

## The edge effect in a forest bird community in Rio Claro, São Paulo State, Brazil

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**RESUMO. O Efeito de Borda em uma comunidade de aves em Rio Claro, São Paulo, Brasil.** Nesse trabalho analisou-se a riqueza e diversidade de espécies de aves de mata, a diferentes distâncias da borda. Foram realizados 160 censos em seis pontos amostrais de uma mata residual mesófila semidecídua de 230 ha em Rio Claro, SP, Brasil, usando amostragem em Pontos e Redes de Neblina, entre janeiro de 1989 e março de 1990. Análises de regressão mostraram que a riqueza e a diversidade de espécies (esta medida pelo índice de Shannon) aumentaram da borda para o interior, independente do método de censo utilizado. Esses resultados contradizem o chamado Efeito de Borda, no qual mais indivíduos e/ou espécies seriam encontrados próximos às bordas, que é uma hipótese normalmente aceita em estudos de fauna em ambientes temperados e aplicada indiscriminadamente em ambientes neotropicais.

**PALAVRAS-CHAVE:** Aves, censo, comunidade, Efeito de Borda, riqueza, Floresta Tropical.

**ABSTRACT.** A series of 160 censuses were run at the edge and in the interior of a 230 ha semideciduous mesophytic forest in São Paulo State, SE Brazil, using "Point-Counts" and "Mist-netting" methods, between January 1989 and March 1990. Regression analyses, F tests and *a posteriori* multiple range tests showed that species richness and diversity (Shannon) increased from the edge to the forest interior in all census types used. These results contradict the hypothesized Edge Effect, in which more individuals or species are found along edges, an idea much emphasized in temperate-zone studies until recent years and indiscriminately used in neotropical environments.

**KEY WORDS:** Birds, Census, Community, Diversity, Edge Effect, Richness, Tropical forest.

Five hundred years before it was colonized, the state of São Paulo, Brazil had 81.8% of its area covered by forests. Today less than 5% of these forests remains (Serra-Filho 1974). The accelerated decrease of vegetation cover has dramatic effects on fauna, since tropical vertebrates are more susceptible to environmental disturbance than their temperate equivalents (Frankel and Soulé 1986).

Edges of forest fragments may have a potentially important influence on the fauna encountered in these forests (Karr 1968, Helle 1984, Lovejoy *et al.* 1986, Tabanez *et al.* 1997, Laurance and Bierregaard 1997, Bierregaard and Lovejoy 1989). The early concept of Edge Effect emerged from the findings that vegetative heterogeneity is increased by the junction of two (or more) habitat types, resulting in an increase of species density and diversity (*e.g.* MacArthur and MacArthur 1961, Roth 1976, then reviewed in Wilcove *et al.* 1986 and Yahner 1988). This concept has acquired a different connotation, and some authors now define Edge Effect as the changes in a community due to the creation of abrupt edges of previously undisturbed habitats (Lovejoy *et al.* 1986). For a critical review, see Reese and Ratti (1988) and Yahner (1988).

Edges were considered beneficial to wildlife and much routine management was (and still is) predicated on the benefits of edges (*e.g.* Johnston 1970, Magro 1988). Today, however, some researchers have found that an excess of edges may reduce populations of species that require large

blocks of forest interior (Whitcomb *et al.* 1981, Thiollay 1992, Mills 1995, Murcia 1995, Stouffer and Bierregaard 1995, Van Horn *et al.* 1995, Laurance and Bierregaard 1997).

The edge effect, however, has not been well tested in tropical environments (but see papers in Laurance and Bierregaard 1997), yet there are researchers who argue the edge effect has important consequences in both tropical and temperate environments (Murcia 1995). The call for more studies testing this hypothesis was synthesized by Willis (1984): "An important field for future study should be the investigation of densities and species compositions at different distances from the edge of reserves". The purposes of this paper are 1) to present and discuss data about the effects of edges on diversity and the composition of a forest bird community in São Paulo State, Brazil; 2) to discuss the possible differences of some ecological principles between tropical and temperate areas, and 3) to provide information that will aid in the planning of parks and reserves.

