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Bird frugivory on *Struthanthus concinnus* (Loranthaceae) in Southeastern Brazil

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RESUMO**. Frugivoria por aves em *Struthanthus concinnus* Mart. (Loranthaceae) no Sudeste do Brasil.** Ervas-de-passarinho são plantas hemiparasitas de caule, cujas sementes são dispersadas principalmente por aves. No Brasil, poucos estudos relatam o consumo dos frutos de lorantáceas por animais. Nesse estudo investigamos o comportamento alimentar de aves durante 80 horas de observações focais em oito indivíduos de *Struthanthus concinnus* em frutificação, localizados na borda de um fragmento florestal em Belo Horizonte, MG. Onze espécies da ordem Passeriformes pertencentes às famílias Tyrannidae (6), Emberizidae (3), Pipridae (1) e Vireonidae (1) foram observados consumindo frutos em 173 registros alimentares. Cinco espécies, *Hylophylus amaurocephalus, Ilicura militaris, Phaeomyias murina, Tersina viridis* e *Piranga flava*, foram as consumidoras mais freqüentes. As táticas de forrageamento observadas foram classificadas em dois tipos básicos: "apanhando empoleirada", sendo esta mais freqüentemente utilizada, e "adejando para apanhar". Todas as espécies ingeriram os frutos inteiros e nenhum consumidor foi considerado predador das sementes. Exceto por *T. viridis*, de maneira geral os pássaros permaneceram um curto período (< 3 minutes) se alimentando na planta. Estas aves podem ser consideradas como potenciais dispersoras das sementes para locais distantes da planta-mãe. O comportamento de regurgitar as sementes intactas após a retirada do exocarpo que é ingerido foi observado (n = 27) em sete espécies. Cinco espécies (Pipridae e Tyrannidae) limparam o bico após regurgitar, deixando as sementes aderidas ao poleiro onde se encontravam (n = 12), sendo esta uma importante forma de deposição das sementes dessa erva-de-passarinho. Foi registrada in loco a germinação de 23 sementes regurgitadas pelas aves, confirmando a importância das aves na dispersão das sementes destas plantas.
PALAVRAS-CHAVE: erva-de-passarinho, *Struthanthus*, frugivoria, aves.

ABSTRACT. Mistletoes are hemiparasitc plants with seeds dispersed mainly by birds. In Brazil few studies report Loranthaceae fruit consumption by animals. In this study we investigated bird feeding behavior during 80 hours of focal observations, in eight fruiting plants of *Struthanthus concinnus* located in a forest fragment border in Belo Horizonte, Minas Gerais state. Eleven species of Passeriformes from four families [Tyrannidae (6), Emberizidae (3), Pipridae (1) and Vireonidae (1)] were observed consuming fruits of *S. concinnus* in 173 feeding bouts. Five species, *Hylophylus amaurocephalus, Ilicura militaris, Phaeomyias murina, Tersina viridis* and *Piranga flava*, were the most frequent consumers. The bird foraging tactics observed were classified in two basic types: "glean", the most commonly utilized, and "sally". All the species swallow fruits whole and no bird was considered seed predator. Birds, except for *T. viridis*, generally stayed short periods of time (< 3 min) feeding on the plants, being considered as potential dispersers of seeds to farther areas. The regurgitation of intact seeds, after peeling and eating the exocarp, was observed in seven species (n = 27). Five species (Pipridae and Tyrannidae) were observed wiping their bills leaving seeds adhered to perches. This behavior is considered an important seed deposition mode for this mistletoe. We registered *in loco* the germination of 23 regurgitated seeds, which confirms the importance of birds as seed dispersers of this plant.
KEY WORDS: mistletoe, *Struthanthus*, birds, frugivory.

Popularly known as mistletoes, the Loranthaceae embrace hemiparasitic plants with a modified root system, the haustorium, that connects them to the host xylem (Calder 1983). Seed dispersal in these plants is mainly ornithochoric (Davidar 1983, Reid 1989, Sargent 1995, Martínez Del Rio *et al*. 1996, López-de Buen and Ornelas 1999, Restrepo *et al*. 2001). In Neotropical areas common mistletoes genera important for frugivorous birds include *Psittacanthus*, *Oryctanthus*, *Phthirusa*, *Phoradendron* and *Struthanthus* (Snow 1981).

