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Original Article

A food interaction network between psittacines and plants in an urban area in the city of São Carlos – SP, southeastern Brazil

Uma rede de interação alimentar entre psitacídeos e plantas em uma área urbana na cidade de São Carlos – SP, sudeste do Brasil

A. M. Leoni[a*], M. G. Reis[a] and M. M. Dias Filho[a]

[a]Universidade Federal de São Carlos – UFSCar, Departamento de Ecologia e Biologia Evolutiva, Laboratório de Aves Neotropicais, São Carlos, SP, Brasil

Abstract

The Psittacidae presents a great diversity of species in the Neotropical region performing fundamental ecological functions for ecosystems. These frugivorous birds can occupy different positions in the antagonistic-mutualistic gradient of food interactions, acting as predators and/or as seed dispersers. Little is known about bird-plant ecological interaction networks focusing on psittacines in urban environments, which may compromise the management of natural areas in anthropic landscapes and hinder the planning of conservation strategies. In this context, the present study aimed to analyze the network of feeding interactions between psittacines and plants that occur in green areas in urban and periurban areas of the municipality of São Carlos, São Paulo State, southeastern Brazil. Starting with an active searching added to the application of the focal animal sampling at 36 systematized sampling points during the years 2019, 2020 and 2021, the plant species consumed by parrots in the study area were observed. Four species of birds of the Psittacidae family were recorded consuming food resources from 46 plant species. The order of relevance of the birds in structuring the ecological network was: *Brotogeris chiriri* (Vieillot, 1851), *Psittacara leucophthalmus* (Statius Muller, 1872), *Forpus xanthopterygius* (Spix, 1843) and *Eupsittula aurea* (Gmelin, 1788). The most consumed plants were *Syagrus romanzoffiana, Salix babylonica, Caesalpinea pluviosa, Mangifera indica* and *Handroanthus heptaphyllus*. The pattern of consumption by birds was significantly different among species, and overall, they had a broad diet and medium niche overlap. Network nesting was low, as was connectance, *i.e.*, the number of interactions or connections observed between pairs of species was considerably less than the total number possible. Network asymmetry was considerably high, with the psittacine group performing interactions with a large number of plant species, while each plant received on average few psittacine species. The results point to a high plasticity in the use of food resources in anthropic landscapes, indicating that the occupation of the urban environment by psittacines has been occurring successfully and may benefit the populations of the species recorded here.

Keywords: urban afforestation, niche, ecological network, Cerrado, Atlantic Forest.

Resumo

A família Psittacidae apresenta grande diversidade de espécies na região Neotropical, as quais desempenham funções ecológicas fundamentais para os ecossistemas. Essas aves frugívoras podem ocupar diferentes posições no gradiente antagonista-mutualista de interações alimentares, atuando como predadoras e/ou como dispersoras de sementes. Pouco se sabe sobre redes de interações ecológicas ave-planta com foco nos psitacídeos em ambientes urbanos, o que pode comprometer a gestão de áreas naturais em paisagens antrópicas e dificultar o planejamento de estratégias de conservação. Nesse contexto, o presente estudo objetivou analisar a rede de interações alimentares entre psitacídeos e plantas que ocorrem em áreas verdes da zona urbana e periurbana do município de São Carlos, estado de São Paulo, sudeste do Brasil. A partir de busca ativa somada à aplicação do método animal-focal em 36 pontos de amostragem sistematizada de 2019 a 2021, foram observadas as espécies de plantas consumidas por psitacídeos na área de estudo. Foram registradas 4 espécies de Psittacidae consumindo recursos alimentares de 46 espécies de plantas. A ordem de relevância das aves na estruturação da rede ecológica foi: *Brotogeris chiriri* (Vieillot, 1851), *Psittacara leucophthalmus* (Statius Muller, 1872), *Forpus xanthopterygius* (Spix, 1843) e *Eupsittula aurea* (Gmelin, 1788). As plantas mais consumidas foram *Syagrus romanzoffiana, Salix babylonica, Caesalpinea pluviosa, Mangifera indica* e *Handroanthus heptaphyllus*. O padrão de consumo pelas aves foi significativamente distinto entre as espécies, sendo que no geral apresentaram uma dieta ampla e sobreposição de nicho mediana. O aninhamento da rede foi baixo, assim como conectância, ou seja, o número de interações ou conexões observadas entre pares de espécies foi consideravelmente menor do que o número total possível. A assimetria da rede foi consideravelmente alta, com o grupo dos psitacídeos realizando interações com um grande número de espécies de plantas, ao passo que cada planta recebeu em média poucas espécies de psitacídeos. Os resultados apontam para uma alta plasticidade no uso de recursos alimentares em paisagens antrópicas, indicando que a ocupação do ambiente urbano por psitacídeos vem ocorrendo com sucesso e pode beneficiar as populações das espécies aqui registradas.

Palavras-chave: arborização urbana, nicho, rede ecológica, Cerrado, Mata Atlântica.

*e-mail: ariane.leoni@gmail.com
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1. Introduction

Psittacines are a prominent group of birds in the Neotropical region (Sick, 2001), being represented in Brazil by 87 species (Pacheco et al., 2021a, b). These are seed- and fruit-consuming birds, although they also include flowers, nectar, leaves, invertebrates and minerals collected in the soil in their diets (Sazima, 1989; Galetti, 1997; Collar, 1997; Sick, 2001; Francisco et al., 2002). They exploit, for the most part, a great diversity of plant resources and their diets can vary considerably throughout the year, according to the seasonal availability of these resources, and along their geographical distributions (Renton et al., 2015).