### METHODS

*The Study Area.* The study was carried out on a forest fragment at 630m elevation at São José farm, Northeast of the town of Rio Claro, São Paulo State, in SE Brazil (22°22'S 48°28'W) (figure 1). For a more general description of the region, see Willis 1979. The São José

forest fragment is 230 ha, irregularly shaped, and is for the most part surrounded by sugar cane plantations. The vegetation is mesophytic semideciduous secondary forest and was highly disturbed by timber extraction several years ago. The forest is tangled with vines and is characterized by an irregular canopy (15-30m). Windfalls are very common, creating a mosaic of successional stages of regeneration. The physical forest border has, due to human activities, the shape defined by Ranney *et al.* (1981) as "cantilevered".

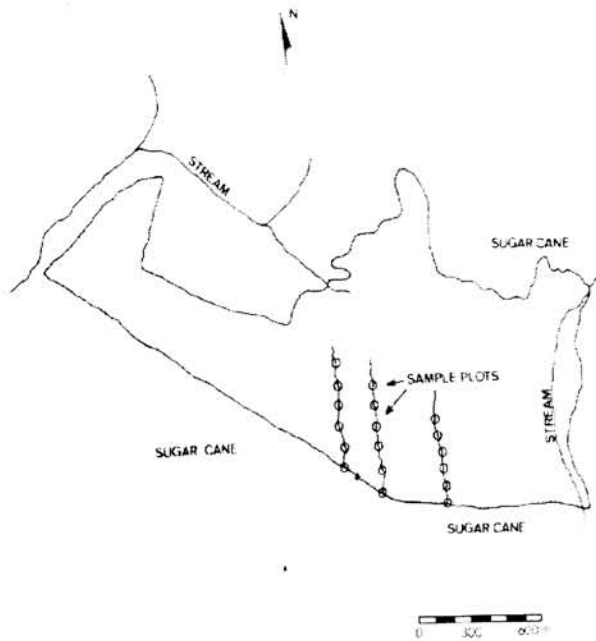


Figure 1. Map of the study area with sample plots.

**Data Collection.** I delimited three parallel trails, perpendicular to the edge. The trails were at least 200m apart. I also delimited 6 sample plots in each trail, at 100 m intervals from the edge to 500m inside the forest.

A hundred sixty censuses were performed between January 1989 until March 1990, using Point Counts and Mist-netting methods. The two methods were chosen because no method alone is appropriate for bird studies, and there is much controversy about it (Ralph and Scott 1981). I conducted the censuses with 7x30 binoculars, tape recording and 12x2,5m 36mm mesh black mist nets.

**Data Analysis.** Since it is frequently difficult to obtain good estimates of the absolute population densities of non-flocking terrestrial bird species, it is necessary to use techniques to estimate richness (Conner *et al.* 1983) of species diversity (Magurran 1988). I adopted two different approaches to data analysis: (1) an evaluation of the richness obtained in each sample plot using Simple Regression Analysis and (2) an evaluation of diversity by calculating the Shannon Index

and comparing the values by F-test and later, a *Posteriori Multiple Comparison Test*, the REGW ("Ryan-Einot-Gabriel-Welsh Multiple Range Test") (SAS 1985). The significance and the linearity of regressions were tested with F-tests. In both cases, a 5% level of significance was adopted.

I performed F-tests to determine if there were significant differences between trails, sample plots, census methods and their possible interactions.

Once the F-tests detected differences between the sample plots, I performed a *posteriori* Multiple Range Test (REGW Test) to determine which sample plots differ from each other. As F-tests detected differences between census types, I performed the analyses separately for each census. Finally, because the F-tests did not show differences between trails, their values were grouped into a unique hypothetical trail.

## RESULTS AND DISCUSSION

After 15 months, 8,327 birds were censused belonging to 61 species (table 1). Figures 2 and 3 show cumulative species-number of censuses and species-individual curves for the three types of censuses. The slopes of the cumulative curves suggest that general totals were reasonably complete.

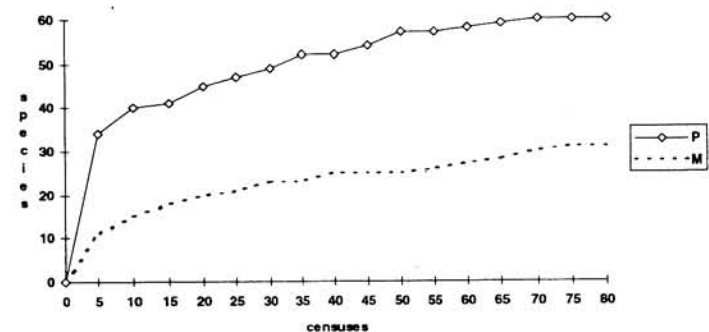


Figure 2. Cumulative numbers of species recorded at given numbers of censuses. (P) Point Counts and (M) Mist nets.

