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HOW MANY PLANT SPECIES DO HUMMINGBIRDS VISIT? ¿CUÁNTAS ESPECIES DE PLANTAS SON VISITADAS POR LOS COLIBRÍES?

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Resumen. - ¿Cuántas especies de plantas son visitadas por colibríes?- Los colibríes son aves nectrívoras que polinizan plantas en América. En esta relación mutualista los colibríes se alimentan de néctar y transportan los gametos de las plantas llevado a cabo su reproducción. Para poder tener un mejor conocimiento del número e identidad de las plantas visitadas por colibríes compilamos una base de datos que incluye datos de reportes publicados y no publicados (tesis, reportes no publicados, y datos personales y de colegas) a nivel comunidad o de pares de especies. Un total de 111 artículos, 43 tesis y 11 libros se revisaron. Encontramos 1339 especies de plantas pertenecientes a 108 familias y 294 especies de colibríes en la matriz de interacción. La matriz se analizó utilizando un análisis de agrupamiento jerárquico agrupando a las plantas por familia y a los colibríes en los clados filogenéticos. Se formaron grupos claros que reflejan relaciones geográficas y preferencias alimenticias.

Abstract. - How many plant species does hummingbird visit? - Hummingbirds are nectar feeding birds that pollinated plants in America. This is a mutualistic relationship where hummingbirds feed on nectar while transporting plant´s gametes helping in plant reproduction. This relationship has received a lot of attention and many studies have been published. In order to provide a more accurate estimate of our knowledge about the number and identity of plant species visited by hummingbirds, we compiled a data set of published and unpublished (including thesis dissertations and reports or other unpublished work form authors and colleges) community level or pair wise surveys of plant-hummingbird interactions. A total of 111 papers, 43 thesis and 11 books were reviewed. A total of 1339 plant species belonging to 108 families and 294 hummingbird species were included in the interaction matrix. The matrix was analyzed using hierarchical clusters grouping by plant families and phylogenetical groups in hummingbirds. Clear groups were formed indicating geographical relationships and preferences.

Key words: Hummingbirds, hummingbird plants, plant-hummingbird interactions

INTRODUCTION

Hummingbirds are specialized nectar feeding birds that live only in the Americas. Here, they are the second most diverse family of birds (328 described species) with specialized morphology and physiology adapted to feed mainly on sugars obtained from flowers. They act as pollinators, transporting gametes among flowers (Stiles 1981, Schuchmann 1999). This large family is divided into two subfamilies:1) Phaethornitinae or Hermit hummingbirds that can be characterized by long, decurved bills, their behavior as understory traplinners (Stiles & Wolf 1979, Stiles 1981, 1985, Cotton 1998, Hilty & Brown 2001), and their higher dominance and diversity in humid lowland forests (lower than 1000 msnm) especially in the Amazon region (Stiles 1981); and Trochilinae that is a more diverse group, with smaller hummingbirds, short to long

bills with a diversity of behaviors from traplining to highly territorial and they live in a variety of environments, from dry warm lowlands to cool wet highlands, and habitats, from scrubby vegetation to dense forest, (Schuchmann 1999). Hummingbirds have been divided into 9 phylogenetical clades (McGuire *et al.* 2007) including Phaethornitinae in one called Hermits and Trochilinae divided into the other 8 clades.

Hummingbird flowers are generally described to be long, tubular and red or of a contrasting color (Faegri & van der Pijl 1979). Nectar produced by hummingbird flowers is a dilute solution frequently between 22 to 26% of mainly sucrose (Baker & Baker 1975, Stiles & Freeman 1993). Pairwise interactions between hummingbirds and their food plants have been described extensively. However, the importance of hummingbird pollination to flowering plants has not been addressed. It has been estimated that hummingbirds pollinate about 400 plant species (Schuchmann 1999).

In order to provide a more accurate estimate of our knowledge about the number and identity of plant species visited by hummingbirds, we compiled a data set of published and unpublished (including thesis dissertations and reports or other unpublished work form authors and colleges) community level or pairwise surveys of plant-hummingbird interactions. Our goals were to determine 1) the number and identity of plants visited by hummingbirds, 2) the existence of a pattern of relationship between plant families and phylogenetic groups of hummingbirds.

METHODS

Data were compiled by searching published indexed papers where hummingbird visitation to specific plant species was recorded. Whole communities or pairwise studies were considered. Also dissertation works were searched from Universities in Mexico, USA and Colombia were they are web accessible. Reports and unpublished data from authors were also used. The resulting database is a matrix with rows including the plant species and column their hummingbird visitors. The matrix entry has a 1 if interaction(s) was reported and 0 if no reference of visitation was found.

Plants were classified in Families and hummingbirds phylogenetically (McGuire et al. 2007, 2009). Descriptive analyses were done and a hierarchical two way cluster analysis to test for associations (JMP SAS).

