BRAZILIAN JOURNAL OF ECOLOGY
REVISTA BRASILEIRA DE ECOLOGIA

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FICHA CATOLOGRÁFICA

Brazilian Journal of Ecology
Revista Brasileira de Ecologia
Vol. 01 Ano 14 – 2012
São Paulo, SP. Ecology Society of Brazil
(Sociedade de Ecologia do Brasil).
V/:il; 27cm

Anual
2010 – 2012, 1

II. Ecologia I. Sociedade de Ecologia do Brasil

BRAZILIAN JOURNAL OF ECOLOGY

A publication on the

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BRAZILIAN JOURNAL OF ECOLOGY
REVISTA BRASILEIRA DE ECOLOGIA

Volume 1 – Ano 14 - 2012

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EVALUATION OF ABOVEGROUND GROWTH AND BIOMASS IN *GLYCINE MAX* PLANTS EXPOSED TO VARIOUS CONCENTRATIONS OF COPPER

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ABSTRACT

Soybean (*Glycine max*) represents a plant-species of considerable economical importance for Brazil, considered one of the main producers worldwide. The aim here was to analyze the influence of copper on the development of the plant's aboveground growth and biomass. With this in mind, an experiment was developed under natural conditions of humidity and temperature using 112 plants cultivated in vases with sand. The randomized block design was adopted, with each containing four blocks, seven treatments and four repetitions, all irrigated for 30 days with a solution of Hoagland & Arnon, enriched with various concentrations of $CuCl^2$. Subsequent variance analysis and Tukey testing showed that plants undergoing treatment with 0.9 g $CuCl^2$ L^{-1} (T6) were

those that presented the least growth in relation to both control plants and those under lower-grade treatments. The values of stem-dry-mass were equivalent to the tendencies encountered in biometrics, whereby the conclusion that copper at high concentrations can exert an influence on growth in Glycine max plants.

Keywords: Soybean, plant biometrics, aerial organs, copper

INTRODUCTION

In general, micronutrients, even though required in reduced amounts, are essential for completion of the plant vegetative cycle. Their deficiency, besides inducing reduced productivity and alterations in the defense system, may even interfere in phenology (7). Among such nutrients, copper is outstanding by being an important co-factor in anti-oxidizing enzymes, as, for example, the activator of some of the enzymes involved in oxidation and reduction, besides participating in the opening and closing of stomata and lignification in some cells (3). Through its involvement in several physiological and structural aspects in plant development, copper, in certain concentrations, can serve as manure, the lack thereof possibly giving rise to damage to the plant in various forms. Some of the main symptoms of copper deficiency can be observed in young leaves, which, besides very often presenting necrotic patches, become dark green in color, rolled up and deformed. Worthy of note, copper deficient plants can manifest lower protein synthesis and diminished photosynthetic activity, through this nutrient being an activator of those enzymes which participate in terminal electronic transport in respiration and photosynthesis. These symptoms of deficiency occur in newer tissues, due to their lower mobility in the plant (18). A good example is a study by Zampieri (2010), comprising an analysis of the effects of copper and zinc on *Aechmea blanchetiana* (Baker) L.B. Smith, whereby it was demonstrated that seedlings cultivated under high concentrations of Cu^{++} were those that presented the highest structural variation in morphometric and anatomic parameters. In studies by Silva *et al*. (2010) on the tolerance of certain Cassia species (*Peltophorum dubium*) seedlings in soils with an excess of copper, it was observed that, inversely to the increase in dose, there was a decrease in plant biometric parameters, such as height and diameter.

Only required in small amounts in cultures, copper is one of the ultimate nutrients whereby symptoms of deficiency develop, when supply does not attend to plant requirements. Generally occurring at very low rates in the soil, its dynamics is very much affected by soil characteristics. Thus, besides pH and humidity, and apart from the plant itself, the degree of organic material and mineral and biological fractions in the soil, are factors that condition its availability and utilization by the plant, insofar as they interfere in the reactions, thereby giving rise to the formation of products of greater or lesser solubility (3).The normal concentration of this metal in the soil is 20mg kg^{-1}, with variations to the rate of 6 to 80mg kg^{-1} (20,11).

Another decisive factor in the activity of copper is the inner of a soil for the capacity cationic change (CTC). CTC is intimately linked to both the concentrations of changeable ions present in the solution of the soil, and the sites of changes on the colloidal intersurfaces of the system. High CTC facilitates greater retention of the metal. Organic material, even though representing only around 5% of soil components, is responsible for about 30% to 65% of the CTC in mineral soils, and for more than 50% in sandy and organic ones (10, 20).

Besides its natural distribution in the soil, copper can be further obtained in several other ways, such as by means of defensive chemicals, agricultural fertilizers, and more recently, through the widespread use of domestic and industrial residues. Emphasis must be given to the use of sewage sludge obtained in treatment stations, a mode which nowadays has been extensively adopted in several monocultures. Nevertheless, caution should be taken, for when in large concentrations, copper can induce toxic effects to plant tissue and cause a deficiency in other essential nutrients through

adverse interactions (8).

Urban residues, for example, through normally presenting high rates of heavy metals, when compared to those present in the soil, are liable to inducing toxicity or altering availability in certain agroecosystems (13). Furthermore, through possible absorption by plants, there is the possibility of their entering the food chains (14).

When in excess, the accumulation of copper in different parts of the plant can always be associated to cellular alteration in various forms, thereby interfering in physiological processes, to the point that, the toxicity so caused can eventually lead to oxidative stress, chlorophyll derangement and effects on Fe translocation, among others (9).

According to Sfredo (2008), over the latter years, leaf analysis has been applied to evaluating the availability of limitative nutrients for plants, thereby furnishing a new tool for improving recommendations as regards manure application, as a further means for increasing productivity.

The agricultural use of organic residues is only plausible, when there are no high inner concentrations of Cd, Pb, Cu, Cr, Ni and Zn, since these metals are prone to absorption by plant roots, with the subsequent transference to various organs (3), and consequently, into foodstuff for human consumption.

For the satisfactory development of a culture of the soybean *Glycine max* (L.), a grain of extreme importance in the Brazilian economy, it is essential that macro- and micronutrients be present in the appropriate concentrations.

OBJECTIVES

The aim of this study was to analyze the aboveground growth and biomass of *Glycine max* (L.), under different copper treatments and natural conditions of temperature and humidity.

METHODOLOGY

Study area

The experiment took place in an open area for experiments of the University 'Nove de Julho', located in metropolitan São Paulo. São Paulo, in southeast Brazil, is located at around 770 meters above sea level, within the coordinates 23º30'S and 46º40'W. Characteristically, winters (from June to August) are dry, and summers (from December to March) humid.

Plant exposure

During the experiment, the plants were individually irrigated weekly with 50 ml of a Hoagland & Arnon solution contaminated with 0.0 (T0); 0.000009 (T1); 0.00009 (T2); 0.0009 (T3); 0.009 (T4) 0.09 (T5) and 0.9 (T6) g, with $CuCl_2$ L^{-1} as element source. Approximately two weeks after germination, and before exposure to the contaminant, the plants were initially measured, both for height, starting from an average height of 10 cm from soil level in the vase up to the apical bud, as well as for stem diameter. The lot was homogeneous, especially as regards the required coloring of cotyledonal leaves. The experiments took place from November 6th to December 3rd, 2009. The plants were measured once again at the end of the experiment, whereat the diameter of the stem was measured with a common pachymeter, and height and leaf measurements with a meter tape.

Subsequent to exposure and the collection of stem and leaf biometric data, the leaf area index (LAI) were calculated for leaves 1-7 through multiplication of the width by the length, i.e.,.

$$LAI = WIDTH \times LENGTH$$

After the experimental period, the plants were collected from the vases and split up by organ, which were then separately weighed on a digital balance, to so obtain the weights of fresh-matter-mass of the aerial parts and stems. These were then placed in identified paper bags, and subsequently dried at 80ºC for 48 hours (12), thereby obtaining dry-matter-mass values.

Statistical analysis

The process adopted was the statistical analysis of randomized blocks containing one *Glycine max* plant per vase with sand, cultivated from the seedling to the fruit stages. The procedure consisted of seven treatments and four repetitions, with four plants per treatment, thus 112 plants all told. The Tukey test was applied to the averages of the results obtained for all the variables in the $CuCl_2$ concentration, using $P \leq 0.05$ in the SISVAR program.

RESULTS

Rainfall was high throughout the expe-riment, even more so than that registered in the preceding years. According to data furnished by the Astronomy, Geophysics and Atmospheric Sciences Institute (IAG), from University of São Paulo (USP), the average during the months of study was around 25% higher than that registered for the years 1993 to 2002 (Table 1).

Although there were no statistic differences between treatments, there was an enhanced tendency for growth in stem diameter at the end of the experiment. The greatest stem heights encountered at the end of the experiment were those corresponding to treatments T0 and T1, whereas those related to high T6 doses were the lowest (Table 2).

As regards leaf biometrics, over time there was greater differentiation between treatments. Thus, in the case of leaves 1 and 2 (the oldest leaves on the main branch), the lowest LAI values were observed in T3, and the highest in T1, whereas for the intermediate ones (3, 4 and 5), the tendency for development remained the same until T4. Once again, T6 proved to be that which presented the lowest development (Table 2).

Amongst the newest leaves in this experiment, it was observed that, throughout the treatment, and in the case of leaf 6, the doses were insufficient to induce statistical differences, whereas for leaf 7, the tendency was similar to that noted for the remainder. In other words, T6 was the treatment in which the plants presented the lowest growth, and T3 and T4 the highest (Table 2).

Equivalence was observed, as regards values for leaf dry-biomass. Moreover, the same tendency encountered for leaves was also observed for stem-dry-mass, in that treatments with higher concentrations of Cu (T5 and T6) were those in which plants accumulated less dry mass.

Tabela 1. Average values of temperature (°C) and relative humidity (%) of the air, rainfall (mm), number of days with rain, irradiation (MJ/m².dia), and wind velocity (m/s) in the city of São Paulo during the period of culture

Month	October	November	December
Temperature (ºC)	19 (24-15)	23 (29-19)	22 (27-18)
Relative humidity (%)	86 (95-67)	80 (95-56)	84 (95-62)
Rainfall (mm)	138.0	234.4	208.5
Number of days with rain (days)	19	21	22
Irradiation (W/m^{-2})	13.3	17.6	16.4
Wind velocity (m/s)	5.9	6.5	5.8

Tabela 2. Results for mean values and standard deviation of biometric variables in stem height (SH), stem diameter (SD) and leaf area index (LAI), obtained at the end of plant exposure to the different concentrations of copper.

	T0	T1	T2	T3	T4	T5	T6
SH	26.6 ±5.6a	27.1 ±3.8a	23.8 ±2.8a	23.4 ±2.3a	24.5 ±2.7a	23.9 ±1.8a	22.4 ±2.8a
SD	0.4 0.03ab	0.4 ±0.04b	0.4 ±0.04a	0.4 0.02ab	0.4 0.02ab	0.4 0.02ab	0.4 ±0.07a
LAI1	14.1±0.7ab	15.6±1.1b	13.8±2.1ab	13.5±0.2a	15.4±2.2b	15.2±1.5ab	13.3±0.2a
LAI2	14.9±2.6ab	15.2±1.5b	12.9±2.7ab	20.2±13.1a	13.5±0.9ab	13.9±1.1b	12.2±1.4a
LAI3	14.3±1.9b	13.1±2.7ab	12.8±1.9ab	12.4±2.0ab	13.2±1.6ab	12.8±2.4ab	10.9±0.8a
LAI4	14.0±1.4b	13.4±0.7ab	12.9±1.6ab	12.6±1.4ab	12.2±1.6ab	13.2±2.3ab	11.2±1.3a
LAI5	16.6±2.1b	16.3 2.2ab	15.1±1.5ab	16.8±3.1b	17.6±2.8b	16.3±1.4b	14.7±3.2a
LAI6	19.2±1.4a	20.3±4.4a	18.6±1.6a	19.7±2.6a	18.5±1.8a	17.6±2.6a	16.5±3.4a
LAI7	20.2±4.6ab	21.8±0.6ab	18.8±2.7ab	22.0±1.4b	19.5±1.04b	19.4±2.03b	12.6±1.8a

Table 3. Mean values in grams and standard deviation of leaf and stem dry mass at the end of the experiment.

Treatment	Dry Mass (leaf)	Dry Mass (stem)
T0	0.96 ±0.08	1.37 ±0.31
T1	1.10 ±0.59	1.30 ±0.26
T2	1.06 ±0.09	1.07 ±0.18
T3	1.00 ±0.20	1.07 ±0.22
T4	1.23 ±0.17	1.17 ±0.30
T5	1.02 ±0.13	1.02 ±0.19
T6	1.11 ±0.24	1.06 ±0.19

DISCUSSION

Heavy rainfall occurred in São Paulo during the period of plant exposure. As was observed by Bertoni *et al*. (1999), since the element Cu^{++} is extremely prone to edaphic conditions, mainly humidity, this may have influenced the results, as regards percolation, the availability of the element and its interaction with the plant. Variations in chemical attributes in the soil may have induced changes in the micronutrient content, consequently leading to its deficiency or toxicity (3). Hence, results which did not present significant differences, such as the diameter of the stem, the LAI values for newer leaves, and biomass variables, could be explained by this momentarily excessive rainfall, with the consequential washing out of the soil. This was observed by Viera *et al*. (2005), who, on studying the availability of nutrients in the soil, the quality of soybean grains and their productivity in soil manured with sewage sludge, and when evaluating the rates of N in the soil in the first cultivation of the plant, demonstrated that, in the treatment I + L3, the amount of biosolids applied may have induced the loss of N by lixiviation. Thus, seeing that the plants were not exposed under controlled conditions of climatic variables, high percolation of the element in the soil may have interfered in the rates of Cu root absorption.

On analyzing stem heights, it was noted that in the first, lower-concentration treatments, the low doses of Cu^{++} probably functioned as manure, hence with a greater tendency to induce growth. Santos *et al*. (2009), when analyzing the effects of Cu^{++} and Zn^{++} on sorghum cultivated in three classes of soils, obtained different results from those observed with soybean, since stem-heights did not present significant differences between treatments, whereas diameters did, both as regards treatments and the soils in which they were cultivated, thus contrary to our results, whence stem heights were significantly greater in treatments 0 and 1.

With the exception of new leaves, leaf measurements followed the same pattern. It was noted that growth was less in the more concentrated treatments, a possible indication of toxicity, with the consequential prejudice to the development of organs. Copper is a prerequisite for the satisfactory development of the plant, seeing that there is a reduction in leaf area in those with a deficiency or excess of this nutrient (13). According to Anjos and Mattiazzo (2000), in studies with corn in soils enriched with a biosolid (sewage sludge), it was noted that the highest rates of this metal were concentrated in the leaves, even though in this method of fertilization, independent of either the treatment or the soil, this element presented no toxic effects for the plants.

According to Rangel *et al*. (2006), when studying the rates of heavy metals in the leaves and grains of corn on applying sewage sludge, it was noted that of the heavy metals assayed, copper was that which presented rates in the leaf within the range considered to be phytotoxic, although, until the third culture, notably not above the upper range of toxicity. Significant effects of the application of doses of sewage sludge were only observed in leaf-copper-rates in the first LB-culture and the third LF, an indication of the absence of response in leaf-rates with the application of increased doses of the sludge. Another factor which came under consideration, not only by Rangel (2006), but also by several other authors (6, 16), is that Cu^{+} tends to accumulate more in roots than in leaves, thereby indicating that the lower response to the addition of sewer sludge, in terms of leaf-copper-rates, could also be related to the low translocation of this nutrient in the plant.

Dry biomass variables presented no statistic differences between treatments. In a study by Araujo *et al*. (2005) of the effects of a textile sludge compound on seedlings of soybean and wheat, it was observed that the increase in concentrations of the compound above 19 g L^{-1}

caused a significant decrease in total dry-matter-mass, height of the aerial part and root length in those of both plant-species. In the case of soybean, there was a reduction, in relation to the control, of 29% to 34% in total dry-matter-mass, 15% to 36% in the height of the aerial part, and 28% to 67% in root length with the application of 38, 76 and 152 g L^{-1}, respectively. The author emphasized that, although the amount of heavy metals present in textile sludge was in accordance with the values stipulated by CETESB, the decrease in total dry matter could be an indication of the effect of toxicity in the plants induced by heavy metals, especially copper and zinc. Moreover, Araujo *et al*. (2005) also noted that in soybean and wheat seedlings, there was a significant decrease in chlorophyll content, simultaneous with a corresponding decrease in liquid photosynthesis, from the 76 g L^{-1} concentration one.

In a study of the growth and mineral nutrition of *Eucalyptus maculata* and *Eucalyptus urophylla* in concentrations of Cu^{++} (19), it was noted that symptoms of phytotoxicity already appeared in the first five days of the experiment, even at the lowest concentrations, such as 32 and 64 µM of Cu^{++} supplied as $CuSO_4$. As to the aerial part and leaf area, there was a decrease in dry matter at concentrations above 32 µM of Cu^{++}. In studies with sorghum (15), it was noted that doses of 1.07, 1.24 and 1.26 mg/Kg of copper applied induced an increase in dry matter.

In certain studies of toxicity with chlorine, no direct relationship linking the element with effects on growth was observed. In neither of two studies, one involving chemical sterilization with chlorine dioxide in an *in vitro* culture of Anthurium (4), and the other (21), the *in vitro* culture of *Eucalyptus pellita* in a medium sterilized by NaOCl, were toxic effects arising from these solutions observed in plant development. On the other hand, there was a considerable increase, distribution and accumulation of copper and zinc in conifers (*Jatropha curcas*), where copper and zinc chlorates were used as sources of contamination (5). The authors only noted toxicological effects on increasing the doses of both elements, which seems to imply that chlorine itself did not interfere in these effects in the cultivars analyzed, thereby facilitating transposition to the present work with specimens of *G. max*, and thus making it possible to attribute tendencies for growth in plants cultivated in more concentrated solutions, only to copper.

CONCLUSION

With these results, it was noted that *Glycine max* plants can present a tendency for aboveground growth inversely proportional to Cu rates, thereby inferring their sensitivity to high doses of this element.

The plants presented no evident toxicological effects under the parameters analyzed in this study, which can be justified by the possible percolation of the element, as a result of the high rainfall which occurred during the experimental period. It is therefore proposed that new experiments be undertaken with *G. max* and copper under controlled conditions, in order to determine the relationship of toxicity between the element and the development of this plant species.

RESUMO

A soja (*Glycine max*) apresenta-se como sendo uma espécie de grande importância econômica para o Brasil, que é considerado um dos grandes produtores desta cultura. O trabalho objetivou analisar a influência do cobre sobre o desenvolvimento de órgãos aéreos da espécie. Para tanto foi desenvolvido experimento em condições naturais de umidade e temperatura utilizando 112 plantas cultivadas em vasos com areia. Foi adotado um delineamento de blocos casualisados contendo, quatro blocos, sete tratamentos e quatro repetições, que foram irrigadas com solução de Hoagland & Arnon enriquecida com diferentes concentrações de $CuCL_2$ por 30 dias. Após este período foram realizadas análises de variância e teste Tukey, onde se observou que as plantas submetidas ao tratamento 0,9 g $CuCl_2$ L^{-1} (T6) foram as que apresentaram menor crescimento em relação as plantas controles ou aos menores tratamentos. Os valores de massa seca do caule apresentaram equivalência às tendências encontradas na biometria. Conclui-se assim que o cobre em altas concentrações pode influenciar no crescimento de plantas de *Glycine max*.

Palavras chave: soja, biometria vegetal, órgãos aéreos, cobre.

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ENVIRONMENTAL CHARACTERIZATION OF THE LAJEADO TUNAS WATERSHED, RS, BRAZIL

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ABSTRACT

Geographic Information System (GIS), Remote Sensing Imagery and Global Positioning System (GPS) coordinates were employed to characterize landscape structure and land use features of the Lajeado Tunas watershed, Frederico Westphalen, Rio Grande do Sul State, Brazil. Based on data so obtained, two land-cover maps were compiled. These were after compared in order to evaluate the methodology employed. The watershed, spread over approximately 650 ha, is apparently on a mild, east-to-west slope (6.95%). Due to this relative flatness, local conditions are favorable for farming. Notwithstanding, preservation is a prerequisite for controlling erosion and protecting water resources. The land uses mapping has shown how the predominant occupation for anthropogenic usage has exerted negative effects on the quality of the environment and the conservation of biodiversity. Even though only a simple set of GIS tools were used for analyzing the focal landscape, these have helped to arrive at an adequate understanding of the structurally important characteristics of the landscape in a regional context. The results obtained have proved to be of interest for understanding which conservation action is more appropriate for improving the maintenance of local and regional biodiversity, to so guarantee the long-term maintenance of agricultural ecosystems, and, in future analyses, for generating knowledge on how local fauna and flora respond to regional landscape characteristics, the key-points for guaranteeing the maintenance of biodiversity.

Key-words: Environmental Planning, Landscape Structure, Sustainable Management, Geographic Information Systems (GIS)

INTRODUCTION

Increased anthropic action has given rise to important alterations in the environment, with consequential impacts. Among the main aspects of these modifications we can cite the loss of habitat, and the fragmentation and decrease in quality in the remaining areas (4). Environmental planning has acquired pre-eminence over the latter decades, due to the interest in redirecting for consideration, not

only the environments so created and modified by human-kind, but also the remaining, surrounding natural environments.

The growing need to present solutions and strategies, with a mind to interrupting and reverting the effects of environmental degradation and the impoverishment of natural resources, has led to intense questioning, mainly as to (a) how to face the agglomeration of environmental problems detected in large urban centers, (b) how to elaborate and develop efficient strategies for their solution, and (c) how to guarantee the application of such strategies.

In order to respond to such questions, the environmental issue should be analyzed within a perspective that surpasses urban limits. We must take into consideration that cities and human-kind do not exist apart from the natural elements (water, air, soil, among others), but all together compile a natural global system – the planet Earth - on which we have been acting and intervening without concern for the eventual accumulative effects, thus compromise not only the present, but especially, the very future of their own existence. We need to recognize that human-kind subsist as part of this controversy. Thus, on contemplating the principles of landscape ecology, anthropic action should come under consideration throughout all the phases of planning, inasmuch as, if well conducted, better equilibrated alternatives may be arrived at, as means of inducing the sustainable usage of the environment.

Even though each study may present distinct forms of partitioning the space to be analyzed or planned (14), several authors give preference to water basins, in special watersheds, since these constitute minimum units in the environment planning approach, due to the agglomeration of important pertinent components aggregated to their structuring, such as characteristic fauna and flora, besides the drainage itself (3.12).

The management of watersheds involves a process that permits formulating an integrated assemblage of actions on the environment (social, economic, institutional and legal structures of a watershed), in order to promote the conservation and sustainable utilization of prevalent natural resources, whereby the prerequisite of acquiring knowledge on the structure, composition and dynamics of the catchment itself and surroundings.

The Geographic Information System (GIS), within the context of the integrated planning of and systemic approach to watersheds, has been the way of applying the methodology and philosophy of analysis and synthesis of organizational problems and questions related to the environment, with world-wide application in terms of relationships and integration (15). Due to its characteristics of data integration, GIS, together with remote sensing products, functions as probably one of the most adequate tools in support of decision making for systemic-focusing, in the management of natural resources.

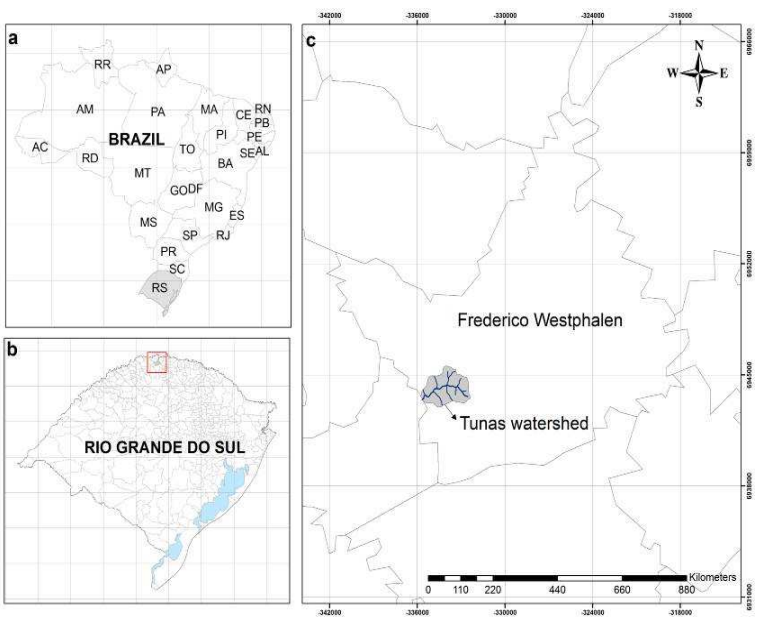

Figure 1 – Localization of the Lajeado Tunas watershed, Frederico Westphalen – RS, Brazil.

Thus, the aim of this study was to apply two methodologies to the analysis and comparison of the land use geographic distribution, as well as to elaborate thematic maps of the study area, with an eye to the environmental characterization of a watershed in the south of Brazil, thereby supplying subsistence for the elaboration of a plan for its territorial management.

METHODOLOGY

Localization of the Study Area

The Lajeado Tunas watershed (Fig. 1) is located in Frederico Westphalen County, Rio Grande do Sul, Brazil, between the parallels 27°22' and 27°33' south and the meridians 53°24' and 53º27' west. It discharges into the Rio Pardo, pertaining to the Rio Uruguay Basin, at around 200 m from the dam of the Companhia Riograndense de Saneamento – CORSAN, thereby contributing to the water supply of the urban area (7).