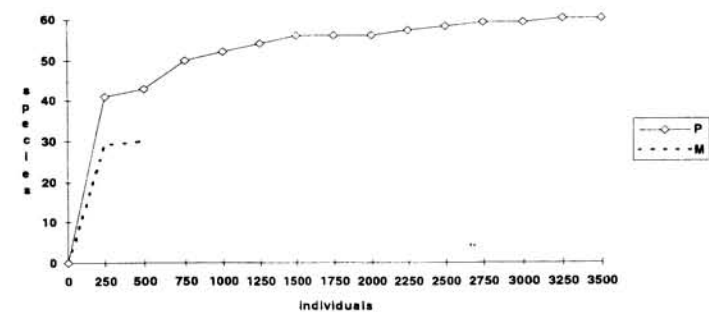


Figure 3. Cumulative numbers of species recorded at given numbers of individuals. (P) Point Counts and (M) Mist nets.

Hummingbirds, which take advantage of greater flower abundance at edges and gaps were poorly represented. The few record of hummingbirds could be related to the area's

Table 1. Distribution trends of the species (following Sick 1997) censused regarding border. Edge - when the bird distribution showed to be most abundant near the physical border; Interior - when the species were found mainly in the interior of the forest; Indifferent - when the species was equally distributed in the forest, and Insufficient - when the total records of the species was below 20.

Species	0m	100m	200m	300m	400m	500m	Trend
<i>Crypturellus tataupa</i>	19	30	67	65	84	98	Interior
<i>Rupornis magnirostris</i>		3	4	1		1	Insufficient
<i>Herpetotheres cachinnans</i>		1	2	4	2	2	Insufficient
<i>Columba cayennensis</i>	41	49	53	45	55	49	Indifferent
<i>Columbina talpacoti</i>	6	7	4	3	1	1	Edge
<i>Leptotila verreauxi</i>	40	37	33	38	36	38	Indifferent
<i>Forpus xanthopterygius</i>	13	14	10	13	15	14	Indifferent
<i>Pionus maximiliani</i>	50	56	60	51	75	67	Indifferent
<i>Piaya cayana</i>	28	27	18	30	33	37	Indifferent
<i>Tapera naevia</i>	1					5	Insufficient
<i>Thalaurania glaucopsis</i>	4	1	1	1	2	1	Insufficient
<i>Amazilia versicolor</i>		7			1		Insufficient
<i>Amazilia lactea</i>	3	1	5	1		3	Insufficient
<i>Trogon surrucura</i>	28	27	27	28	28	33	Indifferent
<i>Picumnus albosquamatus</i>	48	40	37	26	20	23	Edge
<i>Colaptes melanochloros</i>			2	1	2		Insufficient
<i>Campephilus robustus</i>	1	5	3	12	6	3	Indifferent
<i>Psilorhamphus guttatus</i>	38	40	50	64	58	44	Indifferent
<i>Mackenziaena severa</i>	48	35	87	69	52	48	Indifferent
<i>Thamnophilus caerulescens</i>	32	26	11	24	26	19	Edge
<i>Thamnophilus doliatus</i>	9	12	1	2			Edge
<i>Dysithamnus mentalis</i>	58	42	33	58	56	40	Indifferent
<i>Herpsilochmus rufimarginatus</i>	17	25	29	72	74	73	Interior
<i>Drymophila ferruginea</i>	189	190	176	173	123	117	Edge
<i>Drymophila ochropyga</i>	17	17	16	13	9	10	Edge
<i>Pyriglena leucoptera</i>	149	134	142	134	104	98	Indifferent
<i>Conopophaga lineata</i>	45	50	40	48	43	44	Indifferent
<i>Synallaxis frontalis</i>	32	9	14	5	4	7	Edge
<i>Synallaxis ruficapilla</i>	18	15	30	27	27	36	Interior
<i>Synallaxis spixi</i>	1				2	3	Insufficient
<i>Automolus leucophthalmus</i>	5	9	11	19	30	33	Interior
<i>Sittasomus griseicapillus</i>		5	5	15	19	14	Interior
<i>Dendrocolaptes platyrostris</i>	1		2	4	4	8	Interior
<i>Lepidocolaptes fuscus</i>	1		1	3	2	4	Insufficient
<i>Xiphorhynchus guttatus</i>					3		Insufficient
<i>Leptopogon amaurocephalus</i>			1		1		Insufficient
<i>Capsiempis flaveola</i>	38	29	30	40	22	45	Indifferent
<i>Hemitriccus diops</i>	2		2	4	10	13	Interior
<i>Tolmomyias sulphurescens</i>		1	1				Insufficient
<i>Empidonax euleri</i>	6	11	23	29	47	31	Interior
<i>Myiarchus ferox</i>	6	2	4	1	1	3	Insufficient
<i>Pitangus sulphuratus</i>	4	11	7	4	8	1	Indifferent
<i>Myiodynastes maculatus</i>	12	10	30	9	9	24	Indifferent