RESULTS

A total of 111 papers, 43 thesis and 11 books were reviewed. A total of 1339 plant species belonging to 108 families and 294 hummingbird species were included in the interaction matrix. Thrirteen out of the 108 plant families accounted for 57% of all matrix entries (Fabaceae, Bromeliaceae, Rubiaceae, Gesneriaceae, Lamiaceae, Asteraceae, Malvaceae, Heliconiaceae, Bignoniaceae, Campanulacea, Ericaceae, Solanaceae, Acanthaceae; Fig 1). From analyzing the matrix, it is clear that groups of hummingbirds are associated with groups of plants. Mainly south American species, Hermits and Mangoes, are the main visitors to Heliconiaceae, Gesneriaceae, Bromeliaceae and Rubiaceae. Brilliants and Coquettes were recorded visiting more species of Ericaceae, Rubiaceae, Fabaceae and less with Gesneriaceae. Bees and Gems visited more species of Lamiaceae, Rubiaceae and Fabaceae. Emeralds visited many species of Bromeliaceae, Malvaceae, Rubiaceae and Fabaceae.

To analyze 31 families that comprised 80% of the entries and the 294 hummingbird species grouped in the 9 clades a hierarchical cluster analysis was done (Fig. 2). Three groups of plants grouped by their hummingbird visitors can be found. The first one included Acanthaceae, Bignoniaceae, Malvaceae and Lamiaceae associated mainly with Emeralds and Bees but also visited by some Hermits. The second and biggest included 21 plant families and was visited by a variety of hummingbirds in a non

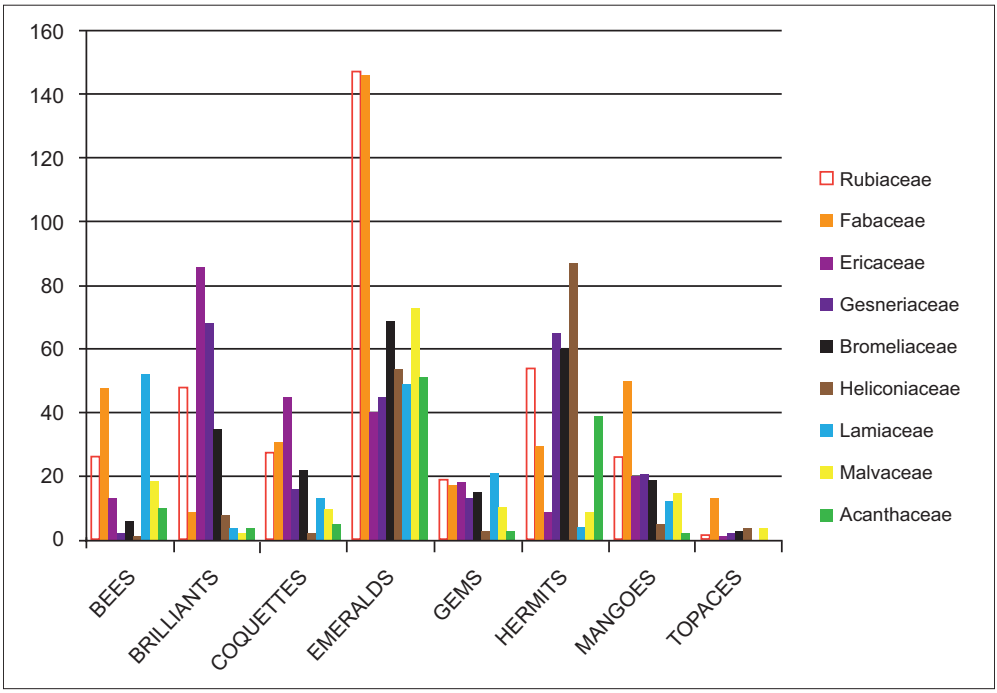

FIG 1. Number of plant species visited by the different Hummingbird clades.

intensive way. The last one included 6 plant families (Bromeliaceae, Gesneriaceae, Heliconiaceae, Ericaceae, Fabaceae and Rubiaceae) is associated with Brilliants, Hermits and Emeralds and with Mangoes, Coquettes, and Bees.

Hummingbirds formed four groups: the first one comprised by Bees, Coquettes, Gems and Mangoes and associated with Ericaceae, Fabaceae, Rubiaceae and Lamiaceae; the second included Topaces and Patagoni where very little information exists; the third included brilliants and emeralds and associated with Rubiaceae, Heliconiaceae, Bromeliaceae, Ericaceae, Gesneriaceae, Fabaceae and Acanthaceae; and the fourth included only Emeralds, which associated with Rubiaceae, Heliconiaceae, Bromeliaceae, Ericaceae, Gesneriaceae, Fabaceae and also with Lamiaceae, Malvaceae, Bignoniaceae and Acanthaceae.

