EFFECTS OF FRAGMENTATION ON *Thamnophilus stictocephalus* (AVES, THAMNOPHILIDAE) IN SEMIDECIDUOUS FOREST OF ALTER-DO-CHÃO, PARÁ

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ABSTRACT

Effects of fragmentation on biodiversity have received much attention in recent decades, as fragmentation can greatly reduce viable areas for living organisms. We studied its effect on *Thamnophilus stictocephalus* (Thamnophilidae), an understory bird, in semideciduous forest fragments in Alter-do-Chão, Santarém, Pará. We tested whether the density of *Thamnophilus stictocephalus* was a function of fragment size and shape, density of vegetation, or arthropod biomass. Density of *Thamnophilus* was positively related to fragment size, but not to the other factors analyzed. Arthropod biomass was positively related to fragment size. The density of *T. stictocephalus* in fragments was significantly higher than it was in continuous forest. Fragmentation processes had a pronounced effect on the relative density of *T. stictocephalus*.

Key words: fragmentation, forests, birds, Amazonia.

RESUMO

Efeitos da fragmentação sobre *Thamnophilus stictocephalus* (aves, Thamnophilidae) em florestas semidecíduas de Alter-do-Chão, Pará

Os efeitos da fragmentação sobre a biodiversidade têm recebido muita atenção nas últimas décadas, pelo fato de reduzirem, drasticamente, áreas viáveis para organismos vivos. Estudou-se o efeito da fragmentação de habitat sobre *Thamnophilus stictocephalus* (Thamnophilidae), uma ave de sub-bosque, em fragmentos de floresta semidecídua em Alter-do-Chão, Santarém, Pará. Testou-se a densidade de *Thamnophilus stictocephalus* como função de tamanho e forma de fragmentos, da densidade da vegetação de sub-bosque e da biomassa de artrópodes. A densidade de *Thamnophilus* foi positivamente relacionada ao tamanho de fragmentos e não foi relacionada significativamente aos outros fatores analisados. A biomassa de artrópodes foi positivamente relacionada ao tamanho de fragmentos. A densidade de *Thamnophilus stictocephalus* foi significativamente maior em fragmentos do que em floresta contínua. A fragmentação teve um efeito pronunciado na densidade relativa de *T. stictocephalus.*

Palavras-chave: fragmentação, florestas, aves, Amazônia.

INTRODUCTION

Effects of forest fragmentation on biodiversity have been the focus of much research in recent decades. Fragmentation is thought to reduce and isolate populations of living organisms, leading to extinctions as population size is reduced (Metzger, 1999); however, in some cases, part of the biodiversity of a forest can be conserved for decades in small fragments (Turner & Corlett, 1996).

The reaction to forest fragmentation depends on the species or taxonomic group, as shown by research in forest fragments in central Amazonia. Fragmentation leads to a decrease in Euglossinae bees and parasitoid wasp richness (Didham *et al.*, 1996), and to the disappearance of ant-following birds and obligatory mixed-flock birds (Stouffer & Bierregaard, 1995b). Richness of some groups, such as frogs (Tocher, 1996) and small mammals (Malcolm, 1991) in central Amazonia increased in fragments. Other groups such as hummingbirds in central Amazonia (Stouffer & Bierregaard, 1995a) and frugivorous pigeons in Australia (Date *et al.*, 1991) did not suffer significant alteration in richness with fragmentation.

One of the main objectives in fragmentation research is to determine the principal factors that control its effects on communities. Fragment size is generally thought to be the most important parameter in explaining variation in species richness (Metzger, 1999). Fragment size explained richness variation in forest beetles in central Amazonia (Didham *et al.*, 1998), as well as forest bird richness in Australia and North America (Howe, 1984; Blake & Karr, 1987; Martin, 1988). Edge effects also affect the fragment community, and may be more important than fragment size, as in the case of Myrtaceae species mortality in fragments in central Amazonia (Ferreira & Laurance, 1997). Fragment shape effects are linked to edge effects because the more irregularly shaped fragments have relatively more edge habitat (Laurance & Yensen, 1991). Consequently, a large but irregularly shaped fragment does not necessarily contain sufficient interior forest habitat to maintain viability of edge-sensitive species populations.

