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Shifting from seed predator to seed disperser in the Picazuro Pigeon: Insights from an urbanized area.

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Abstract

Frugivory supports seed dispersal and the reproductive success of various plants. Environmental degradation can lead to the local extinction of medium and large frugivores, jeopardizing this process. The picazuro pigeon (*Patagioenas picazuro*), typically associated with open and semi-open areas in Brazil, was mainly considered granivorous until the late 20th century but is now recognized as a frugivore or granivore-frugivore. In this study, we assessed its frugivorous diet and role as a seed disperser by collecting seeds from fecal samples on the Unicamp campus and analyzing the condition of the seeds after passing through the digestive tract of *P. picazuro*. We found 45 plant species in its feces, including *Cordia myxa*, *Solanum americanum, Solanum granuloso-leprosum,* and *Cytharexyllum myrianthum*. While *Solanum americanum* and *Solanum granuloso-leprosum* had germination rates of 63% and 28%, respectively, *Cordia myxa* and *Cytharexyllum myrianthum* did not germinate. Thus, *P. picazuro* plays a relevant ecological role as an occasional frugivore in semi-open and anthropized environments in southeastern and southern Brazil.

Keywords: *Patagioenas picazuro,* frugivory, seed dispersal, urban area, germination test.

Introduction

The Picazuro Pigeon (*Patagioenas picazuro*) is a large neotropical pigeon with distinctive white bands on its wings, earning it the popular name "*Pomba asa-branca*" (White-winged pigeon) in Brazil (Baptista, 2020). It is currently distributed in gallery forests and grasslands from central Brazil to Argentina (Baptista, 2020). The species readily invades degraded areas, causing its populations to seemingly continuous growing (IUCN, 2016), as ongoing environmental degradation provides new habitable zones (Baptista et al., 1997). Regarding its feeding patterns, the diet of *P. picazuro* is still poorly understood. It possibly includes seeds, buds, berries, young leaves, and insects found on the ground and in trees (Baptista, 2020). Initially described in the literature as granivorous (Schubart, 1965), subsequent studies have identified the species as also frugivorous, suggesting that fruits may constitute a considerable part of its diet (Sick, 1984; Baptista et al., 1997).

Frugivory is an important mutualism, as seed dispersal is an essential biotic interaction for the maintenance and regeneration of ecosystems (Fenner, 2000). This process transports seeds away from the parent plant to locations where their chances of survival are greater (Jordano et al., 2006), thereby influencing the distribution of plant species (Jordano, 2002). Medium and large-sized birds, such as *P. picazuro*, play a significant role as seed dispersers (da Silva, 2000) because they can ingest larger fruits and carry seeds over longer distances (Ribeiro da Silva, 2015). In the context of ongoing deforestation and defaunation (Ceballos, 2017), medium and large-sized birds are often among the first to disappear from fragmented environments and are some of the most affected (Zaiden, 2015; Wright, 2003; Silva, 2014). The disappearance of these frugivorous birds can have significant consequences for seed dispersal, although the exact impacts are still uncertain. Potential effects include increased seed mortality due to

competition with the parent plant or predation, decreased genetic variability, and reduced seed rain in degraded areas (Jordano et al., 2006; Caves et al., 2013).

Given the critical role these birds play as seed dispersers, local declines in their populations can disrupt important biotic interactions (Loiselle, 2002; Zaiden, 2015). However, *Patagioenas picazuro*, a species that thrives in degraded areas, may compensate for the loss of other bird species by continuing to disperse seeds in these environments. This adaptability makes *P. picazuro* a key player in the maintenance and restoration of degraded areas (Athiê, 2011), especially in the Atlantic Forest domain of southeast Brazil, which has been heavily impacted by deforestation (Ribeiro et al., 2009). The presence of *P. picazuro* in degraded areas could be highly beneficial for ecosystem recovery, as this species can continue the vital process of seed dispersal in the absence of other birds. This highlights the importance of understanding and preserving the ecological roles of resilient species like *P. picazuro* in the face of ongoing environmental change.

Our main objective is to evaluate the frugivory and seed dispersal provided by *Patagioenas picazuro* in an urbanized area (Figure 1). To achieve this, we aim to determine if *P. picazuro* consumes fruits (Figure 1a), understand if its frugivory habits are related to food resource availability due to an opportunistic diet (Figure 1b), and identify the plant species being consumed. If seeds are found in fecal samples, we will analyze the effect of passage through the gastrointestinal tract of *P. picazuro* on seed integrity and germination (Figure 1b).