Frederico Westphalen presents a humid subtropical climate (Cfa), according to the Köppen classification, with average minimum and maximum temperatures of 13°C and 31°C, respectively (8). Annual rainfall, of between 1.800 and 2.100 mm, is well distributed throughout the year (8).

The pattern of drainage in the watershed is dendrite-like, with wide-spreading branches and tributaries at various angles (Howard, 1967). Aluminum-ferric red latosoil predominates in the highest and flattest parts, and neosoils closer to the river mouth (17).

The region of the Upper Uruguay, where Frederico Westphalen county is located, was originally totally covered by Atlantic Forest *latu senso*, composed of deciduous seasonal and mixed ombrophylous forests (17). Based on the biogeographic region delimitation proposed by Silva & Casteletti (2003), the study area corresponds to a transition region between interior and araucaria forests (14). With the introduction of farming, the original native vegetation experienced profound modifications. The present scenario is composed by forest fragments, vegetal cover characterized by the predominance of early secondary forest in various successive stages, diversified farming and other agricultural activities (10).

Methodological procedures

The first step involved the construction of a cartographic base of the study area, using the softwares Idrisi Kilimanjaro (1) and MapInfo (7.8 9), together with information contained in the topographic chart Folha SG.22-Y-C-II-3 MI 2885/3, of Frederico Westphalen, scale 1:50.000, elaborated by the Diretoria de Serviços Geográficos of the Brazilian Army – DSG (IBGE, 1979), and in the LandSat TM 5 satellite image, orbit 223/079, of 8/3/2004 at 13h 12' and 59".

We obtained the watershed delimitation starting from the identification of the corresponding drainage area, or rather that referring to the area drained by the entire fluvial system confined within topographic limits, all projected onto a horizontal plane (21). The perimeter of the watershed consisted of the length of an imaginary line drawn along the water divisors, which in turn coincide with geomorphometric aspects of the region under analysis.

Water bodies and road network were digitized from DSG charts, and complemented with field data obtained with a Garmin 12 GPS. This process allowed us to include roads and other forms of access to rural properties, as well as streams and springs, which do not appear in the official charts.

The ordering of water courses and drainage density were both used to characterize regional drainage. This arrangement, which represents the degree of branching of the system of watershed drainage (23), was defined according to the classification proposed by Strahler (1952), by which, watercourses with no tributaries are considered of the first order, those of the second order only receive tributaries of the first order, independent of the number of tributaries, those of the third order receive two or more tributaries of the second order, although they are also capable of receiving tributaries of the first order, and so on.

Drainage density refers to the efficiency with which rainwater quits the watershed. It is calculated as the relationship between the total combined length of all the water courses present, and the entire area occupied by the system (4).

Hypsometry was elaborated from the interpolation of vectorial maps of the level curves, which gave rise to the generation of a digital elevation

model (DEM). Hypsometry was divided into four different altimetrical classes (400 – 450 m; 450 – 500 m; 500 – 550 m; 550 – 600 m). A clinographic map, elaborated with the aid of models available in Idrisi and using DEM as a base, was applied to classifying the area into five different patterns of declivity (13). Land use mapping was based on the application of two methodologies: (*i*) the supervised classification of satellite images and (*ii*) data obtained in the field with GPS geographic coordinates.

We used methods of image processing, as recommended by Easteman (1998) for the supervised classification of the LandSat TM5 satelite image (bands 3, 4 and 5), thereby simplifying the elaboration of one of the land use maps with Idrisi software.

In this study, the following land use for mapping were defined: (a) *natural vegetation*; all the vegetal forms, as fragment forest, riverine forest and early secondary forest; (b) *agriculture* – areas allocated to annual culture and those with exposed soil in the phase of preparation or implantation of annual cultures; (c) *pasture* - areas with pasture and those allotted to cattle raising; (d) *waterbodies* – water bodies, either naturally formed or reservoirs and ponds; (e) *urban area* – urban lots and rural buildings.

The edition of refinement classification was done with Mapinfo 7.8 software. On completion, the results were introduced into PhotoImpact 4.0 software for the manipulation of images and elaboration of the figures corresponding to consolidated thematic charts.

Geographic coordinates obtained in the field with GPS were used in the second methodology. For mapping the outlines of land use classes in the watershed, area marking was based on the limits of rural properties, urban areas and the main land uses within each rural property. Within the limits that were being investigated and duly registered, each point corresponded to an extremity of the polygon or line that was being mapped.

Simultaneous with the collection of points, a manual outline of the mapped properties was drawn up, this contributing as a source of orientation for elaborating the layers corresponding to differences in land use and occupation, as recognized and identified in the field. Field work lasted for around two months (January and February, 2006), running up to approximately 400 work-hours carried into effect by a team of 2.

The points collected were transferred from GPS to the software GPS Track Maker, and stored in a geographic database. These were introduced into MapInfo 7.8. for the manipulation and development of layers corresponding to the following land use classes: (*i*) *forest* – those with primary or secondary vegetation in an advanced stage of succession; (*ii*) *secondary forest* – areas covered by vegetation in the initial to mid stages of regeneration; (*iii*) *groves* - areas with few trees which do not constitute a forest; (*iv*) *swamp* - flooded areas, generally located near to springs and reservoirs; (*v*) *annual agriculture* – annual cultures and areas with exposed soil; (*vi*) *eucalyptus* – areas for planting eucalyptus; (*vii*) *perennial agriculture* - areas for the plantation of Paraguay tea; (*viii*) *citrus* – areas specifically allotted to producing grapes and oranges; (*ix*) *pasture* – grassland, ultimately used for cattle raising; (*x*) *waterbodies* – bodies of water and artificial lakes (reservoirs); (*xi*) *farms* – small properties, not for farming and without rural installations; (*xii*) *built-up areas* – an area comprising elaborated properties and their respective rural surroundings; (*xiii*) *urban area* – an assemblage of lots with buildings of low standard; (*xv*) *Roads/access routes* – comprising areas for public use (roads, streets, etc.).

RESULTS

The area occupied by the Lajeado Tunas watershed (around 650 ha), with a perimeter of 10.6 km, represented only 2.5% of the total area of Frederico Westphalen county. It was mostly situated in a region occupied by small rural properties characterized as family concerns, which, as such, were strongly exploited as regards natural resources. Orientation was east-to-west, and the main watercourse was around 5 km in extent. The calculated drainage density was 22.3 m/ha.

The watershed itself, comprising an extension of 14.5 km, was drained by a main perennial watercourse composed of 14 springs, three located in the urban perimeter, and the remainder in the rural zone.

The greater part of the watershed was located in the rural zone. The smaller part, which

was in the urban zone, presented a paved federal highway, but only 238 m of which encroached upon watershed limits. Unpaved roads, 22.67 km all told, and characterized as earth roads, also included routes of access to rural properties. We took the drainage density as a base to obtain the density of roads, which was also high (35 m/ha) in the watershed.

The surface of the watershed presented a variation of 200 m in height, between the quotas 400 to 600 m above sea level, the greater part of which (more than 80%) being situated between 450 and 550 m. The two extremes referred to the highest and lowest altitudes, corresponding to 13.3% and 4.1%, respectively, of the whole area.

The biggest part of watershed relief (92.77%) consisted of low declivity areas (0 – 13%), classified as flat, and slightly or moderately wavy. Wavy relief (13 to 20%) occurred in less than 5% of the whole. On the other hand slopes between 20 and 45% were found in 15.57 ha of the whole area, whereas those above 45%, considered mountainous to cliff-like, were not registered. The average declivity was estimated at 6.95%.

Although satellite images interpretation allowed us to classify the study area in five main land use classes, a larger number of classes were diagnosed only through the GPS mapping methodology (Table 1).

(545.69 ha), distributed among 54 small rural family properties, entirely or partially inserted into the watershed. Annual cultures consist of planting corn and soybean, and to a lesser extent, beans and tobacco. Other activities, such as olericulture and fruit culture are also undertaken in some properties, but only for family consumption. Animal breeding is basically restricted to dairy cattle and pigs.

The extension of agriculture diagnosed by GPS mapping methodology occupied 57.63 % of the area and corresponded to annual cultures, including areas of perennial cultures and horticulture, as can be seen in Figure 2. According to field mapping (GPS approach) of this class, this percentage was reduced to 31.56%.

Although eucalyptus, citrus and perennial agriculture were distinguished from annual cultures, their areas were little representative, and occupy only 4.19 ha, 1.87 ha and 2.71 ha, respectively. Other classes lacking in the satellite image mapping, were identified through GPS approach (Figure 3): (*i*) roads/access routes (1.07%); (*ii*) built-up areas (2.97%); and, (*iii*) farms (2.17%). Urban area occupied only 16% of the watershed.

According to GPS mapping approach, pastures occupied 105.2 ha, and natural vegetation around 86 ha. On the other hand, according to image classification approach, pastures occupied 81.89 ha, and natural vegetation was divided in four classes:

Tabela 1. Distribution of land use classes in hectares and percentages of the Lajeado Tunas watershed, based on GPS mapping and LandSat image classifications

Land use classes		LandSat		GPS	
		Area (ha)	Area (%)	Area (ha)	Area (%)
Natural cover	Forest			156.20	24.04
	Secondary forest	86.31	13.29	14.11	2.17
	Groves			5.61	0.86
	Swamp			0.20	0.03
Anthropic cover	Annual agriculture			205.00	31.56
	Eucalyptus	374.41	57.63	4.19	0.64
	Perennial agriculture			1.87	0.29
	Citrus			2.71	0.42
	Pasture	82.53	12.70	105.20	16.19
	Waterbodies	0.09	0.01	5.41	0.83
	Farms			14.10	2.17
	Built-up areas	106.29	16.36	19.28	2.97
	Urban areas			108.80	16.75
	Roads/access routes			6.95	1.07
Total		649.63	100.00	649.63	100.00

The area of the watershed situated in the rural zone corresponded to 84% of the landscape

forest (24.04%), secondary forest (2.17%), groves (0.86%) and swamps (0.03%).

classification, this class was not identified due to the waterbodies being smaller in size than the pixel

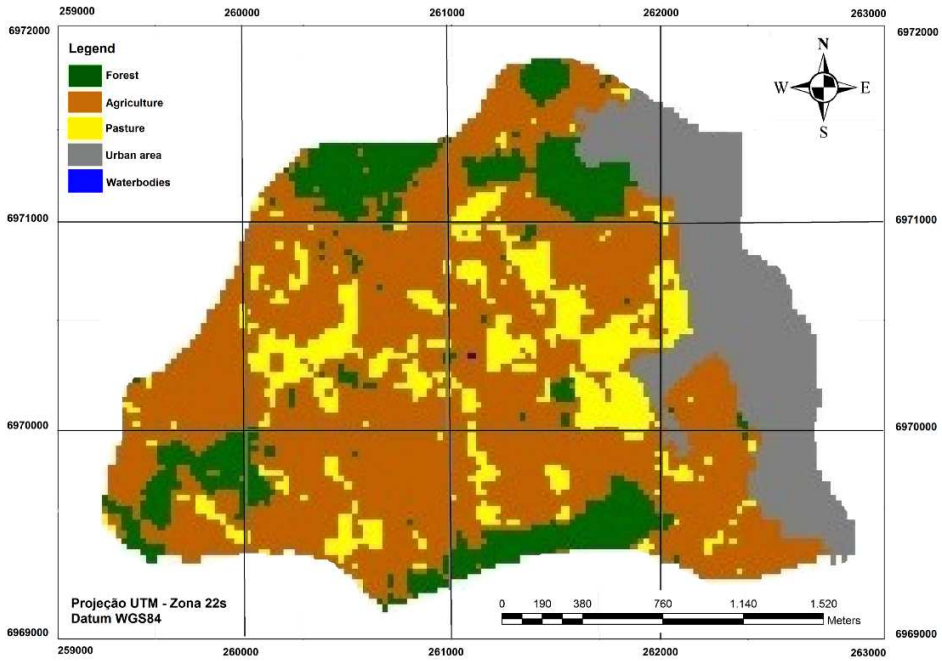

Figure 2 – Chart of land use mapping using LandSat TM5 image classification approach of the Lajeado Tunas watershed, Frederico Westphalen – RS.

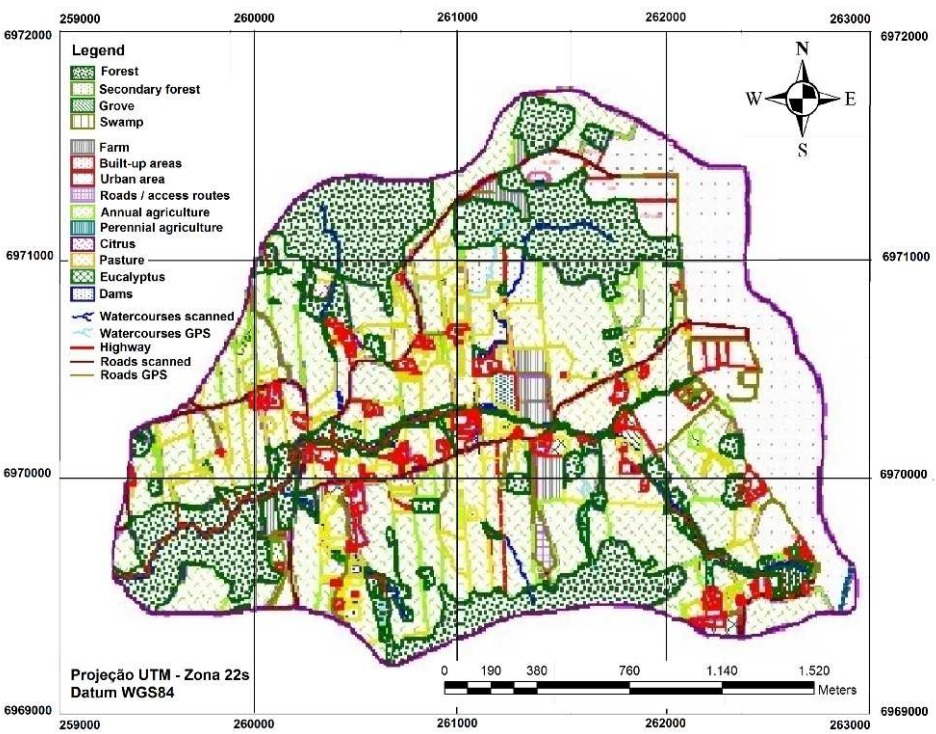

Figure 3 – Chart of land use mapping using GPS field mapping approach of the Lajeado Tunas watershed, Frederico Westphalen – RS.

The class 'waterbodies' corresponded to an area of 5.41 ha in field mapping approach. In image

of the LandSat image employed in the study (pixel = 30 x 30 m).

DISCUSSION

The Lajeado Tunas watershed, classified as of the third order, can be considered a small unit, with high drainage density (4) and thus, with favorable conditions for constraining local intervening factors. This high drainage density means that infiltration is more difficult, with higher surface drainage, and consequently, greater hewing out of permanent channels, due to the hydrological deportment of rocks (2).

The quantification of roads, in relation to the entire area occupied by the watershed, facilitates diagnosing their density. Roads, on one hand, present a positive contribution when considering accessibility among properties. But, on the other hand, they expose natural areas to human presence through easy access, thereby compromising their preservation, both through favoring the entrance of toxic substances, as from the facility in collecting plants and the capture or running over of wild animals (10).

The watershed also presents low average altitude and hypsometric amplitude, factors which influence the amount of radiation received and, consequently, evapotranspiration, temperature and rainfall. According to Tonello *et al.* (2009), the greater the altitude, the less the amount of solar energy that the environment receives, thus resulting in less energy availability. In this sense, the amount of available energy in the watershed can be considered high.

Most of the watershed is considered as appropriate for agriculture, provided that simple steps for controlling erosion are taken. We considered those areas with an accentuated slope as apt for developing annual cultures. However, due to the considerably high susceptibility to erosion in this type of relief, the implantation of this type of culture is conditioned to the implementation of intensive soil conservation techniques. The few areas that present restriction to agriculture due to this high susceptibility, offer adequate conditions for the establishment of permanent cultures such as perennial agriculture and citrus.

Since declivity is intimately related to the distribution of water in a watershed (20), the average slope presented by the watershed plays a significant role in the distribution of water between surface and subterranean drainage, thereby functioning positively in the natural conservation of the drainage system as a whole. Nevertheless, in the present case, signs of erosion in the watershed were observed. This was characterized by ravines in farming areas and gullies along the roads, mainly where there is higher declivity.

As regards land use classification in the study area, image classification was limited, due to low spatial resolution, thereby precluding identification with the same precision as that of some classes mapped with GPS approach. Nonetheless, the classification of this type of image can be an excellent tool when used for larger study areas.

The results obtained from the land use classification permit inferring that the matrix of land use is agriculture, represented by the corn, soybean and tobacco cultivation. These cultures are undertaken with no heed to conservation procedures, thus possibly giving rise to a high loss of soil by erosion.

The divergence among the percentages obtained for the class 'agriculture' in the different methodologies adopted, is possibly related to the period in which the LandSat image classification was obtained, viz., October, as this coincides with a critical period, in which the lowest indices of vegetal cover occur, and when there is a similarity between the coloration of agropastoral cultures and natural vegetation, whereby the spectral response makes identification difficult, especially the case of small forest fragments and secondary forests, which end up being incorporated into the local farming matrix. Besides this, in the GPS approach we could separate annual plantations from the perennial agriculture, eucalyptus and citrus classes.

We believe that roads/access routes, built-up areas, farms, secondary forest, groves, eucalyptus, and swamps, as identified through GPS mapping approach, as well as small forest fragments, were incorporated as agricultural areas in the interpretation of the satellite image. Thus, the difference between the two methodologies of land use classification was significantly increased regarding to the differentiation among distinct land use classes.

It is important to point out that high resolution images are more indicated for small study areas, since they permit the correct differentiation

of various land use classes. However, as the acquisition of this type of image is very costly (1 ha costs around R$10.00 for Quickbird satellite images: spatial resolution = 0.60 m), this can compromise the feasibility of the projects with the required characteristics. Selection of the most adequate image is a preponderant factor in a research project, since there are images available in internet free of charge, as is the case of LandSat images.

GPS mapping approach makes a precise and correct diagnosis, and is also indicated in the study of small areas, due to the intense field work involved. For larger study areas, satellite images are once again recommended, in view of the cost-benefit factor and the rapid task execution, since the difference in results is more significant, regarding to the number of categories in the same class, than in relation to the differentiation between natural and anthropic areas.

Pastures occupy the third largest area, possibly due to the economic importance of dairy-cattle breeding for the region. It is importante to note that pastures, when well-managed, is a form of maintaining the surface of the soil covered throughout the year. This practice reduces the speed of surface drainage, contrary to agricultural activities, which leave the soil exposed during its preparation prior to planting (10). As a rule, animal breeding in the region is developed extensively, with pasture of low productivity. According to field observations, we visualize badly-managed compacted areas, having all the available forage used. The results of these actions let the soil exposed and without protection against the erosive action of rain and wind, and significantly diminishing infiltration and directly affecting the drainage of springs and watercourses.

The difference between the values observed in satellite-image classification and GPS mapping approach is explained by the presence of small areas with pasture, as well as pastures close to or inserted into agricultural areas that possess a similar spectral response, and thus, are not differentiated in satellite-image classification.

Field mapping differentiated vegetation in forest, secondary forest and groves. Forest, that originally occupied all the study area, are mainly located next to springs, accompanying river courses and in areas of high declivity. We considered forest as of fundamental importance in the erosion control and to replenish phreatic water. Accelerated erosive processes prejudice both the environment and society through diminishing the fertility of the soil, and affecting plant growth. They also diminish the capacity of soil water retention, as in near and remote areas, through the drainage of water and sediments, local damage, negative changes in the environment related to floods, the fill-in of rivers, lakes and reservoirs, the contamination of bodies of water, etc.. In such cases, natural vegetation is a potential aid in minimizing these processes (6).

Nevertheless, the area of native forest shows that the watershed represents the conservation status equivalent to the region where it is located. Based on LandSat image classification, Tonial *et al.* (2005) encountered approximately 16% of forest areas in the five water basins located in the northeastern region of the state of Rio Grande do Sul, where the present study area is located. On the other hand, Cemin *et al.* (2009) found a higher coverage (51.96%) of natural vegetation, in a water basin located close to the same study area.

APPs present a large degree of deforestation, as a result of the urban expansion. Thereabouts, the execution of environmental projects should be intensified, as a way of preserving areas where springs occur. We believe this class needs special attention due to the negative impact which can be associated with areas covered by solid material, thereby hindering various physical and biological processes, such as the absorption of rainwater, which normally occur between the soil and the atmosphere. Furthermore, the production of residues and the conversion of areas with natural vegetation into lots constitute two serious recurring problems arising from urbanization (11). Urban expansion should be redirected to locations with more favorable physical conditions, avoiding negative environmental impacts, and so maintain the quality of hydric resources.

We do not identify small watercourses in the image classification due to its scale of 1:50.000, and the pixels size.

CONCLUSIONS

The watershed is considered appropriate for agro-pastural activities, through being on a

plain, and possesses high drainage efficiency, thereby favoring surface drainage and minimizing the aftermath of erosive processes.

Agriculture is the landscape matrix, and thus constitutes the main threat to the environmental quality of the watershed. Farming areas present a lack of adequate management, and require urgent conservation actions, as a means of mitigating the impacts arising from the intense exploitation of natural resources.

Forest recomposition in the study area is imperative, mainly in areas of permanent protection, with the aim of maintaining the ecological functions associated with natural ecosystems, especially the control of erosion and aid in replenishing phreatic water.

The methodologies used for diagnosing the distribution of land use mapping differed, mainly as regards the identification of the different land use classes. Although GPS mapping approach identified a larger number of categories of land use, more time was dedicated to undertaking the task, thereby conditioning the application of this method to small areas. Satellite images of mid-spatial resolution proved to be most indicated in the study of larger areas, due to the adequate relationship cost-benefits.

ACKNOWLEDGMENT

We thank the Universidade Regional Integrada do Alto Uruguai e das Missões – URI – Campus de Frederico Westphalen, and the Laboratory of Geoprocessing for undertaking this work.

RESUMO

Este trabalho analisa o uso da terra e da estrutura da paisagem da sub-bacia hidrográfica do Lajeado Tunas, Frederico Westphalen, RS, Brasil. Sistemas de Informação Geográfica (SIG), imagens de Sensoriamento Remoto e Coordenadas de Global Positioning System (GPS) foram usadas para caracterizar a paisagem e para gerar dois mapas de cobertura da terra, que foram posteriormente comparados para avaliar as metodologias utilizadas. A sub-bacia do Lajeado possui cerca de 650 ha, e os resultados sugerem que o relevo possui declive suave (6,95%), estando orientado de leste a oeste. Devido ao terreno ser ligeiramente plano, a sub-bacia possui condições favoráveis para atividades agropastoris, no entanto, práticas conservacionistas são necessárias a fim de controlar a erosão e proteger os recursos hídricos. O mapeamento dos usos da terra mostrou que a região é predominantemente ocupada por usos antrópicos, que desempenham efeitos negativos para a qualidade ambiental e a conservação da biodiversidade. Embora tenha sido usado um conjunto simples de ferramentas de SIG para analisar a paisagem focal, esses métodos auxiliaram o entendimento de características da paisagem estruturalmente importantes no contexto regional, e os resultados obtidos mostraram-se interessantes para entender quais ações de conservação devem ser usadas para melhorar a manutenção da biodiversidade local ou regional, para garantir a longo prazo a manutenção dos ecossistemas agrícolas, e que, em futuras análises, a compreensão de como fauna e flora locais respondem às características da paisagem regional são os pontos-chave para garantir a manutenção da biodiversidade.

Palavras-chave: Planejamento Ambiental, Estrutura da Paisagem, Manejo Sustentável, Sistemas de Informação Geográfica (SIG)

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STRUCTURE OF AVIAN GUILDS IN A FRAGMENT-CORRIDOR IN LAVRAS, MINAS GERAIS, BRAZIL.

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ABSTRACT

Analysis was centered on avian guild structure of a community of birds in a forest fragment|corridor|farming matrix in the Cerrado, in Lavras county, Minas Gerais, Brazil (21º14'45"S/44º59'51"W). Samples were collected from eight semidecidual forest fragments of 1,0 to 12,1 ha, connected by 5 hedgerow corridors bordered by an adjacent agricultural matrix. Whether the distribution of frequency, diversity and composition of the guilds was similar among the fragments, ecological corridors and matrix. 176 bird species belonging to 44 families were recorded. The main guilds recorded were insectivore, omnivore and granivore. The environments sampled statistically dissimilar guild distribution and composition. Insectivore (68 species) and omnivore (53 species) guilds were predominant. Nevertheless, the average number of species was higher in the matrix and corridors, than in forest fragments. The latter, through functioning more as an efficient way of facilitating the movement of generalist species can mask the reduction in regional species richness.

Key words: birds, forest fragments, avian guilds.

INTRODUCTION

Forest fragmentation, a historical process in the Cerrado biome, increased in the 20th century due to agricultural expansion in the Brazilian center-west. Among the outcomes of the consequential reduction in habitat, a decline in fauna and flora diversity could be observed. Even though there still are natural forest fragments in the Cerrado, it is not known whether the influence of ecological processes is similar to those observed in forest environments of the Atlantic Rain Forest and the Amazon Forest. The impact on tropical ecosystems originating from the fragmentation process has led to alterations in various parameters which, in turn, have given rise to the disappearance of insectivore guilds.(13). Notably, the decline in these guilds in small forest fragments is more strongly related to the capacity for dispersion by way of anthropic matrices than to the low availability of food resources (29).

