Original Research Article

Biodiversity in Forest Fragments Under Different Forms of Environmental Conservation, Jaboticabal, São Paulo, Brazil

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ABSTRACT

Characteristic environments of forests generally harbor significant biodiversity, which is considered an important indicator of local environmental quality, so that the analysis of this indicator can subsidize the decision making on areas for legal reserve. The objective of this work was to evaluate the biodiversity of forest fragments at different levels of anthropization in the municipality of Jaboticabal, State of São Paulo, Brazil. The related research was carried out in three forest fragments, an area under reforested conditions, a natural remnant area and an area under natural regeneration. Each fragment was divided into three sampling units of 240 m^2, constituting the replicates. The total frequency of insects, amphibians, birds, mammals, reptiles and trees was evaluated. Cluster analysis indicated that there were differences between the three fragment types. The analyzed variables were summarized in two main components, which explain 87.1% of the accumulated total variance. It was concluded that the areas of natural remnants and reforestation presented higher frequencies of species and, consequently, greater biological diversity than the natural regeneration area.

Keywords: Environment; ecology; fauna; flora; frequency of species.

1. INTRODUCTION

Environmental problems such as the exploitation of non-renewable resources and deforestation of forest areas are, by nature, issues that require interdisciplinary approaches. By their often complex nature, they evoke not only the natural and physical sciences for their explanation, but also the social sciences to describe their interactions with human activities. It should be noted that forest areas play the main ecological role of carbon sequestration. The growing environmental awareness and the expansion of knowledge between the different knowledge areas have mobilized the scientific community and the population in favor of getting to know these interaction man/environment [1] and design strategies for the sustainable exploitation of the environment by man.

Human exploratory actions have promoted significant changes in the dynamic equilibrium of ecosystems [2], notably because of the disturbances in the natural habitat of several species, such as insect eating birds [3, 4, 5], insect bioindicators [6], and to plant species [7, 8, 9].

To quantify the quality of habitat for wildlife is a task that is extremely challenging, this being essential to the development of quantitative techniques with robustness sufficient to express the real ability of the natural shelters [10].

On the basis of the above, it is emphasized that the stratification of areas to study their quality, is a preponderant step to understand the peculiarities of each environment [11]. Summers et al. [12] point out that areas in reforestation can be divided into three main categories: assisted natural regeneration, direct sowing, and planting of seedlings; these areas being, according to Cunningham et al. [13], essential for the maintenance of biodiversity. Already Botello et al. [14], dealing with areas of natural remnants, reported the contribution of these environments to the richness of fauna and flora. Fiorentin et al. [9] added that processes in natural regeneration areas are highly complex and dynamic due to the interaction of various processes that converge to drive ecological succession.

Owing to the importance of the ecosystems mentioned above, [10] point out that, their quantitative analysis consists of an important strategy for the generation of local environmental quality indicators in order to subsidize the decision making on areas to be destined for legal reserve. However, it is known that the evaluation of forest fragments is usually based on a single taxonomic group, evidencing the need for rapid assessments based on multitax on indicators [15] that can be excellent tools to help conservationists and managers in the definition of environmental conservation strategies [14]. The objective of this work was to analyze the biodiversity of three forest fragments under different forms of environmental conservation.