Because different species respond in different ways to fragmentation, their natural history must be known to better predict fragmentation effects (Bierregaard *et al.*, 1997). Birds are an abundant and diverse group in the tropics, of which the natural history is relatively well known, and have been used in many fragmentation studies (Blake & Karr, 1987; Date *et al.*, 1991; Stouffer & Bierregaard, 1995a, 1995b; Stratford, 1997, 1999; Zanette *et al.*, 2000).

Thamnophilus stictocephalus (Thamnophilidae), which has recently become separated from the *Thamnophilus punctatus* species (Isler *et al.*, 1997), inhabits dry forest edge from central Brazil to the Island of Marajó, in Pará State (Isler *et al.*, 1997). Small populations are found in dry forest fragments in Santarém, Pará (R. Cintra, pers. comm.), where they can remain for at least 5 years in the same fragment (Sanaiotti & Cintra, in press).

We investigated the extent to which relative density of *Thamnophilus stictocephalus* varied with fragment size and shape, vegetation density, and prey availability in Alter-do-Chão, Pará, and whether density varies between fragments and continuous forest.

STUDY AREA

The study was conducted in the vicinity of Alter-do-Chão, a village in the Municipality of Santarém, Pará State, Brazil, between April and September 2000. The region lies between 2º30'10.3''S; 54º51'26.8''W and 2º32'28.8"S 54º57'26.5"W. Located on the right bank of Tapajós River, it lies north of Alter-do-Chão (Albernaz & Magnusson, 1999) and includes one of the largest patches of Amazonian savanna. Alter-do-Chão savannas differ from other Amazonian savannas because in one part of the area, called the Peninsula, the vegetation is mostly shrub, mainly Myrtaceae and Melastomataceae species, and young trees (Sanaiotti & Magnusson, 1995). In most of the area, grasses (*Paspalum carinata* and *Trachypogon plumosus*) have the highest cover (W. Magnusson, personal comm.). The frequent fires in the savanna affect the supply of fruits consumed by birds and occur during the breeding season of many avian species (Sanaiotti & Magnusson, 1995). There are over 60 fragments of semideciduous rain forest in the savanna, most of them varying in size from 2 to 66 ha, and two being larger (190 and 360 ha) (Albernaz, 2001; Bernard *et al.*, 2001).

Dialium guianensis, *Eschweilera* sp., *Vochysia* sp., and *Salacia* sp. are among the most common tree species in the fragments. In the fragments trees sometimes reach 25 to 30 m in height, and the understory has many palms (Albernaz & Magnusson, 1999).

Trail systems were made in 24 fragments, varying in size from 6 to 360 ha (45.41 ± 83.18), and in 8 continuous forest localities in the region of Alter-do-Chão. Each system consisted of four 250 m long parallel trails, separated by 50 m, and marked at 10 m intervals by metal tagging the trees. Some small fragments had only two or three trails. All trails were perpendicular to the fragment edge. There was one trail system in all but the two largest fragments (190 and 360 ha), which contained two systems each.

METHODS

Relative Density of **Thamnophilus stictocephalus**

To estimate the relative density of *T. stictocephalus*, censuses were made in 17 fragments and 3 continuous forest localities. The censuses started at 5:30 a.m., and two successive counts were done during the same morning. Birds were either located visually, using 10 × 20 binoculars, or along the trail system by their calls. Birds were counted at points located at 50 m intervals along the trails. The observer (Sidnei M. Dantas) remained for two minutes at each point, counting individuals seen or heard within 50 m of the trails, after which he walked to the next point to continue the census. Individuals heard while walking between points were also recorded.

To diminish the possibility of counting the same individual repeatedly, the trails used in the censuses were the most distant ones, which in the case of four-trail systems means the first and fourth trails, and in that of the three-trail system the first and third trails. Only the individuals counted on the side outside the trails were taken into account.

The apparent density for each count was calculated as the number of individuals divided by the sampled area, which was 2.5 ha. The apparent density in each fragment and continuous forest locality was the average of the two counts in each area.

