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Original Paper

Acnistus arborescens (Solanaceae): an important food resource for birds in an Atlantic Forest site, Southeastern Brazil

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Abstract

Biotic interactions related to the consumption of floral nectar and fruits as food resource by birds promoting plant pollination and dispersal, are essential for forest ecosystem functioning. The daily interaction of birds with *Acnistus arborescens* (Solanaceae), a shrub-tree, was studied in the Itatiaia National Park and its surroundings. Reproductive phenology was monthly monitored in eighteen individuals in 2015. During flowering (August to November) and fruiting (September to December) the interaction birds-plant was studied. Flowers were visited by seven hummingbird species and several insects. Fruit set was 87.3%. Thirty-five bird species of eleven families consumed its fruit. Thraupidae with sixteen bird species was the family responsible for most of its frugivory (53.9%). Considering that more than 10% of the birds richness of Itatiaia National Park - INP interacts with *A. arborescens*, it can be considered an important plant species in maintaining local bird diverstity. Thus, for attracting many birds, *A. arborescens* can be used in the process of recovery of degraded areas, and also as a focal plant species for environmental education programs and birdwatching.

Key words: birds, frugivory, Itatiaia National Park, nectarivory.

Resumo

Interações bióticas relacionadas ao consumo de néctar e frutos como recurso alimentar de aves promovendo polinização e dispersão de plantas, são essenciais para o funcionamento do ecossistema florestal. A interação diária de pássaros com *Acnistus arborescens* (Solanaceae) foi estudada no interior e entorno do Parque Nacional do Itatiaia. A fenologia reprodutiva foi monitorada mensalmente em dezoito indivíduos durante o ano de 2015. Durante a floração (agosto a novembro) e frutificação (setembro a dezembro) foram estudadas as interações aves-planta. Flores foram visitadas por sete espécies de beija-flores e vários insetos. Quase 90% das flores estudadas tornaram-se frutos. Trinta e cinco espécies de aves, pertencentes a onze famílias, foram consumidores dos frutos. Thraupidae com dezesseis espécies de aves foi a família responsável pela maior parte desse consumo (53,9%). Considerando que mais de 10% da riqueza das aves do Parque Nacional do Itatiaia interagem com *A. arborescens*, essa espécie pode ser considerada como de grande importancia na manutenção da diversidade de aves. Essa característica de atração de aves, faz com que *A. arborescens* seja uma espécie a ter seu uso considerado em projetos de recuperação áreas degradadas, e também como espécie vegetal focal para programas de educação ambiental voltados para observação de aves.

Palavras-chave: aves, frugivoria, Parque Nacional do Itatiaia, nectarivoria.

Introduction

Biotic interactions such pollination and seed dispersal are vital ecological processes for forest ecosystem functioning and recover from disturbances (Reis *et al*. 1999; Roberts & Gandolfi 2000; Silva *et al*. 2002; Ceccon & Varassin 2014). Frugivory, for instance, is an animal-plant interaction considered critical to seed dispersal and recruitment of several plant species (Jordano *et al*. 2006; Côrtes *et al*. 2009; Novoa *et al*. 2011;

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Pizo 2012; Parrini & Pacheco 2014). The diversity of interacting animal species and their foraging efficiency are directly influenced by both quantity and quality of resources offered by different plant species (Malizia 2001; Moegenburg & Levey 2003; Aximoff & Freitas 2009). Thus, plant species that provide resources for sustaining a wide animal species assemblage are extremely important for the conservation of ecosystems (Silva *et al*. 2002; Ceccon & Varassin 2014).

In Neotropical forests, many Solanaceae members stand out by having an association with several frugivorous bird and mammal species (Albuquerque *et al*. 2006). This is one of the most representative families in the Brazilian Atlantic Forest (Oliveira-Filho & Fontes 2000). For instance, *Acnistus arborescens* (L.) Schltdl. was considered a key species to the functioning of the forest ecosystem providing fruits that are eaten by bats (Engriser 1995; Novoa *et al*. 2011), marsupials (Cáceres & Lessa 2012) and birds (Cross 1981; Wheelwright *et al*. 1984; Athiê & Dias 2012; Verçoza *et al*. 2012). Besides that, the nectar of its flowers is also another resource consumed by animals of different groups of insects (Cocucci 2000; Smith *et al*. 2008) and also hummingbirds (Verçoza *et al*. 2012).