(Continue)

Table 1. Continued.

Species	0m	100m	200m	300m	400m	500m	Trend
<i>Antilophia galeata</i>				3	7	11	Interior
<i>Chiroxiphia caudata</i>	5	7	19	42	48	56	Interior
<i>Cyclarhis gujanensis</i>	12	22	15	26	36	47	Interior
<i>Vireo olivaceus</i>					1		Insufficient
<i>Basileuterus flaveolus</i>	25	14	22	22	13	27	Indifferent
<i>Basileuterus hypoleucus</i>	81	77	92	98	88	79	Indifferent
<i>Basileuterus leucoblepharus</i>	6	3	4	25	32	53	Interior
<i>Thlypopsis sordida</i>	7	8	5	25	38	51	Interior
<i>Hemithraupis ruficapilla</i>			3	7	9	8	Interior
<i>Tachyphonus coronatus</i>	3	2	7	6	16	25	Interior
<i>Trichothraupis melanops</i>	10	15	31	50	60	61	Interior
<i>Habia rubica</i>	1	6	20	58	104	96	Interior
<i>Thaupis sayaca</i>		1		1		1	Insufficient
<i>Dacnis cayana</i>	2	4	1		1	1	Insufficient
<i>Conirostrum speciosum</i>	1		1	1	2	6	Insufficient
<i>Zonotrichia capensis</i>	14						Insufficient
<i>Tiaris fuliginosa</i>			2		10	14	Interior
<i>Arremon flavirostris</i>	2	2					Insufficient
<i>Pitilus fuliginosus</i>			3	5	3	22	Interior

size – in small areas hummingbirds may face the problem of finding food all year round, resulting in death or migration (Willis 1979). Nevertheless, Stouffer and Bierregaard Jr. (1995) found more hummingbird species in fragmented areas in Amazonian than in continuous forest. They suggest that understory hummingbirds respond to fragmentation by crossing open areas to use resources in nearby fragments. In São José farm, however, there are no forest fragments close to the study area.

Carnivores such as *Rupornis magnirostris* and *Herpetotheres cachinnans* were unusually absent during the censuses, probably for the same reasons as hummingbirds. The Psittacidae (*Pionus maximiliani* and *Forpus xanthopterigius*), appeared to be indifferent to edges, but almost all sightings were recorded when they were feeding in the canopy or flying above trees.

*Columba cayennensis*, *Leptotila verreauxi*, *Psilorhamphus guttatus* and *Trogon surrucura*, were here classified as “indifferent” to edges, but this may not actually be true. They were almost all registered by their calls, not by sight. Their characteristically loud calls can carry a long distance. Thus, they may have been heard at the edge and thus classified as an edge species when indeed the birds were calling from the forest interior.

*Crypturellus tataupa* (defined here as an “interior” species) has a distribution that changes seasonally. During the hot and wet season, it is recorded by sounds in the interior; in the cool and dry season, this species becomes more visible

at the edges. This change can be related to food scarcity which forces individuals to range over greater areas.

Records of *Pyrrhuloxia leucoptera* and *Basileuterus leucoblepharus* may be overestimated because they are attracted by the presence of the observer due to the observer flushing out insects while walking. I observed several times *Pyrrhuloxia leucoptera* (an ant follower species) following a “coati” group (*Nashua nashua* – Carnivora, Procyonidae) and foraging.

