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FRUGIVORY AND SEED DISPERSAL BY THE HELMETED MANAKIN (*ANTILOPHIA GALEATA*) IN FORESTS OF BRAZILIAN CERRADO

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Resumo. – Frugivoria e dispersão de sementes por soldadinho (*Antilophia galeata*) em matas do Cerrado brasileiro. – *Antilophia galeata* é uma ave frugívora da família Pipridae que tem sido registrada como uma boa dispersora de sementes de diversas espécies vegetais do Cerrado. O objetivo do trabalho foi determinar o comportamento alimentar de *A. galeata* para avaliar seu potencial de dispersão de sementes em três fragmentos florestais. Foram registradas a tática de captura de frutos, o tempo gasto, o número de frutos consumidos e a espécie do fruto. Capturas com rede neblina foram usadas para coleta de material defecado. Foi registrado o consumo de 16 espécies de plantas, sendo Rubiaceae e Melastomataceae, as famílias mais representativas. As táticas de captura de fruto em vôo foram as mais frequentes, sendo que foram consumidos 3,86 ± 1,52 frutos por minuto em cada visita e em 88% dos registros, os frutos foram engolidos inteiros. No conteúdo fecal foram identificados três morfotipos de sementes. Os dados permitem afirmar que *A. galeata* é uma espécie importante nas interações frugívoro-planta e na dispersão de sementes.

Abstract. – The Helmeted Manakin *(Antilophia galeata)* is a frugivorous bird of the Pipridae family and has been registered as a good seed disperser for several plants species from Cerrado. This study is aimed to determine the feeding behavior of the Helmeted Manakin in order to evaluate its potential as a seed disperser in three forests fragments. We registered the fruits consumption, the capture techniques, the time, the number of consumed fruits, and the fruit species. Captures with mist nest were used to analyze defecated material. We recorded 16 plants species (Rubiaceae and Melastomataceae were the most representatives families). Taking fruits on flying were more used, being consumed 3.86 ± 1.52 fruits per minute in each visit and 88% of the registers, the fruits were fully swallowed. In fecal samples, we identified three morphotypes of seeds. These results allow us to propose the Helmeted Manakin as an important species in frugivore-plant interaction and in the seed dispersal. *Accepted 5 February 2011.*

Key words: Helmeted Manakin, *Antilophia galeata*, Pipridae, gallery forest, bird-plant interactions.

INTRODUCTION

Gallery forests, especially their borders, are sources of essential resources for birds of the Cerrado because they are one of the few areas with available fruit during the dry season (Cavalcanti 1988). But despite their importance, these areas are subject to increasing alteration and destruction due to agricultural development in Central Brazil (Oliveira-Filho *et al.* 1990). One of the most damaging consequences of this alteration to biodiversity maintenance is the interference in the mutualistic interactions of fruit consumption and seed dispersion (Restrepo & Gómez 1998, Restrepo *et al.* 1999, Galetti *et al.* 2003).

The zoochorous dispersion of seeds influences the distribution of seeds to germination sites (Jordano 1987, Figueiredo & Perin 1995), being important for the natural regeneration of tropical forests which play a fundamental role in the establishment, development, and evolution of forest species (Rondon-Neto *et al.* 2001). While the success of a seed is usually low, the probability of achieving viable sites can be enhanced by the expertise or the effectiveness of seed dispersal (Schupp 1993).

Schupp (1993) suggests that the effectiveness of the disperser depends of qualitative and quantitative variables that are resulting from factors like time of visit, numbers of consumed fruits (Motta-Júnior & Lombardi 1990), and displacement and deposition in appropriated sites for germination. Ornithochorous activity (dispersion by birds) is very important in the Cerrado (Pinheiro 1999), with the Helmeted Manakin reported as a potential disperser of the seeds of various species in this biome (Melo *et al.* 2003, Coelho 2007, Amâncio & Melo 2008, Melo & Oliveira 2009).

The Helmeted Manakin (*Antilophia galeata* Lichtenstein, 1823) is a piprid endemic to Cerrado forests of Brazil (Silva 1995). As with other members of its family, the Helmeted Manakin presents evident sexual dimorphism in the adult phase. In spite of complementing its diet with arthropods, the Helmeted Manakin is predominantly frugivorous (Marini 1992a). This study is aimed to evaluate the feeding behavior of the Helmeted Manakin, determining the strategies of fruit capture and mode of ingestion, to measure the seed dispersal potential and to identify the plants groups that compose its diet and the features of the ingested fruits.