Considering the prevalence of bird consumption of Solanaceae fruits (Albuquerque *et al*. 2006), one of the most appropriate locations to study this interaction is the Itatiaia National Park (INP), pointed out as one of the areas with the highest diversity of avifauna in the Atlantic Forest (Bencke *et al*. 2006; ICMBio 2013). Pineschi (1990) recorded more than a hundred bird species as dispersers of seven *Rapanea* species (Myrsinaceae) in the INP. Additionally several studies on animal-plant interactions have been conducted in this area, primarily related to reproductive biology of plant species pollinated by hummingbirds (*e.g.*, Canela 2006; Aximoff & Freitas 2010; Wolowski *et al*. 2013a, b), birds (Aximoff & Freitas 2009) and insects (Pires & Freitas 2008; Wolowski & Freitas 2010; Avila Jr. & Freitas 2011; Fonseca 2012; Freitas & Andrich 2013).

Upon this background, our goal was to study the daily interaction of birds with flowers and fruits of *Acnistus arborescens* in the Itatiaia National Park. In this sense, information was provided on the reproductive phenology of the plant species and also on behavior of bird visitors in order to infer on their potential role as pollinators/robbers and seed dispersers/predators.

Material and Methods

Study area

Itatiaia National Park is located in the Southwestern Rio de Janeiro and Southern Minas Gerais states (22º15'–22º30'S, 44º30'–44º45'W) in Southeastern Brazil (Fig. 1). It covers an area of 28,084.3 hectares of Brazilian Atlantic Forest (Oliveira-Filho & Fontes 2000) inserted in the Mantiqueira Mountain range. Vegetation at the elevation of this study is Montane Atlantic Forest (approx. 1,000 m a.s.l.). Climate is "Cfb" (Peel *et al*. 2007), with mild and rainy summers, interspersed with cold periods of low rainfall (Segadas-Vianna & Dau 1965). Annual precipitation averages 1,500 mm (Costa *et al.* 2012).

Species studied

Acnistus arborescens is a pioneer shrub-tree species with fasciculate, pale-green, stem flowers, that measure about 3 ± 0.2 cm (Mean ± Standard deviation) long and 0.5 ± 0.1 cm in diameter (Fig. 1), and exude a sweet and soft smell. Anthesis is diurnal, starting around 06:00 h, lasting approximately 12 hours. The fruit is a globose berry, measuring about 1.0 ± 0.4 cm in diameter, with ca. 13% of sugar (Verçoza *et al*. 2012). These fruits contain ca. 60 seeds (Athiê & Dias 2012) and exhibit features associated with ornithochory, such as fleshy consistency, orange color, and absence of odor (Van der Pijl 1982).

Acnistus arborescens occurs from southern Mexico to Southern Brazil from sea level up to 2,000 m a.s.l. (Hunziker 2001). In Brazil, it has been recorded in several states of the Northeastern, Southeastern, and Southern regions (BFG 2018. In the Itatiaia National Park individuals of *A. arborescens* were found occupying only areas with forest edges, open areas and in degraded areas on natural recovery similar to that identified in other localities (Verçosa 2012; Athiê & Dias 2012).

Sampling procedures

Eighteen individuals in reproductive condition were selected in INP. Phenological monitoring was conducted on a monthly basis between July 2015 and January 2016. The flowering (open flowers) and fruiting (mature and immature) phenophases were recorded considering the presence or absence of each phase. Flowering patterns were analyzed on individual and population levels, and described in terms of their duration, *i.e*., the number of months (Newstrom *et al.* 1994). The synchronization of the

phenophases was evaluated based on the proportion of individuals presenting the same phenophase during a given period (Bencke & Morellato 2002). Measurements of the fruits per flower (fruit set) were taken in all individuals. The largest and smallest distances between individuals were 1 km and 30 m, respectively.

Visitors consuming of nectar and fruits were recorded between 6:00 and 18:00 h, during continuous sampling bouts of 180 minutes totalizing 54 h of observations equally distributed among the fourfocal individuals (Pizo & Galetti 2010). During these observations, visitor type, number of individuals per species and duration of the visits, number of flowers and fruits foraged and consumption behavior were recorded. Birds were classified according to the fruit consumption method (*sensu* Parrini & Pacheco 2011a): a) to macerate the pulp, b) to chew the fruits before ingesting them, or c) to swallow whole fruits, previously chewing them or not.

Foraging strategies for fruit consumption were classified as suggested by Pizo & Galetti (2010): a) perched (when the bird remained on the plant while collecting and consuming the fruit), b) flying (when the bird arrived to the plant, collected the fruit and landed somewhere else to consume it), and c) on the ground (when birds ate fallen fruits lying on the ground).

Visit duration was standardized as suggested by Parrini & Pacheco (2011a): a) short (< 3 minutes), b) medium (3–10 minutes), and c) long (> 10 minutes). Subsequently, the total number of fruits eaten by each species was estimated as follows: (number of visits) × (number of fruits consumed per visit) × (length of each visit) × (number of individuals per visit), adapted from Aximoff & Freitas (2009).

