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Frugivory by birds in *Myrsine coriacea* (Myrsinaceae) inhabiting fragments of mixed Araucaria Forest in the Aparados da Serra National Park, RS, Brazil

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RESUMO: Frugivoria por aves em *Myrsine coriacea* (Myrsinaceae) em fragmentos de habitat de Floresta de Araucária no Parque Nacional dos Aparados da Serra, RS, Brasil. *Myrsine coriacea* (Ruiz e Pav.) Mez (Myrsinaceae), popularmente conhecida como "capororoca", produz muitos frutos pequenos, globosos e com pericarpo fino de coloração negro-arroxeada quando maduros. Este trabalho realizado no Parque Nacional dos Aparados da Serra teve por objetivo identificar as espécies de aves que utilizaram os espécimes de *M. coriacea,* principalmente para o consumo de seus frutos, em áreas com diferentes tamanhos. Foram registradas 31 espécies de aves, sendo que 23 consumiram frutos. As espécies *Tangara preciosa, Cyclarhis gujanensis, Leucochloris albicollis e Zonotrichia capensis* utilizaram a planta somente para pouso e *Colaptes campestris, Xiphorhyncus fuscus, Leptasthenura setari* e *Xenops rutilans* utilizaram a planta a procura de insetos. O tamanho das áreas e a variação mensal não interferiram na riqueza de aves que visitaram a planta, nem no número de eventos registrados para o consumo de frutos, pouso e captura de insetos. Os frutos de *M. coriacea* foram amplamente consumidos por aves e as sementes poderiam ter sido potencialmente dispersadas pelas mesmas, assim contribuindo para a manutenção e regeneração dos fragmentos de floresta tropical, presentes no PNAS.

PALAVRAS-CHAVE: Floresta com Araucária, aves, frugivoria, *Myrsine coriacea.*

ABSTRACT: *Myrsine coriacea,* known as "capororoca", produces a large number of small, round fruits, with a thin pericarp and dark purple colours when ripe. The objective of the present study was to identify bird species using *M. coriacea* for the consumption of fruit and insects or for perching alone in the Aparados da Serra National Park (Brazil). Thirty-one bird species were recorded, among which 23 consumed fruits. The species of birds *Tangara preciosa, Cyclarhis gujanensis, Leucochloris albicollis,* and *Zonotrichia capensis,* the plant used only for landing and *Colaptes campestris, Xiphorhyncus fuscus, Leptasthenura setari* and *Xenops rutilans* used the plant to search for insects. Fragment area size and monthly variation did not affect the diversity of birds that visited the tree or the number of events recorded for each type of behaviour. The fruits of *M. coriacea* were largely consumed by birds and the seeds could have been potentially released by them, thus contributing to the maintenance and regeneration of fragments of tropical forest, in the PNAS.

KEY-WORDS: Araucaria forest, birds, frugivory, *Myrsine coriacea.*

The family Myrsinaceae is distributed throughout the entire southern hemisphere, with approximately 30 genera and more than 1000 species (Mez 1959). This family is represented by tall and small trees alike, with alternate leaves concentrated at the extremity of branches, thereby exposing the fruit agglomerate, which is an abundant feeding source for birds. It is common for a single branch to accommodate more than 100 fruits (Pineschi 1990).

The fruits are small and round, with succulent pulp. They generally have a single seed and very thin pericarp, which has a dark purple colour when ripe (Mez 1959, Barroso 1999). Some *Myrsine* species fructify from summer to mid autumn and can even bear fruit twice a year (Reitz 1988, Barroso 1999), with variations between regions (Irgang and Backes 2002). *Myrsine coriacea* (Sw.) is one of most important native fructiferous trees in the flora of southern Brazil, as much for its relationship with fauna as its importance to forest regeneration (Backes and Irgang 2002).

A number of studies carried out throughout the neotropics have recorded the interaction between Myrsinaceae species and birds. Studying the diet of *Pharomachrus mocinno* (Trogonidae) in Mexico, Ávila *et al.* (1996) recorded the consumption of fruit from *Ardisia compressa.* In Costa Rica, Wheelwright *et al.* (1984) recorded 19 bird species consuming fruit from three Myrsinaceae species. In Brazil, studies conducted by Hasui and Höfling (1998) involving a number of tree species in Brazil recorded five bird species that consume *Myrsine* fruit and

Pizo (2004) recorded the consumption of fruit from *Myrsine umbellata* by several bird species.