Several authors have reported mistletoe fruit consumption in Neotropical areas (Fitzpatrick 1980, Snow 1981, Restrepo 1987, Ridgely and Tudor 1989, 1994, Sick 1997) but few researchers have described frugivory on Loranthaceae in Brazil. Willis and Oniki (1988) observed that *Iodopleura pipra* feed their nestlings mainly with mistletoe fruits, regularly regurgitating sticky seeds under the nest. Monteiro *et al*. (1992) reported the seed dispersal of *Psittacanthus robustus* in areas of Cerrado vegetation.

According to Rizzini (1956) the genus *Struthanthus* has at least 43 species in Brazil, with new species described since then (Rizzini 1980). In Minas Gerais, it can be found in wild and urbanized areas growing on native, exotic, ornamental and fruiting trees, eventually leading some host plants to death (pers. obs. T.J.G.). Usteri (1906) registered a *Bambusa vulgaris* completely covered by *Struthanthus concinnus*. The consumption of *Struthanthus vulgaris* fruits by three bird species and the black lion tamarin *Leontopithecus chrysopygus* was observed by Hasui and Hofling (1998) and Passos (1999), respectively. However,

we found no specific analyses on fruit consumption or seed dispersal on this species in the literature. In this work we report the feeding behavior of a guild of frugivorous birds that consumes *S. concinnus* fruits in the border of an Atlantic Forest fragment surrounded by Cerrado vegetation.

STUDY AREA

We conducted the study in the Special Protection Areas of Watersheds of Mutuca and Barreiro (19º50'S, 43º50'W) owned by the Minas Gerais State Water Company (COPASA) situated in the Metropolitan Region of Belo Horizonte, Minas Gerais state. The region is located in the transition area between the Atlantic Forest and the Cerrado domains. Climate has a well-defined dry season from April to September, and a rainy season between October and March. Vegetation of the study area is composed by a matrix of disturbed cerrado grassland and rupestrian fields with embedded forest fragments in secondary successional stage (CETEC 1993). The most common plant families in the study area include Asteraceae, Fabaceae, Myrtaceae, Melastomataceae and Caesalpinaceae (CETEC 1993). The genera *Copaifera, Miconia, Cabralea, Trichilia, Rapanea, Ficus, Cecropia* and *Trema,* important for frugivorous birds (Snow 1981, Galetti and Pizo 1996, Hasui and Hofling 1998) are found in the area. For a characterization of part of the local avifauna see Maldonado-Coelho and Marini (2000).

METHODS

We searched for mistletoes along 1800 m of a 200 ha forest fragment border, where eight fruiting individuals of *S. concinnus* were selected for observations. The plants were at least 30 m apart from each other and their infructescences could be easily observed. The study was conducted during April, May, June and July of 2000, apparently during the peak of mature fruits. Focal observations were conducted with a 10 x 50 binoculars between 6:00 and 12:00 in 160 periods of 30 min. totaling 80 hours of observation (10 h/plant). Bird taxonomy and nomenclature followed Sick (1997).

We considered as a visit (V) an individual bird arriving to a plant, even when it was in a group, independently of fruit consumption. We considered a feeding bout (FB) any visitation in which was possible to observe fruit consumption. Time spent on plants, the number of fruits eaten and the ingestion mode were recorded. The feeding frequency (FF) was calculated dividing the total number of feeding bouts for each species by the total number of observation hours. The foraging tactics (FT) were classified in two basic types according to Marini (1995): glean, when a bird removes the fruits while perched in a branch very close to the infructescence; eventually some birds were also able to take fruits while perched up side down (G^{-}). Sally, when from a close perch the bird jumps hovering on the infructescences removing a single fruit and returning to the same or another perch. The regurgitation behavior was registered when birds were still on the plant or very close to it. To determine seed viability, the places they were deposited by birds were marked and germination was followed in the field.