2. MATERIAL AND METHODS

2.1 Research Coverage Area

The research was carried out in April 2015 in three forest areas in the municipality of Jaboticabal, State of São Paulo, Brazil. The areas covered by the study, consisting of an average of 720 m^2 each, were characterized according to the level of anthropization, namely: Area under reforestation conditions, denominated fragment 1 (FRA-1), located at 21°14'54.7"S and 48°17'48.5"W; area of natural remnant, fragment 2 (FRA-2), located at 21°14'47.1"S and 48°17'29.4"W; and an area under natural regeneration, fragment 3 (FRA-3), located at 21°15'02.5"S and 48°17'42.3"W. During the month (April) of conduction of the research, climate variables were monitored: relative air humidity (RH%), accumulated rainfall (R mm), mean atmospheric temperature (AT °C), and mean solar radiation (SR MJ m^2), as Illustrated in Figure 1A and B.
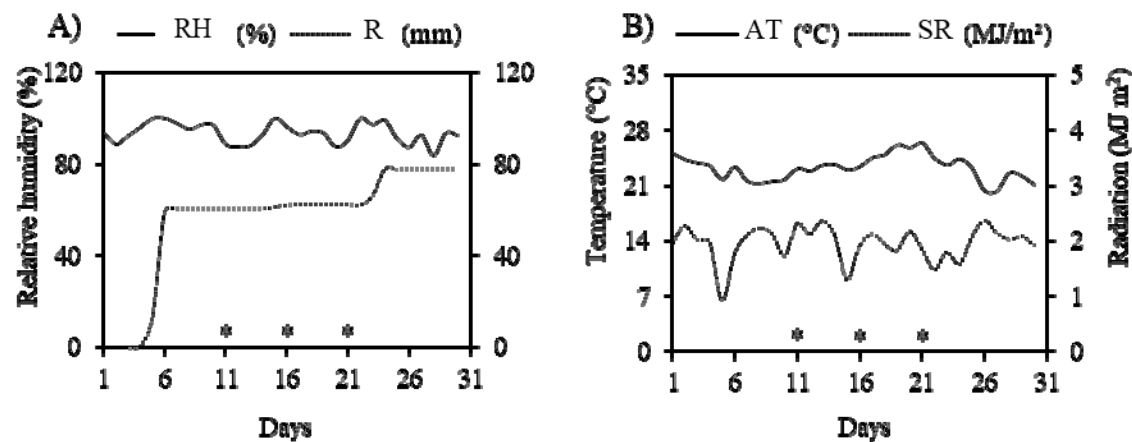
Figure 1. Climate variables. (A) relative humidity (RH) and rainfall (R), (B) atmospheric temperature (AT) and solar radiation (SR), * days the evaluations were performed. Jaboticabal, SP, 2015.

2.2 Experimental Design

The research was conducted in a completely randomized design (DIC), and the treatments represented by three forest fragments [16] with three replicates. To define the sample unit, the fragments were divided into three parts of ≈240 m^2, where each one represented a repetition. In each fragment, three visits were carried out at different times with a duration of three hours, 08:00, 12:00 and 16:00 hours.

2.3 Survey of Data

In the analyzed fragments, variables inherent in the frequency of occurrence of fauna and flora were included in the taxonomic groups: insects (F-INS), amphibians (F-AMP), birds (F-BIR), mammals (F-MAM), reptiles (F-REP), trees (F-TRE), and these are condensed into the variable total species frequency (F-TES). The data obtained from these variables consisted of *in loco* observation. Therefore, these were considered as "clues", in order to facilitate the visualization of copies of the groups; indicators of their existence, such as the diversity of leaves, flowers and fruits that can serve as food and water; trees and soil for shelter; besides aptitude for hunting and coexistence of populations. The research was classified as exploratory [17], of the qualitative type [18].

The collection of vegetation information was carried out based on specialized literature [19], and two species are commonly found in the transition areas of the Atlantic Forest and Cerrado, mainly because they represent the vegetation of the State of São Paulo. The species chosen were araticum-de-terra-fria (*Annona emarginata* (Schltdl.) H. Rainer) and dairy (*Tabernaemontana catharinensis* A. DC.). This categorization was performed for greater precision in the visualization and obtaining of the data [20].

2.4 Statistical Analysis

The original data of the dependent variables were transformed into a sine arc of $\sqrt{(x/100)}$, to normalize the distribution of the deviations [21], data was then subjected to analysis of variance using the 5% probability F-test. For the significant variables, the Tukey test was applied for multiple comparisons of averages [22], in order to detect differences between the fragments. Subsequently, the original data were standardized and subjected to multivariate exploratory analysis, using cluster analysis (Ward's method) and Principal Component Analysis (PCA) [23].