Despite being considered mainly frugivorous, psittacines may not act as seed dispersers, as they commonly act as seed predators (Higgins, 1979; Galetti and Rodrigues, 1992; Francisco et al., 2002; Silva, 2005; Silva, 2007; Galetti et al., 2013). Considering that these birds tend to feed mainly on fruits while still being on the mother plant, they have been recognized as pre-dispersal seed predators (Francisco et al., 2002; Ragusa-Netto, 2014, 2022), with the possibility of influencing the recruitment of plant species with which they interact (Silva, 2007; Blanco et al., 2018).

However, there are several reports in the literature of seed dispersal events by psittacines, with notable emphasis on the dispersal of large fruits. These birds carry the fruits in flight to consume them elsewhere and often drop the fruit after consuming the pulp without causing damage to the seeds (Baños-Villalba et al., 2017; Sazima, 2008; Araújo and Marcondes-Machado, 2011). Even plant species with small seeds can be dispersed by these birds, especially those with tiny seeds immersed in the pulp, which can be swallowed whole during consumption (Fleming et al., 1985; Oliveira et al., 2012). In fact, studies with psittacine feces have verified the presence of viable small seeds for germination, demonstrating the potential role of these birds in the dispersal of plant species, which has been neglected (Blanco et al., 2016).

Bird-plant interactions play a significant role in the ecological dynamics of plant communities and ecosystems (Jordano, 1987). It is now known that psittacines include key species in the structuring of plant populations and communities, because they occupy several positions along the antagonistic-mutualistic gradient of interactions, *i.e.*, they can act as both predators and as seed dispersers (Bahia et al., 2022; Dracxler and Kissling, 2022).

Despite being important frugivores, psittacines have been neglected in most studies of bird-plant interactions (Blanco et al., 2016). The Neotropical region concentrates most of the research on psittacines, that, besides being fewer in number when compared to other groups of frugivorous birds, were mostly developed in natural ecosystems where these birds feed on native plants [*e.g.*, Galetti (1997); Nunes and Santos Junior (2011)], so there is still a large gap in knowledge about the use of exotic plants in altered and urbanized environments (Marques et al., 2018; Bahia et al., 2022).

In the light of ecological network analysis, it is possible to know the elements that structure interspecific interactions, access the complexity of bird-plant interactions, and forecast the dynamics and stability of biological communities (Bascompte, 2009). In addition, knowing the diet of psittacines allows predicting to what extent these birds may respond to anthropogenic pressures, especially in extremely altered areas (*e.g.*, urbanized environments), given their plasticity in diet and foraging strategies (Renton et al., 2015).

In this context, the present work aims to describe the interactions between birds of the Psittacidae family and the plants used as their food source, purposing to build and analyze the network of interactions between these two groups in urban and periurban environments in the municipality of São Carlos, SP.

2. Material and Methods

2.1. Study area

The municipality of São Carlos is located in a transition zone between two Brazilian phytogeographic and morphoclimatic domains, which is why remnants of the Cerrado and the Atlantic Forest are found within its geographic limits (Soares et al., 2003). The climate of the region according to the Köppen classification is Cwa, with an average annual temperature of 19.7 °C and an average annual rainfall of 1440 mm (Alvares et al., 2013).

The sites selected for sampling comprised 36 areas distributed in the following types of environments: urban squares, roads and wooded gardens; riparian environments that correspond to the Permanent Preservation Area - APP of the Monjolinho river and its urban and periurban tributaries; fragments of altered vegetation in an urban environment; remnants of native vegetation in periurban areas.

2.2. Methodology

Data were collected in the field from September 2019 to March 2021. In each of the 36 selected areas, an active searching for species of Psittacidae was conducted during slow walks without pre-defined routes and distances and, when found, the feeding records or "feeding bouts" were noted by the method of focal animal observation (Galetti, 2002; Bibby, 2004; Sutherland, 2004). At each observation of foraging activity, the psittacine species and the number of individuals feeding were recorded, and the plant consumed was marked for later identification. The location of the 36 systematic sampling points can be seen on the map in Figure 1.

The data collected were obtained during visits of at most 1 h in each point, focusing on feeding, when there were psittacines present. The duration of observations was only less than 1 h when there were no psittacines in the area, and the minimum time was of 20 min in these cases, or when birds were present at the beginning of sampling but left the area before the end of the hour. Each place was visited twice a month in the morning and afternoon, totaling 582 h and 26 min of observation.

The observations and records of feeding interactions between psittacines and plants were made through direct visualization with the aid of Bushnell binoculars 10 x 42 mm. Additionally, photographs and filming were obtained with the use of a Nikon Coolpix P900 digital camera.