MATERIAL AND METHODS

Study areas. The study was carried out in three forest fragments in the Mun. of Uberlândia (Minas Gerais State - Brazil): Parque Municipal do Sabiá (48°13'43"W, 18°54'32"S), Estação Ecológica do Panga (48º23'41"W, 19º10'50"S) and Fazenda Experimental do Glória (48º12'24"W, 18º57'11"S). The municipality is located in Central Brazil in the Cerrado biome. It is highly impacted by human influence, with only 11.4% of the territory demonstrating open (cerrado) or woodland (forest and cerradão) characteristics (Brito & Prudente, 2005). The region's climate is Aw according to Köppen classification (Rosa *et al.* 1991).

Methods. Fieldwork was carried out between July 2009 and May 2010, either early in the morning or late in the afternoon, totaling 90 field hours (30 at each area). Trails of 150–300 m were followed in the interior and the borders of gallery forests, where Helmeted Manakin individuals were spotted and followed until visual contact was lost. Strategies of fruit capture, mode of ingestion (fruit and seed), and the time that the bird remained on the fruit-bearing plant were registered, as well as the species of plant from which fruit was consumed. The foraging modes employed for fruit capture were based on Moermond & Denslow (1985). Capture maneuvers used while perching (Picking and Reaching) were differentiated as well as those used in flight (Hovering and Stalling).

Fruit consumption was differentiated as: 1) ingestion of the entire fruit or 2) partial ingestion, in which parts of the fruit were removed with the seeds ingested or not. In partial ingestion, each incidence was counted as the consumption of one fruit, but each effort to remove a piece as a separate capture maneuver.

The species of plants consumed were identified and grouped at the family level in order to verify their representativeness in the diet.

Data were collected from the literature and from observations about fruit type, size, average number of seeds, and predominant coloration in order to characterize them (Table 1). The height at which foraging occurred was also recorded to determine the strata most utilized by the bird.

Tactics of arthropod capture were not differentiated but analyzed quantitatively, and prey was identified to the lowest possible taxon. The number of arthropod foraging incidences was compared to that of fruit foraging to determine which item was more prevalent in the diet.

The ingestion mode, numbers of consumed fruits and the time that the bird remained on the plant has been used as an indicator of the dispersion potential (Motta-Júnior & Lombardi 1990, Schupp 1993), estimated by the consumption efficiency. In this study, the consumption efficiency was calculated by the ratio between the mean of consumed fruits and the mean time that the bird remained on the plant (fruits/min) (Motta-Júnior & Lombardi 1990, Melo *et al.* 2003, Melo & Oliveira 2009).

Concomitantly with the observations, captures were carried out with mist nets at the Fazenda Experimental do Glória, with seven to ten nets exposed simultaneously. The captured birds were removed and accommodated in fabric sacks for up to 10 min to obtain feces samples. After this they were removed from the sacks, selected, tagged with a ring (according to CEMAVE/ICMBio standards), and released. The capture effort was calculated according to Straube & Bianconi (2002).

The feces samples were collected and deposited in Eppendorf tubes, and the number of seeds (if present) was subsequently quantified in each sample. The seeds contained in these samples were divided into morphotypes. However, species identification was not possible with regard to external characters.

RESULTS AND DISCUSSION

During the 90 total hours of observation, there were 106 direct visual contacts with individuals (mean time of each contact = 2.60 $\pm$ 2.26 min). Of the total time of visual contact (280 min), foraging accounted for 25.47% (n = 27 registers). Fruit consumption accounted for 92.59% of the instances of foraging (n = 25), confirming the predominance of this item in the Helmeted Manakin's diet (Marini 1992a).

Although less significant in the diet, arthropod consumption corresponded to 7.41% (n = 2) of foraging instances. Marini (1992a) analyzed the stomach contents of the Helmeted Manakin, and arthropods were present in 24.5% of the samples and never represented more than 20% of the total stomach volume.