Avian ecology studies have recorded four cotinga species (Cotingidae) consuming the fruit of *Myrsine coriacea* and *Myrsine lancifolia* (Pizo *et al.* 2002); *Bailonius bailloni* (Ramphastidae) consuming *Rapanea ferruginea* fruit (Galetti *et al.* 2000); and *Pipile jacutinga* (Cracidae) consuming *Rapanea umbellata* and *R. ferruginea* fruit (Galetti *et al.* 1997, Galetti *et al.* 2000). Franscisco and Galetti (2001) studied frugivory and seed dispersal in *Myrsine lancifolia* and found 11 bird species as potential dispersers. Pineschi (1990) studied seed-dispersing birds for seven species of *Rapanea* and recorded 104 species consuming fruits, of which 60 species were potential dispersers.

Myrsine sp. fruit is consumed by birds of all sizes and according to Carvalho (1994) and Backes and Irgang (2002), *Myrsine* seeds exhibit dormancy caused by the endocarp, but can easily germinate in any kind of soil after passing through the digestive trait of an animal. Therefore, fauna feeding on the fruit is also important to the life cycle of Myrsinaceae species.

The aim of the present study was to identify birds associated to *Myrsine coriacea* and investigate their behaviour in order to answer the following questions: (i) Do birds use *M. coriacea* preferentially for fruit consumption? (ii) Does the size of a fragment of forest influence the number of bird species using *M. coriacea* and the frequency of use categories? (iii) Does bird behaviour on the trees influence the number of bird species using *M. coriacea?* (iv) Does bird behaviour on the trees influence the number of visit events? The potentiality of birds as seed dispersers was also evaluated.

METHODS

Data collection was performed in the Aparados da Serra National Park (ASNP). Three fragments of Mixed Araucaria Forest approximately 20 ha in size, classified as small fragments (P1, P2 and P3), and three fragments approximately 200 ha in size, classified as large fragments (G1, G2 and G3), were selected. A total of six individuals of *M. coriacea* were selected, corresponding to one individual per fragment. The individuals were located at borders or clearings.Three individuals were approximately 13 m high and the other three were approximately 4 m high, distributed randomly by fragments.

The identification of the species from the genus Myrsine was performed by collecting samples and performing exsiccates for comparisons to material from the Anchietan Herbarium of the Vale do Rio dos Sinos University. Authors were also consulted as Barroso 1999 and Backes and Irgang 2002, for example.

In the month of July 2004 were the first search field to individuals of *M. coriacea,* but they did not have fruit yet. Some individuals exhibited initial indications of fructification in August, but only in November 2004 when all six individuals were with fruit, began the remarks, which extended to the month of February 2005.

Varying quantities of fruit were found in both immature and ripe stages within the same tree. Two random observations per month were made for each individual, totalling 96 hours of observation. The sampling effort was the same per day periods (6 am to 7 pm). Each observation spended two hours a day, comprising four hours per month for each individual of *M. coriacea.*

Observations were performed with the use of 10 x 40 mm binoculars. For bird identification *in locus,* field guides by Narosky and Yzurieta (1987) and De La Peña and Rumboll (1998) were employed. The following data were sampled: species of each bird observed on the plant species; bird behaviour (fruit consumption, insect consumption and perching); number of visiting birds; time and visiting duration (measured by chronometer); visiting pattern (the manner in which the bird reached the tree: individually, by pairs, in mono-specific or mixed flocks), agonistic encounters (intraspecific and interspecific); and whether visits were complete (when the bird was seen flying in coming, if not of food or fruit and / or insects and when he left) or incomplete (when just part of the visit could be followed) according to Krügel *et al.* (2006), when we were unable to view all the activity of the bird (due to factors such as the limitation of binoculars focus or sunlight, for example).