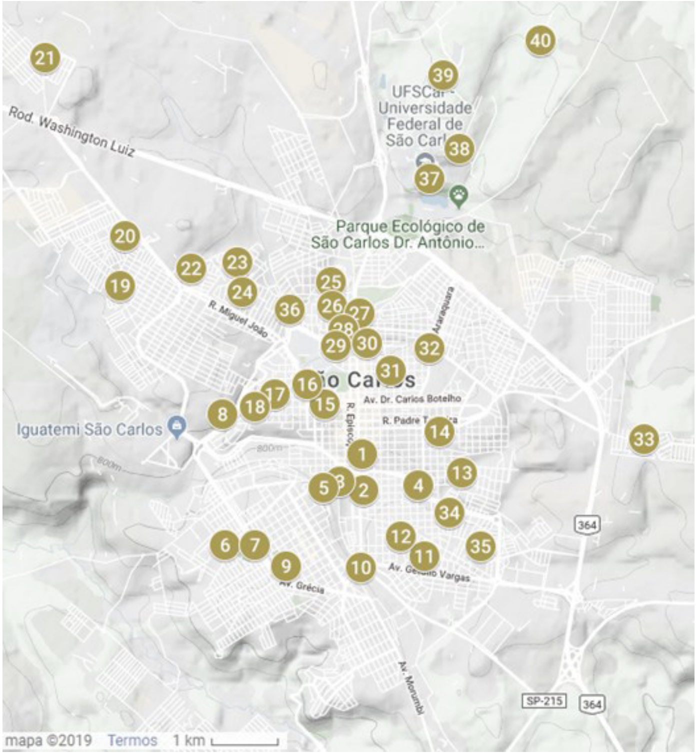

Figure 1. Location of the 36 systematic sampling points in urbanized areas of the city of São Carlos, SP, Brazil.

2.3. Statistical analysis

R software, version 4.1.2 (R Core Team, 2021) and the packages vegan v.2.5-7 (Oksanen et al., 2020) and bipartite v.2.16 (Dormann et al., 2021) were used to create a graph, of the bipartite type, for the interaction network starting from an abundance matrix of interactions between birds and the plants used as resources by them, and for the calculations of community descriptor indices and ecological network metrics. The lack of normality of the feeding data of the bird species was double-checked by the Shapiro-Wilk and Lilliefors tests, and then the non-parametric Kruskal-Wallis test was chosen to evaluate and differences in the data pattern between birds (Zar, 1999).

3. Results

During the systematized sampling in urban and periurban green areas, four bird species of the Psittacidae were recorded obtaining resources from 46 plant species identified to genus or species, totaling 1572 individual bird-plant interactions. The feeding events between bird species and plants are presented in Table 1.

The most abundant bird species, *Brotogeris chiriri* (Vieillot, 1851), was observed making use of resources from 35 plant species in 957 individual records of feeding interactions. *Psittacara leucophthalmus* (Statius Muller, 1872) fed on 32 plant species in 539 interactions, while *Forpus xanthopterygius* (Spix, 1843) fed on 8 plants in 61 interactions and *Eupsittula aurea* (Gmelin, 1788) on 4 plants in 15 interactions. There was a significant difference in the pattern of feeding interactions recorded among the birds (H=55.01; p<0.001).

The calculation of interaction network metrics at the species level, with a focus on birds, indicated that *B. chiriri* has the highest strength in the network and is not nested, showing the second lowest value of the consumed plant specificity index and the second highest value of food item diversity, nevertheless showing the lowest equitability of interactions because it consumed heavily only three of the 35 plants with which it interacted. *Psittacara leucophthalmus* showed similar values, being the second strongest species in the network of interactions and the first in diversity of interactions. *Forpus xanthopterygius* and *E. aurea* stood out as the species with the highest degree of nesting due to higher specificity of interactions (low number of plants accessed), however, the few interactions occurred more evenly distributed among the plants visited (higher equitability). The values of the species-level interaction network metrics are presented in Table 2.

Only two plant species received visits from all four psittacines, *Mangifera indica* and *Syagrus romanzoffiana*. Five plant species were visited by three psittacines, *Bauhinia forficata, Caesalpinia pluviosa, Eriobotrya japonica, Handroanthus heptaphyllus* and *Salix balylonica*, while 17 plant species were visited by 2 psittacines and the majority, 22 plant species, received visits from only one psittacine. The plant with the highest number of interactions was *S. romanzoffiana*, with 452 individuals feeding on its fruits, equivalent to 28.75% of the

Table 1. Number of feeding interactions between birds (columns) and plants (lines) observed in green areas in the urban and periurban zone of São Carlos - SP, Brazil. Scientific nomenclature according to Pacheco et al. (2021a, b) and POWO (2023), respectively for birds and plants, and the asterisks indicate plant species exotic to Brazil.

Botanical families/Consumed plants		Psittacines			
		Brotogeris chiriri	*Psittacara leucophthalmus*	*Forpus xanthopterygius*	*Eupsittula aurea*
Annonaceae	*Annona squamosa*	3	0	0	0
Araucariaceae	*Araucaria angustifolia*	10	0	0	0
Moraceae	*Artocarpus heterophyllus**	2	2	0	0
Fabaceae	*Bauhinia forficata*	17	15	18	0
Fabaceae	*Caesalpinia pluviosa*	116	35	4	0
Lecythidaceae	*Cariniana* sp.	2	0	0	0
Salicaceae	*Casearia sylvestris*	0	2	0	0
Malvaceae	*Ceiba speciosa*	21	8	0	0
Euphorbiaceae	*Croton floribundus*	2	10	0	0
Fabaceae	*Delonix regia**	16	11	0	0
Arecaceae	*Dypsis lutescens**	2	0	0	0
Rosaceae	*Eriobotrya japonica**	4	6	0	2
Myrtaceae	*Eucalyptus* sp.*	8	0	0	0
Myrtaceae	*Eugenia uniflora*	4	15	0	0
Moraceae	*Ficus benjamina**	15	25	0	0
Bignoniaceae	*Handroanthus heptaphyllus*	90	9	4	0
Bignoniaceae	*Handroanthus* sp.	7	7	0	0
Fabaceae	*Hymenaea* sp.	4	1	0	0
Fabaceae	*Inga* sp.	4	0	0	0
Oleaceae	*Ligustrum lucidum**	15	0	4	0
Magnoliacaeae	*Magnolia champaca**	18	19	0	0
Malpighiaceae	*Malpighia emarginata**	0	5	0	0
Anacardiaceae	*Mangifera indica**	63	42	3	1
Lauraceae	*Ocotea* sp.	3	14	0	0
Malvaceae	*Pachira aquatica*	47	15	0	0
Fabaceae	*Paubrasilia echinata**	0	0	2	0
Peraceae	*Pera glabrata*	0	0	0	7
Lauraceae	*Persea americana**	0	6	0	0
Arecaceae	*Phoenix roebelenii**	0	2	0	0
Pinaceae	*Pinus elliottii**	0	4	0	0
Myrtaceae	*Plinia cauliflora*	2	0	0	0
Myrtaceae	*Psidium guajava*	8	8	0	0
Loranthaceae	*Psittacanthus* sp.	2	0	0	0
Lythraceae	*Punica granatum**	0	2	0	0
Arecaceae	*Roystonea oleracea**	15	0	0	0
Salicaceae	*Salix babylonica**	123	79	7	0
Anacardiaceae	*Schinus molle**	10	4	0	0
Fabaceae	*Schizolobium parahyba*	10	0	0	0
Fabaceae	*Senna siamea**	0	11	0	0
Bignoniaceae	*Spathodea campanulata**	0	9	0	0
Arecaceae	*Syagrus romanzoffiana*	291	137	19	5
Bignoniaceae	*Tabebuia roseoalba*	7	7	0	0
Bignoniaceae	*Tecoma stans**	2	1	0	0
Combretaceae	*Terminalia catappa**	4	26	0	0
Fabaceae	*Tipuana tipu*	10	0	0	0
Rosaceae	*Trema micrantha*	0	2	0	0

