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Article

Bird visits and resource use in *Butia odorata* (Arecaceae) palm groves in southern Brazil

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ABSTRACT. We evaluated avian use of a palm grove of *Butia odorata* (Barb. Rodr.) Noblick in the Brazilian Pampa. We recorded bird species richness, frequency of visits, and feeding behavior in palms trees with different flower and fruit availability. From January 2018 to February 2019, we observed 1,094 bird visits in 347 palm trees and identified 53 species. The most frequent visitors were *Sicalis flaveola* (Linnaeus, 1766), *Myiopsitta monachus* (Boddaert, 1783) and *Zonotrichia capensis* (Statius Muller, 1776). Perching was the most frequent use of palm trees by the birds (79%). Our hypothesis that an increase in the availability of flowers and fruits will be followed by a larger number of visits by insectivorous and frugivorous birds was not corroborated. In addition, there was a higher number of species visiting palm trees with no resources. The species composition and the number of guilds of visiting birds varied seasonally, but independently from resources availability. Bird richness, number of visits, and time length of visits did not vary between flowering/fruiting and resourceless palm trees. Based on this we argue that the main contribution of *Butia odorata* to the establishment of bird assemblages in palm groves is their role in offering perching, sheltering, and nesting sites.

KEYWORDS. Ecological interaction, frugivory, palm grove, avifauna.

RESUMO. Visitas de pássaros e uso de recursos em palmares de *Butia odorata* (Arecaceae) no sul do Brasil. Avaliamos as visitas das aves nas palmeiras *Butia odorata* (Barb. Rodr.) Noblick. em um palmar localizado no Pampa brasileiro. Registramos as espécies de aves, a frequênc ia de visitas, e seu comportamento alimentar em palmeiras com diferentes disponibilidades de flores e frutos. Entre janeiro de 2018 e fevereiro de 2019 observamos 1.094 visitas em 347 palmeiras e registramos 53 espécies de aves. As visitas mais frequentes foram feitas por *Sicalis flaveola* (Linnaeus, 1766), *Myiopsitta monachus* (Boddaert, 1783) e *Zonotrichia capensis* (Statius Muller, 1776). O principal uso das palmeiras foi o uso como poleiro (79%). Nossa hipótese de que o aumento de oferta de flores e frutos seria acompanhado por um maior número de visitas de aves insetívoras e frugívoras não foi corroborada. Além disso, houve um maior número de espécies visitando as palmeiras sem recursos do que as com recursos. A riqueza de espécies, o número de visitas, bem como a duração das visitas não variaram entre as palmeiras com e sem flores ou frutos. Com isso nós acreditamos que a principal contribuição da *Butia odorata* no palmar para o estabelecimento da avifauna está relaciona com a oferta de poleiros, abrigos e sítios para nidificação.

PALAVRAS-CHAVE. Interação ecológica, frugivoria, palmar, avifauna.

The presence of birds in ecosystems is generally influenced by resource supply, such as food availability, shelters, perches and nesting sites, which allow their survival, protection and reproduction (Herrera, 1985, 2004; Terborgh, 1986a; Sick, 1997; Galetti & Aleixo, 1998; Alves *et al.*, 2012; Morellato *et al.*, 2016). Many ecosystems such as savannas, steppes, and arid regions, have plants that are considered key species due to their great ecological and nutritional relevance for many species (Terborgh, 1986a; Peres, 1994a,b; Henderson, 1995; Henderson *et al.*, 1995, 2000; Galetti *et al.*, 1999). In general, in tropical forests, there is a high diversity of plants and, consequently, a huge supply of resources for fauna so that it is not always a particular species that stands out as the pivot of the local trophic plot. Still, a seasonal, conspicuous, and large biomass supply may represent an expressive increase in the food chain to which the fauna is linked (WheelWright, 1991; Paise & Vieira, 2005; Vieira & Iob, 2009). Some palm trees, for example, present long and abundant fruiting periods, which make them strong candidates for key plants of trophic webs in phytosociological formations known as palm groves (Dransfield, 1978; Terborgh, 1986b; Galetti & Aleixo, 1998; Galetti *et al.*, 1999; Beck, 2006).

South American palm groves of *Butia odorata* are phytophysiognomies formed by grasslands with the presence of palm trees in relatively high density (Bondar, 1964; Oliveira *et al.*, 2007; Geymonat & Rocha, 2009; Rivas & Barbieri, 2014; Barbieri *et al.*, 2016). In the biome Pampa, there are few remnants of palm groves of the species *Butia odorata* (Oliveira *et al.*, 2007; MMA, 2007; Barbieri *et al.*, 2016), and the species is currently included in the list of endangered species of the flora of the state of Rio Grande do Sul due to the development of several human activities, such as agriculture, forestry, livestock and urban expansion (FZB, 2014; Barbieri *et al.*, 2016). The coastal plain of Rio Grande do Sul, more specifically in the municipalities of Tapes and Barra do Ribeiro, harbors the largest groupings of *B. odorata* groves in southern Brazil (Oliveira *et al.*, 2007; Costa *et al.*, 2017). Even so, details about the participation and influence of *B. odorata* on the trophic plot in which it is inserted are still poorly known. It is estimated that the fruits of *B. odorata* are still a relevant food source for many animals that inhabit and visit these palms in the Pampa (Barbieri, 2015; Barbieri *et al.*, 2016).

Birds are the animals that are most often observed visiting palm groves to use their resources (Bencke *et al.*, 2007; Barbieri, 2015; EMBRAPA, 2015; Barbieri *et al.*, 2016). Besides fruits, insects attracted by the palm flowers are also important food sources for birds, being another potential for bird gathering in palm groves. It is worth remembering that insects are important resources not only for insectivorous species but also for omnivores (Sick, 1997; Ares, 2007; Wilman *et al.*, 2014), which consequently increases the attractiveness of palm trees. However, birds can often make random visits to the branches of plants just to perch and occupy new territories (McClanahan & Wolfe, 1993; Sick, 1997; Athiêa & Diasb, 2016; Portugal *et al.*, 2017).

