The role of alien plants in the composition of fruit-eating bird assemblages in Brazilian urban ecosystems

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Abstract

Between 1985 and 2004, 91 wild fruit-eating bird species were studied in 11 urban areas of Brazil: 78 of these species were seed dispersers and 13 were seed predators. The most representative families of fruit-eating birds in these areas were: Thraupidae with 46 species, Tyrannidae with 19 species, Psittacidae with 11 species and Turdidae with 6 species. Several of these avian species (or part of their populations) are vagrants or visitors (wanderers) and migrants. At least 19 fleshy-fruiting plant species usually dispersed by birds were found growing spontaneously in urban areas: at least 8 of these were indigenous (autochthonous) to the region in which they were found, and 11 were alien (allochthonous). A total of 383 fleshy-fruiting plants were found on 321 plots: 275 (71.8%) plants belonged to autochthonous taxa and 108 (28.2%) plants belonged to alien taxa. In these plots, the fleshy-fruiting plants that most successfully colonized urban environments were those belonging to autochthonous taxa, all of them small-seeded: *Ficus* spp. (Moraceae), *Rhipsalis* spp. (Cactaceae), *Struthanthus* spp. (Loranthaceae) and *Cereus* spp. (Cactaceae). The alien fleshy-fruiting plant species that most successfully colonized urban environments were: *Ficus microcarpa*, *Morus nigra* (Moraceae), *Eriobotrya japonica* (Rosaceae) and *Pittosporum undulatum* (Pittosporaceae). The present study indicates that many of the non-nesting birds that visit urban areas in Brazil are frugivores-insectivores. The results strongly suggest that such birds enter built-up areas to feed on fleshy fruits produced by allochthonous species of plants, especially during winter. The major ecological consequence of fruit-eating bird movements into urban areas is that most of these bird species can transport viable seeds of alien plants in the gut and disperse them in natural and semi-natural areas.

Key words: alien species, birds, fleshy fruits, frugivory, plant colonization, seed dispersal, urban ecology, Brazil.

Resumen. *El papel de las plantas foráneas en la composición de los ensambles de aves frugívoras en ecosistemas urbanos brasileños*

Entre 1985 y 2004, 91 especies de aves frugívoras fueron estudiadas en 11 áreas urbanas de Brasil: 78 de estas especies eran diseminadoras de semillas y 13 eran depredadoras de semillas. Las familias de aves frugívoras más representativas en estas áreas fueron: Thraupidae, con 46 especies, Tyrannidae, con 19 especies, Psittacidae, con 11 especies y Tur-

didae, con 6 especies. Diversas de estas especies (o parte de ss poblaciones) de aves son divagantes o visitantes y migratorias. Como mínimo 19 especies de plantas que producen frutos carnosos, normalmente dispersadas por aves, fueron encontradas creciendo espontáneamente en áreas urbanas: como mínimo 8 de ellas eran especies indígenas (autóctonas) en la región donde fueron encontradas y 11 eran foráneas (alóctonas). Un total de 383 plantas que producen frutos carnosos fueron encontradas en 321 cuadrantes: 275 (71.8%) plantas pertenecieron a *taxa* autóctonos y 108 (28.2%) plantas pertenecieron a *taxa* foráneos. En estos cuadrantes, las especies de plantas que mejor colonizaron los ambientes urbanos fueron aquellas pertenecientes a *taxa* autóctonos, todas ellas productoras de semillas pequeñas: *Ficus* spp. (Moraceae), *Rhipsalis* spp. (Cactaceae), *Struthanthus* spp. (Loranthaceae) y *Cereus* spp. (Cactaceae). Las especies de plantas foráneas productoras de frutos carnosos que mejor colonizaron los ambientes urbanos fueron: *Ficus microcapa*, *Morus nigra* (Moraceae), *Eriobotrya japonica* (Rosaceae) y *Pittosporum undulatum* (Pittosporaceae). El presente estudio indica que muchas de las aves no nidificantes que visitan áreas urbanas en Brasil son frugívoro-insectívoras y los resultados sugieren que estas aves entran en los pueblos y grandes ciudades para alimentarse de frutos carnosos producidos por especies de plantas alóctonas, especialmente durante el invierno. La principal consecuencia ecológica de los movimientos de las aves frugívoras hacia las áreas urbanas es que muchas de estas especies de aves pueden transportar, en el trato digestivo, semillas viables de plantas foráneas y dispersarlas en áreas naturales y seminaturales.

Palabras clave: aves, Brasil, colonización de plantas, dispersión de semillas, ecología urbana, especies foráneas, frugivoria, hábitos alimentarios.

Introduction

Human-related disturbances have been considered the major causes of avian extinction over the last few centuries. In addition to direct persecution for various purposes (e.g., hunting for meat supply and feathers), the human impact on natural vegetation and landscape have contributed to the decline of avian populations.