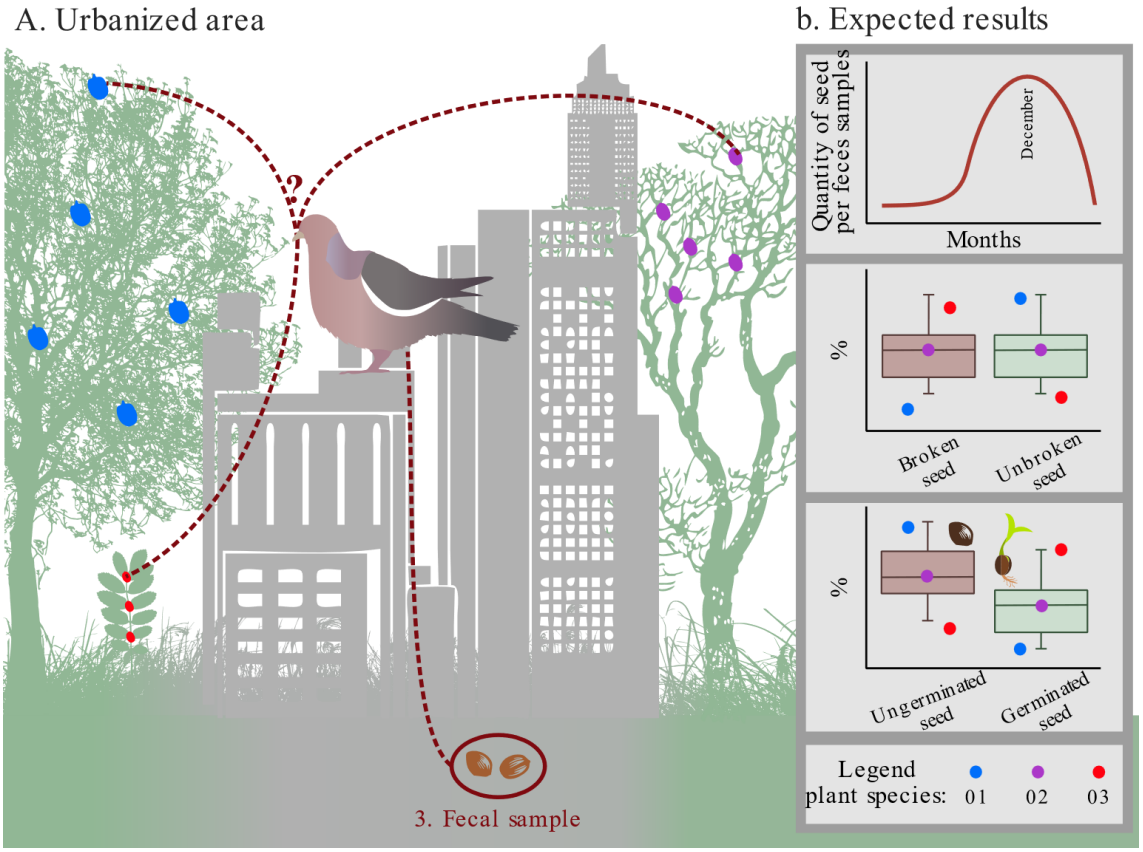


Figure 1. Hypothesized expectations for our results. A) We anticipate that *P. picazuro* consumes fruits within urban areas. B) This feeding behavior is expected to predominantly correlate with fruit abundance during summer. Additionally, based on our seed analysis, we expect to find both broken and intact seeds in equal proportions. Furthermore, we anticipate that most seeds will not germinate, but despite the higher proportion of non-germinated seeds compared to germinated seeds, the amount that does germinate will be significant enough not to be disregarded in terms of their ecological importance.

Methodology

Study area

The project was developed in the Campus of the State University of Campinas (Unicamp) (Figure 02). The campus design features a central plaza with a green area to foster student sociocultural interaction, surrounded by the institutes, and its establishment spurred urban and economic growth but also led to issues typical of rapid development, such as changes in land use in an area previously dedicated to agriculture due to its fertile soil (Rodrigues, 2002).

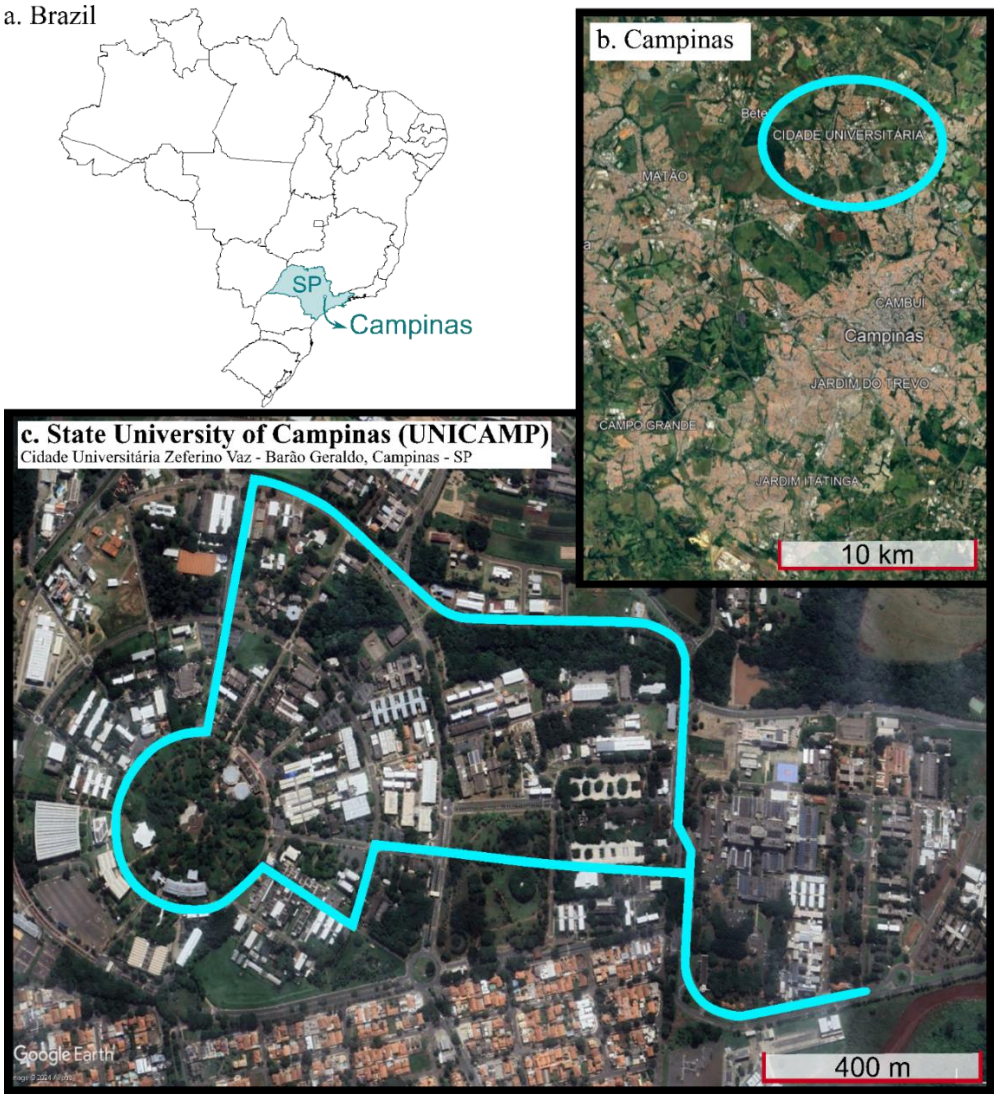


Figure 2. A) Map of Brazil highlighting the São Paulo state and indicating the location of Campinas. B) Map of Campinas showing the location of the State University of Campinas (Unicamp) within the city. C) Map of Unicamp displaying the route taken on campus for collecting fecal samples of *Patagioenas picazuro* (Source: Google Earth Pro, 2024).

Data collection

From September 15, 2018, to April 28, 2019, we collected fecal samples from *P. picazuro* once or twice a week, while walking on a predetermined route (Figure 2C) in areas where *Patagioenas picazuro* maintained fixed perches, where droppings from several individuals were found together. When found, the droppings location was marked on the GPS, and both the seeds and the feces were stored in paper bags. Subsequently, in

the laboratory, all the collected material was sorted under a stereo microscope using tweezers and protective masks to avoid any contamination from the feces (Haag-Wackernagel & Moch, 2004). The seeds found in each sample were counted and separated according to their species and integrity (whole or broken).