Research related to forest fragmentation involves the theory of biogeography and metapopulation dynamics (19). The former defines a diminishing in isle surface or as being associated to an exponential decrease in the number of species, and the reduction in relationships (17). The formation of metapopulations is favored by habitat fragmentation, with each species occurring in a fragment, even though these populations can also occur in continuous habitats. The theory of metapopulations has supplanted that of biogeography through its potential to explain the dynamics of populations in fragmented areas.

Forest mosaics or fragmentation can cause profound impacts on species that require large areas for survival. These, known as interior species, tend to quickly disappear in deforested or impacted areas. Meanwhile, under these circumstances, other species adapted to margin or conditions become dominant. Can be maintained through adequate management, to so guarantee immigration from larger contiguous areas (17). From studies dealing with fragmented environments, it can be inferred that parameters, such as area (3), and isolation, exert an influence on the distribution of the flora and the movement of wild fauna (28).

Other ecological aspects of structures, such as, vertical stratification and heterogeneity, comprise important parameters in the determination of environmental avian guild diversity (21).

OBJECTIVE

In the present work, the response of the different avian guilds to the elements of a fragmented agricultural landscape was evaluated. The hypothesis to be tested was that the distribution of avian guild frequency, diversity and composition between forest fragments, ecological corridors and matrix remains unchanged.

METHODOLOGY

Study site

The corridor-fragment studied is located in Lavras county, the Alto Rio Grande region, in the south of Minas Gerais State (21º17'15.1"S/44°58'59.3"W) (Figure 1).

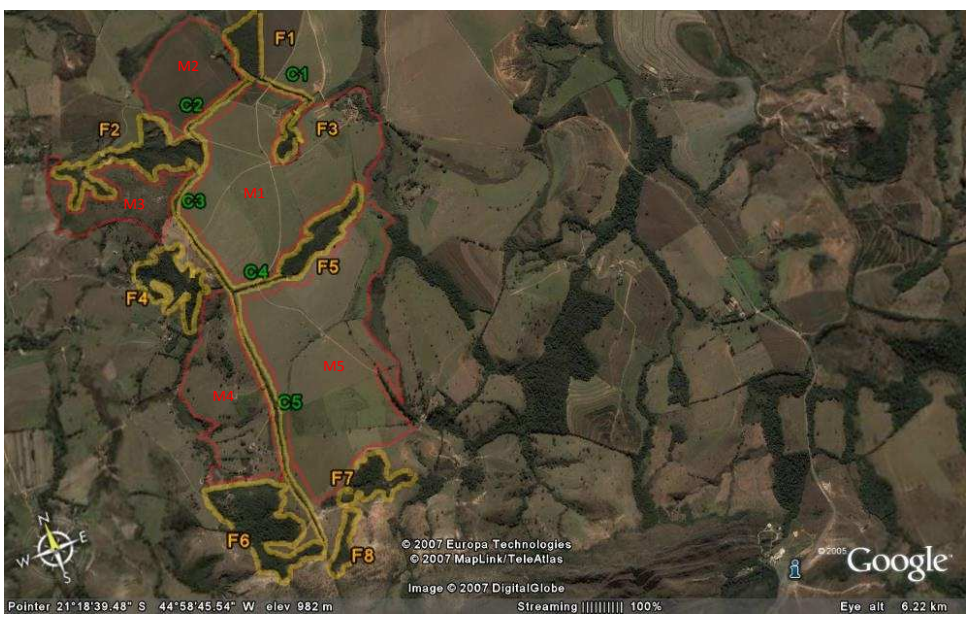

Figure 1. Map of the area studied, Lavras city/Minas Gerais State, at the base of the Serra do Carrapato (Source: http://earth.google.com).

Piratelli & Pereira (2002) emphasized the importance of studying avian guilds, as a source of relevant data on community trophic structures, as well as abiotic parameters. As regards small fragments, even though connected, the be poor, and, with the association of a reduced area. Fire, agricultural defensives, invading vegetal species, etc., the occurrence of populations could become unfeasible, or there might even be the exclusion of certain ecological groups (18).

The study site is located around 6 km from Lavras, on the slopes of the Serra do Carrapato. In all, there are eight fragments (F), interlinked by a vegetal corridor (C) composed of a main axis and four branches (Figure), in which seven of the fragments present an interior river course, within an agricultural matrix (old regional farming properties). The total area of the properties is 51,1624 ha, varying from 1,0302 ha (21º17''51''S/44º59''13''W) to 12,40 ha (21º19''01''S/44º59''47''W). The corridors dealt with in the present study are defined as lineal

vegetal structures of various origins, of reduced width (between 3 and 6 meters), which can be connected to various-sized fragments (6).

In the area studied, it was possible to identify: a) a farming matrix (M), comprising annual cultures, i.e., corn, soybean and beans, among others, planted pasture (*Brachiaria spp.*) for raising cattle, and natural farmland. Through dealing with a fragmented area, the matrix was defined as any farming area, without any form of forest formation, such as forest fragments or vegetal corridors, since, from the beginning of the 20th century, these phytophysiognomies have been gradually substituted by open areas, due to the regional expansion of agriculture; b) corridors of regenerating (30 years) arboreal vegetation occurring in hollows; c) portions of mosaic type habitat, consisting of secondary stage cerrado vegetation in the broad sense, secondary stage man-formed galleries and patches of secondary stage semideciduous forest (6).

The climate of the region can be defined as of the Köppen Cwa type, with an average annual rainfall of 1.529,7 mm, and an average annual temperature of 19,4°C (5). The minimum altitude is 920 meters and the maximum 1.180 meters.

a total of 132 days (924 hours) of field work. Work began at 5:30 a.m. and finished around 9:30 a.m. The visits took place twice a week, at twilight (4:00 p.m. to 7:00 p.m.). One and the same point was visited only once a day. The identification of species and the nomenclature used was according to basic references on the birds encountered in the Comitê Brasileiro de Registros Ornitológicos (2011).

One of the parameters used for studying bird communities in closed environments is the composition of avian guilds (24). Trophic category analysis was applied to understanding bird community composition patterns within the system fragment|corridor|matrix.

For guild characterization, information on the foraging form was used, whence, according to Pimm (1991), guilds could be defined as: Carnivores, Frugivores, Granivores, Insectivores, Nectarivores, Omnivores and Piscivores.

In order to discern the differences in inter-environment guild composition, data was submitted to NMDS (nonmetric multi-dimensional scaling) analysis. Accordingly, the program is applied to calculating similarity among samples, by cartesian grouping of the more similar points, as to guild composition and abundance (7). This method was

Tabela 1. Areas studied within each environment, with the points shown.

Environments	Áreas (ha)	Physiognomy	Successional stage	Points shown	Sampling area (m^2)	Altitude	Coordinates
Fragment Florest							
F1	7,19	Semid seas for	Secondary	8	2513 m^2	965 m	21°17'28''S/44°59'13''W
F2	11,84	Semid seas for	Secondary	8	2513 m^2	971 m	21°17'43''S/44°59'40''W
F3	1,03	Semid seas for	Secondary	8	2513 m^2	977 m	21°17'51''S/44°59'13''W
F4	7,36	Semid seas for	Secondary	8	2513 m^2	973 m	21°18'08''S/44°59'48''W
F5	7,80	Semid seas for	Secondary	8	2513 m^2	977 m	21°18'13''S/44°59'16''W
F6	12,40	Semid seas for	Secondary	8	2513 m^2	996 m	21°19'01''S/44°59'47''W
F7	2,25	Semid seas for	Secondary	8	2513 m^2	990 m	21°19'01''S/44°59'47''W
F8	1,25	Semid seas for	Secondary	8	2513 m^2	1044 m	21°19'13''S/44°59'32''W
Corridors							
C1	0,2	Semid seas for	Secondary	8	628 m^2	960 m	21°17'39''S/44°59'10''W
C2	0,28	Semid seas for	Secondary	8	628 m^2	985 m	21°17'38''S/44°59'24''W
C3	0,44	Semid seas for	Secondary	8	628 m^2	996 m	21°17'58''S/44°59'41''W
C4	0,12	Semid seas for	Secondary	8	628 m^2	991 m	21°18'17''S/44°59'29''W
C5	0,72	Semid seas for	Secondary	8	628 m^2	1002 m	21°18'43''S/44°59'35''W
Matrix							
M1	71,0	Anthropized field	Secondary	8	10053 m^2	985 m	21°17'46''S/44°59'23''W
M2	27,0	Agric cultivation	Secondary	8	10053 m^2	980 m	21°17'33''S/44°59'28''W
M3	24,0	Cerrado	Secondary	8	10053 m^2	997 m	21°17'50''S/44°59'43''W
M4	28,0	Cerrado	Secondary	8	10053 m^2	934 m	21°18'33''S/44°59'53''W
M5	93,0	Anthropized field	Secondary	8	10053 m^2	1022 m	21°18'49''S/44°59'19''W
Total fragments	51,16			64	20104 m^2		
Total corridors	1,76			40	3140 m^2		
Total matrix	243,0			40	50265 m^2		
Total	295,92			144	73509 m^2		

Sampling Planning

The Point (32) Sampling Method, with 10 minutes per point, was used for qualitative and quantitative surveying.

Observations were carried out three times a week, between February and December, 2005, to

basically used to represent differences in guild composition in fragment, corridor and matrix environments. The Bray-Cutis similarity index was used for analysis.

One-way ANOSIM testing was used to statistically verify the differences among groups

formed by NMDS. This is a nonparametric test which, based on Bray-Curtis similarity (7), furnishes a way of testing whether there is a significant difference between two or more groups, according to the formula:

$$R = \frac{r_b - r_w}{N(N-1)/4}$$

r_b average of all the distances among the groups
r_w average of all the distances within the groups
N: samples

The SIMPER (Analysis of similarity of percentages) test was used for examining the inter-environment contribution of each group, according to Bray-Curtis dissimilarity, and to determine the contribution of each to intra- environment similarity (7).

RESULTS

176 bird species belonging to 44 families were registered. The main guilds were comprised of insectivores, omnivores and granivores .

The insectivore guild presented the highest species richness with 68 species (38,0%) in fragment environments. Insectivore species richness was similar to that of omnivores in corridor environments (18 species each {10%}). As to the matrix environment, there was a reduction in insectivore species richness (21 species) in relation to omnivore (23 species). Behavior of the omnivore guild was the contrary to that of insectivores. There was a gradual rise in omnivore species richness matrixwise. In general, granivore species richness was inferior (22 species), followed by nectarivores (12 species), carnivores (11 species), frugivores (10 species) and piscivores (3 species). Distribution in the matrix was different from that of the other environments. In fragments and corridors distribution was more grouped (Figures 2 and 3). In axis 1, the omnivore guild contributed to the overall appearance of the fragment-corridor-matrix grid. In axis 2, there were differences in distribution among fragments, corridors and matrix. Once again, the greater contribution towards these differences came from the omnivores.

Analysis of similarity (ANOSIM) detected

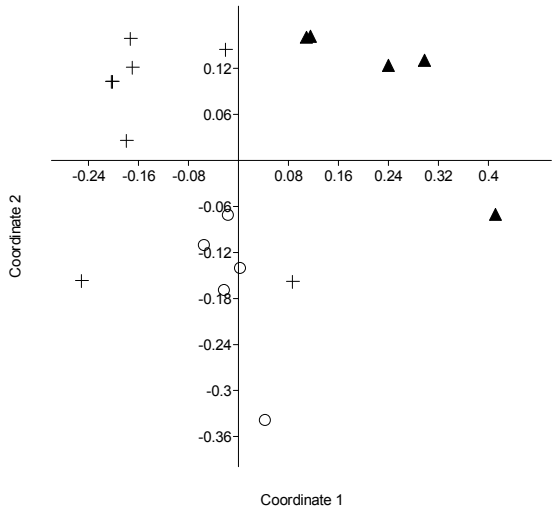

Figure 2. NMDS testing of inter-environment guilds (species diversity) (Symbols: + = fragment; o = corridor; ▲ = matrix).

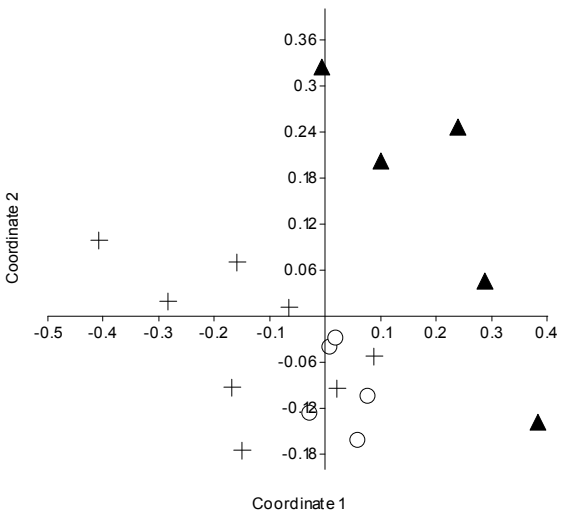

Figure 3. NMDS testing of inter-environment guilds (number of individuals) (Symbols: + = fragment; o = corridor; ▲ = matrix).

significant differences among the inter-environment guilds studied, both by species (r = 0.67, P=0.0001, average dissimilarity =27.4), and individuals (r = 0.53; P<0.0001, average dissimilarity =34.2). Significant differences of guilds among the components of the system were obvious: Fragment and Corridor by species (r = 0.46, P<0.012, average dissimilarity=23.84); by individuals (r = 0.26, P<0.05, average dissimilarity=26.02); Fragment and Matrix by species (r = 0.70, P<0.001, average dissimilarity =29.83); by individuals (r = 0.76, P<0.008, average dissimilarity=42.13); Corridor and Matrix by species

(r = 0.91, P<0.007, average dissimilarity=29.81); by individuals (r = 0.66, P<0.008, average dissimilarity = 35.81). The aim was to evaluate the importance of the guilds (Table 2).

among the three cited environments, with higher average abundance in corridors (106) than in matrices (93.6) and fragments (76.3) (Table 4).

Table 2. Analysis of Similarity (ANOSIM) and the percentage of dissimilarity (SIMPER) of guilds in the different environments.

	Species			Individuals		
Interactions	R	P	Average dissimilarity	R	P	Average dissimilarity
Fragment x Corridor	0.46	0.011	22.84	0.26	0.0448	26.02
Fragment x Matrix	0.70	0.001	29.83	0.76	0.0008	42.13
Corridor x Matrix	0.91	0.007	29.81	0.66	0.0079	35.81

On separating the 3 environments evaluated, viz., fragments, corridors and matrices, SIMPER species analysis showed that the insectivore guild presented the most expressive result, 10.98 (40.44% accumulated). The average abundance of insectivore species was greater in fragments (27.8) than in corridors (14) and matrices (13.6). Omnivores, as the second most abundant guild, contributed with 4.136 (15.23% accumulated). Average omnivore abundance was a little higher in the matrix (19.2) than in fragments (15.4) and corridors (13.2) (Table 3).

DISCUSSION

Among the environments studied, the matrix was clearly dissimilar to fragments and corridors, as regards avian guild structure, frequency and diversity. The guilds with greatest relative importance in the matrix were the insectivore and omnivore, thus corroborating studies on avian guilds in tropical environments (23.9). The greater part of the insectivores registered presented preference for the matrix. In tropical forests, the high percentage of insectivore bird species is common (9,26).

Table 3. Results from similarity analysis (SIMPER) among and within the environments evaluated, using the number of species as an indicator of the importance of a guild.

Guilds	Contribution	% Accumulated	Average abundance in fragments	Average abundance in corridors	Average abundance in matrices
Insectivores	10.98	40.44	27.8	14	13.6
Omnivores	4.13	55.67	15.4	13.2	19.2
Frugivores	3.91	70.09	2.25	0.6	7.8
Granivores	3.01	81.18	7.63	7.8	12.8
Carnivores	2.68	91.06	2.25	1.4	6.4
Nectarivores	2.02	98.5	6.25	8.2	6
Piscivores	0.40	100	0	0	0.8

SIMPER analysis by individuals presented different results from those by species. The omnivore guild contributed with 13.19 (39.3% accumulated) towards distinction the 3 environments (fragments, corridors and matrices) evaluated. Average omnivore abundance was higher in matrices (191) than in corridors (107) and fragments (73.8). Granivores contributed with 9.83 (29.33%) towards distinction

Among insectivore guilds, most were Passeriformes (72.4%), with a predominance of species from the families Tyrannidae (21.7%) and Furnariidae (18.8%). With the exception of insectivores and omnivores, the matrix environment is normally associated to places which offer little attraction to birds in fragmented landscapes (12). There was a reduction in the relative importance

Table 4. Results of similarity analysis (SIMPER) among and within the environments evaluated, by using the number of individuals as an indicator of the importance of the guild

Guilds	Contribution	% Accumulated	Average abundance in fragments	Average abundance in corridors	Average abundance in matrices
Omnivores	13.19	39.35	73.8	107	191
Granivores	9.83	68.68	76.3	106	93.6
Nectarivores	3.31	78.57	21	43.4	21
Insetivores	3.29	88.40	40.5	50.2	23
Carnivores	2.09	94.66	12.1	4.2	22.6
Frugivores	1.69	99.72	6.88	5	16
Piscivores	0.09	100	0	0	1

of insectivore and omnivore guilds, in corridor environments. Corridors, besides contributing towards reducing the isolation of these and other guilds, makes the conservation of diversity in farming areas possible (1). The use of corridors, by way of perches, shelters and food resources (33), facilitates the slightly more efficient distribution of forest bird guilds (11, 14, 16)

Generally speaking, forest fragments presented low insectivore diversity, possibly related to variations in their structure (4). According to Ribon *et al*. (2003) and Develey & Metzger (2005), as habitat-specialist bird guilds are more sensitive to alterations in landscape elements, such as fragmentation, this could possibly account for local extinction. These aspects are thus relevant for enlightenment on the use of the most appropriate landscape elements for each guild. .

As regards matrix environments, normally, omnivore guilds are the most relatively important, followed by granivores. In the present case, omnivore guilds were the most abundant (15.23%). This guild was mainly formed by Passeriformes (75.4%), predominantly by species of the family Thraupidae (24.5%). The greater omnivore density in relation to granivores presumes that alterations in a landscape are capable of inducing structural changes in the environment, which would reflect on local bird-guild abundance. Corroborating Willis (1976), the increase in omnivores is expected in small environments, since omnivorousness would have a buffer effect against fluctuations in the available food supply thereabouts. Habitat structure is a relevant factor in the composition of bird-guild communities in tropical environments (30). MacArthur & Whitmore (1979) noted that, depending on its size, guild diversity in a forest fragment can endure distance from a source and the prevailing habitat structure. As regards the fragment environment, granivore guilds were relatively the most important, followed by the omnivores. Marini (2001) also registered the highest diversity of granivores in small forest patches of the cerrado. On the contrary, in the corridor environment, the omnivore guild presented the highest relative importance, followed by the granivores. In the highly man-formed environments, omnivore guilds were on the increase (23). In the matrix environments, granivore guilds presented the highest relative importance, followed by the omnivores. A guild distribution pattern in relation to the three environments sampled became apparent. This pattern indicated that guilds that are the most adaptable to an environment, and to establishing therein, are those capable of movement among landscape elements (31) (Figure 4). All the environments sampled appeared to undergo direct influence from the matrix. Through being reduced environments (1 to 12 ha), fragments functioned as islands, with the available resources limited to some, less sensitive, groups. Apparently, certain factors, such as original habitat loss and a reduction in remnants (2), are limiting factors to the presence of certain groups.

Guild distribution in the environments under study seemed to be linked to bird community composition and the physical structure of the vegetal mosaic. As to individuals, omnivore and granivore guilds were apparently predominant in corridors and matrices. The low frugivore density could be related to seasonal variation in the offer of fruits, and the dependency on fruits and insects (15). Semi-

dependent insectivore guilds were observed in several fragments and corridors. The capacity of dispersion of these groups was favored by the structure and availability of landscape elements.

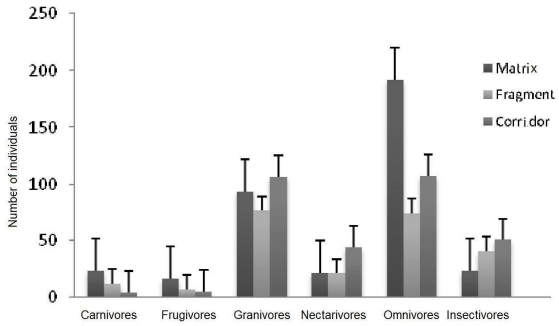

Figure 4. Relative abundance of bird guilds in the three environments.

CONCLUSION

The response of the various avian guilds to the elements of a fragmented agricultural landscape showed the importance of insectivores in the separation of the three environments evaluated, viz., fragments, corridors and matrices. On considering species and individual analysis, it was noted that the distribution of frequency was not the same, the distribution of diversity remained the same, and avian guild composition was not maintained among the three.

RESUMO

Foi analisada a estrutura de guildas alimentares na comunidade de aves num sistema fragmento-corredor-matriz em ambiente de Cerrado, no município de Lavras, Minas Gerais (21o14'45''S/44o59'51''W). Foram amostrados oito (8) fragmentos de floresta estacional semidecidual de 1,0 a 12,1 ha, conectados por 5 corredores ecológicos delimitados por uma matriz agrícola adjacente. A hipótese a ser testada é se a distribuição da freqüência, diversidade e composição das guildas alimentares é similar entre os fragmentos, corredores ecológicos e matriz. Foram registradas 176 espécies de aves, pertencentes a 44 famílias. As principais guildas registradas foram insetívoros, onívoros, granívoros. Os ambientes amostrados são estatisticamente dissimilares para a distribuição e composição das guildas. A composição das guildas é alterada pelos diferentes componentes da paisagem. Houve predomínio das guildas de insetívoros (68 espécies) e de onívoros (53 espécies), de maneira geral. Contudo, a média de espécies da guilda de onívoros e granívoros foi maior na matriz e nos corredores que nos fragmentos. Os corredores ecológicos funcionam de maneira eficiente para o deslocamento de espécies generalistas, fato que pode mascarar a redução da riqueza de espécies na área.

Palavras chave: aves, fragmentos florestais, guildas alimentares.

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Brazilian Journal of Ecology ISSN 1516-5868

EMERGENCE AND GROWTH OF *ATELEIA GLAZIOVEANA* BAILL. SEEDLINGS IN DIRECT SOWING IN AN EARLY SECONDARY SUCCESSION STAGE

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ABSTRACT

Ateleia glazioveana Baill. (Fabaceae), a pioneer tree species from south and southeastern Brazil, reaches a high population density in Seasonal Forests. The aim was to analyze the emergence, growth and survival of *A. glazioveana* seedlings under natural conditions. The experiment was installed in an eleven-year-old post-agricultural site, with herbaceous vegetation in an early stage of secondary succession. The plots measured 2 x 3 m, with four random replications in four blocks. The experimental design was factorial 2 x 2 x 2, in two different conditions of vegetation management (with and without the removal of herbaceous and shrubby plants), two levels of fertilizer (with and without the addition of 33 g/m^2 of NPK 4:20:12), and with and without seed sowing. Each plot received 200 seeds, i.e., 33 seeds/m^2. Dates of emergence and survival were recorded at the second, fifth and twelfth months. Growth data (height and diameter) were obtained after 12 months. Spontaneous emergence was nil. Emergence from direct sowing reached a total of 48 (1.5%) seedlings after two months, and 77 (2.4%) after 12 months, from which 56 survived, viz. 5.833 per hectare. Although the removal of vegetation had no effect on seedling height and survival, diameters were increased. Moreover, differences with the addition of fertilizer were insignificant. The average height was 11.96 cm (± 4.08). Direct sowing was viable. Even so, frost damage after the winter of 2010 was general, thus indicating the possibility of microclimate limitations to recruitment.

Key words: secondary succession, Forest restoration, Semideciduous Seasonal Forest.

INTRODUCTION

Although pre-colonial cover by Subtropical Semideciduous Forest was 1,000,000 km^2, including Brazil, Argentina and Paraguay, nowadays this has been reduced to only 6% of the original area (4). The remnants present high reduction and fragmentation, with an expressive degree of isolation (23).

Forest fragmentation leads to significant modifications in the composition, structure and dynamics of local communities and populations, with a corresponding reduction in species habitat and ecological niche (19). Forest restoration could be helpful in reducing wild ecosystem fragmentation, promoting the improvement of degraded areas, and recovering environmental services. Seedling planting with a combination of tree species from different successional groups, is a frequently used method for restoring forest cover (16, 15, 24). Notwithstanding, direct sowing and spontaneous

regeneration are promising alternatives for minimizing costs, and making restoration feasible from a socioeconomic point of view (10). Direct sowing is particularly recommended for both pioneer and early secondary species, and for sites without vegetal cover. It is also recommended for late successional species in secondary forest enrichment (15).

Secondary succession is the transformation, over time, of the community structure, following a local disturbance (13). The first species to colonize a given site are denominated pioneers. Pioneers are capable of facilitating, hindering, or simply playing a neutral role, in the settlement and growth of other species (9).