3. RESULTS AND DISCUSSION

It was verified that there were significant differences ($P < .001$) between the analyzed fragments for the variables, total frequency of species (F-SPE), F-INS, F-BIR, F-MAM, and ($P = .05$), F-AMP, while for frequencies of occurrence of F-REP and F-TRE no significant differences were found ($P = .05$) as summarized in Table 1.

Table 1. Summary of variance analyses for the total frequency of species (F-TSP), insects (F-INS), amphibians (F-AMF), birds (F-BIR), mammals (F-MAM), reptiles (F-REP) and trees (F-TRE). Jaboticabal, SP, 2015.

F.V.	GL	Medium Squares						
		F-TSP	F-INS	F-AMF	F-BIR	F-MAM	F-REP	F-TRE
Fragments	2	144.81[**]	99.74[**]	33.88[*]	57.16[**]	43.03[**]	3.66[ns]	2.54[ns]

Residue	6	8.80	9.10	6.45	5.16	1.99	7.32	0.63
CV (%)		17.19	32.25	68.30	26.68	32.86	212.13	10.49

124 **, * and [ns]* - significant at 1 and 5% probability of error and not significant by the Fischer test, F.V. -
125 *sources of variation, GL - degrees of freedom and CV - coefficient of variation.*
126

127 By analyzing the total frequency of verified species, it was possible to verify that fragment
128 two (FRA-2), expressed superiority of 26.7 e 80.0% in relation to the fragments (FRA-1) it's
129 three (FRA-3), though FRA-2 and FRA-3 have not differed statistically from one another,
130 with averages of 11 and 15. The FRA-1 was superior in 72.7% when compared with FRA-3,
131 with an average frequency of 3 (Figure 2A). The same behavior was observed when the F-
132 INS was analyzed, having recorded averages of 4.3, 5.3 and 0.6 for FRA-1, FRA-2 and
133 FRA-3, respectively, with percent differences of 86.0 and 88.7% when comparing FRA-1 and
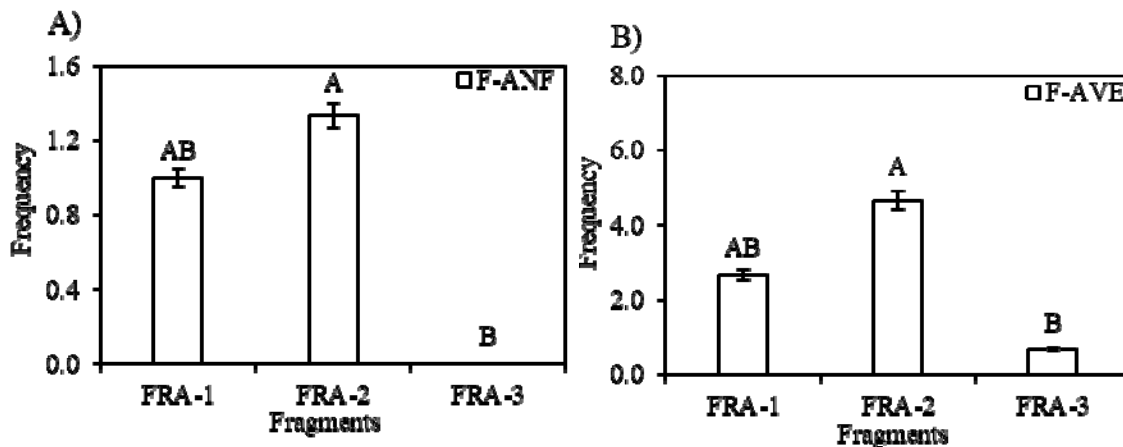134 FRA-2 with FRA-3 (Figure 2B).
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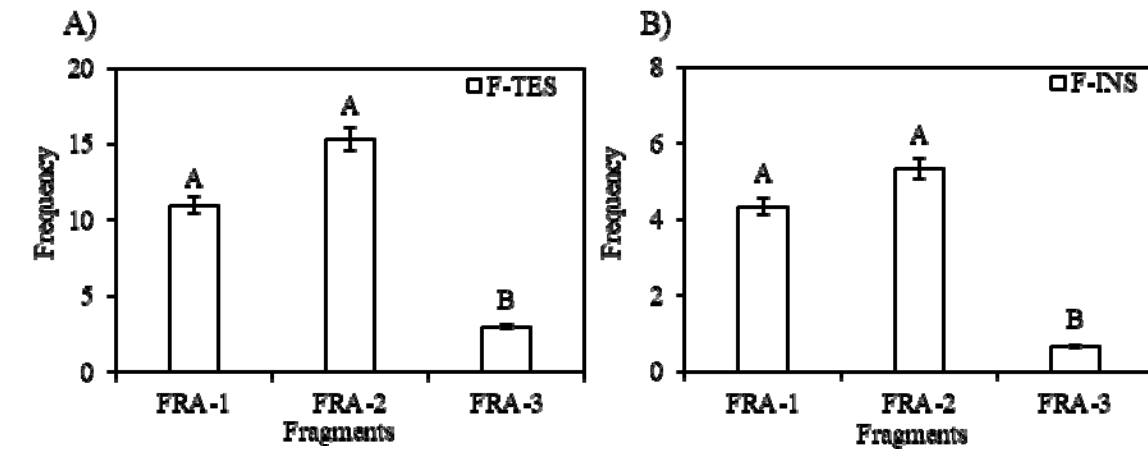
136
137 **Figure 2. Total species frequency (A), with minimum significant difference (MSD) of**
138 **7.43 and frequency of insects (B), with MSD of 7.53, verified in three forest fragments.**
139 **Mean data of three untransformed sine-arc replicates of the $\sqrt{(x/100)}$. Jaboticabal, SP,**
140 **2015.**
141