Nevertheless, several species of birds around the world exploit (temporarily or on a long term basis) urban landscapes that show different degrees of anthropization (Beissinger & Osborne, 1982; Dickman, 1987; Sick, 1985, 1993;). This use of urban environments has long been a subject of interest to biologists (Beissinger & Osborne, 1982; Gavareski, 1976; Leveau & Leveau, 2006; Marzluff, 2001; Marzluff et al., 2001).

Urbanization usually entails major disturbances to the environment, such as large impacts on landscape, natural vegetation, soil structure and animal communities. While former elements of the ecosystems are destroyed (e.g., rivers, wetlands, rock promontories) new elements are incorporated to the landscape (e.g., building structures, allochthonous vegetation, artificial lakes, new preys and predators) (Matarazzo-Neuberger, 1995). In tropical and subtropical regions of Brazil, major threats to forest birds include habitat loss, forest fragmentation and increase of interpatch distances.

The effect of urbanization on bird communities have been poorly studied in the Neotropical region. In a recent review, Chace & Walsh (2006) identified a lack of information concerning the urban effects on native communities of birds from

regions of high avian diversities, such as tropical forests. The aim of this study is to describe and discuss the role of urban areas in the feeding habits of Brazilian fruit-eating birds.

Materials and methods

Between 1985 and 2004, observations of bird species were conducted in 11 urban areas of Brazil located in zones of tropical and subtropical forests (Fig. 1). Bird species were identified mainly through visualization with binoculars. Some species were also photographed and/or hand-examined. Bird species that eat fleshy fruits were divided into seed dispersers (i.e., species that defecate or regurgitate seeds able to germinate away from the mother plant) and seed predators (i.e., species that destroy seeds of fleshy fruits) (Guix, 1995).

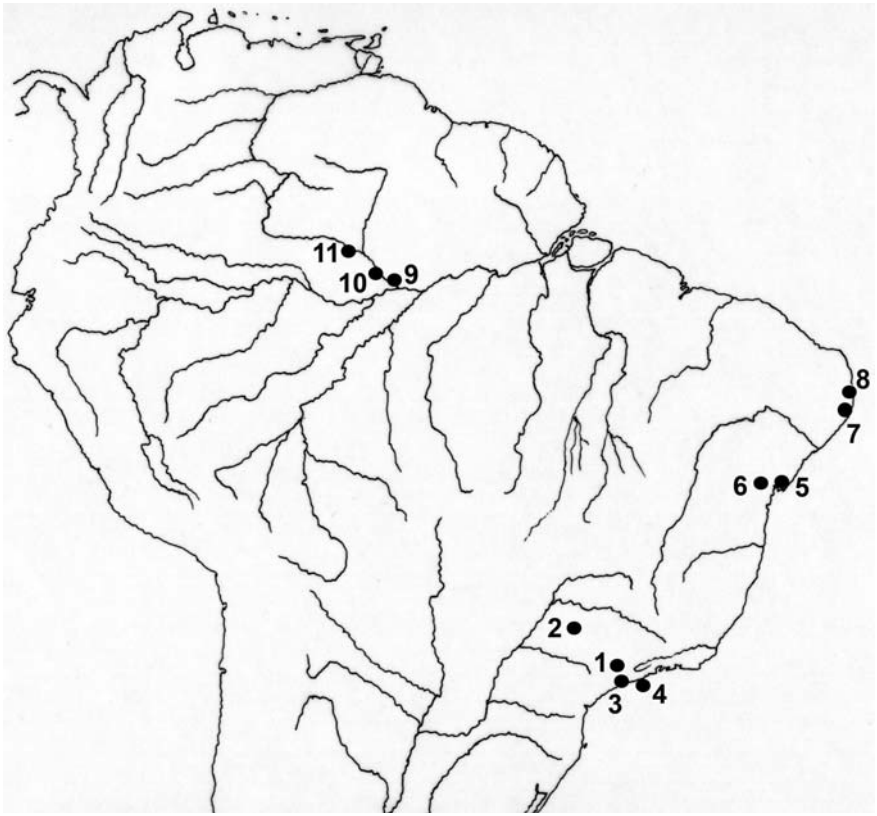

Fig. 1. Map of the north and central zones of South America indicating the location of the cities studied (represented by dot). Cities: 1. São Paulo; 2. São José do Rio Preto; 3. São Vicente and Santos; 4. Ilhabela; 5. Salvador; 6. Cachoeira; 7. Recife; 8. Olinda; 9. Manaus; 10. Novo Airão; 11. Carvoeiro.

Food and feeding observations were conducted in these urban areas. The feeding bouts were based both on direct observations of food consumption and on the examination of feces and/or regurgitations of birds. The fleshy fruits consumed by birds were divided into *indigenous* (I: an autochthonous species in the region of each urban area according to Hoehne *et al*., 1941 and Hueck, 1956, 1972) and *alien* ones (A: an allochthonous species introduced by humans in the region of each urban area after the 15th century, when the first Europeans arrived in the region) (Guix, 2004). Data on feeding observations included in this study are only from the urban study areas.