Germination tests

Whenever the number of seeds per species was sufficient (number of whole seeds > 100) and the seed species could be identified, germination tests were carried out. Broken seeds were excluded from the germination tests. This left us with four species selected for germination: *Cordia myxa* (Boraginaceae), *Solanum americanum* (Solanaceae), *Solanum granuloso-leprosum* (Solanaceae), and *Citharexyllum myrianthum* (Verbenaceae). Whole seeds were washed with running water and detergent to remove as much fecal residue as possible. The cleaned seeds were then placed in an antifungal solution for 5 minutes, washed again, and distributed in Petri dishes with filter paper. The plates were placed in a greenhouse under 70% shade, at room temperature, and moistened with distilled water on alternate days. The number of germinated seeds was recorded weekly. Seeds were considered germinated when radicle extrusion was visible within a maximum of 30 days, and after this period, ungerminated seeds were discarded.

Data analysis

All analyses were conducted using R software (R Core Team, 2022), and all graphs were produced using ggplot2 (Chang, 2018). We used the "*Atlantic frugivory: a plant–frugivore interaction data set for the Atlantic Forest*" (Bello, 2017) database to obtain information on interactions between bird species and plants, as well as fruit diameter information. We only included interaction information in the analysis when there was data available on fruit diameter. Additionally, we used AVONET (Tobias,

2022) to obtain values for the Hand-Wing Index. To determine which species will be included in Hand-Wing Index analysis we used occurrences registered for the southeast region of Brazil in the *Handbook of Birds Alive site*, excluding species from other biomes and exotic species. Subsequently, we retained all restricted and occasional frugivores based on the *Atlantic Frugivory dataset* (Bello, 2017), with facultative frugivores only being included if at least 30% of their diet consisted of fruits, according to the *EltonTraits* dataset (Wilman, 2014) or Degree of Frugivory information (Gomes, 2022). We used the shapiro.test from the stats package to identify data distribution, and ANOVA, wilcox.test, and TukeyHSD to identify significant differences.

Results

We georeferenced 211 fecal patches, of which 153 contained seeds, accounting for a total of 6186 seeds found belonging to 42 different plant species. We identified seven plant species (*Cordia myxa, Solanum americanum, Solanum granuloso-leprosum, Phoenix canariensis, Sebastiania brasiliensis, Citharexyllum myrianthum, and Peltophorum dubium*) and ten families (Boraginaceae, Verbenaceae, Solanaceae, Annonaceae, Moraceae, Poaceae, Euphorbiaceae, Urticaceae, Arecaceae, and Fabaceae). Table 1 presents the main data obtained, and Table S1 of the Supplementary Material presents photographs of all species and morphospecies.

Table 01. Species of seeds found in the feces of *Patagioenas picazuro* in the Unicamp campus, between September 2018 and April 2019, with information on the species, family, months of occurrence, number of whole seeds in the feces (N_i), number of broken seeds in the feces (N_b), average fruit size according to the literature, and the size of the largest and smallest sides of the seed.

Species	**Family**	**Month**	**N_i**	**N_b**	**Fruit size (mm) *literature***	**Range seed size (mm)**
Solanum granuloso-leprosum	Solanaceae	N, D, J, F, M	163	51	1.5	2.1-2.8

Solanum americanum	Solanaceae	S, O, D	208	55	0.5-1	1.2-1.8
Cordia myxa	Boraginaceae	D, J, F, M, A	3595	25	10-30	8.7-10
Citharexylum myrianthum	Verbenaceae	J, F, M	332	335	10	6-10
Solanum spp. 1	Solanaceae	O, J, F, M	852	160	NA	2.7-3.5
Solanum ssp. 2	Solanaceae	J	1	0	NA	1.14-1.52
Solanum ssp. 3	Solanaceae	J	2	0	NA	3-3.63
Ssp. 8	NA	N	0	2	NA	7-9
Ssp. 9	NA	D	1	0	NA	9-10
Ssp.10	NA	D	1	0	NA	6-9
Ssp.11	NA	D	1	0	NA	8-10
Ssp.12	NA	D	0	1	NA	7-10
Ssp.13	NA	D	1	0	NA	0.5-1
Xylopia sp.	Annonaceae	D	1	0	NA	4-5.5
Poaceae ssp. 1	Poaceae	D, J	78	17	NA	2.44-3.05
Ssp.16	NA	D	1	0	NA	8.69-11.26
Ssp. 17	NA	D	5	0	NA	1.23-1.9
Ssp. 18	NA	D, J, F	3	0	NA	1.9-3.87
Sebastiana brasiliensis	Euphorbiaceae	J	2	0	10-20	5.14-6.83
Ssp.20	NA	J	1	0	NA	5.98-6.85
Ssp.21	NA	J	1	1	NA	1.41-2.06
Poaceae ssp. 2	Poaceae	J	1	0	NA	1.41-1.69
Ssp.23	NA	J	1	0	NA	6.83-8.78
Ssp.24	NA	J	0	1	NA	4.7-5.23
Ssp.25	NA	J	1	0	NA	8.26-9,56
Ssp.26	NA	J	1	0	NA	2.22-2.7
Ssp.27	NA	F	0	1	NA	4.91-5.72
Ssp.28	NA	M	3	0	NA	1.49-1.89
Ssp.29	NA	F	1	1	NA	2.67-4.55
Ficus sp. 1	Moraceae	F	1	0	NA	1.57-1.98
Ssp.31	NA	F	2	0	NA	5.35-6.97
Ssp.32	NA	M	1	0	NA	6.6-10.6
Ssp.33	NA	F	1	0	NA	5.08-8.4
Cecropia sp.	Urticaceae	F	2	0	NA	1.24-1.91
Ssp.35	NA	F	1	0	NA	1.49-4.69
Phoenix canariensis	Arecaceae	M	1	0	10- 20	6.81-11.17
Peltophorum dubium	Fabaceae	M	1	0	NA	3.88-10.57
Ssp.38	NA	A	1	0	NA	4.91-7.07
Ssp.39	NA	M	177	86	NA	1.89-2.46
Ssp.40	NA	M	0	2	NA	8.31-11.17
Ssp.41	NA	M	2	0	NA	6.92-12.08
Ssp.42	NA	M	1	0	NA	2.25-2.86
Total Ni and Nq	5448	738	**Total seeds**			6186

Fecal spots with seeds represent approximately 67% of the total fecal spots found and are especially concentrated during the months of December to March (Figure 3a;

Table S2). Higher seed abundances are also observed during these months (Figure 3a; Table S2). Our analysis revealed that a significant portion of the seeds pass through the gastrointestinal tract of this pigeon without being broken (Figure 3b; Wilcoxon rank sum test, *p-value* = 0.02984; Tabel S3). However, this process appears to impact the germination rates, which were overall low (Figure 3c; Tabel S3).