Arthropod consumption was performed by green-colored individuals (females or immature males) in November, i.e., the species' reproductive period. In spite of males consume arthropods, the females tend to adopt a more protein-rich diet during this period because they have a greater demand for it (Robbins 1981) due to their responsibility for the generation and care of offspring (Marini 1992b).

One of the sightings involved the capture of Isoptera caught in spider webs. This behavior was also reported in another study involving various species (Waide & Hailman 1977) and could function as an alternative for birds that are not specialized insectivores, since immobilized prey is much easier to capture. In another sighting, it was not possible to identify the arthropod prey.

In relation to consumption of fruits, the predominant strategy of foraging was Hovering (Fig. 1) with 70 instances (50.38%), followed by Picking with 35 instances (28.69%). Hovering was observed in 80% of the visits with fruit consumption. In-flight fruit con-

TABLE 1. Morphological characteristics of consumed fruits and dispersion potential of the Helmeted Manakin. Indices: [1](Lozenzi 2008), [2](Lorenzi 2002), [3](Durigan *et al.* 2004), [4](Santin 1989), [5](Antunes *et al.* 1998), [6](Melo *et al.* 2003), [7](Pereira & Barbosa 2006), [8](Oliveira 2008).

Plant	Family	Fruit morphology			Fruit consumption			
		Length (mm)	Color	Seed no.	Consumed fruits	No. of visits	Time of visits (mean ± SD)	Dispersion potential
Astronium nelson-rosae[4]	Anacardiaceae	12	brown	1	2	1	0.53	3.77
Tapirira obtusa[1]	Anacardiaceae	15	purple	1	10	2	1.33 ± 0.33	3.76
Cecropia pachystachya[1]	Cecropiaceae	120	brown	>100	1 (partial)	1	1.53	-
Ocotea spixiana[2]	Lauraceae	15	dark purple	1	12	4	0.93 ± 0.54	3.23
Leandra sp.	Melastomataceae	8	green	>100	4	1	1.83	2.19
Miconia albicans[3]	Melastomataceae	6	green	25–35	9	3	0.56 ± 0.46	5.36
Miconia chamissois[5]	Melastomataceae	5	purple	33	4	1	0.82	4.88
Miconia selloviana	Melastomataceae	4	purple	6–9	5	2	0.47 ± 0.38	5.32
Guarea macrophylla[2]	Meliaceae	50	brown/red (seed)	2–4	1 (partial)	1	0.68	-
Siparuna guianensis	Monimiaceae	11	wine-colored	4–10	3	1	1.38	2.17
Myrsine umbellata[2]	Myrsinaceae	4.5	dark purple	1	19	2	1.88 ± 0.61	4.26
Alibertia edulis	Rubiaceae	45	dark purple	35	1 (partial)	1	1.23	-
Faramea cyanea[6]	Rubiaceae	8	purple	1	5	1	1.12	4.46
Psychotria hoffmannseggiana[7]	Rubiaceae	2.5	purple	1	9	2	0.67 ± 0.02	6.72
Psychotria prunifolia[8]	Rubiaceae	4.5	purple	2	6	1	4.58	1.31
Psychotria sp.	Rubiaceae	8	dark purple	1	5	1	1.78	2.81

