

Frugivory by five bird species in agroforest home gardens of Pontal do Paranapanema, Brazil

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Abstract The inefficiency of conservation efforts based exclusively on natural habitat patches has called the attention of some conservationists to the matrix. Described as the major component of a landscape, the matrix is often agricultural, particularly in the tropics. In this context, agroforestry practices have been recognized for their ability to support a rich fauna and flora. Besides the extensive literature concerning bird communities in agroforestry systems, very few studies analyze how different species respond to the management of such practices. Our study describes the diet and habitat use frequency of five frugivorous bird species in agroforest home gardens, secondary forests,

and pastures in the region of Pontal do Paranapanema, Brazil. The focal species were *Ramphastos toco* (Toco Toucan), *Pteroglossus castanotis* (Chestnut-eared Aracari), *Amazona aestiva* (Blue-fronted Amazon), *Ara chloroptera* (Green-winged Macaw), and *Cyanocorax chrysops* (Plush-crested Jay). We gathered both habitat use frequency and diet using the “feeding-bout” method. Overall frequency was higher in the secondary forest when compared to pasture and home gardens for all bird species except *A. aestiva*. The number of feeding bouts was higher in home gardens than in forests for all species with the exception of *C. chrysops*. Differences in monthly median feeding activity were only statistically significant for *C. chrysops* and for *A. aestiva*. The latter was the only species observed feeding in pasture habitats. The total number of food taxa was larger in home gardens than in the forest. Our results reinforce the importance of agroforestry systems as a resource-rich habitat for frugivorous birds.

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Introduction

For many decades conservation biologists have focused their work within protected areas. The inefficiency of this strategy in maintaining biodiversity is threefold: they protect only a small amount of

biodiversity, they are temporal when viewed through a long-term perspective, and finally their insular nature implies high extinction rates (Perfecto and Vandermeer 2008; Chazdon et al. 2009; Goulart et al. 2009). Rodrigues and Gaston (2002) suggested that 90% of the world's biodiversity resides outside reserves. Viability models focused on mammal species show that, even in large and well managed parks, extinction rates can be incredibly high (Newmark 1995). Therefore, parks alone are not enough to prevent biodiversity loss. Consequently, special attention has recently been paid to the landscape as a whole, considering the matrix, defined as the major component of the landscape (Forman 1995), an important repository for biodiversity (Perfecto and Vandermeer 2008). Several studies have shown that certain kinds of agricultural matrix can support substantial amount of biodiversity. Agroforestry systems, such as shade-coffee plantations (Moguel and Toledo 1999; Greenberg et al. 1997; Wunderle and Latta 2000; Komar 2006), jungle rubber (Thiollay 1995; Gouyon et al. 1993), shade cocoa plantations (Faria et al. 2006), shade grown yerba-mate (Cockle et al. 2005) and small scale agriculture (Marsden et al. 2006) are known to support a high diversity of birds. High richness was also found for other groups such as mammals, amphibians, trees, epiphytes (Moguel and Toledo 1999), bats, beetles (Piñeda et al. 2005) and ants (Perfecto and Snelling 1995).

Although there is growing interest in patterns of biodiversity among distinct classes of agroecosystems, little is known about how species respond individually to these human-constructed landscapes. In particular, very few studies have quantified food preferences of birds in agroforest systems. Carlo et al. (2004) analyzed the diet of five frugivorous passerines in shade coffee habitats. Their data suggests that, even though there is a general pattern of greater use of secondary growth forest when compared to shade coffee, the use of agroforest by the focal species is higher in some months. Their findings also indicate that fleshy fruit trees, such as those in the genera *Cecropia*, *Guarea*, *Phoradendron*, and *Shefflera* in agroecosystems may increase habitat quality for both migrants and resident birds. A study concerning a vulnerable parrot (*Primolius maracana*) in the Brazilian Atlantic forest shows that even when inhabiting a large forest patch, the birds feed in the agricultural matrix (Nunes and Galetti 2007).

