Oecologia Australis
14(1): 67-99, Março 2010
doi:10.4257/oeco.2010.1401.03

BEYOND HUMMINGBIRD-FLOWERS: THE OTHER SIDE OF ORNITHOPHILY IN THE NEOTROPICS

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ABSTRACT

Bird pollination in the Neotropical region is by far known as an important interaction to ecosystem function, but perching birds visiting flowers are still very often observed as merely opportunist visitors. Although these other birds do not rely only on floral resources, there are many plant species that do depend solely on them for pollination. These flowers display some features, including morphology and different kinds of resources, quite different from the ornithophilous flowers pollinated by hummingbirds. We review the syndrome of ornithophily in the Neotropical region and tear it apart into the two exploitation methods to determine the floral features that might favor pollination by hovering birds or by perching birds. We listed the Neotropical perching bird species mentioned in the literature as pollinators to take a look at that avian richness. We expect that as more studies on forest canopies are taken in the Neotropics, more interactions between perching birds and flowers may be observed and reveal its real role in the biology of both groups.
Key-words: Hovering birds, perching birds, nectar, gelatinous nectar, jelly-flowers, food-bodies, bird pollination.

RESUMO

MUITO ALÉM DAS FLORES PARA BEIJA-FLORES: O OUTRO LADO DA ORNITOFILIA NOS NEOTRÓPICOS. A polinização por aves na região Neotropical é amplamente conhecida como uma importante interação ecossistêmica, mas as aves que pousam e que visitam flores são ainda vistas como meras oportunistas. Apesar dessas outras aves não dependerem somente de recursos florais, existem muitas plantas que dependem exclusivamente delas para a sua polinização. Essas flores apresentam características, incluindo morfologia e diferentes tipos de recursos, muito diferentes daquelas de flores ornitófilas polinizadas por beija-flores. Revisamos a síndrome de ornitofilia e a subdividimos nas duas formas de exploração para determinar as características florais que devem favorecer a polinização por aves que adejam e por aves que pousam na região Neotropical. Listamos as aves que pousam mencionadas na literatura para ter uma visão da riqueza de aves neotropicais que atuam como polinizadoras. Esperamos que quanto mais estudos no dossel florestal nos Neotrópicos, mais interações entre aves que pousam e flores devem ser observadas e revelar seu real papel para a biologia de ambos os grupos.
Palavras-chave: Aves que adejam, aves que pousam, néctar, néctar gelatinoso, flores de goma, corpúsculos alimentares, polinização por aves.

RESUMEN

MÁS ALLA DE LA RELACIÓN COLIBRIS-FLORES: EL OTRO LADO DE LA ORNITOFILIA EN EL NEOTRÓPICO. La polinización por aves en la región Neotropical es ampliamente conocida como una interacción ecosistémica relevante, mientras que las aves de percha que visitan flores continúan

siendo consideradas como especies oportunistas. A pesar de que estas aves no dependen exclusivamente de recursos florales, existen muchas plantas que dependen de éstas para su polinización. Estas flores presentan características morfológicas y diferentes tipos de recursos, muy distintos de flores ornitófilas polinizadas por colibrís. Revisamos el síndrome de ornitofilia en la región Neotropical y lo subdividimos en las dos formas de explotación de recursos para determinar las características florales que favorecen la polinización por aves que planean y por aves que perchan. Listamos las aves percheras (que forrajean posadas) mencionadas en la literatura, para tener una visión de la riqueza de aves neotropicales que actúan como polinizadoras. Esperamos que cuantos más estudios sobre el dosel forestal sean realizados en la región Neotropical, más interacciones entre las aves que perchan y las flores serán descriptas, revelando su función para la biología de ambos grupos.
Palabras clave: Aves que planean, aves de percha, néctar, néctar gelatinoso, flores de goma, corpúsculos alimentarios, polinización por aves, ornitofilia.

INTRODUCTION

Bird pollination is pretty common in warmer regions of America, Asia and Africa (van der Pijl 1937), charming naturalists due to bright colored flowers and, most of times, also birds (Endress 1994). Therefore, birds are a very important component for plant reproduction in the Tropics (Snow 1981), playing an important role in ecosystems services of pollination of noncultivated and even cultivated plants (Whelan *et al*. 2008). Birds may be even higher pollinators in quality than insects (Sekercioglu 2006), and hummingbirds are the most important vertebrate pollinators in the Neotropics (Bawa 1990). However, it was only by the end of XIX century that the role of vertebrates (birds and bats), mainly in the tropics, was discovered to be also important to flowers, and investigations were first conducted by O. Porch in 1924, and by K. Grant & V. Grant from 1968 on (Endress 1994).

The first studies about the interaction between hummingbirds and flowers in the Atlantic rain forest were taken by Snow & Teixeira (1982) and Snow & Snow (1986). Interactions between hummingbirds and flowers were studied latter by some other authors – and a review on bird pollination in Brazil was published including studies from 1975 to 2003 (Mendonça & Anjos 2003).

Displaying different methods of exploitation, hovering birds and perching birds may visit and pollinate flowers or inflorescences that present also different architectures (van der Pijl 1937, Westerkamp 1990, Rocca & Sazima 2008). Old dogmas advocated that Paleotropical bird-flowers would be adapted to perching bird pollination (except in Europe and Northern Africa, where would lack bird pollination, cf. Faegri & van der Pijl 1979, Stiles 1981) - and the Neotropical bird-flowers by hovering birds (Knuth 1905, van der Pijl 1937, Westerkamp 1990), as modern hummingbirds are confined to the Neotropics. On the other hand, surprise hummingbird fossils were found in Europe (in Germany: Mayr 2004, 2005, 2007; in Poland: Bochenski & Bochenski 2008; and in France: Louchart *et al*. 2008,), demonstrating that the group was not restricted to the Neotropics and dating the evolution of the interaction between birds and flowers back to the Oligocene. In addition, it also opened new possibilities to evolution of bird pollination in the Old Word (Mayr 2004). That was followed by the first confirmation of a native bird-pollinated species in Europe (SW Spain by Ortega-Olivencia *et a*l. 2005), definitely taking to an end the old dogmas.

In fact, studies on the assemblage of bird-pollinated species or on floral resource to birds in the Neotropics present a great variety of hummingbird-pollinated species (e.g., Stiles 1978, Snow & Snow 1980, Araujo 1996, Cotton 1998, Buzato *et al*. 2000, Araujo & Sazima 2003, Rosero-Lasprilla & Sazima 2004, Canela 2006, Rocca-de-Andrade 2006), which may be the reason why Neotropical bird-pollinated floras have been considered to be adapted mainly to hummingbirds (Cruden & Toledo 1977, Westerkamp 1990). In the Neotropics, perching bird-pollinated species have not been included in assemblage studies, and were only considered in case histories (exception in Rocca-de-Andrade 2006).

Yet, in 1977, Toledo pointed out that very little attention had been paid to other nectar-feeding birds in Neotropical rain forests, and that perching birds would be more common pollinators in those canopies. This was based on the idea that the life cycles of low-strata shrubs and herbs are shorter than that of trees, which would permit more rapid differentiation of flower size and shape, and also produce many plants adapted to hummingbird pollination (Snow & Snow 1972; and see Schmidt-Lebuhn *et al*. 2007 for a phylogenetic insight) - in contrast, occurrence of perching bird pollination should be less common than hummingbird pollination in the Neotropics. As ornithophilous flowers (ornithophily *sensu* Faegri & van der Pijl 1979) may represent up to 22% of Angiosperms in tropical communities (Stiles 1981, Feinsinger 1983, Bawa 1990, Morellato & Sazima 1992, Machado & Lopez 2004; see a good review for woody plants in Aizen *et al*. 2002, which may vary from 0.6% to 24.6%), the proportion of perching bird pollination must be even a smaller part of it (e.g., in the only ground and canopy-based studies in the Atlantic rain forest, it ranged from zero to 4% of the assemblage of bird-pollinated species, respectively, from Canela 2006 and from Rocca-de-Andrade 2006).

Toledo (1977) also suggested that the scarcity of studies on perching-bird pollinated flowers in rain forests could be partly due to the difficulties to observe upper-canopy species, which limited data about ornithophilous species in the Neotropics to ground-based studies. More than 30 years after Toledo's paper, there are still few studies on bird pollination with canopy-based data in Tropical rain forests, from case histories (Gill *et al*. 1996, Vicentini & Fischer 1999, Cotton 2001, Rocca *et al*. 2006, Azambuja 2008) to assemblage surveys (Canela 2006, Rocca-de-Andrade 2006). Since canopies in Tropical forests are considered to be the most complex of any forest type (Lowman & Moffet 1993), this scenario of sub sampling may be even worse (Rocca-de-Andrade 2006). Other vegetation types shorter than rain forests (like the Brazilian Restinga scrub, Cerrado, the wet savanna-like in Pantanal, or the subantartic vegetation of continental South America) permit easier sampling of canopy species and, therefore, we expect that the perching bird pollinated species in these vegetation types should be easier studied (like, respectively, Sazima *et al.* 1993, Sérsic & Cocucci 1995, Barbosa 1999, Sazima *et al.* 2001).

Very few studies focused also on non-ornithophilous flowers, looking at the whole group of species visited and not necessarily pollinated by birds, as these birds also look for resources in flowers adapted to pollination by other animals (Feinsinger 1976, Stiles 1978, Araujo 1996, Araujo & Sazima 2003, Dziedzioch *et al*. 2003, Rocca-de-Andrade 2006). While visiting non-ornithophilous flowers, birds (in most of the studies, hummingbirds) may act merely like thieves (e.g., Rocca & Sazima 2006) or even as co-pollinators (e.g., Wolff *et al*. 2003, Freitas *et al*. 2006). Therefore, hummingbirds and perching birds visiting flowers are more common than strictly during pollination interactions with ornithophilous flowers (see Rocca & Sazima 2010).

Although the pollination syndrome concept (*sensu* Faegri & van der Pijl 1979) has been criticized based on the evidence of wide generalization in pollination (which means high numbers of visitor species per plant species; see Waser *et al*. 1996), when floral visitors are clusted into functional groups of pollinators, as different groups they may exert different selective pressures, reflected by floral features (Fenster *et al*., 2004). Indeed, some plant species in the Neotropics are clearly adapted to perching birds rather than to hummingbirds, since they display special floral features, like morphology and even different types of resources.

In this review, we look at the original syndrome of ornithophily (*sensu* Faegri & van der Pijl 1979) and tear it apart to determine floral and reproductive features that might favor pollination by hovering birds or by perching birds in the Neotropics. But before that, we describe features of both birds that visit flowers and flowers pollinated by birds.

BIRDS THAT VISIT FLOWERS IN THE NEOTROPICS

In addition to hummingbirds, other birds are also known to make use of floral resources in the Neotropics (Sick 1997). Those birds that pollinate in the Neotropical region (Appendix 1) display low to moderate level of specialization to nectarivory compared to hummingbirds, and they were often regarded as "parasites" of the pollination system involving hummingbirds and their flowers (Stiles 1981).

In fact, we found as many as 166 species of perching-bird pollinators in the Neotropical region mentioned in the literature, from 20 families, being Passeriformes or non-Passeriformes (Appendix 1). It is a big group in diversity of families and generas, but small in number if compared to the near 320 species of hummingbirds (in only one family, the Trochilidae) that may exist (Grantsau 1989).

