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Research Article

The Influence of Landscape and Microhabitat on the Diversity of Large- and Medium-Sized Mammals in Atlantic Forest Remnants in a Matrix of Agroecosystem and Silviculture

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Fragmentation and destruction of a habitat are strongly relevant aspects to determine the richness and the dynamics of the mammals in ecosystems. This study, developed from October, 2010 to July, 2011 in three Atlantic Forest remnants in Ipumirim, SC, Brazil, aims at identifying the diversity of large- and medium-sized nonflying mammals and verifying associations of the patterns obtained with features of the researched areas. The approximate measurement of the inventoried areas is 51 ha. The data collection of the mammal fauna was obtained through direct registers, with the use of a photographical trap, and indirect records through the search of material that indicated the presence of species. The total amount of species studied was 13, pertaining to nine families: Canidae (1), Cebidae (1), Dasyproctidae (1), Dasypodidae (2), Didelphidae (2), Felidae (2), Mustelidae (2), and Procyonidae (2). In addition, landscape data was obtained through the development of a chorological matrix of the areas and the data about the microhabitats. From these data, 20 models for analysis were stipulated and this selection was determined with the corrected Akaike Information Criterion (AICc). The aspect of greater influence on the magnitude of the obtained data was the degree of human occupation in the landscape.

1. Introduction

Several human activities are eroding ecosystems, species, and biological features in an alarming pace and such loss will certainly alter the way the ecosystems and their goods and services operate. This alteration, to different degrees, forces the ecosystems to critical thresholds tending to approximate to a problematic planetary scale. Besides that, there are very scarce data about the geographical and taxonomical distribution for most species, which have been called Wallacean and Linnean deficiencies, respectively. This perspective invariably shows that plenty of information on ecology is being lost, mainly in less known groups in tropical environments, previously to its understanding [1–4].

The fragmentation of tropical forests has a strong impact on biodiversity [5], with more than one-third of the species disappearing when the habitats are fragmented [6, 7]. By that means, the conservationist biology in fragmented tropical ecosystems has to concentrate not only on preserved areas, but also on managed ecosystems [8]. Throughout time, diversity tends to decrease and eventually reaches a less diverse steady state [9]. Several authors consider that habitat loss and fragmentation are the main factors for the decrease of diversity. For instance, Chiarello [10] studied the effects of fragmentation on mammals in the Atlantic Forest and it has shown that fragments smaller than 200 ha are too small and perturbed to keep the assemblies intact and, in addition to the impoverished group of species, the size of the population is reduced.

The future of species in tropical forests thus depends partially on their ability to survive in landscapes altered by human activity [11]. Historically, plenty of research has concentrated on the fragmentation of habitats, the importance of the area, the degree of isolation, and the persistence of species. Although the decrease in biodiversity in altered landscapes is well documented, Perfecto and Vandermeer [8] argue that the conservationist paradigm generally concentrates on forest reserves ignoring the agricultural landscape where they are placed due to the fragmented nature of the majority of the tropical ecosystems.

The Atlantic Forest is considered one of the five most important biodiversity hotspots and one of the most endangered ecosystems in the world [12]. The expansion of the agricultural frontier, the construction of infrastructure, the expansion of the cities, and the nonsustainable exploration of forests are the main causes of the deforestation process [13]. Approximately 88% of the original forest cover of the Atlantic forest biome has been lost and, in a landscape scale, the remaining cover is incorporated in the dynamics of agromosaics and the monoculture of exotic species [14]. In the state of Santa Catarina, there are only 23.37% of the original Atlantic Forest cover remaining [15], and nineteen species of large- and medium-sized nonflying terrestrial mammals (approximately 1/4) are in any of the categories of risk of extinction [16].

The Atlantic Forest mammal fauna comprises 298 species, with 90 endemisms [17] and several studies are noteworthy in Brazil regarding the mammal fauna. These studies make use of several research methodologies and of important results. Studies on the mammal fauna in Santa Catarina between the decade of 1990 and the beginning of the years 2000 focused on the shore regions and islands (e.g., [18, 19]). In the last decade, however, this framework has been altered due to some studies on species register and distribution (e.g., [20–22]). A number of studies has been developed in the western mesoregion of Santa Catarina in recent years, and indicated that the region has shown an important richness of mammals (e.g., [23, 24]).

For this reason, the aim of this study is assessing the richness of large- and medium-sized mammals in three areas in Ipumirim, a municipality in the middle-west region of Santa Catarina, associating the magnitude of the data to local factors which potentially influence on the richness of mammals in the sampled areas, assuming as a hypothesis that richness and diversity (presence/absence) suffer the influence of the predominance of human occupation in the areas, the microhabitats, and the species registers in the meteorological variables.

2. Materials and Methods

2.1. Area of Study. Located in the Atlantic forest biome, the region is characterized for the large number of small rural properties and has been effectively colonized from the 1940s and its main activity is logging (Figure 1) [25]. This activity has decreased in present days due to the efficacy of legislation though there are many reforesting areas with exotic species. The area presents phytophysionomic characteristics of the Mixed Ombrophilous and the Stational Semidecidual forest, hydrologically the main basins are the ones of Jacutinga, Irani, and Engano rivers, the pedological formation follows the characteristics of Serra Geral and the climate is humid mesothermal with average temperature between 17°C and 28°C [26]. Three fragments with average size of 51 ha were studied featuring low direct anthropic activity though areas B and C suffered the logging process (larger trees) approximately 40 years ago. The relief of the area is uneven and water is provided from springs and drainage troughs. The general climatic conditions during the research period presented large temperature amplitude with an average of 21.7°C (maximum 33.5°C and minimum −1.9°C), average relative humidity 77.32%, and precipitation accumulation of 1,795 mm.

2.2. Sampling. There is a great variation in body size, habits, and preferred habitats among mammals, and these factors force the use of several specific methodologies in order to inventory the mammal fauna [27]. As they are discreet animals and have nocturnal habits, techniques of direct and indirect registers were employed [28]. The set of methods employed to obtain the information concerning the richness of mammals in the areas included the use of photographic trap, visualization, and observation of traces.