Seedlings and juvenile plants of fleshy-fruiting species usually dispersed by birds (see Guix, 1995) were sampled in gardens, parks, old and abandoned buildings and on the street, when growing spontaneously. Also, epiphytic plants found growing spontaneously on trees, walls, roofs and other urban structures were also sampled. Each seedling and juvenile plant up to a height of 0.50 m was counted in 321 plots of 1 × 1 m. Only plots with one or more seedlings and juvenile plant were considered.

For the analysis of plant composition in plots the following mathematical descriptors were used: the numerical percentage of each plant genus in the collection of plots (%N), their percentage of occurrence in the plots (%OCC), and the Probabilistic Index ($PI = \Sigma Pi^2$, where Pi is the number of plants belonging to a given genus "i" in one plot divided by the total number of plants found in the same plot)(Ruiz, 1985; Jover, 1989). Also, the Use Index (UI) was used to describe the dominance of each plant genus in the total sample: $UI = \%N_i * \%E_i$, where:

$$E_i = \frac{- \log \Sigma(f_j / f^*)^2}{- \log (1 / n)}$$

"n" is the total number of plots, "f_j" the number of plants of each genus "i" in one plot, and "f*" the number of individuals belonging to one genus "i" in relation to the total number of plots (Jover, 1989).

The Probabilistic Index and the UI combines both the numerical percentage and the percentage of occurrence to assess the relative importance of each genus found. In order to make the index values independent of sample size, they were calculated as $PI' = (PI/n) \times 100$ (where "n" is the total number of plots), and $PI'' = (PI'/\Sigma PI') \times 100$ to give the values in percentage. The same procedure was applied for the UI (Ruiz, 1985).

To estimate the diversity of plants in each plot, two indexes were used: a- the Shannon-Weaver Index (H): $H = -\Sigma p_i \log_2 p_i$ (Shannon & Weaver, 1963); b- the Brillouin Index (BI): $BI = (1/N) (\log_2 N! - \Sigma \log_2 Ni!)$, where N is the total number of plants in the collection and Ni is the number of plants of a given genus "i" in a plot (see Brillouin, 1956; Hurtubia, 1973; Ruiz, 1985). The diversity of plants in the collection of plots was calculated by the same index (BI), using the Jackknife procedure (Zahl, 1977).

The values of population diversity (Shannon-Weaver Index and Brillouin Index) were obtained accumulating the diversity of plants of each plot in the ma-

trix; in the case of the Brillouin Index the Jackknife procedure was used to accumulate de diversity values (Heltshe & Forrester, 1983; Jover, 1989).

Since not all seedlings and juvenile plants could be identified to species level, the analysis of dominance and diversity was based on genus. Nevertheless, native species of *Ficus* and alien ones belonging to a same genus were considered separately. Also, when one or more species in a genus may be involved, this information is indicated.

In order to improve our assessment of the role of each bird species in seed dispersal/predation patterns (e.g., seed mobility), they were divided in: *nestings* (N: observations on nest construction and/or incubation of eggs and rearing), *migrants* (M: regular encounters in more than two years of species known to migrate) and *vagrants* or *visitors* (V: occasional findings, normally of few individuals, of species known to be *wanderers*). More than one category can appear associated with one species (e.g., nesting and migrant). This means that this species was detected both through nesting individuals or populations in the area, and also through migrant individuals or populations, which are not necessarily the same as the nesting populations (e.g., juvenile individuals). These categories were based on the observations performed in the 11 urban areas during the present study and on data from other authors who performed field studies in areas or regions located around or near these urban areas (see Borges et al., 2001; Isler & Isler, 1987; Mendonça-Lima & Fontana, 2000; Olmos, 1996; Sick, 1993; Willis, 1979; Willis & Oniki, 1981). "Migrant" and "vagrant/visitor" were considered as provisional categories for some species, since few studies with long-term bird banding programs were available in the study areas.

Ecological studies of urban effects on avifauna have considered an urbanized center as a concentration of humans in residential and industrial settings containing more than 2500 people (see Chace & Walsh, 2006). Nevertheless, many Amazonian urban areas are smaller than eastern and southeastern Brazilian cities and towns. Thus, observations made at the small Amazonian village of Carvoreiro (located on the right margin of the Middle Negro river) was also included, due to the large number of fruit-eating bird species seen eating alien fruits in this area.

Study areas

The urban areas were chosen because of their location (both in relation to the latitude and longitude), their size (e.g., from small villages and town to large cities), and characteristics (coastal and inland areas), covering a wide range of altitudes: from sea level to 800 m high (Fig. 1).

São Paulo megalopolis

The city of São Paulo is located in south-eastern Brazil (23º 33' S, 46º 39' W; Altitude 650-800 m), and has about 11 million habitants. During the urban growth of São Paulo, this and other neighboring cities merged to form a megalopolis that hosts more than 18 million people. This megalopolis, locally called "A Grande São Paulo" (i.e., the Large São Paulo) includes several cities and urban areas of

the municipalities of Osasco, Taboão da Serra, Diadema, São Bernardo do Campo, São Caetano do Sul, Santo André da Borda do Campo, Mauá and Guarulhos.