Studies on sex ratio of birds in shade coffee plantations indicate a male-biased ratio in those areas. It is suggested that the high abundance of males defending their territory in these systems indicates high resource quality (Wunderle and Latta 2000). Despite this fact, some ornithologists have contested these results (M. Rodrigues and R. Laps, personal communication), noting that the simple presence of more males does not necessarily mean they are successful. An alternative explanation would be that low quality agroforestry holds fewer females, implying the reverse pattern of the original study's explanation. Shade coffee plantations are also known to have high winter site fidelity for some bird species (Wunderle and Latta 2000). Therefore, the high incidence of individuals wintering at the same sites in agroforest suggests that this habitat has high resource quality.

Yet, little is known about the diet of large frugivorous birds in agroforestry systems, especially in home-gardens. In this study, we describe the diet and frequency of five frugivorous birds in agroforest home-gardens, secondary forest and pasture. The focal species were: *Ramphastos toco* (Toco Toucan), *Pteroglossus castanotis* (Chestnut-eared Aracari) (Ramphastidae, Piciformes), *Amazona aestiva* (Blue-fronted Amazon), *Ara chloroptera* (Green-winged Macaw) (Psittacidae, Psittaciformes), *Cyanocorax chrysops* (Plush-crested Jay) (Corvidae: Passeriformes).

Methods and study site

Field work was carried in the municipality of Euclides da Cunha Paulista, in Pontal do Paranapanema, located in the extreme west of São Paulo State, Brazil. The region's vegetation type is Semideciduous Seasonal Forest and it is situated in the Atlantic Forest Biome (Ditt 2002). Home gardens are characterized by a mixture of exotic and native fruit trees, annual crops, and small shade-coffee plantations adjoining to pastures and silvopastoral areas. Native trees, such as *Peltophorum dubium*, *Inga vera*, *Tabebuia* spp., *Cedrela fissilis*, *Shefflera morototoni*, *Cordia eucalyculata* and *Guarea guidonia* are common in the systems. Exotic trees are planted for fruit or timber, like *Eucalyptus* spp., *Acacia mangium*, and *Melia azedarach* (Cullen et al. 2003). Shade coffee systems were initiated in 1997, by the non-governmental organization IPÊ (Instituto de Pesquisas

Ecológicas) together with settlers in a participatory process (Rodello et al. 2006). Although many agroforestry experiences were done in settlements linked to the Landless Worker Movement (Movimento dos Trabalhadores Sem Terra), the sampling sites were in settlements not directly associated with this organization.

We used the “feeding-bout” methodology, which consists of walking along transects and recording every time a bird is seen feeding (Galetti 1993). This method was also used to assess frequency, measured by the presence or absence of the species in the habitat in the morning or afternoon regardless of how many individuals or flocks were observed. This methodology was used to avoid counting the same flock or individual more than once.

We used 300 m transects, which were censused 16 times every month, from January to December, 2006, 4 h after dawn and 4 h before dusk. A well-trained local informant helped gather the field data. Each habitat was sampled with three transects (three replicates for each habitat) so that distance between them was of 200 m or more. Birds were recorded in a 100 m radio from transects and forest transects were disposed in an edge habitat. Transects in the pasture were disposed at the distance of 1400, 750 and 450 m from the forest and gardens were established at a distance of 1200, 700 and 840 m. The forest fragment is ≈ 2000 ha and characterized as a secondary forest subjected to logging and sporadically grazed by cattle, but with complete canopy cover. The pasture areas investigated are composed of grasses, a few bushes and scattered trees.

We created an index of Feeding Bouts per Frequency (FBPF) in order to assess in which habitat birds present more foraging activity, in spite of their frequency. This was done by dividing the number of feeding bouts per frequency by each species in each sampling unit. Median monthly feeding between habitats were compared through a Kruskal Wallis non-parametric test and the threshold of statistical significance was 0.05. Although we used median in the statistic test, graphic outputs express mean values and standard deviation for better visualization. We used Microsoft Excel to create the graphics.