* = exotic plants.

Table 2. Species-level metrics calculated from the network of feeding interactions between psittacines and plants in green areas of the urban and periurban zone of São Carlos - SP, Brazil.

Interaction network metrics	*Brotogeris chiriri*	*Psittacara leucophthalmus*	*Forpus xanthopterygius*	*Eupsittula aurea*
N consumed plants (*degree*)	35	32	8	4
Number of bird-plant interactions	957	539	61	15
% consumed plant species (*degree normalized*)	76.09%	69.57%	17.39%	8.70%
Strength of the species in the network (*species strength*)	23.69	19.37	1.73	1.18
Nested rank (*nested rank*)	0	0.33	0.66	1
Specificity Index (*species specificity index*)	0.35	0.29	0.44	0.58
Consumed plants diversity (H' *index*)	2.53	2.79	1.83	1.27
Equitability of consumed plant species (*Equitability*)	0.71	0.80	0.88	0.92

N = number; % = percentage.

total recorded interactions, followed by *S. babylonica* (n=209 interactions or 13.3%), *C. pluviosa* (n=155; 9.86%), *M. indica* (n=109; 6.93%) and *H. heptaphyllus* (n=103; 6.55%). These 5 species were visited by 3 or 4 psittacines and together accounted for 65.4% of all recorded bird-plant interactions.

A total of 22 species or 47.82% of the total number of plants recorded are considered exotic, while 24 or 52.47% occur naturally in native vegetation remnants in the central São Paulo state. Among the five species with the highest number of visits, three are native and two are exotic.

Considering the two species groups (birds and plants), the interaction network metrics indicate that the average number of links (interactions between species pairs) was 32.62 for birds and 2.97 for plants. The average number of plants shared among psittacines was 7.33, while plants shared an average of 1.08 visiting bird species. Niche overlap among psittacines was 0.59, a median value, considering that the index ranges from 0 (no overlap at all) to 1 (fully overlapped).

At the community level, network metrics point to a median connectance (0.42), with this index representing the proportion of interactions observed in the network in relation to what would be possible. The studied network shows high asymmetry (web asymmetry = -0.84), since psittacines interacted with many plant species, while these interacted with few psittacine species. The weighted nesting is medium to low (wNODF = 43.53), since the maximum possible value is equal to 100. This metric indicates the degree to which interactions are arranged in structured subsets within the community, considering all observed interactions. The network of food interactions between the Psittacidae and plants is presented in Figure 2.

4. Discussion

The results point to a great diversity of plants that provide food resources for birds of the Psittacidae family in anthropic landscapes. *Ad libitum* observations in the city, made outside the sampling points and/or the period dedicated to systematic data collection, point to a considerably greater richness of plants consumed by the four species of birds recorded, in addition to the occurrence of two other psittacine species, *Amazona amazonica* (Linnaeus, 1766) and *A. aestiva* (Linnaeus, 1851), in fragments present in urbanized areas.

All four bird species have a wide geographic distribution and are frequently found in various cities in Brazil (Sick, 2001). Marques et al. (2018) also recorded four psittacines in wooded squares in the urban area of Uberlândia, state of Minas Gerais, consuming resources from 33 plant species. Three birds are the same as those recorded in this study, with the exception of *F. xanthopterygius*, whereas these authors recorded *Diopsittaca nobilis* (Linnaeus, 1758). We highlight the fact that the order of abundance of foraging records was the same as in the present study, replacing *F. xanthopterygius* with *D. nobilis* as the third most recorded species. The authors also recorded a high proportion of exotic plants in psittacine's diets, higher than in the present study, ranging from 54.17% to 77% depending on the bird species. Even though metrics of ecological networks of interactions were not analyzed by Marques et al. (2018), it is noted that *B. chiriri* and *P. leucophthalmus* showed a greater number of records of interactions with a greater number of plant species, a strong indication of the importance of these species in the community, a similar result to this study. At least 14 plants correspond to the same species or genera identified in this work. There are also some observational studies in cities, focused on native trees used in urban afforestation, but not recorded in the present work, showing resource use by the same psittacines species in anthropic areas [*e.g.*, Gonçalves and Vitorino (2014); Melo et al. (2009)].