Visiting birds were classified into different feeding guilds, as described in Sick (1997) and Azpiroz (2001), as frugivorous (FR, diet predominantly of fruit, vegetables and occasionally invertebrates), granivorous (GR, diet based on grains), nectarivorous (NC, diet based on nectar and occasionally small invertebrates), insectivorous (IN, diet exclusively based on invertebrates) and onivorous (ON, diet including fruit, invertebrates and small vertebrates).

The observation of frugivorous species included the recording of fruit consumed, collection behaviour and fruit ingestion treatment. Collection behaviour was classified according to descriptions by Moermond and Denslow (1985): Stalling (S): the bird flies toward the fruit and plucks it without stopping; Hovering (Hv): the bird stops in the air in front of the fruit; Picking (P): the bird collects the fruit next to its perch without stretching or assume a special position; Reaching (R): the bird stretches out its body to pluck the fruit; Hanging (Hg): entire body and legs are under the perch, with the ventral side facing upward. Fruit ingestion treatments were classified into Swallowing (when the fruit is swallowed whole); Mashing (when the bird macerates or grinds the fruit with its jaws before ingesting); Pecking (when the

bird pecks the fruit with its beak, pulling out portions of it).

Factorial ANOVA was used to evaluate bird behaviour, taking into account the size of the forest area, species richness and number of events. Kruskal-Wallis was applied to compare the richness of birds visiting *M. coriacea* in different forest fragments. Repeated Measures ANOVA was applied to assess the variation in richness between months according to the size of the area.

RESULTS

Thirty-one bird species were recorded visiting the *M. coriacea* individuals, among which 23 species consumed fruits; 18 also used the tree for perching and five also foraged, capturing invertebrates. Considering species richness (F = 7.536; df = 2.12; P = 0.008) and the number of events for each behaviour (F = 6.809; df = 2.12; P = 0.011), the birds preferentially used the tree for fruit consumption. The interaction between bird behaviour and area size did not affect species richness or the number of events recorded for each behaviour (F = 1.488; df = 2.12; P = 0.265 and F = 1.291; df = 2.12; P = 0.310, respectively) (Figure 1 and 2).

Among the birds visiting *M. coriacea,* nine species were only observed in large areas, eight were only seen in small areas and another 14 were recorded in both area sizes. Area size (F = 0.062; df = 3.12; P = 0.979), variation between months from November to February (F = 3.5; df = 1; P = 0.658) and the interaction of these factors (F = 0.639; df = 3.12; P = 0.604) did not affect species richness of birds visiting *M. coriacea* (Figure 3 and 4).

74.2% of the birds recorded (23 species) were classified as insectivorous and, despite feeding basically on invertebrates, 82.6% of these (19 species) also consumed fruits, whereas 17.4% (four species), namely *Colaptes campestris, Xiphorhyncus fuscus, Leptasthenura setaria* and *Xenops rutilans,* consumed only insects. The frugivorous guild represented 12.9% of the total. 75% of this guild (four species) consumed fruit; *Tangara preciosa* is a species within this guild, but did not consume fruit. The omnivorous guild represented 6.5% of the total (two species): *Cyclarhis gujanensis,* which was only observed perching; and *Cyanocorax caeruleus,* which consumed fruit. The granivorous and nectarivorous guilds each represented 3.2% of the total, each with one species, respectively, *Zonotrichia capensis* and *Leucochloris albicollis* (Table 1).

A total of 348 visits were recorded, 31, 03% (108 visits) of which were complete, 60.34% (210) were incomplete and 8.63% (30) were of pairs or flocks reaching the tree, which were not accompanied. 284 visits were made by birds arriving to the tree individually, 26 by birds in pairs, four by mono-specific flocks and four by mixed flocks. For complete visits, fruit consumption totalled 64 visits (60%); perching totalled 36 visits (34%); and

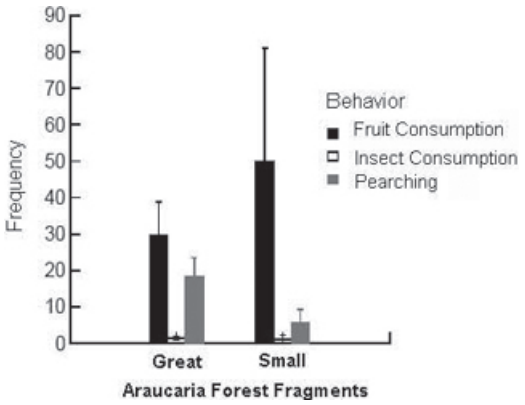

FIGURE 2: Frequency of fruit consumption, insect consumption and perching in different sizes of Araucaria Forest fragments.