BIRD MORPHOLOGY, DIET AND VERTICAL STRATIFICATION

As the beak is an adaptation to food habits, hummingbirds with their relative long bills and tongues, are among the most specialized feeders (Young 1983) – in addition, animals feeding on liquids are often highly specialized (Schmidt-Nielsen 1997). In contrast, perching birds that visit flowers display a wide variety of bill shapes, as a result of feeding on a wide diversity of items (Pough *et al*. 1996; Appendix 1). Bills may vary from short, thin, pointed bills of insectivorous birds, to short, thick, strong ridged bills of seed eaters, or to longer and wider of generalist feeders (Young 1983), or to the hooked bill of flowerpiercers (*Diglossa* spp. and *Diglossopis* spp.), which is a clear adaptation to pierce and rob nectar (Schondube *et al*. 2003).

Among these perching birds reported visiting flowers, the ones that have not been described as nectar drinkers are fruit eaters (cf. Höfling & Camargo 1993, Sick 1997, Develey & Endrigo 2004), an evolutionary step close to nectar intake (Faegri & van der Pijl 1979) – exceptions are few arthropod and seed eaters (Appendix 1). The subfamilies Coerebidae and Thraupidae (Passeriformes) display a generalist diet but nectar is a very important component of it (Snow & Snow 1971, Feinsinger *et al.* 1979, Steiner 1979, Neill 1987, Sazima *et al*. 1993, Sick 1997). The idea of flowerpiercers being parasitic floral visitors (Stiles 1981) would not be always the case of *Coereba flaveola* (Coerebidae), which visits many hummingbird- flowers and also pollinates a few of them (Snow & Snow 1971, Feinsinger 1976, Sazima & Sazima 1999, Fumero-Cabán & Meléndez-Ackerman 2007), and even bat-flowers (Martén-Rodriguez & Fenster 2008), besides other perching bird flowers (Sazima *et al*. 1993, Gill *et al*. 1996, Sazima *et al*. 2001, Rocca & Sazima 2008, Azambuja 2008), totaling 14 species pollinated by this bird (Appendix 1).

While richness of understory birds is based mainly on insectivores, canopy strata in tropical forests are dominated by omnivorous and frugivorous birds (Pearson 1971, Greenberg 1981, Loiselle 1988, Levey & Stiles 1994), which supports the high probability to find more perching birds visiting flowers in this stratum (Toledo 1977, Rocca & Sazima 2008).

Bird species that live in Neotropical forest canopies may represent 40 to 50% of forest bird species (Stiles 1983). As a matter of fact, canopy avifauna may share species with scrubby second growth and open areas (Greenberg 1981), and 47% of the species observed in a study in the Atlantic rain forest were common in these areas (Rocca & Sazima 2008). While bird pollination is completely dominated by hummingbirds in the understory in Tropical rain forests, ornithophilous canopy species may be visited and pollinated by hummingbirds or by perching birds (Rocca-de-Andrade 2006) – which means that to look for perching bird pollinated species in a Neotropical forest, one should do it in the forest canopies.

METHODS OF EXPLOITATION AND ECOLOGICAL ROLES OF BIRDS

The hovering flight of hummingbirds is the extreme specialization of the flapping flight (Pough *et al*. 1996), only compared to sphingid moths (Sick 1997). Hummingbirds are the only birds able to forage most of the time while hovering, but they may perch whenever possible (Feinsinger & Colwell 1978, Westerkamp 1990 and references therein). Several other birds may hover in a more (gulls, pigeons and doves) or less (crows and starlings) similar way to hummingbirds, but only hummingbirds display flight muscles up to 25-30% of the body mass (Schmidt-Nielsen 1997). Therefore, although many perching birds are reported to visit flowers during small hovers, although "not as elegant as trochilids" (Westerkamp 1990), most of their forage is from a perch (Fleming & Muchhala 2008). If the importance of bird traits is not the determining factor to hover-pollination, since the ability to hover may not be as constrained as previously thought, then floral traits may play an even more important role in determining the methods of exploitation (Geerts & Pauw 2009, and see the remarkable example of an invasive hummingbird-flower in Africa pollinated there by a heavy sunbird while hovering).

Hummingbirds are always solitary and they may play different ecological roles (*sensu* Feinsinger &

Colwell 1978) due to the availability of resource (Feinsinger & Colwell 1978, SanMartin-Gajardo & Freitas 1999, Buzato *et al*. 2000, Rocca-de-Andrade 2006). They may follow a repeated foraging circuit (trapline) or set up territories against any bird, depending on the hummingbird morphology, flower density and corolla length or nectar per flower (Feinsinger & Colwell 1978). However, as hummingbirds tend to maintain territories for clumped moderate to rich flowers (Feinsinger & Colwell 1978, Stiles 1978, 1981), if they receive pollen loads, they may be poor vectors for outcrossing pollen in this situation (Canela & Sazima 2003, Rocca & Sazima 2008, and references therein).

Perching birds are most of the time in pairs or in flocks that tend to visit different plants with many open flowers per day (Sazima *et al*. 1993, Rocca & Sazima 2008, Azambuja 2008), quickly exhausting the resources even of large trees and compelling the flock to move on to the next tree, promoting cross-pollination (Stiles 1978, 1981). Functionally, they are regarded as generalists (*sensu* Feinsinger & Colwell 1978), visiting not only ornithophilous flowers, but also avoiding species highly defended by aggressive hummingbirds (Colwell *et al*. 1974).

Even the solitary perching bird *Coereba flaveola*, a common floral visitor in South America (Sick 1997), may act as a good cross-pollinator, once it visits flowers and moves to other clumps (Sazima & Sazima 1999), not maintaining territories, like many hummingbirds.

FLOWERS POLLINATED BY BIRDS IN THE NEOTROPICS

Some groups of plants are highly dependent on hummingbird pollination. Examples in the Atlantic rain forest are many species of Bromeliaceae, Gesneriaceae, Fabaceae, Heliconiaceae, Lobeliaceae, Rubiaceae and Acanthaceae (Araujo 1996, Buzato *et al*. 2000, Lopes 2002, Canela 2006, Rocca-de-Andrade 2006), most of them herbaceous plants. Rubiaceae and Bromeliaceae species also predominate in three vegetation types in the Amazonian Colombia (Rosero-Lasprilla & Sazima 2004), and Heliconiaceae in Central America (Wolf *et al*. 1976, Stiles 1978, 1981), but other families may be more important in other regions and vegetation types in the Neotropics (Barbosa 1997, Araujo & Sazima 2003).

Perching birds pollinate species in many different families, but a few species per family: Clusiaceae (3 spp.), Combretaceae (2 spp.), Euphorbiaceae (1 sp.), Fabaceae (8 spp.), Malvaceae (4 spp.), Marcgraviaceae (1 sp.), Myrtaceae (2 spp.), Proteaceae (1 sp.), Rutaceae (1 sp.), all woody species, being trees or climbers (Gryjl *et al*. 1990, Sazima *et al*. 1993, Ducroquet & Hickel 1997, Roitman *et al*. 1997, Smith-Ramírez & Armesto 1998, Barbosa 1999, Vicentini & Fischer 1999, Sazima *et al*. 2001, Ragusa-Neto 2002, Agostini *et al*. 2006, Sazima & Sazima 2007, Rocca & Sazima 2008, Sazima *et al*. 2009; see Appendix 2) – which brings back the importance of life cycles (Snow & Snow 1972) in the differentiation of pollination modes. However, perching birds as pollinators or co-pollinators of other kinds of life forms are known such as a perennial herb (Scrophulariaceae; Sérsic & Cocucci 1995), a herbaceous Agavaceae species (Ornelas *et al*. 2002), some epiphyte species of Bromeliaceae (Snow & Snow 1971, Sazima & Sazima 1999, Fumero-Cabán & Meléndez-Ackerman 2007), one shrub species of Onagraceae (Traveset *et al*. 1998), and one shrub species of Gesneriaceae (Martén-Rodriguez & Fenster 2008).

FLORAL TRAITS: HOVERING X PERCHING BIRD POLLINATION

Under the selective pressure of bird features (Table I), floral features have been adapted to bird pollination – known as a whole as the syndrome of ornithophily (*sensu* Faegri & van der Pijl 1979). Floral features as diurnal anthesis, bright and contrasting colors (see a good essay about this in Rodríguez-Gironés & Santamaría 2004), absence of floral scent, capillary system bringing nectar up or preventing it to overflow, and possible large distance between resource and reproductive organs (pollen and stigma), all from the original ornithophilous syndrome of Faegri & van der Pijl (1979), clearly fit to both groups of pollinators. Flowers tend to have large nectaries, and robust, sclerified tissues at periphery of floral organs, especially where they may be damaged by bills or feet of visitors, and, in this sense, a bias toward inferior ovary may exist (review in Endress 1994). However, differences in bird foraging modes (hovering and perching) are also reflected in floral morphology

Table I. Flower bird characteristics (after Faegri & van der Pijl 1979) and depicted into hovering birds and perching birds in the Neotropical region. Note that only when characteristics are different for hovering and perching birds they are mentioned. Empty cells mean equal characteristics, and flower bird characteristics inside parentheses were not mentioned in the original table from Faegri & van der Pijl (1979).

Flower birds	Hovering birds	Perching birds
Diurnal		
Visual with sensitivity for red, not for UV	Also for UV[1]	Also for UV[1]
Too large to alight on the flower itself		
(Need a perch)	No perch is needed	Need a perch
Hard bill		
Scarcely any sense of smell		
Large – and great consumers	Larger than insects	Usually larger than hovering birds
(Sociability)	Always solitary	Often in pairs or in flocks
Long bill and tongue	Very long bill and tongue	Bill and tongue shorther than hovering birds'[2]
Large, long bill; large body	Long bill	Large, shorter bill; large body
Intelligent in finding an entrance		Even in explosive flowers[3]

[1] Chen *et al*. (1984); [2] Sick (1997); [3] Agostini *et al*. (2006): *Cacicus haemorrhous* (Icterinae) knows how to open *Mucuna japira* (Fabaceae) flowers (Figure 1C) to take nectar and bugs.

(Westerkamp 1990) – not only as an adaptation to the group of pollinators (Faegri & van der Pijl 1979), but also, paradoxically, avoiding visitors that could act as robbers (cf. Endress 1994; a good review on adaptations away or towards possible pollinators, and an elegant experiment on one-trait modification in Castellanos *et al*. 2004). Hence, many other features may be depicted into the hovering or the perching bird syndrome (Table II and Appendix 2), as bird morphology, methods of exploitation and ecological role are quite different between them.

Hummingbird-pollinated flowers may vary in shape from tube-like corolla (tube, bell, gullet, flag), with the lip or margin curved back (Faegri & van der Pijl 1979), to an open corolla of easy access, like a dish flower, but the tube is the most frequent shape (e.g., 78% in Buzato *et al*. 2000). This corolla type fits well hummingbird bills but also excludes other visitors (cf. Faegri & van der Pijl 1979, Endress 1994). Pollen loads are more precisely placed (e.g., on bills or on the top of the hummingbird heads) in tubular narrow corollas, as it fixes the right position of the pollinator to the reproductive floral organs (Wester & Claβen-Bockhoff 2006, Rocca-de-Andrade 2006, Muchhala 2007).