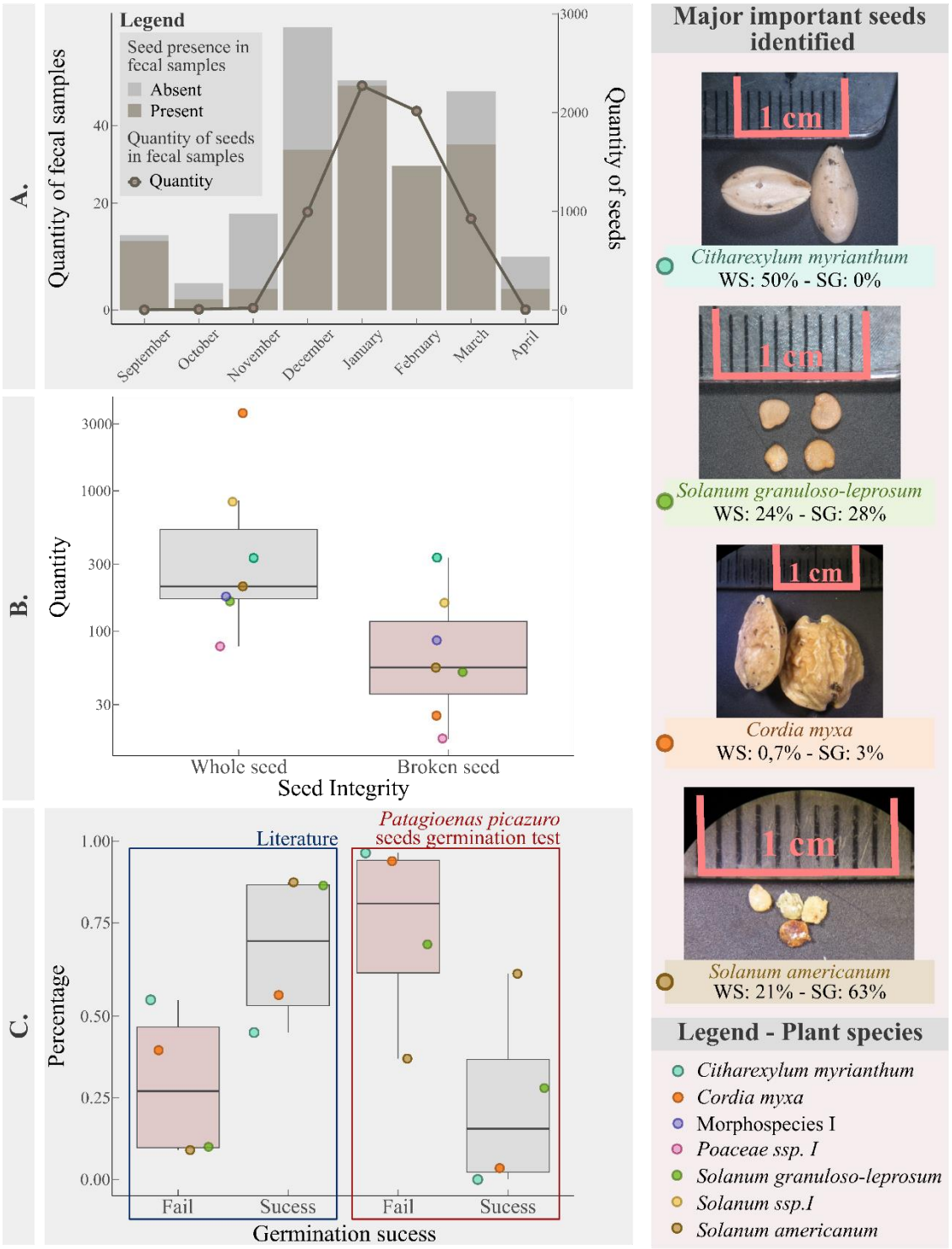


Figure 03. Results related to seed abundance and their characteristics. A) The bars depict the quantity of fecal samples from *P. picazuro* with and without seeds during each month of the study period, while the line represents the monthly count of seeds found in *P. picazuro* feces. CB) Shows the percentage of intact and broken seeds across all samples, highlighting the most abundant species. c) Shows the percentage of intact and broken seeds across all samples, highlighting the identified species, including data sourced from both literature and experimental findings. At right we represent the most important seeds identified in our study (WS denotes the percentage of seeds that break when passing through the digestive tract of *P. picazuro*, and SG denotes the percentage of seeds that germinated). Literature germination rates: Barroso, 2009; Amaral, 2013; Rossaneis, 2015; Castellani, 2009.