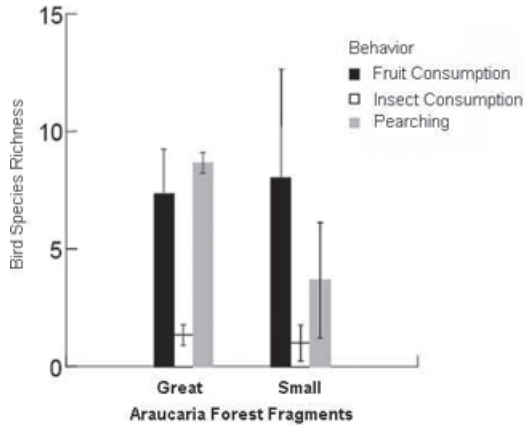

FIGURE 1: Bird species richness regarding fruit consumption, insect consumption and perching in different sizes of Araucaria Forest fragments.

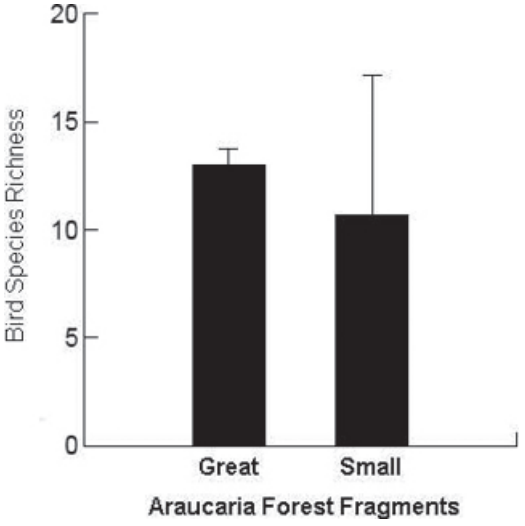

FIGURE 3: Species richness of birds visiting *Myrsine ferruginea* in different sizes of Araucaria Forest fragments.

TABLE 1: Bird species guilds that visited *Myrsine coriacea* (FR: frugivorous, GR: granivorous, NC: nectarivorous, IN: insectivorous, ON: omnivorous). The systematic ordination is based on the Brazilian Committee of Ornithology (CBRO 2007).