On the other hand, flowers pollinated by perching birds may vary from dish or brush types, usually pollinated by many species with quite different diets and bills (Toledo & Hernandez 1979, Gryj *et al*. 1990, Sazima *et al*. 1993, Roitman *et al*. 1997, Sazima *et al.* 2001, Sazima & Sazima 2007, Rocca & Sazima 2008), to flag or lip-type flowers, with fewer pollinators (Morton 1979, Steiner 1979, Toledo & Hernandez 1979, Sérsic & Cocucci 1996, Vicentini & Fischer 1999, Etcheverry & Aleman 2005, Agostini *et al*. 2006, Sazima *et al.* 2009). Flowers or inflorescences functioning as brush pollination units are common in perching bird-pollinated species (Westerkamp 1990, Endress 1994), and they are appropriate to promote disperse pollen placement on pollinators: different parts of the pollinator head, under parts of the body, legs and even feet (Sazima *et al*. 1993, Endress 1994; Figure 1A). When pollinated by the feet of the bird, even the gynoecium is extremely robust, sessil (Barbosa 1999), and pollen and stigma are very sticky (Westerkamp 1990, Pinheiro *et al.* 1995, Endress 1994, Barbosa 1999). Moreover, because they are frequently wide open (Westerkamp 1990) and easily accessible, if they are nectar-flowers they can be pollinated by both large perching birds and even small hummingbirds (Sazima *et al*. 1993, Rocca & Sazima 2008; Figure 1B) – but relative importance of each group to pollination vary. Conversely, flag or lip-type flowers pollinated by perching birds will function more similar to tubular ones pollinated by hummingbirds, and place pollen in a more precisely way, with the match of a specific visitor (e.g., related references above; Figure 1C). Exceptions in floral shape of perching bird flowers are the ones co-pollinated by *Coereba flaveola,* with tubular short

Table II. The syndrome of ornithophily (bird flowers after Faegri & van der Pijl 1979) and depicted into hovering and perching bird flower features in the Neotropical region. Note that only when characteristics are different for hovering and perching bird flowers they are mentioned. Empty cells mean equal characteristics, and characteristics inside parentheses were not mentioned in the original table from Faegri & van der Pijl (1979).

Bird flowers	Hovering bird flowers	Perching bird flowers
Diurnal anthesis		
(Flower longevity)	Often one-two days	Generally more than one day
(Flowers per day)	From one to many	Always many flowers
(Flowering phenology)	From annual to sub-annual	Generally from annual brief to intermediate
(Season)	Any season	Any season[1]
Vivid colours, often scarlet or with contrasting parrot-colours		
Lip or margin absent or curved back, flower tubate and/or hanging, zygomorphy unnecessary	Lip or margin absent or curved back, flower tubate and/or hanging, zygomorphy unnecessary	Brush-like nectar flowers, always oriented upwards, actinomorphy in generalist flowers and zygomorphy in specialized ones
Hard flower wall, filaments stiff or united, stiped or otherwise protected ovary, nectar stowed away	From delicate to hard flower wall	Always hard flower wall
(Floral pedicel and inflorescence axis)	Pedicel may be alongated, and both may be delicate	Both always robust
Absence of odour		
(Presence of a perch)	No perch	With a perch nearby or the pollination unit itself
(Types of resource)	Nectar	Nectar, food bodies, jelly-nectar, antheroil
Nectar abundant	Nectar less abundant than perching bird flowers	Nectar more abundant than hummingbird flowers
(Sugar nectar concentration)	Nectar more concentrated	Nectar less concentrated
(Sucrose:hexose ratio)	High ratio	Low ratio
(Nectar color)	No color	Colored nectar may be present
Capillary system bringing nectar up or preventing its flowing out		Only if nectar-flower
Possibly deep tube or spur, wider than in butterfly flowers	Very common	Tube shorter and wider than in hovering bird flowers, but only when nectar is present
Distance nectar-sexual sphere may be large		(Not only nectar, but also other resources)
(Pollen load)	More precise pollen load	More disperse pollen load, but more precise as more specific pollinators
(Pollen type)	From dusty deposited on feathers to more sticky, on bills	From sticky to antheroil
(Reproductive system)	Self-compatible or incompatible species	Generally self-incompatible species
Nectar-guide absent or plain		Only if nectar-flower
(Plant habit)	Any habit	Generally woody plants (trees or climbers)[2]

[1] Although some authors still discuss that perching bird visit flowers only in the dry season, when resource availability is low – see text and many references of the opposite; [2] Exception is the herb *Calceolaria uniflora* (Scrophulariaceae; Sérsic & Cocucci 1995)

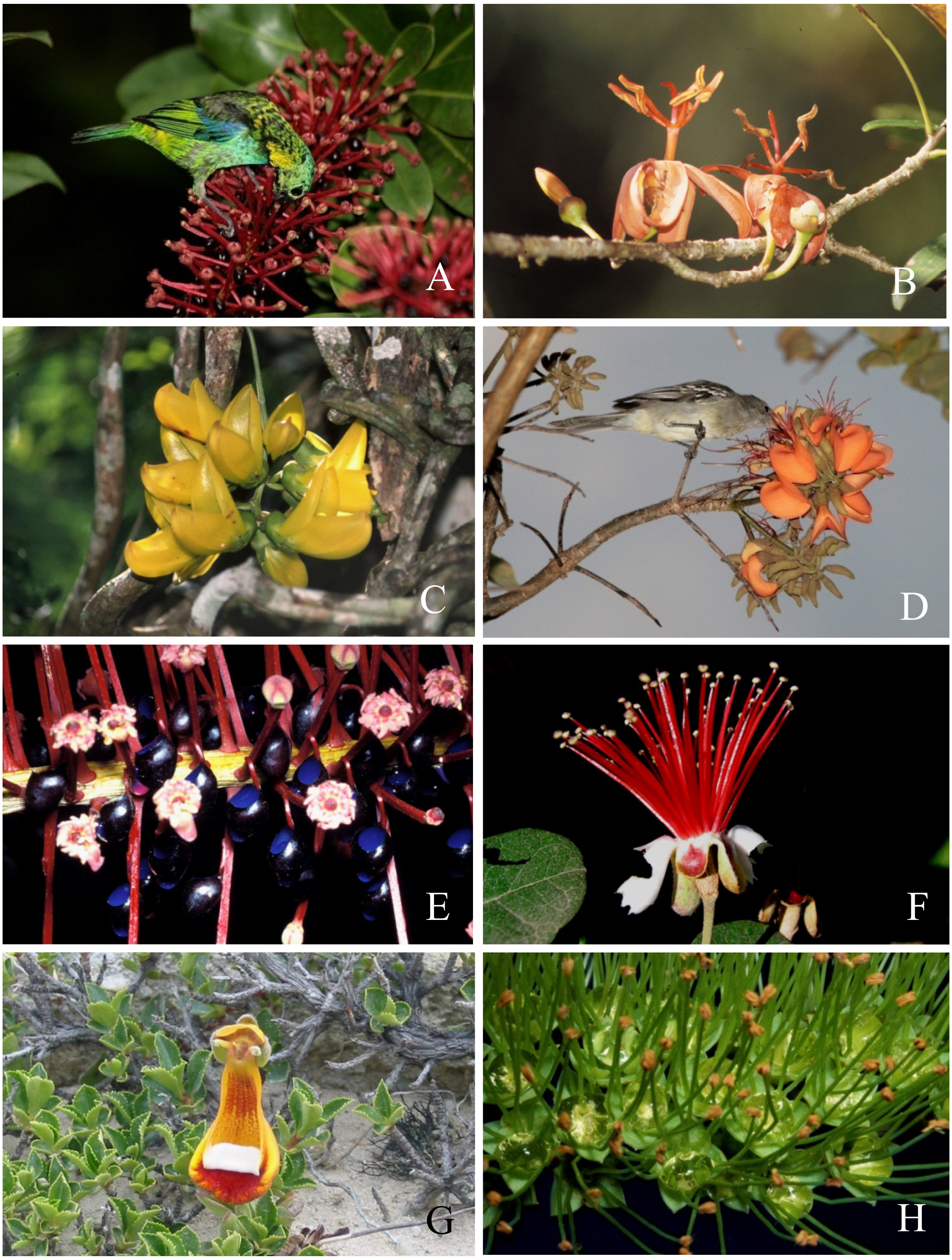

Figure 1. Perching birds and their flowers. **A**, *Tangara seledon* perching on and visiting the brush-like inflorescence of *Schwartzia brasiliensis* (Marcgraviaceae); **B**, the wide open and easily accessible flower of *Spirotheca rivieri* (Malvaceae); **C**, the explosive flowers of *Mucuna japira* (Fabaceae); **D**, *Elaenia ridleyana* visiting *Erythrina velutina* (Fabaceae) from a perch nearby; **E**, *Schwartzia brasiliensis* and its blue nectar; **F**, *Acca sellowiana* (Myrtaceae) petals as food-bodies, partially eaten; **G**, the white-colored appendage as a food-body on the lower lip of *Calceolaria uniflora* (Scrophulariaceae) not eaten yet; **H**, *Combretum lanceolatum* (Combretaceae) and the jelly-nectar.

corolla (Snow & Snow 1971, Sazima & Sazima 1999), which is easily accessed by its hooked bill (and pollen loads are deposited on the tip of it), or not so short tubular corolla (Fumero-Cabán & Meléndez-Ackerman 2007), and a campanulate corolla, which the bird may insert its head while looking for nectar (Martén-Rodriguez & Fenster 2008). A mixture of pollen and fluid oil – the antheroil – is reported to some perching bird-pollinated Clusiaceae species (Bittrich & Amaral 1996, Maués & Venturieri 1996, Vicentini & Fischer 1999, Azambuja 2008) and may improve pollen adherence to the smooth beak of birds (Bittrich & Amaral 1996). Although this type of mixture may have other advantages, it is also an adaptation to the pollination of the pore-like stigma (Bittrich & Amaral 1996, Vicentini & Fischer 1999). In this sense, the tapetal oil (= antheroil, but with a precise place of production) of *Souroubea guianensis* (Marcgraviaceae) may promote the same improvement in pollen adherence, but still lack the confirmation of an effective (perching bird?) pollinator (Machado & Lopes 2000).

Solitary flowers prevail in hummingbird-flowers (Westerkamp 1990), but generally if pollinated by trapliners (the "disperse rich flowers", Feinsinger & Colwell 1978), while some inflorescences may bare few flowers in anthesis per day (Buzato *et al*. 2000, Rocca-de-Andrade 2006). Flowers are always oriented toward free space, which can neither be reached nor pollinated by perching animals (Westerkamp 1990), to any orientation and even hanging upside-down (Aizen 2003), in flexible pedicels (Endress 1994). Inflorescences are vertically oriented and the flowers are pointing outward (Westerkamp 1990). But unlike the solitary flowers, vertically oriented inflorescences may be reached by the acrobatic (Sick 1997) perching bird *Coereba flaveola*, which, in fact, is a co-pollinator of some species (Snow & Snow 1971, Sazima & Sazima 1999, Fumero-Cabán & Meléndez-Ackerman 2007).