142 Forest fragments, given the nature of their classification, express structural differences
143 perceptible to the animals, in order to interfere with their behavior [24]. These authors
144 attribute these behavioral changes, above all, to changes in the natural habitat of the
145 species, while [25] contribute to changes in predation patterns. In a natural remnant
146 fragment, the biological richness is undoubtedly superior to that of anthropized areas [14],
147 reducing the incidence of solar radiation and temperature, increasing the relative air humidity
148 and, thus, favoring the development of several species of fauna and flora [26].Even in man-
149 altered areas, some species can adapt and take advantage of this situation [27], justifying
150 the frequency of species verified in natural regeneration areas in this work. Among the
151 various species indicative of the quality of ecosystems, insects are often mentioned. For
152 example, beetles [28, 29], caterpillars [30], bee species [31], and ants [32, 33, 6], are often
153 quantified to express the level of environmental disorder based on how often they occur in
154 environments.
155

156 Regarding the F-AMP, it was verified that FRA-2 had a higher mean (1.3), although it did not
157 differ significantly from FRA-1 that had an average of 1, whereas FRA-3 expressed average
158 0, differing from FRA-2 being calculated a percentage difference of 100% between these two
159 fragments (Figure 3A). For the variable F-BIR, this was also found to be superior to FRA-2,