Wolfe *et al.* (2014), in a study in Costa Rica, confirmed that the availability of food and structural attributes of the habitat influence its use by birds. These authors showed synchrony between the arrival of migratory birds in a region and the increase in the supply of ripe fruits in the environment. In addition, they observed that frugivorous species are strongly related to fruit availability, while insectivorous species are related to habitat structure (Wolfe *et al.*, 2014). Kissling *et al.* (2011), on the other hand, demonstrated that variations in species richness and bird trophic guilds across the latitude gradients are mainly determined by the environment's net primary productivity and climate variations between different geographical regions (Jetz & Rahbek, 2002; Hawkins *et al.*, 2003). In most cases, the increase in the availability of food resources in habitats may also berelated to these factors and influence bird richness and abundance in the environment (Mckey, 1975; Pizo, 1997; Francisco & Galetti, 2002).

The number and time length of bird visits to fruit trees vary according to the size and abundance of fruits in plants as well as their nutritional aspects (WheelWright, 1991; Jordano, 2000, 2014; Lord, 2004). This fact may be related to a foraging optimization behavior, adjusting the best way to get resources. The length of the visit to the plant may represent its relevance for bird nutrition. It is also possible that there is a cost/benefit ratio between the bird's length of visit to the plant and fruit supply. Theoretically, a bird would tend to maximize the number of ingested fruits and, to do so, it would stay longer feeding on the same plant if it has a large fruit supply. On the other hand, a bird would tend to remain less time in each plant when there is a fruit shortage in order to visit as many plants as possible. Those are some of the possible predictions that are present in the Optimal Foraging Theory (Charnov, 1976; Chaves & Alves, 2010). The distance between fruit trees can also be crucial for birds to spend more time feeding on the same plant (Murray, 1987; Westcott & Graham, 2000; Khamcha *et al.*, 2012). In addition, arthropod abundance is also directly affected by seasonal changes in plant productivity, which indirectly influences insectivorous birds due to the increased population of these organisms (Janzen & Schoener, 1968; Levings & Windsor, 1982; Del-Claro, 2012). In the present study, we evaluated whether the number of visits, length of visits, species composition and use of food resources by birds vary according to the flower and fruit supply in palm trees.

MATERIAL AND METHODS

Study area. The study was carried out between January 2018 and February 2019 in a remnant of *Butia odorata* palm grove in the municipality of Tapes, Rio Grande do Sul State, Brazil (Fig. 1). Due to the absence of well-preserved palm groves, our sample focused on a single continuous palm grove located in a private property (30°31'49.83"S, 51°21'24.62"W). The sampled area consists of 840 hectares of natural Pampa biome (Becker *et al.*, 2007; Medeanic *et al.*, 2007).

We considered each palm tree as a sampling unit. To minimize the effects of spatial dependence between the sample sites, we selected three sampling locations of about 22 ha each and with a minimum distance of 500 m from each other (Fig. 3). All three sites have the same average palm density and similar phytophysiognomy (Fig. 2).

Bird sampling. The sampling was carried out systematically, been each sampling location sampled once a month. In a same month, all sites were sampled along three consecutive days in order to reduce the effects of climatic changes on activity of birds. Sampling occurred between 6:00 a.m. and 12:00 a.m., and between 2:00 p.m. and 5:00 p.m. when the palm trees were scanned for birds with the aid of binoculars (10x42). Observations started at a randomly selected point at the border of each sampling location and, when a bird was observed on a palm tree, the tree was classified as a focal palm and the data recording process began, lasting 15 minutes (focal observation method; Altmann, 1974). Birds were observed at a minimum distance of 15 meters (Pizo & Galetti, 2010). We called a "visit" the event starting from the first sighting of a bird until it departed from a focal palm tree. For each individual that visited a focal palm tree, we recorded: (a) species, (b) total amount of time spent in the palm, (c) total amount of time dedicated to the consumption of fruits, flowers or insects. The amount of time spent at the palm with no consumption of food was registered as "total amount of time spent perching/resting". We are considering the broader concept of "resource use" which would include not only the use of the palm tree for food (fruits or insects) but also its use as a temporary habitat (*e.g.*, perch). The use of each resource by the same individual during the same visit was computed as one event,