Plant population renewal or recruitment presents a series of limitations. These limiting factors can be divided into three groups, namely source and fecundity, dispersion and establishment. The source and fecundity refers to limitations in seed production by adult plants. Such limitations could be related to climate variation (lack or excess of rain, late frosts, etc.) or biotic factors (lack of pollinators and flowers, or fruit predation). Moreover, seed availability, besides being variable year to year, is also affected by landscape structure and the size of neighboring, wild remnant vegetation. Dispersion efficiency depends on the available dispersion agents and propagule quality (8). *A. glazioveana* is wind-dispersed, so that the force, amount and direction of the winds are all determinant for dispersion efficiency.

Establishment factors refer to seedling survival and development. Losses throughout the process could be due to predation, competition or the inadaptability of seedlings to local ecological conditions. In the case of early succession stages in abandoned cropland (old-field succession), competition with herbs and climbing plants could be the most limiting factor for woody species (5). Herbaceous vegetation withdrawal or topsoil removal could improve the germination rates and early growth of woody species (25,12).

Ateleia glazioveana Baill. (Fabaceae), a pioneer tree species in Seasonal Subtropical Forest and secondary forest formations in south and southeastern Brazil, Argentina (Misiones) and Paraguay, is outstanding by its high-capacity to occupy sites with adverse conditions. The fruit is an orbicular, samaroid, indehiscent legume with only one seed that reaches maturity between May and August. Dispersion is anemochoric (6). The species, through association with nitrogen fixative bacteria, provides an excellent green manure. The foliage in dry matter can reach 3.5 to 4.9 % of nitrogen (1). This species, dominant in the first stages of forest succession, remains as a canopy component in the late succession stages and frequently forms spontaneous monospecific stands denominated 'timbozais' in the vernacular (2). Thus, the presence and regeneration of *A. glazioveana* can play a key role in nutrient cycling processes and the recruitment of other species.

The aim was to evaluate spontaneous and induced recruitment through the direct sowing of *A. glazioveana* seeds under various management conditions. The experiment was carried out in an 11-year-old post-agricultural site with herbaceous vegetation in an early stage of secondary succession. The spontaneous emergence of other tree species was also quantified.

METHODOLOGY

Study site

The experiment was carried out in a forest remnant named 'Mato do Silva', in Chiapetta, State of Rio Grande do Sul, Brazil (27° 55' 02" S and 53° 53' 18" W). The climate is SL PU perhumid subtropical, with an average annual temperature of 19 ºC, and annual rainfall of 1,800 mm (17). The altitude ranges between 400 and 472 m above mean sea level. The forest remnant comprises 240 ha of late successional semi-deciduous seasonal forest, and around 50 ha of areas of secondary herbaceous or secondary forest vegetation (2).

The area of the experiment was an abandoned cropland, which after 11 years has become dominated by Poaceae such as *Saccharum villosum* Steud. (dominant), *Schizachyrium microstachyum* (Ham.) Roseng. *et al*., *Leersia hexandra* Sw., and *Calamagrostis viridiflavescens* Steud. Sparse individuals of various woody species also occur, especially *Schinus terebinthifolius* Raddi and *Aegiphila brachiata* Vell. The topographic level ranges between 402 and 403 m above mean sea level (Figure 1). The late successional Semi-deciduous Seasonal Forest begins 100 meters from the 408 m

quota. Physicochemical soil data were provided by UNIJUÍ Soil Laboratory (Table 1).

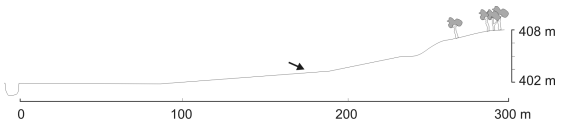

Figure 1. Topographic diagram in a northeast-southwest direction between the Inhacorá River, on the left, and the beginning of secondary forest dominated by *A. glazioveana*, on the right. The arrow indicates the location of the experiment, between the quotas 402 and 403 m above sea level.

Table 1. Soil physiochemical profile in an old-field with secondary vegetation, Mato do Silva, Chiapetta-RS, Brazil, 2009.

pH	P	K	S	Cu	Zn	Mn	Ca	Mg	Al	H + Al	CEC (pH = 7.0)	V %	M %	O.M. (%)
			mg/dm³					$cmol_c/dm^3$						
5.9	4.2	73.0	4.3	8.3	4.9	54.1	7.0	2.9	0.0	4.2	14.6	71.0	0.0	4.0

Experimental protocol

Seeds of *A. glazioveana*, gathered between July and September, 2009, were first cleaned and then stored at room temperature in sealed recipients. It was sowing by casting was in October, 2009, in plots measuring 2 x 3 m. Data on emergence, survival and growth were obtained between December, 2009 and October, 2010. The experimental design was factorial 2 x 2 x 2, under two different conditions of vegetation management, viz., with and without the removal of herbaceous and shrubby plants, with and without the addition of fertilizer, and with and without seed sowing.

The fertilizer used was 33 g/m^2 of NPK 4:20:12. Two hundred seeds, corresponding to 33 per m^2, were sowed in each plot.

Each treatment consisted of four replications distributed at random, one per block. The blocks were located in transverse strips in relation to the slope of the site. The northward-sloping inclination of the site was 2%.

Emergence and survival were recorded after 60 days (December, 2009), 150 days (March, 2010) and one year (October, 2010). After one year, the maximum height and the diameter of the basal portion of the stem were measured with ruler and pachymeter.

Seed germination capacity, determined in a greenhouse in the IRDeR- Instituto Regional de Desenvolvimento Rural (UNIJUÍ), at ambient temperature and in a PLANTMAX ® substrate (a mixture of vermiculite and *Pinus* residues), was 55%.

Statistical Analysis

Considering as experimental factors vegetation removal and the addition of fertilizer, analysis of seedling emergence with direct sowing was by one-factor ANOVA, whereas comparative analysis of maximum height and diameter was by two-factor ANOVA. Seeing that emergence without seed sowing under the prescribed conditions was zero, these experiments were excluded from the analysis.

RESULTS

Emergence only occurred in treatments with sowing (Table 2), thus spontaneous emergence was nil.

After one year, there was no significant difference among treatments as regards emergence or the number of remnant seedlings. The highest emergence rate occurred in the first 60 days, reaching 48 seedlings. After one year, 77 seedlings had emerged (Figure 2), corresponding to a density of 8.021 seedlings per ha.

Table 2. Survivor seedlings (% of seeds) of *Ateleia glazioveana* obtained through direct sowing, Mato do Silva, Chiapetta-RS, 2009-2010. There was no difference at any time among treatments ($P > 0.05$).

	R	RF	NR	NRF	Total
December, 2009	2.1	1.4	0.9	1.6	1.5
March, 2010	0.9	1.4	4.6	0.4	1.8
October, 2010	0.5	1.4	4.9	0.3	1.8

R = removal of vegetation without fertilizer, RF = removal of vegetation with fertilizer, NR = without both vegetation removal and fertilizer, NRF = without vegetation removal, but with the addition of fertilizer

Between 150 days and one year, 21 seedlings (36% of the total emergence) had disappeared, the remaining 56 thus corresponding to a density of 5.833 seedlings per hectare.

As to average height, no difference was observed among treatments, the overall average height reaching11.96 cm (± 4.08).

The average diameter of seedlings in treatments with vegetation removal was higher than those without

removal. There was no significant difference with the addition of fertilizer (Table 3 and Figure 3).

On the 60th day, three seedlings of other species were observed, two of *Eugenia uniflora* L. and one of *Allophylus edulis* (A. St.-Hil.) Niederl. One *E. uniflora* seedling disappeared between 150 days and one year.

In October, 2010, all the seedlings presented signs of frost damage, which caused loss of the shoot apex and the absence of lateral bud expansion.

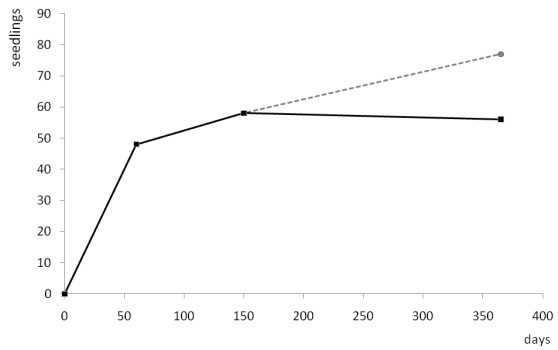

Figure 2. As a sum of all treatments, accumulated emergence (dashed line) and survival (solid line) of *A. glazioveana* seedlings in direct sowing, Mato do Silva, Chiapetta, State of Rio Grande do Sul, 2009-2010.

Table 3. Two-factor ANOVA results for the variable 'diameter'; comparison among treatments R, RF (with vegetation removal) and NR, NRF (without vegetation removal). * indicates $P < 0.05$.

-Source of Variation	Df	Mean square	F	*P*
Interaction	1	1.19	0.834	0.368
Vegetation removal	1	6.25 *	4.375	0.045 *
Fertilizer added	1	0.358	0.251	0.620
Residual	30	1.43		

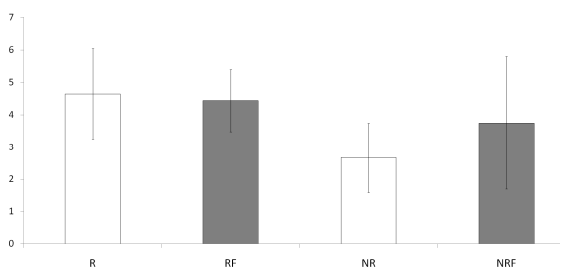

Figure 3. Stem basal diameter (mm) of *A. glazioveana* seedlings after one year of direct sowing in Mato do Silva, Chiapetta, State of Rio Grande do Sul, 2010. Treatments R and RF are with vegetation removal, treatments NR and NRF, without. The gray columns indicate the addition of fertilizer (33 g/m² of NPK 4:20:12). Vertical bars indicate standard error.

DISCUSSION

Seedling emergence only occurred in treatments that received seeds. The absence of spontaneous emergence could be explained by insufficient seed dispersion or high predation prior to initiating the experiment. Furthermore, data on sowed plots showed that emergence continued after 150 days (after April, 2010), a sure indication that the winter of that year was not severe enough to hinder the course of seedling emergence.

Curiously, although local seed rain was apparently insufficient, the production of seeds was high during 2009 and *A. glazioveana* is abundant in the vicinity, reaching dominance above the quota 405 m. a. s. L., 70 m from the experiment (7).

The addition of fertilizer caused no increase in seedling growth during the first year. As a rule, pioneer tree species respond to fertilization with an increase in growth, whereas late successional species respond either weakly or insignificantly (21). To several species, with direct sowing, both in greenhouse (3), and in the field (14), the addition of fertilizers or organic soil increases seedling growth.

The removal of vegetation induced an increase in stem diameter, since the presence of herbaceous plants can reduce light intensity, a possible cause of thinner stems. In spite of such low-light-intensity conditions are capable of inducing an increase in height, damage to the shoot apex caused by the frosts of 2010 supposedly prevented differences among treatments.

Shoot-apex damage, which suggests sensitivity to frost in the seedling stage, could have been a limiting factor to species settlement. The experiment was located 150 meters from, and less than one meter above, the Inhacorá River, thus favorable to the occurrence of subzero temperatures, since cold air tends to move to lower topographic levels (20). The species is considered only moderately tolerant to cold, whereby it presents growth limitations when subjected to heavy frosts during experimental planting (6). Furthermore, as wind intensity can be low in the bottom of valleys, seed dispersion is less and consequently recruitment reduced.

Seedling height after one year of experimentation can be considered low when

compared with other experimental studies with direct sowing. For example: Soares & Rodrigues (2008) recorded a wide variation in the heights of Fabaceae tree species sowed in abandoned cropland, of 30 cm for *Bowdichia virgilioides* Kunth to 3 m for *Acacia polyphylla* DC, after 13 months; Mattei & Rosenthal (2002) registered heights between 29 and 66 cm for *Peltophorum dubium* (Spreng.) Taub., in secondary forest enrichment through direct sowing, after 18 months; Engel & Parrotta (2001) observed heights ranging from 20 cm (*Ceiba speciosa* [A. St.-Hil] Ravenna) to 170 cm for *Schizolobium parahyba* (Vell.),Blake, after two years of direct sowing in Botucatu, São Paulo; Camargo *et al.* (2002),noted heights ranging between 38 and 85 cm for *Caryocar villosum* Aubl., and 20 and 45 cm for *Parkia multijuga* Benth. in Amazonia, after one year of direct sowing; and finally, Ferreira *et al.* (2007) reported heights ranging from 200 to 250 cm after 15 months of direct sowing for *Trema micrantha* (L.) Blüme, *Senna multijuga* (L. C. Rich) Irwin & Barneby, *S. macranthera* (Collad.) Irwin & Barneby, and *Solanum mauritianum* Scopoli.

Data indicate that the regeneration of *A. glazioveana* through direct sowing is viable, even without vegetation removal. On the other hand, the occurrence of severe frosts car hamper species survival and recruitment. Direct sowing, though being a low-cost restoration method, requires a longer period of monitoring, in order to check whether plants can reach sufficient densities, to so establish a viable forest structure.

ACKNOWLEDGEMENTS

To Ilsi Boldrini (UFRGS) for helping with taxonomic identification. To Jorge Schirmer (IRDeR/UNIJUÍ) for assistance in the determination of seed germination capacity. To Andressa Felipin for the English revision.

RESUMO

Emergência e crescimento de plântulas de *Ateleia glazioveana* Baill. em semeadura direta em um estágio sucessional inicial. *Ateleia glazioveana* (Fabaceae) é uma espécie arbórea pioneira que ocorre no Sul e Sudeste do Brasil, alcançando grandes densidades populacionais na Floresta Estacional. O objetivo deste trabalho foi analisar a emergência, crescimento e sobrevivência de plântulas de *A. glazioveana* em condições naturais. O ensaio foi instalado em uma área agrícola abandonada por 11 anos, com vegetação herbácea em fase inicial de sucessão secundária. As parcelas tinham 2 x 3 m, com 4 repetições, em 4 blocos casualizados. O desenho experimental foi um fatorial de 2 x 2 x 2, com duas diferentes condições de manejo da vegetação (com e sem remoção da vegetação herbácea e arbustiva), dois níveis de fertilização (adição de 33 g/m^2 de NPK 4:20:12 e sem adição de fertilizante) e com ou sem adição de sementes. As parcelas com semeadura receberam 200 sementes, o que corresponde a 33 sementes/m^2. O registro de dados de emergência e sobrevivência foi feito aos dois, cinco e 12 meses. Os dados de crescimento (diâmetro do colo e altura) foram obtidos após 12 meses. A emergência espontânea de *A. glazioveana* foi nula. A emergência produzida pela semeadura direta atingiu um total de 48 (1,5%) plântulas após dois meses e 77 (2,4%) plântulas após 12 meses. Destas, 56 plântulas sobreviveram após 12 meses, o que corresponde 5.883 plântulas por hectare. Os tratamentos não diferiram quanto à altura e sobrevivência, entretanto os tratamentos submetidos à retirada da vegetação apresentaram plântulas com maior diâmetro do colo. A adição de fertilizante não gerou diferenças significativas. A altura média das plântulas após 12 meses foi de 11,96 cm (± 4,08). A semeadura direta se mostrou viável, porém todas as mudas apresentaram danos causados pela geada após o inverno de 2010, indicando limitações microclimáticas ao recrutamento.

Palavras chave: sucessão secundária, restauração florestal, Floresta Estacional Semidecidual.

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PLANT RICHNESS IN EXOTIC TREE PLANTATIONS IN RIO GRANDE MUNICIPALITY, RIO GRANDE DO SUL STATE, BRAZIL

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ABSTRACT

The aim was to investigate vegetal richness inside two exotic tree-species plantations, as well as to analyze the influence of light and litter. One of the areas was a 30 ha plantation of *Eucalytus tereticornis* Sm. and *E. robusta* Sm., and the other a 3 ha plantation of *Pinus elliottii* Engelm. In each, twenty-five 5x10 m plots were marked out, so as to investigate the structure of the vegetal community. The presence of tree, bush, epiphyte, climbing and herb species was registered. 25 samples of litter from each area were collected by way of square frames measuring 625 cm². Light intensity was measured in all the plots. Spatial richness and the distribution of species were correlated with the distance from the plantation-edge, litter-disposal and light-intensity. Richness was measured and analyzed according to the number of species. The area of Eucalyptus spp. presented 18 species and that of P. elliottii 14. *Tillandsia aeranthos* Desf. ex Steud., the most frequent species in both areas, was registered in all the plots. In the P. elliottii plantation, richness diminished with the increase in distance from the edge and with the reduction in light-intensity. In both study-areas, the number of species decreased in accordance with the increase of litter. Concomitantly, richness presented a higher correlation with light intensity. The data indicate the need for monitoring and amplifying the intensity of light as a strategy for regenerating vegetal communities.

Key-words: richness, invasive tree species; exotic-species monoculture; *Pinus*; *Eucalyptu*s.

INTRODUCTION

The coastal regions of Rio Grande do Sul State, Brazil, through comprising a varied assortment of environments, such as swamps, salt marshes, dunes and prairies, facilitate the formation of distinct vegetal contions with high plant diversity, herbaceous plants and trees amongst others (15). Recent anthropic activities have caused negative impacts and disturbance. Exotic tree and rice cultivation, cattle raising and real estate expansion are among the human activities accountable for degradation in the southern Rio Grande do Sul coastal region (6, 4). The introduction of exotic-tree species is one of the greatest threats to local biodiversity, through the introduction of pathogens, competition, allelopathy and the formation of physical barriers (19).

Exotic species are defined as those that occur outside the natural and historically known limits, as a result of accidental or intentional human dispersion. Invasive species are those which, once having been introduced and adapted to the new environment, begin spontaneous reproduction and

occupy the space of native species, thereby inducing modifications in ecological processes, reaching to dominance (26). Biological contamination is pointed out as being the second main cause of extinction worldwide, surpassed only by fragmentation and habitat loss (19).

Pinus species, natives of the Northern Hemisphere, are among those with the highest invasive potential worldwide. Around the 1950's, they were introduced into Brazil for pulp production, their culture being largely stimulated by tax incentives. *Pinus* spp. is cultivated in the coastal region of Rio Grande do Sul State for resin production. It is anemophilous and wind-dispersed, with a dispersal range of 25 km. The more than 90% seedling emergence facilitates its adaptation to any ecosystem. Furthermore, it is highly fire resistant. The slow degradation and accumulation of pine needles in layers more than 20 cm deep acidifies the soil (19, 25).

The genus *Eucalyptus*, native of Oceania, was introduced into Brazil at the end of the nineteenth century. *Eucalyptus* species were widely used for railroad sleepers, fence posts, lamp posts, the drainage of bogs and marshes, and as windbreaks. Besides the fast growth rate, their extensive cultivation was much favored by their innate capacity for adaptation to various soil types and fertility levels (13). Since the 1970's, they have been used for pulp production, recently with the inclusion of genetically modified species. In 2000, *Eucalytpus* cultivation occupied an area of 3.0 million hectares of the 4.8 million dedicated to forestry in Brazil (1).

Whereas some authors advocate the importance of planting exotic trees in the regeneration of native vegetation (8, 20, 23), little research has been carried out to measure the impact of *Pinus* or *Eucalyptus* homogeneous plantations on local biodiversity (26, 16, 21), with a complete lack along the Southern Brazilian coastal region.

The aim was to describe the richness and structure of the plant communities inside two exotic plantations, one of *Pinus elliottii* Engelm. and the other of *Eucalyptus tereticornis* Sm. and *E. robusta* Sm. The correlations among litter accumulation, light intensity and plant spatial patterns were also analyzed.

METHODOLOGY

The sites are located on the coastal plains of Rio Grande municipality, Rio Grande do Sul State. According to the Köppen system, the climate is Cfa humid subtropical. The average temperatures are: annual 17.9 °C., in the hottest month 23.3 °C; and in the coldest month 12.7 °C. The average annual rainfall is 1,252 mm, and relative humidity around 80%. The predominant wind direction in all seasons is northeast (18).

Plantations were with 2x3m spacing and with no commercial exploitation. The study took place between April, 2008 and November, 2009.

The nearly 25-year-old *P. elliottii* plantation, within an area of three ha, was located in the campus of the Rio Grande Federal University (FURG), 2 meters above sea level, at the coordinates 32º 04' 58.67" S and 52º 09'21.10"W. The adjacent areas were meadows, urban areas, and other *Pinus* and *Eucalyptus* cultivations.

The nearly 30-year-old *Eucalyptus* spp. plantation, comprising two species, *E. tereticornis* and *E. robusta*, was located in an area of 35 ha in the 6th Industrial District of Rio Grande, within the coordinates 32º 07' 40.54"S and 52º 08'21.60" W, 19 meters above sea level. The adjacent areas consisted of meadows, woody fields, swamps, and a sandbank forest inside a conservation area.

Richness was measured and analyzed through species quantification. Frequency and the number of species were estimated using the fixed-plot method (14). Five demarked areas of 5x50m were each divided into five plots, to a total of 25 plots of 50 m^2 and 1250 m^2 of total sampled area in the two sites. Within each spot, two plots of 1 x 1 m were delimited for herbaceous sinusia sampling. The demarked areas were placed so that the first were situated on the border and those subsequent towards the interior (Figure 1). For herbaceous sinusia, plants smaller than 30 cm high were recorded. For tree sampling, plants with DBH (diameter breast height) $\geq$ 5.0 cm at a height of 1.30 m above ground level were included. All epiphytic plants observed in the plots were recorded, this including hemi-epiphytic species. Terrestrial plants that use others as support were included as climbing plants, together with woody lianas (10). The sample was evaluated through the sample sufficiency curve.

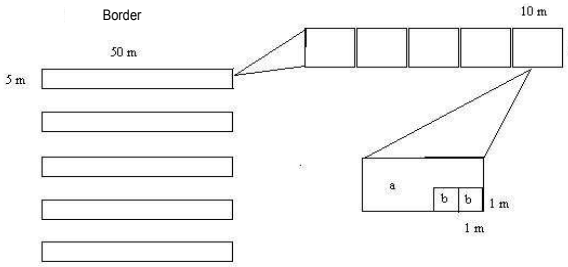

Figure 1 – Distribution of plots in the plantations, 'b' is the sampling spot used for herbs, and 'a' the spot for other sinusiae.

Other species observed inside the plantations, but not encountered in the plots, were registered to so complement the floristic survey.

Species were identified according to the literature, and by consulting herbaria (HURG), experts, the Digital Data Bank of the Brazilian Flora Species Checklist, Flora Brasiliensis, the New York Botanical Garden, and the Missouri Botanical Garden. The delimitation of *taxa* at the family level is according to the proposition for the Angiosperm Phylogeny Group III (3).

Litter was estimated by way of 25 samples obtained by a square iron frame with 25 cm sides. Samples were dried in a stove at 70 ºC, and weighed with a precision balance (15). Light intensity (expressed as μ mol s^{-1} m^{-2}) was estimated with a LI-COR Radiation Sensor in each sampling spot.

The Spearman rank correlation was determined for analyzing relationships between richness, litter and light intensity.

RESULTS

In the *Eucalyptus* plantation, there were 18 species belonging to 15 families (Table 1), two species each from Cyperaceae, Poaceae and Polypodiaceae, and only one each from the others. Sixteen (88%) species were native, one exotic and one cosmopolitan (Table 1).

Tabela 1. Absolute (FA) and relative (FR) frequency of the species recorded in the *Eucalyptus* spp. plantation.

Species (Family)	Life form	Origin	FA	FR
Eucalyptus spp. (Myrtaceae)	AR	EX	100	26,32
Tillandsia aeranthos Desf. ex Steud. (Bromeliaceae)	E	N	100	26,32
Axonopus fissifolius (Raddi) Kuhlm. (Poaceae)	H	N	76	20
Microgramma vacciniifolia (Langsd. & Fisch.) Copel. (Polypodiaceae)	E	N	40	10,53
Eleocharis bicolor Chapm. (Cyperaceae)	H	N	12	3,16
Ficus cestrifolia Schott *ex* Spreng. (Moraceae)	Eh	N	12	3,16
Smilax campestris Griseb. (Smilacaceae)	T	N	12	3,16
Myrsine parvifolia A.DC. (Primulaceae)	AR/AB	N	8	2,11
Pycreus polystachyos (Rottb.) P.Beauv. (Cyperaceae)	H	N	4	1,05
Dichanthelium sabulorum (Lam.) Gould & C.A. Clark (Poaceae)	H	N	4	1,05
Pleopeltis pleopeltifolia (Raddi) Alston (Polypodiaceae)	E	N	4	1,05
Centella asiatica (L.) Urb. (Apiaceae)	H	C	4	1,05
Citharexylum montevidense (Spreng.) Moldenke (Verbenaceae)	AR/AB	N	4	1,05
Lithrea brasiliensis Marchand (Anacardiaceae)	AB	N	-	-
Hydrocotyle bonariensis Lam. (Araliaceae)	H	N	-	-
Senecio brasiliensis (Spreng.) Less. (Asteraceae)	H	N	-	-
Rhipsalis teres (Vell.) Steud. (Cactaceae)	E	N	-	-
Daphnopsis racemosa Griseb. (Thymelaeaceae)	AR/AB	N	-	-

AB= tree; **AR=** shrub; **E=** epiphyte; **H=** herb; **T=** climbings; **N=** native; **C=** cosmopolitan; **EX=** exotic; Eh = hemiepiphyte; - = species observed out the sampling plots.

For *P. elliottii*, there were 14 species belonging to 12 families (Table 2), among which 11 (79%) were native and 3 (21%) exotic. There were two species each from Fabaceae and Myrtaceae, and only one each from the other 10 (Table 2).