	FR	GR	NC	IN	ON
APODIFORMES Peters, 1940					
TROCHILIDAE Vigors, 1825					
TROCHILINAE Vigors, 1825					
Leucochloris albicollis (Vieillot, 1818)			X		
PICIFORMES Meyer e Wolf, 1810					
PICIDAE Leach, 1820					
Picumnus nebulosus Sundevall, 1866				X	
Veniliornis spilogaster (Wagler, 1827)				X	
Piculus aurulentus (Temminck, 1821)				X	
Colaptes campestris (Vieillot, 1818)				X	
PASSERIFORMES Linné, 1758					
TYRANNI Wetmore e Miller, 1926					
FURNARIIDA Sibley, Ahlquist e Monroe, 1988					
FURNARIOIDEA Gray, 1840					
DENDROCOLAPTIDAE Gray, 1840					
Xiphorhynchus fuscus (Vieillot, 1818)				X	
FURNARIIDAE Gray, 1840					
Leptasthenura setaria (Temminck, 1824)				X	
Xenops rutilans Temminck, 1821				X	
TYRANNIDA Wetmore e Miller, 1926					
TYRANNIDAE Vigors, 1825					
ELAENINAE Cabanis e Heine, 1856					
Elaenia sp.				X	
Elaenia flavogaster (Thunberg, 1822)				X	
Elaenia parvirostris Pelzeln, 1868				X	
Elaenia mesoleuca (Deppe, 1830)				X	
Phylloscartes ventralis (Temminck, 1824)				X	
FLUVICOLINAE Swainson, 1832					
Knipolegus cyanirostris (Vieillot, 1818)				X	
Knipolegus lophotes Boie, 1828				X	
TYRANNINAE Vigors, 1825					
Pitangus sulphuratus (Linnaeus, 1766)				X	
Myiodynastes maculatus (Statius Muller, 1776)				X	
Empidonomus varius (Vieillot, 1818)				X	
Tyrannus melancholicus Vieillot, 1819				X	
PASSERI Linné, 1758					
CORVIDA Sibley, Ahlquist e Monroe, 1988					
VIREONIDAE Swainson, 1837					
Cyclarhis gujanensis (Gmelin, 1789)					X
Vireo olivaceus (Linnaeus, 1766)				X	
CORVIDAE Leach, 1820					
Cyanocorax caeruleus (Vieillot, 1818)					X
PASSERIDA Linné, 1758					
TURDIDAE Rafinesque, 1815					
Platycichla flavipes (Vieillot, 1818)				X	
Turdus rufiventris Vieillot, 1818				X	
Turdus albicollis Vieillot, 1818				X	
THRAUPIDAE Cabanis, 1847					
Thraupis sayaca (Linnaeus, 1766)	X				
Stephanophorus diadematus (Temminck, 1823)	X				
Pipraeidea melanonota (Vieillot, 1819)	X				
Tangara preciosa (Cabanis, 1850)	X				
EMBERIZIDAE Vigors, 1825					
Zonotrichia capensis (Statius Muller, 1776)		X			
PARULIDAE Wetmore, Friedmann, Lincoln, Miller, Peters, Van Rossem, Van Tyne e Zimmer, 1947					
Basileuterus culicivorus (Deppe, 1830)				X	
Total	4	1	1	21	2

foraging along the trunk to capture invertebrates totalled six visits (6%). For incomplete visits, fruit consumption was observed in 172 visits (81, 9%), perching in 38 visits (18, 1%) and no foraging was recorded.

Elaenia flavogaster, Elaenia parvirostris, Elaenia mesoleuca and *Elaenia* sp. accounted for 64.3% (205) of the visits, followed by *Turdus rufiventris* and *Vireo olivaceus,* with 5.3% and 5% (17 and 16, respectively), and *Stephanophorus diadematus,* with 3.8% (12). A total of 1209 fruits were removed. *T. rufiventris, Turdus albicollis, Myiodinastes maculatus* and *Veniliornis spilogaster* were the species that consumed the largest amount of fruit per visit

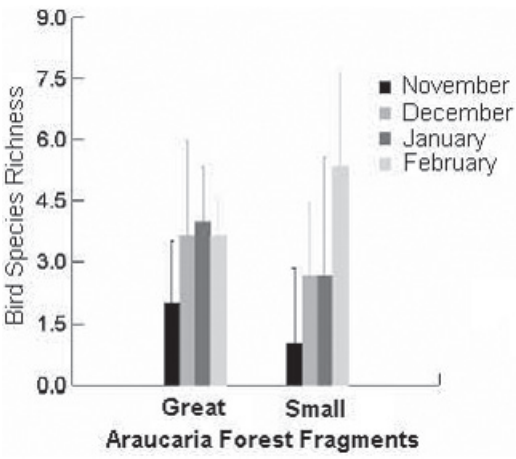

FIGURE 4: Species richness of birds visiting *Myrsine ferruginea* from November 2004 to February/2005 in different sizes of Araucaria Forest fragments.

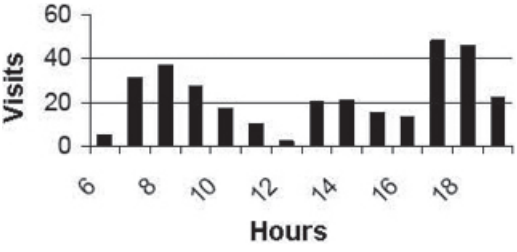

FIGURE 5: Frequency of visits to *Myrsine ferruginea* according to time of day.

