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article

Agroforestry system as a buffer zone in a Brazilian Atlantic Forest conservation unit: an artificial nest predation perspective

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Abstract: Here we inferred about the effectiveness of a buffer zone composed by an Agroforestry System (AS) for providing reproductive conditions for Atlantic Forest birds by comparing artificial nest predation rates between a buffer zone, a primary forest area, and a set of small and isolated Atlantic Forest fragments. We have used 237 nests throughout the three areas, of which 100 (42.2%) were depredated. Predation frequencies were 28.6% in the continuous forest, 100% in the AS, and 51.9% in the fragments, differing significantly. We could detect nest predators in 48 of the 100 depredated nests (48%) using camera traps. Differences between areas may be attributed to changes in nest predator species. We support previous evidences that the conservation of bird communities may not rely on buffer zones as an extension of their breeding habitats.

Keywords: *Protected areas, management, mesopredators, birds, camera traps*

Sistema Agroflorestal como zona de amortecimento em uma Unidade de Conservação da Mata Atlântica brasileira: uma perspectiva de predação de ninho artificial

Resumo: O presente estudo teve como objetivo avaliar a efetividade de uma zona tampão composta por um sistema agroflorestal (SA) para a reprodução de aves da Mata Atlântica. Para isto, as porcentagens de predação em ninhos artificiais foram comparadas entre as zonas tampão, uma área de floresta primária e em um conjunto de fragmentos de Mata Atlântica pequenos e isolados. Um total de 237 ninhos foi utilizado nas três áreas e 100 deles (42,2%) foram predados. As porcentagens de predação foram 28,6% na área de floresta primária, 100% no SA e 51,9% nos fragmentos, havendo diferença significativa. Os predadores puderam ser identificados em 48 das 100 predações (48%) com o uso de câmeras *trap*, o que gerou evidências de que as diferenças possam ser atribuídas a mudanças na composição de espécies de predadores entre as áreas. Esta análise dá suporte a estudos prévios de que as zonas tampão não devam ser consideradas como extensão dos hábitats naturais para a conservação de comunidades de aves.

Palavras-chave*:* *áreas protegidas, gestão, mesopredadores, aves, câmeras trap*

Introduction

Buffer zones correspond to areas surrounding conservation units where human activities are subject to rules and restrictions, in order to minimize negative impacts on protected areas. They are generally complex and some of the practices often forbidden in these areas include burning vegetation, logging, and the use of conventional agriculture (Sayer 1991, Bennet & Mulongoy 2006). Over the last few decades a number of works have provided mixed evidences for the effectiveness of buffer zones to the conservation of faunal components, and this is still an important open debate for the management of protected areas (Goodale et al. 2014, Mammides et al. 2015). The Agroforestry Systems (ASs) are agricultural systems that incorporate food production together with environmental conservation (Schroth et al. 2004). They are believed to hold more biodiversity than mono-crops, and for this reason are considered good buffer zones (Goodale et al. 2014), but they have never been evaluated under the faunal perspective in Brazil.

Nest predation rates are often believed to increase with habitat disturbance (Oniki 1979, Robinson et al. 2000), and this can be a valuable indicative of habitat quality for birds (Alvarez & Galetti 2007). The main hypothesis that attempt to explain the inflated nest predation rates in impacted areas imply that in this condition, with the extinction of top predators, middle-sized animals, that are the main nest predators, increase their densities putting a lot more pressure over the nests (mesopredator-release hypothesis) (Terborgh 1974, Oniki 1979). Artificial nests are known to result in different predation rates compared with natural nests because they lack the anti-predatory strategies adopted by the different species of birds, and eggs are not similar (Buler & Hamilton 2000). On the other hand they have standardized format, they permit prompt evaluations using large samples, and nest predation rates in artificial nests are often indexes of predation rates of natural nests (Buler & Hamilton 2000). Then, it can be considered as a useful tool for comparative purposes of habitat conditions (Oja et al. 2015).