Results

Monthly frequency was higher in secondary forest when compared to either pasture or home garden for

all bird species except for *Amazona aestiva*, which had higher values in home gardens (Fig. 1). *Ara chloroptera* and *Pteroglossus castanotis* were absent from pastures but present in home gardens, although in less than half of the number recorded for forest. Monthly mean feeding bouts was higher in home gardens in comparison to forest and pasture for all species except *Cyanocorax chrysops* (Fig. 2). The total number of food taxa consumed by the five bird species was 45, including plant species belonging to 22 botanical families, invertebrates, and other birds' eggs and chicks (Table 1). Concerning the habitats, the number of food taxa recorded was 19 in secondary forest, 28 in agroforest home gardens and two in the pasture. Monthly mean feeding bouts per frequency (FBPF) were 0.3 and 1.67 for *A. aestiva*, 0.27 and 0.54 for *A. chloroptera*, 0.98 and 0.54 for *C. chrysops*, 0.1 and 0.63 for *R. toco*, and 0.09 and 0.75 for *P. castanotis* in forest and home garden habitats, respectively (Fig. 3).

Differences in monthly median feeding activity were statistically significant for *A. aestiva* ($P < 0.0001$) and *C. chrysops* ($P = 0.0020$), but not for the other three species (Table 2). For *Amazona aestiva* the quantity of feeding bouts recorded in home gardens in the dry season (from June to September) was smaller than in the rest of the year. Contrarily, June and August were the months in which *A. aestiva* had a larger number of feeding birds records in the secondary forest. *Ara chloroptera* and *C. chrysops* presented a similar pattern between the two habitats along the year (Fig. 4).

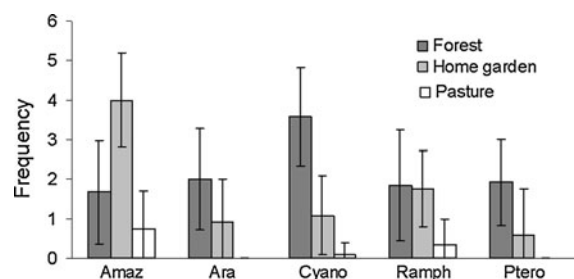


Fig. 1 Monthly mean frequency and standard deviation recorded for the five bird species in secondary forest, agroforest home gardens and pasture areas of Pontal do Paranapanema, Brazil. Frequency is given by the number of shifts in which the species were observed. *Amaz* *Amazona aestiva*, *Ara* *Ara chloroptera*, *Cyano* *Cyanocorax chrysops*, *Ramph* *Ramphastos toco*, *Ptero* *Pteroglossus castanotis*

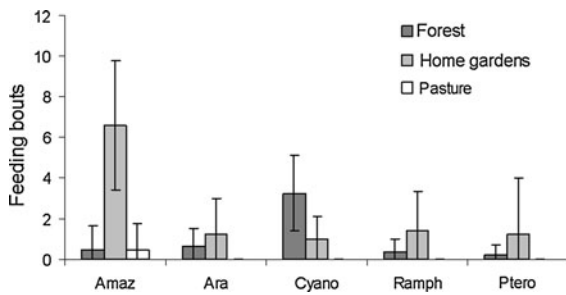


Fig. 2 Monthly mean feeding bouts and standard deviation recorded for the five bird species in secondary forest, agroforest home gardens, and pasture areas of Pontal do Paranapanema, Brazil. *Amaz* *Amazona aestiva*, *Ara* *Ara chloroptera*, *Cyano* *Cyanocorax chrysops*, *Ramph* *Ramphastos toco*, *Ptero* *Pteroglossus castanotis*

Discussion

The results show that frugivore birds frequent and feed in home gardens and forest but not on pastures. The only species that feeds preferably in home gardens is *A. aestiva*, and *C. chrysops* is the only one that notably feeds preferentially in forests. The explanation for the *A. aestiva*'s preference for feeding in gardens is that, even though Silva (1995) considers it a forest-dependent species, according to many ornithologists it uses open country environments as well (M. Rodrigues, personal communication), suggesting adaptations that enable this species to use other habitats than native forest. The preference of this species for home-gardens reinforces that this environment provides greater quantity of food resources. One possible explanation for the preference of *C. chrysops* for forest lies in the low capability of long distance flights in comparison to the four other species. For instance, in forest areas we found two nests of *P. castanotis* and one of *C. chrysops*. Besides breeding and sleeping in these habitats, *P. castanotis* would spend most of the time away from the nests. On the other hand, the group of *C. chrysops* would spend most of the day foraging close to the nest, even in the non-breeding season.