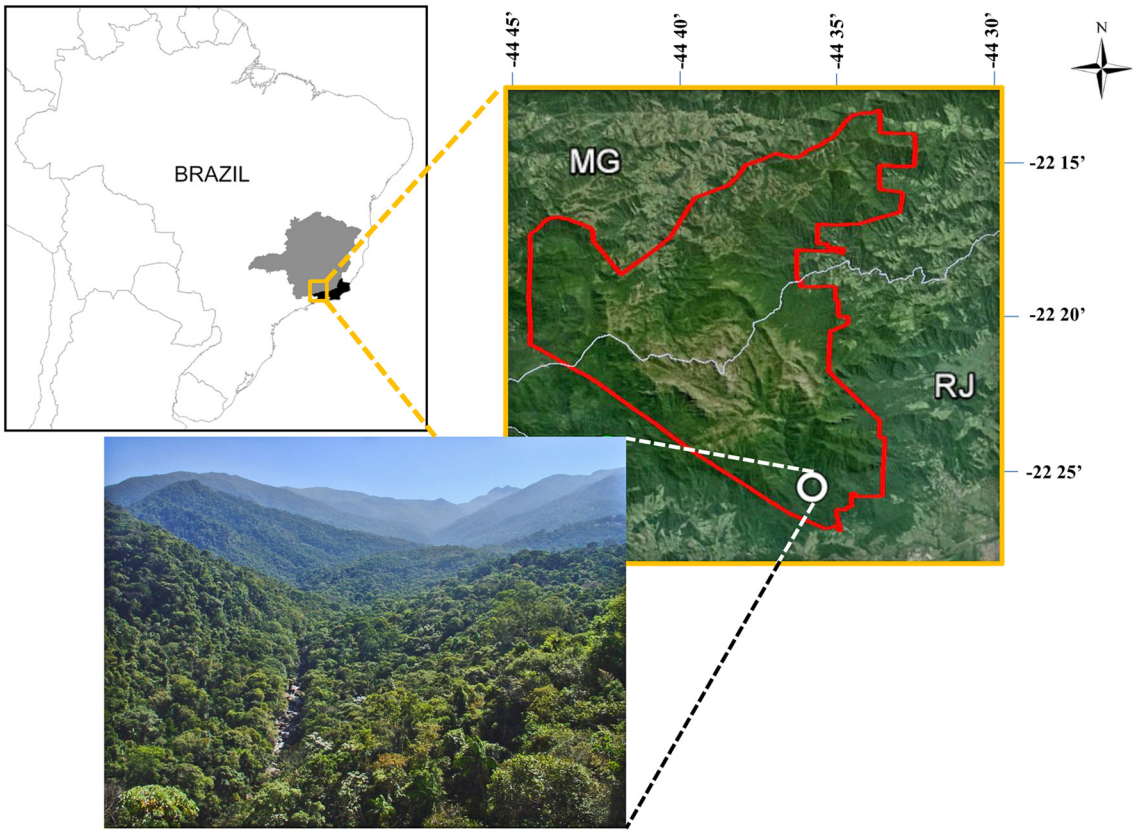

Figure 1 – a-c. Location of study site in the Itatiaia National Park - INP – a. in Southeastern Brazil, Minas Gerais state - MG (gray), Rio de Janeiro state - RJ (black) and the Itatiaia National Park (golden square); b. the location of the study area in the south part (white circle), inside limits of the INP (red line); c. the physiognomy of Brazilian Atlantic Forest in INP (left).

Identification of birds was done in the field according to Ridgely *et al*. (2015). Additionally, photographs were sent to experts to confirm the identification. Classification and nomenclature of bird species follow the list of Brazilian Committee of Bird Ornithological Records (CBRO 2014). Endangered species were identified based on the official lists of the state of Rio de Janeiro (SEMA 1998) and on the national list (MMA 2014). Endemic species of Atlantic Forest were identified based in specific literature (Cracft 1985; Sick 1997; Silva *et al.* 2004; Bencke *et al.* 2006).

Results

Phenology and plant features

Flowering of *Acnistus arborescens* occurred between August and November with 2.6 ± 0.6 months per individual (Mean ± Standard deviation), with a higher number of individuals flowering simultaneously in September and October (44.4%). Fruiting occurred from September to December with 2.2 ± 0.9 months per individual, with a higher number of individuals bearing fruits in November (38.8%). All plants had flowering and fruiting phenophases at the same time after the first month of flowering, but in December only fruiting was registered (Fig. 2). Fruit set was 87.3%. The average number of flowers and fruits produced per individual was 3.024 ± 32.4 and 2.782 ± 24.5, respectively.