Here we aim to infer about the effectiveness of a buffer zone composed by an AS for providing reproductive conditions for birds, by addressing predation rates in artificial nests. Specifically, we have compared nest predation rates between an AS buffer zone and a well-preserved primary forest area, that has served as a positive control, and a set of small and isolated Atlantic Forest fragments that have served as a negative control. We predict that the AS should present intermediate nest predation rates between the continuous forest and the isolated fragments. We also tested the hypothesis that variations in nest predation rates can be caused by changes in the composition of nest predators communities in these different habitats. To achieve this purpose, we have used a set of camera traps to identify nest predators.

Materials and Methods

1. Study areas

We assessed artificial nest predation frequency in undisturbed areas from "Carlos Botelho" State Park (CBSP), São Paulo State, Brazil, in an AS adjacent to the Park, and in a set of isolated fragments (Figure 1). CBSP (24º06'55"S, 47º47'18"W) holds 37.644 ha of Atlantic Forest and is among the few areas that still preserve original faunal elements such as jaguars, tapirs, and large primates. The elevation ranges from 20 to 1.000 m above sea level, and annual mean temperature varies between 18 and 20ºC, with annual precipitation from 1.500 to 2.200 mm (Ferraz & Varjabedian 1999). Our work was conducted at an altitude of 714 to 837 m, where the vegetation is classified as submontane rain forest.

The AS is a private property located in the city of "Sete Barras" (24°11'19"S, 47°53'19"W; altitude 35 m), adjacent to CBSP, with a total area of approximately 200 ha. Formerly, the whole area was used for traditional agriculture, but these practices have been abandoned about 20 years ago, when an AS of mixed shrub-crops (including coffee, banana, cocoa, guava, and pupunha palm heart) has initiated. In this system, patches of Coastal Atlantic Forest were permitted to regenerate to provide organic matter, soil protection, pollinators, and parasitism control for the intermixed crops. We have placed the nests in a area where mixed cultures of banana, cocoa, guava, and pupunha were managed in the middle of approximately 5 to 10 ha secondary Atlantic Forest fragments.

The Atlantic Forests fragments (n = 12) were located in private areas nearby "Capão Bonito" National Forest (CPNF) (23°54'29" S, 48°30'38" W; altitude 670 m), which is about 60 km far from CBSP. These fragments varied from 2 to 50 ha, and they were 360 m to 15 km distant from one another. They were imbedded in a complex mosaic of mono-crops that included corn, soy bean, wheat, sylvicultures of *Araucaria angustifolia*, and *Pinus spp*., and pasturelands.

2. Artificial nests experiment

To infer about the relative habitat quality for birds reproduction, we have set a number of artificial nests in each study site, during 2014 and 2015, from August to February. We used cup nests commercially available for domestic canaries, each containing two eggs of quail (*Coturnix coturnix*). Latex gloves were used to manipulate the nests and eggs to avoid predators attraction by human odor. Nests were placed at least 30 m apart in transects. We have alternated nests placed on the ground with nests attached to tree branches, 1-2 m above ground, and transects were at least 100 m far from each other. Each nest was exposed for 15 days which represents the incubation period of many birds occurring in the study areas (Sick 1997), and nests in which only one egg has been damaged or removed were also considered as depredated.

At CBSP we have set 14 transects of 10 nests each, totaling 140 nests, and at AS we used 2 transects of 10 nests each, totaling 20 nests, being this number proportional to the size of the area. In the fragments we have set 12 transects (one in each fragment), where the number of nests in each fragment and fragment sizes were 3 (2 ha), 4 (2 ha), 5 (20 ha), 5 (20 ha), 5 (30 ha), 5 (30 ha), 5 (10 ha), 5 (10 ha), 10 (50 ha), 10 (20 ha), and 10 (30 ha), 10 (30 ha), totaling 77 nests. In the AS, in which habitats are heterogeneous,