FBPF were higher in home gardens than in forest habitats suggesting that most species feed more often in the former, in spite of their higher frequency in the latter. This is especially important for *C. chrysops*, which has a significantly higher monthly median in the forest but, because of its high frequency in the forest, has higher FBPF in home gardens. This fact

suggests that for all focal species, agroforest home gardens are rich in food resources. Therefore, even if birds do not go very often to these habitats, when they do go they spend most of the time foraging. The fact that they do not spend more time in agroforests might be due to high predation pressure, as these home-gardens have high richness of birds of prey typical of open-habitats (Goulart 2007). Another possible explanation for not spending much time in agroforest is that there might be lack of nest sites, or evolutionary predisposition of the species to avoid non-forest environments.

Feeding activity for all species showed instability in both environments. Calvo and Blake (1998) suggest that resources in agroforest habitats are extremely ephemeral and our results reinforce this argument. Nevertheless, a similar variation was observed in the secondary forest habitat, showing that this pattern is not exclusive to agroforests. There is no clear pattern of feeding seasonality for *P. castanotis*, *C. chrysops*, *A. chloroptera*, and *R. toco*. For *A. aestiva*, the lowest scores found in home gardens coincide with the peak of feeding in forest habitats. This fact suggests that this species feeds preferentially in agroforests rather than in forest habitats. In the dry season, food resources might decrease in home gardens more than it does in forests. Due to this fact, the population moves to the secondary forest, where there is still some availability of fruits. It can be concluded, therefore, that even for species with low habitat requirement, such as *A. aestiva* (Carrara et al. 2007), home gardens alone are not sufficient to fulfill their year-round food resource need. This suggests that besides the fact that *A. aestiva* uses open habitats, it depends on forest, corroborating Silva's (1995) that considers this species a forest-dependent bird.

The total number of food taxa found was higher in the agroforest home gardens, followed by the secondary forest and the pasture, respectively. The wide variety of food taxa provided by agroforest habitat for the conservation of these species is threefold. First, food diversity can lead to more stable resource dynamics. The consumption of a wide variety of fleshy fruits suggests that the habitat is less likely to generate a drastic seasonal decrease of food resources. Our data show that *A. chloroptera*, *C. chrysops*, and *A. aestiva* feed in agroforest home gardens even in the dry season (from June to August), supporting our argument. Similar results for shade

Table 1 Food taxa consumed by five bird species in home gardens (AF), secondary forest (FOR) and pasture (PAS) in the Pontal do Paranapanema, Brazil