Beside the city of São Paulo, there are two protected parks: the Parque Estadual da Cantareira, an area of 10000 ha mainly covered by secondary subtropical forests; and the Parque Estadual das Fontes do Ipiranga (former Parque do Estado), an area of 542 ha, which includes around 300 ha of a secondary forest composed by floral elements of both the Brazilian Atlantic rainforest and the subtropical forests (*sensu* Hueck, 1956; 1972). Both protected areas of native forests (separated from each other by 21 km of a continuous urban area) were not included in this study.

São José do Rio Preto

A city of about 330000 inhabitants located in north-western São Paulo state (20º 49' S, 49º 22' W ; Altitude: 489 m). The city is surrounded by farms (especially with sugarcane plantations), small forest fragments, woodlots, pastures, and *Eucalyptus* spp. plantations.

São Vicente and Santos

São Vicente (23^0 58' S, 46^0 23' W; Altitude: 2-30 m) and Santos (23^0 56' S, 46^0 20' W; Altitude: 2-35 m) are two connected cities located on the eastern coast of the São Paulo state, in south-eastern Brazil. They are surrounded by some mangroves and mountains covered by the remains of secondary Atlantic rainforest, small banana plantations and several roads. These two cities together have about 740000 inhabitants.

Ilhabela

Town located at the São Sebastião Island in the northern coast of the São Paulo state (23^0 50' S, 45^0 20'W; altitude: 2-60 m), south-eastern Brazil. This 33593 ha island is separated from the continent by a 1.76 km sea channel and it is located 5 km from the Serra do Mar, a mountain range of the coast of south-earten Brazil. The town of Ilhabela is beside the Parque Estadual de Ilhabela, a 25981 ha protected area mainly covered by native secondary Atlantic rainforest. Due to tourism, the population varies from 26000 (during winter) to 85000 (during summer).

Salvador

Large coastal city of more than 2600000 inhabitants located in eastern Bahia state (13^0 04' S; 38^0 31' W; Altitude: 2-60 m; NE Brazil), surrounded by pastures, plantations, small native forest fragments and woodlots.

Cachoeira

A town located 110 km inland from Salvador (12^0 36' S; 38^0 58' W; Altitude: 50 m; Altitude), north-eastern Brazil, on the left margin of the Paraguaçu river. This

town of about 16000 inhabitants is surrounded by extensive pastures, small native forests fragments and scant riparian vegetation.

Recife

Large coastal city of about 1400000 inhabitants located in eastern Pernambuco state (08^0 04' S; 34^0 55' W; Altitude: 4 m; Altitude), north-eastern Brazil. It is surrounded by plantations, pastures, some small native forest fragments, small farms and mangroves. There are also some small remnant mangroves in the city.

Olinda

A coastal city located in eastern Pernambuco state (08^0 01' S; 34^0 51' W; Altitude: 2-16 m), north-eastern Brazil, 6 km from center of the city of Recife. This city has about 350000 inhabitants and it is surrounded by native secondary forest fragments and farms with small pastures and plantations. As Olinda and Recife today are connected by urban areas, they could also be considered as part of a same large urban complex.

Manaus

A large city of about 1600000 inhabitants located on the left margin of the Negro river, close to it confluence with the Solimões river (03^0 04' S; 59^0 01' W; Altitude: 35-47 m), state of Amazonas (NW Brazil). This city is surrounded by large native forest fragments (e.g., the Reserva Florestal Adolpho Ducke, a 10072 ha protected Amazonian *terra firme* forest), large extensive forests and farmlands with pastures. The Reserva Florestal Adolpho Ducke and the Mata do Campus da Universidade Federal do Amazonas (a 546 ha of native forest located in the city) were not included in the present study.

Novo Airão

A town of about 7000 inhabitants located on the right margin of the Negro river (02^0 40' S; 61^0 00' W; Altitude: 37-42 m), 200 km from Manaus, state of Amazonas (NW Brazil). This town is surrounded by extensive forests (mainly *terra firme* and *igapó* forests).

Carvoeiro

A village of about 800 inhabitants located on the right margin of the Negro river (01^0 21' S; 62^0 07' W; Altitude: 40-42 m), close to its confluence with the Branco river, state of Amazonas (NW Brazil). This village is surrounded by large extensive forests (mainly *terra firme* and *igapó* forests).

See also LANDSAT TM satellite images of these cities and towns and surrounding areas at EMBRAPA 2000-2003, and in GOOGLE-MAPS).