In the *Eucalyptus* site, the lowest values for accumulated litter were in the edge plots and the highest in the intermediate (Figure 3), whereas species richness was inversely proportional to litter levels (Figure 3 on left), with r = -0.60.

Tabela 2. Absolute (FA) and relative (FR) frequency of the species recorded in the *Pinus elliottii* plantation.

Species (Family)	Life form	Origin	FA	FR
Pinus elliottii Engelm. (Pinaceae)	AB	EX	100	32,47
Tillandsia aeranthos Desf. ex Steud. (Bromeliaceae)	E	N	100	32,47
Axonopus fissifolius (Raddi) Kuhlm. (Poaceae)	H	N	40	12,99
Acacia longifolia (Andrews) Willd. (Fabaceae)	AR/AB	EX	16	5,18
Schinus terebinthifolius Raddi (Anacardiaceae)	AB	N	16	5,19
Ipomoea cairica (L.) Sweet (Convolvulaceae)	T	N	12	3,90
Desmodium adscendens (Sw.) DC. (Fabaceae)	H	N	8	2,60
Hydrocotyle bonariensis Lam. (Araliaceae)	H	N	4	1,30
Rumohra adiantiformis (G.Forst.) Ching (Dryopteridaceae)	H	N	4	1,30
Sida rhombifolia L. (Malvaceae)	H	N	4	1,30
Syzygium cumini (L.) Skeels (Myrtaceae)	AR/AB	EX	4	1,30
Sapium glandulosum (L.) Morong (Euphorbiaceae)	AB	N	-	-
Myrsine parvifolia A.DC. (Primulaceae)	AR/AB	N	-	-
Eugenia uniflora L. (Myrtaceae)	AB	N	-	-

AB= tree; **AR=** shrub; **E=** epiphyte; **H=** herb; **T=** climbing; **N=** native; **C=** cosmopolitan; **EX=** exotic; Eh = hemiepiphyte; - = species observed out the sampling plots.

The two sites contained four species in common: *Tillandsia aeranthos*, *Hydrocotyle bonariensis, Myrsine parvifolia, Axonopus fissifolius*. Seven woody species were recorded in the two sites, four in the *P. elliottii* (Table 2) and another three in the *Eucalytptus* (Table 1).

Tillandsia aeranthos was present in all the plots in both sites. *Axonopus fissifolius* was the second most common species (Table 1 and 2).

On considering only plots, the *Eucalyptus* and *Pinus* sites presented 13 and 11 species, respectively. All the sinusiae were represented in both areas, with the predominance of herbs (Table 3). Although epiphytes comprised the second richest sinusia in the *Eucalyptus* site, only one was observed in the *Pinus*.

Whereas in the *Eucaplyptus* site sample sufficiency analysis indicated stabilization in the seventeenth spot (Figure 2), in the *Pinus* the absence of a clear stabilization (Figure 2) could be related to differences in richness between edge and interior plots.

Table 3 – Richness and sinusia in the sampling plots on each site

Sinusia	Eucalyptus	Pinus
Herbs	5 (38%)	5 (46%)
Trees	2 (15%)	2 (18%)
Shrubs	1 (8%)	2 (18%)
Epiphytes	4 (34%)	1 (9%)
Climbing	1 (8%)	1 (9%)
Total	13	11

Litter accumulation in the *Pinus* site was higher than in the *Eucalyptus*, and was inversely proportional to the distance from the edge (Figure 3). Furthermore, species richness was inversely proportional to accumulated litter (Figure 3 on the right), with r = -0.87.

In the *Eucalyptus* site, the lowest light intensity was registered in the intermediate plots. There was a significant correlation of richness with light intensity (r = 0.90) (Figure 4 on the left).

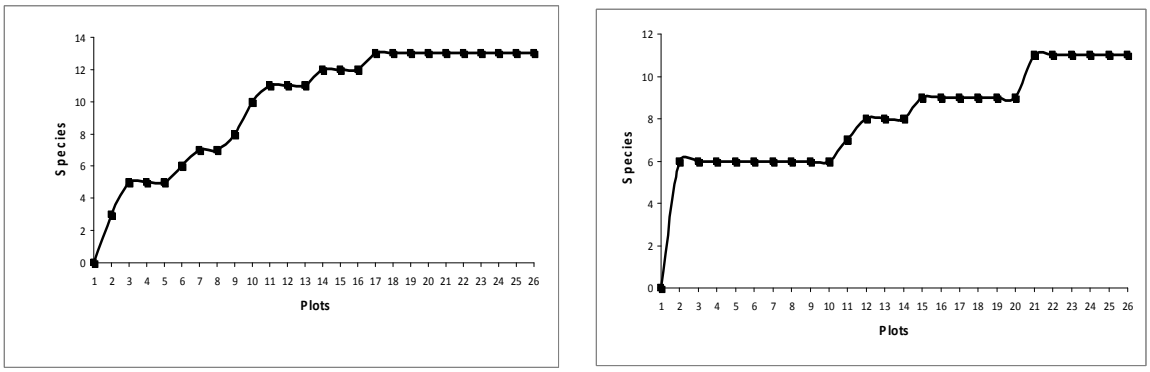

Figure 2 – Cumulative curve of species per spot in a monoculture *Eucalyptus* area (on the left) and a *Pinus* area (on the right).

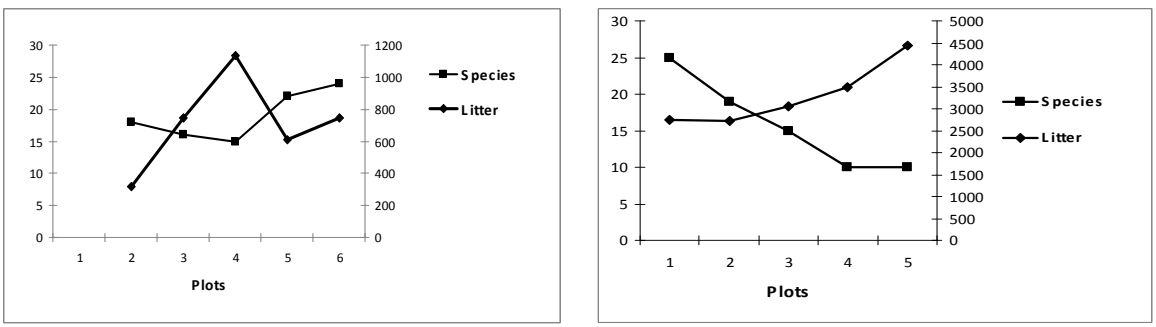

Figure 3 - Relationship between accumulated litter and richness in the *Eucalyptus* plantation (on the left) and in the *Pinus* (on the right).

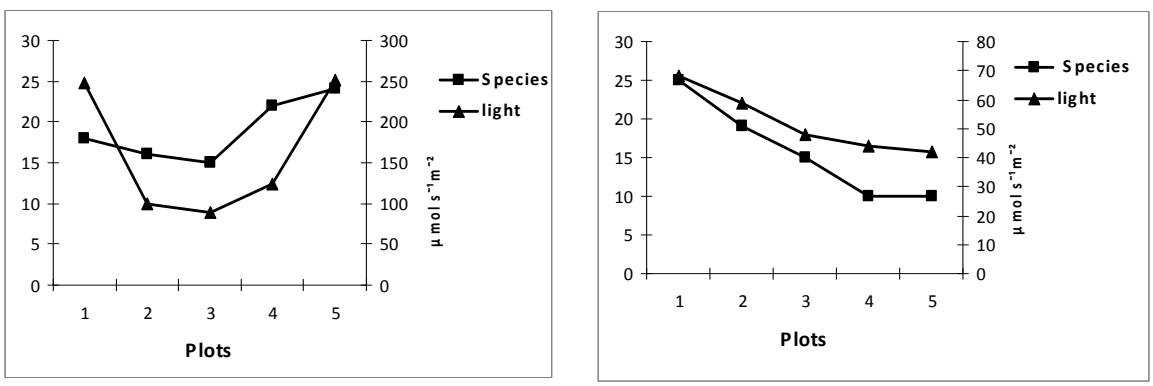

Figure 4 – Correlation between light intensity (triangles) and richness (squares) in the *Eucalyptus* site (on the left) and in the *Pinus* site (on the right).

In the *Pinus* site, light intensity was closely related to distance from the border. This pattern was accompanied by a significant correlation of richness with light intensity (r=0.97) (Figure 4 on right).

DISCUSSION

In spite of difficulties related to differences in method, the richness observed in our study could be considered low for both the *Eucalyptus* and *Pinus* sites, when compared to other inventories in the same or other regions. It should be emphasized that, at the most, no more than one sinusia had been studied in those other inventories.

In native coastal ecosystems, plant richness is normally high, much more so than that noted in the present report. On recording the presence of 78 vascular plant species (including three endangered ones) in the Lagoa Verde Environmental Protection Area, Rio Grande municipality, Batista *et al.* (2007) used this to emphasize the extreme human disturbance in the area. Marangoni (2003) recorded 29 vascular

species in a site in the Lagoa dos Patos estuary. Porto & Dillenburg (1986) registered 151 vascular plants in two forest formations, one in a swamp and the other in sandy soil, located in the Taim Ecological Station. Kindel (2002) reported 158 vascular plants in a swampy forest in Torres municipality, Rio Grande do Sul State. In the Lagoa do Peixe National Park, Záchia (2006) recorded 100 plant species and Dorneles & Waechter (2004) 21 tree species.

Neri *et al.* (2005) recorded 47 species in a *Eucalyptus* site in the Brazilian Cerrado. The authors stressed that such low diversity, when compared to Cerrado diversity in general, could be attributed to shading.

In another similar study in the Cerrado, Saporetti *et al.* (2003) encountered 39 woody species. The authors, on pointing out that Eucalypti hinder the arrival of zoochoric and wind-dispersed native species, proposed *Eucalyptus* girdling and the permanence of dead trees to serve as perches.

Floristic studies of *Pinus* monocultures are few, in spite of species of this genus pointedly possessing high invasive potential and causing local diversity loss (26, 19). Even so, Andrae *et al.* (2005) reported understory establishment of 121 woody-plant species under 25-30-year-old pines in plantations in the Central Region of Rio Grande do Sul State.

Generally speaking, scientific papers refer to *Pinus*, *Eucalytus* and other exotic tree species plantations as 'planted forest', 'commercial planted forest' (23) or 'reforestation' (2). Notwithstanding, a forest is a complex ecosystem, in which, not only one or two, but several species of plants, animals, fungi, protists and bacteria are involved.

Some studies indicate examples of *Pinus* and *Eucalyptus* as facilitating native forest regeneration (23). Nonetheless, the commercial management of such areas implies the use of agrochemicals to control plants, animals, fungi and bacteria, thereby hampering their complete development, whence the origin of the so-called "green deserts". The above mentioned studies were actually developed in non-commercial or abandoned areas of exotic tree plantations, thus where agrochemicals are no longer used, and where fallen trees generate gaps, thereby inducing native plant species development, beginning at the edges. According to light availability, native plant regeneration could further expand to the interior, thus characterizing true restoration.

Nonetheless, even in noncommercial areas, the absence of patches of native forest, in regions with extensive *Pinus* and *Eucalyptus* plantations, could be a hinderance to native forest regeneration, since this requires seeds and propagules originating from other areas.

In the *Pinus* site, it was noted that the lowest plant richness was correlated to the highest litter accumulation, which, in turn, increased from the edges towards the interior. On the other hand, plant richness was positively correlated to light intensity. The scenario was similar in the *Eucalyptus* plantation. As plant richness was more highly correlated with light intensity than with litter accumulation and distance from the border, it can be deduced that a reduction in richness is strongly linked to the prevailing shade. However, the complementary contribution of litter to the decrease in richness cannot be discarded.

Although some authors point to the possibility of regeneration in homogeneous stands of exotic species through shading (2, 16, 21), this would be impossible in old plantations with trees of 30-meters or more in height. Hinderance would be especially stronger for tree species, when considering the observed predominance of herbs and epiphytes. In the *Eucalyptus* area only one tree species presented individuals with DBH $\geq$ 5.0 cm at 1.3 m above ground level, and in the *Pinus*, only one exotic woody species (*A. longifolia*) was observed, whence it is impossible to demonstrate regeneration in a plant community.

Considering the importance of biodiversity conservation, the adequate management of exotic-tree-species plantations, focusing native plant community restoration, requires top priority. This could be achieved through techniques that increase light intensity, such as tree girdling, as also proposed by previous authors (22).

However, the lower diversity found in exotic species monoculture may be due to other factors, such as allelopathy, a phenomenon in which substances released by the leaves and branches of tree species may hinder the development of other surrounding plants (9).

In Canada, Newmaster *et al.* (2006) proposed reforestation with native conifers, as the first step towards rehabilitating conifer forests that had been

converted to agriculture and then abandoned. However, in Brazil, *Pinus* may interfere in plant diversity, since its own regeneration is stimulated in detriment of native plants, insofar as light availability increases (5). On the other hand, abandoned non-commercial plantations that present well-developed understories, could serve as a source of seeds or seedlings for environmental restoration projects, an issue that needs further evaluation in the Atlantic Rain Forest Biome.

CONCLUSION

Plant richness, reduced inside *Eucalyptus* and *Pinus* plantations, when compared to wild environments in the coastal ecoregion, is directly correlated to light intensity and inversely correlated to litter accumulation inside the plantations.

ACKNOWLEDGMENTS

To Adriano Jacobi and Andressa Felipin for the English revision.

RESUMO

Este estudo teve como objetivo investigar a riqueza vegetal no interior de dois plantios de espécies arbóreas exóticas, analisando também as influências da luz e serrapilheira. Uma das áreas foi um plantio de *Eucalytus tereticornis* Sm. e *E. robusta* Sm., com 30 ha. A outra área foi um plantio de *Pinus elliottii* Engelm. com três ha. Em cada área foram demarcadas 25 parcelas de 5 x 10 m para investigar a estrutura da comunidade vegetal. Registrou-se a presença de espécies arbóreas, arbustivas, epifíticas, trepadeiras e herbáceas. Foram coletadas 25 amostras de serrapilheira de cada área com o auxílio de uma moldura quadrada com 625 cm². A intensidade de luz foi medida em todas as parcelas. A riqueza e a distribuição espacial das espécies foram correlacionadas com a distância da borda, a deposição da serrapilheira e a intensidade de luz. A riqueza foi mensurada e analisada através da quantidade de espécies. A área de *Eucalyptus* spp. apresentou 18 espécies e a área de *P. elliottii* 14 espécies. *Tillandsia aeranthos* Desf. ex Steud. foi a espécie mais freqüente em ambas as áreas, sendo registrada em todas as parcelas. Na plantação de *P. elliottii* a riqueza diminuiu com o aumento da distância da borda e com a redução da intensidade de luz. O número de espécies diminui de acordo com o aumento de serrapilheira nas duas áreas. Em ambas as áreas a riqueza apresentou maior correlação com a intensidade luminosa. Os dados indicam a necessidade de monitorar e ampliar a intensidade luminosa como estratégia para a regeneração das comunidades vegetais.

Palavras-chave: riqueza, espécies arbóreas invasivas; monocultura de espécies exóticas; *Pinus*; *Eucalyptu*s.

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Brazilian Journal of Ecology ISSN 1516-5868

THE INFLUENCE OF FEEDING TREE SPATIAL DISTRIBUTION AND FRUIT ABUNDANCE IN THE LOCATION OF SLEEPING TREES IN THE COMMON MARMOSET, *CALLITRIX JACCHUS* (PRIMATES: CALLITRICHIDAE).

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ABSTRACT

Security against predators, the proximity of food sources and cohesion within the group are factors which can have an influence on the localization of sleeping trees in primates. The aim was to investigate the influence of spatial distribution of gum and fruit trees, and the abundance of fruit in the localization of sleeping trees in the common marmoset. Two groups of marmosets living in the Parque das Natal, Rio Grande do Norte State were studied. Instantaneous scan sampling was used to register, at 5 minute intervals, their position on maps of the area, and to identify the localization of sleeping trees. Frequency of use of the same trees was also recorded. The species of trees used for fruit consumption, the extraction of gum and for sleeping were identified. Phenological data were collected monthly to determine the periods of fruit abundance. Sleeping trees were randomly distributed, without any apparent relationship to the aggregated distribution of gum and fruit trees. 38, Nonetheless, the abundance of fruit seemed to be an important factor in the use of space and in the localization of sleeping trees. Both, the presence of potential predators and the nonconsecutive use of sleeping trees, seem to indicate protection against predators as being another important factor in the localization of sleeping trees in the study-area.

Key words: common marmoset; sleeping trees; food sources; predators

INTRODUCTION

Arboreal primates typically sleep in trees. They use either the forks of branches, holes in the trunk (38, 43) the surface of leaves (23, 47, 5), nests they themselves build (26) or even bird´s nests (29) in the process.

Predator risk has been defined as the main determinant in the location of sleeping trees (15, 25, 22, 1, 17, 7, 3, 37). Nevertheless, other variables, such as the proximity of food and water resources, ranging patterns and territoriality aspects, security from falls, physical comfort, hygiene, parasite avoidance, group cohesion, resource availability and thermoregulation, are also important (16, 20, 44, 4, 23, 1, 3, 27, 14, 5).

Some species of primates (e.g. *Ateles geoffroyi* (11), *Colobus guereza* (46), *Hylobates pileatus (36), Saguinus fuscicollis* and *S. mystax* (40), *Trachypithecus leucocephalus* (28) prefer to sleep close to available food resources. The strategy to wake up close to food, decrease the time and energy spent in foraging. Apparently, in the case of these species, this factor is more important than sleeping in safety against predators.

The common marmoset (*Callitrix jacchus*) is a primate species endemic to the Brazilian northeast. Although its distribution was originally

restricted to this part, introduced populations can now be found in other regions of Brazil (43). It is now found in Atlantic Forest fragments, in the Caatinga (21), and in mangrove swamps (32). Through its adaptability to various environments, by living in the Atlantic Forest, this species inhabits one of the most threatened biomes in the world. This biome has been extensively transformed into a fragmented landscape (35), through convertion to alternative land usage, such as agriculture and pasture (45). Incidentally, several studies of small fragments of this forest have reported on the proximity of trees that serve for sleeping to feeding trees (1,8).

OBJECTIVES

Under this perspective, the aim was to investigate the influence of gum and fruit tree spatial distribution, and fruit abundance in the location of sleeping trees.

METHODOLOGY

Study area

The study took place in a conservation area, in the Parque Estadual das Dunas (PED), in northeast Brazil (5° 48' S – 35° 12' W). PED comprises a 1.175 ha fragment of the Atlantic Forest, 7 ha of which corresponding to a public area (24). There are large trees, extensive plant cover, a vast and continuous canopy, and high epiphyte density. With an idea to conservation, access is restricted to research and educational trails, with daily, though partial, monitoring.

The public area, with many exotic plants and gaps, harbors around a thousand tree species. There is also a touristic infrastructure for receiving more than 2.000 people daily. Each year, about 65.000 visitors find entertainment in the structure of the park itself, walking trails and picnicking, or simply by enjoying nature.

There are records of the presence of boa constrictors (*Boa constrictor),* black vultures *(Coragyps atratus),* turkey vultures *(Cathartes aura),* roadside hawks *(Buteo magnirostris),* great black hawks *(Buteogallus urubutinga),* white-tailed kites *(Elanus leucurus*), and the southern carcara *(Polyborus plancus)* (24), all liable *Callithrix jacchus* predators.

Data collection

From January to December, 2007, two groups of common marmosets (A and L) came under observation. Both inhabited the public area, and only used the forest area sporadically. In the former, there are trees conducing to fruit and gum consumption, and sleeping. Both groups were accustomed to the presence of researchers, and had already undergone capture and individual identification in previous years.

Instantaneous scan sampling (2), at 5-minute intervals, was chosen for recording the location of the marmosets on area maps containing alphanumeric system 20x20m quadrants, and for identifying the location of sleeping trees. These data also constituted the base for calculating the home range of each group, obtained as a sum of the quadrants visited. Frequency-of-use of sleeping trees was recorded, to so determine the proportion of use, by plant species.

The tree species turned to use for fruit consumption, gum extraction and sleeping, were identified taxonomically by on-the-spot floristic studies (18). Phenological data were collected monthly to determine the peak periods of fruit abundance. Fruiting was quantified using the semi-quantitative method (19), whence five classes of abundance are inferred, 0) absence of fruit; 1) 1-25% of fruit; 2) 26-50% of fruit; 3) 51-75% of fruit; and 4) 76-100% of fruit (19). Sleeping trees were identified, and measurements taken of height and diameter at breast height.

The distance from the nearest neighbor (R) was used to define spatial patterns of gum and fruit tree, and sleeping tree distribution. R=1 indicates random distribution; R>1 uniform distribution, and R<1 aggregated distribution (12). The frequencies of monthly marmoset visits recorded for each quadrant in the home range were compared through one-way ANOVA (5%) and Tukey testing (5%). Spearman correlation analysis was used to investigate the relationship between frequency of use for sleeping and tree-height, frequency of use for sleeping and diameter of sleeping trees, and sleeping-tree height and diameter.

RESULTS

Eight different trees belonging to five species were used for sleeping. *Coccoloba* sp. (Polygonaceae); *Bowdichia virgilioides* HBK, (Fabaceae); *Cassia apoucoita* Aubl. (Leg. Caesalpinoideae) and *Pouteria grandiflora* (Sapotaceae) were used by group L, and *Coccoloba* sp.; *Buchenavia capitata* (Combretaceae) and *Pouteria grandiflora* by group A. Diameters at breast height (DBH) ranged from 28.3 to 236.82 cm, and heights from 12 to 24 m (Table I).

No significant correlations were found between DBH and height of sleeping trees (r=0,02; p=0,95 N=16), DBH and frequency of use of sleeping trees (r=-0,09; p=0,82; N=16), and height and frequency of use of sleeping trees (r=0,59; p=0,12; N=16), whereby the inference of other variables influencing choice.

Gum trees were located between 10 and 42 meters from sleeping trees, whereas fruit trees were between 8 and 27 meters away. Of the eight trees used by groups for sleeping, two were located at the edge of the main forest (n=3) and six in the public area (n=26) between 20 and 80 meters from the main forest edge (Table I). Sources of fruit, gum and sleeping trees were distributed over the 0.94 ha $\pm$ 0.4 ($\pm$ standard deviation) and 1.3 ha $\pm$ 0.7 ($\pm$ standard deviation) areas, corresponding to the

Tabela 1. Identification of species, height and location of sleeping trees by groups of common marmosets.

Species	**Nº**	**Height**	**Records of use as sleeping trees (n)**	**Location**
Coccoloba sp.	1	12 m	3	Public area
Coccoloba sp.	2	14 m	5	Public area
Bowdichia virgilioides	3	17,5 m	4	Public area
Bowdichia virgilioides	4	24 m	6	Public area
Cassia apoucoita Aubl.	5	20 m	1	Edge of remnant
Coccoloba sp.	6	18 m	3	Public area
Buchenavia capitata Eichl.	7	17 m	2	Edge of remnant
Pouteria grandiflora	8	22 m	5	Public area

For sleeping purposes, Group L showed a preference (50)% for *Bowdichia virigiloides*,, whereas Group A preferred (75%) *Coccoloba* sp.. Although re-use of sleeping trees was detected on several occasions, this did not occur on consecutive days.

Table 2. Fruiting periods and location of trees used by groups L and A for fruit consumption. Where PA = Public area and F = Forest

Family	**Species**	**Fruiting**	**Group**	**Location of fruit trees**
Cecropiaceae	*Cecropia adenopus*	February to March	L	PA/F
Myrtaceae	*Campomanesia dichotoma*	March and April	L/A	PA/F
Myrtaceae	*Hexaclamys itatiaiae*	January, February and March	L/R	PA/F
Poligonaceae	*Coccoloba* sp.	February and March	L/A	PA/F
Boraginaceae	*Cordia superba*	January	A	PA
Rhamnaceae	*Zizyphus joazeiro*	December and January	A	PA/F
Myrtaceae	*Sizygium jambolanum*	January, February, March and April	A	PA
Anacardiaceae	*Anacardium occidentale*	November, December, January	L/A	PA
Anacardiaceae	*Mangifera indica*	December, January and February	A	PA
Myrtaceae	*Eugenia malaccensis*	December	A	PA

home ranges of groups A and L, respectively.

The fruit consumed by both groups came from ten tree-species with overlapping fruiting periods (Table II). There were significant differences in the frequency of monthly visits to the various quadrants, mainly as regards group A (F=3.48 df= 4; p=0.01). Visits were significantly higher in January, February and March, when a higher number of fruiting species was recorded. Most visited quadrants were those containing fruiting trees, with overlapping where at least one sleeping site was located. Trees for fruit consumption and gum extraction were distributed in the aggregate (R_A=0.78 and R_L=0.71), and sleeping trees randomly (R_A=1.27 and R_L= 1.23).

Despite the presence of marmoset predators, no actual predation was recorded in the study area. Nonetheless, marmosets were vigilant on a number of occasions. Upon perceiving a great black hawk (*Buteogallus urubitinga*) in flight, they vocally warned other members of the group, before hiding behind branches and foliage.