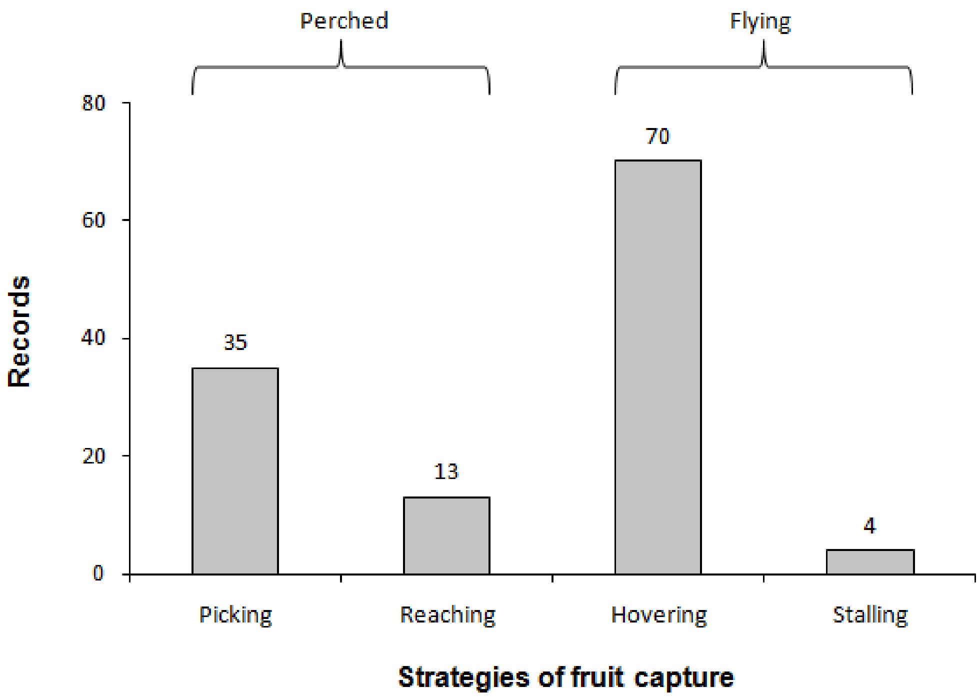

FIG. 1. Records of fruit capture tactics utilized by the Helmeted Manakin. For partially consumed fruits, each attack to acquire part of the fruit corresponded to a different record. The following tactics were differentiated: Picking, Reaching, Hovering, and Stalling (Moermond & Denslow 1985).

sumption strategies (66.66%; n = 74) were significantly more used (χ^2 = 5.54; gl = 1; *P* = 0.02) than perching events (39.34%; n = 48), like in other Pipridae who usually prefer in-flight capture and the retrieval of each fruit with a single effort (Levey *et al.* 1984). Although this strategy requires more energy, it allows them greater precision and access to fruit (Moermond & Denslow 1985). It has been detected that birds tend to maintain one specific type of foraging, independent of habitat (Gomes *et al.* 2008).

There was complete consumption in 88% (n = 22) of the observed incidences of fruit ingestion, seeing that small fruits (≤ 20 mm in length) were swallowed whole, without to mandibulate or break them apart. Larger fruits or infructescences (> 20 mm) were partially consumed, since it was necessary to bite off pieces, and in such cases the seed/s may or may not have been ingested. Consequently, consumption of the entire fruit increases the chances that dispersion is more effective (Jordano & Schupp 2000).

During each visit to a fruiting plant (n = 25), an average of 3.88 ± 2.57 fruits were consumed, with a mean time of 1.18 min ± 0.89 spent at each plant (Table 1). Since fruits vary in terms of energy reward and nutritional value among different species (Herrera 1985, Melo 2003), it is necessary to optimize the time spent in consumption. Some factors influence this time: the proportion of fruit in the diet, the bird's cryptism, and reproductive behavior (Pratt & Stiles, 1983).

In spite of the small number of observed samples, green-colored individuals spent on average 2.98 min ± 2.26 (n = 2) per visit to fruiting plants, which is longer but not significantly different (χ^2 = 0.96; gl = 1; *P* = 0.63) from the time spent by adult and subadult males (1.02 ± 0.55 min; n = 23). Experiments have demonstrated that birds with cryptic coloration tend to spend more time in fruiting plants, since predation and competition are reduced in comparison with birds of more evident coloration (Pratt & Stiles 1983).

In this study, bird coloration could have been a factor that determined the wide difference in visit time between *Psychotria prunifolia* (4.58 min; visited by a green-colored individual) and *P. hoffmannseggiana* (0.67 ± 0.02 min, n = 2; visited by adult males), even though both had morphologically quite similar fruits.

The dispersion potential (fruits consumed per minute) of the Helmeted Manakin ranged from 1.31 to 6.72. Other studies measuring the dispersion potential of the Helmeted Manakin have encountered different values. In *Miconia theaezans* (Amâncio & Melo 2008) and *Rapanea lancifolia* (Francisco & Galetti 2001), values (calculated based on the presented data) of 12.61 and 6.15 fruits per minute were found, respectively. With *Faramea cyanea* (Melo *et al.* 2003) and *Lacistema hasslerianum* (Melo & Oliveira 2009), the measured dispersion potential was lower, with 2.15 and 2.82 fruits consumed per min, respectively.