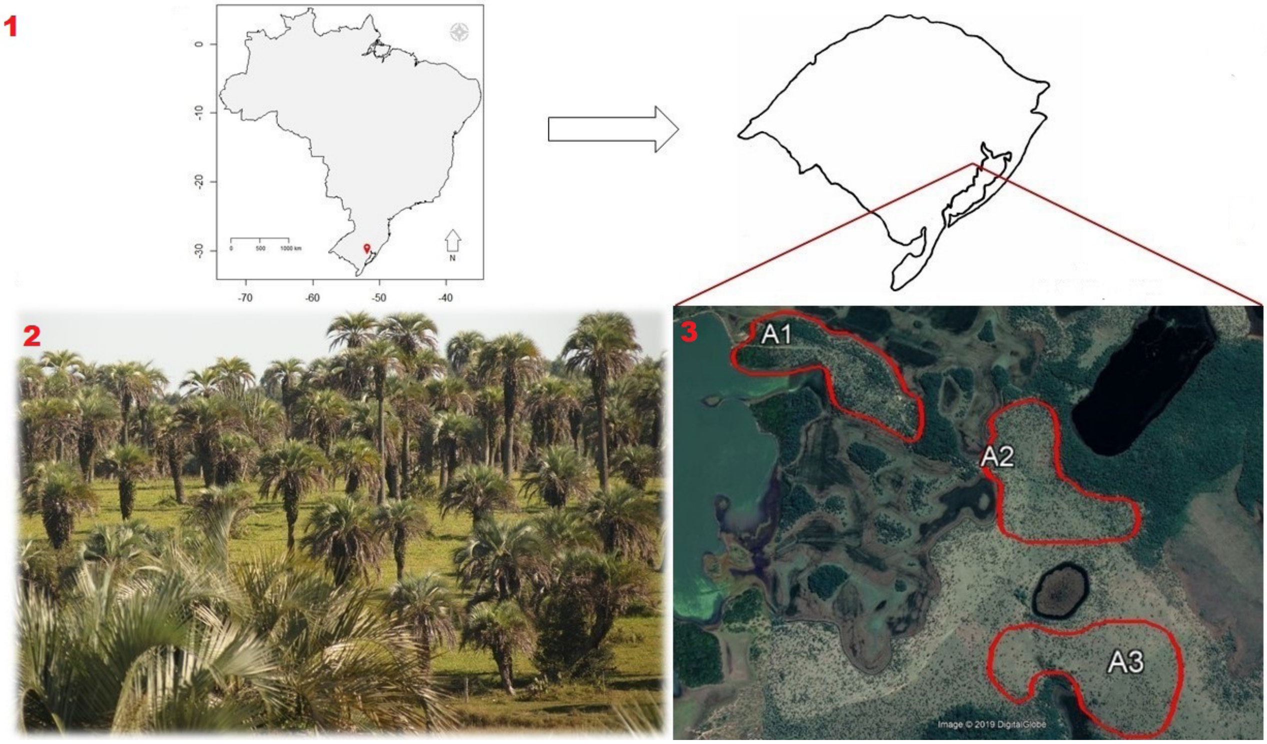

Fig. 1. 1. Study site location at municipality of Tapes, Rio Grande do Sul, Brazil. 2. Photo of an area of the palm grove (Photo by Cyro Menezes da Gloria). 3. Sampling area outlined in red; Map image created in R Studio; Study area in Google Earth, Google (C), 2019 (Edited by Cyro Menezes da Glória).

regardless of the number of fruit or insects eaten by the bird. We consider as "consumption" the partial or complete use of a food resource (fruits or insects). For palm fruits, we considered as consumption the following events: swallowing of the whole fruit, partial consumption (pulp pieces) of the fruit, mandibulation and suction of pulp juice (PIZO, 1997). After 15 minutes of observation, a new search started at a minimum distance of 200 meters from the already evaluated place. The nomenclature followed the standards of the Brazilian Ornithological Records Committee (CBRO, 2015). Species were classified according to their trophic guilds following SICK (1997) and WILMANN *et al.* (2014).

Evaluation of flower and fruit supply. We considered flowers and fruits as resources since fruits can be an indirect attraction or be consumed directly by some common birds in the study area [*Aramides cajaneus* (Statius Muller, 1776), *Coereba flaveola* (Linnaeus, 1758), *Myiopsitta monachus* (Boddaert, 1783), *Penelope obscura* Temminck, 1815, *Pyrrhura frontalis* (Vieillot, 1817), *Tangara sayaca* Cabanis, 1847, *Turdus rufiventris* Vieillot, 1818, among others]. In addition, flowers can be an indirect attraction for many insectivorous birds as flowers attract insects (MOERMOND & DENSLOW, 1985; SICK, 1997; CHIN & RAJATHURAI, 2005; KOH, 2008; DEL-CLARO, 2012). The evaluation of flower and fruit supply was made in the focal palm (observation palm) and in three adjacent palm trees, called satellite palms (the three closest trees to the focal palm), which are defined to evaluate the flower/fruit supply. For this, we estimated the measures of length (vertical measurement = height) and width (horizontal measurement = diameter) in centimeters of the focal palm and satellite clusters and estimated the percentage of mature flowers or fruits present in the clusters. The bunch dimensions were visually estimated by the approximation of a ruler suspended by a retractable extension cable that served as a reference for the measurements. Based on the length and width of the bunch, its volume (cm^3) was calculated by the cylinder volume formula ($v = \pi * r^2 * h$), where, v = bunch volume, r = bunch width / 2, h = bunch length. The same procedure was repeated for focal palms and satellites. The percentage value of flowers and fruits in palm trees was adapted from FOURNIER (1974), aiming to evaluate the variation in the intensity of flowering and fruiting in the bunches between the estimated proportion categories (Tab. I).

Data analysis. Because the distribution of the data is not normal, we applied the Kruskal-Wallis test to assess whether there was a significant difference between visit parameters (number of visits and length of visit) in palm trees with flowers, fruits and resources. To minimize the effect of the difference between the number of fruiting and flowering palm trees, bird species richness between these phases was compared by the rarefaction method (SANDERS, 1968). Richness was estimated from an extrapolated value for 1000 random repetitions of the samples, calculated by means of the program Estimates 8.2.0 (COLWELL, 2009). We evaluated mean and standard deviation and applied the coefficient of variation in cluster volume to detect whether there was a low or high difference in the obtained values so that they could be considered relevant for the evaluation of the supply (percentage of fruits and flowers in the bunches). After

Tab. I. Evaluation of the intensity of the flowering and fruiting phenophases of palm trees, according to the estimated percentage of ripe fruits and flowers in the bunches.

Level	Flowers/Fruits %	Productivity condition	Category
0	0	Absence of ripe flowers/fruits	Absent
1	10 to 39	Small number of ripe flowers/fruits	Low
2	40 to 69	Average number of ripe flowers/fruits	Intermediate
3	70 to 100	Large number of ripe flowers/fruits	High

confirming the high coefficient of variation, we multiplied the volume of the bunch by the percentage value of its phenological supply to obtain the value of the flower or fruit supply index between the focal palms and satellites. Analyses were performed using the programs PAST version 3.18 and BioEstat version 5.3.