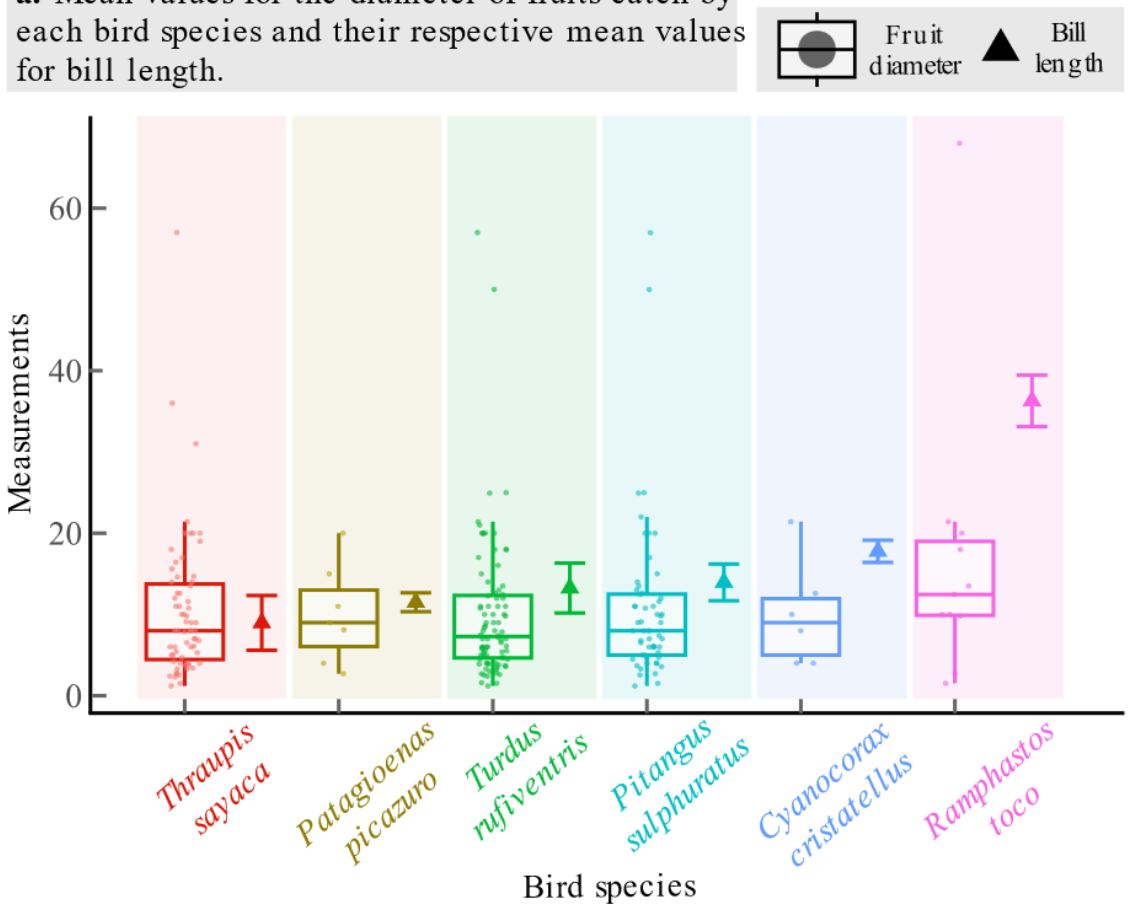
The most abundant seed found was *Cordia myxa,* a shrub or small tree up to 12 meters tall (Al-Snafi, 2016) and an exotic species in the study area (Sivalingam et al., 2012). *Cordia myxa* fruits are a sweet-tasting drupe, 2–3.5 cm long, with up to two seeds, which take around 40 to 60 days to germinate (Burkill, 1985; Oudhia, 2007; Al-Snafi, 2016). According to our data, we found that more than 99% of its seeds remained intact after passing through the digestive tract of *P. picazuro,* however, most seeds did not germinate (93%) (Figure 3; Table S3). Another abundant seed found was *Citharexyllum myrianthum*, a medium-sized tree species of the Verbenaceae family that occurs in the northeast, southeast, and south of Brazil (Queiroz-Alves, 2020). Its fructification occurs between January and March, and the fruits are about 1 cm with two seeds, whose germination takes around 20 to 40 days (Lorenzi, 1992; Machado, 2005). According to our data, we found that approximately 50% of *C. myrianthum* seeds broke while passing through the digestive tract of the *P. picazuro* (Supplementary table; Figure 3) and none of its seeds germinated (Figure 3; Table S3).

Solanum americanum belongs to the family Solanaceae and is a fast-growing pioneer herbaceous plant ranging from 40 to 70 cm in height (Usman, 2018; Forte, 2019). Its fruits are 5 to 10 mm in diameter, containing numerous small seeds (Edmonds, 1977).

According to our data, the majority of *S. americanum* seeds (79%) remained unbroken after consumption by *P. picazuro*, and 63% germinated in our tests (Figure 3; Table S3). Lastly, *Solanum granuloso-leprosum* also belongs to the family Solanaceae and is distributed in South and Southeast of Brazil (Picoli, 2013). It is a small pioneer tree that occurs in secondary forests and colonizes disturbed areas (Picoli, 2013; Jacomassa, 2016). Its fruits are approximately 15 mm in diameter, containing many small seeds (Jacomassa, 2016). We found that 76% of the seeds were defecated intact, but we had only 28% success in germination tests (Figure 3; Table S3).

We compared the average diameter of fruits swallowed by five other generalist frugivorous species (*Thraupis sayaca, Turdus rufiventris, Pitangus sulphuratus, Cyanocorax cristatellus*, and *Ramphastos toco*), which are sympatric and syntopic with *Patagioenas picazuro*. We found a significant difference in bill length among these species (ANOVA *p-value* = 2×10^{-16}) (Figure 4; Table S4), with *P. picazuro* having a bill size significantly smaller than that of *Cyanocorax cristatellus* (ANOVA *p-value*: 0.0000171) and *Ramphastos toco* (*p-value*: ~0), but no significant difference compared to the other three species. However, we also found that despite having an overall smaller bill length than *Cyanocorax cristatellus* and *Ramphastos toco*, there was no difference in the mean fruit diameter consumed by *P. picazuro* when compared to these larger-billed species (ANOVA *p-value* = 0.381) (Figure 4; Table S5). Additionally, we identified that *P. picazuro* has a higher dispersal ability compared to *T. rufiventris*, *P. sulphuratus*, *R. toco,* and *T. sayaca* (Figure 4), and a high hand-wing value between all fruit-eating birds in the southeastern Atlantic Forest.

a. Mean values for the diameter of fruits eaten by each bird species and their respective mean values for bill length.



b. Values of Hand-Wing Index for each species analyzed among all fruit-eating species in the Southeastern Atlantic Forest