Some species were registered as well while they foraged outside the São José fragment, in the sugar cane plantation. They were *Basileuterus flaveolus*, *B. hypoleucus*, *Capsiempis flaveola*, *Thamnophilus caerulescens*, *Drymophila ferruginea*, *Picumnus squamatus*, *Synallaxis frontalis* and *Zonotrichia capensis*. All are insectivores, except the last one, and they were classified as “edge” species or “indifferent” to edges. The sugar cane plantations can, therefore, constituted a foraging place, but they did not protect against heat at midday nor as refuge once birds return to the forest at midday and at night. Moreover, the sugar cane is burned and harvested twice a year, making constant foraging impossible.

I even detected a preponderance of generalist insectivore species and a low record of migrant species in censuses, evidence that perhaps the São José fragment is not sufficient for local avifauna preservation and not favorable to migrants due to its small size and possible food and shelter limitations (Askins and Philbrick 1987).

Figure 4 shows a simple regression analysis taking the richness (number of species censused) in each sample plot of each trail and each census method plotted against the distance between the sample plots and the physical border. The estimated line is a significant fit to the observed data.

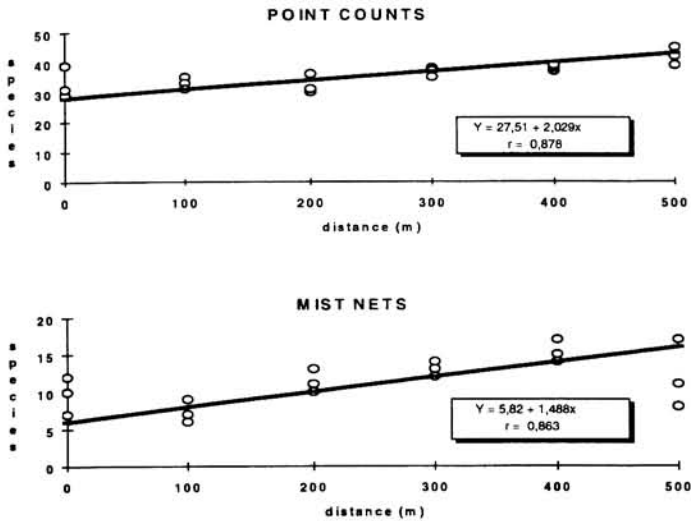


Figure 4. Richness obtained in each sample plot of each trail as a function of the distance from the forest fragment edge.

The Shannon's diversity index also suggests a negative correlation between proximity to edge and diversity (table 2). There are many problems with regarding the use of Shannon's index as well as other indices (e.g. Pielou 1975 and Magurran 1988). Nevertheless, one can assume that the same biases in Shannon's index will emerge at edges and in the interior of the forest, such that there is no *a priori* significant bias to analyses.

Table 2. Shannon's diversity index for each sample plot and method.

Point counts					
Trail 1		Trail 2		Trail 3	
Sample Plot	Diversity	Sample Plot	Diversity	Sample Plot	Diversity
0	1.2849	0	1.3361	0	1.3364
1	1.3111	1	1.3050	1	1.3439
2	1.3261	2	1.2877	2	1.3096
3	1.4171	3	1.3828	3	1.3806
4	1.4065	4	1.4243	4	1.4163
5	1.4731	5	1.4627	5	1.5108

Mist netting					
Trail 1		Trail 2		Trail 3	
Sample Plot	Diversity	Sample Plot	Diversity	Sample Plot	Diversity
0	0.7424	0	0.8636	0	0.9744
1	0.6074	1	0.7205	1	0.7439
2	0.9651	2	0.8192	2	0.8021
3	0.9660	3	0.9235	3	0.9849
4	1.0188	4	0.1705	4	1.1083
5	1.0062	5	0.7747	5	1.0887

The data analyses detected differences between sample plots and between census types (table 3) and showed that for any census method chosen, there is a significant increase of richness and diversity from border to interior (table 4). The results presented here contradict the majority of the papers of temperate areas (e.g. Lay 1938, Oelke 1966, Hogstad 1967, Gates and Gysel 1978 and Haila *et al.* 1980), but they agree with the work of Terborgh *et al.* (1990) which was completed in a tropical area.

Table 3. Summary of the Analysis of Variance performed with the census data.

Source	D.F.	FCALC
Trails	2	3.17 ns.
Sample Plot	5	17.81 *
Census Type	2	415.76 *
Trails x Sample Plot	10	1.13 ns.
Trails x Census Type	4	0.96 n.s.
Sample Plot x Census Type	10	2.71 ns.