Most of the other studies published on the diet of psittacines in Brazil have presented low similarity of plant species, because they were developed in natural environments with native vegetation [*e.g.*, Francisco et al. (2002); Galetti and Rodrigues (1992); Galetti (1997); Marcondes-Machado and Oliveira (1987); Nunes and Santos Junior (2011); Pizo et al. (1995); Ragusa-Netto (2022)], this corroborates the results of the literature review by Bahia et al. (2022), which points to the low amount of research conducted in urbanized environments and the need to better understand the networks of food interactions in anthropic landscapes. However, in these studies, the same psittacines species and/or species of the same genus,

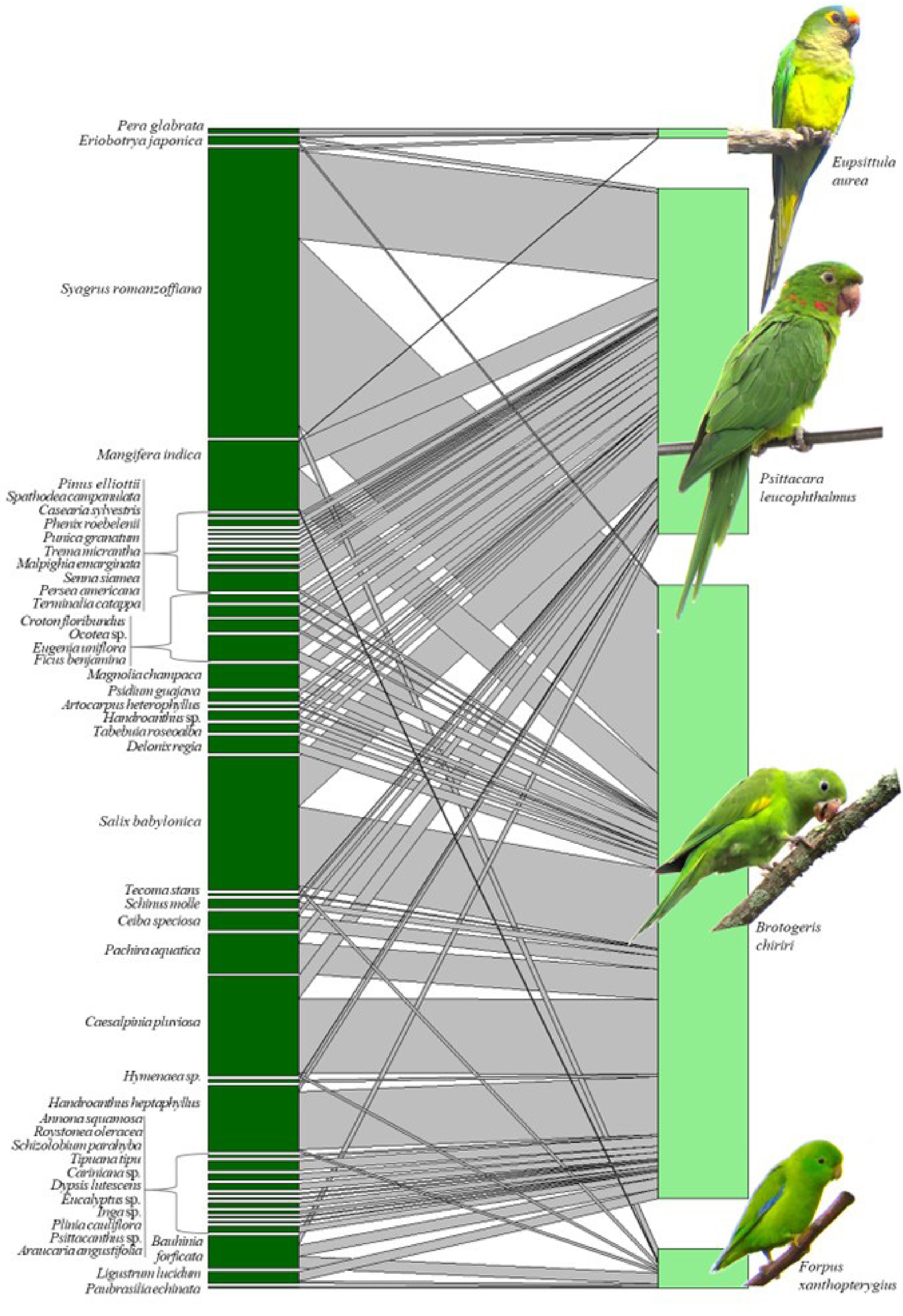

Figure 2. Feeding interactions network between Psittacidae and plant species in urban and periurban green areas. The size of the polygons is proportional to the number of recorded species and the width of the connection lines are proportional to the number of recorded interactions.

morphologically similar, were recorded, replacing the species observed here in other regions, such as *B. tirica*, as well as species of the genus *Aratinga*, the former genus of *E. aurea* and *P. leucophthalmus* before recent changes in taxonomic nomenclature. It is possible to state, therefore, that the birds recorded here have a broad capacity to occupy different habitats and feed on a greater variety of plants than was known until now, varying their diet considerably along the gradient of anthropogenic alterations.