Flower visitors

Flowers were visited by seven species of hummingbirds, one bird and several bees, wasps, butterflies and flies. Flower visits started around 8:00 h, increased from 10:30 to 13:00 h and then decreased, ending at 16:30 h. During the observation period nectar from 405 flowers was consumed. Most flower visits were made by hummingbirds being *Phaethornis ruber* the main visitor with 32.1% of total visits (Tab. 1). Visits of all hummingbirds were concentrated during early morning until 10:00 (48%) and mid to late afternoon (32%), with some visits at different times throughout the morning and afternoon (20%). During visits, hummingbird's beak contacts anthers and stigma, confirming their legitimate behavior and evidencing they can pollinate (Fig. 3). Only *Coereba flaveola* (Thraupidae) was observed visiting flowers as nectar thief. There were no records of agonistic interactions and only three species were recorded with more than one individual on the same plant (*P. ruber*, *L. magnificus* and *A. lactea*). Three hummingbird species are endemic to the Brazilian Atlantic Forest (Tab. 1).

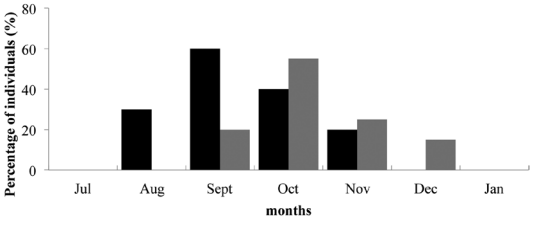

Figure 2 – Percentage of individuals (n = 18) in flowering (black bars) and fruiting phases (gray bars) of *Acnistus arborescens* in Itatiaia National Park - INP.

Frugivory

We recorded 35 bird species consuming fruits of *Acnistus arborescens*, including *Coereba flaveola* (Tab. 2). Most visits were performed by members of the family Thraupidae with 53.9 % of total. The species with the highest number of visits were *Tangara desmaresti* (10.9%), *Euphonia pectoralis* (7.7%), *Tangara cayana* (7.3%) and *T. cyanoventris* (6.8%) (Tab. 2). Most species (78%) made short visits (Fig. 4).

All Psittacidae and three Thraupidae species (*Tangara desmaresti*, *T. seledon* and *T. cayana*) had the highest number of visits on intraspecific flocks of up to six individuals in the same plant. Mixed flocks with *Tangara sayaca*, *T. cyanoventris*, *Ramphocelus bresilius* and *Cyanoloxia brissonii* were identified. Intra- and interspecific agonistic interactions were rare, only in 10.5% of visits. Birds avoided confrontations changing places and exploring other branches, as observed with a group of *Tangara seledon* and between *T. ornata* and *T. cyanoventris*.

All Pipridae and almost all of Tyrannidae species (75% of total), were observed performing flights to collect fruits. In Turdidae, some species collected fruits perching on the branches and then flew. Most Thraupidae (80% of total) collected fruits while perching on branches. Only the Dusky-legged Guan (*P. obscura*) was recorded feeding on fallen fruits on the ground, but also eating on the branches of *A. arborescens*. All the other species were recorded feeding perching on branches.

In most records, the consumption mode was chewing associated with macerating fruits. After collecting fruits, Psittacidae, Thraupidae, and Fringilidae chewed and macerated them. All

Table 1 – Nectarivorous bird species and behavior in flowers of *Acnistus arborescens* (Solanaceae) in Itatiaia National Park. AF = Atlantic Forest; Nº = number.

Order, Family Species	Common name	AF Endemic	Visits			Visited flowers		
			Nº	Minutes	Nº of individuals	Average per visit	Legitimate (%)	Illegitimate (%)
Apodiformes, Trochilidae								
Phaethornis ruber (Linnaeus 1758)	Reddish Hermit	-	12	5.7 ± 0.9	1.9 ± 1.1	10.8	130 (39.3)	-
Lophornis magnificus (Vieillot 1817)	Frilled Coquette	-	6	2.3 ± 1.6	1.4 ± 0.7	7.2	47 (15.0)	-
Thalurania glaucopis (Gmelin 1788)	Violet-capped Woodnymph	X	7	2.5 ± 1.2	1.0 ± 0	6.6	38 (12.0)	-
Amazilia versicolor (Vieillot 1818)	Versicolored Emerald	-	3	1.5 ± 0.6	1.0 ± 0	2.7	5 (1.4)	-
Amazilia fimbriata (Gmelin 1788)	Glittering-throated Emerald	-	4	1.2 ± 0.8	1.0 ± 0	3.4	14 (4.0)	-
Amazilia lactea (Lesson 1832)	Sapphire-spangled Emerald	X	10	3.3 ± 1.9	1.5 ± 0.6	7.4	74 (22.4)	-
Leucochloris albicollis (Vieillot 1818)	White-throated Hummingbird	X	4	1.3 ± 0.5	1.0 ± 0	4.8	19 (5.8)	-
Passeriformes, Thraupidae								
Coereba flaveola (Linnaeus 1758)*	Bananaquit	-	8	2.2 ± 0.2	1.0 ± 0	9.2	-	78 (100)
Total			**54**	**-**	**-**	**-**	**327**	**78**

Psittacidae species, as well as some Traupidae species (*T. desmaresti*, *T. sayaca*, *T. palmarum* and *T. ornata*), were additionally observed consuming green fruits (Fig. 5). Of the 3,388 fruits accounted for the observations, 52.3% were consumed by Thraupidae species. Other families with representative values were Turdidae (16%), Fringilidae (9%) and Psittacidae (6%). The most frequent fruit consumers were: *T. desmaresti* (11.8%), *Turdus rufiventris* (10.3%) and *E. pectoralis* (8.9%).