\*) Significant at 5%.

Table 4. Results of a posteriori Multiple Range Test (REGW) of the means of H' to each census method. Means with the same bar do not significantly differ at 5%.

Point counts			Mist netting		
Sample Plot	Means of H'	Analysis	Sample Plot	Means of H'	Analysis
5	1.4822	■	4	1.0659	■
4	1.4157	■	3	0.9581	■
3	1.3935	■	5	0.9565	■
1	1.3200	■	2	0.8621	■
0	1.3191	■	0	0.8401	■
2	1.3078	■	1	0.6906	■

There could be several factors to explain these different results:

1) *The study area's size.* Much of work performed in temperate places was accomplished in very small areas, such as Forman *et al.* (1976) with areas smaller than 24 ha, Whitcomb *et al.* (1981) who worked in areas less than 14 ha, Helle (1984) who used areas between 3 and 100 ha and Yahner and Wright (1985) who worked in areas of 1 ha. The problem with respect to the use of these small areas is that they may be so small that the entire plots are edges in and of themselves or they are at least greatly influenced by edges as pointed out by Williamson (1975). Therefore, many researchers may be testing only "internal" versus "external" edges. Perhaps only larger areas will support forest "interior" species. In this case, generalist species, which explore edges and adjacent areas, are more frequent in small places, whereas specialized species are more common in greater forest areas.

2) *The differences between tropical and temperate areas.* Tropical environments have intrinsic characteristics that many times are quite different from temperate ones regarding either biological or physical characteristics of

the environment. Temperate forests normally have few dominant species (animal or plant) and have low environmental heterogeneity which increases near edges (E.O. Willis pers. comm., 1989). Tropical forests, in contrast, are rich in species and have great environmental heterogeneity in the interior as well as edges.

3) *Habitat selection by passerine birds.* Habitat selection by passerine birds in tropical environments does not seem to be as closely related to the physical structure of the vegetation as it is in temperate environments. The presence/absence of species in temperate areas can be predicted by measurements of the habitat's structure (MacArthur and MacArthur 1961, Anderson and Shugart 1974) regardless of its species composition. Terborgh (1971) and Diamond (1973) mention that these predictions will have less success in tropics. Diamond states, however, that tropical birds must select habitats not as a function of the structure of the vegetation, but by the presence of conspecific individuals and by the absence of competition. Another aspect related to bird communities in temperate and tropical environments is the proportion between rare and common species (evenness). Karr and Roth (1971) showed that rare species (less than 2% of total frequency) were 36-37% of total individuals of the tropical communities while in temperate areas they were just 3-14% (Illinois, USA) or less than 6% (Texas, USA). In the present study, they were 28% of the community. I suggest that those species are rare because their ecological requirements are usually found in the forest interior. It makes sense, then, that if there are proportionately more rare species in tropical forests, the diversity would tend to be greater in the forest interior rather than at the edges.

4) *Nest predation near edges.* If predation is intense near edges, birds might avoid them. I did not test for nest predation, but there was some evidence that seems to indicate that predation exists, mainly because I found some nests predated near the edges and saw many potential predators there such as "gambá" (*Didelphis* sp), "furão" (*Galictis cuja*), "macaco-prego" (*Cebus apella*), "irara" (*Eira barbara*), "teiú" (*Tupinambis teguixim*), and occasionally there were sightings of "lobo-guará" (*Chrysocyon brachyurus*) and "coati" (*Nasua nasua*). The last one was the most frequent potential predator in the São José fragment, and were always observed near edges (the coati groups were seen many times, walking along edges, between 5 to 30m inside woodlot). The existence of the sugar cane fields around the São José fragment may contribute to nest predation as well. Andrén *et al.* (1985) found that the predation taxa in artificial ground nests increased with the expansion of the cultivation surrounding the fragment. That happened probably because the expansion of agriculture increases the food availability to herbivores and insectivores and, as a result, the availability

of food to generalist predators who explore the forest edges. In the São José fragment this foraging is certainly more intense between October to April when the sugar cane is burned, harvested, and the land is plowed.

## CONCLUSIONS

Species richness and diversity (Shannon) increased from the edge to the forest interior in all census types used. These results contradict the hypothesized Edge Effect, in which more individuals or species are found along edges, an idea much emphasized in temperate-zone studies until recent years and indiscriminately used in neotropical environments.