Perching bird-pollinated flowers may be erect solitary ones (Figure 1B), or be on terminal horizontal inflorescences (Cruden & Toledo 1977; Figure 1A), or on dangling inflorescences (Agostini *et al*. 2006), with many flowers in anthesis per day, which are possible to be visited from a single perch without additional movement (Westerkamp 1990). Flowers are usually curved (back and resupinate or upwards), so that they can be reached by a perch nearby (Figure 1D). In addition to the existence of a perch, as these flowers are usually wide open, they may also be visited by non-flying visitors, among mammals and lizards (Janson *et al*. 1981, Westerkamp 1990, Sazima *et al*. 2001, Sazima *et al*. 2009). Perches may be grouped (Westerkamp 1990) as: outside the inflorescence (on the ground or on the neighboring structure, respectively, e.g., Sérsic & Cocucci 1996 and Vicentini & Fischer 1999), and within the inflorescence (proximal, distal or central perches, and sterile or fertile perches, e.g., proximal fertile perches on the inflorescence of some Bromeliaceae; Sazima & Sazima 1999). Inflorescence axis and also floral pedicels are very resistant to mechanical shocks of these perching birds (Barbosa 1999).

FLOWER LONGEVITY

Several hummingbird flowers last one day, although some of them last longer (e.g., Araujo *et al*.1994, Canela 2006, M.A. Rocca, pers. obs.). In contrast, the duration of perching bird-flowers seems to be always longer than a single day, which is the case of several species (Schemske 1980, Bernardello *et al.* 1994, Sérsic & Cocucci 1995, Roitman *et al*. 1997, Sazima *et al*. 2001, Cotton 2001, Ragusa-Neto 2002, Agostini *et al*. 2006, Rocca & Sazima 2008, Sazima *et al.* 2009) – but flowers of a few Clusiaceae species last almost only one day (Gill *et al*. 1996, Vicentini & Fischer 1999, Azambuja 2008), and flowers of one Scrophulariaceae species (Sérsic & Coccucci 1996). In fact, flower longevity is inversely related to visitation rate, and also flowers of outbreeders tend to remain open longer (Primack 1985), thus long-lived flowers enhance the chance of pollination by birds that are not solely dependent on floral resources and, therefore, may be unpredictable visitors (Rocca & Sazima 2008). On the other hand, hummingbirds, which diet is based on nectar and insects (Sick 1997), are very predictable visitors.

RESOURCES

Nectar is the most common resource produced by flowers (Endress 1994), and also by ornithophilous species (e.g., Araujo 1996, Buzato *et al*. 2000, Araujo & Sazima 2003, Dziedzioch *et al*. 2003, Rocca-de-Andrade 2006). It is basically a solution of water, sugar (sucrose, glucose and fructose) and amino acids, but it may also contain other compounds, like other sugars, lipids, antioxidants and potential deterrents, such alkaloids, phenolic substances and glycosides (Baker & Baker 1983, 1990).

When compared to melittophilous flowers, hummingbird flowers produce great amounts of nectar at low concentrations (e.g. Faegri & van der Pijl 1979, Opler 1983, Cruden *et al*. 1983, Ackermann & Weigend 2006). However, hummingbirds may take nectar from a very wide range of sugar concentration and from flowers of different pollination syndromes [e.g. from 3.1 to 40.9% Brix in an Atlantic Rain Forest site (Rocca-de-Andrade 2006), or up to 55.0% Brix in some high elevation species of Loasaceae in South America (Ackermann & Weigend 2006)]. Relatively low sugar concentration (from 4.6 to 14.0% Brix) and very high volume, when compared to hummingbird-flowers (e.g., accumulated nectar by the end of the morning in an Atlantic Rain Forest site, Rocca-de-Andrade 2006: from 34.3 to 141.9µl against from 1.6 to 71.3µl, respectively), are features found in the nectar of perching bird-flowers (Gryj *et al*. 1990, Sazima *et al.* 1993, Gill *et al.* 1996, Bittrich & Amaral 1996, Baker *et al.* 1998, Vicentini & Fischer 1999, Cotton 2001, Ragusa-Neto 2002, Agostini *et al*. 2006, Rocca & Sazima 2008, Sazima *et al*. 2009). Another paradigm is about the ratio sucrose:hexose in nectar, which Baker & Baker (1983, 1990) suggested a driving selective force for nectar sugar composition mediated by pollinator preference to support this dichotomy: hummingbird-flowers are often derived from bee-flowers, which are sucrose rich and hummingbirds are able to digest it, meanwhile perching birds show a taste for hexose from the use of fruits in their diet, therefore selecting nectar features more similar to fruit sugar. But this paradigm was recently reviewed: some studies support pollinator preference selection and one paper also suggest that two bird clades cannot digest sucrose, meanwhile several species of birds consistently preferred sucrose concentrated nectar to hexose diluted one – which means that the paradigm is not always the case (review in Brandenburg *et al*. 2009, and references therein). Johnson & Nicolson (2008) suggested to the Paleotropics that the dichotomy of nectar features should involve instead of the dichotomy hummingbird and passerine flowers, the difference between specialized and generalized (nectarivores) bird pollination systems, comparing the African sunbird-pollinated species to the hummingbird-pollinated ones, and they against flowers pollinated by omnivorous birds.

In some species, nectar can be colored and easily seen deep into open flowers, also as an attraction to birds, like the blue nectar of *Schwartzia brasiliensis* (Choisy) Bedell ex Gir.-Cañas (Marcgraviaceae; Sazima *et al*. 1993, Figure 1E) and the yellow nectar of *Spirotheca rivieri* (Decne.) Ulbr. (Malvaceae; Rocca & Sazima 2008). Beside these two species, other 32 species pollinated only by hummingbirds in an Atlantic Rain Forest site (Rocca-de-Andrade 2006) did not have colored nectar (M. A. Rocca, pers. obs.). Therefore, not only does colored nectar seem to be correlated with pollination by vertebrates, mainly by birds (Hansen *et al*. 2007), but with pollination primarily by perching birds (Rocca & Sazima 2008). Most perching-bird pollinated species which produce colored nectar have easily accessible flowers and nectar that can often be seen from a distance, forming visible drops and a sharp contrast with the background and providing an honest visual floral cue to potential pollinators (Hansen *et al*. 2007, although it point out that there are also other explanations for colored nectar, and even non-functional ones). Nectar color is an interesting feature that needs more attention as there are few records on it (cf. Hansen *et al.* 2007). In addition to pigments, the role of secondary compounds in nectar also needs more attention (Brandenburg *et al*. 2009).

But different rewards may be favored by selection to capture a segment of the pollination community not used by other plants or to achieve greater constancy of pollination (Simpson & Neff 1981). Besides nectar, other types of resources can be explored by birds in the Neotropical region. Completely different from the former that may be replenished, other resources resemble a fruit in terms of availability (Sazima *et al.* 2001), as they are not replenished after consumption. In contrast, these resources are not of easy intake to hummingbirds, once these birds have to probe to take it.

Floral tissue from petals, stamen tips and from other flowers parts may serve as resources for pollinators (Pellmyr 2002). However, ornithophilous flowers reported to offer these food bodies are restrict to present fleshy petals generally rich in starch, sugar, lipids or proteins (Sérsic & Cocucci 1996, Ducroquet & Hickel 1997, Roitman *et al*. 1997, Sazima & Sazima 2007; Figure 1F e 1G). No hummingbird was ever reported to take this kind of resource (that must be chewed) and, therefore, flowers that produce food bodies may be seen as specialized exclusively on perching bird pollination.

A rare example of other kind of resource occurs in one species of Combretaceae (*Combretum lanceolatum* Pohl), whose nectary produces a sweet gelatinous secretion in form of pellets, instead of fluid nectar, full of mannan and free hexoses (Sazima *et al*. 2001; Figure 1H). This jelly-flower is unique within the genus and so far in the literature (Sazima *et al*. 2001) – already called "the Willy Wonka of the botanical world" (Whitfield 2001). An assemblage of 34 bird species was recorded, mainly perching birds, which picked up the pellets, besides one hummingbird species, which just licked on the surface of the pellets in the morning hours when dew was still present, taking advantage of the water-solubility of the jelly (Sazima *et al*. 2001, Silva & Rubio 2007).

Another even rarer example of floral resource is the antheroil intermixture of pollen and oil. Although it is produced by a few species of Clusiaceae (Bittrich & Amaral 1996, Maués & Venturieri 1996, Vicentini & Fischer 1999, Azambuja 2008), it was only observed being used (in addition to the nectar) by the parakeet *Brotogeris chrysopterus* (Psittacidae) visiting flowers of *Moronobea coccinea* (Clusiaceae) in Central Amazon (Vicentini & Fischer 1999).

BREEDING SYSTEM

Plant breeding system reflects the interaction between attributes of both plants (floral morphology and gender, floral display, plant size, pollen morphology and presentation) and pollen vectors (abundancy, diversity and behaviour; see Tammy *et al*. 2005). As many other animal pollinated species (see discussion in Pellmyr 2002), hummingbird pollinated flowers are mainly xenogamous, depending on outcrossing. However, self-compatibility is quite common among epiphytes *sensu lato* (Gentry & Dodson 1987), and most of them are Bromeliaceae species (Martinelli 1997, Benzing 2000). The majority of bromeliads are pollinated by hummingbirds (Araujo *et al.* 1994, Martinelli 1997, Sazima *et al.* 2000, Canela & Sazima 2003, 2005, and references above), and although self-compatibility is widespread in the family, most of the self-compatible bromeliad species need pollinator services (Canela & Sazima 2005, and references therein). Self-incompatibility in Bromeliaceae is not common, with *Aechmea pectinata* being one example of it (Canela & Sazima 2003).

Genetic self-incompatibility occurs in some perching bird-flowers (Schemske 1980, Bernardello *et al*. 1994, Pinheiro *et al.* 1995, Roitman *et al*. 1997, Rocca-de-Andrade 2006). Perching bird behavior of exhausting the resources, visiting all flowers before moving to another plant (Stiles 1978, 1981, Sazima *et al*. 1993, Rocca & Sazima 2008), may select mechanisms for selfing avoidance, as floral traits mediate outcrossing (see Pellmyr 2002).

FLOWERING PHENOLOGY

Although there is a dogma in the literature that perching bird visit flowers during periods of food scarcity in the dry season (e.g., Toledo 1977, Pettet 1977, Terbourgh 1986, Gryjl *et al*. 1990, Olmos & Boulhosa 2000, Ragusa-Netto 2002, Silva 2008, Sazima & Sazima 1999, Sazima *et al.* 2009), as an opportunist behavior, this does not correspond to all species, as some plants do flower during the wet season and depend solely on perching birds as pollinators (Sérsic & Cocucci 1996, Vicentini & Fischer 1999, Sazima & Sazima 2007, Rocca & Sazima 2008). Therefore, perching bird-pollination may not be related only to periods of food scarcity in the Neotropics, as a merely opportunistic syndrome (Rocca & Sazima 2008).

CONCLUSIONS AND PERSPECTIVES

Westerkamp (1990) already pointed out that "to understand bird-flowers the actual functioning of flowers must be in focus, and not the geographic distribution nor the systematic affiliation of their visitors". In fact, in this interaction between birds and flowers, it seems that plants have a proeminet role, rather than birds, in determining the kind of exploitation (hovering or perching) during pollination, which leads to the question of why hovering bird flowers do not occur outside the Neotropics (Geerts & Pauw 2009).