The dispersion potential values in this study varied among the different species of plants, demonstrating that this can be influenced, for example, by the characteristics of the plant. Since the dispersion potential is the ratio between the number of fruits consumed and length of visit to the plant, both factors should be taken into consideration.

The 25 visits involving fruit consumption occurred in 16 plant species that can be divided into eight families (Table 1). During these visits, the consumption of 97 fruits occurred. With five species (31.25%), the family Rubiaceae was represented most, followed by Melastomataceae with four species (25%). Studies have placed these two families among the most important ones for frugivorous tropical birds (Snow 1981, Stiles & Rosselli 1993). In Marini (1992a), the Helmeted Manakin was observed to consume fruits from 17 species, including three Melastomataceae and three Rubiaceae.

The genera *Psycothria* (Rubiaceae) and *Miconia* (Melastomataceae), which produce small fleshy fruits commonly consumed by opportunistic frugivores, were most represented in this study, with three species each. These have been documented as the most important genera in the diet of several Pipridae species in tropical forests (Charles-Dominique 1993, Poulin *et al.* 1999).

Among the consumed fruits, the coloration of 62.50% (n = 10) was purple or purplish. Frugivorous birds frequently present a fruit color preference when all other factors are constant (Wilson *et al.* 1990), although characteristics such as size, proportion of seeds, nutritional value, and availability of fruit can also influence their consumption preference.

Foraging occurred in several forest strata, from heights of 0.5 m to 10 m (3.38 ± 2.66 m; *t* = 4,85; *P* = 0), with a clear preference for strata lower than 4 m (68.75%; n = 11), due probably to the great abundance of ornithochorous fruits in these strata, principally in more altered areas (Levey 1988).

Tests have demonstrated that animals tend to be more selective regarding the fruit that they eat when there is an abundance of food (Moermond & Denslow 1983). The fruit of *Astronium nelson-rosae*, which is anemochorous (Lorenzi 2002), was consumed. The immature fruit of *Faramea cyanea* and *Guarea macrophylla* were consumed when there were no mature fruits of this or other species available in the proximity. For reason that these fruits are nutritionally inferior, they must be consumed in greater quantities, a factor that increases foraging time (Foster, 1977).

The effort to capture Helmeted Manakins with fog nets covered 14,409 h per m^2. During the study period, 12 individuals were captured, with four (33.33%) leaving feces samples, in which three seed morphotypes were found (4.24 ± 3.30 seeds per sample). The seeds were externally intact, without evidence of having been crushed and/or damaged by passage through the digestive tract. Although germination tests were not carried out in this study, other analyses have indicated neutrality or an increase in germination efficiency in many seeds after passage through the digestive tracts of birds (Traveset 1998) but this factor varies between each seed species.

Snow (1981) classified frugivores as specialists when they ingest high-quality fruit that is rich in proteins and lipids with few large seeds, and as opportunists when they ingest small fruit of little nutritional value, rich only in carbohydrates, and having many small seeds. Apparently, the Helmeted Manakin falls between these two categories since it consumes both types of fruit from pioneer species (e.g., *Cecropia pachystachya*) as well as climax species (e.g., *Myrsine umbellata*), not to mention complementary items, such as arthropods.

Schupp (1993) proposed qualitative and quantitative parameters for seed dispersion effectiveness. We verified among the quantitative parameters: 1) a high abundance of the Helmeted Manakin individuals in the forest fragments of the study area (pers. observ.); 2) a predominance of fruit in their diet; and 3) ingestion of whole fruits and short visits to each mother plant. Predominating among the qualitative factors was the consumption of whole fruits, which caused neither digestive seed damage nor, in all probability, inhibition of germination capacity. Furthermore, the movement pattern would not be affected, since the territorial male (Marini & Cavalcanti 1992) actively moves throughout his territory, although in a limited way beyond it.

These results allow us to propose the Helmeted Manakins as a potentially good seed disperser for a great variety of fruits, besides the fact that it is a common species in forest fragments of various sizes (Marini 2001) including urban fragments (Franchin & Marçal Junior 2004). It can be considered a key species in frugivore-plant mutualism and therefore in the regeneration and maintenance of forest fragments.

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