Sixteen bird species recorded consuming fruits are considered endemic to the Brazilian Atlantic Forest (Tab. 1). *Cyanoloxia brissonii* is threatened in Rio de Janeiro State (*i.e.* Vulnerable, SEMA 1998).

Discussion

Acnistus arborescens is an important food source for bird species in Itatiaia National Park. The 42 bird species observed feeding on floral nectar and fruits represents nearly 10% of total bird species recorded in the park (ICMBio 2013). Besides that, richness of birds consuming nectar of *A. arborescens* at INP (8 species) was higher than that reported in previous studies. In the Pedra Branca State Park, a stretch of Atlantic forest located in western city of Rio de Janeiro, only two hummingbird species were recorded (Verçosa *et al.* 2012). In Ecuador and Peru, *A. arborescens* was visited exclusively by insects while hummingbird species visited other plant species (Smith *et al*. 2008).

The largest number of hummingbird species in INP, than those recorded by Smith *et al*. (2008), may allow that some of these animals act as specific visitors of *A. arborescens*. Only two of the seven hummingbird species observed feeding on *A. arborescens* were also detected as nectar consumers in the assemblage of 40 ornithophilous plant species at Itatiaia National Park (Canela

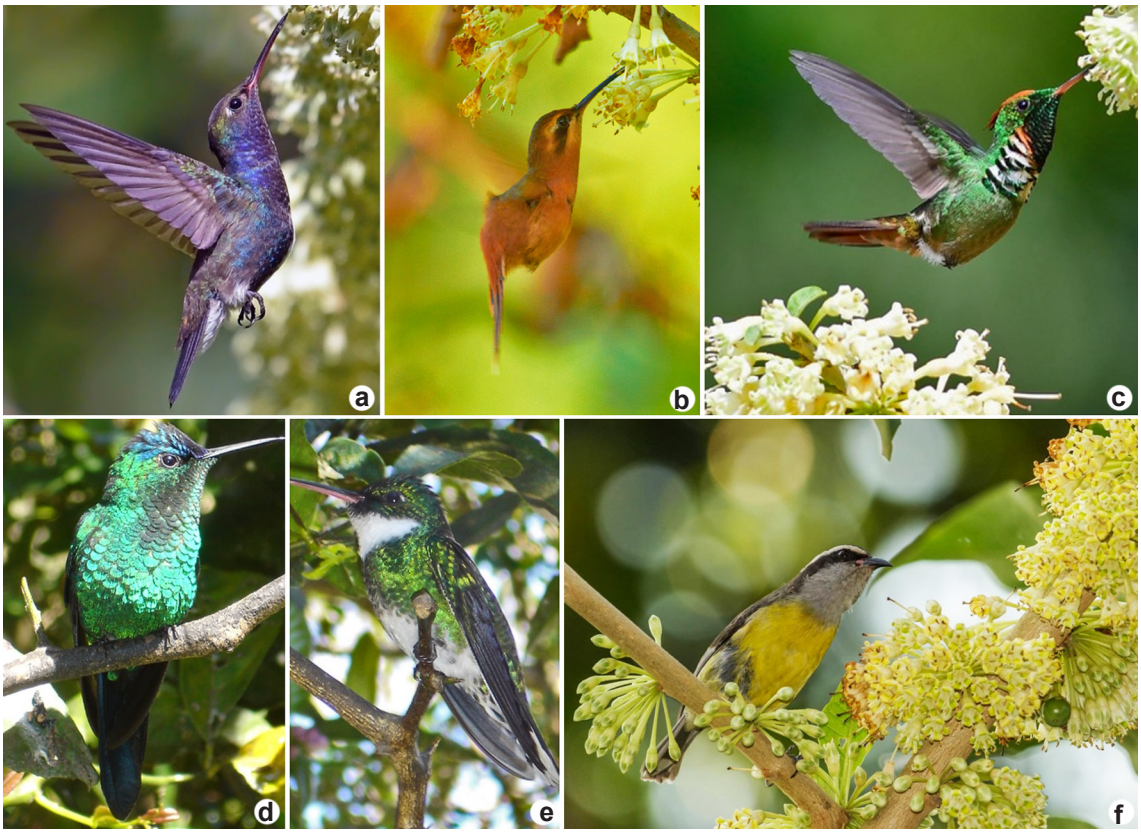

Figure 3 – a-f. Some of the nectarivorous bird species in flowers of *Acnistus arborescens* in Itatiaia National Park – a. *Amazilia lactea*; b. *Phaethornis ruber*; c. *Lophornis magnificus*; d. *Thalurania glaucopis*; e. *Leucochloris albicollis* Trochilidae; f. *Coereba flaveola* Thraupidae.