160 with an average 4.6, although this did not differ from FRA-1, with an average 2.6, with FRA-2
161 higher in 86.9% to FRA-3, where the mean was 0.6 (Figure 3B).
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168 Rapid assessments and biotic integrity indexes, although generally based on a single
169 taxonomic group, are effective methods for assessing biodiversity conservation [15]. These
170 researchers confirm the longing for this research by suggesting that multiparameter-based
171 assessments, for example, the frequency of occurrence of amphibians and birds, provide a
172 more robust assessment of environmentally disturbed forest fragments. Studying the
173 distribution of amphibians, reptiles, birds and mammals, [14] mentions that anthropic
174 habitats are unsuitable for these species, while natural remnants and reforested fragments
175 are potentially habitable, explaining the high frequency of amphibians and birds in FRA-2,
176 followed by intermediate frequencies in FRA-1 and critical values evidenced in FRA-3 in this
177 research. It should be noted that amphibians are one of the most endangered animal
178 classes, mainly because of their sensitivity to environmental changes (for example, habitat
179 destruction, climate change, as well as the reduction of air humidity, or the emergence of
180 new pathogens, such as the quitrídio fungus, *Batrachochytrium dendrobatidis*) due to its
181 dependence on water and its permeability of the skin [34]. The distribution results of birds
182 verified by [15] corroborate the findings of this research, certainly due to the characteristics
183 of a particular reduction of the presence of ornithopters in places of intense antropic activity.
184 [24], studying bird species, reported that, although the vast majority of bird species are
185 classified as highly and moderately sensitive to environmental disturbances, there are,
186 although in a smaller number, less sensitive species, justifying the occurrence of birds in the
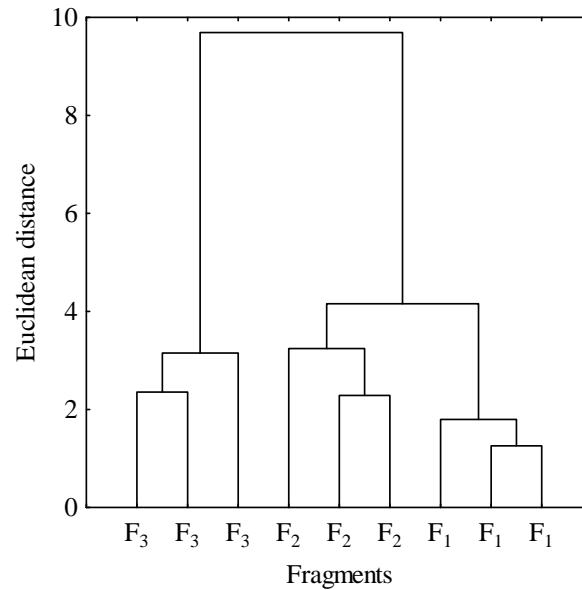187 FRA-3 of this study.
188

189 No significant difference was recorded between the means 1.0 and 1.6 of the FRA-1 and
190 FRA-2, respectively, when analyzed against the variable F-MAM, however, these two
191 fragments differed significantly from the FRA-3, where there was no presence of mammals,
192 characterizing the superiority of 100% of FRA-1 and FRA-2 in relation to FRA-3 (Figure 4A).
193 For the variables F-REP and F-TRE, no significant differences were found (Figure 4B),
194 which can be justified by the high variation of the original data, reflecting a high coefficient of
195 variation of 212.13% for F-REP absence of normal distribution of data F-REP and F-TRE.
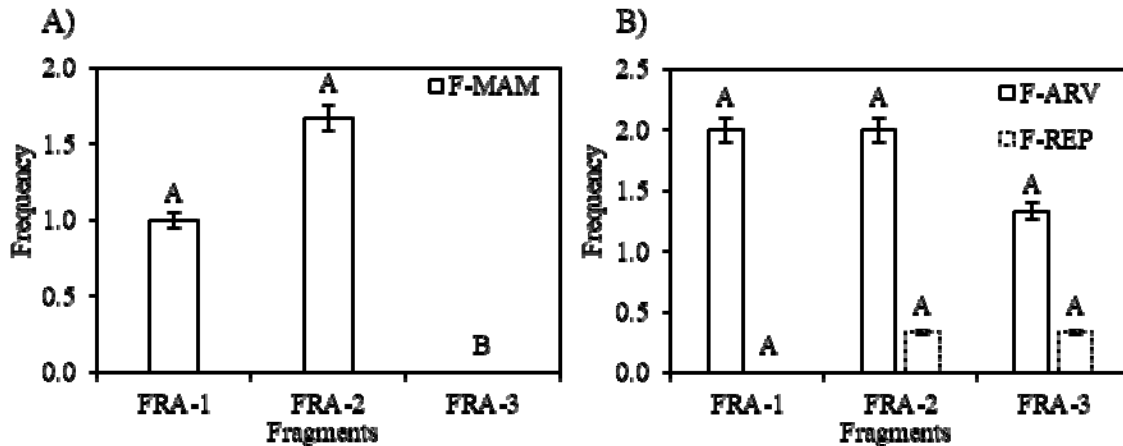
Figure 4. Frequency of mammals (A), with MSD of 3.54, reptiles and trees (B), with MSDs of 6.78 and 1.99, respectively, verified in three forest fragments. Mean data of three untransformed sine-arc replicates of the $\sqrt{(x/100)}$. Jaboticabal, SP, 2015.