The habitat requirements of consumers were classified in three categories; forest dependent for those birds that are restrict to woods, semi-dependent for those that are observed in woods and also open areas like cerrado vegetation and independent for those that are observed mainly outside forests, based in Ridgely and Tudor (1989, 1994), Sick (1997) and personal observations. Diet of consumers were classified according to Fitzpatrick (1980), Pineschi (1996), Galetti and Pizo (1996), Sick (1997), Hasui and Hofling (1998) and Marini and Cavalcanti (1998).

RESULTS

Struthanthus concinnus bear green ellipsoid berries with conspicuous yellowish color when ripe, which become purple afterwards (figure 1) and are still consumed by birds. Its fruits are 6.88 ± 0.35 mm long and 4.95 ± 0.23 mm wide; the weight of the whole fruit is 0.09 ± 0.01g and the exocarp without seed is 0.04 ± 0.006g (n = 30), respectively. The single seed is nude and green, with two cotyledons enlarged in the apex in an adhesive disk. Seeds are involved by a sticky tissue that adheres them to the bill and branches after released by birds.

Feeding frequency. Twenty-eight bird species were observed in 246 visitations, but only 11 Passeriformes species from four families were actually recorded consuming fruits in 173 feeding bouts (table 1). The most frequent consumers were *Hylophilus amaurocephalus* (FF = 0.63), followed by *Ilicura militaris* (FF = 0.41). Six Tyrannidae, all from Elaeniinae sub-family, were observed feeding (n = 51) (table 1), but only *Phaeomyias murina* was a frequent consumer (FF = 0.31). Three Emberizidae were registered, but only *Tersina viridis* (FF = 0.30) and *Piranga flava* (FF = 0.16) were considered frequent consumers.

Seed ingestion and release. All bird consumers were observed ingesting fruits whole, without damaging the seeds and no bird could be considered a seed predator. "Glean" was the most common foraging tactic utilized by all bird consumers. Fruit consumption rate per species is in table 1. Time average spent in feeding bouts was generally short (< 3 minutes) for almost all birds, except for *T. viridis* which stayed in the plants for long periods of time.

Figure 1. Ripe fruits of *Struthanthus concinnus*: yellowish ones (white) and purple (black), approximately 5x real size.

Table 1. Bird feeding behavior in eigth fruiting plants of *Struthanthus concinnus* (Loranthaceae).

Species	NV	NPV	FB	FF	Forage tatic			Fruit consumption per FB				Time spent in FB		Regurgitation		Diet	Habitat
					Glean	G↓	Sally	Max	Aver	SD	Min	Aver	SD	Wipe	Dropp		
Saltator similis	2	1	1	0.01	1			5			5					I	A
Tersina viridis	24	2	24	0.30	24	1		20	9.8	6.0	1	600	528		13	I	B
Piranga flava	16	2	13	0.16	13			6	2.8	1.6	1	78	28			III	B
Camptostoma obsoletum	7	5	5	0.06	5		3	6	3.8	1.7	1	84	32	1		II	C
Elaenia flavogaster	11	2	5	0.06	5			8	4.8	2.2	2	96	32			I	C
Mionectes rufiventris	8	4	8	0.10	7		6	6	4.2	1.5	2	90	31			II	A
Phaeomyias murina	31	7	25	0.31	24		1	10	3.8	2.0	2	98	54	5		I	C
Phyllomyias fasciatus	7	4	7	0.08	7		3	4	2.8	0.7	2	85	31	1		I	A
Phylloscartes ventralis	1	1	1	0.01	1			6			6			1		II	C
Ilicura militaris	36	6	33	0.41	33	2	6	20	5.9	3.7	1	152	148	4		III	A
Hylophylus amaurocephalus	60	8	51	0.63	51	3	2	11	5.0	2.7	1	116	52		2	III	A

(NV) Number of visits, (NVP) Number of visited plants, (FB) Feeding bouts, (FF) Feeding frequency (FB/80 h), (1) Time spent in FB in seconds, (I) Mainly frugivorous, II = Feeds on insects and fruits, (III) Poorly known diet but probably frugivorous; (A) Forest dependent, (B) Forest semi-dependent, (C) Forest independent.