2006; Aximoff & Freitas 2009; Wolowski *et al*. 2013a). The other five hummingbird species act almost exclusively at *A. arborescens* during their flowering. This may be related to the fact of hundreds of open flowers available in *A. arborescens* compensate the small amount of nectar available in each one (Smith *et al*. 2008). In this sense, it reinforces the local importance of *A. arborescens* in providing resources for the maintenance of some hummingbird species.

Richness of birds consuming fruits of *A. arborescens* at INP (35 species) was also higher than that reported in previous studies: 21 species in Costa Rica (Wheelwrigh *et al*. 1984), 16 species in Jamaica, (Cruz 1981), and in Brazil, 13 species (Verçoza *et al*. 2012) and 15 species (Athiê & Dias 2012). In the Brazilian Atlantic Rain Forest, some plant species presented high richness of fruit consuming birds: 32 in *Alchornea triplinervia* (Euphorbiaceae) (Parrini & Pacheco 2011a), 30 in *Cupania oblongifolia* (Sapindaceae) (Parrini & Pacheco 2014), and 63 species in *Rapanea schwackeana* (Myrsinaceae) (Pineschi 1990). The high richness of consuming fruit birds in INP, including endangered species, can be directly related to the more than 400 bird species already recorded in this protected area (ICMBio 2013).

Some features of *A. arborescens* may be considered as effective to attract more consumers and potential dispersers (Athiê & Dias 2012; Verçosa *et al*. 2012). One of them would be the high proportion of fruit pulp during the rainy season (Morellato & Leitão Filho 1992; Pereira & Mantovani 2007; Parrini & Pacheco 2011a,b, 2014). The greater resources supply in the rainy season may be identified as the main factor responsible for the seasonal movements of birds to these places (Galetti *et al*. 2000; Morellato *et al*. 2000; Malizia 2001). Indded, a greater number of bird species was identified in the rainy season (n = 68) than in the dry season (n = 42) in specific locality in Itatiaia National Park (Gouvea *et al*. 2005). Another important feature would be the high amount of fruits produced and their extended period of exposure to

Table 2 – Frugivorous bird species and behavior in fruits of *Acnistus arborescens* (Solanaceae) in Itatiaia National Park. AF = Atlantic Forest; Nº = number.

Order, Family Species	Common name	AF Endemic	Visits			Fruit Consumption			
			Nº	Minutes	Mode	Method	Average per visit	Strategy	Total (%)
Galliformes, Cracidae									
Penelope obscura Temminck 1815	Dusky-legged Guan	X	6	0.7 ± 0.3	S	P, G	15.8	SW	95 (2.8)
Columbiformes, Columbidae									
Patagioenas picazuro (Temminck 1813)	Picazuro Pigeon	-	5	0.6 ± 0.2	S	P	17.4	SW	87 (2.6)
Psittaciformes, Psittacidae									
Pyrrhura frontalis (Vieillot 1817)	Maroon-bellied Parakeet	X	18	2.2 ± 0.7	B	P	4.4	CH, MC	79 (2.3)
Forpus xanthopterygius (Spix 1824)	Blue-winged Parrotlet	-	12	1.5 ± 0.8	B	P	5.4	CH, MC	65 (1.9)
Brotogeris tirica (Gmelin 1788)	Plain Parakeet	X	9	1.1 ± 0.9	B	P	5.8	CH, MC	52 (1.5)
Passeriformes, Pipridae									
Manacus manacus (Linnaeus 1766)	White-bearded Manakin	-	7	0.9 ± 0.5	S	V, P	3	MC	21 (0.6)
Chiroxiphia caudata (Shaw & Nodder 1793)	Swallow-tailed Manakin	X	8	1.0 ± 0.2	S	V, P	2.8	MC	22 (0.6)
Passeriformes, Tyrannidae									
Elaenia flavogaster (Thunberg 1822)	Yellow-bellied Elaenia	-	8	1.0 ± 0.3	S	P	2.4	MC	19 (0.6)
Pitangus sulphuratus (Linnaeus 1766)	Great Kiskadee	-	34	4.2 ± 1.1	S	V, P	0.7	MC	23 (0.7)
Megarynchus pitangua (Linnaeus 1766)	Boat-billed Flycatcher	-	13	1.6 ± 0.5	S	V, P	4.2	MC	54 (1.6)
Myiozetetes similis (Spix 1825)	Social Flycatcher	-	11	1.4 ± 0.4	S	V, P	3.9	MC	43 (1.3)
Passeriformes, Turdidae									
Turdus flavipes (Vieillot 1818)	Yellow-legged Thrush	-	12	1.5 ± 0.3	S	V, P	2.6	MN	31 (0.9)
Turdus leucomelas (Vieillot 1818)	Pale-breasted Thrush	-	31	3.8 ± 1.1	S	P	4.3	MN	133 (3.9)
Turdus rufiventris (Vieillot 1818)	Rufous-bellied Thrush	-	37	4.6 ± 1.4	S	V, P	9.5	MN	350 (10.3)