DISCUSSION

In the present study, gum and fruit trees were distributed in the aggregate and sleeping trees randomly. Aggregate distribution signifies the individual tendency to stay together at particular sites in the environment, whereas in random distribution, there is the likelihood of individual disposition at any point whatsoever (13). On the other hand, distances between gum, sleeping and fruit trees were short, to so facilitate marmoset locomotion to neighboring areas when searching for food, thereby reducing overall travel costs. A similar pattern has already been noted in several primates, such as *Ateles geoffroyi* (11), *Saguinus mystax* and *Saguinus fuscicollis* (23) and *Callithrix jacchus* (33).

The home range of primates from the *Callitrix* genus varies from 0.5 to 5 ha, with C. *jacchus* presenting the smallest ever recorded. The home range in this case is closely related to the distribution pattern of gum and fruit trees (38). The aggregate-type pattern of both justifies the establishment of two small territories wherever they occur. Above all, even though *C. jacchus* requires a minimum area to survive, the adequate availability of gum trees is essential (39).

Differences in visit-frequency to quadrants in the home range, clearly shows the influence of fruit abundance on space-use patterns and sleeping-tree location. The strong influence of gum trees and fruit abundance on the use of space, is especially manifest in groups of marmosets living in forest remnants or orchards (9)

Common marmosets may sleep in trees with or without dense foliage or epiphyte cover (1, 33), high up in palm trees (30), or much lower in the canopy (8, 33). The sleeping trees used by marmosets in the PED area were robust, with DBH ranging between 28.3 and 236.82 cm, and heights ranging from 12 to 22 m. They slept in the forks of branches, where group members aggregated in a ball-like formation. This behavior probably serves to confuse possible predators through taking on the appearance of either a much larger animal or even a termite nest (16). According to an early study, the sleeping trees used by *Callitrix flaviceps* varied in height from 8 to more than 20 m. Through being densely overgrown with climbers, they were relatively isolated from the surrounding vegetation, thus offering safe sleeping-quarters for the group members huddled together in a large ball (17).

There are many potential marmoset predators in the PED. A study of an area where predators had been eradicated demonstrated that sleeping trees were located in the sites of highest feeding-tree concentration (33). Regardless of its structure, the authors considered that the key variable defining sleeping-site location was the availability and location of immediate food sources. In the present study the availability of food, especially fruits, was more important than the location of their sources.

Although there are no records of common marmoset predation in PED, their response to potential aerial predators, such as the black hawk (*Buteogallus urubutinga*), presupposes that marmosets are capable of recognizing the characteristic flight profile of falconiforms, with the consequential and immediate reaction through avoidance. This response to potential aerial predators has been recorded in *Callitrix jacchus* (29), and *C. flaviceps* (17). The loud alarm call sometimes elicits a response from other group members, while in the act of taking cover and remaining completely

motionless. On taking cover at relatively low levels in the forest, the animals normally move to the underside of the supporting branch by way of a rapid lateral movement. Other studies have recorded a collared forest-falcon (*Micrastur semitorquatus*) predating an adult marmoset (1), a roadside hawk (*Rupornis magnirostris*) predating an infant (29), and an unsuccessful attempt on a group (8).

Earlier studies identified aspects related to the structure and location of sleeping trees in areas where predators were present. Totally hidden by a dense entangled mass of lianas, climbers and epiphytes (1, 43, 6,17), and located at the edge of the forest, bordering open fields (42, 41), they were distributed throughout the home range, and remained without use for several successive nights (41). This is in accordance with the present findings, in that the sleeping trees used by both groups in PED were close to the forest edge and not used on consecutive days.

Sleeping tree location is crucial for survival where predation risk is high, albeit less so, where predators are extinct (33). In the latter case, daily-food acquisition, rather than predators, would be the limiting factor. In the case of PED, and in spite of the importance of fruit abundance in space-usage and sleeping-tree location, the local presence of predators, and the non-consecutive use of sleeping trees, point to protection as an important factor in the location of sleeping trees among marmosets.

Differences in these results and those obtained in earlier studies (31, 8, 34, 33) reveal diversity in the strategies adopted by the common marmoset to selectively locate sleeping trees under the prevailing circumstances.

CONCLUSION

This study offers important contributions to an understanding of the prevailing strategies among primates, when selectively locating sleeping trees. Location, as employed by two groups of marmosets in the Parque das Dunas, was not influenced by the distribution pattern of gum and fruit trees, but by fruit abundance and the presence of potential predators, thereby showing the relationship between the strategy adopted and the type of pressure encountered. Finally, the understanding of resource distribution and sleeping tree location, perceptibly furnishes relevant factors towards the conservation of primates, in that their correct management could contribute to primate population viability.

ACKNOWLEDGEMENT

We are grateful to Mary Savage Praxedes and Alexandre Gusmão, managers of the Parque Estadual das Dunas, for permission to carry out this study in the Conservation area, as well as to the Instituto de Defesa do Meio Ambiente do Rio Grande do Norte (IDEMA) for financial support.

RESUMO

A segurança contra os predadores, a proximidade das fontes de alimento e a coesão do grupo são fatores que podem influenciar a localização de árvores de dormir em primatas. Este estudo objetivou investigar a influência da distribuição de árvores de goma e de frutos e a abundância de frutos na localização das árvores de dormir dos sagüis. Dois grupos de sagüis que vivem no Parque Estadual das Dunas, em Natal, RN, foram estudados. A varredura instantânea de amostragem foi utilizada para registrar a cada 5 min a localização dos sagüis nos mapas da área e para identificar a localização das árvores para dormir. A freqüência de uso de árvores para dormir foi registrada. As espécies das árvores utilizadas para o consumo de frutas, extração de goma e dormitório foram identificadas, e os dados fenológicos foram coletados mensalmente para determinar os períodos de abundância de frutos. As árvores de dormir estavam distribuídas aleatoriamente, aparentemente não possuindo relação com a distribuição agregada das árvores de goma e de frutos. No entanto, a abundância de frutos se apresentou como um fator importante na utilização do espaço e na localização das árvores para dormir. A presença de pontenciais predadores do sagüi, e o uso não-consecutivo de árvores de dormir apontam a proteção contra os predadores como um outro fator importante na localização das árvores de dormir na área do estudo.

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Brazilian Journal of Ecology ISSN 1516-5868

ENVIRONMENTAL IMPACTS CAUSED BY ROADS AND TRAILS IN THE ALTOMONTANA PRIVATE RESERVE, ITAMONTE, MINAS GERAIS.

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ABSTRACT

The adequate planning and management of highways contribute to reducing environmental impacts. In conservation units, the evaluation of possible environmental impacts caused by roads has facilitated the adoption of preventive action, with a view to avoiding biodiversity loss. In this sense, impacts caused by roads and trails in the Altomontana Private Reserve, Itamonte, Minas Gerais State, Brazil, were assessed, as a means of obtaining information for improving road and trail management in the unit, as well as mitigating those impacts that generate local environmental degradation. Internal roadways of the property were scoured, and points along the altitude gradient marked. A grading impact array was used for standardizing observations. Marks of 0 to 3 were attributed to characterizing the intensity of impacts, with positive or negative signs added, according to the type of impact. Among the observed environmental impacts caused by roads, erosion, the most outstanding variable, occurred at all altitudes, with discarded waste as runner up. All told, local vegetation appeared to be well-conserved, with the variation in altitude favoring the formation of various physiognomies, thereby constituting an appropriate environment for developing local community activities as part of environmental education programs.

Key words: Environmental impact assessment; roads; conservation unit.

INTRODUCTION

The divulgation of environmental damage by organizations dedicated to the protection of the environment has contributed decisively towards consolidating the Evaluation of Environmental Impacts (EEI), as a tool for registering data applied to measuring the consequences arising from anthropic activities in natural ecosystems, and as a forerunner of means for taking the necessary steps towards maintaining the quality of the environment (22). Following the United Nations Conference on the Environment, in 1972, there have been modifications in the policies for development and economic intervention, which are no longer exclusively orientated by economic-financial parameters. From there on, environmental and socio-economic questions have also been inserted (9), thereby leading to the publication of literature specialized in evaluation and reports on environmental impacts (25, 23, 17).

Around this time, the EEI turned up in Brazil, as a prerequisite for financial research by international organizations (24). Subsequently, this was inserted into the National Policy for the Environment (NPE), regulated according to the Federal Law 6.938/81. This later became obligatory on licensing processes involving polluting activities or those modifying the natural environment (22). The advance in the protection of Brazilian ecosystems continued with the Federal Law 9.605|98. Law of Environmental Crimes (5), and the Federal Law 9.985|00, which instituted the National System of Nature Conservation Units (6) thereby establishing criteria and norms for the creation, implantation and management of Conservation Units (CU). Among these, and within the group Sustainable Use, the Private Reserve of Natural Patrimony (PRNP) is a private area which aims at perpetually conserving biodiversity, and, according to article 21, permits scientific research, as well as tourism, recreation and educational visits.

The evaluation of impacts caused by roads is a recent line of research, and over the past few years, studies have been developed with the aim of acquiring knowledge on the possible effects on ecosystems (4, 8, 15, 18, 7). According to Gumier-Costa & Sperber (200), some of these have emphasized the impact of routes inside CUs, when considering that trails and roads possibly induce the isolation and fragmentation of environments, besides animal-hits when crossing. The impacts pointed out by Forman & Alexander (1998) include difficulty in dispersion by native plants, the introduction of exotic species, noise, changes in the levels of lighting, the attraction and repulsion of fauna, problems with drainage, erosion, atmospheric pollution through the emission of gases from fuel combustion, and the increase of dust in the air. The evaluation of environmental impacts caused by roads in CUs would effectively contribute towards the improvement of management planning, thereby facilitating the adoption of preventive and corrective action.

The aim was to assay and analyze environmental impacts caused by roads and trails inside the Altomontana PRNP, in Itamonte, Minas Gerais State, Brazil. As this unit is in the initial creation phase, this study will contribute with relevant information towards the elaboration of management planning. The specific aims were: a) describe environmental impacts caused by roads; b) analyze and systematize data referring to road impacts, to so improve CU management; and c) propose mitigating solutions for degraded areas.

METHODOLOGY

Study Area

The study took place in the Altomontana PRNP, in Itamonte county, Minas Gerais State (22º21'51"S and 44º48'29"W). The steep altitude gradient varies from 1.450 to 2.400 meters. An inner road gives access to water slides, where the altitude reaches 2.140 meters. Close to the buildings at the entrance of the unit, trails lead away to the waterfalls. The total CU area is 672 hectares, comprising a mosaic of phytophysiognomies, that of semi deciduous seasonal forest being the most representative (*sensu* 27). The climate is of the Köppen Cwb type, and mesothermic, with dry winters and mild, rainy summers. The average annual temperature varies from 17.4ºC to 19.8ºC. The dry season extends from May to September, with the driest period occurring in June and July, and the rainiest during December and January (21). The PRNP, a private property inserted within the Area of Environmental Protection (AEP) of the Serra da Mantiqueira, contains a large area with remnant Atlantic Rain Forest.

Sampling

The inner roads (main and adjacent, as well as trails) were scoured and points marked at the extremities and along the altitude gradient, by means of GPS Garmin GPSMAP® 76Csx apparatus. Collected data was systematized in an impact grading matrix, adapted from Leopold *et al*. (1971), for standardizing observations and analyzing impacts. Impacts were characterized and analyzed by way of spot road-width measurements and respective intervention on roadside vegetation. The height of the embankment was evaluated in accordance with the roadside-presence of developed and adult native tree species, and vegetal soil cover. Visual and risk characterization of the occurrence of impacts, such as fire, erosion and waste, as well as other anthropic activities, were also investigated. The impacts were quantitatively classified as to magnitude; points from zero to

three were attributed for characterization, and qualitatively as to intrinsic value, to which were added positive and negative signs, according to the type of impact. Summation indicated the most impacted sights. Employees were interviewed as to outstanding natural events prior to the study period, with visual documentation (photographs) of the impact.

RESULTS

Impacts caused by anthropic activity, such as visits, animal raising, the traffic of vehicles, and the points of erosion arising from these activities, were the most marked negative environmental impacts encountered along the road crossing the property. Vegetal conservation and soil cover were the most relevant positive aspects, these acquiring the highest marks. Environmental impacts analyzed on the inner road of the CU appear in Table 1. According to summation, the most impacted environment was located at point 1, close to the entrance of the PRNP. As informed, the largest area of erosion (Point 1), acquired its present form due to a land-slide that occurred in 2005, thereby starting the formation of a roadside ravine, at the moment 30 meters wide at the northern end, and with a 13-meter-wide crater in the south (Figures 1A and 1B). Points of erosion were also noted at higher altitudes, this type of visual impact being the most remarkable. In some spots of the road, the incorrect drainage of rain-water has given rise to large natural ruts, thereby indicating the formation of fresh points of erosion (Figure 1C). Artificial ditches for better rain-water drainage were also seen.

Although small areas of erosion were noted in points 2 and 3, generally speaking, final summation of positive and negative impacts indicated adequate conservation of the stretch of road, roadside vegetation and height of embankments. A large clump of bamboo was noted at a higher level
(Point 4). Its origin is unknown, and further studies are required, as it was impossible to relate it to the presence of a road (Figure 1D).

The highest negative impact caused by anthropic activities along the road was in point 6, where an artificial clearing had been made for the installation of a telecommunication antenna. At this point, besides complete soil exposure, there was a considerable amount of remnant material. At the highest point, 2.140 meters (Point 7), vestiges of unauthorized camping were found, clear evidence of area vulnerability. This included signs of a bonfire (Figure 3), non-biodegradable packaging, and the opening of a trail in the vegetation. Old scrawls on the rocks were noted as a main negative visual impact (Figure 3).

Table 1: Environmental impacts on the road inside the Altomontana PRNP, Itamonte/MG.

	Sampling points							
	1	2	3	4	5	6	7	Summation
Altitude (m)	1.533	1.560	1.645	1.800	1.960	2.130	2.140	
Erosion	-3	-1	-1	-1	0	-1*	0	-7
Fire	0	0	0	0*	0	0	-2*	-2
Waste	-1	-1	0	0	0	-3	-3*	-8
Anthropic activity	-2	-1	-1	0	0	-3	-1*	-8
Preservation of vegetation	+1	+2	+2	+1	+3	+1	+2*	+12
Height of canopyt	+3	+2	+1	+1	+3	0	0	+10
Soil vegetation cover	+1	+2	+2	0	+3	0	+3	+11
Visual impact	-3	-1	+2	-1	+3	-3	+2	-1
Total impact at the point	-4	+2	+5	0	+12	-9	+1	+7
Extent of roadside vegetation (m)	10,20	9,50	6,50	8,00	7,70	**	**	41,90
Road-width (m)	5,40	5,30	4,30	5,00	4,40	**	**	24,40

Legend:
Types of impact: [-] Negative impact; [+] Positive impact
Intensity of the impact: [0] None; [1] Low; [2] Medium; [3] High
*Vulnerable; **Artificial clearing

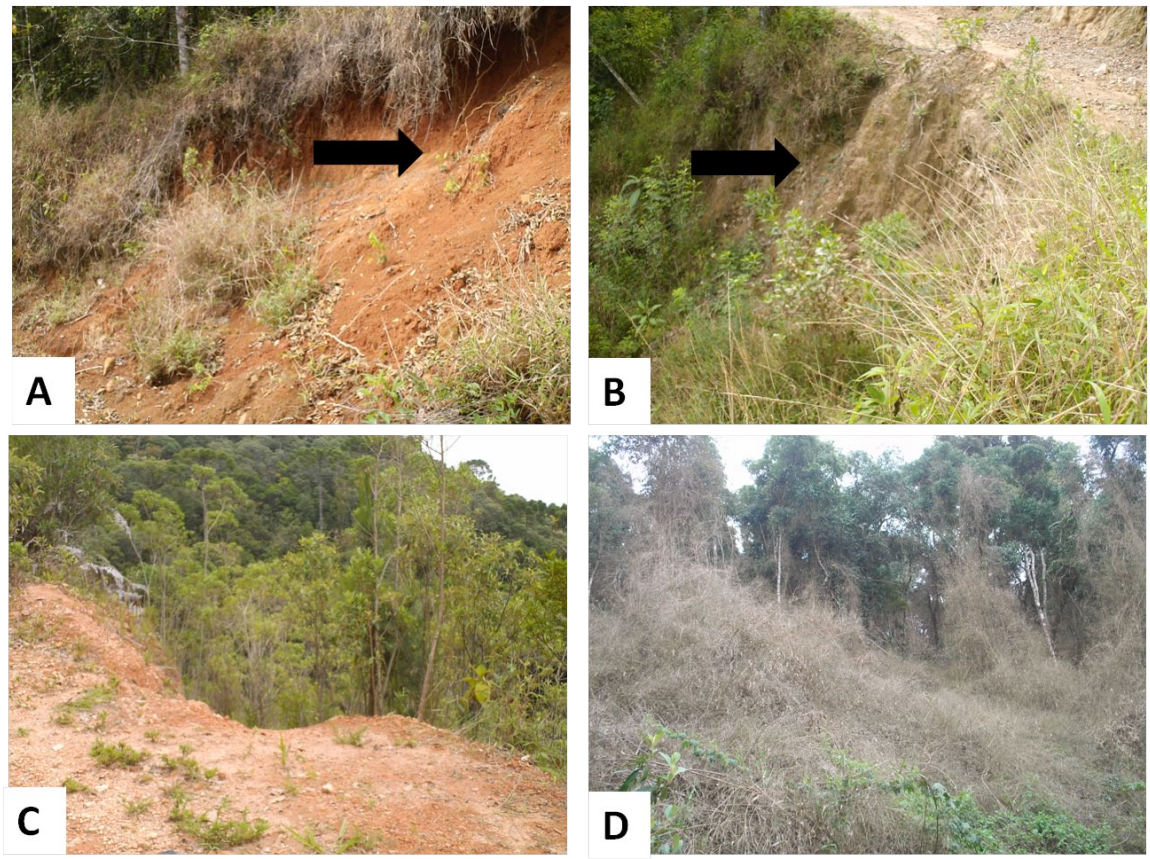


Figure 1: Heavy erosion at the edge of the main road. A) Northern part: 30m long. B) Southern part: crater 13 meters wide. Arrows: recent land-slides. Altitude: 1530 m. C) Natural ravine caused by hydro-erosion. Altitude: 1640 m. D) Long bamboo grove close to the road-side. Altitude: 1800 m.

Figure 2: Diversity of species as indicators of the satisfactory quality of the environment. Bromeliaceae and Orchidaceae families, respectively.

Apart from the main road, there are two trails, the Trail to the Waterfall (Points 10, 11 and 12) and to the Forest of the Elves (Points 14,15 and 16). Both were scoured for signs of impacts (Table 2). The main vestiges found were the residues of a bonfire, discarded non-biodegraded objects and small points of erosion. Around the higher-placed waterfall, the visual impact was great, due to stone arches built by the former proprietor (Figure 4B). This did not occur at the better conserved, lower-placed waterfall. Positive points were the presence of alcoves appropriate for leisure, with well-installed grills. Nonetheless, the wrongly placed bonfire residues close to the waterfall was a clear indication of the need for dedicating more attention to visitor orientation on the best use of the area.

Figure 3: Visual and environmental impacts caused by unauthorized camping. The remains of a bonfire and scrawls.

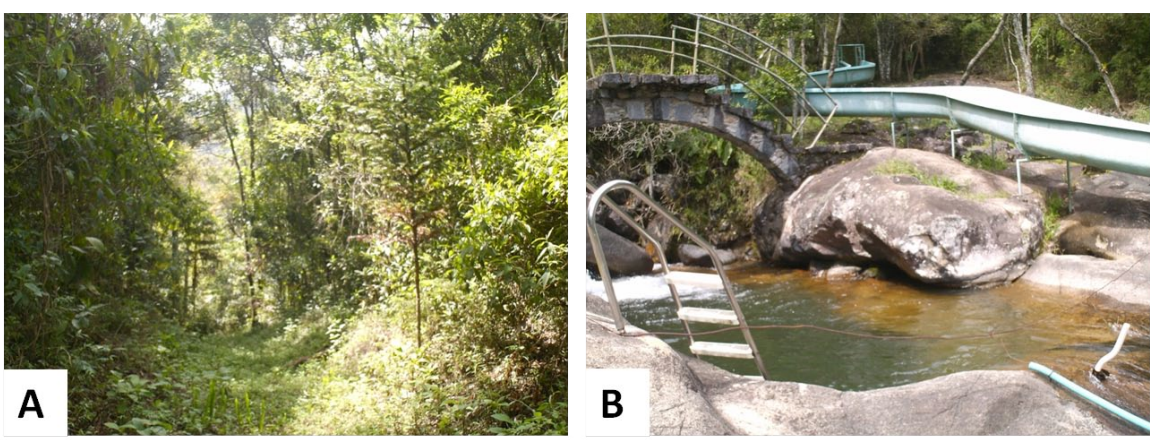
All along the trail, the well-preserved vegetation (Figures 4C and 4D) with enclosing canopy, and the appearance of pioneer plants along the edges, were clear indications of initial regeneration processes (Figure 4A). Nowhere on the trails or around the waterfalls were there garbage cans for the selective collection of waste.

In point 9, 1.563 meters high, there is an 8-meter-wide road, adjacent to the main one and leading to an abandoned building. The road is around 800 meters long, and has been out of use for more than 5 years. It is in the regeneration stage, with the beginning of soil coverage by creepers. Several points of erosion were also observed, with

Tabela 1. Environmental impacts on the road inside the Altomontana PRNP, Itamonte/MG.

	Sampling points									
	8	9	10	11	12	13	14	15	16	Summation
Altitude (m)	2.110	1.563	1.490	1.465	1.455	1.475	1.490	1.445	1.435	
Erosion	0	-3	0	-1	0	-2	0	-1	-1	-8
Fire	0*	0	0	0	-3	0	0	0	0	-3
Waste	0	-2	0	0	-3	-2	0	0	0	-7
Anthropic activity	0	-2	0	0	-3	-3	0	-3	-3	-17
Preservation of vegetation	+3	+3	+3	+3	+3	+1	+3	+1	+1	+21
Height of canopy	+1	+3	+3	+3	+3	0	+3	0	0	+16
Vegetation soil cover	+3	+3	+3	+2	+2	0	+3	+1	+1	+18
Visual impact	+1	-2	+3	-1	-2	-2	+1	-2	-2	-6
Point total impact	+8	0	+12	+6	-3	-8	+10	-4	-4	+17
Extent of roadside vegetation (m)	5,80	4,50	4,40	2,80	2,00	**	3,00	6,00	6,00	34,50
Road-width (m)	3,00	4,00	2,40	2,00	2,00	**	3,00	6,00	6,00	28,40

Legend:
Types of impact: [-] Negative impact; [+] Positive impact
Impact Intensity: [0] None; [1] Low; [2] Medium; [3] High
*Vulnerable; **Artificial clearing



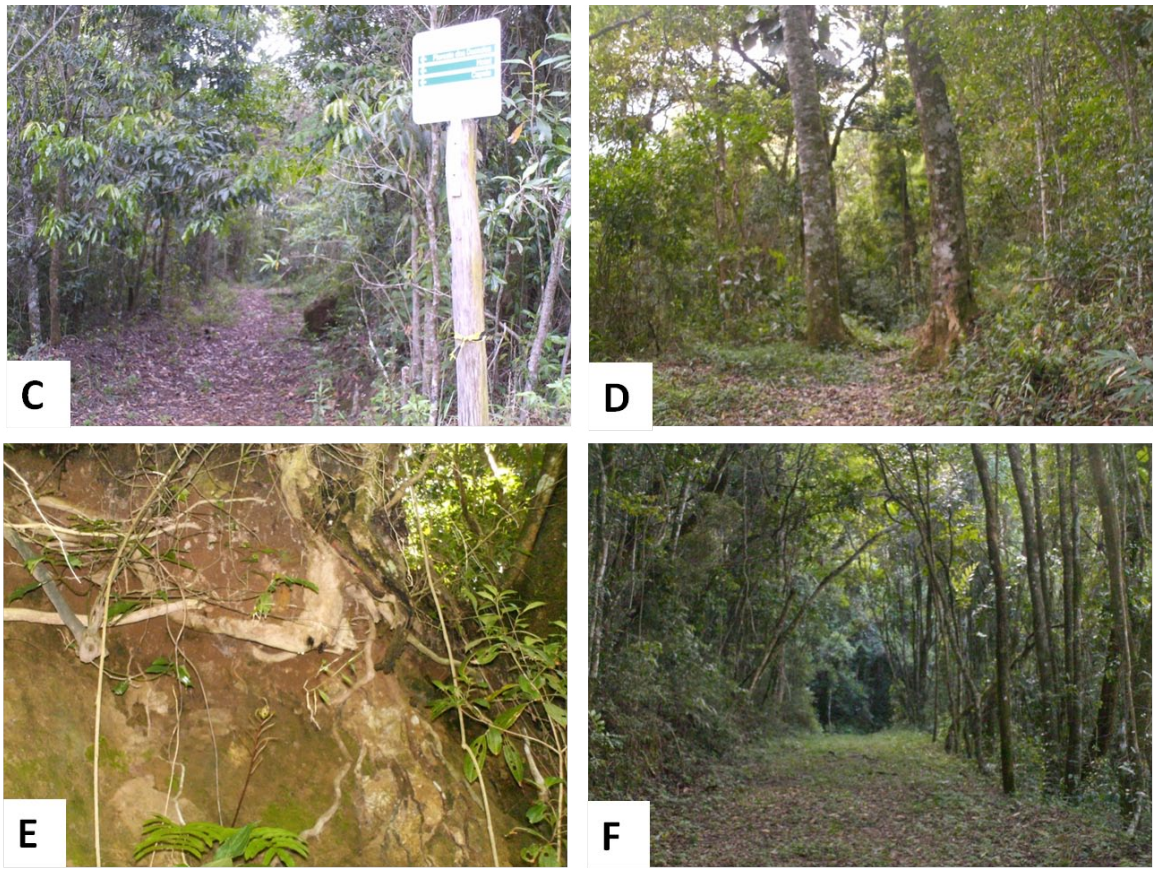


Figure 4: Trails on the property. A) Trail to the waterfall. B) Upper waterfall: Visual impact caused by construction. C) Entrance to the Trail to the Forest of the Elves. D) Trail of the Elves. – Out-of-use. E) Exposal of roots through erosion 1,80m high. F) Inclined trees due to erosion.

heights varying between 1,80 and 3 meters on the northern edge. In some points inclined trees and marked root exposure were apparent (Figure 4E). The vegetation in this area is well-preserved with an estimated 15-meter canopy (Figure 4F). The negative points for visual impact were the occurrence of non-biodegraded waste, mainly around the abandoned building. Tires, cans of oil and several types of plastic packaging were also found. No indicative signs or indications of strategic planning, to facilitate animal crossing or avoid accidents with the local fauna, were observed in any of the points evaluated.