Index of **Thamnophilus stictocephalus** *from edge to the center of the fragments and continuous forest*

The apparent density of *T. stictocephalus* was determined from the edge of the fragments and in the continuous forest by dividing the trails in five 50 m long sections and estimating the density for each section. Counts were made only on the sides of the trail outside the plots, and only individuals within 50 m of the trail were included. For each trail system, the corresponding sections of the two trails were summed to calculate the final index of density. In very small fragments, in which the trails run from one side of the fragment to another, only the densities within 150 m of the start of the trails were estimated. For these plots, we took the average between the density in the first and the fifth sections and between the second and the fourth sections. Fragments and continuous forest areas in which the trails ran parallel to the edge were not analyzed.

Fragment area and shape index

The area of fragments was measured from georeferenced Landsat TM5 images, and perimeters were measured from vectors of the fragments, after digitization (Albernaz, 2001).

The shape index (SI) indicates the degree of irregularity of fragment shapes, with the minimum value being one (for circular fragments). The greater the SI value is, the larger the perimeter fraction of the fragment/area, and the more irregular the shape. The SI was calculated as:

$$SI = \frac{P}{200[(\pi TA)^{0.5}]}$$

where:
SI = shape index; P = perimeter of fragment; TA = total area of fragment (Laurance & Yensen, 1991).

Density of understory and biomass of arthropods

Density of understory vegetation was measured in the trail systems in 21 fragments and 8 continuous forest localities, using the checker-board method (Bibby & Burgess, 1997), in which a 1 m² sheet is held 1.5 m above the ground and 3 m from the observer. Density of understory vegetation was considered as the percentage of the sheet covered by understory as estimated visually by the observer. Estimates were made every 20 m along two trails per fragment and, to minimize the effect of the trails, 5 m to one side of them. This resulted in an average of 12 estimates per trail.

Arthropods were sampled with sweep nets every 30 m along the trails and on two trails per area; this totaled 16 sampling stations in each fragment or continuous area. Between 8:00 and 10:00 am, collections were made 5 m from, and on one side of the trail in a 10 m² area in the understory. Arthropods were preserved in 70% alcohol; individuals from taxonomic categories not previously recorded as being eaten by *Thamnophilus* (Sick, 1997; Schubart *et al*., 1965; Oniki, 1975), such as ants (Hymenoptera), stink bugs (Hemiptera), and very large arthropods (> 8 cm) were separated from the samples and not used in the analyses. Samples were weighed with 10 g scales, and the biomass at each location was considered as the total fresh weight of the samples in the total sampled area (160 m² per fragment or continuous forest plot).

Statistical analysis

A multiple regression analysis was used to determine if the apparent density of *Thamnophilus stictocephalus* was related to the independent variables. Statistical analyses were done using the Systat 8.0 Program (Wilkinson, 1998). We estimated the arthropod biomass only in the wet season, to which analysis for this variable was restricted.

Multiple regressions between the independent variables were used to verify if the variables were influencing one another.

An analysis of variance (ANOVA) was used to determine if there were differences between the apparent density of *Thamnophilus* in fragments and continuous forest. A paired t-test was used to verify possible differences in the density of *Thamnophilus* between seasons.

A simple regression was used to determine if density varied with the distance from the edge.

RESULTS

Area and shape index of fragments, density of understory, and biomass of arthropods

The density of *Thamnophilus* was positively related to fragment size ($R^2 = 0.516$; n = 17; p = 0.036) (Fig. 1). There was no other significant relation between density of *Thamnophilus* and other variables (Appendix 1).

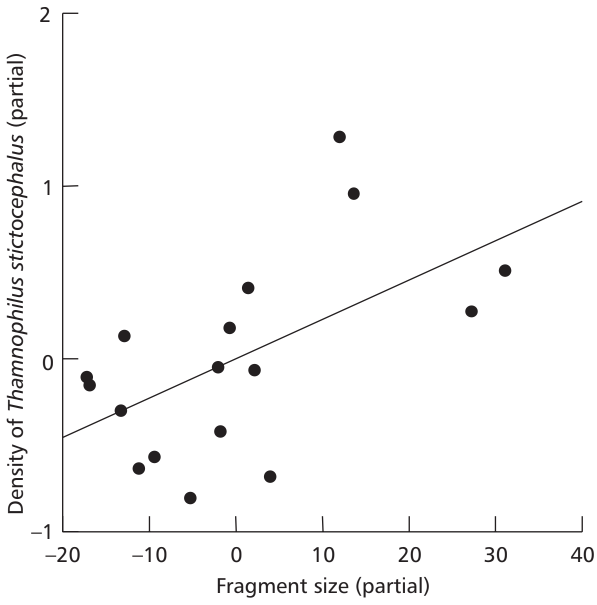

Fig. 1 — Partial fragment size X partial density of *Thamnophilus stictocephalus* in Alter-do-Chão.

