations that assure pollination services in the community (Rosas-Guerrero & *al.* 2014).

The network showed low modularity ( $Q=0,34$ ) and low nestedness ( $WNODF=6,33$ ). The index  $Q$  ranged from 0 (low modularity), to a maximum value of 1 (high modularity).  $WNODF$  ranged from 0 (non-nested) to 100 (perfectly nested). Nestedness is a widespread pattern in pollination networks (Bascompte & *al.* 2003). However, in this study, nestedness was low, maybe because of the particular features of the habitat. The flowers of plants are very small due to the low availability of water, and nectar is toxic because of the high concentration of heavy metals (Meindl & *al.* 2013), which could cause morphological and physiological constraints to the pollinators of these plants (Olesen & *al.* 2011b). Cuartas-Hernández & Medel (2015) found a non-nested pattern in a Colombian mountain forest. This indicates that although nestedness is a general pattern, especially in the tropics (Vizentin-Bugoni & *al.* 2018), some ecosystems may differ. The low modularity found could have two probable causes. The first one is that small networks are nonmodular due to low connectance (Olesen & *al.* 2007). The second one is that the community of pollinators is not compartmentalized because coevolutionary processes structure this serpentine ecosystem as a single unit (Zhang & He 2017).

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#### AUTHORS' CONTRIBUTIONS

D. Alameda conceived the original idea, designed the research, identified the pollinators, analyzed the data, and wrote the first version of the manuscript. B. Falcón managed the research, identified plant species and critically revised the first version of the manuscript. G. Rijo designed the research, identified the pollinators, and interpreted the results. A. Castañeda and L.M. Leiva identified the plant species. All authors contributed to sampling, discussion of results, and critical revision of the manuscript.

#### COMPLIANCE WITH ETHICAL STANDARDS

**Conflict of interest:** The authors declare that they have no conflict of interest.

**Ethics approval:** All authors have carried out fieldwork and data generation ethically, including obtaining appropriate permitting.

**Consent for publication:** All authors have consented to publishing this work.

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