Hummingbird special floral features took Sick (1997) to suggest the use of the term *trochilogamy* as a specialization for plants to this group of birds inside the ornithophily. But following the use of the suffix –phily, the term *trochilophily* should be used so far (Machado & Rocca 2008). Besides trying to bring to use this term – and a quick search in the internet (Web of Science) may result in only six papers with this terminology (*trochilophily* or *trochilophilous*) – we should also find another one for the perching bird syndrome.

In fact, ornithophily is quite an expensive syndrome of pollination. Plants must invest in big flowers to accommodate somehow pollinators, and also produce a great volume of rich resource (nectar or any other), as they require more energy than small insects (Cronk & Ojeda 2008). This means that plants also have to protect this resources against robbers, which demands even more energy (Stiles 1978), and also against these strong pollinators, protecting reproductive floral parts (cf. Endress 1994). Therefore, the ocurrence of this pollination syndrome may be limited in environments with low plant productivity, as in cold, hyper-arid, and nutrient-poor environments, being common in tropical and subtropical shrublands, open woodland, and riverine communities (Cronk & Ojeda 2008). Ornithophilous flowers may represent up to 22% of Angiosperms in tropical communities (Morellato & Sazima 1992), but they may reach as low as 1.8% in others (see Machado & Lopes 2004 for comparison among different Neotropical communities). In the sense of cost, perching bird flowers may be more expensive than hovering bird flowers, putting more energy into robbust floral parts, flower numbers, inflorescence axis, and resources. This, together with the ideia of rapid differentiation of low-strata shrubs and herbs under hummingbird selective pressure (Snow & Snow 1972), may in part explain the low proportion of perching bird flowers in Neotropical communities, which means very few species inside this range of 1.8 to 22.0% in a community.

Moreover this low proportion of perching bird flowers in different communities, the still current idea of many researches that perching bird floral visitors are simply displaying an opportunistic behavior, helps in part to neglect to perching birds their real importance as pollinators in the Neotropics, beside (although far away, if one compare only bird adaptations and forget the role of floral traits) the hummingbirds. But maybe this scenario has been changing as more studies are being published on perching bird pollination, even on very accessible plant species (e.g., as principal pollinators, Sazima *et al*. 2001, Agostini *et al*. 2006, or as co-pollinators, Ornelas *et al*. 2002, Fumero-Cabán & Meléndez-Ackerman 2007), which raises the question why these species and their pollination system were realized only recently.

In addition to the low occurrence of perching bird flowers and the prejudice of many researches, there is also a sampling problem to find and observe these flowers, especially in forest canopies. Comparing two studies from the Atlantic rain forest, one ground-based (Buzato *et al*. 2000) and the other canopy-based (Rocca-de-Andrade 2006), there were only two perching bird-pollinated species common in both studies, one of them already known as it (*Schwartzia brasiliensis,* Marcgraviaceae; Sazima *et al*. 1993). The other species (*Spirotheca rivieri*, Malvaceae) was registered as hummingbird-pollinated in the first study, and its pollination biology was published only recently (Rocca & Sazima 2008). In this example, all other species of pollinators could be completely neglected if no climbing techniques were used in the study of Rocca & Sazima (2008). The point is that still most studies about canopy species in Tropical rain forest are ground-based, and thus, we have no idea about the amount of information that is not being recorded. The study of Rocca-de-Andrade (2006) confirmed Toledo (1977), who considered perching bird-flowers would be more common in the canopy of Neotropical forests (Rocca-de-Andrade 2006). It also confirms Nadkarni & Matelson (1989), who pointed out that "researchers should note that gathering information from observation positions within the canopy greatly enhanced their ability to discriminate between the sources and types of resources used by birds, and also that the degree of specialization on resources within the canopy and even on single plants would be impossible to discern if observations were made only from the ground".

We expect that as more studies on forest canopies are taken in the Neotropics, more interactions between perching birds and flowers may be observed, thus helping to understand the important role in the biology of both groups theses interactions may play. Nonetheless, we should give the real importance of these birds to pollination of some plant species that actually depend solely or mostly on them.

ACKNOWLEDGEMENTS: To Romari A. M. Montano, who gave MAR computer support. To Martín R. Del Valle Alvarez, who helped with the *Resumen*. To Ivan Sazima and Kayna Agostini which gently shared some photos with us. To Petra Wester for comments on the manuscript. To an anonymous referee which improved this review through many exciting questions. To CNPq and FAPESP for financial support. To the Sociedade de Ecologia do Brasil (SBE) and its support to participate in the IX Congresso Brasileiro de Ecologia, to PAEX-CAPES, UESC and The Ashoka Trust for Research in Ecology and the Environment (ATREE) for financial support to participate in the 5th International Canopy Conference –the presentation of this topic during both meetings greatly improved this manuscript.

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Submetido em 29/05/2009
Aceito em 20/12/2009

Appendix 1. Perching birds which pollinate flowers in the Neotropics. Nomenclature and taxonomic arrangement follow CBRO (2008). [1]Sociability according to Sick (1997); mean group size each study. [2]Predominant diet according to Develey and Endrigo (2004): Arthropods (A), flowers (FL), fruits (F), seeds (S), nectar (N), and omnivorous (O). [3]apud Sazima *et al*. (2001)

Bird species	Sociability[1]	Basic diet[2]	Pollinated species	Localities	References
GALLIFORMES					
Cracidae					
Ortalis canicollis	couple		*Combretum lanceolatum* (Combretaceae)	Brasil	Silva & Rubio (2007)
CHARADRIIFORMES					
Thinocoridae					
Thinocorus rumicivorus			*Calceolaria uniflora* (Scrophulariaceae)	Argentina	Sérsic & Cocucci (1995)
COLUMBIFORMES					
Columbidae					
Columbina passerina			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Patagioenas cayennensis	solitary	S, F	*Combretum lanceolatum* (Combretaceae)	Brazil	Sazima *et al*. (2001)
Patagioenas picazuro	couple	S, F	*Combretum lanceolatum* (Combretaceae)	Brazil	Sazima *et al*. (2001)
Zenaida auriculata noronha			*Erythrina velutina* (Fabaceae)	Brazil	Sazima *et al*. (2009)
PSITTACIFORMES					
Psittacidae					
Aratinga aurea	groups	S, F	*Combretum lanceolatum* (Combretaceae) *Platonia insignis* (Clusiaceae)	Brazil Brazil	Sazima *et al*. (2001), Silva & Rubio (2007) Azambuja (2008)
Aratinga acuticaudata	groups		*Erythrina dominguezzii* (Fabaceae)	Brazil	Ragusa-Netto (2002)
Aratinga aztec			*Bernoullia flammea*	Mexico	Toledo (1977)
Aratinga leucophthalmus	groups	S, F	*Platonia insignis* (Clusiaceae) *Combretum lanceolatum* (Combretaceae) *Erythrina falcata* (Fabaceae) *Erythrina verna* (Fabaceae)	Brazil Brazil Brazil Brazil	Maués e Venturieri (1996) Sazima *et al*. (2001), Silva & Rubio (2007) Parrini & Raposo (2008) Parrini & Raposo (2008)
Aratinga nenday	groups		*Erythrina dominguezzii* (Fabaceae)	Brazil	Ragusa-Netto (2002)

Appendix 1. Continuation

Bird species	Sociability[1]	Basic diet[2]	Pollinated species	Localities	References
Aratinga weddellii			*Erythrina fusca* (Fabaceae)	Colombia	Cotton (2001)
Brotogeris chrysoptera	groups (5-12)		*Platonia insignis* (Clusiaceae) *Moronobea coccinea* (Clusiaceae)	Brazil Brazil	Maués e Venturieri (1996) Vicentini & Fischer (1999)
Brotogeris chiriri	groups	S, F	*Combretum lanceolatum* (Combretaceae) *Platonia insignis* (Clusiaceae)	Brazil Brazil	Sazima *et al*. (2001) Azambuja (2008)
Brotogeris cyanoptera			*Erythrina fusca* (Fabaceae)	Colombia	Cotton (2001)
Brotogeris tirica			*Erythrina falcata* (Fabaceae) *Erythrina verna* (Fabaceae)	Brazil Brazil	Parrini & Raposo (2008) Parrini & Raposo (2008)
Diopsittaca nobilis	groups	S, F	*Combretum lanceolatum* (Combretaceae) *Platonia insignis* (Clusiaceae)	Brazil Brazil	Sazima *et al*. (2001) Maués e Venturieri (1996)
Enicognathus leptorynchus		G	*Embothrium coccineum* (Proteaceae)	Chile	Smith-Ramírez & Armesto (1998)
Pionites leucogaster			*Platonia insignis* (Clusiaceae)	Brazil	Maués e Venturieri (1996)
Pionus menstruus			*Platonia insignis* (Clusiaceae)	Brazil	Azambuja (2008)
Primolius auricollis (?)	couple		*Combretum lanceolatum* (Combretaceae)	Brasil	Silva & Rubio (2007)
Pyrrhura frontalis			*Erythrina falcata* (Fabaceae) *Erythrina verna* (Fabaceae)	Brazil Brazil	Parrini & Raposo (2008) Parrini & Raposo (2008)
PICIFORMES					
Picidae					
Campephilus melanoleucos			*Platonia insignis* (Clusiaceae)	Brazil	Azambuja (2008)
Celeus flavescens	solitary	A,F	*Spirotheca rivieri* (Malvaceae) *Schwartzia brasiliensis* (Marcgraviaceae) *Platonia insignis* (Clusiaceae)	Brazil Brazil Brazil	Rocca *et al*. (2006), Rocca & Sazima (2008) Azambuja (2008)
Celeus grammicus	solitary		*Symphonia globulifera* (Clusiaceae)	Brazil	Pivetta (2003)
Celeus undatus			*Symphonia globulifera* (Clusiaceae)	Fr.Guiana	Gill *et* al. (1996)
Centurus aurifrons			*Bernoullia flammea* (Malvaceae)	Mexico	Toledo (1977)
Centurus hypopolius			*Erythrina oliviae* (Fabaceae)	Mexico	Toledo & Hernadez (1979)