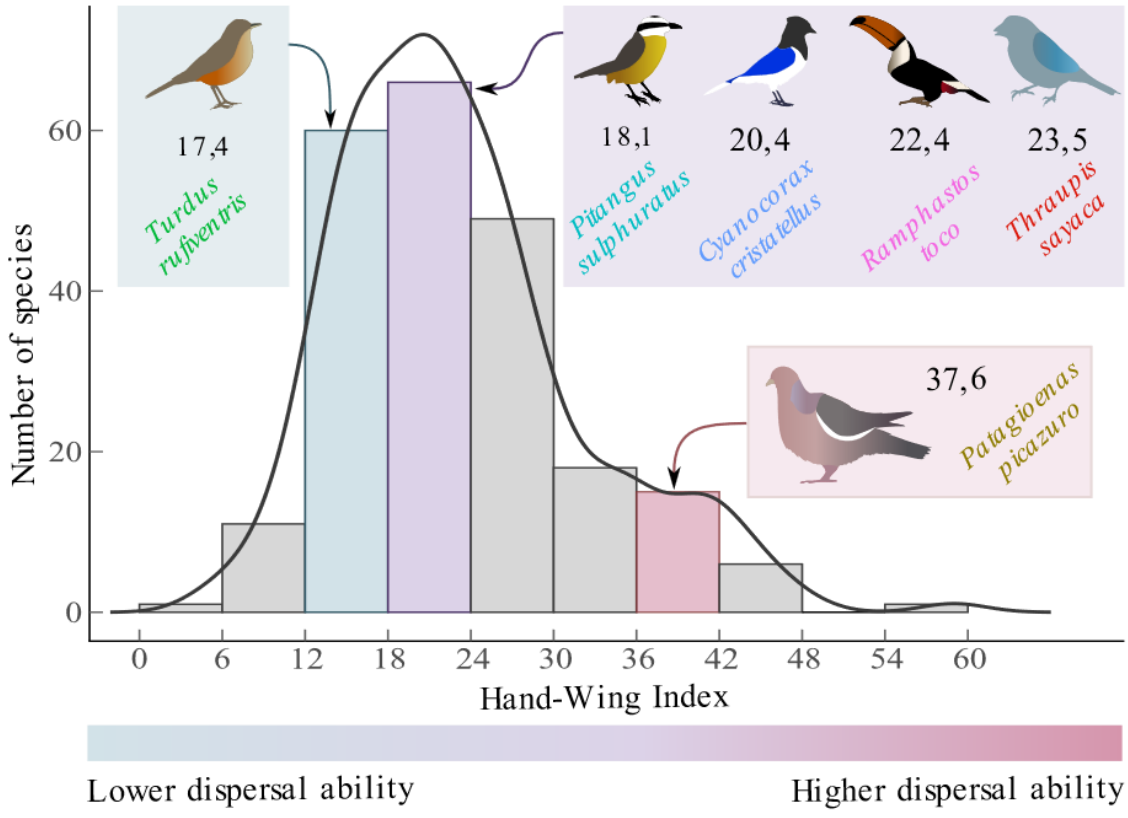


Figure 04. Results found utilizing public databases. A) Mean values for the diameter of fruits eaten by *Thraupis sayaca, Turdus rufiventris, Pitangus sulphuratus, Cyanocorax cristatellus*, *Patagioenas picazuro* and *Ramphastos toco* and their respective mean values for bill length. B) Values of Hand-Wing Index for each species analyzed among all fruit-eating species in the Southeastern Atlantic Forest.

Discussion

We found that most seeds were found during the rainy season, which in southeast Brazil spans from October to March (Bellprat, 2015). This variation in the number of seeds found seems to reflect phenological differences in fruit production (Freire, 2013) and the diet preferences of *Patagioenas picazuro*, which appears to consume this resource opportunistically when it is more abundant.

Across all species found in fecal samples, *Patagioenas picazuro* seems to have a strong preference for the fruits of *Cordia myxa*, which accounts for approximately 58% of the total seeds found. The fruits of this species are relatively large, measuring 2–3.5 cm in diameter (Al-Snafi, 2016), and the seeds are defecated whole by the pigeon. This demonstrates the capacity of *P. picazuro* to ingest and disperse larger seeds. However, it was not possible to observe the frugivory on this species directly, as the pigeon is extremely discreet while eating (Checon, 2020), making it difficult to accurately infer the largest diameter of the fruit that the species is capable of ingesting. However, utilizing database information, we found that the Picazuro pigeon can disperse fruits equivalent to those dispersed by frugivores with beak widths up to 17.77 ± 1.37 mm, even though its average beak width is less than 12 mm (11.50 ± 1.17) (Figure 4; supplementary table).

Considering the percentages of intact seeds found in its feces, as well as the germination rates obtained, which vary depending on the plant species, we reinforce that *P. picazuro* can be considered an occasional frugivore (Sick, 2001; Baptista et al. 1997). Its effect on the dispersal of different plant species can be quite varied and distinct, as

found in this study. We observed positive results for *Solanum americanum* and *Solanum granuloso-leprosum*, and negative results especially for *Citharexyllum myrianthum*. These results align with various data in the literature identifying the species as either frugivorous or granivorous (Sick, 2001; Baptista et al., 1997).

Being a medium-sized bird capable of traveling long distances (Nunes, 2004), *P. picazuro* has significant potential to contribute to seed dispersal for various plant species. This is particularly crucial in highly degraded environments where it can move between habitat fragments, succeed in deforested areas, and recently exploit urbanized regions (Baptista, 2020). In such areas, larger frugivores are often absent (Loiselle, 2002; Wright, 2003; Silva and Pedroni, 2014; Zaiden, 2015), making the role of *P. picazuro* even more important. The positive germination results for *Solanum americanum* and *Solanum granuloso-leprosum*, both pioneer species, highlight its potential to aid in the regeneration of these disturbed landscapes. By dispersing these pioneer species, *P. picazuro* can facilitate the initial stages of ecological succession, thereby contributing to the restoration and resilience of degraded ecosystems.

However, the role of a generalist and occasional frugivore also poses some biodiversity threats, as *P. picazuro* includes seeds of some exotic species in the diet, like *Cordia myxa*, *Phoenix canariensis*, and at least two grass species. Being both a granivorous and frugivorous bird, enables this pigeon to disperse exotic and possibly invasive species in natural habitats, as seems to be the case for *Cordia myxa*, a native Tropical Asian species introduced in many tropical regions of the world (Sivalingam et al., 2012; Checon, 2020) and largely used in restoration projects in southeast Brazil (Assis et al., 2013).

Conclusions

Patagioenas picazuro can be considered an occasional frugivore, capable of legitimately dispersing native and exotic fleshy fruit species up to 10 mm in diameter. This gives it a secondary, yet significant, ecological role in the community of generalist frugivorous birds in semi-open and anthropized environments of southeastern and southern Brazil. Our results highlight that some species traditionally underestimated for seed dispersal can benefit the maintenance and restoration of degraded habitats and largely outweigh some possible ecological counterfeits.