Economic interests, to meet the demands of the growing population, have motivated predatory hunting, animal trafficking, forest deforestation, and expansion of arable land [35]. These researchers add that, fragmented forests tend to harbor fewer mammals compared with intact areas. It should be noted that the distribution dynamics of mammals in fragmented areas is also associated with their size. In fact, [36] report that the population of small rodent mammals can be increased in areas where the frequency of large mammals is reduced. In a complementary sense, [37] explain that changes in the distribution of mammals can be influenced by increasing land occupation for agriculture and livestock, as well as suppression of part of vegetation, alteration of hydrological cycles, burning regime and nutrient cycling in ecosystems. The nonoccurrence of differences between the fragments for the frequency of trees and reptiles can be justified by the fact that local climatic conditions favor the propagation and development of the trees, providing an adequate ecosystem for the occurrence of reptiles in the area of the three fragments studied [38].

On the basis of the Euclidean Distance used to summarize the homogeneity between the experimental units within the groups and heterogeneities between the groups, there were two main groups, the first group being represented by fragment three (FRA-3) and the second group by fragments one (FRA-1) and two (FRA-2), denoting the dissimilarities between the groups based on hierarchical grouping (Figure 5).

In a research to compare two multivariate methodologies in the study of similarities between fragments of Atlantic forest, [39] point out that there is dissimilarity between groups of forest fragments, emphasizing that fragment groupings are due to the similarities of their variables, justifying these similarities due to their geographical proximity. [40]also observed that floristic similarity decreased with increasing distance between areas, in agreement with the ideas of [41] and [42], according to which geographical proximity would be the only reliable factor to predict the similarity between areas. These evidences allow us to infer that, due to the high geographic proximity of the fragments investigated in this research, the differences observed are due to the particular characteristics of these fragments, mainly anthropization in fragments of natural regeneration and reforestation.

It is observed in Table 2, that the set of seven categories (variables) analyzed was summarized in two latent variables (constructs), called Principal Components 1 (PC_1) and 2 (PC_2), which were selected based on eigenvalues, 4.83 and 1.26 because they were ≥1, satisfying the criterion of Kaiser-Meyer-Olkin (KMO).

Table 2. Eigenvalues (AV), relative variance (S^2_r) and absolute (S^2_a) and variable loads. Jaboticabal, SP, 2015.

PCs	AV	S^2_r (%)	S^2_a (%)	F-TES	F-INS	F-ANF	F-AVE	F-MAM	F-REP	F-ARV
						Variable Loads				
PC_1	4.83	69.07	69.07	-0.98	-0.93	-0.91	-0.96	-0.85	0.09	-0.73
PC_2	1.26	18.03	87.11	0.17	0.25	-0.06	0.19	-0.18	0.97	-0.38

PCs: Principal Components.