Appendix 1. Continuation

Bird species	Sociability[1]	Basic diet[2]	Pollinated species	Localities	References
Colaptes campestris			*Platonia insignis* (Clusiaceae)	Brazil	Azambuja (2008)
Colaptes melanochloros			*Platonia insignis* (Clusiaceae)	Brazil	Azambuja (2008)
Melanerpes candidus	pairs	I, F	*Combretum lanceolatum* (Combretaceae)	Brazil	Sazima *et al*. (2001), Silva & Rubio (2007
Melanerpes chrysogenis			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Melanerpes hypopolius			*Agave marmorata* (Agavaceae)	Mexico	Ornelas *et al*. (2002)
Melanerpes rubricapillus			*Erythrina fusca* (Fabaceae)	Tobago	Feinsinger *et al*. (1979)
PASSERIFORMES					
Furnariidae					
*Pseudoseisura unirufa (*as *P. cristata* in Sazima *et al.* 2001*)*	pairs	I	*Combretum lanceolatum* (Combretaceae)	Brazil	Sazima *et al*. (2001), Silva & Rubio (2007)
Tyrannidae					
Anairetes parulus		I	*Embothrium coccineum* (Proteaceae)	Chile	Smith-Ramírez & Armesto (1998)
Elaenia albiceps		F, I, N	*Fuchsia magellanica* (Onagraceae) *Embothrium coccineum* (Proteaceae)	Chile Chile	Traveset *et al*. (1998) Smith-Ramírez & Armesto (1998)
Elaenia flavogaster	solitary	I, F	*Mabea fistulifera* (Euphorbiaceae) *Combretum lanceolatum* (Combretaceae)	Brazil Brazil	Olmos & Boulhosa (2000) Sazima *et al*. (2001)
Elaenia chiriquensis			*Mabea fistulifera* (Euphorbiaceae)	Brazil	Olmos & Boulhosa (2000)
Elaenia mesolenca			*Acca sellowiana* (Myrtaceae)	Brazil	Ducroquet & Hickel (1997)
Elaenia parvirostris		I, F	*Myrrhinium atropurpureum* (Myrtaceae) *Acca sellowiana* (Myrtaceae)	Argentina Brazil	Roitman *et al*. (1997) Sazima & Sazima (2007)
Elaenia ridleyana			*Erythrina velutina* (Fabaceae)	Brazil	Sazima *et al*. (2009)
Machetornis rixosa	pairs	I	*Combretum lanceolatum* (Combretaceae)	Brazil	Sazima *et al*. (2001)
Myiarchus sp.	solitary		*Combretum lanceolatum* (Combretaceae)	Brazil	Silva & Rubio (2007)
Pitangus sulphuratus	solitary	I, F	*Myrrhinium atropurpureum* (Myrtaceae) *Combretum lanceolatum* (Combretaceae)	Argentina Brazil	Roitman *et al*. (1997) Sazima *et al*. (2001), Silva & Rubio (2007)

Appendix 1. Continuation

Bird species	Sociability[1]	Basic diet[2]	Pollinated species	Localities	References
Tityridae					
Oxyruncus cristatus	solitary	F,A	*Spirotheca rivieri* (Malvaceae)	Brazil	Rocca & Sazima (2008)
Tityra semifasciata			*Bernoullia flammea* (Malvaceae) *Ceiba pentandra* (Malvaceae)	Mexico Mexico	Toledo (1977) Toledo (1977)
Vireonidae					
Vireo gracilirostris			*Erythrina velutina* (Fabaceae)	Brazil	Sazima *et al*. (2009)
Vireo hypochryseus			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Vireo sp.			*Ceiba pentandra* (Malvaceae)	Mexico	Toledo (1977)
Corvidae					
Cyanocorax cristatellus			*Platonia insignis* (Clusiaceae)	Brazil	Azambuja (2008)
Cyanocorax cyanopogon			*Platonia insignis* (Clusiaceae)	Brazil	Azambuja (2008)
Cyanocorax sanblasiana			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Troglodytidae					
Campylorhynchus bruneicapillus			*Erythrina oliviae* (Fabaceae)	Mexico	Toledo & Hernadez (1979)
Campylorhynchus jocosus			*Agave marmorata* (Agavaceae)	Mexico	Ornelas *et al*. (2002)
Campylorhynchus rufinucha			*Erythrina oliviae* (Fabaceae)	Mexico	Toledo & Hernadez (1979)
Campylorhynchus turdinus	couple		*Combretum lanceolatum* (Combretaceae)	Brazil	Silva & Rubio (2007)
Campylorhynchus zonatus			*Bernoullia flammea* (Malvaceae) *Ceiba pentandra* (Malvaceae)	Mexico Mexico	Toledo (1977) Toledo (1977)
Turdidae					
Turdus amaurochalinus		A, F	*Myrrhinium atropurpureum* (Myrtaceae) *Acca sellowiana* (Myrtaceae)	Argentina Brazil	Roitman *et al*. (1997) Sazima & Sazima (2007), Silva & Rubio (2007)
Turdus assimilis			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Turdus leucomelas	solitary	O	*Mabea fistulifera* (Euphorbiaceae) *Combretum lanceolatum* (Combretaceae) *Platonia insignis* (Clusiaceae)	Brazil Brazil Brazil	Olmos & Boulhosa (2000) Sazima *et al*. (2001) Azambuja (2008)

Appendix 1. Continuation

Bird species	Sociability[1]	Basic diet[2]	Pollinated species	Localities	References
Turdus rufiventris	solitary	O	*Combretum fruticosum* (Combretaceae)	Argentina	Bernardello *et al*. (1994)
			Myrrhinium atropurpureum (Myrtaceae)	Argentina	Roitman *et al*. (1997)
			Combretum lanceolatum (Combretaceae)	Brazil	Sazima *et al*. (2001)
			Acca sellowiana (Myrtaceae)	Brazil	Ducroquet & Hickel (1997), Sazima & Sazima (2007)
			Platonia insignis (Clusiaceae)	Brazil	Azambuja (2008)
Turdus rufopalliatus			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Mimidae					
Mimus frater			*Acca sellowiana* (Myrtaceae)	Brazil	Ducroquet & Hickel (1997)
Mimus gilvus			*Erythrina fusca* (Fabaceae)	Tobago	Feinsinger *et al*. (1979)
Mimus polyglottos			*Agave marmorata* (Agavaceae)	Mexico	Ornelas *et al*. (2002)
Mimus saturninus		I, F	*Myrrhinium atropurpureum* (Myrtaceae)	Argentina	Roitman *et al*. (1997)
			Hortia brasiliana (Rutaceae)	Brazil	Barbosa (1999)
Toxostoma curvirostre			*Agave marmorata* (Agavaceae)	Mexico	Ornelas *et al*. (2002)
Coerebidae					
Coereba flaveola	solitary	N,A	*Aechmea nudicaulis* (Bromeliaceae)	Trinidad	Snow & Snow (1971)
			Erythrina fusca (Fabaceae)	Trinidad and Tobago	Feinsinger *et al*. (1979)
			Erythrina megistophylla (Bromeliaceae)	Ecuador	Steiner (1979)
			Schwartzia brasiliensis (Marcgraviaceae)	Brazil	Sazima *et al*. (1993)
			Symphonia globulifera (Clusiaceae)	Fr.Guiana	Gill *et* al. (1996)
			Aechmea bromeliifolia (Bromeliaceae)	Brazil	Sazima & Sazima (1999)
			Aechmea distichantha (Bromeliaceae)	Brazil	Sazima & Sazima (1999)
			Acanthostachys strobilacea (Bromeliaceae)	Brazil	Sazima & Sazima (1999)
			Combretum lanceolatum (Combretaceae)	Brazil	Sazima *et al*. (2001)
			Pitcairnia angustifolia (Bromeliaceae)	Puerto Rico	Fumero-Cabán & Meléndez-Ackerman (2007)
			Spirotheca rivieri (Malvaceae)	Brazil	Rocca & Sazima (2008)
			Platonia insignis (Clusiaceae)	Brazil	Azambuja (2008)
			Gesneria pedunculosa (Gesneriaceae)	Puerto Rico	Martén-Rodriguez & Fenster (2008)
			Erythrina falcata (Fabaceae)	Brazil	Parrini & Raposo (2008)
			Erythrina verna (Fabaceae)	Brazil	Parrini & Raposo (2008)

Appendix 1. Continuation

Bird species	Sociability[1]	Basic diet[2]	Pollinated species	Localities	References
Thraupidae					
Chlorophanes spiza	couple	F,A,N	*Erythrina megistophylla* (Bromeliaceae)	Ecuador	Steiner (1979)
			Schwartzia brasiliensis (Marcgraviaceae)	Brazil	Sazima *et al*. (1993)
			Symphonia globulifera (Clusiaceae)	Fr.Guiana	Gill *et* al. (1996)
			Spirotheca rivieri (Malvaceae)	Brazil	Rocca & Sazima (2008)
Conirostrum bicolor			*Mabea fistulifera* (Euphorbiaceae)	Brazil	Olmos & Boulhosa (2000)
Cyanerpes caeruleus			*Symphonia globulifera* (Clusiaceae)	Fr.Guiana	Gill *et* al. (1996)
			Platonia insignis (Clusiaceae)	Brazil	Maués e Venturieri (1996)
Cyanerpes cyaneus			*Bernoullia flammea* (Malvaceae)	Mexico	Toledo (1977)
			Symphonia globulifera (Clusiaceae)	Fr.Guiana	Gill *et* al. (1996)
			Mabea fistulifera (Euphorbiaceae)	Brazil	Olmos & Boulhosa (2000)
Dacnis cayana	couple	F,A,N	*Schwartzia brasiliensis* (Marcgraviaceae)	Brazil	Sazima *et al*. (1993)
			Symphonia globulifera (Clusiaceae)	Fr.Guiana	Gill *et* al. (1996)
			Mabea fistulifera (Euphorbiaceae)	Brazil	Olmos & Boulhosa (2000)
			Acca sellowiana (Myrtaceae)	Brazil	Sazima & Sazima (2007)
			Spirotheca rivieri (Malvaceae)	Brazil	Rocca & Sazima (2008)
			Platonia insignis (Clusiaceae)	Brazil	Azambuja (2008)
			Erythrina falcata (Fabaceae)	Brazil	Parrini & Raposo (2008)
			Erythrina verna (Fabaceae)	Brazil	Parrini & Raposo (2008)
Dacnis lineata			*Erythrina megistophylla* (Bromeliaceae)	Ecuador	Steiner (1979)
			Symphonia globulifera (Clusiaceae)	Fr.Guiana	Gill *et* al. (1996)
Dacnis nigripes	couple		*Erythrina falcata* (Fabaceae)	Brazil	Parrini & Raposo (2008)
			Erythrina verna (Fabaceae)	Brazil	Parrini & Raposo (2008)
Hemithraupis guira			*Platonia insignis* (Clusiaceae)	Brazil	Azambuja (2008)
Hemithraupis ruficapilla	solitary		*Schwartzia brasiliensis* (Marcgraviaceae)	Brazil	Sazima *et al*. (1993)
Mitrospingus cassinii			*Erythrina megistophylla* (Bromeliaceae)	Ecuador	Steiner (1979)
Nemosia pileata			*Mabea fistulifera* (Euphorbiaceae)	Brazil	Olmos & Boulhosa (2000)
			Platonia insignis (Clusiaceae)	Brazil	Azambuja (2008)
Piranga flava			*Platonia insignis* (Clusiaceae)	Brazil	Azambuja (2008)
Piranga ludoviciana			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Piranga rubra			*Bernoullia flammea* (Malvaceae)	Mexico	Toledo (1977)
			Combretum fruticosum (Combretaceae)	Mexico	Gryjl *et al*. (1990)