Table 1. Bird species that disperse seeds of fleshy fruits in 11 urban areas of Brazil. 1. São Paulo; 2. São José do Rio Preto; 3. São Vicente and Santos; 4. Ilhabela; 5. Salvador; 6. Cachoeira; 7. Recife; 8. Olinda; 9. Manaus; 10. Novo Airão; 11. Carvoeiro. Categories: N: *nestings* (observations on nesting construction and/or incubation of eggs in these and other Brazilian urban areas), M: *migrants* (regular encounters in more than two years of species known to migrate in these and other Brazilian urban areas), V: *vagrants* or *visitors* (occasional findings, normally of few individuals, of species known to be *wanderers* in these and other Brazilian urban areas).

Family, species and categories	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
CAPITONIDAE:											
Capito niger, V										x	x
PICIDAE:											
Celeus elegans, V										x	
Celeus flavus, V											x
Melanerpes cruentatus, N, V										x	x
TYRANNIDAE:											
Elaenia flavogaster, V	x	x		x							
Elaenia cf. *parvirostris*, V									x		
Elaenia sp.3		x									
Elaenia sp.4					x						
Elaenia sp.5								x			
Empidonomus varius, V		x		x				x	x	x	x
Megarynchus pitanga, V				x		x		x		x	x
Mionectes cf. *oleagineus*, V										x	x
Myiarchus cf. *swainsoni*, M				x				x			
Myiarchus sp.2					x						
Myiarchus sp.3	x										
Myiodynastes maculatus, M	x			x			x	x	x	x	
Myiozetetes cayenensis, V			x						x	x	x
Myiozetetes similis, V	x	x		x		x	x	x			x
Pitangus sulphuratus, N	x	x	x	x	x	x	x	x	x	x	x
Tyrannus melancholicus, N, V	x	x	x	x	x	x	x	x	x	x	
Tyrannus savana, M	x			x					x	x	x
Tityra cayana, V	x				x	x			x		x
Tityra inquisitor, V					x			x			
COTINGIDAE:											
Laniisoma elegans, V	x			x							
Phibalura flavirostris, V			x	x							
TURDIDAE:											
Turdus albicollis, V			x	x	x				x	x	x
Turdus amaurochalinus, N, V	x	x	x	x	x	x					
Turdus flavipes, N, V	x			x							
Turdus fumigatus, V							x	x	x	x	x
Turdus leucomelas, V		x			x	x		x	x		
Turdus rufiventris, N, V	x	x	x	x	x		x	x			
COEREBIDAE:											
Coereba flaveola, N, V	x	x		x				x			

Family, species and categories	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
THRAUPIDAE:											
Chlorophanes spiza, V				x							
Chlorophonia cyanea, V			x								
Dacnis cayana, V	x			x					x	x	x
Dacnis lineata, V									x		
Euphonia cayennensis, V									x		
Euphonia chalybea, V			x								
Euphonia chlorotica, V	x	x		x						x	x
Euphonia chrysopasta, V									x	x	
Euphonia minuta, V									x		x
Euphonia musica, V		x									
Euphonia pectoralis, V			x	x							
Euphonia plumbea, V									x	x	
Euphonia rufiventris, V											x
Euphonia violacea, V	x	x					x	x			
Hemithraupis flavicollis, V					x				x		
Hemithraupis guira, V		x									
Hemithraupis ruficapilla, V			x								
Nemosia pileata, V		x					x				
Pipraeidea melanonota, V			x	x							
Piranga flava, V			x								
Piranga rubra, V									x	x	
Ramphocelus carbo, V		x							x	x	x
Ramphocelus bresilius, M, V			x	x				x			
Tachyphonus coronatus, V	x	x		x							
Tachyphonus cristatus, V			x								
Tachyphonus luctuosus, V										x	
Tachyphonus phoenicius, V											x
Tachyphonus rufus, V					x			x			
Tachyphonus surinamus, V									x	x	
Tangara cayana, V	x	x			x	x	x	x		x	x
Tangara chilensis, V									x	x	
Tangara cyanocephala, V				x							
Tangara cyanoventris, V			x								
Tangara mexicana, V										x	
Tangara peruviana, V			x	x							
Tangara punctata									x		
Tangara seledon, V	x		x	x							
Tangara varia, V									x		
Tangara velia, V									x		x
Tersina viridis, V		x	x								
Thlypopsis sordida	x			x							
Thraupis cyanoptera, V			x	x							
Thraupis episcopus, V									x	x	x
Thraupis ornata, V	x		x	x	x						
Thraupis palmarum, V	x		x	x	x		x	x	x	x	
Thraupis sayaca, N, V	x	x	x	x	x	x	x	x			

Table 2. Bird species that destroy seeds of fleshy fruits (seed predators) in 11 urban areas of Brazil. 1. São Paulo; 2. São José do Rio Preto; 3. São Vicente and Santos; 4. Ilhabela; 5. Salvador; 6. Cachoeira; 7. Recife; 8. Olinda; 9. Manaus; 10. Novo Airão; 11. Carvoeiro. Categories: N: *nestings* (observations on nesting construction and/or incubation of eggs in these and other Brazilian urban areas), M: *migrants* (regular encounters in more than two years of species known to migrate in these and orther Brazilian urban areas), V: *vagrants* or *visitors* (occasional findings, normally of few individuals, of species known to be *wanderers* in these and other Brazilian urban areas).