Order, Family Species	Common name	AF Endemic	Visits			Fruit Consumption			
			Nº	Minutes	Mode	Method	Average per visit	Strategy	Total (%)
Turdus amaurochalinus (Cabanis 1850)	Creamy-bellied Thrush	-	18	2.2 ± 0.7	S	P	2.4	MN	43 (1.3)
Passeriformes, Mimidae									
Mimus saturninus (Lichtenstein 1823)	Chalk-browed Mockingbird	-	8	1.0 ± 0.1	S	P	4.1	SW	33 (1.0)
Passeriformes, Passerellidae									
Zonotrichia capensis (Statius Muller 1776)	Rufous-collared Sparrow	-	13	1.6 ± 0.2	S	P	3.5	SW	45 (1.3)
Arremon semitorquatus (Swainson 1838)	Half-collared Sparrow	X	12	1.5 ± 0.4	S	P	4.6	SW	55 (1.6)
Passeriformes, Thraupidae									
Coereba flaveola (Linnaeus 1758)*	Bananaquit	-	22	2.7 ± 0.3	S, M	V, P	3	CH, MC	67 (2.0)
Saltator similis (d'Orbigny & Lafresnaye 1837)	Green-winged Saltator	-	21	2.6 ± 0.7	S	P	2.1	CH, MC	45 (1.3)
Thlypopsis sordida (d'Orbigny & Lafresnaye 1837)	Orange-headed Tanager	-	12	1.5 ± 0.2	S	P	2.7	CH, MC	32 (0.9)
Tachyphonus coronatus (Vieillot 1822)	Ruby-crowned Tanager	X	46	5.7 ± 0.5	S	P	2.1	CH, MC	98 (2.9)
Ramphocelus bresilius (Linnaeus 1766)	Brazilian Tanager	X	20	2.5 ± 0.9	S, M	P	2.3	CH, MC	45 (1.3)
Tangara seledon (Muller 1776)	Green-headed Tanager	X	18	2.2 ± 0.4	B	P	3.7	CH, MC	67 (2.0)
Tangara cyanoventris (Vieillot 1819)	Gilt-edged Tanager	X	55	6.8 ± 0.9	S, B, M	P	4.5	CH, MC	250 (7.4)
Tangara desmaresti (Vieillot 1819)	Brassy-breasted Tanager	X	88	10.9 ± 2.3	B	V, P	4.5	CH, MC	400 (11.8)
Tangara sayaca (Linnaeus 1766)	Sayaca Tanager	-	39	4.8 ± 1.7	S, M	P	5	CH, MC	194 (5.7)
Tangara palmarum (Wied 1823)	Palm Tanager	-	12	1.5 ± 0.2	S	P	1.9	CH, MC	23 (0.7)
Tangara ornata (Sparrman 1789)	Golden-chevroned Tanager	X	37	4.6 ± 0.7	S	P	4.3	CH, MC	158 (4.7)
Tangara cayana (Linnaeus 1776)	Burnished-buff Tanager	-	59	7.3 ± 3.7	B	P	4.2	CH, MC	250 (7.4)
Cissopis leverianus (Gmelin 1788)	Magpie Tanager	-	8	1.0 ± 0.5	S	P	2.6	CH, MC	21 (0.6)

Order, Family Species	Common name	AF Endemic	Visits			Fruit Consumption			
			Nº	Minutes	Mode	Method	Average per visit	Strategy	Total (%)
Dacnis cayana (Linnaeus 1766)	Blue Dacnis	-	19	2.4 ± 0.9	S	V, P	2.4	CH, MC	45 (1.3)
Hemithraupis ruficapilla (Vieillot 1818)	Rufous-headed Tanager	X	19	2.4 ± 0.7	S	P	4.1	CH, MC	78 (2.3)
Passeriformes, Cardinalidae									
Cyanoloxia brissonii (Lichtenstein 1823)	Ultramarine Grosbeak	-	8	1.0 ± 0.3	S, M	P	8.1	CH	65 (1.9)
Passeriformes, Fringillidae									
Euphonia pectoralis (Latham 1801)	Chestnut-bellied Euphonia	X	62	7.7 ± 2.5	S	P	4.8	CH, MC	301 (8.9)
Total		**-**	**807**	**-**	**-**	**-**	**-**	**-**	**3389**

consumers (Cruz 1981; Wheelwrigh *et al*. 1984; Levey 1987; Verçoza *et al*. 2012). Its annual reproductive phenology (5 months) promotes the supply of important resources for foraging of the birds richness of Itatiaia National Park.