Regurgitation behavior was recorded (n = 27) for seven bird species. They removed the edible exocarp regurgitating seeds involved in a lacteous and sticky tissue, which sometimes (n = 17) got adhered to the birds bills. *Ilicura militaris* (n = 4) and four flycatchers (n = 8) were observed wiping their bills leaving the seeds attached to perches (table 1). *Tersina viridis* regurgitated seeds dropping them on leaf surfaces under the parent plant (n = 8). When a

regurgitated seed adhered to its bill, *T. viridis* expelled it not by bill wiping, but with abrupt movements of the head (n = 5). *Hylophylus amaurocephalus* were observed dropping the regurgitated seeds under the parent plant (n = 2).

Twenty-three out of 27 regurgitated seeds were found and marked, of which 12 were on branches and 11 over leaves surfaces, some of them on branches and leaves of the parent plant. All seeds were intact (n = 23) and started to germinate between three to five days after they were expelled by birds.

DISCUSSION

According to Snow (1981) epiparasites and epiphytes seem to have their own set of avian dispersers, which are more or less specialized for such fruits. Restrepo *et al*. (2001) analyzing the degree of association between New World mistletoes and vertebrates concluded that seed dispersal in Lorantaceae is endozoocoric and their dispersers are passerines, mainly from Cotingidae, Tyrannidae, Pipridae, Emberizidae and Vireonidae families. They recorded *Zimmerius villissimus, Piranga flava, Mionectes olivaceus*, *Vireo* sp., *Myiozetetes similis* and *Columba subvinacea* as consumers of *Struthanthus oerstedii* in Costa Rica. Leck (1972) observing another mistletoe, *Oryctanthus occidentalis*, in Barro Colorado island, Panama, registered 13 species of birds from five families [Emberizidae (5) including *Piranga rubra*, Tyrannidae (4) including *Mionectes oleaginea*, Vireonidae (2), Pipridae (1) and Columbidae (1)] feeding on its fruits. Our data seems to corroborate Restrepo *et al*. (2001) hypothesis which states that vector-mistletoe local assembleges in Neotropics are likely reflecting a long-term history of associations.

Hasui and Hofling (1998) observed three common passerines *Turdus rufiventris, Pitangus sulphuratus* and *Tyrannus melancholicus* feeding on *Struthanthus vulgaris* in São Paulo state. Sick (1997) suggests that *Antilophia galeata* (Pipridae) consumes *Psittacanthus robustus*, which, according to Monteiro *et al*. (1992), is also consumed by three tanagers: *Thraupis sayaca*, *Schistoclamys ruficapillus* and *T. viridis*.

Border habitats allowed us to observe consumers with different habitat requirements. Two of the most frequent consumers, *H. amaurocephalus* and *I. militaris*, are forest birds while *P. murina* is more easily found in open areas and forest borders (Ridgely and Tudor 1989, 1994, Sick 1997), *T. viridis* is also found in forests, as well as open and even urban areas (Sick 1997).

Hylophylus amaurocephalus was recently confirmed as a valid species (Raposo *et. al.* 1998) and its natural history is still poorly known. It was the most frequent consumer and those fruits could be an important item in its diet, at least in the dry season. According to Sick (1997), the Vireonidae feed mostly on insects, but they also eat small fruits which can be more consumed than insects in species such as *Hylophylus poicilotis*. Leck (1972) also observed two *Vireo* species consuming *O. occidentalis* fruits.

Ilicura militaris is a Brazilian endemic forest species with poorly known diet (Sick 1997), which might be rightly frugivorous like other manakins. It is a forest bird and was a frequent consumer of *S. concinnus* fruits. Leck (1972) observed that *Manacus vittelinus* (Pipridae) was an irregular consumer of *O. occidentalis*.