The low numbers of hummingbirds, hawks and large frugivores can be due to the census method used, illegal hunting present in the area, and the small size of the São José fragment, inducing emigration or local extinction. The low record of migrant species may indicate that the São José fragment is not favorable to such species due to its small size and possible food and shelter limitations. A preponderance of generalist insectivores species was detected, denoting that perhaps the São José fragment is not sufficient for the preservation of all local avifauna. A larger area and/or another shape to minimize edges may create better conditions for bird preservation.

The results here presented should alert tropical planners and managers such as Magro (1988), who have applied plans based on the temperate belief that edges are beneficial to wildlife, to consider the Edge Effect in tropical environments with "renewed skepticism and carefully assess impacts of edge creation, location and manipulation" (Reese and Ratti 1988).

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## REFERENCES

- Anderson, S. H. and H. H. Shugart (1974) Habitat selection of breeding birds in an east Tennessee deciduous forest. *Ecology* 55: 828-837.
- Andrén, H., P. Angelstam, E. Lindström, P. Widen (1985) Differences in predation pressure in relation to habitat fragmentation: an experiment. *Oikos* 45: 273-277.
- Askins, R. A. and M.J. Philbrick (1987) Effect of changes in regional forest abundance on the decline and recovery of a forest bird community. *Wilson Bull.* 99 (1): 7-21.