Thraupidae, Turdidae and Tyrannidae were the main dispersers of *A. arborescens* (78%) in Itatiaia. These families were also present among those with higher number of species in studies of *A. arborescens* in Jamaica (Cruz 1981), Costa Rica (Wheelwrigh *et al*. 1984) and Brazil (Athiê & Dias 2012; Verçoza *et al*. 2012). Other plant species of the Atlantic Rain Forest, as *Cupania oblongifolia* (Sapindaceae) (Parrini & Pacheco 2014) and *Miconia* spp. (Melastomataceae) (Parrini & Pacheco 2011b) were also dispersed by these bird families. Thraupidae species accounted for more than half of fruit consumers, a close percentage recorded for shrub-tree species of the Atlantic Rain Forest of southeastern Brazil (Manhães *et al*. 2003; Parrini *et al*. 2008; Parrini & Pacheco 2011a,b, 2014). Tyranidae (26 species) and Thraupidae (21 species) were the families with the highest number of species recorded as dispersing species of *Rapanea* (Myrsinaceae) in the Itatiaia National Park (Pineschi 1990). Although we have not evaluated the seed dispersal efficiency, this is directilly related to feeding behavior and with the different ways of fruit consumption of *A. arborescens* (Cruz 1981).

Habitat characteristics where *A. arborescens* grows, such as clearings, secondary forests and edges of trails and roads, can also encourage visitation by bird species that use open and disturbed areas (Galetti *et al*. 2003; Athiê & Dias 2012), as other typical forest areas (Fadini & Marco Jr. 2004; Jordano *et al*. 2006). This can also facilitate the arrival of seeds brought by birds from adjacent conservation areas. The importance of birds species tipically found in forest interior that are attracted to fruting plants at the forest borders could transport seeds from plants located in forest interior to forest borders, and potentially increase plant diversity in this disturbed areas has to be highlighed (Pizzo 2007; Campos *et al.* 2012). The use of resources by *Chiroxiphia caudata* (obligatory frugivore) varied according to the availability of fruits and the conservation status (structural complexity) of forests (Hasui *et al.* 2009).

Birds are preferentially used to evaluate the effectiveness of restored areas because of their mobility, the speed at which they colonize new environments, their ability to connect habitats through seed dispersal, and their maintenance of gene flow among plant populations (Campos *et al.* 2012; Cavallero *et al.* 2013; Vogel *et al.* 2015). In Brazil, the main species of birds related to the process of forest regeneration are those that are more generalist, with a diet of fruits and insects and that live on forest edges and open areas (Pizo

Figure 4 – a-h. Some of the main frugivorous birds of *Acnistus arborescens* in Itatiaia National Park – a. *Turdus leucomelas* Turdidae; b. *Tangara cyanoventris*; c. *T. sayaca*; d. *T. ornata*; e. *T. cayana* Thraupidae; f. *Cyanoloxia brissonii* (threatened) Cardinalidae; g. *Euphonia pectoralis* - male; h. *Euphonia pectoralis* - female Fringillidae.

2007). These species belong mainly to the families Tyrannidae, Turdidae and Thraupidae (Campos *et al.* 2012). In addition, the birds of these families present great potential as dispersers, since they generally feed on the fruits without destroying the seeds (Athie & Dias 2012).

The Ultramarine Grosbeak *Cyanoloxia brissonii* was the only endangered species feeding on *A. arborescens*. This bird is territorialist, and if there is a couple in a certain location, it will only be possible to find another couple at a distance, and if one male invades the territory of another, there will surely be a conflict, and it will be very violent (Sick 1997). In 20 years (1992 to 2012) this was the species with the highest number of seizures (more than 4,000 individuals) by the environmental police in one of the largest cities in Brazil (*i.e.* Belo Horizonte in the state of Minas Gerais) (Souza & Vilela 2013).

Figure 5 – a-e. Some of the green fruits consumers of *Acnistus arborescens* and that also had the highest number of visits on intraspecific flocks in the same plant – a. *Tangara desmaresti*; b. *T. seledon*; c. *T. palmarum* (Thraupidae); d. *Pyrrhura frontalis*, *Brotogeris tirica*; e. *Forpus xanthopterygius* (Psittacidae).

Considering that *Acnistus arborescens* can support a wide assenblage of nectarivorous and frugivorous birds, this can be used as attractive plants for nucleation process during recover of disturbed sites in Atlantic Forest, favoring the local ecological succession.

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