Fitzpatrick (1980) reports that *Phaeomyias* and *Phyllomyias* feed mostly on small berries during the whole year, especially of Loranthaceae that they take using perch-and-sally gleaning techniques, although no plant species is mentioned by the author. *Elaenia* and other related species can also be considered partially frugivorous according to Pineschi (1990) and this study. Leck (1972) observed four tyrant flycatchers feeding frequently on *O. ocidentalis*, three belonging to the Elaeninae subfamily. The author suggests that they regurgitate seeds some time after ingesting them, but does not mention bill wiping behavior. Marini and Cavalcanti (1998) studying the diet of seven species of *Elaenia* registered the consumption of only one mistletoe (*Tristerix*) by *Elaenia albiceps*.

According to Davidar (1983) the seeds of mistletoes are deposited in the branches of the hosts in two different ways in relation to the fruit structure. In species with hard exocarp as *Phoradendron*, dispersed mainly by *Euphonia* and *Clorophonia* (Sargent 1995, Restrepo *et al*. 2001), the exocarp is removed by mandibulation, dropped away, and the ingested seeds are defecated intact in viscous masses. In other plants, the digestible exocarp is easily separated from the seed that is regurgitated singly as it happens in *Oryctanthus* and *Psittacanthus* (Leck 1972, Davidar 1983, Monteiro *et al*. 1992). The mode birds release seeds of *S. concinnus* must be classified in the second group. Due to the similarity of fruit and seed structure among the plants in this genus (Rizzini 1995) the same pattern of seed deposition can be predicted for other species of *Struthanthus*. Davidar (1983) also suggests that mistletoes with seeds dispersed by defecation are considered more specialized and their seed dispersal is associated with a narrow range of bird dispersers that belong to a few taxa, as observed latter by Reid (1989), Sargent (1995) and Martinez Del Rio *et al.* (1996). According to Monteiro *et al*. (1992) plants with seeds dispersed by regurgitation and bill wiping are considered to be less specialized and are associated with a larger assemblage of bird dispersers. Although seed dispersal was not fully studied in this work, our data seem to agree with these conditions.

Differences in fruit handling and seed deposition mode by birds depend on fruit and seed size and these behaviors have important consequences for seed dispersal (Levey

1987). All birds ingested the fruits whole without damaging the seeds, even the three Emberizidae species considered seed mashers by Levey (1987). Only seven species were observed regurgitating seeds, although other consumers might also do the same.

Mistletoes are plants with very specific requirements for seed dispersal because seeds must be placed onto host branches to have any chance of establishment (Sargent 1995). *Hylophylus amaurocephalus, I. militaris, P. murina* and *T. viridis* were the most frequent consumers, but our data suggests that they differ in the quality of dispersed seeds because they present differences in feeding and regurgitation behavior and also differences in habitat requirements. *Ilicura militaris, P. murina, P. fasciatus, P. ventralis* and *C. obsoletum* were observed wiping their bills on perches where seeds adhered. Once perched in a appropriate host the seed deposition behavior of these birds must be important for seedling establishment and must be better investigated in future studies of seed dispersal in this genus.

Data on establishment and survival of dispersed seeds and seedlings are important for determining differences in disperser efficiency and effectiveness (Reid 1989). According to Pratt and Stiles (1983) those species that stay shorter periods on plants could actuate positively for long distance seed dispersal, as was the case for all birds but *T. viridis* in this study. The number of regurgitations registered for *T. viridis* must be related to its long periods feeding on plants. The low total number of regurgitation events registered did not allow a detailed analysis of seed germination rates or quality of deposition sites. However, they indicate that a small amount of the ingested seeds is released close or on the host plant. The observation of regurgitated seeds germinating *in loco* confirms that being ingested and released by birds is important for *S. concinnus* seed dispersal.

There are many other aspects to consider in the seed dispersal system of mistletoes such as: host specificity (Monteiro *et al*. 1992), host infection susceptibility and host selection by avian consumers (López-de Buen and Ornelas 1999), deposition site quality (Sargent 1995) and density-dependent mortality of sister seeds (Davidar 1983). Many questions about the interactions among birds and these plants must be better investigated in the future due to the ecological importance of parasites in natural plant communities (Gilbert and Hubbell 1996).

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