The collections of direct registers of the mammals were carried out between October 2010 and July 2011 with a photographic trap model *Tigrinus* 6.0D and the direct visualization of the animal. The trap was exposed in each area for 2,160 hours, being weekly checked and equally switched from one area to another every 360 hours and, in order to maximize the possibility to register the species, fresh attractive baits, such as fruit, birds entrails and blood, sardines and coarse salt, we use between 100 and 200 grams each bait type and all were used together. The trap was set between 35 and 45 cm from the ground. The visual registers were obtained through 12 expeditions with random walks of three hours each per area, in a total of 36 hours per area.

Indirect registers indicating the presence of species were obtained during the same period and through the methodology of random walks employed by Rabinowitz [29], Carrillo et al. [30], Gibbs [31], and White and Edwards [32]. The search for traces (footprints, feces, and other signs) was carried out through 18 expeditions of three hours each per area, in a total of 36 hours to obtain the indirect registers. Each register was photographed and measured to be used as evidence. All the registers comprised a data matrix of the presence or absence of species. Dubious cases were discarded, especially the ones related to indirect registers. Registers of the genus *Leopardus* (both direct and indirect) were included as *Leopardus* spp..

The meteorological variables during the sampling period (temperature, humidity, and pluviosity) were provided by the meteorological station of the Brazilian Agricultural Research Corporation (Embrapa) Swines and Birds (Concórdia, SC).

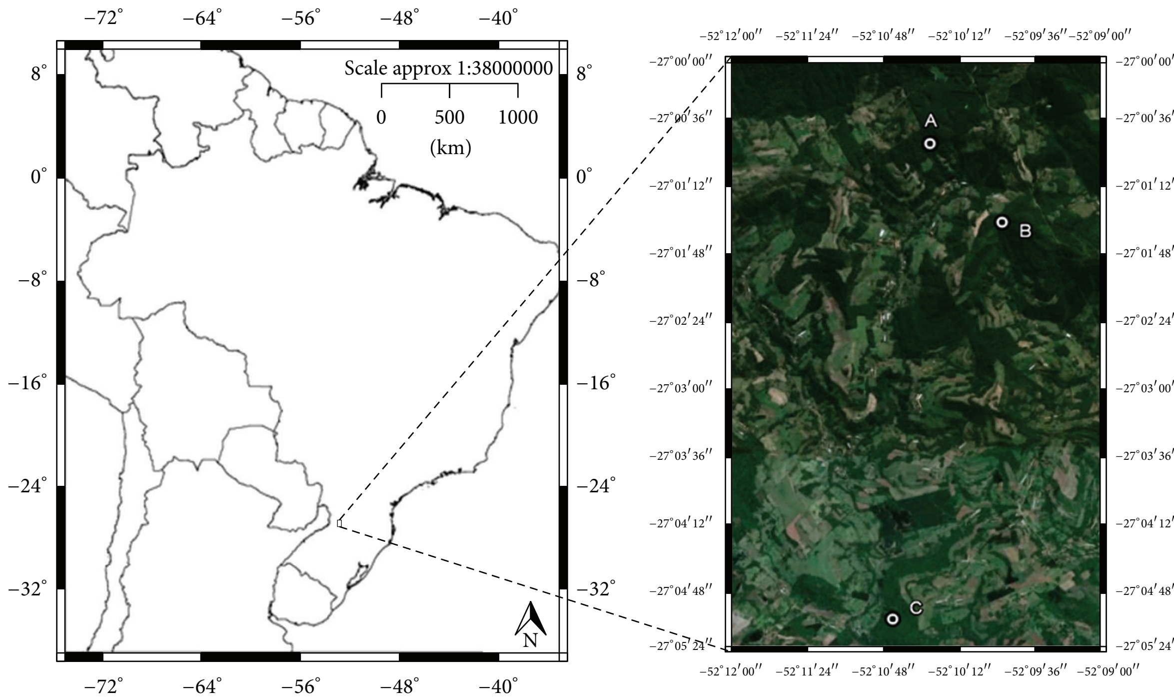


Figure 1: Area of study in the municipality of Ipumirim-SC utilized for the sampling of medium and large mammals through camera trapping between October 2012 and July 2011. The upper left area A (27°01′39″S, 52°09′58″O, 893 m, 55 ha), upper right area B (27°02′20″S, 52°09′43″O, 899 m, 47 ha), below the area C (27°05′10″S, 52°10′30″O, 664 m, 51 ha). Source: National Geophysical Data Center (NOAA) and *Google Earth*.

Concomitantly with it, the *Software R* was employed in order to elaborate a chorological matrix of an area of 12.5 km^2 (area average of the life of the species registered (or genus, as in the case of *Galictis*) according to Sunquist et al. [33], Gentile et al. [34], Parera [35], Cheida et al. [36], and Saab et al. [37]) surrounding the central coordinates of each area, subdivided into quadrants of 100 m^2, through a data matrix obtained with the spatial analysis of the satellite image of *Google Earth*. Conflict values were attributed, being 0 (preserved forest area), 1 (pasture/farming/field area), 2 (silviculture), and 3 (area with human occupation and/or roads) in order to obtain visual information that evidences potential conflicts with the local fauna for subsequent pattern selection.

In addition to the data of mammal fauna and landscape conditions, the environmental characterization of the sampling sites (microhabitats) was made in each of the fragments, following a protocol of a series of measurements in each sampling site, through the adapted quadrant-point method [38], being a cross allocated in the collection sites demarcated into four quadrants (N, S, E, W) and vegetation and environment measured. In each quadrant, trees with diameter at breast height (DBH) greater than 16 cm and shrubs with DHB smaller than 16 cm and height smaller than 1 m closer to the center of the cross, had their distances from the cross measured as well as their height, the diameter of their canopies and trunks. The diameter was measured at breast height (1.3 m) for the trees and at ankle height (0.1 m) (DAH) for the shrubs. Furthermore, the height of the undergrowth vegetation and the terrain inclination were measured in each quadrant, at 1 m^2, as well as the percentage of undergrowth vegetation cover, green cover, exposed soil, and canopy cover in the four directions through visual estimation. The latter measurement was carried out with the support of a square of 10 cm^2, set at a distance of 40 cm from the observer's view, at an inclination of 20° in relation to the zenith [39]. In addition to these measurements, the distance of each site in relation to the closest watercourse was also measured. The averages of the four quadrants were considered for each site, and for each area the average of all the sites.