Arthropod biomass was positively related to fragment size ($R^2 = 0.696$; n = 17; p = 0.001) (Appendix 2, Fig. 2), being excluded from posterior analysis.

There was no other significant relation between the variables. A simple regression was made between the density of *Thamnophilus* and arthropod biomass; it showed no significant relation ($R^2 = 0.180$; n = 17; p = 0.090).

Comparison of apparent density of* Thamnophilus stictocephalus *between fragments and continuous forest, and from forest edge to its center

The apparent density of *T. stictocephalus* was significantly greater in fragments than in continuous areas (ANOVA, $F_{1,18} = 4.419$; p = 0.050) (Fig. 3). The density was not related significantly to distance from the edge ($R^2 = 0.040$; n = 59; p = 0.127).

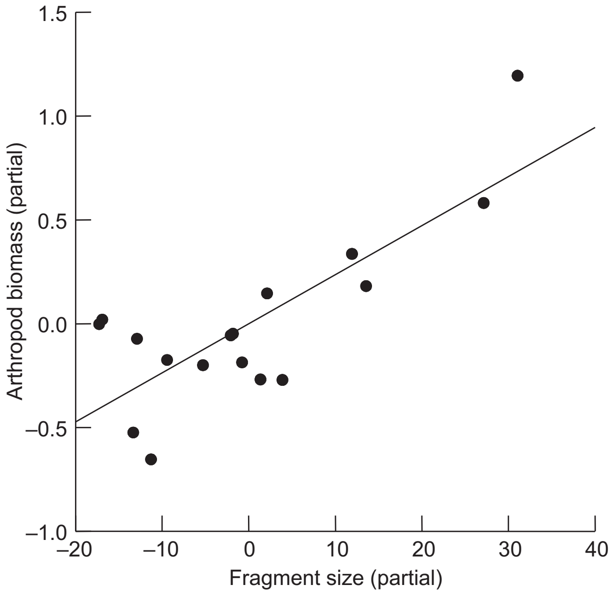

Fig. 2 — Partial fragment size X partial arthropod biomass in Alter-do-Chão.

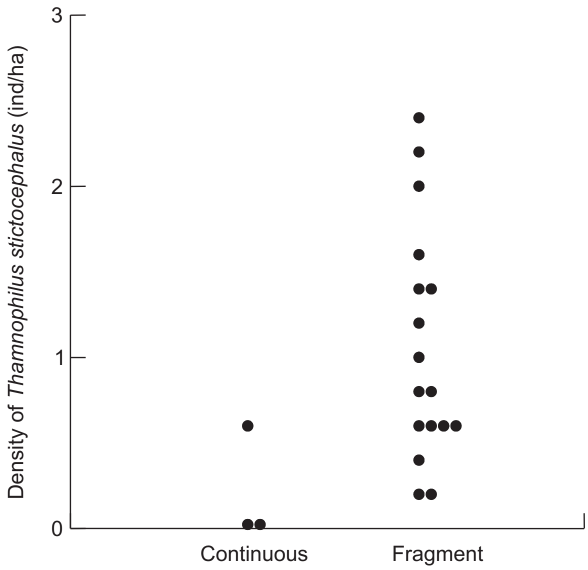

Fig. 3 — Density of *Thamnophilus stictocephalus* in continuous forest areas and in fragments.