Family and species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PSITTACIDAE:											
Amazona amazonica, V								x			x
Amazona farinosa, V				x							x
Amazona festiva, V										x	
Aratinga leucophlthalmus, V		x								x	
Brotogeris chiriri, V		x									
Brotogeris chrysopterus, V									x	x	x
Brotogeris tirica, N, V	x			x							
Forpus crassirostris, V	x										
Forpus passerinus, V									x		
Pionus menstruus, V										x	x
Pyrrhura frontalis, V	x			x							
CARDINALIDAE:											
Saltator maximus, V										x	
Saltator similis, V	x			x							

Results

Ninety-one (91) species of wild fruit-eating birds were found in the 11 urban areas studied; 78 species were seed dispersers and 13 were seed predators (Tables 1 and 2). The most representative families of fruit-eating birds in these areas were: Thraupidae with 46 species, Tyrannidae with 19 species, Psittacidae with 11 species and Turdidae with 6 species.

Several species categorized as migrants and vagrants/visitors were observed feeding on fleshy fruits of alien species especially during winter. In general, feeding bouts of fleshy fruiting birds in large cities were related to ornamental alien plant species (e.g., *Ficus microcarpa, Pyracantha fortuneana, P. coccinea, Fatsia japonica, Pittosporum undulatum, P. tobira, Archontophoenix cunninghamiana, Ligustrum lucidum, L. ovalifolium, Schefflera actinophylla*) while feeding bouts in towns and the village of Carvoeiro were related to alien fruit species found in house gardens planted for human consumption (e.g., *Carica papaya, Psidium guajava, Mangifera indica, Persea americana, Musa* spp. *, Coffea arabica, Coffea canephora*, *Averrhoa carambola*, *Eriobotrya japonica*, *Genipa americana*, *Syzygium malaccense*) (see also Guix, 1996; 2004).

The fruit-eating bird species that had most feeding bouts in the urban areas studied were (in parenthesis the number of feeding bouts is given): *Turdus ru-*

fiventris (57), *Turdus albicollis* (38), *Thraupis sayaca* (33), *Turdus amaurochalinus* (24), *Pitangus sulphuratus* (22), *Turdus fumigatus* (19), *Thraupis palmarum* (18), *Turdus leucomelas* (16), *Euphonia chlorotica* (11), *Tyrannus melancholicus* (10), *Ramphocelus carbo* (9) and *Tangara cayana*, *T. seledon* (7).

During the study, at least 19 fleshy-fruiting plant species dispersed by birds (seeds transported in the gut and regurgitated or defecated entire) were found colonizing spontaneously in 11 urban areas of Brazil: at least 8 of them were indigenous (autochthonous) species in the region where they were found, and 11 were alien (allochthonous). Most of the plant specimens found were juveniles and seedlings, but adult ones were also found (e.g., specimens of *Rhipsalis* spp., *Ficus* spp., *Cecropia* spp., *Struthanthus* spp., *Rapanea* spp. and *Morus nigra* and *Solanum pseudocapsicum* fructifying) were seen growing spontaneously inside urban areas (Fig. 2).

From the plots analyzed, seedling and juvenile plants belonging to 18 genus and 19 species were identified. A total of 383 plants were found in the plots: 275 (71.8%) plants belonged to autochthonous taxa and 108 (28.2%) plants belonged to alien taxa. The number of plants per plot varied from 1 to 7. In these plots, the fleshy-fruiting plants that best colonized urban environments were those belonging to autochthonous taxa, all of them small-seeded: *Ficus* spp. (PI" = 26.23), *Rhipsalis* spp. (PI" = 19.59), *Struthanthus* spp. (PI" = 18.33), *Cecropia* spp. (PI" = 12.64) and *Cereus* spp. (PI" = 6.64). The alien fleshy-fruiting plant species that most successfully colonized urban habitats were: *Ficus microcarpa* (PI" = 5.41), *Morus nigra* (PI" = 2.43), *Eriobotrya japonica* (PI" = 2.28) and *Pittosporum undulatum* (PI" = 1.10) (Table 3). The cumulative diversities of the fleshy-fruiting plants found in the 321 urban plots were: H = 3.409 and, using the Jackknife procedure, BI = 3.441 (se = 0.105).

Discussion

Large cities houses more alien plant species than small ones. Thus large cities would be more visited by migrant and wandering species of fruit-eating birds than towns and villages. Nevertheless, data obtained in the present study do not show any tendency in this sense: the number of fruit-eating birds found in each urban area is given in parenthesis. São Paulo (27), São José do Rio Preto (22), São Vicente and Santos (23), Ilhabela (35), Salvador (16), Cachoeira (9), Recife (11), Olinda (20), Recife+Olinda (21), Manaus (29), Novo Airão (31), Carvoeiro (26). Despite the area effect (size), landscape complexity is an important factor in bird diversity (Donnelly & Marzluff, 2004).