Using the program Multiv version 3.55b, we performed a multivariate analysis of variance (MANOVA) to evaluate the variation in the composition of the variables (53 species and six trophic guilds) between the sample units (347 palm trees). Thus, we sought to confirm if there was significant variation ($p < 0.05$) in the composition of trophic species and guilds recorded throughout the evaluated seasons (summer, autumn and spring), having as a sample unit the number of visits of each species, between the evaluated palm trees of each season. To evaluate the composition of trophic species and guilds in relation to the availability of resources in palm trees (flowers and fruits), another similar matrix was created for the same test (MANOVA) to evaluate if there were significant differences ($p < 0.05$) in the composition of trophic species and guilds between flowering, fruiting and resourceless palm trees. When ordering the data, we used, as a measure of similarity, Euclidean Distance to compare sample units and principal coordinate analysis (PILLAR & ORLÓCI, 1996).

To evaluate the type of foraging behavior in relation to resource supply (flower or fruit), we generated four generalized linear mixed models (KNUDSON, 2018) by means of the program R (R DEVELOPMENT CORE TEAM, 2019). In all models, each palm tree was considered as a single sampling unit. Time and number of frugivory and insectivory events were considered as response variables. Fruit and flower supply index in focal palm and satellite palms were considered as fixed effects in the model. Since weather conditions of the month may have influenced bird activity, the effect of the sampling month was also included in the models as a random effect. The following models were generated: 1- fruit supply *vs.* frugivory events, 2- fruit supply *vs.* frugivory time, 3- fruit and flower supply *vs.* insectivory events, 4- fruit and flower supply *vs.* insectivory time.

RESULTS

Number of species. In a total of 348 hours of observations, we recorded 53 bird species distributed in 18 families (Tab. II). We recorded six trophic guilds, with the larger number of species being insectivores (26 species), omnivores (16) and granivores (8) (Fig. 2). Perch use was recorded in 52 species (6 trophic guilds) in a total of 987 visits. Insectivory events was observed in 20 species (3 trophic guilds) in a total of 77 visits. We also recorded 8 species in frugivory events (from 4 trophic guilds) in a total of 30 visits (Tab. II). The species with the largest number of visits were *Sicalis flaveola* (n=236 records; 94% of visits were for perching, 4% for nesting and 2% for insect consumption), *Myiopsitta monachus* (n=133; 50% of visits were for perching, 47% for nesting and 3% for fruit consumption) and *Zonotrichia capensis* (n=126; 94% of visits were for perching, 5% for insect consumption and 1% for fruit consumption).

Among the birds visiting the palm trees (visitors assembly), 32% of the recorded species richness occur inside forests (17 species, 10 families), while 68% do not occur inside forests (36 species, 16 families). Concerning the trophic guild, among the forest species, ten are insectivorous, four omnivorous, two granivorous and one frugivorous. Among the non-forest species, fifteen are insectivorous, twelve omnivorous, six granivorous, two carnivorous and one scavenger.

The assembly formed by visiting birds in resourceless palm trees was larger than in those with some type of food resource (flower or fruit) (Tabs II, III). The rarefaction method revealed that resourceless palm trees were visited by a larger number of species (between 17 and 26), while in flowering or fruiting palm trees the number of visiting species was smaller and ranged between 16 and 23 (Tab. III). Thus, richness did not vary between flowering, fruiting and resourceless palm trees (Kruskal-Wallis: $H_{20,269} = 2.02$, $p = 0.3071$).

Variation of species composition between seasons and resource supply. We recorded significant variation in species composition between seasons, but the effect of variation was only 1% (MANOVA: $R^2 = 0.01$, $p = 0.04$). Similarly, there was variation in trophic guild composition throughout the seasons but with an effect of only 2% (MANOVA: $R^2 = 0.02$, $p = 0.004$). There was no significant variation in species composition between palm trees with different types of resource supply (flowering, fruiting and resourceless, MANOVA: $R^2 = 0.01$, $p = 0.257$). There was also no significant variation in trophic guild composition between flowering or fruiting palm trees and resourceless palm trees (MANOVA: $R^2 = 0.01$, $p = 0.318$).

Tab. II. Bird species observed visiting *Butia odorata* with different resource supply, in southern Brazil. Trophic guilds: O, omnivore; G, granivore; I, insectivore; C, carnivore; S, scavenger; F, frugivore. PE = perch events; FR = frugivory events; IN= insectivory events.