Emeralds, Bees, and Gems are typically the hummingbirds that dominate North America. The three groups were associated with Lamiaceae, Malvaceae, Bignoniaceae and Acanthaceae, being families of plants key for hummingbird conservation in North America. On the other hand, Hermits, Mangoes, Brilliants and Coquettes are dominant in South America and their association with Rubiaceae, Heliconiaceae, Bromeliaceae, Ericaceae, Gesneriaceae, Fabaceae and Acanthaceae is strong.

DISCUSSION

Hummingbirds are important visitors and pollinators for plants in America. This study demonstrates that hummingbirds visit a much wider array of plants than previously reported and this makes them an important group of pollinators. Other works have highlighted their importance (Grant & Grant 1966, Schuchmman 1999) but there was no compliance about which plants depend on them for pollination. The associa-

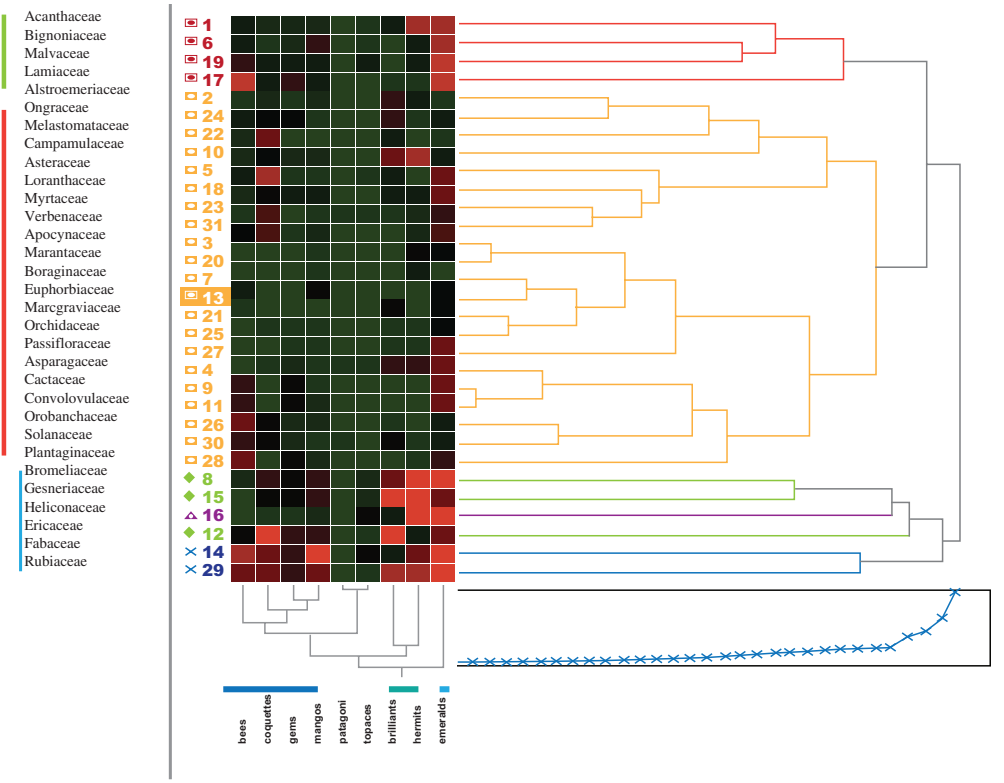

FIG 2. Hierarchical cluster analysis of plant families and Hummingbird clades showing the interrelation of both groups.

tions of some hummingbird groups with specific plant groups have received much attention. For example, Hermits have been associated with Heliconiaceae (Stiles 1975) being those plants their preferred food and being their main pollinators in the lowlands of central and south America. This association is fully corroborated here, enhanced by the association with other families as Gesneriaceae, Acanthaceae and Bromeliaceae (Stiles 1975, McDade 1984, Machado & Semir 2006). Mangoes visited many of the same plants as Hermits in Amazonian lowlands (Stiles 1975, McGuire . 2009). On the other side, Bees and Gems visited more species of Lamiaceae, Rubiaceae and Fabaceae plants more diverse in North and Central America (Grant & Grant 1966, Grant 1994). Coquettes and Bees visited more Ericaceae, Fabaceae and Rubiaceae, while Emeralds were regular visitors of Bromeliaceae, Malvaceae, Rubiaceae and Fabaceae. These hummingbirds are smaller, short-straight-billed species and are more diverse in Central and South America low and highlands (Schuchman 1999).

Hummingbird-plant interactions represent a key process in biodiversity conservation (Stiles 1978). Its knowledge is crucial in order to effectively address the resulting conservation issues facing hummingbirds specifically and pollinators generally. Conservation of pollination mutualisms is important to preserve biodiversity and also to secure food for humans (Kearns 1998, Aizen et al 2009, Ollerton *et al.* 2011).

Conservation of plants used by hummingbirds can ensure conservation of birds but

also monitoring the phenological processes of both mutualists is also crucial, as climate change can be acting and decoupling can be one of the results of this global ongoing problem (Hegland *et al.* 2009).

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