2.3. Data Analysis. The statistical analyses employed were carried out with the *Software R*. The normality and homocedasticity tests were used for the analyses.

The species accumulation curve [40] was carried out to indicate the sampling sufficiency. The species richness, which makes no distinction among species and treats equally the species that are exceptionally abundant or rare [41], was estimated through the Chao2 index [40, 42]. Classical diversity measurements were developed with the Shannon-Wiener index [43] and Pielou's equitability index [44]. In order to ascertain the existence of difference among the diversity obtained in the three areas, the nonparametric test of Kruskall-Wallis [43], followed by the Wilcoxon test with Bonferroni correction [43] were carried out in the case of statistically significant results. The dissimilarity between the mammal fauna composition and the environmental characteristics among the areas was estimated with Jaccard's index [45]. Due to the nonnormality of the data, the correlation analyses of Spearman [43] was employed in order to ascertain if the meteorological variables had any relation with mammals temporal registers.

Twenty candidatemodels were established *a priori* through the data of landscape and environmental characterization, and the corrected Akaike Information Criterion (AICc) was employed in the selection of the most parsimonious model regarding these conditions and the richness of species, and between these data and the presence or absence matrix. The AIC is one of the methods of model selection that determines which better minimizes the expected discrepancy, once it is an unbiased estimator which assumes that all model candidates contain the real model [46]. For this context, it was assumed that there are data and a set of models and that statistical inference is based on the models. Thus, based on the classical idea, it was presumed that there is a single model or at least a better model though the identity of the model is unknown, and it was also presumed that this identity may be estimated [47]. In order to avoid the increase in the probability of model selection with too many parameters (overfitting), the AICc was employed [48–50].

For the direct register of species in 25% of the collections or more in one area, the individual model selection with AICc was carried out following the same conditions previously described and the same models. However, one model was added for each microhabitat conditions, comprising 35 candidate models, in order to establish the most preponderant variables in relation to these species register.

3. Results

Three hundred and forty-three direct registers, including one visualization, and 28 indirect registers were obtained. Thirteen mammal species were registered altogether. Only *Procyon cancrivorus* (G.[Baron] Cuvier, 1798) and *Puma concolor* (Linnaeus, 1771) out of the 13 species were registered in altitudes higher than 830 meters, and only 46.15% below 830 m, especially in area C. Some species recorded are shown in Figure 2.

The species accumulation curve for A, B, and C and for the total set of species in the mammals' community of the three areas showed that the sampling effort was effective, the stabilization of the curve taking place in the third collection for areas A and B, and in the fourth collection in area C. When considering the three areas together the stabilization occurred from the fourth collection (Figure 3).

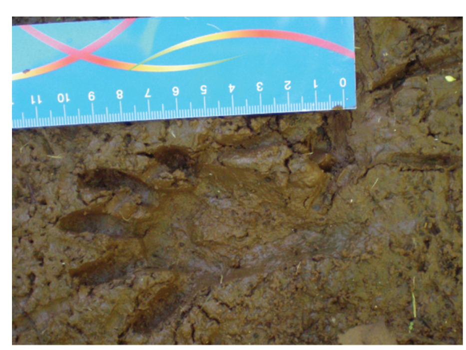
Area A showed diversity estimated in 22,5 by Chao2 index; for area B, it was 7.1 and 8.2 for area C. The diversity index of Shannon-Wiener was, respectively, 2.117, 1.795, and 1.696 (Table 1). Through Kruskall-Wallis there was no significant difference among the sampled areas [x^2 = 2.315; df = 2; P = 0.314].

The dissimilarity index of Jaccard was smaller between A and B (10%), intermediate between B and C (38%), and greater between A and C (45%). For the environmental characterization of the microhabitats the dissimilarity was smaller between areas B and C (15%), intermediate between A and C (44%), and greater between A and B (48%) (Figure 4).

(a)

(b)

(c)



(d)

Figure 2: Some recorded species of medium and large mammals of three Atlantic Forest fragments located in the western of Santa Catarina state. (a) *Eira barbara* (Linnaeus, 1758); (b) *Leopardus* sp.; (c) *Dasypus novemcinctus* (Linnaeus, 1758) and (d) *Procyon cancrivorus* (G.[Baron] Cuvier, 1798).

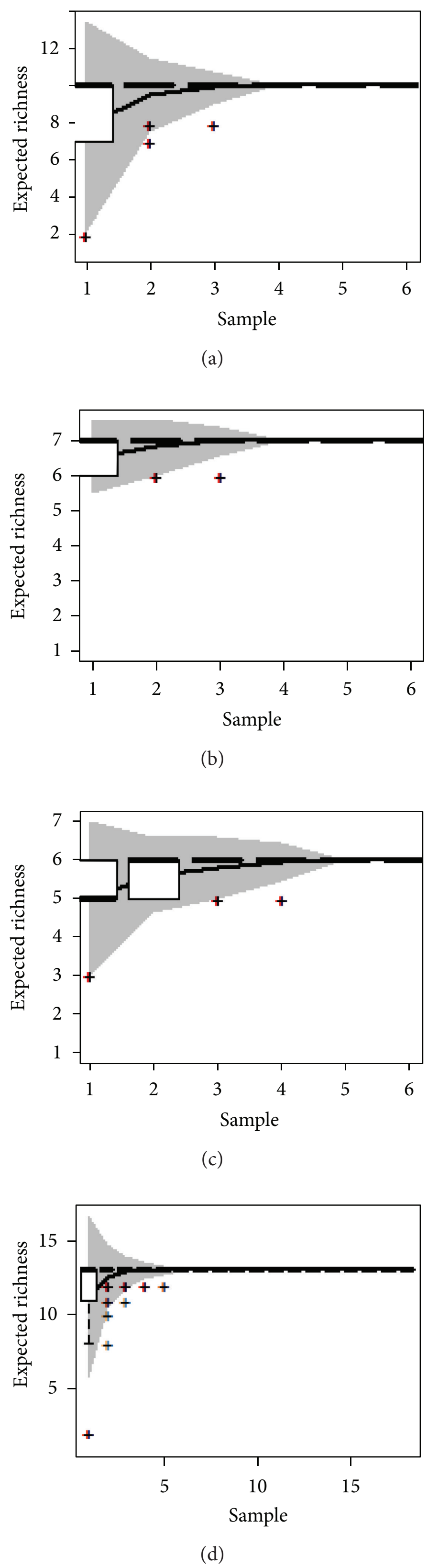


Figure 3: Accumulation curve with a confidence interval of 95% (gray), standard and error deviation (bars) and cumulative number of species per collection (+) of medium and large mammals of three Atlantic Forest fragments located in the western of Santa Catarina state. (a) Area A; (b) Area B; (c) Area C and (d) total of all areas.