DISCUSSION

The most impacted areas are located at either end of the main road, the outstanding points being the presence of erosion, discarded material and the remains of fire. This could be related to the permanence of people, seeing that the road is used only for passage between the lower part and the gliding ramps. One factor that may have contributed to the advance of erosion on the main road could be the recent entrance of heavy vehicles, for the installation of telecommunication antennas. This occurred before the present assaying. The crater cause by the landslide in 2005 presented visible signs of instability. Moreover, before this, the road was 10 meters wide, whereas now it is only 5,40m. Small landslides were noted and it is interesting to point out the possibility of the crater increasing in size, since vegetation is not in the process of regeneration. The slope of the land could be the main cause of erosion, thus corroborating Oliveira *et al*. (2010a), and Antonangelo & Fenner (2005), who pointed out declivity as being one of the generating factors of erosion. Further studies are required, with specific methodologies on declivity and erosion, to evaluate local vulnerability and instability.

Concrete gutters were built along the road to improve rainwater drainage. However, their inefficiency was apparent, seeing that incorrect

drainage was the means of accelerating erosion in some points. Surface drainage of rainwater is a preponderant factor in the formation of erosive processes, according to WEPP (Water Erosion Prediction Project), and as cited by Machado *et al.* (2003) and Garcia (2001). The adoption of preventive measures and the subsequent monitoring are attitudes which are simple, efficient and financially cheaper, when compared to corrective measures (20) Certain measures can be taken, such as the recuperation and contention of canopy, the maintenance of adequate gutters, planting seedlings of native plants where erosion is in an advanced stage (20), programs of environmental education, supervision in areas of easy access, and studies on the influence of vehicle traffic on vertebrate communities, as suggested by Bager & Rosa (2010), who proposed specific studies and the use of an index for implanting mitigating measures against wild-fauna hits.

The presence of discarded non-biodegraded material, such as tires, oil cans, glass bottles and plastic packaging, was observed in isolated points. Even though it was impossible to estimate the time this material has been in the area, their very presence is a sign of vulnerability. The withdrawal of this material is indispensable, since these residues are prejudicial, both visually and to the native fauna. Although roads are necessary structures for the flow of material and people, their very existence can negatively affect the fauna (4, 7, 15, 26). Some studies, besides outlining the high diversity and abundance of biota, demonstrate their fragility in the face of anthropic impacts caused in their environment. Thus, it can be perceived that the Altomontana PRNP does not present the necessary structure or the required preventive measures against the loss of biodiversity through the ingestion of residues, the isolation of subpopulations, or road-hits, whence the need for undertaking appropriate studies in this field.

The presence of well-preserved vegetation, the various phytophysiognomies encountered on the altitudinal gradient and the wide expanse of the CU, go well towards affirming that the PRNP had reached a high level of environmental heterogeneity and complexity. Similar situations have been the focus of a series of studies, such as by August (1983) and Vera Y Conde & Rocha (2006). Heterogeneity in any environment is represented by the vertical stratum developed. Apart from the characteristics of woody plants, the presence of epiphytes is considered a positive factor as it concerns environmental heterogeneity. According to Gatti (2000), they are extremely important as indicators of the maintenance of biological diversity and the interactive equilibrium among species, since their successful establishment and diversity is highly dependent on environmental conditions (13). Through their sensitivity to anthropic impacts, their role as indicators of environmental quality is further enhanced. Thus, the presence of epiphytic plants was a clear indication of preservation along roads and trails. .

The presence of a bamboo grove at a fixed altitude caused a visual impact. As it extended over the areas of other properties, always at the same variations in altitude, its origin can probably be associated to a natural occurrence. Even so, additional more detailed studies are required to better understand the occurrence.

As the management plan for the CU is in the elaboration phase, and together with the results of this evaluation of impacts, the proposal is to charge an entrance fee for recreational visits and access to water slides, as a form of maintaining the roads and trails on the property, since, through being a CU of sustainable use, the use of areas for recreation and environmental education is permitted. Nevertheless, it is recommended that the entrance of visitors be limited, and selective garbage cans installed in the entrance of the reserve, in the areas of recreation at the waterfalls, and alongside water slides.

The elaboration of environmental education programs should also become an alternative for the better enlightenment of visitors, as to the preservation of the area.

CONCLUSION

Among the various environmental impacts caused by the road, erosion at all altitudes is extremely prominent, with the presence of discarded waste as a close runner up. The vegetation on the edges of trails and roads was found to be well-preserved, thus comprising a propitious environment for the development of insertion activities among the local community, as part of programs on environmental education. The most impacted strips are the extremities of roads

and trails, where preventive supervision is required. The proposal is the adoption of a series of measures, such as the control of visitor entrance, the creation of educational activities on environmental conservation for PRPN-user enlightenment, the supervision of critical points, the restoration of unstable points of erosion with native plants, signs at various points on the road, with emphasis on the existence of fauna, and the need to reduce speed, as administrative tools to better conserve the area.

ACKNOWLEDGEMENT

Thanks are extended to the owners of the Altomontana PRPN for logistic support and accompaniment throughout the work .

RESUMO

Planejamento e gestão adequada de estradas contribuem para a redução dos impactos ambientais. Em Unidades de Conservação, a avaliação de possíveis impactos ambientais causados pelas estradas permite a adoção de ações preventivas, visando evitar a perda de biodiversidade. Nesse intuito, foi realizado um levantamento de impactos causados pelas estradas e trilhas da RPPN Altomontana, Itamonte (MG/Brasil), objetivando fornecer informações para um melhor manejo das estradas e trilhas da unidade de conservação, bem como mitigar impactos que geraram degradação ambiental da área. As extensões das estradas internas da propriedade foram percorridas, sendo marcados pontos nos extremos e ao longo do gradiente altitudinal. Uma matriz de gradação de impactos foi utilizada para padronizar as observações. Foram atribuídas notas de zero a três para caracterizar a intensidade dos impactos, acrescidos dos sinais positivo e negativo conforme o tipo de impacto. Dentre os impactos ambientais observados causados pelas estradas, a erosão foi a variável de maior destaque, ocorrendo em todas as faixas de altitude da propriedade, seguida da presença de lixo descartado. De modo geral, a vegetação da área encontra-se bem conservada e a variação de altitude favorece a formação de diferentes fitofisionomias, sendo um ambiente propício ao desenvolvimento de atividades de inserção da comunidade local em programas de educação ambiental.

Palavras-chave: avaliação de impacto ambiental, estradas, Unidade de conservação.

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Brazilian Journal of Ecology ISSN 1516-5868

FLORISTIC AND SPATIAL DISTRIBUTION OF ORCHIDACEAE SPECIES IN THE SERRA DO MUCAMBO, CONCEIÇÃO DO COITÉ, BAHIA, BRAZIL

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ABSTRACT

The aim of the present study was to evaluate the Orchidaceae family in the Serra do Mucambo, Conceição do Coité, Bahia and to describe the local population distribution patterns, as well as discuss local factors that influenced species distribution. Sixteen species in 14 genera were found. The genera *Trichocentrum* and *Vanilla* presented the highest number of species, with two each. All species displayed aggregated distribution. The highest abundance and species richness were found at higher altitudes. Availability of resources is possibly the main factor influencing species distribution.

Key-words: resources, elevation, abundance

INTRODUCTION

The Orchidaceae family contains around 850 genera and 20,000 species, amongst which, 235 genera and 2.419 species have been registered in Brazil (6). Distribution of the family is cosmopolitan, Pantropical, and probably the second largest among the angiosperms (5), with the main centers of diversity in the tropical regions of America and Asia (9). Besides taxonomic representability, the family is valued by the ornamental potential of the flowers (16).

The use of the flowers for ornamentation purposes represents one of the threats to orchid species diversity, through removal from their natural habitats. Another ominous factor is the constant destruction of habitats through the advance of agriculture (16, 22). Thus, extinction could also be a consequence of the reduction in area of occupancy, since only larger areas sustain large populations. (18)

In a plant community, plants are aggregated according to the various intra and interspecific associations throughout their natural distribution (14). Besides anthropic alterations, which incur vegetal impacts, there are also natural alterations arising from differences in the soil, and variations in humidity and altitude, which contribute to floristically characterizing certain areas of the mountain range (34). Altitude, a possible relevant factor, can induce a soil and climate grid, an important aspect in the repartition of the various floristic aggregates, thereby contributing to the different vegetation patterns in the landscape (24, 10). The distribution of the different ecological substrata and refuges is related to the degree of local shade or illumination, whence the selective process of appropriate environments for the development of certain types of vegetation in detriment of others (10). Through humidity, as well as the presence of a substratum, being limiting factors in the distribution of epiphytic orchids (7), epiphyte diversity can be used as an ecological indicator of the quality and conservation of humid forests (22).

On the whole, in Bahia, botanical studies in the field are concentrated in the Chapada Diamantina (3, 4, 12, 19, 20, 32, 36, 40, 37), with only a few studies having been undertaken in the

center-western part of the state (15). Further on, the findings will be commented on, since a list of citations without contents would not be informative. Studies on Orchidaceae spatial distribution are still scarce, especially in northeast Brazil.

On considering the work done on orchid spatial distribution, the importance of the family, the threats to its diversity, the scarcity of studies of northeast Bahia, and the need for a better understanding of the factors that influence the distribution of these species, the aim of the present study was to undertake a floristic survey of orchid species in the Serra do Mucambo, thereby identifying the spatial distribution of populations and investigating factors defining their occurrence and distribution.

METHODOLOGY

Characterization of the study area – Conceição do Coité is located in the northeastern part of Bahia State (11°31' S and 39°19' W). The study area was at the highest point of the municipality, at an altitude of 575 meters. The surroundings and some parts of the Serra have already been deforested for sisal (*Agave sisalana* Perrine) hemp production and cattle raising.

The climate is semiarid, with temperatures ranging from 16.1 to 33ºC, and an average rainfall of 500 to 800 mm. Vegetation is mixed, with elements from the arboreal Caatinga and arboreal-bushy Caatinga, and with the presence of palm trees (Arecaceae) of the species *Syagrus coronata* (Mart.) Becc.

Collection of data – 20 fixed and noncontiguous quadrats measuring 10×10m, in total 2.000m², were marked out according to methodology developed by Almeida *et al.* (2007), but with modifications, with random distribution at various altitudes, an irregular number at each, along a sloping gradient of 449 to 575m, with no fixed difference between. Elevation and coordinates were obtained with a GPS Garmin eTrex Vista HCx, Personal Navigator. The fertile orchids in each quadrant were collected, pressed, identified and quantified. The amount of available resources was also measured, taking into account, trees, lianas, soil and palm trees. Rock, as a source, was eliminated. Trees and lianas were measured as to the percentage of cover, and soil, as to the available area. Palm trees were counted. The total of available resources was obtained by substituting scarce, abundant and very abundant by the numbers 2, 3 and 4, respectively, and with the summation of values attributed to soil, trees and lianas, and the number of palm trees. As regards epiphyte species, even individuals that had accidentally fallen, and were still alive on the soil and remained fixed to dry branches, were included. Collections took place from January to December, 2010, thus twelve in total. Specimens were deposited in the herbarium of the Universidade Estadual de Feira de Santana (HUEFS).

Analysis of data – species identification was from specialized literature by Pabst & Dungs (1975, 1977). When necessary, the material was compared to specimens from the collection of HUEFS. Species binomials were standardized in accordance with the World Check List of Selected Plant Families, the Royal Botanic Gardens, Kew (http://apps.kew.org/wcsp/qsearch.do).

The Morisita index (27) was used for identifying species distribution patterns. Absolute taxon frequency was calculated by the formula described by Maracajá *et al.*(2003):

$$Fat = \frac{100.Pt}{20}$$

where F_{At} is the absolute taxon frequency, P_t the number of plots where the taxa occurred, and P the number of sampled plots.

Analysis of correlations between the amount of resources and orchid frequency was performed to evaluate the influence of resource availability. Cluster analysis of qualitative and quantitative data with the UPGMA method in the PCORD 4.0 software, using the Sorensen Index for qualitative, and the Morisita-Horn Index for quantitative, was used to evaluate whether more similar quadrants, in terms of resources, would be more similar as to floristic composition. Correlation analysis with SPSS for Windows was to evaluate the relationships between abundance and richness among species at different altitudes.

RESULTS

Sampling involved 821 individuals belonging to 14 genera and 16 species (Table 1). On considering the two habits, epiphytes were found to be the most common. There were only five terrestrial species and one facultative.

Average abundance among quadrants was 41.5, with standard deviation of ± 44.56 individuals each. Richness varied from 1 to 10 species per quadrant; the most frequent was two species each.

Individuals of *G. barbata, C. micranthum* and *Notylia* sp. represented 67% of those sampled (Table. 1), whereas individuals of *O. maculata*, *V. palmarum* and *T. cebolleta* together represented 22%, and the remaining 10 species 11%. The most abundant species were also the most frequent (Table 1).

Groups of qualitative (Figure 2) and quantitative (Figure 3) similarity were formed in the same quadrants in both dendrograms. Whereas the first group was formed by quadrants without the presence of *C. luridum*, in the second, this species was present in all, together with *S. coronata*, the only phorophyte to be used by this species. This phorophyte was also the only one on which *V. palmarum* and *C. saintlegerianum* occurred. According to the Sorensen Index, the most similar quadrants were P6 and P7 (Figure. 2), with 100% similarity in floristic composition, followed by P1 and P20 with more than 90%. As regards qualitative-quantitative similarity, and as indicated by the Morisita-Hom Index, the most similar quadrants were P3, P6 and P7, with 100% similarity.

Resource and orchid abundance ($r = 0.223$; $p > 0.05$), and resource and orchid-species richness ($r = -0.317$; $p > 0.05$) were not correlated.

Tabela 1. List of the species from the family Orchidaceae found in the Serra do Mucambo, Conceição do Coité, Bahia, Brazil. Legend: N. IND = number of individuals sampled, MI= Morisita Index, AF= absolute frequency, Epi. = epiphyte, Ter.= terrestrial, Fa.Epi= facultative epiphyte. Species

	N. IND.	M.I	A.F. %	Habit	Voucher
Campylocentrum micranthum (Lindl.) Rolfe	191	22,5	55	Epi.	Carvalho, D. N. 19
Catasetum luridum Lindl.	27	4,2	35	Epi.	Carvalho, D. N. 7
Cyrtopodium saintlegerianum Rchb.f.	5	3,3	10	Epi.	Carvalho, D. N. 15
Eltroplectris triloba (Lindl.) Pabst	4	3,3	15	Ter.	Carvalho, D. N. 17
Encyclia oncidioides (Lindl.) Schltr.	17	4,9	20	Epi.	Carvalho, D. N. 20
Gomesa barbata (Lindl.) M.W.Chase & N.H.Williams	272	33,6	60	Epi.	Carvalho, D. N. 4
Notylia sp.	109	27,8	45	Epi.	Carvalho, D. N. 2
Oeceoclades maculata (Lindl.) Lindl.	74	9,3	55	Ter.	Carvalho, D. N. 3
Pelexia trachyglossa (Kraenzl.) Pabst.	13	4,2	15	Ter.	Carvalho, D. N. 12
Polystachya concreta (Jacq.) Garay& H. R.-Sweet	2	2	5	Epi.	Carvalho, D. N. 9
Prescottia sp.	1	1	5	Ter.	
Sarcoglottis sp.	14	4,5	20	Ter.	
Trichocentrum cebolleta (Jacq.) M.-W.-Chase & N.-H.-Williams	51	8,8	60	Epi.	Carvalho, D. N. 18
Trichocentrum pumilum (Jacq.) M.-W.-Chase & N.-H.-Williams	3	0,9	15	Epi.	Carvalho, D. N. 16
Vanilla bahiana Hoehne	10	4,9	10	Epi. Fa.	
Vanilla palmarum (Salzm ex. Lindl.) Lindl.	60	14	30	Epi.	Carvalho, D. N. 6

No species occurred in all the quadrants, and only four occurred in more than half, viz., *G. barbata* and *T. cebolleta* (60%), and *C. micranthum* and *O. maculata* (55%). In relative abundance among the total of individuals studied, *G. barbata* 32.3%, *C. micranthum* 22.3%, *O. maculata* 8.8%, *T. cebolleta* 2.3%, and the remaining 10 species 11.7% were noteworthy.

Although the quadrants at higher altitudes presented a significantly higher abundance of individuals ($r = 0.547$; $p < 0.05$), no significant correlation between species richness and elevation could be found ($r = 0.419$; $p > 0.05$).

Most of the species presented aggregated distribution (14 species), and only two, *T. pumilum* and *Prescottia* sp., presented random and uniform

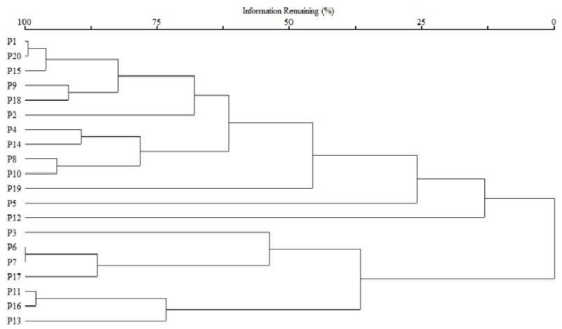

Figure 2. Floristic similarity dendogram, by the UPGMA method and using the Sorensen Index, based on data on the presence or absence of Orchidaceae in quadrants in the Serra do Mucambo, Conceição do Coité, Bahia, Brazil.

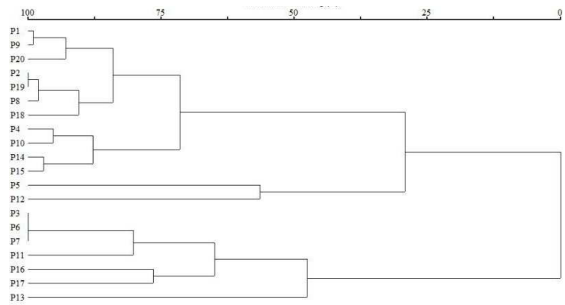

Figure 3. Floristic similarity dendogram by the UPGMA method and using the Morisita-Index, based on data on Orchidaceae species abundance in quadrants on the Serra do Mucambo, Conceição do Coité, Bahia, Brazil.

DISCUSSION

Most of the sampled orchids are widely distributed geographically, some of them even occurring in other countries, as well as in various biomes, such as *restingas*, rocky outcrops, mountain forests, ecotone areas, semideciduous forests and dense ombrophilous forests.

The species *C. micranthum*, *C. luridum*, *E. triloba, O. maculata*, *P. concreta* and *V. bahiana* are to be found in the 'restingas' of Espírito Santo State (23). *Campylocentrum micranthum* also occurs in the same ecosystem in the state of São Paulo (28) as well as in rocky ground in Mucugê, Bahia State (3). The species *E. oncidioides*, *V. bahiana* and *P. concreta* are incidental in the ecotonal area between the Atlantic Rain Forest and the 'Cerrado' in São Paulo (22). *Vanilla palmarum* occurs in remnants of the Atlantic Rain Forest in the south of Bahia (21).

Gomesa barbata occurs in semiarid regions in Pernambuco State (38). *Cyrtopodium saintlegerianum, O. maculata*, *P. concreta*, *T. cebolleta*, *Trichocentrum pumilum* and *V. bahiana* have been registered by Batista and Bianchetti (2003) among species occurring in the Brazilian Federal District. *T. pumilum* is also encountered in areas of the 'Cerrado' in São Paulo (16). *Campylocentrum micranthum*, *O. maculata*, *P concreta* and *T. pumilum* have been registered in the Serra de São José, Minas Gerais State (2) as well as in riverine forests in Rio Grande do Sul State (39).

Species richness observed in the present study can be considered small when compared to that in plant corridors in the Cerrado, where 100 species were registered (9), and the 226 species registered in the Parque Nacional do Itatiaia, in the Serra da Mantiqueira (5). Nonetheless, many studies presented richness values close to those encountered herein, such as the 25 species found in an area undergoing regeneration in the Montane Dense Ombrophilous Forest (34), or the nine, even 10, species found in vegetal isles in parts of the Morro do Pai Inácio Plateau, also in Bahia (1, 20). Indeed, although Orchidaceae species richness is high in humid and montane regions, it is much lower in dry and seasonal areas.

Cyrtopodium saintlegerianum was registered as a rare species in dry forests, *O. maculata* as common in both dry and humid forests, *T. cebolleta* occasional in dry forests, *T. pumulum* rare in dry forests, *P. concreta* occasional in dry forests, and *V. bahiana* occasional in both dry and humid forests (8).

The species *O. maculata* was very frequent in shady or well-illuminated spots in areas with bushy and arboreal vegetation. The high frequency indices of this species have been associated to efficient reproductive organisms, such as autogamy and anemochorous dispersion (40). *O. maculata* and *E. triloba* were encountered in sheltered spots inside closed formations and in open areas (23), thereby corroborating their occurrence in both 'restinga' as well as dry forests, as was the case in the present study. This indicates the capacity of these species to inhabit areas with various grades of luminosity. Species that occur in the lower and upper part of trunks possibly prefer or tolerate more humid and shadier environments (39).

Rogalski and Zanin (2002) noted the existence of two groups, those that required less luminosity and more humidity, and those that tolerate higher luminosity and less humidity. Some species, such as *E. oncidioides*, were more present in tree canopies than in the lower part of the trunks where vegetation was more closed and large-sized. The species *C. luridum*, *V. palmarum*, and *C. saintlegerianum* always occurred associated with *S. coronata*, in quadrants with more open vegetation and higher solar radiation. Species requirements limit their distribution. A possible motive for this association could be the substratum conditions that this phorophyte offers, this favoring the growth and maintenance of symbiontic mycorrhizic fungi, and self maintenance as a microecosystem with the adequate luminosity and humidity for the development of these species. It was confirmed that, as cover becomes more open, other species begin to appear, especially those which are more tolerant to luminosity (23). Gonçalves & Waechter (2002) attributed high diaspore production and resistance against isolation to the outstanding capacity for colonizing and high abundance of vascular epiphytes. Lower species richness could be related to environments with microclimatic instability (higher solar radiation and wind exposure), and to the lower exposal of phorophytes to epiphyte diaspores (13). In other words, where there are more aged phorophytes, species richness is generally higher in the regions closer to the climax. Higher abundance, density and diversity is expected in canopy epiphytic orchids in mature forest fragments (35).

Cavatti (2007) related distribution of the terrestrial species *Epidendrum* sp. to the abundance of litter in the soil. This factor could also be related to the distribution of other terrestrial orchid species. In the 'Caatinga', the production of litter is not high, as it is in other ecosystems. Even so, in the present study, some areas notably accumulated a large amount of substratum in the soil, appropriate for the establishment of terrestrial species, such as *E. triloba, P. trachyglossa, Prescottia* sp., *Sarcoglottis* sp. and *O. maculata* .

Although no relationship between elevation and species richness was found, there was a positive relationship between elevation and abundance. Jacquemyn (2005) encountered higher diversity between 400 and 800 meters, presumably due to the presence of an altitudinal distribution zone with many overlapping species. The high diversity between 500 and 2.000 meters is supposedly a result of high habitat diversity (41). In the present study, no relationship was found between habitat availability (resources) and species richness abundance.

High richness and diversity can be characterized as effected by climate (25). Temperature can be a limiting factor, whereas climate changes can contribute to changes in distribution and abundance in orchid populations (17). Thus, less richness and abundance in quadrants where temperature and humidity have been modified by human action, can be expected, as is the case of those near the edges in lower areas, where there is less humidity, and variations in the temperature, besides being greater during the day, are seasonal. This interference of the edge-effect was aggregated to the grid of elevation-liable humidity. Possibly, these two factors are directly linked with less abundance at lower placed areas undergoing the edge effect.

As observed by Pereira and Ribeiro (2004), members of Orchidaceae maintained aggregate distribution in three areas in the process of regeneration, as also occurred with young and old individuals of the species *Mesadenella cuspidata* (Lindl.) Garay (14). Thus, the present study confirms a tendency which has already been observed in orchids. The aggregation of these populations could be due to the incidence of light, or characteristics of the substratum, such as trunk texture and specificity in arboreal species (35). Some phorophytes harbored numerous epiphytes in a few quadrants, whereas others harbored very few.