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Authors' contribution statement

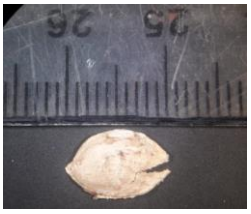
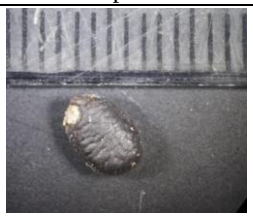
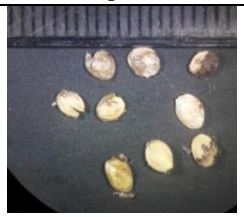
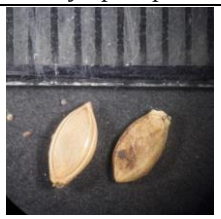
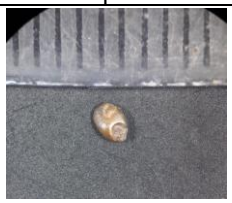
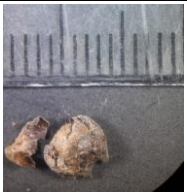
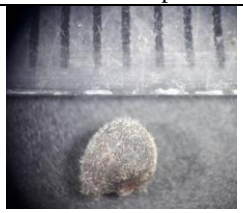
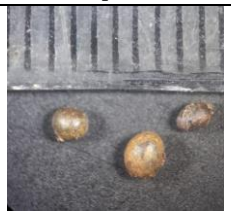
C.T.C., W.R.S. and M.F.C. Conceptualized the Ideas and did the Study Design, W.R.S. did the supervision. M.F.C. performed the Data collection, Screening and Curation. M.F.C. did the Data Analysis and Interpretation. M.F.C. wrote the original draft, W.R.S. and C.T.C. did the review and editing.

Conflict of interest statement

The authors declare that there is no conflict of interest.

Supplementary material

Table S1. Photographs of all species and morphospecies found in the feces samples.

 *Solanum granuloso-leprosum*	 *Solanum americanum*	 *Cordia myxa*	 *Citharexylum myrianthum*
 *Solanum spp. 1*	 *Solanum ssp. 2*	 *Solanum ssp. 3*	 Ssp. 8
 Ssp. 9	 Ssp. 10	 Ssp. 11	 Ssp. 12
 Ssp. 13	 *Xylopia sp*	 *Poaceae* ssp. 1	 Ssp. 16.
 Ssp. 17	 Ssp. 18	 *Sebastiana brasilensis*	 Ssp. 20
 Ssp. 21	 *Poaceae* ssp. 2	 Ssp. 23	 Ssp. 24
 Ssp. 25	 Ssp. 26	 Ssp. 27	 Ssp. 28

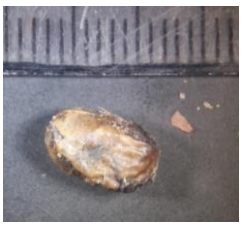
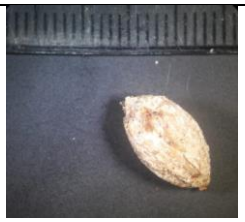
 Ssp. 29	 *Ficus sp. I*	 Ssp. 31	 Ssp. 32
 Ssp. 33	 *Cecropia sp.*	 Ssp. 35	 *Phoenix dactylifera*
 *Peltophorum dubium*	 Ssp. 38	 Ssp. 39	 Ssp. 40
 Ssp. 41	 Ssp. 42		

Table S2. Quantity of fecal spots with and without seeds, and quantity of seeds, found each month.

Month	Quantity of spots without seeds per month	Quantity of spots with seeds per month	Quantity of seeds collected per month
September	1	13	3
October	3	2	8
November	14	4	22
December	23	30	995
January	1	42	2273
February	0	27	2001
March	10	31	884
April	6	4	5
Total	58	153	7191

Table S3. Quantity of intact and broken seeds found in fecal samples for the most abundant species identified, along with germination rates observed in our tests and in the literature.

Species	Intact seeds	Broken seeds	Germination rates	Germination (literature)
Cordia myxa	3595	25	0.03	0.56
Citharexylum myrianthum	332	335	0	0.45
Solanum americanum	208	55	0.63	0.91

Solanum granuloso-leprosum	163	51	0.28	0.9
Solanum spp. I	852	160	NA	NA

Table S4. Values for bill lengths for different individuals of *Thraupis sayaca*, *Turdus rufiventris, Pitangus sulphuratus, Patagioenas picazuro*, *Cyanocorax cristatellus*, and *Ramphastos toco*.

Thraupis sayaca	*Turdus rufiventris*	*Pitangus sulphuratus*	*Patagioenas picazuro*	*Cyanocorax cristatellus*	*Ramphastos toco*
10	15.3	11.6	12.85	20.5	44.3
9.5	14.5	15	13.34	18.2	36.4
7.8	16.8	17.7	11.73	17.3	32.8
12.8	15.2	10.4	11.4	19.3	37.4
12.4	15.5	15.3	9.86	19.1	34.5
12	15.8	15.7	12.15	17	36.2
12.7	13.5	14.4	9.69	16.4	33.5
8.13	14.6	16	11.18	16.5	35.8
11.9	14.5	15.4	10.93	16.2	35.2
10.6	16.1	14.6	11.89	17.4	36.8
12	15.2	15.1		17.6	
12.4	15.4	16.9			
10.1	13.8	15.6			
13	13.3	16.3			
12.5	16	15.1			
9.7	17.9	14.3			
11.2	13.8	15.8			
10.2	16.6	15.2			
9.7	8.3	10.1			
9.3	19.5	10.4			
9.4	16.7	10			
10.4	16.4	9.8			
9.7	16.6	10.1			
10	15	10.2			
11.5	13.7	16.3			
7.87	12.9	15.1			
8.83	15	14.5			
8.44	14.7	14			
7	11.1	14.3			
6.7	10.8	14.9			
8.1	11.3	14.2			
8.1	13	13.4			
6.3	11.3	13.6			
7	11.1	13			
	12.2				
	13.6				
	12.3				
	13.84				
	14.02				
	13.88				

	14.54				
	13.4				
	12.8				
	12.3				
	13				
	11.9				
	11.7				
	6.6				
	6.3				
	5.6				
	7.1				
	6.5				
	6.6				
	15.7				
	13				
	14.1				

Table S4. Interactions between bird species and plant species identified in "Atlantic frugivory: a plant–frugivore interaction data set for the Atlantic Forest" when fruit diameter was available in the dataset.