Table 1: Records of medium and large mammal's species per sampling points between October 2010 and July 2011 in three Atlantic Forest remnants located in the municipality of Ipumirim-SC, Brazil. With its richness, diversity index of Shannon-Wiener, evenness of Pielou, and estimated diversity by Chao2 index.

Specie	Area A	Area B	Area C
Sapajus nigritus (Goldfuss, 1809)	0	2	1
Cerdocyon thous (Linnaeus, 1766)	2	6	2
Dasyprocta azarae (Lichtenstein, 1823)	1	0	0
Dasypus novemcinctus (Linnaeus, 1758)	0	1	1
Didelphis aurita (Wied-Neuwied, 1826)	3	0	0
Eira barbara (Linnaeus, 1758)	3	2	3
Euphractus sexcinctus (Linnaeus, 1758)	1	0	0
Galictis cuja (Molina, 1782)	0	2	2
Leopardus spp.	3	4	0
Nasua nasua (Linnaeus, 1766)	1	2	1
Philander frenatus (Olfers, 1818)	1	0	0
Procyon cancrivorus (G.[Baron] Cuvier, 1798)	3	0	0
Puma concolor (Linnaeus, 1771)	1	0	0
Richness	10	7	6
Shannon-Wiener	2.117	1.795	1.696
Equitability	0.946	0.922	0.946
Chao2	22.500	7.125	8.250

The correlation analyses of Spearman between the abiotic factors and the temporal richness of species demonstrated that there is significant negative correlation for relative humidity and precipitation ($S = 1720.298$, rho $= -0.775$, $P < 0.01$; $S = 1500.406$, rho $= -0.548$, $P < 0.05$) and nonsignificant for temperature ($S = 701.260$, rho $= 0.276$, $P = 0.267$).

Through the chorological matrix (Figure 5), it was observed that 35.5% of area A and surroundings are occupied by silviculture, 26.4% by open fields, farming or pastures, 9.1% by human occupation (buildings and roads), and 29.0% of remaining native forest. In area B and surroundings 31.6% is occupied by fields, farming or pastures, 22.7% by silviculture, 8.7% by human occupation and 37% of native forest. In area C and surroundings, the farming, fields, and pastures are predominant (38.4%) followed by human occupation (15.3%) and silviculture (14.7%), remaining 31.6% of native forest (Figure 4).

The results of the measurements of environmental characterization (microhabitat) showed that area A has larger trees with lower density, besides being closer to watercourse and presenting lower canopy cover and undergrowth vegetation and, also, lower inclination (Table 2).

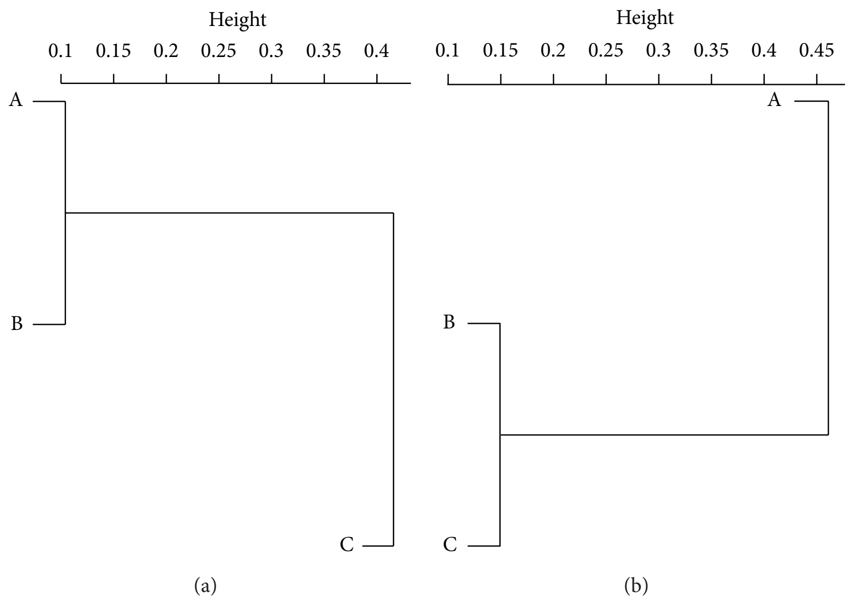


Figure 4: Dissimilarity dendrogram obtained by the Jaccard index for (a) medium and large mammals records of three Atlantic Forest fragments located in the municipality of Ipumirim-SC, Brazil obtained from October 2010 to July 2011 and (b) between the microhabitat features presented in the same areas. Agglomerative coefficient of 0.5 (a) and 0.45 (b). Where: A: Area A; B: Area B and C: Area C.