Food taxa	Taxonomical family	Bird species	Habitat
<i>Acacia mangium</i>	Mimosaceae	Cyano	AF
<i>Aegiphyla sellowiana</i>	Verbenaceae	Cyano	FOR
<i>Bird egg</i>	???	Cyano, Ramph	FOR
<i>Casearia sylvestris</i>	Flacourtiaceae	Cyano	FOR
<i>Cecropia glaziovii</i>	Moraceae	Ptero	FOR
<i>Cecropia pachystachya</i>	Moraceae	Cyano, Amz, Ramph, Ptero	FOR, AF, PAS
<i>Cedrela sp</i>	Meliaceae	Ara	AF
<i>Cordia eucalyculata</i>	Boraginaceae	Ramph	AF
<i>Croton floribundus</i>	Euphorbiaceae	Amaz	AF
<i>Delonix regia</i>	Caesalpinaceae	Amaz	AF
<i>Shefflera morototoni</i>	Araliaceae	Ramph, Ptero	FOR
<i>Eugenia gracillima kiaersk</i>	Myrtaceae	Cyano	FOR
<i>Eugenia jambolona</i>	Myrtaceae	Amaz, Ramph	AF
<i>Ficus enormis</i>	Moraceae	Ara	FOR
<i>Gallus gallus</i>	Phasidae	Cyano	AF
<i>Gliricidia sepium</i>	Papilionaceae	Amaz	AF
<i>Guarea guidonia</i>	Meliaceae	Ptero	AF
<i>Heteropterys sp</i>	Malpighiaceae	Cyano	FOR
<i>Hymenaea courbaril</i>	Caesalpinaceae	Ara	AF
<i>Inga vera</i>	Mimosaceae	Cyano, Amz, Ramph, Ptero	FOR, AF
<i>Invertebrates</i>	???	Cyano	FOR
<i>Machaerium scleroxylon</i>	Fabaceae	Amaz	AF
<i>Mangifera indica</i>	Anacardiaceae	Amz, Ramph	AF
<i>Matayba cf. eleagnoides</i>	Sapindaceae	Cyano	FOR
<i>Melia azedarach</i>	Meliaceae	Ara, Amz, Ramph, Ptero	AF
<i>Morus nigra</i>	Moraceae	Amz, Ramph, Ptero	AF
<i>Myrciaria cauliflora</i>	Myrtaceae	Cyano	AF
<i>Myrciaria floribunda</i>	Myrtaceae	Cyano	FOR
<i>Carica papaya</i>	Caricaceae	Cyano, Ptero	AF
<i>Parapiptadenia rigida</i>	Mimosaceae	Amaz	AF
<i>Peltophorum dubium</i>	Caesalpinaceae	Amaz	AF
<i>Piptatenia sp</i>	Mimosaceae	Cyano	FOR
<i>Pouteria ramiflora</i>	Caesalpinaceae	Ara, Amz	AF
<i>Protium heptaphyllum</i>	Sapotaceae	Cyano, Amz	FOR
<i>Psidium guajava</i>	Myrtaceae	Cyano, Amz	AF
<i>Serjania mansoniana</i>	Sapindaceae	Cyano	FOR
<i>Spondias mombin</i>	Anacardiaceae	Cyano	AF
<i>Spondias purpurea</i>	Anacardiaceae	Ptero	AF
<i>Syagrus romanzoffiana</i>	Arecaceae	Ara, Cyano, Amz, Ptero	FOR, AF, PAS
<i>Tabebuia alba</i>	Bignoniaceae	Amaz	AF
<i>Tabebuia avellaneda</i>	Bignoniaceae	Amaz	FOR
<i>Terminalia catappa</i>	Combretaceae	Ara, Amz	AF
<i>Zea mays</i>	Poaceae	Cyano	AF

Table 1 continued

Food taxa	Taxonomical family	Bird species	Habitat
<i>Zeyeria tuberculosa</i>	Bignoniaceae	Amaz	FOR

Ara Ara chloroptera, *Cyano Cyanocorax chrysops*, *Amaz Amazona aestiva*, *Ptero Pteroglossus castanotis*, *Ramph Ramphastos toco*

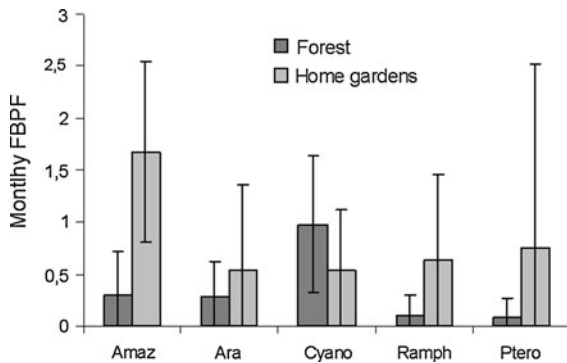


Fig. 3 Monthly mean feeding bouts per frequency values and standard deviation recorded for the bird species in secondary forest and agroforest home gardens of Pontal do Paranapanema, Brazil. *Amaz Amazona aestiva*, *Ara Ara chloroptera*, *Cyano Cyanocorax chrysops*, *Ramph Ramphastos toco*, *Ptero Pteroglossus castanotis*