The PC_1 and PC_2 account for 87.1% of the total cumulative variance, with PC_1 accounting for 69.07% of this total, with PC_2 accounting for 18.04%. It is observed that the FRA-3

247 presented greater dissimilarities compared with the FRA-2, with the FRA-1 occupying
248 intermediate position (Figure 6).
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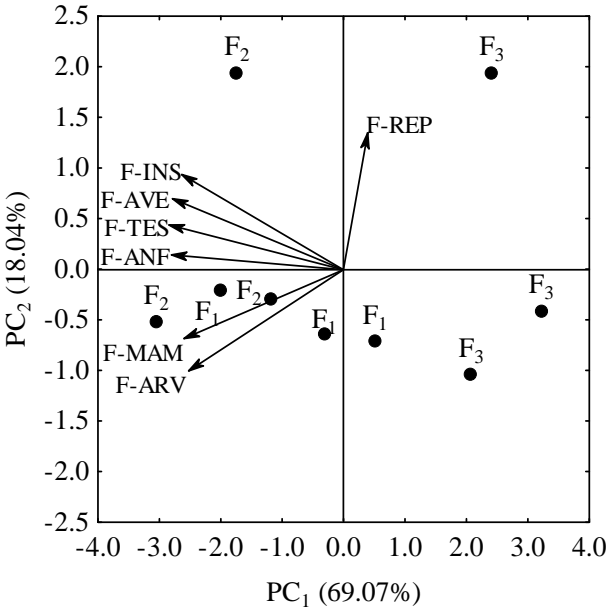
250
251 **Fig. 6. Two-dimensional projection (Biplot) of three forest fragments (F) and**
252 **representatives of fauna and flora in two Principal Components (PC$_1$ and PC$_2$).**
253 **Jaboticabal, SP, 2015.**
254

255 Analyzing forest fragments through Principal Component Analysis, [35] report that the first
256 two components account for 56% of the total variation in mammalian distribution among the
257 sampled sites. These researchers point out that the lower incidence of mammalian species
258 in altered areas can be explained by the hunter's pursuit of animals, especially game
259 animals and those that cause damage to agricultural crops, while trees and nontarget
260 species of hunting tend to be seen more frequently in anthropized areas.
261

262 On the basis of the results, the use of Principal Component Analysis is justified, since it
263 provides a structural simplification of the original data. In fact, in the research carried out by
264 [39], 462 dimensions were reduced in 10 Principal Components resulting from linear
265 combinations between original variables. Therefore, these authors report that using the first
266 10 PCs is as efficient as the use of the 462 initial variables with regard to the explanation of
267 the variance. Thus, the use of two PCs in this research was sufficient enough to explain the
268 variance under study.
269

270 On the basis of this information, it is believed that the divergences evidenced between the
271 fragments of this research can be a reflection of the anthropic actions, especially of the
272 illegal hunting that can occur in these places. For [39], each fragment exhibits a species
273 composition that appears to result from a series of factors that varied differently over time
274 and space. Perhaps that is why it is so difficult to establish these areas. This difficulty,
275 however, indicates that each fragment presents a set of its own characteristics, which
276 emphasizes its importance in terms of conservation.
277

4. CONCLUSION

There are differences in the biodiversity of the forest fragments analyzed, highlighting the areas of natural remnants and reforestation with greater biological diversity, to the detriment of the natural regeneration areas with insufficient biological indicators, denoting adequacy of the first two fragments and inadequacy of the latter with respect to the potential of use as a legal reserve.

Two groups of environments were evidenced according to the potential hierarchy for use as legal reserve, the first group being characterized as inadequate and the second as adequate. Of the seven analyzed variables, six were considered essential to the correct evaluation of the environments.

COMPETING INTERESTS

The authors have not declared any conflict of interests.

AUTHORS' CONTRIBUTIONS

This work was carried out with the collaboration of all authors. All authors read and approved the final manuscript.

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