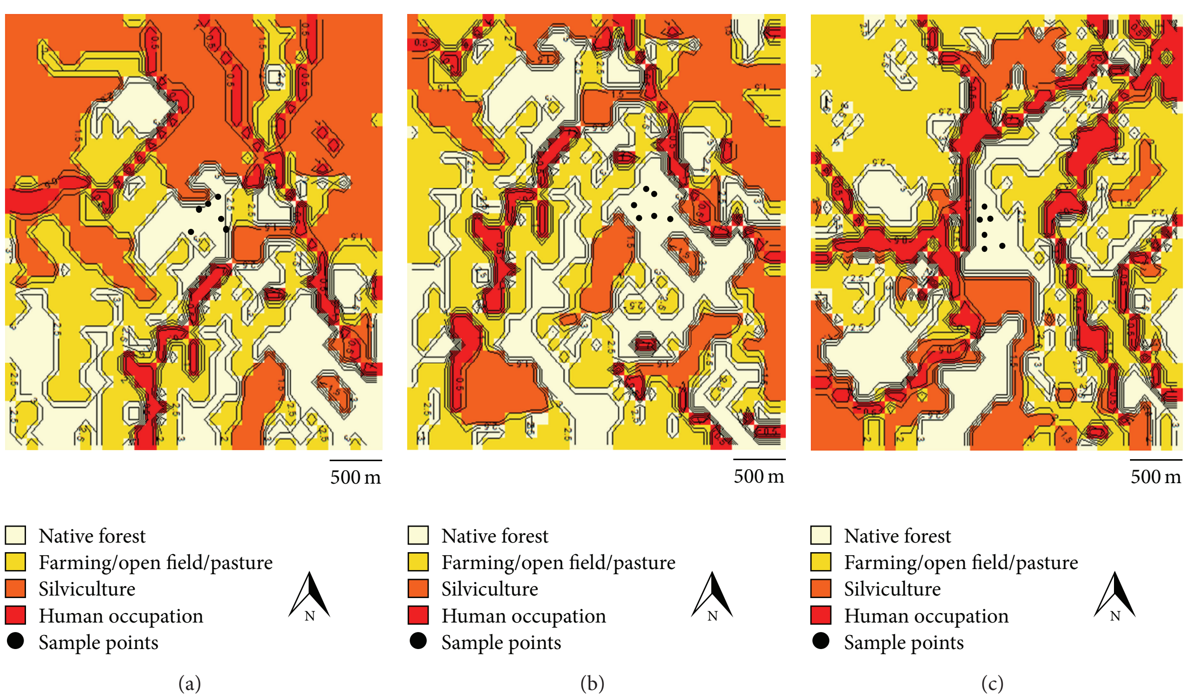


Figure 5: Chorological matrix of three Atlantic Forest fragments in the municipality of Ipumirim-SC, Brazil where the mammals were sampled from October 2010 to July 2011, showing the types of occupation of the landscape and enumerating (dark colors) for possible conflicts of medium and large mammalian fauna. (a) Area A, (b) Area B, and (c) Area C.

The model calculations of the parameters of landscape and environmental characterization made through the AICc show that the three most parsimonious models for the data of richness and qualitative matrix (presence/absence) in the assessed areas are the ones which include landscape criteria such as the proportion of human occupation (AICc = 70.78; AICc = 140.61) followed by farming, field, and pasture areas for species richness (AICc = 71.61) and altitude for species presence/absence (AICc = 140.82).

Amongst the microhabitat conditions, the best model of richness prediction was the canopy cover (AICc = 74.88) although a model containing landscape and microhabitat

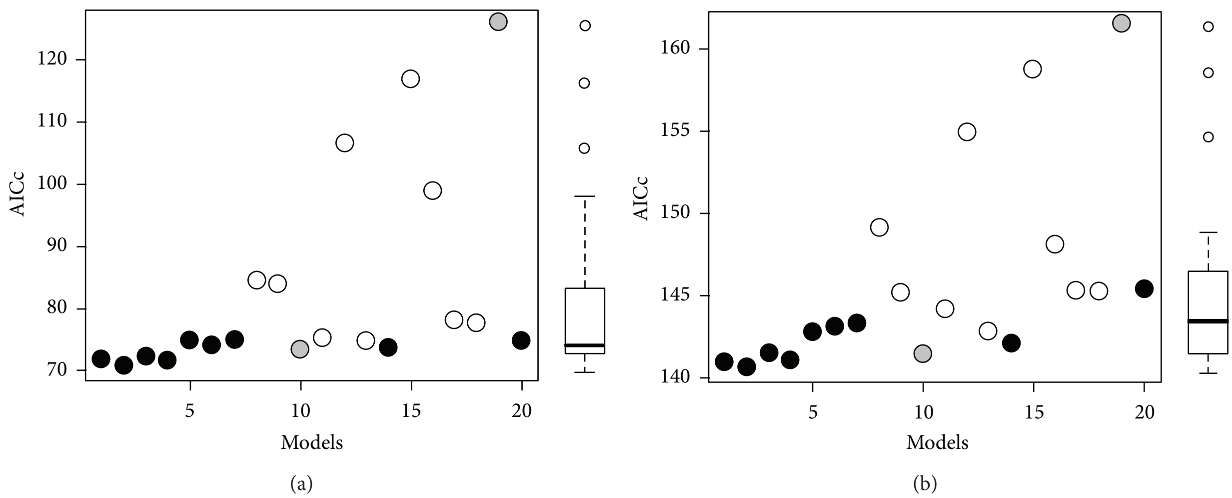


FIGURE 6: Scatter the result of the selection of 20 candidate models based on AICc for (a) species richness of mammals and (b) matrix of presence/absence in time. In black predictors models of landscape conditions, in white microhabitat models and gray mixed models (see Table 2).

TABLE 2: Mean (±SD) of environmental characterization of three Atlantic Forest areas sampled in the municipality of Ipumirim-SC, Brazil.