Registered bird taxon	Trophic guilds (WILMANN *et al.*, 2014, SICK, 1997)	Visits to flowering palm trees (12 days)	Visits to fruiting palm trees (16 days)	Visits to resourceless palm trees (27 days)	PE	FR	IN
COEREBIDAE							
Coereba flaveola (Linnaeus, 1758)	O	1	15	7	7	11	5
COLUMBIDAE							
Columbina talpacoti (Temminck, 1811)	G	-	1	-	1	-	-
Leptotila verreauxi Bonaparte, 1855	G	-	1	-	1	-	-
Patagioenas picazuro (Temminck, 1813)	G	-	-	1	1	-	-
Zenaida auriculata (Des Murs, 1847)	G	2	4	23	29	-	-
CUCULIDAE							
Guira guira (Gmelin, 1788)	I	-	4	18	21	-	1
Piaya cayana (Linnaeus, 1766)	I	-	-	1	1	-	-
EMBEREZIDAE							
Zonotrichia capensis (Statius Muller, 1776)	O	8	15	103	118	1	7
FALCONIDAE							
Falco femoralis Temminck, 1822	O	-	-	2	2	-	-
Caracara plancus (Miller, 1777)	C	-	-	4	4	-	-
Milvago chimango (Vieillot, 1816)	S	-	-	28	28	-	-
FURNARIDAE							
Anumbius annumbi (Vieillot, 1817)	I	-	-	2	2	-	-
Cranioleuca obsoleta (Reichenbach, 1853)	I	-	1	1	1	-	1
Furnarius rufus (Gmelin, 1788)	I	5	6	43	52	-	2
HIRUNDINIDAE							
Progne chalybea (Gmelin, 1789)	I	-	-	22	22	-	-
Tachycineta leucorrhoa (Vieillot, 1817)	I	-	-	3	3	-	-
ICTERIDAE							
Agelaioides badius (Vieillot, 1819)	I	-	2	5	5	1	1
Icterus pyrrhopterus (Vieillot, 1819)	O	-	3	4	4	1	2
Molothrus bonariensis (Gmelin, 1789)	O	3	4	15	20	-	2
Pseudoleistes guirahuro (Vieillot, 1819)	O	-	3	10	13	-	-
MIMIDAE							
Mimus saturninus (Lichtenstein, 1823)	O	-	-	32	32	-	-
PARULIDAE							
Basileuterus culicivorus (Deppe, 1830)	I	-	1	-	1	-	-
Setophaga pytiayumi (Vieillot, 1817)	I	3	3	4	3	2	5
PICIDAE							
Colaptes campestris (Vieillot, 1818)	I	1	5	35	35	-	6
Colaptes melanochloros (Gmelin, 1788)	I	-	1	13	5	-	9
Melanerpes candidus (Otto, 1796)	I	-	-	1	1	-	-
Verniliornis spilogaster (Wagler, 1827)	I	-	3	-	1	-	2
PSITTACIDAE							
Myiopsitta monachus (Boddaert, 1783)	G	5	39	89	128	5	-
Pyrrhura frontalis (Vieillot, 1817)	F	-	9	2	7	4	-
RHYNCHOCYCLIDAE							
Poecilotriccus plumbeiceps (Lafresnaye, 1846)		-	-	1	1	-	-

Tab. II. Cont.

Registered bird taxon	Trophic guilds (Wilmann *et al.*, 2014, Sick, 1997)	Visits to flowering palm trees (12 days)	Visits to fruiting palm trees (16 days)	Visits to resourceless palm trees (27 days)	PE	FR	IN
THRAUPIDAE							
Coryphospingus cucullatus (Statius Muller, 1776)	O	-	3	5	6	-	2
Paroaria coronata (Miller, 1776)	G	2	1	17	20	-	-
Pipraeidea melanonota (Vieillot, 1819)	O	-	-	1	1	-	-
Saltator similis d'Orbigny & Lafresnaye, 1837	I	1	-	-	1	-	-
Sicalis flaveola (Linnaeus, 1766)	G	19	38	179	232	-	4
Sporophila caerulescens (Vieillot, 1823)	G	-	10	7	17	-	-
Tangara sayaca (Linnaeus, 1766)	O	-	10	15	12	5	8
TROGLODYTIDAE							
Troglodytes musculus Naumann, 1823	I	2	3	33	26	-	12
TROGONIDAE							
Trogon surrucura Vieillot, 1817	I	-	-	1	-	-	1
TURDIDAE							
Turdus amaurochalinus Cabanis, 1850	O	1	-	5	6	-	-
Turdus rufiventris Vieillot, 1818	O	1	-	1	2	-	-
TYRANNIDAE							
Camptostoma obsoletum (Temminck, 1824)	I	2	-	9	11	-	-
Elaenia flavogaster (Thunberg, 1822)	O	-	-	3	3	-	-
Elaenia mesoleuca (Deppe, 1830)	O	-	-	1	1	-	-
Elaenia obscura (d'Orbigny & Lafresnaye, 1837)	O	-	-	1	1	-	-
Lathrotriccus euleri (Cabanis, 1868)	I	-	1	-	1	-	-
Machetornis rixosa (Vieillot, 1819)	I	2	7	30	37	-	2
Pitangus sulphuratus (Linnaeus, 1766)	O	-	-	3	3	-	-
Serpophaga subcristata (Vieillot, 1817)	I	1	1	4	6	-	-
Tyrannus melancholicus Vieillot, 1819	I	-	1	-	1	-	-
Tyrannus savana Vieillot, 1808	I	1	-	25	26	-	-
Xolmis cinereus (Vieillot, 1816)	I	-	-	19	18	-	1
Xolmis irupero (Vieillot, 1823)	I	2	-	9	7	-	4
Total = 53 spp., 18 families	6 trophic guilds	19 spp., 18 fam. and 3 guilds.	29 spp., 18 fam. and 4 guilds.	44 spp., 18 fam. and 4 guilds	n= 987, spp.= 52, guilds= 6	n= 30, spp.= 8, guilds=4	n= 77, sp= 20, guilds= 3

Visits and resource supply. We observed 1,094 visits distributed among 347 palm trees (fruiting = 194 visits, flowering = 62, resourceless = 838). On average, each palm received from 3.1 to 3.3 visits during each observation (Tab. III). There was no significant variation in the number of visits between flowering, fruiting and resourceless palm trees (Kruskal-Wallis: $H_{20,269} = 0.3688$, $p = 0.8248$). The average length of visit of birds to the focal palm was 188 seconds (SD = 239.33). The total length of visits of the birds to the palm trees (sum of the length of each visit in each palm tree) did not vary significantly between flowering, fruiting and resourceless palm trees (Kruskal-Wallis: $H_{20,269} = 1.686$, $p = 0.4304$). Likewise, the average length of visit of each bird did not vary significantly between flowering, fruiting and resourceless palm trees (Kruskal-Wallis: $H_{20,269} = 1.53$, $p = 0.4653$).