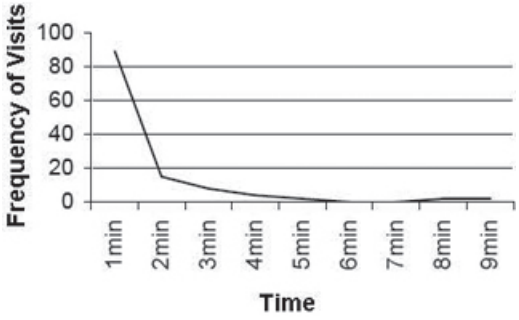

FIGURE 6: Duration of visits by birds to *Myrsine ferruginea.*

(25 to 45). Among these species, *V. spilogaster* was the only one to visit the tree just once.

Elaenia were also the most representative species in fruit consumption, accounting for approximately 53.9% (652) of the total, followed by *T. rufiventris* with 14.4% (174), *V. olivaceus, M. maculatus* and *T. albicollis,* which each consumed 4% of the fruits (48).

Fruit collection and ingestion behaviour was recorded for the 23 bird species that consumed *M. coriacea* fruits. The Picking (P) collection behaviour was common to all species, followed by Hanging (Hg) by 52, 17% of these birds (12). Stalling (S) was performed by 39.13% (9), while Hovering (Hv) and Reaching (R) were performed by 21, 74% (five) these bird species.

Piculus aurulentus, Knipolegus lophotes, Empidonomus varius, Tyrannus melancholicus, Platycichla flavipes, Thraupis sayaca, Pipraeidea melanonota, Basileuterus culicivorus and *C. caeruleus* were the species of birds that had only one way (Picking) to collect the fruits of *M. coriacea.* Already the species *E. flavogaster* and *M. maculatus* were recorded collecting the fruits of all types in the study.

Elaenia species and *M. maculatus* exhibited all fruit collection and ingestion behaviours. The ingestion treatment of swallowing the fruit whole was the only behaviour observed among the birds (100%) that consumed *M. coriaceae* fruits. There was one observation recorded of *S. diadematus* and *V. olivaceous* arranging the fruit on the beak before ingestion.

Once, two fruits fell from the beak of a young individual of *S. diadematus.* Three birds (*Elaenia* sp., *S. diadematus* and *T. albicollis*) were seen defecating on the mother plant while feeding on *M. coriacea* fruits and no bird was recorded regurgitating. Peak activity was from 7 to 9 am and from 5 and 6 pm, with 47 visits.

The periods of the day of increased activity of birds in specimens of *M. coriacea* were between seven am and 12:00, with approximately 32 visits, and between 17:00 and 18:00 hours, with approximately 47 visits to the observation period of two hours per day (Figure 5).

The residence time of birds in *M. coriacea* varied. Visits were recorded from birds with less than a minute, even with consumption of fruits, and visits with up to nine minutes in duration, with only the landing, for example (Figure 6).

Agonistic behaviors were recorded 20 encounters between the birds (6.3%) in visits to individuals of *M. coriacea.* For complete visits, four intra-specific agonistic encounters were recorded for *Elaenia* sp.; three for *E. flavogaster;* and two for *E. parvirostris.* Only one interspecific agonistic encounter was recorded between *Zonotrichia capensis* and *S. diadematus,* in which *Z. capensis* drove *S. diadematus* away from its perch. For incomplete visits, seven intra-specific agonistic encounters were recorded for *Elaenia* sp. and three for *E. flavogaster.*

DISCUSSION

Area size and its degree of isolation influence species richness and abundance, as well as the colonisation, evolution and persistence of species in a habitat (MacArthur and Wilson 1967, Saunders *et al.* 1991, Andrén 1994, Turner 1996). Other important factors are the layout of the remaining forest fragments and how surrounding areas are used (Saunders *et al.* 1991, Rodewald 2003). There have been an increasing number of studies quantifying these effects on bird communities in recent decades (Moore and Hooper 1975, Galli *et al.* 1976, Leck 1979, Robbins 1980, Blake and Karr 1984, Lynch and Whigham 1984, Harper 1989, Wilcove and Robison 1990, Soulé *et al.* 1992, Thiollay 1992, Hamel *et al.* 1993).