Appendix 1. Continuation

Bird species	Sociability[1]	Basic diet[2]	Pollinated species	Localities	References
Ramphocelus bresilius	couple		*Schwartzia brasiliensis* (Marcgraviaceae)	Brazil	Sazima *et al*. (1993)
			Erythrina falcata (Fabaceae)	Brazil	Parrini & Raposo (2008)
			Erythrina verna (Fabaceae)	Brazil	Parrini & Raposo (2008)
Ramphocelus carbo	groups	F	*Platonia insignis* (Clusiaceae)	Brazil	Maués e Venturieri (1996)
			Symphonia globulifera (Clusiaceae)	Fr.Guiana	Gill *et* al. (1996)
			Combretum lanceolatum (Combretaceae)	Brazil	Sazima *et al*. (2001), Silva & Rubio (2007)
			Erythrina fusca (Fabaceae)	Trinidad, Colombia	Feinsinger *et al*. (1979), Cotton (2001)
Ramphocelus icteronotus			*Erythrina megistophylla* (Bromeliaceae)	Ecuador	Steiner (1979)
Ramphocelus nigrogulares			*Erythrina fusca* (Fabaceae)	Colombia	Cotton (2001)
Schistochlamys melanopis			*Platonia insignis* (Clusiaceae)	Brazil	Azambuja (2008)
Schistochlamys ruficapillus			*Hortia brasiliana* (Rutaceae)	Brazil	Barbosa (1999)
Stephanophorus diadematus		F, A, FL	*Myrrhinium atropurpureum* (Myrtaceae)	Argentina	Roitman *et al*. (1997)
			Acca sellowiana (Myrtaceae)	Brazil	Ducroquet & Hickel (1997), Sazima & Sazima (2007)
Tachyphonus cristatus	couple		*Schwartzia brasiliensis* (Marcgraviaceae)	Brazil	Sazima *et al*. (1993)
Tachyphonus rufus	couple	F	*Erythrina fusca* (Fabaceae)	Trinidad and Tobago	Feinsinger *et al*. (1979)
			Combretum lanceolatum (Combretaceae)	Brazil	Sazima *et al*. (2001)
Tachyphonus surinamus			*Symphonia globulifera* (Clusiaceae)	Fr.Guiana	Gill *et* al. (1996)
Tachyphonus sp.			*Combretum cacoucia* (Combretaceae)	Amazon	St. Vogel (unpubl.)[3]
Tangara cayana	couple		*Mabea fistulifera* (Euphorbiaceae)	Brazil	Olmos & Boulhosa (2000)
			Erythrina falcata (Fabaceae)	Brazil	Parrini & Raposo (2008)
			Erythrina verna (Fabaceae)	Brazil	Parrini & Raposo (2008)
Tangara chilensis			*Symphonia globulifera* (Clusiaceae)	Fr.Guiana	Gill *et* al. (1996)
Tangara cyanocephala	flocks		*Schwartzia brasiliensis* (Marcgraviaceae)	Brazil	Sazima *et al*. (1993)
Tangara desmaresti	flocks		*Schwartzia brasiliensis* (Marcgraviaceae)	Brazil	Sazima *et al*. (1993)
Tangara preciosa		F, A	*Acca sellowiana* (Myrtaceae)	Brazil	Sazima & Sazima (2007)
Tangara seledon	flocks		*Schwartzia brasiliensis* (Marcgraviaceae)	Brazil	Sazima *et al*. (1993)
Thraupis abbas			*Bernoullia flammea* (Malvaceae)	Mexico	Toledo (1977)
			Ceiba pentandra (Malvaceae)	Mexico	Toledo (1977)

Appendix 1. Continuation

Bird species	Sociability[1]	Basic diet[2]	Pollinated species	Localities	References
Thraupis bonariensis		F, A	*Myrrhinium atropurpureum* (Myrtaceae) *Acca sellowiana* (Myrtaceae)	Argentina Brazil	Roitman *et al*. (1997) Ducroquet & Hickel (1997), Sazima & Sazima (2007)
Thraupis episcopus			*Platonia insignis* (Clusiaceae) *Erythrina fusca* (Fabaceae)	Brazil Trinidad and Tobago Colombia	Maués e Venturieri (1996) Feinsinger *et al*. (1979), Cotton (2001)
Thraupis palmarum	groups	F	*Platonia insignis* (Clusiaceae) *Mabea fistulifera* (Euphorbiaceae) *Combretum lanceolatum* (Combretaceae) *Erythrina fusca* (Fabaceae)	Brazil Brazil Brazil Trinidad Colombia	Maués e Venturieri (1996) Olmos & Boulhosa (2000) Sazima *et al*. (2001) Feinsinger *et al*. (1979) Cotton (2001)
Thraupis sayaca	groups	F	*Acca sellowiana* (Myrtaceae) *Myrrhinium atropurpureum* (Myrtaceae) *Mabea fistulifera* (Euphorbiaceae) *Combretum lanceolatum* (Combretaceae) *Erythrina falcata* (Fabaceae) *Erythrina verna* (Fabaceae)	Brazil Argentina Brazil Brazil Brazil Brazil	Ducroquet & Hickel (1997), Sazima & Sazima (2007) Roitman *et al*. (1997) Olmos & Boulhosa (2000) Sazima *et al*. (2001), Silva & Rubio (2007) Parrini & Raposo (2008) Parrini & Raposo (2008)
Thraupis virens			*Bernoullia flammea* (Malvaceae) *Ceiba pentandra* (Malvaceae)	Mexico Mexico	Toledo (1977) Toledo (1977)
Thraupis sp.	groups (2)	F,A,FL	*Spirotheca rivieri* (Malvaceae)	Brazil	Rocca & Sazima (2008)
Emberizidae					
Coryphospingus cucullatus	solitary	S	*Hortia brasiliana* (Rutaceae)	Brazil	Barbosa (1999)
Cyanocompsa parellina			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Paroaria capitata	groups	S	*Combretum lanceolatum* (Combretaceae)	Brazil	Sazima *et al*. (2001), Silva & Rubio (2007)
Poospiza lateralis		S	*Myrrhinium atropurpureum* (Myrtaceae)	Argentina	Roitman *et al*. (1997)
Sporophila sp.			*Combretum lanceolatum* (Combretaceae)	Brazil	Silva & Rubio (2007)
Volatinia jacarina	groups	S	*Combretum fruticosum* (Combretaceae) *Hortia brasiliana* (Rutaceae)	Mexico Brazil	Gryjl *et al*. (1990) Barbosa (1999)

Appendix 1. Continuation

Bird species	Sociability[1]	Basic diet[2]	Pollinated species	Localities	References
Zonotrichia capensis	pairs	S, A	*Combretum fruticosum* (Combretaceae) *Myrrhinium atropurpureum* (Myrtaceae) *Hortia brasiliana* (Rutaceae) *Acca sellowiana* (Myrtaceae) *Embothrium coccineum* (Proteaceae)	Argentina Argentina Brazil Brazil Chile	Bernardello *et al*. (1994) Roitman *et al*. (1997) Barbosa (1999) Sazima & Sazima (2007) Smith-Ramírez & Armesto (1998)
Cardinalidae					
Passerina leclancherii			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Passerina versicolor			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Saltator aurantiirostris		S	*Myrrhinium atropurpureum* (Myrtaceae)	Argentina	Roitman *et al*. (1997)
Saltator coerulescens	solitary	S, F	*Erythrina fusca* (Fabaceae) *Combretum lanceolatum* (Combretaceae)	Trinidad Brazil	Feinsinger *et al*. (1979 Sazima *et al*. (2001), Silva & Rubio (2007)
Saltator maximus			*Platonia insignis* (Clusiaceae)	Brazil	Azambuja (2008)
Saltator stricollis			*Hortia brasiliana* (Rutaceae)	Brazil	Barbosa (1999)
Parulidae					
Dendroica coronata			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Dendroica nigrescens			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Dendroica virens			*Bernoullia flammea* (Malvaceae) *Ceiba pentandra* (Malvaceae)	Mexico Mexico	Toledo (1977) Toledo (1977)
Icteria virens			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Mniotilta varia			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Oporornis tolmiei			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Parula mericana			*Ceiba pentandra* (Malvaceae)	Mexico	Toledo (1977)
Parula pitiayumi		I	*Combretum fruticosum* (Combretaceae) *Myrrhinium atropurpureum* (Myrtaceae)	Mexico Argentina	Gryjl *et al*. (1990) Roitman *et al*. (1997)
Vermivora ruficapilla			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Wilsonia pusilla			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)

Appendix 1. Continuation

Bird species	Sociability[1]	Basic diet[2]	Pollinated species	Localities	References
Unidentified			*Erythrina oliviae* (Fabaceae)	Mexico	Toledo & Hernadez (1979)
Icteridae					
Agelasticus cyanopus (?)	groups		*Combretum fruticosum* (Combretaceae)	Brazil	Silva & Rubio (2007)
Cacicus cela	solitary	F, I	*Platonia insignis* (Clusiaceae)	Colombia	Maués e Venturieri (1996)
			Combretum lanceolatum (Combretaceae)	Brazil	Sazima *et al*. (2001)
			Erythrina fusca (Fabaceae)	Colombia	Cotton (2001)
Cacicus haemorrhous	groups (8)	A,F	*Mucuna japira* (Fabaceae)	Brazil	Agostini *et al*. (2006)
			Spirotheca rivieri (Malvaceae)	Brazil	Rocca & Sazima (2008)
			Erythrina falcata (Fabaceae)	Brazil	Parrini & Raposo (2008)
			Erythrina verna (Fabaceae)	Brazil	Parrini & Raposo (2008)
Cacicus melanicterus			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Cacicus solitaries			*Erythrina fusca* (Fabaceae)	Colombia	Cotton (2001)
Curaeus curaeus		I, F	*Embothrium coccineum* (Proteaceae)	Chile	Smith-Ramírez & Armesto (1998)
Gnorimopsar chopi	solitary	I, F	*Combretum lanceolatum* (Combretaceae)	Brazil	Sazima *et al*. (2001)
Gymnostinops montezuma			*Bernoullia flammea* (Malvaceae)	Mexico	Toledo (1977)
			Ceiba pentandra (Malvaceae)	Mexico	Toledo (1977)
Icterus cayanensis	solitary	F, I	*Myrrhinium atropurpureum* (Myrtaceae)	Argentina	Roitman *et al*. (1997)
			Combretum lanceolatum (Combretaceae)	Brazil	Sazima *et al*. (2001)
			Erythrina falcata (Fabaceae)	Argentina	Etcheverry & Aleman (2005)
Icterus cucullatus			*Combretum fruticosum* (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Icterus galbula			*Bernoullia flammea* (Malvaceae)	Mexico	Toledo (1977)
			Ceiba pentandra (Malvaceae)	Mexico	Toledo (1977)
			Combretum fruticosum (Combretaceae)	Mexico	Gryjl *et al*. (1990)
Icterus jamacaii	solitary	F, I	*Combretum lanceolatum* (Combretaceae)	Brazil	Sazima *et al*. (2001), Silva & Rubio (2007)
			Erythrina fusca (Fabaceae)	Colombia	Cotton (2001)
Icterus nigrogularis			*Erythrina fusca* (Fabaceae)	Trinidad	Feinsinger *et al*. (1979)
Icterus parisorum			*Agave marmorata* (Agavaceae)	Mexico	Ornelas *et al*. (2002)
Icterus prosthemelas			*Bernoullia flammea* (Malvaceae)	Mexico	Toledo (1977)