Variation in foraging events regarding palm resource supply. The result of the Generalized Linear Mixed Model (GLMM) indicated that there was no significant relationship between the number of frugivory events and fruit supply in the focal palm trees (GLMM: $F = 0.012713$, $p = 0.183$), nor the satellite palm trees (GLMM: $F = -0.018457$, $p = 0.145$). There was a positive and significant relationship between frugivory time and fruit availability in both focal palm trees (GLMM: $F = 0.031843$, $p < 0.001$) and satellite palm trees (GLMM: $F = -0.019454$, $p < 0.001$). However, the estimated coefficients for fixed effects are less than 0.1, which suggests a weak relationship (Tab. IV).

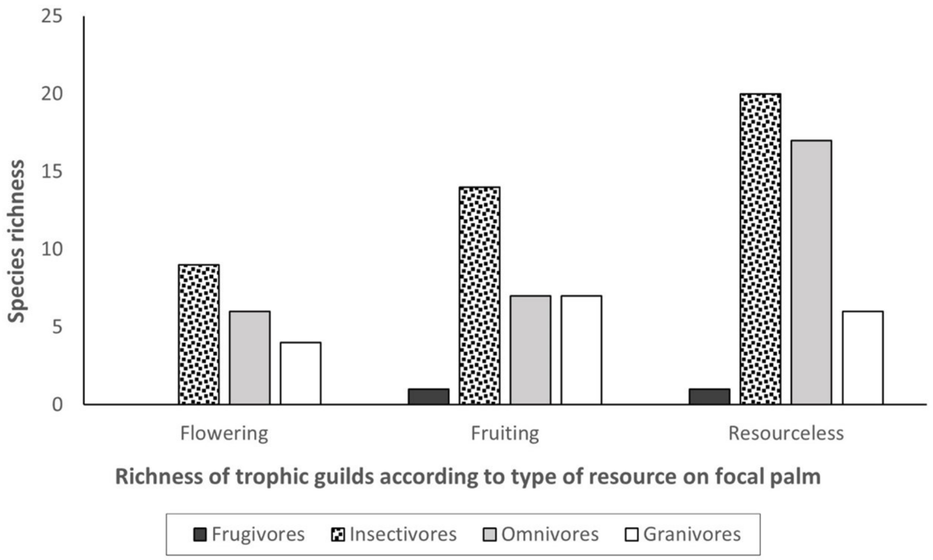

Fig. 2. The trophic guilds with the larger number of species in palm trees, Tapes, Rio Grande do Sul, Brazil.

Tab. III. Variation in the number of absolute and estimated rarefaction records of species in relation to the resource supply in the palms *Butia odorata* (With Fruit = fruiting palm trees; With Flower = flowering palm trees; FR = frugivory events; IN = insectivory events; NR = non-resource visits) among fruiting, flowering and resourceless palm trees.

Palm	No. of Palm Trees	Species (mean per palm tree ± SD)	Estimated minimum number of species	Estimated maximum number of species	Total trophic guilds	Trophic guilds (mean ± SD)	Total visits	No. of visits (mean ± SD)	Average length of each visit (s)	FR (mean± SD)	IN (mean± SD)	NR (mean± SD)
With Fruit	58	29 (1.8 ± 1.2)	16	23	4	1.5 ± 0.7	194	3.3 ± 3.1	178.2 ± 200.8	30 (0.5 ± 0.8)	14 (0.2 ± 0.5)	144 (2.5 ± 3.2)
With Flower	20	19 (2.1 ± 1.0)	16	23	3	1.6 ± 0.5	62	3.1 ± 1.9	229.5 ± 249.3	-	7 (0.4 ± 0.6)	48 (2.4 ± 1.4)
NR	269	46 (1.8 ± 1.0)	17	26	6	1.5 ± 0.6	838	3.1 ± 2.4	219.9 ± 236.7	-	56 (0.2 ± 0.5)	676 (2.5 ± 2.3)

Tab. IV. Generalized Linear Mixed Model demonstrating the effect of flower and fruit supply of *Butia odorata* and month on the number and length of frugivory and insectivory events. (FOC, offer on focal palm trees; SAT, offer on satellite palm).

	Frugivory events			Frugivory length			Insectivory events			Insectivory length		
Fixed effects	Std	F	p	Std	F	p	Std	F	p	Std	F	p
Fruits (FOC)	0.01	0.01	0.18	0.00	0.03	0.00	0.01	-0.00	0.83	0.00	-0.02	0.00
Fruits (SAT)	0.01	-0.02	0.15	0.00	-0.02	0.00	0.01	-0.01	0.39	0.00	-0.02	0.00
Flowers FOC)	-	-	-	0	0	0	0.01	0.01	0.19	0.00	0.01	0.00
Flowers SAT)	-	-	-	0	0	0	0.01	0.02	0.00	0.00	0.03	0.00
Months	0.97	0.86	0.19	6.19	10.72	0.04	1.99	3.53	0.04	5.09	10.17	0.00

There was a positive and significant relationship between flower supply in satellite palm trees and insectivory events (GLMM: F = 0.018572, p = 0.001). However, we did not detect a significant relationship between focal palm flower supply and insectivory events (GLMM: F = 0.008169, p = 0.1873). Insectivory time showed a positive and significant relationship with flower supply in both focal palm trees (GLMM: F = 0.010531, p < 0.001) and satellite palm trees (GLMM: F = 0.026525, p < 0.001).