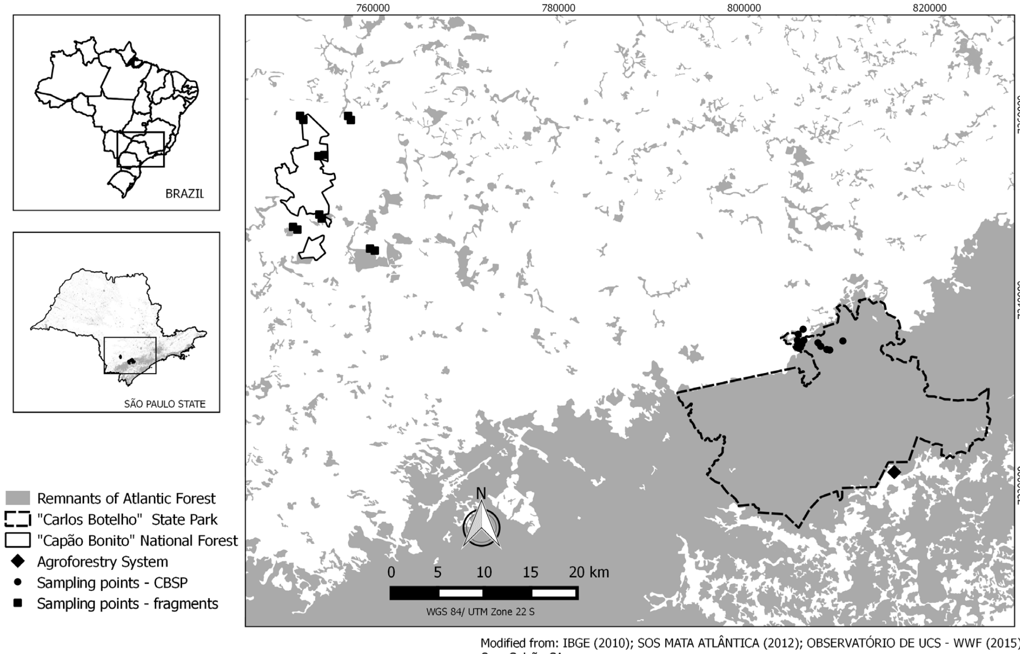

Figure 1. Study areas: Carlos Botelho State Park (CBSP); fragments in the region of Capão Bonito National Forest (CBNF), and the private property containing the Agroforestry System (AS). Markings indicate the study sites.

we established transects randomly crossing the area in its longer extension, in such a way that some nests fell in forest fragments and others in crop plants.

3. Predators identification using camera traps

In each nest we have used a camera trap Bushnell Trophy Cam HD in an attempt to identify nest predators. These cameras were placed 1 to 3 m from the nests, depending on the availability of nearby branches to attach them. Cameras were programmed for recording 30s videos, with 3s intervals. To avoid over-exposure of the films, infra-red leds were programmed to low exposure, and we have used the maximum level of sensitivity of the movement sensor. Videos were recorded in 2GB memory cards and were analyzed in laboratory.

4. Data analyses

The proportions of depredated nests between the areas, and the proportions of depredated nests on trees and on the ground were compared through contingence tables using the *G*-test, and the data from the fragments surrounding Capão Bonito National Forest were pooled together. To compare the proportions of predator species across the areas, we also performed a *G*-test by constructing a contingency table in which rows represented the species detected by the cameras depredating the nests, the columns represented the study sites, and the cells contained the number of nests depredated by each species in each area. All of the statistical analyses were performed using the Program BioEstat 5.0 (Ayres et al.2007), with 5% significance level.

Results

We have used a total of 237 nests throughout the three areas, of which 100 (42.2%) were depredated. Predation frequencies were 28.6% (40 out of 140 nests) in the CBSP, 100% in the AS (20 out of 20 nests), and 51.9% in the fragments (40 out of 77 nests). The proportions of nest predations have differed significantly between the study areas ($G = 48.6$, $P = 0.001$).

Overall, 59 out of 119 (49.6%) nests placed on the ground were depredated, against 41 out of 118 (34.7%) nests placed on tree branches, and the proportion of nest predations was significantly higher on the ground ($G = 5.36$, $P = 0.02$). Considering each specific area, predation was significantly higher on the ground in CBSP, and no significant differences were detected in AS and in the fragments (Table 1).