Parameters	A (Mean (±SD))	B (Mean (±SD))	C (Mean (±SD))
Distance tree (m)	2.97 (0.29)	1.98 (0.22)	3.53 (1.01)
DAP tree (cm)	86.83 (31.25)	39.48 (11.45)	56.83 (28.2)
Height tree (m)	10.02 (1.91)	7.66 (2.27)	9.76 (3.69)
Diameter tree (m)	6.02 (2.13)	3.73 (1.17)	4.61 (2.43)
Distance shrub (m)	1.84 (0.68)	0.95 (0.32)	1.34 (0.29)
DAT shrub (cm)	7.67 (0.81)	9.36 (3.1)	7.1 (1.81)
Height shrub (m)	2.16 (0.24)	2.44 (0.54)	2.29 (0.5)
Diameter shrub (cm)	97.2 (13.76)	111.2 (24.25)	70.9 (16.77)
Litterfall height (cm)	2.6 (0.96)	3.8 (0.42)	2.6 (0.87)
Litterfall coverage (%)	78 (9.59)	99.67 (0.52)	90.49 (3.99)
Green coverage (%)	48.83 (16.91)	12.92 (3.32)	30.2 (7.2)
Exposed soil (%)	22 (9.59)	0.33 (0.52)	9.51 (3.99)
Rocky out distance (m)	1.44 (0.24)	2.02 (0.56)	1.2 (0.12)
Canopy coverage (%)	77.63 (9.29)	89.75 (5.34)	80.21 (12.68)
Inclination (°)	16.17 (1.65)	22.83 (5.36)	22.88 (6.92)
Distance of stream (m)	25.64 (15.88)	329.5 (36.33)	336.17 (37.56)

Where: A: Area A, B: Area B, and C: Area C.

parameters was ranked in the fifth place. For the presence and/or absence of species, the most parsimonious model of microhabitat predictor data was also the canopy cover (AICc = 142.82) also showing a mixed model as the fourth best (Table 3).

The microhabitat conditions as predictive factors for species richness presented as the most parsimonious model the conditions that included parameters of the canopy cover, followed by soil cover, undergrowth vegetation, green cover, exposed soil, and rocky outcrop. Amongst the microhabitat explanatory variables listed and their respective model candidates for the prediction of the patterns of presence and absence, the same models previously described were also the most parsimonious (Figure 6).

The result of the model selection through AICc for species which presented detectability ≥25% in all samples showed that the factor with greater importance for predictors of landscape was the proportion of native forests in the sampled areas and surroundings for all species, except for *D. aurita*. As a microhabitat criterion there was a great variation among species although conditions of rocky outcrop, undergrowth vegetation and green cover have been relevant for the majority of species (Table 4).

Table 3: Results of the model selection based on AICc of a predefined set of candidate models for predicting richness and presence/absence of nonflying mammals of three Atlantic Forest remnants in the municipality of Ipumirim-SC, Brazil.

RV	Model description[a]	Criterion[b]	K	AICc	ΔAICc	WAIC	LL
Richness	HM OCCP	Landscape	3	70.78	0.00	0.53	−24.59
	Farm/OPN field/pasture	Landscape	3	71.61	0.83	0.24	−23.38
	ALT	Landscape	3	71.78	1.00	0.17	−19.76
	SILV	Landscape	3	72.41	1.63	0.01	−31.53
	ALT + INCL	Landscape + microhabitat	6	73.48	2.70	0.01	−31.56
	CAN COV	Microhabitat	6	74.88	4.10	0.00	−31.53
	LIT HGT + LIT COV + GRN COV + EXP SOIL + RCK OUT	Microhabitat	6	75.18	4.40	0.00	−33.02
	LIT HGT + CAN COV	Microhabitat	8	77.70	6.92	0.00	−25.37
	GRN COV + CAN COV	Microhabitat	11	78.18	7.40	0.00	−33.50
	DIST TREE + DAP TREE + HGT TREE + DMT TREE + DIST SHR + DAT SHR + HGT SHR + DMT SHR + CAN COV + FRG SIZE	Landscape + microhabitat	4	125.91	55.13	0.00	−32.35
Presence/absence	HM OCCP	Landscape	3	140.61	0.00	0.12	−66.96
	ALT	Landscape	3	140.82	0.21	0.12	−66.98
	Farm/OPN field/pasture	Landscape	3	141.03	0.42	0.11	−67.07
	ALT + INCL	Landscape + microhabitat	6	141.42	0.81	0.10	−66.12
	SILV	Landscape	3	141.44	0.84	0.10	−63.16
	CAN COV	Microhabitat	7	142.82	2.21	0.06	−61.72
	LIT HGT + LIT COV + GRN COV + EXP SOIL + RCK OUT	Microhabitat	6	144.19	3.58	0.04	−67.03
	DIST TREE + DAP TREE + HGT TREE + DMT TREE	Microhabitat	4	145.17	4.56	0.04	−68.07
	LIT HGT + CAN COV	Microhabitat	9	145.18	4.57	0.03	−65.27
	DIST TREE + DAP TREE + HGT TREE + DMT TREE + DIST SHR + DAT SHR + HGT SHR + DMT SHR + CAN COV + FRG SIZE	Landscape + microhabitat	4	161.54	20.93	0.00	−62.77

[a]Abbreviations used: RV: response variable; M: model; K: parameters number of model; AIC: AIC value; ΔAIC: AIC delta; WAIC: AIC weight; LL: Likelihood; LIT HGT: litterfall height; LIT COV: litterfall covering; GRN COV: green covering; EXP SOIL: exposed soil; RCK OUT: rocky out; INCL: inclination of terrain; CAN COV: canopy covering; HM OCCP: human occupation; SILV: silviculture; FARM: farming; OPN FLD: open field; FRG SIZE: fragment size; ALT: altitude; DIST STR: distance of stream; DIST TREE: distance of tree; HGT TREE: height tree; DMT TREE: diameter tree; DIST SHR: distance of shrub; HGT SHR: height shrub; DMT SHR: diameter shrub.

[b]We present only the four best models each criterion, except Landscape + Microhabitat that only two models were defined.

Table 4: Result of the model selection-based AICc of a predefined set of candidate models for mammalian species with greater detectability in three remnants in the Atlantic Forest located in the municipality of Ipumirim-SC, Brazil.