There was no significant relationship between fruit supply and number of insectivory events in either focal palm trees (GLMM: F = -0.00193, p = 0.8322) or satellite palm trees (GLMM: F = -0.00794, p = 0.3943). However, for the evaluation of the relationship between fruit supply and insectivory time, the effect was positive in both focal palm trees (GLMM F = -0.02139, p < 0.001) and satellite palm trees (GLMM: F = - 0.02022, p < 0.001). Overall, insectivory events varied significantly over the year (Tab. IV; Fig. 3).

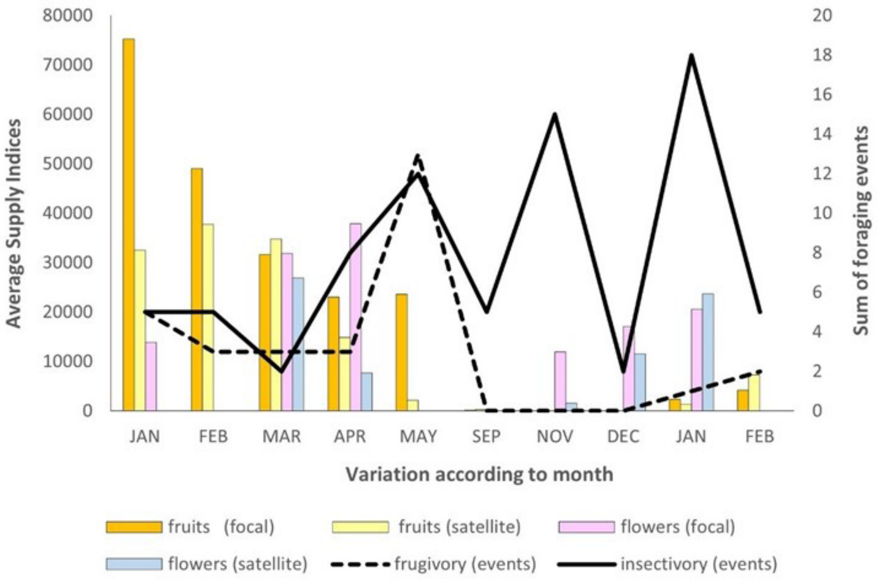

Fig. 3. Average indices of flower and ripe fruit supply of *Butia odorata* and number of frugivory and insectivory events in the evaluated months, Tapes, Rio Grande do Sul, Brazil.

DISCUSSION

We recorded 53 bird species visiting *Butia odorata*, which represent 11% of the Brazilian Pampa species and 22% of the species recorded in the vicinity of the study site (BENCKE *et al.*, 2007; DEVELEY *et al.*, 2008). Considering that all records were based exclusively on the observation of birds on a single plant species, the evidence shows that *B. odorata* palm groves may represent a relevant habitat to the local avifauna. Probably the palm clusters are important for birds because they increase habitat heterogeneity, offering food opportunities, shelter and protected breeding sites (SICK, 1997; BENCKE *et al.*, 2007; ARES, 2007). Other systems have reported that the ability to access higher strata in the vegetation is a relevant element in microhabitat selection by birds (CODY & DIAMOND, 1975; NORBERG, 1977, 1983; CODY, 1985b; GILL, 1990; AZHAR *et al.*, 2013; CASTAÑO-VILLA *et al.*, 2014). Because this palm grove is an extensive cluster of palm trees that form islands spaced across the grassland, birds can safely move and take refuge among them when crossing wide areas of open habitats.

The species that most frequently searched for some type of palm resource were relatively common in the region: *Myiopsitta monachus*, *Sicalis flaveola* and *Zonotrichia capensis*. Such species are usually abundant and frequently recorded in several ecosystems in southern Brazil, especially in rural environments (BELTON, 1985; SICK, 1997; AZPIROZ, 2012). It is worth noticing that *M. monachus*, a gregarious species, usually builds collective nests in the palms and often consumes their fruits. We believe that this is one of the species with the widest range of resource use on *B. odorata* (shelter, nesting and fruit consumption).

The hypothesis that there would be more visits to palm trees with more resources was refuted. In fact, most of the bird visits in the palm trees was limited to perch use. It means that palms were not mainly attractive by their food offering. However, it is possible that, like many other tropical ecosystems, the surrounding ecosystem in which palm trees are inserted offers many food resources. The palm groves of *B. odorata* occur in an angiosperm-rich field matrix that offers large seed biomass and small fruits and certainly attracts a large number of arthropods, offering abundant resources especially for omnivorous and insectivorous birds (BECKER *et al.*, 2007; OLIVEIRA *et al.*, 2007; BARBIERI, 2015; BARBIERI *et al.*, 2016). This hypothesis is reinforced by the fact that most of the recorded species are insectivorous, omnivorous or granivorous, which can find food in several other habitats (CODY, 1985a; SICK, 1997; WILMAN *et al.*, 2014). Thus, the presence of flowers and fruits in these palms would not represent such a significant increase in regional productivity to the point that we could detect an increase in the number of visits to palm trees. For a better assessment of the role of palms in the observed bird food chain, a complementary approach would be needed, including the use of tools such as stable isotope analysis to verify the carbon source (primary source) that supports the trophic web of birds (PETERSON & FRY, 1987). Our data also showed that palm trees without flowers or fruits (without measured resources) were visited by a larger number of species than those with resources. Despite going against our premises, this fact reinforces the idea that the presence of birds in palm trees is not related to aspects of fruit consumption but rather to search for shade, shelter, refuge and nesting place (CODY & DIAMOND, 1975; HOWE, 1979; GILL, 1990; SICK, 1997; CHIN & RAJATHURAI, 2005; ARES, 2007; AZHAR *et al.*, 2013).