Pooling the three areas together, our camera effort has corresponded to 3.555 cameras/day and 85.320 hrs/camera, distributed in 50.400 hr/camera in CBSP, 7.200 in the AS, and 27.720 in the fragments. We could detect nest predators in 48 out of the 100 depredated nests (48%), being 18 in the CBSP (45%), six in the AS (30%), and 24 in the fragments (58.5%). Overall, we detected 19 predator species, being 10 bird species, eight mammals, and one reptile (Figure 2). Birds were responsible for 50% of the observed predations, followed by mammals (48%), and reptiles (2%). Most of the recorded predations caused by birds were on nests placed on tree branches (15 out of 24; 62.5%), whereas most of the detected predations caused by mammals were on nests placed on the

Table 1 – Numbers and percentages of predations on artificial nests placed on the ground and on nests placed on tree branches. Proportions of predations in each substrate were compared using *G*-test for each of three study areas: Carlos Botelho State Park (CBSP), Agroforestry System (AS), and a set of fragments located in an anthropic matrix represented by Capão Bonito National Forest (Fragments). *P* represent G-tests significance levels.

	Ground	Tree branches	Significance
CBSP	26 out of 70 (37.1%)	14 out of 70 (20%)	$G = 5.09$, $P = 0.02$
AS	9 out of 9 (100%)	11 out of 11 (100%)	$G = 0$, $P = 1.0$
Fragments	24 out of 39 (61.5%)	16 out of 38 (41.0%)	$G = 2.93$, $P = 0.08$

Figure 2. Images obtained from camera trap videos depicting predations by: (A) Wild Boar (*Sus scrofa*) in the fragments, (B) Azure Jay (*Cyanocorax caeruleus*) in the AS, (C) Collared Forest-Falcon (*Micrastur semitorquatus*) in CBSP, and (D) Red-ruffed Fruitcrow (*Pyroderus scutatus*) in the fragments.

ground (21 out of 23; 91%), so was the only predation performed by a reptile. Species of predators observed in each area and their impact on predation are presented in Table 2. The *G*-test revealed a significant difference in the proportion of the identified predator species between the study areas ($G = 72.9$, $P = 0.0001$).

Table 2 - Number of artificial nest predations caused by each species identified using camera traps in each study area: Carlos Botelho State Park (CBSP), Agroforestry System (AS), and a set of fragments located in an anthropic matrix represented by Capão Bonito National Forest (Fragments).

Species	Sampling areas			Total
	CBSP	AS	Fragments	
Birds				
Order Tinamiformes				
Family Tinamidae				
Tinamus solitarius	2	0	0	2
Order Galliformes				
Family Cracidae				
Penelope obscura	1	0	2	3
Family Odontophoridae				
Odontophorus capueira	1	0	0	1
Order Falconiformes				
Family Falconidae				
Micrastur semitorquatus	1	0	0	1
Order Passeriformes				
Family Dendrocolaptidae				
Dendrocolaptes platyrostris	3	0	0	3
Family Cotingidae				
Pyroderus scutatus	0	0	1	1
Family Vireonidae				
Cyclarhis gujanensis	0	0	1	1
Family Corvidae				
Cyanocorax chrysops	0	0	7	7
Cyanocorax caeruleus	0	4	0	4
Family Thraupidae				
Lanio melanops	1	0	0	1
Mammals				
Order Didelphimorphia				
Family Didelphidae				
Philander frenatus	4	0	0	4
Didelphis aurita	0	2	4	6
Order Rodentia				
Family Sciuridae				
Guerlinguetus brasiliensis ingrami	0	0	1	1
Family Cricetidae				
unidentified*	1	0	0	1
Order Carnivora				
Family Procyonidae				
Nasua nasua	1	0	3	4
Family Mustelidae				
Eira barbara	2	0	1	3
Order Artiodactyla				
Family Suidae				
Sus scrofa	0	0	4	4
Reptiles				
Order Squamata				
Family Teiidae				
Tupinambis merianae	1	0	0	1
TOTAL	18	6	24	**48**

(*rodent that could not be identified at the species level).