Species	Fruit diameter	*Patagioenas picazuro*	*Turdus rufiventris*	*Pitangus sulphuratus*	*Cyanocorax cristatellus*	*Ramphastos toco*
Acacia auriculiformis	15	1	0	1	0	0
Acnistus arborescens	7	0	1	1	0	0
Aegiphila integrifolia	8	0	1	1	0	0
Alchornea glandulosa	6	0	1	1	0	0
Alchornea sidifolia	5	0	1	1	0	0
Alchornea triplinervia	4.7	0	1	1	0	0
Allophylus edulis	7.86	0	1	0	0	0
Amaioua guianensis	10	0	1	0	1	1
Archontophoenix cunninghamiana	9.8	0	1	1	0	1
Aureliana fasciculata	8.4	0	1	0	0	0
Cabralea canjerana	25	0	1	1	0	0
Casearia sylvestris	4	0	1	1	1	0
Cecropia glaziovii	12.62	0	1	1	0	0
Cecropia pachystachya	1.52	0	1	1	0	1
Citharexylum myrianthum	9	1	1	1	0	0
Clusia criuva	11	0	1	1	0	0

Copaifera langsdorffii	21.42	0	1	0	1	1
Cordia ecalyculata	7.5	0	1	0	0	0
Cordia sellowiana	16.42	0	0	0	0	0
Coussapoa microcarpa	17	0	1	1	0	0
Cupania oblongifolia	24.93	0	1	1	0	0
Cupania riodocensis	20	0	0	1	0	0
Dendropanax cuneatus	5.6	0	1	0	0	0
Diospyros kaki	50	0	1	1	0	0
Endlicheria paniculata	18	0	1	0	0	0
Erythroxylum ambiguum	5.5	0	1	0	0	0
Erythroxylum deciduum	4	1	1	1	1	0
Erythroxylum pulchrum	7.18	0	1	0	0	0
Eugenia cerasiflora	11	0	1	1	0	0
Eugenia hiemalis	5.7	0	1	0	0	0
Eugenia uniflora	18	0	1	0	0	1
Eugenia uruguayensis	13	0	1	1	0	0
Euterpe edulis	12.46	0	1	1	0	1
Euterpe oleracea	10	0	1	1	0	0
Ficus citrifolia	14	0	0	0	0	0
Ficus enormis	14	0	1	0	0	0
Ficus eximia	10	0	1	1	0	1
Ficus insipida	20	0	0	1	0	0
Ficus luschnathiana	12.3	0	1	0	0	0
Ficus microcarpa	8	0	1	1	0	0
Ficus organensis	7	0	1	1	0	0
Genipa americana	68	0	0	0	0	1
Guapira opposita	6.53	0	1	1	0	0
Guarea guidonia	12	0	0	1	0	0
Guarea macrophylla	20	0	1	0	0	0
Guatteria sellowiana	4.5	0	1	0	0	0
Guettarda viburnoides	9.8	0	0	0	0	0
Hyeronima alchorneoides	2.6	0	1	0	0	0
Ilex brevicuspis	2.8	0	1	0	0	0

Ilex paraguariensis	4.7	0	1	1	0	0
Ilex theezans	8.6	0	1	0	0	0
Inga laurina	22	0	0	1	0	0
Ixora burchelliana	36	0	0	0	0	0
Leandra variabilis	3.2	0	1	0	0	0
Ligustrum lucidum	5	0	1	1	0	0
Livistona chinensis	13.5	0	1	1	0	1
Maclura tinctoria	12.6	0	0	0	1	0
Magnolia ovata	1.2	0	1	1	0	0
Marlierea obscura	9	0	1	0	0	0
Matayba elaeagnoides	8	0	0	0	0	0
Matayba guianensis	16.04	0	1	0	0	0
Melia azedarach	20	1	1	1	0	0
Miconia albicans	4	0	0	1	0	0
Miconia chartacea	4	0	1	0	0	0
Miconia cinerascens	4.5	0	1	0	0	0
Miconia cinnamomifolia	2.54	0	1	1	0	0
Miconia cuspidata	3.7	0	0	1	0	0
Miconia elegans	4	0	0	0	0	0
Miconia inconspicua	3	0	1	0	0	0
Miconia ligustroides	3.3	0	0	0	0	0
Miconia minutiflora	3.6	0	0	1	0	0
Miconia prasina	3.4	0	0	0	0	0
Miconia pusilliflora	3.5	0	1	0	0	0
Miconia racemifera	3.9	0	1	0	0	0
Miconia sellowiana	2.4	0	1	0	0	0
Miconia theizans	1.6	0	1	0	0	0
Miconia tristis	3.6	0	1	0	0	0
Miconia valtheri	3.9	0	1	0	0	0
Morus nigra	20	0	0	1	0	1
Muntingia calabura	14	0	0	1	0	0
Myrceugenia myrcioides	7	0	1	0	0	0
Myrcia brasiliensis	11	0	1	0	0	0

Myrcia palustris	5.3	0	1	1	0	0
Myrcia spectabilis	14.7	0	0	0	0	0
Myrcia splendens	6.1	0	1	1	0	0
Myrcia tomentosa	4.2	0	0	0	0	0
Myrciaria cuspidata	6	0	1	0	0	0
Myrsine coriacea	3.3	0	1	1	0	0
Myrsine umbellata	3.8	0	1	0	0	0
Nectandra lanceolata	18	0	1	0	0	0
Nectandra megapotamica	7.4	0	1	1	0	0
Ocotea corymbosa	8	0	0	1	0	0
Ocotea puberula	5.9	0	1	0	0	0
Ocotea pulchella	6.8	0	1	1	0	0
Pera glabrata	2.3	0	0	0	0	0
Persea willdenovii	12	0	1	0	0	0
Phytolacca dioica	15	0	1	0	0	0
Plinia cauliflora	19	0	0	0	0	0
Protium heptaphyllum	10.76	0	1	1	0	0
Protium spruceanum	12	0	1	0	0	0
Prunus myrtifolia	11	0	1	1	0	0
Psidium cattleianum	31	0	0	0	0	0
Psidium guajava	57	0	1	1	0	0
Psychotria vellosiana	3.7	0	1	0	0	0
Richeria grandis	8	0	0	0	1	0
Roystonea oleraceae	9	0	0	1	0	0
Sapium glandulosum	6	0	1	1	0	0
Schinus terebinthifolius	6	0	1	1	0	0
Sloanea hirsuta	20	0	1	0	0	0
Solanum americanum	8.1	1	0	0	0	0
Solanum granuloso-leprosum	11	1	0	0	0	0
Sorocea bonplandii	9.1	0	0	1	0	0
Styrax leprosus	8	0	0	0	0	0
Symplocos uniflora	5	0	1	0	0	0

Tapirira guianensis	11.6	0	0	1	0	0
Trema micrantha	2.7	1	1	1	0	1
Trichilia catigua	5.4	0	1	0	0	0
Trichilia clausseni	6	0	0	1	0	0
Virola bicuhyba	21	0	1	0	0	0
Virola sebifera	9	0	1	0	0	0
Vitex megapotamica	20	0	1	0	0	0
Vitex polygama	15.6	0	0	0	0	0
Xylopia brasiliensis	4.5	0	0	1	0	0
Xylopia sericea	14.6	0	0	0	0	0

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