Specie	Landscape[a(1)]	AICc	Major[1]	Minor[2]	Microhabitat[a(1)]	AICc	Major[1]	Minor[2]	Microhabitat[b(2)]
Cerdocyon thous	FRAG SIZE	25.6	34.30%	30.30%	RCK OUT	24.71	1.64 m	1.28 m	GRN COV
Eira barbara	FRAG SIZE	33.21	32.00%	33.00%	RCK OUT	25.96	1.34 m	1.64 m	CAN COV
Galictis cuja	FRAG SIZE	20.79	35.20%	32.00%	HGT TREE	16.95	5.84 m	9.8 m	DMT TREE
Sapajus nigritus	FRAG SIZE	20.79	35.20%	32.00%	LIT HGT	17.78	4.07 cm	2.82 cm	DIST SHR
Nasua nasua	FRAG SIZE	26.61	34.00%	32.20%	RCK OUT	21.83	1.76 m	1.42 m	LIT HGT
Didelphis aurita	DIST STR	13.97	20.80 m	272.3 m	GRN COV	17.49	51.30%	26.50%	DAP TREE

[a]Abbreviations used: AICc: AICc value; FRG SIZE: fragment size; DIST STR: distance of stream; RCK OUT: rocky out; HGT TREE: height tree; LIT HGT: litterfall height; GRN COV: green covering; DMT TREE: diameter tree; DIST SHR: distance of shrub; DAP TREE: diameter at breast height of tree.

[1]Conditions of greatest occurrence.

[2]Conditions of minor occurrence or absence.

[(1)]Best model.

[(2)]Second best model.

4. Discussion

4.1. Registered Species. The review of the list of Brazilian mammals indicates the occurrence of 701 species, classified into 243 genera, 12 orders, and 50 families [17]. In Santa Catarina, whose territory is completely inside the Atlantic Forest biome, 178 species have confirmed and/or potential occurrence and more than 64% of the total number of species belong to the orders Chiroptera and Rodentia [51]. Therefore, 64 are species of orders likely to be sampled with the methodology adopted in this research, and based on these numbers, 20.3% of the species of mammals of this category, for this biome, were registered. Although, we infer that the region in particular, the number of species reported by us was higher than 65% can still occur. According to Caro et al. [52] and Coelho et al. [53], we highlight that medium and large mammals do not usually have seasonal variations in subtropical environments.

Mammals of the order Carnivora compose the main guild of predators of vertebrates in the terrestrial ecosystems [54]. It was observed that they corresponded to more than half of the mammals registered, indirectly indicating the existence of resources for the maintenance of these predators and/or the use of the researched sites as foraging and/or breeding areas. *C. thous* and *E. barbara* were the most frequently registered species. Once the first is an opportunistic and generalist species, it is potentially less susceptible to environmental changes having a wide geographical distribution in America [35, 55]. *E. barbara* is featured by the occupation of more densely wooded areas [35] which allows to infer that there is heterogeneity of environments. The description of habitat occupation for other species is considerably variable, from the occupation of large areas (e.g., *P. concolor* and *Leopardus* spp.), to species with great ecological flexibility (e.g., *P. concolor*, *N. nasua*, *D. aurita,* and *S. nigritus*), edge environments (e.g., *Euphractus sexcinctus* (Linnaeus, 1758) and *Dasyprocta azarae* (Lichtenstein, 1823), environments whose important condition is the presence of waterbody (*P. frenatus* and *P. cancrivorus*) and animals whose occurrence takes place in forests and occasionally in open areas (e.g., *Dasypus novemcinctus* (Linnaeus, 1758) and *G. cuja*) [35, 56].

Thus, even the studied fragments with considerably small areas for species that generally live in large areas, and being a fragmented region with strong evidences of predatory hunting, in addition to the lack of studies in the field, the results obtained were of great importance, once endangered species of great ecological importance such as *P. concolor*, were registered [16]. The richness observed in the three areas was similar to the one found in studies carried out in protected natural areas in the same biome, as in Kuhnen's study [57], which registered 16 species in the Sea ridge (Serra do Mar) in Santa Catarina. The study conducted by Luiz [58] in Aguaí's Ecological Station (Estação Ecológica do Aguaí) registered 10 species. Cherem [20], using a similar methodology, including an interview, studied seven areas in southeast Santa Catarina and along Uruguai River and registered 46 species. In the western region of Santa Catarina, Cherem et al. [23] registered 27 species (employing several methodologies) in the areas that suffer influence of the Quebra Queixo Hydroelectric Power Plant, located between Ipuaçu and São Domingos, two towns in Santa Catarina, approximately 90 km from the areas studied in this research. In the basin of the Irani River, Santa Catarina, Cherem et al. [24] registered 26 species in a sampling period of four years, including several different methodologies.

4.2. Comparison among the Fragments. Among the studied areas, where the richness observed varied between six and ten species and the estimated richness by the Chao2 index showed amplitude between 22.5 and 7.13, the greatest variation happened due to the characteristics of the registers, which in area A, six (46.1%) of the thirteen species registered were exclusive. Although the richness estimated presented great variation among the areas, the result of the Kruskall-Wallis test showed that the areas are statistically similar in relation to the composition of the mammal fauna. The equitability index of Pielou also showed very similar results, with a variation of 0.044 among the areas, what does not indicate the increase in dominance, and the same also happened with the classical index of Shannon-Wiener, which did not show great variations. Even though area A presented greater richness and exclusive species, the similarity index of Jaccard demonstrated that areas A and B are similar, as well as B and C. The environmental characterization presented greater similarity between areas B and C, which had previously been lodging areas. Thus, even with the differences between the adopted indexes, the results lead to the conclusion that the three areas presented a great similarity.

4.3. The Influence of Biotic and Abiotic Factors. Through the model selection based on the AICc for the variables response richness and presence/absence, in the magnitude of occupation of the areas, the factors that stood out were, in order, conditions of human occupation, open field, farming and/or pastures and silviculture (richness), and altitude (presence/absence). The landscape conditions, despite the amount of ongoing studies, do not allow many generalizations regarding the consequences for the communities [59] and the conditions, which include the spatial structure originated from processes of temporal and spatial scales, involve several parameters interfering in a single diversity measurement [60, 61]. Even considering these difficulties, it is perceptible that the three main factors are conditions that suffer strong and direct human interference (except for altitude), either decreasing or altering the native areas thus confirming the aspect of conflicts because of human occupation and the fauna. The altitude also presented a clear effect because 13 species were registered in altitudes higher than 830 meters, even though part of them were also found in lower altitudes, what confirms the smaller indirect anthropic impact due to conditions of access and relief.