The most important birds for the network of interactions in this study were *P. leucophthalmus* and *B. chiriri*. The first presented low food specificity and the greatest diversity in the diet (considering qualitative and quantitative data), an indication of the high behavioral plasticity for obtaining resources in an urban environment, followed by *B. chiriri,* whose great abundance of feeding records places it as a main species in the interaction network, also presenting the largest number of plant species consumed. Possibly the differences observed between these two species and *F. xanthopterygius* and *E. aurea* may have been more influenced by their low abundance in the study areas than by behavioral limitations in the ability to exploit different types of resources in anthropic landscapes. After all, just their presence in urbanized areas is already an indication of adaptive capacity.

The proportion of exotic plants, originating from other regions of the country, continent, or world, is remarkable. All the exotic species recorded are commonly used in urban forestry for different purposes (*e.g.*, landscape aesthetics, provision of fruits for human consumption) not only in the study area, but in many cities in Brazil. The use of these resources that are not present in natural areas with remnants of conserved native vegetation suggests a high plasticity in the exploitation of food sources and adaptability to anthropized environments. It is also possible to state that exotic plants are a relevant food source in the diet of psittacines and may be a crucial factor that favors the expansion of populations of some other bird species in urban environments (Schneiberg et al., 2020).

The median connectance observed influenced the result on niche overlap, which was also median. It is possible that the wide variety of plant species that provide food resources allows the consumption of species to have less overlap than expected by chance, even though the five plant species with the highest number of consumption records have been exploited by all or most psittacines. In this context, added to the high trophic niche range of *B. chiriri* and *P. leucophthalmus*, the nesting of the ecological network was medium to low, and it was not possible to identify cohesive subgroups of species that exhibit interactions with higher specificity, even though *A. aurea* and *F. xanthopterygius* consumed few species. The asymmetry of the ecological network of interactions is considerably high, as psittacines interacted with a large number of plants, whereas most plants received visits from few bird species.

Even with the increased information on feeding interactions between psittacines and plants in urban environments obtained in this study, little is known about the ecological functions as predators and effective seed dispersers performed by the birds in each specific interaction, since the size of the fruit, the seeds, and the manipulation and ingestion behavior directly influence the positioning of each psittacine within the antagonist-mutualist gradient of ecological interactions. Moreover, as observed in other studies, there is great variation in the diet and niche occupied by species throughout their respective geographic distributions, considering each type of environment they inhabit, requiring further studies in different cities and regions to fill the gap in knowledge about food interactions in anthropic landscapes. Finally, we highlight that the large number of plant species consumed by these birds and their occurrence in urbanized environments reinforce the great adaptive capacity and behavioral plasticity of some species of Psittacidae facing the rapid process of loss and degradation of natural areas by the expansion of human activities.

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References

ALVARES, C.A., STAPE, J.L., SENTELHAS, P.C., GONÇALVES, J.L.M. and SPAROVEK, G., 2013. Koppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, vol. 22, no. 6, pp. 711-728. http://dx.doi.org/10.1127/0941-2948/2013/0507.

ARAÚJO, C.B. and MARCONDES-MACHADO, L.O., 2011. Diet and feeding behavior of the yellow-faced parrot (*Alipiopsitta xanthops*) in Brasilia, Brazil. *Ornitologia Neotropical*, vol. 22, pp. 79-88.

BAHIA, R., LAMBERTUCCI, S.A., PLAZA, P.I. and SPEZIALE, K.L., 2022. Antagonistic-mutualistic interaction between parrots and plants in the context of global change: biological introductions and novel ecosystems. *Biological Conservation*, vol. 265, p. 109399. http://dx.doi.org/10.1016/j.biocon.2021.109399.

BAÑOS-VILLALBA, A., BLANCO, G., DÍAZ-LUQUE, J.A., DÉNES, F.V., HIRALDO, F. and TELLA, J.L., 2017. Seed dispersal by macaws shapes the landscape of an Amazonian ecosystem. *Scientific Reports*, vol. 7, no. 1, p. 7373. http://dx.doi.org/10.1038/s41598-017-07697-5. PMid:28785083.

BASCOMPTE, J., 2009. Disentangling the web of life. *Science*, vol. 325, no. 5939, pp. 416-419. http://dx.doi.org/10.1126/science.1170749. PMid:19628856.

BIBBY, C.J., 2004. Bird diversity survey methods. In: W.J. SUTHERLAND, I. NEWTON and R.E. GREEN, eds. *Bird ecology and conservation: a handbook of techniques*. Oxford: Oxford University Press, pp. 1-16. http://dx.doi.org/10.1093/acprof:oso/9780198520863.003.0001.

BLANCO, G., BRAVO, C., PACÍFICO, E.C., CHAMORRO, D., SPEZIALE, K.L., LAMBERTUCCI, S.A., HIRALDO, F. and TELLA, J.L., 2016. Internal seed dispersal by parrots: an overview of a neglected mutualism. *PeerJ*, vol. 4, pp. e1688. http://dx.doi.org/10.7717/peerj.1688. PMid:26925322.

BLANCO, G., HIRALDO, F. and TELLA, J.L., 2018. Ecological functions of parrots: an integrative perspective from plant life cycle to ecosystem functioning. *Emu-Austral Ornithology*, vol. 118, no. 1, pp. 36-49. http://dx.doi.org/10.1080/01584197.2017.1387031.

COLLAR, N.J., 1997. Family Psittacidae (parrots). In: J. DEL HOYO, A.E. ELLIOT and J. SARGATAL, eds. *Handbook of the birds of the world*. Barcelona: Lynx Edicións, pp. 280-477.

DORMANN, C.F, FRUEND, J. and GRUBER, B., 2021. *Bipartite: visualizing bipartite networks and calculating some (ecological)* *indices. Version 2.16. 2021* [software]. Vienna: R Foundation for Statistical Computing.