We did not record a significant change in species composition or trophic guilds of birds in relation to changes in flower and fruit supply in palm trees, despite several studies reinforcing that seasonal variation in the availability of food resources and the breeding period influence the composition of birds in the environment (Alves & Cavalcanti, 1996; Machado, 1999; Develey & Peres, 2000). We assume, therefore, that the abundance of resources in the palm grove areas is not wholly dependent on the palm trees and is scattered over several associated microhabitats.

Another important element linked to foraging resources (food demand, habitat dispersal) concerns the reproductive period. Reproductive cycles directly affect the intensity and way species look for resources in space and consequently affect species composition in the environment (Cody & Diamond, 1975; Snow, 1981; Cody, 1985a; Belton, 1985; Alves & Cavalcanti, 1996; Sick, 1997). Our data suggest a slight tendency in the variation of species composition and trophic guilds between seasons but the percentage of species that explains this variation is low. There is possibly the influence of the fact that there are more insectivorous species in the environment, among which few are migratory (Sick, 1997; Bencke *et al.*, 2007; Donatelli *et al.*, 2017). On the other hand, it is possible that reproduction-related aspects, in addition to seasonal variation of arthropods and climatic conditions, may also be influencing trophic species and guild composition in some way (Belton, 1985; Poulin *et al.*, 1994; Sick, 1997; Brereton & Taylor, 2000; Khamcha *et al.*, 2012; Donatelli *et al.*, 2017). In general, changes in temperature, humidity and precipitation tend to affect the abundance of arthropods, which in turn influence the presence of birds in ecosystems (Wolda, 1988; Oliveira *et al.*, 2006; Ares, 2007). In our data, we recorded a significant variation in insectivory events over the year, possibly due to seasonal arthropod variation in the environment, in addition to the variation in the energy demand of birds due to the metabolic changes in their natural cycles (Janzen & Schoener, 1968; Payne, 1972; Levings & Windsor, 1982; Wolda, 1988; Sick, 1997; Ares, 2007). In addition, insectivory was more related to the supply of satellite palm flowers around the focal area (local scale), which may indicate that there is an influence of environmental conditions regarding the offer of this resource in the palm to increase insectivory (Wolda, 1988; Oliveira *et al.*, 2006). Among the bird species that fed on palm arthropods, *Troglodytes musculus*, *Colaptes melanochloros*, *Tangara sayaca* and *Zonotrichia capensis* stood out in our study.

In general, the increase in supply did not influence the number of birds consuming fruit on palm trees but favored an increased length of visit during foraging. In addition, we observed more fruit consumption events in the period of lower supply. A possible explanation for this is the fact that, under low fruit supply in the region, there would be a higher concentration of frugivory events in a smaller number of palm trees, enhancing their observation. In other words, the few palm trees with fruit supply would have a greater focus on foraging and, thus, would concentrate frugivory events on the palm. Following this logic, in a period with greater fruit availability, frugivory would occur in a dispersed way in the habitat, being recorded less frequently by our method of recording (observation of focal palm). Fruit weight and seed size are known to influence frugivory rate, with light (less than 3.5 g) and small fruits generally being the most consumed by birds (Herrera, 1985; WheelWright, 1985, 1991). Because the fruits of this palm species are fibrous and relatively heavy (7 to 14 g; Rivas & Barbieri, 2014), few bird species in this palm grove may be able to consume them since the vast majority are small passerine birds (Passeriformes), among which few have the beak adapted for the effective consumption of this type of fruit (Snow, 1971, 1981; Moermond & Denslow, 1985; Gautier-Hion *et al.*, 1985; Sick, 1997; Ares, 2007). Fruit consumption was characterized by species (n = 5) that plucked pieces and macerated the pulp, and by species (n = 3) that drilled and sucked the pulp, both cases without ingestion of the seed. Among these records, only two species (*T. sayaca* and *M. monachus*) were observed transporting the fruit away from the mother plant. We recorded a total of eight species feeding on fruits, among which the following four included the largest number of recorded frugivory events: *Coereba flaveola*, *Myiopsitta monachus*, *Tangara sayaca* and *Pyrrhura frontalis*. Villalobos & Bagno (2012), in their study on *Mauritia flexuosa* L.f. frugivory by birds, recorded eight bird species feeding on the fruits of this palm (buriti), where parrot species were their main consumers and dispersers. Likewise, in our study, the two recorded parrot species (*M. monachus* and *P. frontalis*) stood out as the main consumers of *Butia odorata* fruits, which is possibly due to the adaptive and evolutionary aspects of their beak type, which enables them to pull off pieces of the fruit fibers from palm trees, as well as their ability to handle the fruit with their feet while feeding during foraging (Snow, 1971; Herrera, 1985; Moermond & Denslow, 1985; Sick, 1997; Ares, 2007). Weight and size of fruits as well the beak morphology could limit the consumption by birds (WheelWright, 1991; Sick, 1997; Jordano, 2000, 2014; Lord, 2004). Most of the birds observed in this study did not have a specialized beak for the consumption of *Butia odorata* fruit (Rivas & Barbieri, 2014), and the majority of species are insectivorous or omnivorous (Snow, 1981; Gautier-Hion *et al.*, 1985; WheelWright, 1991; Sick, 1997). The results of this study indicated that many birds that are not potential consumers of the fruits of *Butia odorata* used palm groves. Thus, we consider that other factors of the palm may be more relevant to the presence of birds, such as other food opportunities, shelter and protected breeding sites. However, more studies need to be carried out to infer with greater precision these observed issues concerning the main attractive factors for birds in the *Butia odorata* palms.

Our results shown a seasonal variation in the number of bird visits in the palms. Insectivorous species were the most frequent observed species. Among the most used resources along the visit, we highlighted the use of palms trees as perch, shelter and nesting site. This suggests the importance of formation of the palm groves of *Butia odorata* to the establishment of avifauna, whatever was their feeding behavior.

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