Discussion

Our main finding was that artificial nest predation rate in a buffer zone composed by an AS was extremely high. Our data corroborated the premise that nest predation rate should be higher in a set of fragments embedded in anthropogenic habitats than in continuous forests, but not that the AS should present intermediate nest predation levels. In CBSP seven of the 18 predations recorded on camera were performed by species that rely on large tracts of forest to survive, i.e. *T. solitarius*, *O. capueira*, *M. semitorquatus*, and *D. platyrostris* (Willis 1979, Ribon et al. 2003). Of 24 predations recorded in the fragments, seven were caused by *C. chrysops*, a bird typical of forest borders and secondary habitats (Sick 1997), and four were caused by *Sus scrofa*, an alien species typically associated with crops (Pedrosa et al. 2015). Then, these species may not be involved in mesopredator-release adjustments. On the other hand, all of the other detected predators can occur in both continuous forests and in anthropic habitats (Willis 1979, Sick 1997, Ribon et al. 2003, Reis et al. 2006), and could potentially have their densities inflated in the disturbed areas due to the lack of top predators. Testing the mesopredator-release effect is beyond the scope of this work, but here we corroborate the hypothesis that changes in predator types may also govern nest predation variations. Although other nest predator species may occur in our study sites (see for instance Menezes & Marini 2017), especially those that can be eventual nest predators, our hypothesis was based on the assumption that our cameras have registered the species that are more willing to depredate nest's contents in each area. The fact that all of the predator species detected by the cameras occur from sea level to higher altitudes (Ridgely & Tudor 1994, Sick 1997, Reis et al. 2006) also suggests that altitudinal variation between our study areas alone may not have played a significant role in our predator species survey.

The higher predation level on ground nests in CBSP corroborated the conclusions of a wide review for tropical forests (Söderström 1999). As most of the predators we detected (birds and mammals) could potentially forage both on the ground and on tree branches, lower nest concealment on the ground than in tree branches may explain this difference (see also Söderström 1999). In the AS and in the fragments, inflated nest predation rates in general may have contributed to uncover this effect.

The 100% predation in the AS was unexpected and one of the reasons may be the presence of *C. caeruleus* in the area. Jays are omnivorous birds (Sick 1997) that commonly visit orchards to consume fruits (personal observation), and the concentration of this type of resource in the AS is what may have attracted them. Notably, corvids are also typical predators of nests of smaller birds (Martin & Joron 2003), and we provide evidences that this context may be unfavorable to birds willing to reproduce in the AS we studied. The vegetation cover around the nests is another important parameter determining the risks of predation by visually oriented predators such as birds, and there is at least one good evidence that nest predation by corvids can increase with decreasing vegetation cover (Martin & Joron 2003). In both CBSP and in the fragments nests were placed in forested habitats, while in the AS part of the nests has been placed in crop plants, which may have favored nest uncover. We believe, however, that placing nests randomly across Atlantic Forest patches and crop plants in the AS did not represent an unrealistic situation, because various tropical passerine species build their nests in crop trees (Skutch 1954).

In conclusion, here we depict one case in which an AS could potentially work as reproductive trap for birds. ASs are certainly one of the types of buffer zones that are structurally more similar to the original habitats (Schroth et al. 2004, Mcneely & Schroth 2006), and we provide new evidences that benefits envisioned for ASs as buffer zones must focus on avoiding soil erosion, reducing physical edge effects, or on preserving the diversity of fauna from the soil (Schroth et al. 2004, Junqueira et al. 2013), but the conservation of bird communities, especially endangered species, may not rely on buffer zones as an extension of their breeding habitats.

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Author contributions

Camila André Galvão: substantial contribution in the concept and design of the study; contribution to data collection; contribution to data analysis and interpretation; contribution to manuscript preparation; contribution to critical revision, adding intelectual content.

Mercival Roberto Francisco: substantial contribution in the concept and design of the study; contribution to data analysis and interpretation; contribution to manuscript preparation; contribution to critical revision, adding intelectual content.

Marcelo Nivert Schlindwein: substantial contribution in the concept and design of the study; contribution to data collection; contribution to data analysis and interpretation; contribution to manuscript preparation; contribution to critical revision, adding intelectual content.

Conflicts of interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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