DRACXLER, C.M. and KISSLING, W.D., 2022. The mutualism–antagonism continuum in Neotropical palm–frugivore interactions: from interaction outcomes to ecosystem dynamics. *Biological Reviews of the Cambridge Philosophical Society*, vol. 97, no. 2, pp. 527-553. http://dx.doi.org/10.1111/brv.12809. PMid:34725900.

FLEMING, T.H., WILLIAMS, C.F., BONACCORSO, F.J. and HERBST, L.H., 1985. Phenology, seed dispersal, and colonization in *Muntingia calabura*, a neotropical pioneer tree. *American Journal of Botany*, vol. 72, no. 3, pp. 383-391. http://dx.doi.org/10.1002/j.1537-2197.1985.tb05362.x.

FRANCISCO, M.R., LUNARDI, V.O. and GALETTI, M., 2002. Massive seed predation of *Pseudobombax grandiflorum* (Bombacaceae) by Parakeets *Brotogeris versicolurus* (Psittacidae) in a Forest Fragment in Brazil. *Biotropica*, vol. 34, no. 4, pp. 613-615. http://dx.doi.org/10.1111/j.1744-7429.2002.tb00582.x.

GALETTI, M. and RODRIGUES, M., 1992. Comparative seed predation on pods by parrots in Brazil. *Biotropica*, vol. 24, no. 2, pp. 222-224. http://dx.doi.org/10.2307/2388679.

GALETTI, M., 1997. Seasonal abundance and feeding ecology of parrots and parakeets in a lowland Atlantic forest of Brazil. *Ararajuba*, vol. 5, pp. 115-126.

GALETTI, M., 2002. Métodos para avaliar a dieta de psitacídeos. In: M. GALETTI and M. A. PIZO, eds. *Ecologia e conservação de psitacídeos no Brasil*. Belo Horizonte: Melopsittacus Publicações Científicas, pp. 113-122.

GALETTI, M., GUEVARA, R., CÔRTES, M.C., FADINI, R., VON MATTER, S., LEITE, A.B., LABECCA, F., RIBEIRO, T., CARVALHO, C.S., COLLEVATTI, R.G., PIRES, M.M., GUIMARÃES JUNIOR, P.R., BRANCALION, P.H., RIBEIRO, M.C. and JORDANO, P., 2013. Functional extinction of birds drives rapid evolutionary changes in seed size. *Science*, vol. 340, no. 6136, pp. 1086-1090. http://dx.doi.org/10.1126/science.1233774. PMid:23723235.

GONÇALVES, G.L. and VITORINO, B.D., 2014. Comportamento alimentar de aves em *Cecropia pachystachya* Trécul (Urticacea) em um ambiente urbano no município de Luz, Minas Gerais, Brasil. *Biota Amazônia*, vol. 4, no. 3, pp. 100-105. http://dx.doi.org/10.18561/2179-5746/biotaamazonia.v4n3p100-105.

HIGGINS, M.L., 1979. Intensity of seed predation by *Brosium utik* by mealy parrots (*Amazona farinosa*). *Biotropica*, vol. 11, no. 1, p. 80. http://dx.doi.org/10.2307/2388177.

JORDANO, P., 1987. Patterns of mutualistic interactions in pollination and seed dispersal: connectance, dependence asymetries, and coevolution. *American Naturalist*, vol. 129, no. 5, pp. 657-677. http://dx.doi.org/10.1086/284665.

MARCONDES-MACHADO, L.O. and OLIVEIRA, M.A., 1987. Comportamento alimentar de aves em *Cecropia* (Moraceae), em Mata Atlântica, no estado de São Paulo. *Revista Brasileira de Zoologia*, vol. 4, no. 4, pp. 331-339. http://dx.doi.org/10.1590/S0101-81751987000400005.

MARQUES, C.P., AMARAL, D.F., GUERRA, V., FRANCHIN, A.G. and MARÇAL JÚNIOR, O., 2018. Exploração de recursos alimentares por psitacídeos (Aves: Psittaciformes) em uma área urbana no Brasil. *Biotemas*, vol. 31, no. 2, pp. 33-46. http://dx.doi.org/10.5007/2175-7925.2018v31n2p33.

MELO, C., OLIVEIRA, A.D., BORGES, C.A., RIBEIRO, G. and TAVARES, J., 2009. Impact of *Forpus xanthopterygius* (Spix, 1824) (Aves, Psittacidae) on flowers of *Handroanthus serratifolius* (Vahl.) SO Grose (Bignoniaceae). *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 69, no. 4, pp. 1149-1151. http://dx.doi.org/10.1590/S1519-69842009000500020. PMid:19967187.

NUNES, A.P. and SANTOS JUNIOR, A., 2011. Itens alimentares consumidos por psitacídeos no Pantanal e planaltos do entorno, Mato Grosso do Sul. *Atualidades Ornitológicas On-line*, vol. 162, pp. 42-50.

OKSANEN, J., BLANCHET, F.G., KINDT, R., LEGENDRE, P., MINCHIN, P.R., O'HARA, R.B., SOLYMOS, P., STEVENS, M.H.H., SZOECS, E., WAGNER, H., BARBOUR, M., BEDWARD, M., BOLKER, B., BORCARD, D., CARVALHO, G., CHIRICO, M., CACERES, M., DURAND, S., EVANGELISTA, H.B.A. and OKSANEN, M.J., 2020. *Package 'vegan'. Community ecology package, version 2.5-7, 2, no. 9, pp. 1-295* [software]. Vienna: R Foundation for Statistical Computing.