Regarding the conditions of microhabitats listed by us, especially the case of canopy cover,Jennings et al. [62] describe that the cover promoted controls the quantity, quality and spatial and temporal distribution of luminosity, determining differentiated levels of humidity, temperature, and conditions of soil humidity. Thus, the canopy cover is the greatest determinant of the internal microhabitat of the forest once it directly affects the growth and development of seedlings determining the floristic composition of the community [63]. Several authors reinforce this condition assuming the intensity of incident light as the main determinant of these systems, and the microclimatic factors dependent on this variable [64, 65]. In the event of the undergrowth vegetation, Portes et al. [66] indicate that its deposition is influenced by the type of vegetation, successional stages, altitude, latitude, wind, precipitation, temperature, herbivory, hydric availability, and the storage of nutrients in the soil. This way, it works as a bioindicator responding with alterations of deposition processes because of alterations in the environment [67]. These conditions therefore provide a contribution regarding the resulting conditions.

Biological communities undergo changes as there is variation among the abiotic factors along a spatial gradient. Species richness tends to increase towards lower latitudes [68–70]. Nevertheless, the effects on the latitudinal change have rarely been considered distinct from this factor [71]. Furthermore, specific microclimatic changes such as temperature and precipitation interact in order to ascertain conditions and resources available for plant growth, which in turn influence the local fauna. However, both the intensity and the frequency of the events along time are relative measures which depend on the organism that suffers them [72]. Thus, the conditions of great amplitude for obtaining registers temporally may be directly or indirectly associated to meteorological factors. It was confirmed through the correlation analysis between the outcome of the species registers and the abiotic factors obtained in the period, with emphasis to relative humidity and precipitation.

The faunal responses to fragmentation depend on a series of factors, especially if the species will use the fragment edges, if there is fidelity to the interior sections of the fragment [73] or the interior sections present single attributes [74]. The generality of the edge effect, however, may be limited as well as the results vary among different systems [75]. Fragmentation is an important problem for biodiversity preservation, which has received special attention from the scientific community. Consequently, the perception and evaluation of landscape fragmentation are recommended and presumably necessary in any assessment, assistance, or decisive process which involve landscape alteration [76].

A good example to be considered is the study by Lantschner et al. [77] in the Argentinian Patagonia where they assessed the habitat and landscape characteristics and the presence of species of wild carnivores, registering four species and two of them (*Lycalopex culpaeus* (Molina, 1782) and *Conepatus chinga* (Molina, 1782)) used continuous native vegetation with greater frequency but also used dense coniferous plantations, while *Leopardus geoffroyi* (d'Orbigny and Gervais, 1844) was almost totally restricted to native forest. On the other hand, individuals of *P. concolor* did not show any preferences, being detected in all types of habitats.

Most studies regarding microhabitat selection carried out in the Atlantic Forest are developed with small mammals (e.g., [78–80]), while investigating microhabitat use by large- and medium-sized mammals in Atlantic Forest environments revealed tendencies to differential uses by the mammal community. In relation to microhabitat from the perspective of foraging, a fragment which is used for this purpose may occasionally be used as a refuge once it presents richer food resources, even though it is structurally different or distant from central areas.

Under such circumstances, the distance and the structure of the microhabitat may have effects on the risk of predation and in the animals' decision making [81]. All the organisms may potentially alter their environments. This ecological trait leads to spatial self-organized heterogeneity of the environments and, consequently, to the limits of species distribution. Within concurrent systems, the capacity of alteration leads to competitive alternative consequences, resulting in trade-offs among the competition abilities, colonization and niche construction, becoming important for the competitive coexistence [82]. The habitat heterogeneity hypothesis [83] states that structurally more complex and thus more diverse habitats tend to an increase in the diversity of species in the landscape [84].

The individualization in models selection through species with greater numbers of registers has provided distinct results. Conditions of quantity of native areas in the landscape were predominant, although generalist species such as *C. thous* presented a greater number of registers in larger though less preserved areas, based on microhabitat criteria. In an opposite way, *E. barbara*, more sensitive to alterations, was registered in greater numbers in smaller areas, though with better conditions in local scale. This condition of quantity of native areas was an exception solely for *D. aurita* whose condition of importance was closeness to water (although the analysis has not been carried out for *P. cancrivorus*, this condition has also been important once the species was registered solely in the area closest to water).

When species were assessed individually, the main microhabitat condition for half of the species was the density of rocky outcrop, although in opposite conditions (smaller or greater quantity) among some species. This condition influences on vegetation dynamics and composition, creating insular environments in the landscape and refuges for plants sensitive to grazing [85, 86]. Other important criteria were the green cover of the soil, height, DBH and diameter of the trees, height of undergrowth vegetation, canopy cover, and shrub density. These conditions provide an overview of the local quality. They determine the success of a population and in heterogeneous sites the variation of these conditions is common, leading to the formation of microhabitats of higher or lower quality in a reduced scale [72, 87]. It is thus argued that the landscape conditions are relevant associated with the quality conditions in local scale and they exert influences of different magnitude on different species.

5. Conclusions

The use of associated methodologies and the climatic conditions must be taken into consideration in the faunal inventory of mammals, as well as aspects and paradigms of landscape alteration. Notwithstanding, a great number of mammals likely to be inventoried was registered with the methods employed. Yet considering that several species of large- and medium-sized mammals are no longer found, the areas presented, in fact, a considerable richness and it was estimated that the study has registered more than 65% of species that are potential dwellers of the region. The ecological aspects of the areas match with the results, attesting the ecological importance of the Atlantic Forest remnants for the maintenance of the biological diversity.

The richness and presence/absence of mammals had influence on the landscape, with emphasis on the proportion of human occupation and open areas for farming, fields and pastures, potential foraging areas as well as the altitude of the areas, due to the lower anthropic disturbance. In the microhabitat scale, the most noteworthy aspects were canopy cover, undergrowth vegetation cover and height, percentage of green cover, exposed soil and rocky outcrop, which are usually indicators of environmental conditions in spatial-temporal scales allowing contributions regarding the resulting conditions.

Several of the environmental and climatic conditions here emphasized may be included in the development of maneuver plans as well as in the establishment of new areas of environmental preservation in Santa Catarina aiming at preserving the diversity of large- and medium-sized mammals and their structural and ecological ecosystemic relationships.

Conflict of Interests

The authors reported no conflict of interests.

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