coffee agroforests were also reported by Greenberg et al. (1997). Second, habitats with a high diversity of food taxa can fulfill the species' nutrition requirements more than habitats that provide narrow feeding resources can. A better balanced and mixed diet could increase the possibility of extracting specific compounds (Jordano 1988; Mack 1998) and reduce the accumulation of certain toxic secondary compounds (Jordano 1988). Finally, a wide variety of resources can support richer frugivore assemblages. It has been suggested that agroforest habitats can support a substantial diversity of frugivorous birds (Carlo et al. 2004; Goulart 2007), and this might be due to such variety of fleshy fruit trees in these habitats.

Therefore, agroforests can support not only a rich assemblage of frugivore species, but also healthy populations by providing a wide range of food resources. Our data suggest that agroforest home gardens are important as a resource-rich environment for frugivorous birds, especially when forest fragments close to them are small and impoverished. The amount and variety of fleshy fruits found in these habitats support species during the wet and the dry seasons. Yet, long term viability of these populations is unknown.

Conclusion

Our data corroborate the burgeoning literature that suggests that non-intensified agricultural practices, such as agroforestry systems, can serve as an extra-habitat for forest species (Wunderle and Latta 2000; Cockle et al. 2005; Komar 2006; Faria et al. 2007, 2006; Dietsch et al. 2007). More specifically, home garden is a resource-rich environment for frugivores, providing high abundance and high diversity of food items for this guild during all the year, even though with some seasonal variation. This flux between natural patches and the inter-patch matrix or *spillover effect* is very common in agricultural landscapes (Tscharntke et al. 2008). Especially for species with high dispersal capabilities, like large frugivores birds, the degree of intensification of agricultural environments surrounding the patch seems to play a major role on the population dynamics. Considering this

Table 2 Comparison of median feeding bouts per month by the five bird species in the three habitats of Pontal do Paranapanema, Brazil (between brackets, mean \pm standard deviation)

Species	Home garden	Forest	Pasture	Kruskal–Wallis	P value
<i>A. aestiva</i>	(6.6 \pm 3.2) 6.5	(0.5 \pm 1.2) 0.0	(0.5 \pm 1.2) 0.0	25.22	<0.0001
<i>A. chloroptera</i>	(1.2 \pm 1.8) 0.5	(0.7 \pm 0.9) 0.5	–	0.19	0.6590
<i>C. chrysops</i>	(1.0 \pm 1.1) 1.0	(3.2 \pm 1.9) 3.0	–	9.51	0.0020
<i>P. castanotis</i>	(1.2 \pm 2.7) 0.0	(0.2 \pm 0.4) 0.0	–	0.05	0.8192
<i>R. toco</i>	(1.4 \pm 1.9) 0.5	(0.3 \pm 0.6) 0.0	–	0.25	0.1340

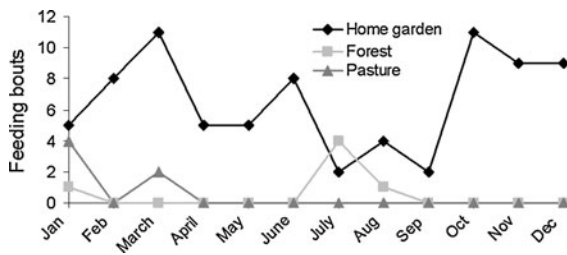


Fig. 4 Total number of feeding bouts recorded for *Amazona aestiva* during one year in pasture, secondary forest and agroforest home gardens of Pontal do Paranapanema, Brazil

fact, dichotomization between insular natural patches in an inhospitable matrix, which interspaces traditional conservation theories and management practices, is not applicable to the species and the landscape investigated here. Finally, we suggest that in fragmented landscapes, land-reforms that substitute extensive pastures and monocultures for heterogeneous settlements with agroecologically oriented subsistence agriculture, such as agroforestry home gardens, enhance conservation of forest frugivorous birds.

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