OLIVEIRA, A.K.M., NUNES, A.C. and FARIAS, G.C., 2012. Predation of *Curatella americana* seeds by *Aratinga aurea* parrots. *Revista Brasileira de Biociências*, vol. 10, pp. 526-529.

PACHECO, J.F., SILVEIRA, L.F., ALEIXO, A., AGNE, C.A., BENCKE, G.A., BRAVO, G.A., BRITO, G.R.R., COHN-HAFT, M., MAURÍCIO, G.N., NAKA, L.N., OLMOS, F., POSSO, S.R., LEES, A.C., FIGUEIREDO, L.F.A., CARRANO, E., GUEDES, R.C., CESARI, E., FRANZ, I., SCHUNCK, F. and PIACENTINI, V.Q., 2021a. Annotated checklist of the birds of Brazil by the Brazilian Ornithological Records Committee: second edition. *Ornithology Research*, vol. 29, pp. 94-105. http://dx.doi.org/10.1007/s43388-021-00058-x.

PACHECO, J.F., SILVEIRA, L.F., ALEIXO, A., AGNE, C.E., BENCKE, G.A., BRAVO, G.A. and PIACENTINI, V.Q., 2021b. Annotated checklist of the birds of Brazil by the Brazilian Ornithological Records Committee: second edition. *Ornithology Research*, vol. 29, pp. 94-105. http://dx.doi.org/10.1007/s43388-021-00058-x.

PIZO, M.A., SIMÃO, I. and GALETTI, M., 1995. Diet and flock size of sympatric parrots in the Atlantic Forest of Brazil. *Ornitologia Neotropical*, vol. 6, pp. 87-95.

PLANTS OF THE WORLD ONLINE – POWO, 2023 [viewed 14 April 2023]. *Welcome to Plants of the World Online* [online]. Royal Botanic Gardens/Kew. Available from: http://www.plantsoftheworldonline.org/

R CORE TEAM, 2021 [viewed 7 June 2023]. *R: a language and environment for statistical computing. Version 4.1.2* [software]. Vienna: R Foundation for Statistical Computing. Available from: https://www.R-project.org/

RAGUSA-NETTO, J., 2014. Crop damage of *Eriotheca gracilipes* (Bombacaceae) by the blue-fronted Amazon (*Amazona aestiva*, Psittacidae), in the Brazilian Cerrado. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 74, no. 4, pp. 837-843. http://dx.doi.org/10.1590/1519-6984.04713. PMid:25627593.

RAGUSA-NETTO, J., 2022. Feeding ecology of a parrot assemblage in the Brazilian Cerrado. *Ornitologia Neotropical*, vol. 33, pp. 109-119. http://dx.doi.org/10.58843/ornneo.vi.755.

RENTON, K., SALINAS-MELGOZA, A., DE LABRA-HERNÁNDEZ, M.Á. and DE LA PARRA-MARTÍNEZ, S.M., 2015. Resource requirements of parrots: nest site selectivity and dietary plasticity of Psittaciformes. *Journal of Ornithology*, vol. 156, no. S1, pp. 73-90. http://dx.doi.org/10.1007/s10336-015-1255-9.

SAZIMA, I., 1989. Peach-fronted Parakeet feeding on winged termites. *The Wilson Bulletin*, vol. 101, pp. 656-657.

SAZIMA, I., 2008. The parakeet *Brotogeris tirica* feeds on and disperses the fruits of the palm *Syagrus romanzofûana* in Southeastern Brazil. *Biota Neotropica*, vol. 8, no. 1, pp. 231-234. http://dx.doi.org/10.1590/S1676-06032008000100026.

SCHNEIBERG, I., BOSCOLO, D., DEVOTO, M., MARCILIO-SILVA, V., DALMASO, C.A., RIBEIRO, J.W., RIBEIRO, M.C., GUARALDO, A.C., NIEBUHR, B.B. and VARASSIN, I.G., 2020. Urbanization homogenizes the interactions of plant-frugivore bird networks. *Urban Ecosystems*, vol. 23, no. 3, pp. 457-470. http://dx.doi.org/10.1007/s11252-020-00927-1.

SICK, H., 2001. *Ornitologia brasileira*. Rio de Janeiro: Nova Fronteira, 862 p.

SILVA, P.A., 2005. Predação de sementes pelo maracanã-nobre (*Diopsittaca nobilis*, Psittacidae) em uma planta exótica (*Melia azedarach*, Meliaceae) no oeste do estado de São Paulo, Brasil. *Revista Brasileira de Ornitologia*, vol. 13, pp. 183-185.

SILVA, P.A., 2007. Predação de sementes por periquitos *Brotogeris chiriri* (Psittacidae) em *Chorisia speciosa* (Bombacaceae). *Revista Brasileira de Ornitologia*, vol. 15, no. 1, pp. 127-129.

SOARES, J.J., SILVA, D.W. and LIMA, M.I.S., 2003. Current state and projection of the probable original vegetation of the São Carlos region of São Paulo State, Brazil. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 63, no. 3, pp. 527-536. http://dx.doi.org/10.1590/S1519-69842003000300019. PMid:14758712.

SUTHERLAND, W.J., 2004. Diet and foraging behaviour. In: W. J. SUTHERLAND, I. NEWTON and R. E. GREEN, eds. *Bird ecology and conservation: a handbook of techniques*. Oxford: Oxford University Press, pp. 233-250. http://dx.doi.org/10.1093/acprof:oso/9780198520863.003.0010.

ZAR, J.H., 1999. *Biostatistical analysis*. 4th ed. Upper Saddle River: Prentice Hall, 944 p.