- Bierregarrd, R. O. and T. E. Lovejoy (1989) Effects of forest fragmentation on amazonian understory bird communities. *Acta Amazonica* 19: 215-241.
- Conner, R. N., J. G. Dickson and J. H. Williamson (1983). A comparison of breeding bird census techniques with mist netting results. *Wilson Bull.* 95 (2): 276-280.
- Diamond, J. M. (1973) Distributional ecology of New Guinea Birds. *Science* 179: 759-769.
- Forman, R. T. T., A. E. Galli and C. F. Leck (1976) Forest size and avian diversity in New Jersey woodlots with some land use implications. *Oecologia* 26: 1-8.
- Frankel, O. H. and M. E. Soulé (1986) *Conservation and Evolution*. Cambridge: Cambridge Univ. Press.
- Gates, J. E. and L. W. Gysel (1978) Avian nest dispersion and fledging success in field-forest ecotones. *Ecology* 59 (5): 871-883.
- Haila, Y., O. Jarvinen and R. A. Vaisanen (1980) Effects of changing forest structure on long-term trends in bird populations in SW Finland. *Ornis Scand.* 11: 12-22.
- Helle, P. (1984) Effects of habitat area on breeding communities in northeastern Finland. *Ann. Zool. Fenn.* 21: 421-425.
- Hogstad, O. (1967) The edge effect on species and population density of some passerine birds. *Nytt. Mag. Zool.* 14: 40-43.
- Johnston, D. W. (1970) High density of birds in a modified deciduous forest. *Wilson Bull.* 82: 79-82.
- Karr, J. R. (1968) Habitat and avian diversity on strip-mined land in east-central Illinois. *Condor* 70: 348-357.
- \_\_\_\_\_ and R. R. Roth (1971) Vegetation structure and avian diversity in several new world areas. *Am. Nat.* 105 (945): 423-435.
- Laurance, W. F., R. O. Bierregaard Jr. (1997) *Tropical forest remnants*. Chicago, Univ. Chicago Press.
- Lay, D. W. (1938) How valuable are woodland clearing to birdlife. *Wilson Bull.* 50: 254-256.
- Lovejoy, T. E., R. O. Bierregaard Jr., A. B. Rylands, J. R. Malcom, C. E. Quintela, L. H. Harper, K. S. Brown Jr., A. H. Powell, G. V. N. Powell, H. O. R. Schubart and M. B. Hays (1986) Edge and other effects of isolation on Amazon forest fragments, p. 257-285. In: M. E. Soulé (ed.) *Conservation Biology: the science of scarcity and diversity*. Sunderland: Sinauer.
- MacArthur, R. H. and J. W. MacArthur (1961) On bird species diversity. *Ecology* 42 (3): 594-598.
- Magro, T. C. (1988) *Avaliação da qualidade de habitat faunístico pela análise de bordas*. Dissertação de Mestrado. Viçosa: Universidade Federal de Viçosa.
- Magurran, A. (1988) *Ecological diversity and its measurement*. Cambridge: Univ. Press.
- Mills, L. S. (1995) Edge effects and isolation: Red backed voles on forest remnants. *Conserv. Biol.* 9 (2): 395-403.
- Murcia, C. (1995) Edge effects in fragmented forests: implications for conservation. *Trends Conserv. Evol.* 10: 58-62.
- Oelke, H. (1966) 35 years of breeding bird census work in Europe. *Audubon Field Notes* 20: 635-642.
- Pielou, E. C. (1975) *Ecological diversity*. New York: John Wiley and Sons.
- Ralph, C. J. and J. M. Scott (eds.) (1981) *Estimating numbers of terrestrial birds*. Lawrence: Allen. (Studies in Avian Biology 6).
- Ranney, J. W., M. C. Bruner and J. B. Levenson (1981) The importance of edge in the structure and dynamics of forest islands. In: R. L. Burgess and D. M. Sharpe (eds.) *Forest island dynamics in man-dominated landscapes*. New York: Springer-Verlag. (Ecological Studies 41).
- Reese, K. P. and J. T. Ratti (1988) Edge effect: a concept under scrutiny. *Trans. N. Am. Wildl. Nat. Resour. Conf.* 53: 127-136.
- Roth, R. R. (1976) Spatial heterogeneity and bird species diversity. *Ecology* 57(4): 773-782.
- SAS Institute Inc. SAS/STAT (1985) *Guide for personal computers, version 6 edition*. Cary: SAS Institute.
- Serra-Filho, R. (1974) Levantamento da cobertura vegetal natural e do reflorestamento no estado de São Paulo. *Bol. Téc. Inst. Florest, São Paulo*, 11: 1-53.
- Sick, H. (1997) *Ornitologia brasileira*. Rio de Janeiro: Ed. Nova Fronteira.
- Stouffer, P.C. and R. O. Bierregaard Jr. (1995) Effects of forest fragmentation on understory hummingbirds in Amazonian Brazil. *Conserv. Biol.* 9 (5): 1085-1094.
- Tabanez, A. A. J., V. M. Viana and A. D. S. Dias (1997) Fragmentation and edge effect consequences on structure, diversity and sustainability of a plateau forest fragment in Piracicaba, São Paulo. *Rev. Brasil. Biol.* 57 (1): 47-60.
- Terborgh, J. (1971) Distribution on environmental gradients: theory and a preliminary interpretation of distributional patterns in the avifauna of the Cordillera Vilcabamba, Peru. *Ecology* 52: 23-40.
- \_\_\_\_\_, S.K. Robinson, T. A. Parker III, C. A. Munn and N. Pierpont (1990) Structure and organization of an Amazonian bird community. *Ecol. Monogr.* 60: 213-238.
- Thiollay, J. M. (1992) Influence of selective logging on bird species diversity in a Guianan Rain Forest. *Conserv. Biol.* 6 (1): 47-63.
- Van Horn, M. A., R. M. Gentry and J. Faaborg (1995) Patterns of ovenbird *Sceiurus aurocapillus* pairing success in Missouri forest tracts. *Auk* 112 (1): 98-106.
- Whitcomb, R.F. et al. (1981) Effects of forest fragmentation on avifauna of eastern deciduous forest, p.125-205. In: R. L. Burgess and D. M. Sharp (eds.) *Forest island dynamics in a man-dominated landscapes*. New York: Springer-Verlag.
- Wilcove, D. S., C. H. McClennon and A. P. Dobson (1986) Habitat fragmentation in the temperate zone, p. 237-256. In: M. E. Soulé (ed.) *Conservation Biology: The science of scarcity and diversity*. Sunderland: Sinauer Associates.

- Williamson, M. (1975) The design of wildlife preserves. *Nature* 256: 519.
- Willis, E. O. (1979) The composition of avian communities in remanescent woodlots in Southern Brazil. *Pap. Avulsos Zool.*, São Paulo, 33 (1): 1-25.
- \_\_\_\_\_ (1984) Conservation, subdivision of reserves, and the anti-dismemberment hypothesis. *Oikos* 42 (3): 396-398.
- Yahner, R. H. (1988) Changing wildlife communities near edges. *Conservation Biology* 2: 333-339
- \_\_\_\_\_ and A.L. Wright (1985) Depredation on artificial ground nests: effects of edge and plot age. *Jour. Wild. Manage* 49 (2): 508-513.