Other factors can be related to the species richness of fruit-eating birds that uses urban areas. Some of them may be related to natural conditions, such as the relief and altitudinal movements of birds in a given region, and others may be related to human disturbances around urban areas (e.g., the degree of human impact on natural vegetation and habitat loss, forest fragmentation and increase of interpatch distances) and inside them (e.g., the existence of remnant habitats with native vegetation for forest species inside urban areas).

Fig. 2. Above: an adult *Cecropia* sp. (Cecropiaceae) growing spontaneously in ruins of the city of Cachoeira (State of Bahia); Below: Adult individuals of native *Ficus* spp. (Moraceae) growing spontaneously in an abandoned house of Recife (State of Pernambuco). The seeds of *Cecropia* spp. and *Ficus* spp. are mainly dispersed by frugivorous birds and bats.

Table 3. Plant species dispersed by birds and found colonizing spontaneously in 11 urban areas of Brazil (see Materials and methods): %OCC = percentage of occurrence, %N = numeric percentage, PI" = Probabilistic Index and UI" = Use Index; A = *Alien* (allochthonous) species in the region of each urban area; I = *Indigenous* (autochthonous) species in the region of each urban area.

Species	**Total**	**% OCC**	**% N**	**PI"**	**UI"**
Archontophoenix cunninghamiana, A	8	1.25	2.09	0.6803	0.7336
Morus nigra, A	24	3.43	6.27	2.4273	3.4709
Ficus microcarpa, A	19	5.61	4.96	5.4076	4.2608
Eugenia uniflora, A	1	0.31	0.26	0.3160	0.0000
Psidium guajava, A	4	1.25	1.04	0.9832	0.4372
Ligustrum lucidum, A	3	0.62	0.78	0.3950	0.1390
Pittosporum undulatum, A	17	1.25	4.44	1.1029	1.5488
Eriobotrya japonica, A	16	3.12	4.18	2.2758	2.7046
Coffea arabica, A	7	0.93	1.83	0.5355	0.5842
Solanum pseudocapsicum, A	8	1.25	2.09	0.9832	0.6735
Alchornea sp., I	2	0.62	0.52	0.3358	0.1093
Rapanea spp., I	6	1.25	1.57	0.7308	0.6059
Didymopanax sp., I	1	0.31	0.26	0.3160	0.0000
Cecropia spp., I	40	12.46	10.44	12.6411	11.6335
Ficus spp., I (native species)	85	25.86	22.19	26.2304	29.3156
Struthanthus spp., I	58	18.07	15.14	18.3296	18.5677
Rhipsalis spp., I	62	19.31	16.19	19.5938	20.1743
Cereus spp., I	21	6.54	5.48	6.6366	5.0408
Livistona australis, A	1	0.31	0.26	0.0790	0.0000

ARALIACEAE: *Didymopanax* sp., *D. morototonii* or *D. pachycarpum*; CACTACEAE: *Cereus* spp. may include *C. peruvianus* and *C. pernambucensis*; *Rhipsalis* spp. may include *R. baccifera, R. capilliformis, R. trigona, R. cribata, R. dissimilis, R. pachyptera* and *R. puniceo-discus*; CECROPIACEAE: *Cecropia* spp. may include *C. glaziovi, C. hololeuca, C. pachystachya, C. purpurascens* and *C. sciadophylla*. EUPHORBIACEAE: *Alchornea* spp., *A. triplinervia* or *A. iricurana*. LORANTHACEAE: *Struthanthus* spp. may include *S. concinnus* and *S. uraguensis*. MORACEAE: *Ficus* spp. (native species) may include *F. guaranitica*, *F. enormis*, *F. insipida*, *F. luschnathiana*, *F. calyptroceras*, *F. organensis* and *F. catappifolia.* MYRSINACEAE: Rapanea *spp*. may include *R. ferruginea, R. parvifolia* and *R. umbellata.*

Several migrant and vagrant species (especially frugivores-insectivores) that occur in the studied urban habitats probably use other forests fragments, woodlots and parks and move between large surrounding protected areas, such as the Serra do Mar mountain chain in South-eastern Brazil or the Amazonian forests around Manaus, Novo Airão and Carvoeiro in northern Brazil (Borges & Guilherme, 2000; Guix, 1996, 2004). In other regions whose forests were heavily fragmented by intensive deforestations in the last centuries, such as around Olinda, Recife, Salvador and Cachoeira (north-eastern Brazil) and around São José do Rio Preto (south-eastern Brazil), fruit-eating bird species that were found in these urban areas seem to use small surrounding farmlands to move. In such cases, urban parks and gardens seems to have the function of "small intermediary islands" for birds that visit native forests fragments.

In fact, several Brazilian large and medium-sized cities, today surrounded by wide extensions of sugar cane and very simplified pastures with few trees, have parks with large body masses, composed of alien and/or native woody plant species, which are structurally similar to forest fragments.