DISCUSSION

Fragment size, which was correlated with the density of *Thamnophilus*, is an important factor in influencing the density and richness of birds (Blake & Karr, 1987; Kilgo *et al.*, 1997; Stratford & Stouffer, 1999; Bellamy *et al.*, 2000). The density of *Thamnophilus* had a quadratic relation with fragment size, being greater in medium-sized fragments. The density in continuous forest was lower than it was in fragments. This could indicate that *Thamnophilus stictocephalus* is not a forest-based bird, and we can suppose that larger fragments, which should be more similar to continuous forest than the small fragments, have smaller populations than those of medium-sized fragments. However, few continuous areas were analyzed, and this result might not represent a general situation. According to Ridgely & Tudor (1994) and Isler *et al*. (1997), the species does not occur in continuous or tall forests, but only in low or dry woodlands.

Density of *T. stictocephalus* was not related to SI. The shape of fragments is a factor directly linked to edge effects, and according to Fahrig & Merriam (1994), population dynamics may differ between fragments of the same size, but with different proportions of edge areas. Many forest birds have lower densities in edge areas (Ortega & Capen, 1999; Rosenberg *et al*., 1999). The density of *Thamnophilus stictocephalus* was not related to the distance from the edge of the analyzed areas. Thus, the amount of edge appears to be of little or no importance for this species. However, it never occurs far from the edges in tall-forest zones.

Density of understory vegetation was not significantly related to the density of *T. stictocephalus*, as it was not to any other variable (fragment size, shape index, and arthropod biomass). Perhaps the variation of density of understory was too small between the fragments to influence bird density, or it may even be of little importance in any case to *Thamnophilus stictocephalus*. In addition, *T. stictocephalus* could compensate for reductions in understory foraging area by exploring higher forest strata, which were not analyzed in this study.

Arthropod biomass was significantly related to fragment size. Arthropod richness and abundance can be directly affected by fragmentation processes, and sometimes abundance is greater in small fragments because the edge is colonized by edge-habitat species (Didham *et al*, 1996; Zanette *et al.*, 2000).

While our sampling of the arthropod biomass of showed no significant effect on the density of *T. stictocephalus*, arthropod availability is normally a crucial factor in the response of insectivorous birds to habitat fragmentation (Zanette *et al*., 2000), and one study showed that it profoundly affected the seasonal variation of mixed-species bird flock sizes in a section of the Brazilian Atlantic forest (Develey & Peres, 2000). *Thamnophilus stictocephalus* is a territorial species that can survive for at least 5 years in the same territory (Sanaiotti & Cintra, in press). For this species, fragment size and habitat availability of may have a more important role than prey availability. However, the relation between their biomass and fragment size could mask the real role played by arthropods in the dynamic of the population of *Thamnophilus*.

Although *Thamnophilus stictocephalus* seems to be a forest edge bird, and thus its relative density may increase with fragmentation, this process can be also affect them negatively. In any case, the extent of fragmentation effects on this species requires further study.

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APPENDIX 1

Quadratic regression between the density of *Thamnophilus stictocephalus* and independent variables at Alter-do-Chão.

Effect	Coefficient	Standard error	Standard coefficient	Tolerance	t	p
Constant	2.523	1.185	0.000	–	2.129	0.055
Fragment size	0.023	0.010	2.777	0.029	2.365	0.036
Density of understory	–0.016	0.014	–0.238	0.924	–1.138	0.277
Shape index	0.873	0.631	0.291	0.912	1.384	0.192
(fragment size)²	–0.000	0.000	–2.902	0.029	–2.445	0.031

Analysis of variance

Source	Sum-of-squares	df	Mean squares	F-ratio	p
Regression	3.829	4	0.957	3.198	0.053
Residual	3.592	12	0.299		

APPENDIX 2

Quadratic regression between arthropod biomass and independent variables at Alter-do-Chão.

Effect	Coefficient	Standard error	Standard coefficient	Tolerance	t	p
Constant	–0.105	0.654	0.000		–0.160	0.876
Fragment size	0.024	0.005	4.136	0.029	4.447	0.001
Density of understory	–0.016	0.008	–0.341	0.924	–2.062	0.062
Shape index	0.509	0.348	0.244	0.912	1.462	0.169
(fragment size)²	–0.000	0.000	–3.835	0.029	–4.078	0.002

Analysis of variance

Source	Sum-of-squares	df	Mean squares	F-ratio	p
Regression	2.507	4	0.627	6.876	0.004
Residual	1.094	12	0.091		