Appendix 1. Continuation

Bird species	Sociability[1]	Basic diet[2]	Pollinated species	Localities	References
Icterus pustulatus			*Combretum fruticosum* (Combretaceae) *Agave marmorata* (Agavaceae)	Mexico Mexico	Gryjl *et al*. (1990) Ornelas *et al*. (2002)
Icterus sclateri			*Erythrina oliviae* (Fabaceae)	Mexico	Toledo & Hernadez (1979)
Icterus spurious			*Bernoullia flammea* (Malvaceae) *Ceiba pentandra* (Malvaceae) *Erythrina fusca* (Fabaceae) *Combretum fruticosum* (Combretaceae) *Agave marmorata* (Agavaceae)	Mexico Mexico Mexico Mexico	Toledo (1977) Toledo (1977) Morton (1979) Gryjl *et al*. (1990) Ornelas *et al*. (2002)
Icterus wagleri			*Erythrina oliviae* (Fabaceae) *Combretum fruticosum* (Combretaceae) *Agave marmorata* (Agavaceae)	Mexico Mexico Mexico	Toledo & Hernadez (1979) Gryjl *et al*. (1990) Ornelas *et al*. (2002)
Icterus sp.			*Ceiba pentandra* (Malvaceae)	Mexico	Toledo (1977)
Molothrus badius			*Combretum fruticosum* (Combretaceae) *Myrrhinium atropurpureum* (Myrtaceae	Argentina Argentina	Bernardello *et al*. (1994) Roitman *et al*. (1997)
Molothrus bonariensis		I	*Embothrium coccineum* (Proteaceae) *Combretum lanceolatum* (Combretaceae)	Chile Brazil	Smith-Ramírez & Armesto (1998) Silva & Rubio (2007)
Procacicus solitarius			*Combretum lanceolatum* (Combretaceae)	Brazil	Silva & Rubio (2007)
Psarocolius decumanus	solitary	F, I	*Erythrina fusca* (Fabaceae) *Combretum lanceolatum* (Combretaceae) *Mucuna japira* (Fabaceae) *Erythrina falcata* (Fabaceae) *Erythrina verna* (Fabaceae)	Trinidad and Tobago Brazil Brazil Brazil Brazil	Feinsinger *et al*. (1979) Sazima *et al*. (2001), Silva & Rubio (2007) Agostini *et al*. (2006) Parrini & Raposo (2008) Parrini & Raposo (2008)
Pheucticus chrysopeplus			*Erythrina oliviae* (Fabaceae)	Mexico	Toledo & Hernadez (1979)
Phrygilus patagonicus		F, G	*Embothrium coccineum* (Proteaceae)	Chile	Smith-Ramírez & Armesto (1998)
Scaphidura oryzivora (?)			*Combretum lanceolatum* (Combretaceae)	Brazil	Silva & Rubio (2007)
Tangavius aeneus			*Erythrina oliviae* (Fabaceae)	Mexico	Toledo & Hernadez (1979)
Fringillidae					
Carduelis barbatus		G	*Embothrium coccineum* (Proteaceae)	Chile	Smith-Ramírez & Armesto (1998)

Appendix 1. Continuation

Bird species	Sociability[1]	Basic diet[2]	Pollinated species	Localities	References
Carpodacus mexicanus			*Agave marmorata* (Agavaceae)	Mexico	Ornelas *et al*. (2002)
Euphonia chlorotica	couple	F	*Combretum lanceolatum* (Combretaceae)	Brazil	Sazima *et al*. (2001)
Euphonia hirundinaceae			*Ceiba pentandra* (Malvaceae)	Mexico	Toledo (1977)
Euphonia saturata			*Erythrina megistophylla* (Bromeliaceae)	Ecuador	Steiner (1979)
Euphonia violacea	couples		*Schwartzia brasiliensis* (Marcgraviaceae)	Brazil	Sazima *et al*. (1993)
Euphonia sp.			*Bernoullia flammea* (Malvaceae) *Ceiba pentandra* (Malvaceae)	Mexico Mexico	Toledo (1977) Toledo (1977)

Appendix 2. Features of plant species pollinated or co-pollinated (*) by perching birds in the Neotropics. Nomenclature and taxonomic arrangement follow APG (Angiosperm Philogeny Group) II *apud* Souza & Lorenzi (2005). [1]Pollinators cited here are only perching bird species; [2] Flower longevity in days.

Plant species	Habit	Floral type	Pollination unit	Resource	[1]Pollinators (N of spp.)	[2]Flower longevity	Breeding system	Flowering period	Locality	Vegetation type	Reference
Agavaceae											
Agave marmorata	Herb	Tube	Flower	Nectar	9	4 d	Protandrous	May-Jun	Mexico	Arid tropical scrub	Ornelas *et al*. (2002)
Bromeliaceae											
*Acanthostachys strobilacea**	Epiphyte	Tube	Flower	Nectar	1	1d		Sep-Nov	Brazil	Tropical rain forest	Sazima & Sazima (1999)
*Aechmea bromeliifolia**	Epiphyte	Tube	Flower	Nectar	1	1d		Jun-Ago	Brazil	Tropical rain forest	Sazima & Sazima (1999)
*Aechmea distichantha**	Epiphyte	Tube	Flower	Nectar	1	1d		Apr-Jun	Brazil	Tropical rain forest	Sazima & Sazima (1999)
*Aechmea nudicaulis**	Epiphyte	Tube	Flower	Nectar	1	1d			Trinidad	Forest, savana	Snow & Snow (1971)
Pitcairnia angustifolia	Rupicu-lous	Tube	Flower	Nectar	1	1 d	SC	May-Sep	Puerto Rico	Moist and wet forest	Fumero-Cabán & Meléndez-Ackerman (2007)
Clusiaceae											
Platonia insignis	Tree	Tube	Flower	Nectar	27	1 d	SI	Jul-Ago	Brazil	Tropical rain forest	Maués e Venturieri (1996), Azambuja (2008)
Moronobea coccinea	Tree	Tube	Flower	Nectar, Anther-oil	1	1 d		Nov-Dec?	Brazil	Tropical rain forest	Vicentini & Fischer (1999)
Symphonia globulifera	Tree	Tube	Flower	Nectar	11	1-2 d		Sep?	Fr.Guiana, Brazil	Tropical rain forest	Gill *et* al. (1996), Pivetta (2003)

Appendix 2. Continuation

Plant species	Habit	Floral type	Pollination unit	Resource	Pollinators (N of spp.)	[2]Flower longevity	Breeding system	Flowering period	Locality	Vegetation type	Reference
Combretaceae											
*Combretum fruticosum**[3]	Climber	Brush	Infloresc.	Nectar	30	3-4 d	SI	Jan-May	Mexico Argentina	Sub-deciduous evergreen forest, Galery forest	Gryjl *et al*. (1990), Bernardello *et al*. (1994)
Combretum lanceolatum	Shrub or climber	Brush	Infloresc.	Jelly-nectar	34	5 d	Protogynous	Apr-Aug	Brazil	Savanna-like shrub	Sazima *et al*. (2001)
Euphorbiaceae											
Mabea fistulifera	Tree	Brush	Infloresc.	Nectar	10	3 d	SI	Feb-Jun	Brazil	Cerrado	Olmos & Boulhosa (2000)
Fabaceae											
Erythrina dominguezzii	Tree	Flag	Flower	Nectar	2			Aug-Sep	Brazil	Deciduous/ semi-deciduous forests	Ragusa-Netto (2002)
Erythrina falcata	Tree	Gullet	Flower	Nectar	12	5-6 d	SI, Protandrous	Aug-Sep	Argentina Brazil	Semi-deciduous forest, Atlantic rain forest	Etcheverry & Aleman (2005) Parrini & Raposo (2008)
Erythrina fusca	Tree	Flag	Flower	Nectar	17	1-2 d		Dec-Mar Jun-Sep	Trinidad and Tobago, Colombia	Tropical rain forest	Feinsinger *et al*. (1979) Morton (1979) Cotton (2001)
Erythrina megistophylla	Tree	Flag	Flower	Nectar	6	1 d		Jul-Aug?	Ecuador	Tropical rain forest	Steiner (1979)
Erythrina oliviae	Tree	Flag	Flower	Nectar	8			Apr-Jun	Mexico		Toledo & Hernadez (1979)
Erythrina velutina	Tree	Gullet	Flower	Nectar	3	2 d		Oct-Nov	Brazil		Sazima *et al.*(2009)
Erythrina verna	Tree	Flag	Flower	Nectar	11			Aug-Sep	Brazil	Atlantic rain forest	Parrini & Raposo (2008)

Appendix 2. Continuation

Plant species	Habit	Floral type	Pollination unit	Resource	Pollinators (N of spp.)	Flower longevity	Breeding system	Flowering period	Locality	Vegetation type	Reference
Mucuna japira	Climber	Flag	Flower	Nectar	2	7 d		May-Jun	Brazil	Atlantic rain forest	Agostini *et al*. (2006)
Gesneriaceae											
Gesneria pedunculosa	Shrub	Campanulate	Flower	Nectar	1	2-3 d	SC, Protandrous		Puerto Rico	Central western karst	Martén-Rodriguez & Fenster (2008)
Malvaceae											
Bernoullia flammea	Tree	Brush	Flower	Nectar	18			Mar-Apr	Mexico	3 different forest types	Toledo (1977)
Ceiba pentandra	Tree	Brush	Flower		13				Mexico		Toledo (1977)
Chiranthodendron pentadactylon	Tree		Flower	Nectar	?				Mexico		Toledo (1975)
Spirotheca rivieri	Strangler	Brush	Flower	Nectar	7	3-5 d	SI	May-Jul	Brazil	Tropical rain forest	Rocca *et al*. (2006), Rocca & Sazima (2008)
Marcgraviaceae											
Schwartzia brasiliensis[4]	Climber	Brush	Infloresc.	Nectar	11	6 d	SI, Protandrous	Dec-Feb	Brazil	Tropical rain forest	Sazima *et al*. (1993), Rocca *et al*. (2006), Rocca & Sazima (2008)
Myrtaceae											
Acca sellowiana	Tree	Brush	Flower	Food-body	11			Oct-Jan	Brazil		Sazima & Sazima (2007)
Myrrhinium atropurpureum	Tree	Brush	Flower	Food-body	14	3 d?	SI	Aug-Oct	Argentina	Subtropical gallery forest and xerophyllous scrub	Roitman *et al*. (1997)
Onagraceae											
Fuchsia magellanica	Shrub	Tube	Flower	Nectar	1	6 d	SC, protogynous	Nov-Apr	Chile	Mixed evergreen deciduous forests	Traveset *et al*. (1998)

Appendix 2. Continuation

Plant species	Habit	Floral type	Pollination unit	Resource	Pollinators (N of spp.)	Flower longevity	Breeding system	Flowering period	Locality	Vegetation type	Reference
Proteaceae											
Embothrium coccineum	Tree	Tube	Flower	Nectar	8	3-5 d	Protandrous	Sep-Nov	Chile	Temperate rainforests	Smith-Ramírez & Armesto (1998)
Rutaceae											
Hortia brasiliana	Tree	Brush	Infloresc.	Nectar	6				Brazil		Barbosa (1999)
Scrophulariaceae											
Calceolaria uniflora	Herb	Gullet	Flower	Food-body	1				Argentina		Sérsic & Cocucci (1995)

[3]Bernardello *et al*. (1994) suggested that for the ornithophilous *Combretum fruticosum* (Combretaceae) hummingbirds are more efficient pollinators
[4]Floral features from Pinheiro *et al*. (1995)