Otherwise, large cities have more human related disturbances than towns and villages. However, most of the large cities, including the São Paulo megalopolis, have parks and gardens with alien and/or native woody plant species that are structurally similar to forest fragments. These gardens could have the function of "small intermediary islands" for birds that visit large and medium sized parks.

Urban parks and gardens are important areas to rest and feed for several migrant and wandering species of birds in subtropical and tropical areas (Anjos & Laroca, 1989; Argel-de-Oliveira, 1987; Guix, 1995, 2004; Matarazzo-Neuberger, 1995; Souza, 1995; Voss, 1979a, 1979b). Among them, several species of Tyrannidae, Turdidae and Thraupidae are regular visitors to urban areas.

Many of the most common species of frugivorous Passeriformes found in the urban areas studied are canopy- and edge-dwelling species, mainly frugivore-insectivores, belonging to the families Thraupidae, Tyrannidae and Turdidae (see Table 1). Several of them (or at least parts of their populations) are vagrants, wanderers or passage migrants that can exploit the resources of small and medium sized forest fragments isolated in intensively cultivated regions of south-eastern Brazil (Guix, 1996; Willis, 1979). Such regions include towns (e.g., Novo Airão) and small villages (e.g., Carvoeiro) located in large regions mainly covered by well preserved forests in north-western Amazonia, which attract several Tyrannidae and Thraupidae species.

In south-eastern and north-eastern Brazil the detection of new migrants or vagrant species or populations of these groups in the study areas frequently coincides with the entrance of cold air masses from the South Pole (Guix, 2004). Moreover, urban areas could be easier to locate when birds are migrating than natural geographic features, such as rivers in the Lowlands of the Amazon basin.

Data on feeding observations, made in these and other urban areas of Brazil, suggest that fleshy-fruits of alien plant species available in urban parks and gardens are an important resource for frugivorous-insectivorous bird species during their movements (see also Guix, 1988, 1996, 2004). This fact, together with the

low amount of potential wild predators in urban areas, turns large cities into supporting areas for several passerine fruit-eating birds. In South-eastern and North-eastern Brazil, where the incidence of deforestation and habitat loss for passerine birds has been higher than in the north-western Amazonia, cities constitute a crucial habitat for several frugivor-insectivore species. During winter movements, if fruit availability in forest fragments is low, frugivore-insectivore birds enters urban areas to find alien plants that fructify abundantly.

Chace & Walsh (2006), who analyzed the effects of urban areas on the native avifauna, based on published information around the World, concluded that urbanization tends to select for omnivorous, granivorous and cavity nesting species. Nevertheless, the present study indicates that many of the non-nesting birds (mostly wandering or migrant species) that use urban areas in Brazil are frugivores-insectivores and strongly suggests that, during their movements they enter in towns, villages and large cities to feed on alien fleshy fruits.

In large and medium sized urban areas, alien fleshy fruits sources are available during all year seasons and relatively easy to find. Usually the same fruiting-species plant (e.g., *Ficus microcarpa*, *Morus nigra*; Moraceae) can provide ripe fruits for several days. The regular availability of fruits in Neotropical urban landscapes, in relation to surrounding agricultural areas and native forest woodlots, is probably associated with the high number of alien plant species (with a wide range of fruiting phenology) proceeding to almost all continents that are cultivated in house gardens and public parks.

Many of the feeding bouts in the study areas came from thrushes (*Turdus* spp., Turdidae). Although the thrush species found in urban areas are relatively small (40-83 g) and short billed they have wide gapes and can ingest relatively large fleshy fruits whole, such as those of *Syagrus romanzoffiana*, *Livistona australis* (Arecaceae), *Eugenia uniflora* (Myrtaceae) *Coffea arabica* (Rubiaceae), and *Solanum pseudocapsicum* (Solanaceae). When the seeds ingested are relatively large they are regurgitated and not pass through the digestive tract.

Several tropical species of *Ficus*, *Cecropia* and *Cereus* can be dispersed by frugivorous bats (Family Phyllostomidae). Some of them frequently use urban areas to rest and feed. Nevertheless, most of the juvenile and adult plants found growing spontaneously in the cities studied show an ornithochoric pattern of seed dispersal (Charles-Dominique, 1986; Guix, 1996, 2000, 2004). Thus, the spontaneous colonization of these fleshy fruiting native species in towns and large cities strongly suggests that seeds of these species were mainly transported in the gut by fruit-eating birds from surrounding areas.

The major ecological consequence of fruit-eating bird movements into urban areas is that most of these birds can transport viable seeds of alien species in the gut and disperse them in natural and semi-natural areas (see also Guix et al., 2000a, 2000b for Mediterranean areas). In fact, several of these plants (e.g. *Coffea* spp.*; Psidium guajava, Pittosporum* spp.*, Eriobotrya japonica, Morus nigra, Archontophoenix cunninghamiana, Ligustrum lucidum*) can colonize successfully protected areas (Guix, 1996).

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