The Rain forest has significant importance in the joint history of occupation of the south, not only the territorial extension that was, but mainly by the economic value it represented for nearly a century (Klein, 1985). Different sizes of Araucaria Mixed Forest fragments in the present study are the result of both natural processes of evolution and human interference. According to Pillar and Quadros (1997), soil water availability may be a limiting factor to forest expansion, thereby explaining the predominance of grassland vegetation in the region. However, the grasslands form a matrix among the forest fragments, which exhibit very similar flora and fauna richness, despite the distances between them. This indicates that differences in size and distance are not determinant factors for plant and animal dispersal in this system. It is possible that the local particularities neutralise the effect of area size on the species richness of frugivorous birds. It is important to point out that the bird species recorded are altered environment species and no specialist species were recorded. Therefore, there is a need to conserve and even restore the fragments.

Elaenia species were the most representative regarding both number of visits and fruit consumption, but are generally considered insectivores. In a diet study on this genus, Marini and Cavalcanti (1998) discuss its position in the insectivore guild and conclude that five *Elaenia* species are highly frugivorous and consume fruit throughout the year. Foster (1987) and Poulin *et al.* (1994) also cite species from this genus with high fruit consumption rates. Marini and Cavalcantti (1998) consider *Elaenia* generalists with regard to the type of fruit, as they consume diverse sizes, forms and colours of fruits, often from Myrsinaceae, Moraceae and Melastomataceae. Franscisco and Galetti (2001) also indicate the genus *Elaenia* as having the greatest relative percentage of fruit consumption.

According to Schupp (1993), dispersal efficiency is measured by the following factors: the way fruit is handled before ingestion, the length of time birds stay on the plant, the number of visits they perform, whether the birds defecate on the mother plant, etc. The present study found that all *Elaenia* species consumed the fruit whole, without mashing it. Marcondes-Machado (2002) recorded similar behaviour for these species on *Miconia rubiginosa* (Melastomataceae). This bird genus remained a short time on the plant, performed a greater number of visits and was only observed defecating once while feeding on *M. coriacea* fruits. Based on these factors, *E. flavogaster, E. parvirostris, E. mesoleuca* and *Elaenia* sp. can be considered probable potential dispersers of *M. coriacea* fruits in the ASNP.

Three Emberezidae species from the frugivorous guild were recorded consuming *M. coriacea* fruit. These species swallowed the fruit whole, which may be related to the small size of the fruit and the thin pericarp (Mez 1959). According to Snow (1981), the frugivorous vertebrate diet can be described as either specialised or generalised, depending upon the size and nutritional value of the fruits and seeds offered by plants. Fruits and seeds consumed by generalist species are typically small and have very low nutritional value, thereby demonstrating the close association between plants and dispersers. *Platycichla flavipes, T. rufiventris* and *T. albicollis* (Muscicapidae) also swallowed *M. coriacea* fruit whole and similar behaviour for these species has been observed in *Rapanea* (Myrsinaceae) by Pineschi (1990).

Aggressiveness was greater among individuals of the same species, which has also been observed in other frugivory studies (Leck 1969, Cruz 1974, Foster 1987). *Elaenia* sp. performed the highest number of agonistic encounters, which was also observed in *R. lancifolia* by Franscisco and Galetti (2001), who state that intraspecific and interspecific agonistic encounters are a negative factor to the dispersal process, but in small numbers do not seem to constitute a determinant factor.

M. coriacea is a pioneer and abundant species in the edges of clearings and patches of Araucaria Mixed Forest in ASNP (Snow 1976, Howe 1993). The fragment structures of the forest patches, however, did not impede the birds to dislodge among patches and disperse the seeds. In this exchange that occurs between the trees, which provide the fruit (a nutritional content in the form of a fleshy pericarp (Snow 1981, Van der Pijl 1982, Coates-Estrada and Estrada 1988)), and birds, that can consume fruits and disperse their seeds to far from mother-plants, the rates of plant populations are enhanced, rates of seedlings predation and competition among adult plants are reduced (Janzen 1970 and Connell 1971). Many studies show that frugivory by birds and other various animals may be important for the management plans and recovery in tropical forests (Howe 1984).

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