Among the factors that exert an influence on orchid spatial distribution, two are of extreme importance, seed dispersion and an adequate substratum for germination and growth. Seed dispersion is a critical process in plant life, since these need to arrive at adequate substrata (31) in forest areas, protected from wind dispersal, and where young seedlings are always capable of germinating and growing close to the mother plant, thereby forming groups. This is especially the case of terrestrial orchids that form large groups on the

soil. Furthermore, infection and colonization of the habitat by compatible micorrhizic fungi is obligatory for supplying the necessary carbohydrates for seedling germination, initial growth, and nutrition on the substratum (11). Thus, only seeds which have fallen onto the adequate substratum are viable.

Even though Orchidaceae populations, on the whole, give evidence of being sensitive to human environmental interference, it cannot be said that this is the only factor influencing the distribution of individuals. Environmental alterations in the Serra do Mucambo still need to be studied, through the monitoring of other local populations and communities.

RESUMO

O presente estudo objetivou inventariar a família Orchidaceae na Serra do Mucambo, Conceição do Coité, Bahia e descrever a distribuição das populações na área, discutindo os fatores que influencia na distribuição das espécies. Foram encontradas 16 espécies e 14 gêneros. Os gêneros com maior número de espécies foram *Trichocentrum* e *Vanilla*, com duas espécies cada. As espécies distribuíram-se de forma agregada. As maiores abundâncias e riqueza específica foram encontradas nas maiores elevações. A disponibilidade de recursos pode ser o fator que influencia na distribuição destas espécies.

Palavras-chave: recursos, elevação, abundância

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Brazilian Journal of Ecology ISSN 1516-5868

FLUCTUATING ASYMMETRY IN THREE *BASILEUTERUS* (PASSERIFORMES, PARULIDAE) SPECIES IN A SEMIDECIDUOUS FOREST FRAGMENT IN THE BRAZILIAN CERRADO

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ABSTRACT

Habitat fragmentation in small remnants may compromise aptitude in some bird species. Fluctuating Asymmetry (FA) is the morphological alteration of bilateral characters caused by genetic or environmental stress, this can be used in environmental biomonitoring studies and programs. The objectives were to define FA levels of tarsus and wing in three species of genus *Basileuterus* (*B. hypoleucus, B. flaveolus* and *B. leucophrys)*, and to verify the hypothesis of FA being more pronounced in birds that inhabit fragment edges than those inside. The highest FA values in wing were found in *B. flaveolus* and *B. hypoleucus*, and for tarsus in *B. hypoleucus*. *Basileuterus leucophrys* was the least assymetric for both characters. FA values were different, both among the three *Basileuterus* species and between environments, thereby indicating that the characteristics of the environment in which the species concentrates its activities appear to be the most important factor in determining character stability.

Key words: morphometry; avifauna; forest fragment

INTRODUCTION

Habitat fragmentation is a process in which a large and continuous patch of vegetation is split into two or more isolated fragments that function as islands surrounded by nonforested habitats (24). Various techniques have been used for monitoring the effects of habitat fragmentation on biota.

One of these is Fluctuating asymmetry (FA) analysis. This deals with random differences between the two sides of characters with bilateral symmetry (23, 8). FA has proved to be one of the most used indices when describing phenotypic variations caused, not only by disturbances of an environmental nature, such as susceptibility to habitat degradation, parasites, or disease, but also genetic factors, as a result of genic disharmony caused by endogamy, heterozygosity or recombination (15, 8, 11).

Bird fluctuating symmetry has been proposed as a tool in the studies of the conservation of natural and forest fragment populations. In Passeriformes of Atlantic Rain Forest, the highest FA levels occurred in the more fragmented areas when compared to the continuous, thereby demonstrating that wing FA levels are higher in smaller areas (2). In Passeriformes in Minas Gerais State, symmetric fluctuation in coracoids, ulnae, tarsi and femurs was a clear indication that intense regional deforestation affected populations (1).

FA is a practical and trustworthy conservation index, due to the facility in obtaining data and superiority in relation to other indices (2). On considering the susceptibility of asymmetry levels to individual localization, higher in populations whose activities are more concentrated on the edges (20), the differentiated use of the environment by species furnishes data for studies of environmental quality.

In the Cerrado, three species of the genus *Basileuterus* (*B. hypoleucus, B. flaveolus* and *B. leucophrys)* are potentially apt for testing this model. They are sympatric and essentially forest species, with spatial niche partitioning as a result of competition exclusion (12). Birds of the genus *Basileuterus* (Passeriformes, Parulidae) are insectivores, with differentiated usage of the environment (19).

OBJECTIVES

To determine fluctuating asymmetry levels in three species of *Basileuterus, viz., Basileuterus hypoleucus, Basileuterus flaveolus*, and *Basileuterus leucophrys)*, and to verify the hypothesis of FA being more accentuated in individuals inhabiting regions closer to the fragment forest edge than those inside.

METHODOLOGY

Study site:

Captures occurred from November, 2007 to June, 2008, and from August, 2008 to October, 2008 in fragment of semideciduous forest fragment (37 hectares) in the Glória Experimental Farm, Uberlândia, Minas Gerais (18º57'06.31"S and 48º12'17.12"W). According to Köppen classification, the climate is megathermic, with rainy summers and dry winters (17)

Collection:

Mist nets (12,0m x 3,0m and 6,0m x 2,5m) were placed at the edge of and inside the dry and flooded interior of a forest fragment. After being ringed (CEMAVE/ICMBio), the captured birds were then weighed with manual dynamometers (30 g and 60 g).The length of each wing and tarsus was sequentially measured twice with a manual calliper kingtools (0,1mm precision) in the following order: left wing, left tarsus, right wing, right tarsus. The animals were released immediately after the measurements. The arithmetic mean of the measurements of each character was determined later.

According to Straube and Bianconi (2008), the capture effort was calculated by the simple multiplication of the area of each net by the time of exposure, plus the number of nets. The total effort was the sum of daily samplings.

Statistic analysis

Fluctuating asymmetry (FA) was evaluated separately for the wing and tarsus of each species, following calculations defined by Palmer and Strobeck (1986) for the wings and tarsi separately: [| R – L | / (R + L / 2)], where: R= average of the right-side measurement for each individual, and L=average of the left-side measurement for each individual.

According to Palmer & Strobeck (1986), it is necessary to distinguish FA from other types of asymmetry, such as directional asymmetry and antisymmetry. For this, t-tests were used to verify that the difference in the mean measures of the right and the left (D - E) was significantly equal to zero and the Kolmogorov-Smirnov test was used to examine the normality of the (D - E) distribution. When the average of the measure of the right and left sides was equal to zero and normally distributed, the occurrence of directional asymmetry and antisymmetry was discarded, respectively. The dependence of FA on the size of the original measure was tested for each sample using a Pearson correlation between the |FA| and the average of the measure on the right side (13).

Kruskal-Wallis was used to verify the interspecific differences in the FA values for wings and tarsi and Mann-Whitney was used to compare the differences between FA values for birds captured in the edge and inside. The species with the most pronounced FA was also that which presented the highest FA value for wing and tarsus.

RESULTS

Twenty two individuals of the genus *Basileuterus* were captured, of which five were *B. hypoleucus*, seven *B. flaveolus* and ten *B. leucophrys*, in 80.199,3 hours.m^2.

The distribution by wings and tarsi was not normal. According to Babbit *et al*. (2006), there can be a slight deviation in the distribution of data frequency, without impeding the occurrence of fluctuating asymmetry.

Directional asymmetry was discarded, or rather, the data presented averages equal to zero for both the wings ($t = 0.462$; $df = 21$; $p = 0.150$) and tarsi ($t = 0.246$; $df = 21$; $p = 0.220$). FA values for wing did not correlate with the average of the original

measurements (r_s = -0.327; gl = 22; p > 0.05), as neither did tarsus FA values (r_s = -0.036; gl = 22; p > 0.05).

There were differences between interspecific FA levels for wing (H= 1.728; p= 0.004; N= 22) and tarsus (H= 6.271; p= 0.009; N= 22). The highest FA values for wing were found in *B. flaveolus* (AF= 0.0142 ± 0.0135) and *B. hypoleucus* (0.0130 ± 0.0122), and for tarsi in *B. hypoleucus* (AF= 0.0573 ± 0.0728). *Basileuterus leucophrys* was the least asymmetric for both characters (Figure 1).

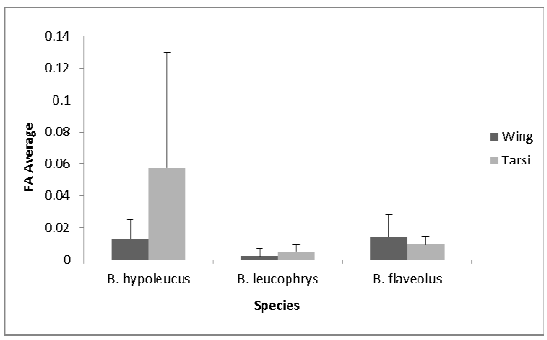
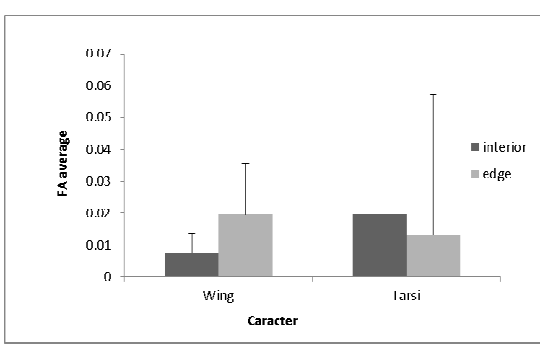


Figure 1. Fluctuating asymmetry (FA) (average± standard error) in the wings and tarsi of *Basileuterus hypoleucus*, *B. leucophrys* and *B. flaveolus*, captured in semideciduous forest in the Gloria Experimental Farm, Uberlândia, MG.

Of the 22 individuals captured, one *B. hypoleucus* and four *B. flaveolus* were caught in the edges of fragment, whereas *B. leucophrys* individuals were from the inside. Although there was a significant difference between edge and interior, for FA levels for wing (U= 35; p= 0.025; N= 22), this was not the case for tarsi (U= 40; p= 0.41; N= 22) (Figure 2). FA for wing was higher in species captured on the edge (AF= 0.0194 ± 0.0161), and lower in individuals from the inside (AF= 0.0075 ± 0.0063).

Figure 2: Fluctuating asymmetry (FA) (AF) (average± standard error) in individuals from three species of *Basileuterus* captured in Semideciduous Forest in the Gloria Experimental Farm, Uberlândia, MG.



DISCUSSION

The interspecific difference between fluctuating asymmetry (FA) values for wings and tarsi in the individuals implies that the differentiated use of characters is a factor that exerts an influence on FA levels (2). According to Balmford *et al*. (1993), the FA of a character depends on its functional importance, whereby the possible appearance of different values between characters and species. Furthermore, FA specificity for a character (13, 14) is liable to generate variations among characters in the same individual, and even among characters related to morphological structure development (7).

Basileuterus hypoleucus and *Basileuterus flaveolus* presented the highest wing FA levels, which is probably associated to the expressive allocation of time for flight in these species (4).

Tarsi in *Basileuterus hypoleucus* were more asymmetric. The use, by this bird, of various strata (19), and its greater movement inside forest fragments, possibly more frequently expose wings and tarsi to the prevailing environmental conditions, with the consequentially high FA levels (12, 2).

Basileuterus flaveolus and *B. hypoleucus*, through being capable of foraging on forest edges where the microenvironment is different from the inside, and levels of light, temperature and wind higher (16), undergo environmental stress which would influence FA values. According to Van Valen (1962) and Lomônaco & Germanos (2001), FA has become the most used index for describing phenotypic variations caused by environmental noise.

In their studies, Evans and Marshall (1996) presented a correlation between fitness and asymmetry, in which FA increases with environmental and genetic stress. A possible mechanism of the relationship between FA and stress is that organisms require more energy to compensate stress, thereby resulting in less expenditure with reproduction and growth (10), or, in other words, stress reduces the available energy for the development of character precision (21). Thus, higher levels of habitat disturbance could increase population asymmetry levels prior to a decrease in survival becoming apparent (9).

Species that presented higher FA levels, such as *B. hypoleucus* and *B. flaveolus*, could represent groups which are more sensitive to disturbance in the process of character development (2). The effects of genetic and environmental stress are cumulative. Hence, organisms under genetic stress are useful as biological indicators of environmental stress quantified through FA, and can thus be efficiently employed in biomonitoring programs (5, 15).

Basileuterus leucophrys is more exigent as regards the microhabitat, and so, in this study, was only captured inside the forest, and thus presented the lowest wing and tarsus FA values. The interior of a forest fragment is more isolated from edge-effects ((16), thus anthropic disturbance has less influence on the development of character stability (20). Furthermore, FA levels are often higher among individuals undergoing environmental stress and located in ecologically marginal habitats (22).

CONCLUSION

Fluctuations in asymmetry values varied among the three species of *Basileuterus*, and between environments (interior and edge), this being more so in *B. hypoleucus* and *B. flaveolus* species, which use the edge for foraging, and less so in *B. leucophrys* species, which were captured only inside the forest fragment. Thus, the characteristics of the environment in which the species concentrates its activities appear to be the predominating factor in determining character stability, whence the usefulness of FA in the relative diagnosis of impacts arising from forest fragmentation.

ACKNOWLEDGMENT

Thanks are extended to Professors Dr. Oswaldo Marçal Júnior and Dr. Cecília Lomônaco for the corrections and criticisms, and to my collegues Eurípedes Luciano da Silva Júnior, Péricles Rocha da Silva and Giâncarlo Ângelo Ferreira for the help in collecting data.

RESUMO

A fragmentação do habitat em pequenos remanescentes pode comprometer a aptidão de algumas espécies de aves. A assimetria flutuante (AF) é uma alteração morfológica em caracteres bilaterais causada por estresse genético ou ambiental, que pode ser utilizada em estudos e programas de biomonitoramento ambiental. Os objetivos deste trabalho foram: determinar os níveis de AF de asas e tarsos em três espécies de *Basileuterus* (*B. hypoleucus, B. flaveolus* e *B. leucophrys)* e testar a hipótese da AF ser mais acentuada em aves que habitam regiões mais próximas da borda do fragmento daquelas restritas ao interior de um remanescente florestal. Os maiores valores de AF para asa foram encontrados em *B. flaveolus* e *B. hypoleucus*, e para tarso foi em *B. hypoleucus*. *Basileuterus leucophrys* foi o menos assimétrico para ambos os caracteres. Os valores de AF foram diferentes entre as três espécies de *Basileuterus* e entre os ambientes indicando que a característica do ambiente no qual a espécie concentra suas atividades parece ser o fator mais importante na determinação da estabilidade do carácter.

Palavras chave: morfometria; avifauna; fragmento florestal

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VASCULAR PLANT DIVERSITY AND SUBSTRATUM PARAMETERS AS INDICATORS OF ECOLOGICALLY BASED DEGRADEDAREA RECUPERATION

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ABSTRACT

In order to be characterized as restoration on an ecological basis, the recovery of a degraded area should increase natural biodiversity. The aim was to establish experiments that reveal the processes involved in the advance of spontaneous vegetation in areas degraded by coal mining. Plant species were first planted for primary coverage of a substratum formed by a coal refuse deposit already covered by regional B-horizon soil, the two pioneer species, *Cynodon dactylon* (L.) Pers. and *Indigofera campestris* Bong. *ex* Benth, being those chosen. Spontaneous plant species diversity was monitored by three abundance and cover surveys. The experiment consisted of two plots, one for each species, divided into 9 sub-plots. From April, 2009 to February, 2011, *C. dactylon* cover dropped from around 40 to 5%, thereby facilitating the establishment of a higher number of local spontaneous plants. In each survey, *I. campestris* covered around 80% of the soil. Shannon index between the two species differed significantly ($f=0.0141$, $\alpha=0.05$). According to substratum fertility analysis, both at the beginning and the end of the experiments, fertility in organic material increased throughout, with a reduction in acidity at the end of the experiment. Although both species retained substratum, *I. campestris* contributed towards its more pronounced fertilization, whereas *C. dactylon* facilitated natural succession and diversity. Hence the latter is more adequate for restoration.

Key words: recovery on an ecological basis: degraded area recuperation; species diversity; mining areas; coal

INTRODUCTION

The criteria applied in recuperation processes, besides being variable, will initially depend on the characteristics of the degraded area. Independently, recuperation, at least over long-term, should re-establish ecological interactions, thereby facilitating the increase of local biodiversity. Only after these prerequisites have been fulfilled, will it be possible to affirm that recovery, on an ecological basis, has begun.

As also stated by Ser (2004), the recovery of an area on an ecological basis consists of re-establishing the dynamics of ecosystem processes,

through actions and procedures based on natural principles, and for ecological restoration in itself, and not simply for detaining certain processes of substratum loss by the use of any form of vegetal cover. The principle of recovery on an ecological basis will make it possible to reach a state of equilibrium, even though only close to that prior to the disturbance. In order to accomplish this, it is very important that, at the very beginning, vegetal cover of the areas to be restored be preferentially adopted from native species (13). Nonetheless, there are occasions in which the environment to be restored is so adverse to local species, that the use of exotic species, or even a mixture of these with domesticated exotic plants, and on the prior condition of their not presenting characteristics of invaders (7), is more appropriate, as a means of modifying the environment, in such a way as to facilitate the posterior establishment of native species (5, 3, 1), thereby giving continuity to the succession process. However, simply promoting vegetal cover, without necessarily taking into account ecological processes, could be considered as only recovering with vegetation or simply recuperation.

Connell and Slatyer (1977) presented three mechanisms, viz., facilitation, tolerance and inhibition, for explaining the process of vegetal succession. In the first, facilitation is defined as the modification of an environment by pioneer species, in such a way that this would facilitate the establishment of species characteristic of a more advanced stage in succession. Through tolerance, there is initial modification, but without affecting the recruitment of species of posterior succession stages. Finally, through inhibition, pioneer species modify the environment with such intensity, that this becomes only little or less adequate for any species of subsequent succession stages. Of the three mechanisms, that which would be more detectable is facilitation, especially in the initial stages of a succession. Even though it is not always possible to detect whether any one of the mechanisms is functioning alone in a succession, or even whether this is possible, probably all the three play their respective role throughout the succession process (9).

With these mechanisms in mind, over long term, restoration should not only re-establish those ecological interactions which facilitate succession and system efficacy, but also induce local biodiversity (13, 12).

In this study, vegetal species diversity is considered, as a possible indicator of the initial phases of the ecological-based recovery process of degraded areas, according to Connell and Slatyer (1977) criteria, as to the first mechanism (facilitation), and Reis *et al*. (2003) criteria as to biodiversity inducement. Thus, the establishment of new species follows a dynamically sequential and natural process of substitution and entrance of organisms, as outlined by Rogalski *et al*. (2005), until reaching an equilibrium phase, in accordance to local and regional environmental conditions (climatic and geomorphological).

The different types of interaction among living organisms, as, for example, predation, herbivority, pathogeny, mutualism and decomposition, at the different trophic levels, are prerequisites for characterizing an ecological restoration process (11), through inducing natural processes, such as vegetal succession, by the establishment of facilitating pioneer species in the processes of species entrance and substitution in the system (1). The processes unleashed in this first sequential phase will facilitate the entrance of spontaneous species from the native fauna, thus increasing diversity in vegetal species, to be followed by those of the associated fauna (14).

Nonetheless, success in a recuperation process carried out on an ecological basis, also depends on the initial conditions of the abiotic component of an ecosystem. An important point which should be considered – and contemplated – is soil retention against possible erosion. During the process of soil degradation, with the accompanying modifications in structure, and chemical and biological composition, organic-matter loss, as the main consequence, tends to retard the natural restoration process. One way of incrementing available organic matter is by transposing soil from neighboring areas, thereby recomposing fertility with mineral and organic nutrients and ionic exchange capacity, as well as part of the biota of this compartment of the ecosystem (13, 19). Furthermore, the seed bank and other propagules present in the transported soil can increase the diversity of

colonizing species in the new environment (19).

By the aforementioned motives, substratum fertility at two moments (initial and final), as well as the loss of this substratum through surface drainage during the period of observation, were chosen as additional indicators of the process.

In the phenomenon studied here, a descriptive approach on a temporal scale was chosen, starting from a completely bare substratum (time zero), although, through dealing with inedited knowledge and an emergent topic for subtropical areas in the south of Brazil, there were limits to a deeper statistical approach. In the present case, deeper statistical analysis would require having accompanied the process over several years, with direct dependence on environmental dynamics. Nonetheless, in spite of the short period of observation (32 months), clear tendencies of the established processes towards recovery on an ecological basis, were observed.

OBJECTIVE

The aim was to obtain experimental data on the initial processes which lead to the recovery of degraded areas on an ecological basis, having as the substratum, refuse from the processes of washing and beneficiating mineral coal in Treviso county, southern Santa Catarina State.

METHODOLOGY

The area chosen for field experiments corresponds to the taluses built by Mineradora Metropolitana, Treviso, SC, for the recuperation of areas of mineral coal deposits, whose geographic coordinates are 28º29'02.33"S and 49º27'33.53"W. Refuse from washing and beneficiating deposited coal, and accumulated at the base of each talus, has been covered by B horizon soil from the region. These taluses are encountered in an environment of the Atlantic Forest. They are located on various platforms placed around the heap of refuse, each platform measuring around 2000 m in length (Figure 1). The experiments were begun at the moment zero (control), in bare substratum, and consisted of setting up two plots on the taluses (Figure 2) for recovery experiments.

Figure 1. Delimitation of the refuse deposit and location of the study area on the deposit.

Initially, two species, *C. dactylon* and *I. campestris*. were implanted, one each, into two plots, each measuring 10 m x 20 m (Figure 2B). Planting took place on May 6th, 2008. Stolons were planted at a distance of 0.40m between rows and 0.20m between each plant (Figure 2A), in substratum without any correction of acidity or the addition of any type of manure. It is important to point out that the substratum used in this area for covering refuse had been taken from local B horizon soil, with low organic matter and nutrient rates, especially of nitrogen (Table 1).

The collection of substratum compound samples was by boring till a depth of 20cm. This was done in each of the two plots in the beginning (zero moment – control), on May 6th, 2008, and at the end (32 months) of the experiment. This substratum was analyzed for fertility, according to the method described by Tedesco *et al*. (1995). Soil pH was defined with a potentiometer in a soil-water suspension, at a proportion of 1:1. The organic matter rate was defined by humid digestion, using potassium dicromate and sulfuric acid. The micronutrients were obtained according to the methods described in Cqfs - Comissão de Química e Fertilidade do Solo (2004).

Due to high seedling mortality, in September it became necessary to plant more seedlings in both plots. In order to evaluate the amount of sediments through artificial drainage, 0.5 m x 5 m troughs were installed in both plots (Figure 2A).

As a form of comparing the efficiency of each species in substratum coverage and inducing colonization by new species, after the seedlings of both species had reached an adequate growth,

surveys of abundance and cover, according to Braun-Blanquet (1979), but modified, were carried out in April and October, 2009 and February, 2011, in 9 sub-plots measuring 0.5m x 0.5m (0.25m²), with systematic selection procedures for localizing planted pioneer species in each plot (Figure 2B). Species diversity was estimated according to the Shannon index (1948) in both planted plots. As a complement, the *t* test was applied for estimating the significance of results between the two species. Both the significance test and diversity index were obtained with PAST software (10).

Figure 2. General view of the plots at the time of planting in May, 2008, with surface drainage gutter (A) and the scheme of experimental delimitation in plots and sub-plots (B).

RESULTS

The substratum analyzed corresponded to material used for covering refuse from coal mining (B horizon of local soil). Thus, generally speaking, fertility was very low and acidity high (pH = 4.5). The initial degree of organic matter was almost zero (0.3%). Nonetheless, an increase in organic matter and a drop in acidity were noted following planting and the subsequent advance in revegetation. The same could be observed through the increase in ions that are important for vegetal development and growth, and the decrease in the concentration of some heavy metals and aluminum, whereby the inference that the species planted are capable of contributing to the phytoremediation process, i.e., the absorption of toxic ions by tolerant plants.

Table 1. Physical and chemical characteristics of the substratum (B horizon local soil) used for covering carboniferous refuse in the area of implanting recovery plots, obtained in the beginning and at the end of experiments.

	Rates		
	Dec - 2008	Feb – 2011	
Substratum fertility	Talus/bare area	*Cynodon dactylon*	*Indigofera campestris*
Clay (%)	15	13	13
pH	4.5	4.7	4.8
SMP Index	4.7	4.7	4.8
Phosphorus (mg dm^{-3})	4.5	2.1	1.7
Potassium (mg dm^{-3})	127	142	153
Organic matter (%)	0.3	1.9	2.6
Changeable aluminum ($cmol_c\ dm^{-3}$)	8.3	3.0	2.7
Changeable calcium ($cmol_c.dm^{-3}$)	0.7	2.4	3.6
Changeable magnesium ($cmol_c\ dm^{-3}$)	0.9	1.9	2.8
Aluminum + Hydrogen ($cmol_c.dm^{-3}$)	19.4	19.4	17.3
Cation change capacity (CCC) ($cmol_cdm^{-3}$)	21.4	24.1	24.1
CCC saturation as bases (%)	9	19	28
CCC saturation as Al (%)	80.9	38.9	28.3
Correlations Ca/Mg	0.8	1.3	1.3
Correlations Ca/K	2.1	7	9
Correlations Mg/K	2.8	5	7
Súlfur (mg dm^{-3})	84	45	31
Zinc (mg dm^{-3})	2.6	1.8	1.4
Copper (mg dm^{-3})	14.0	1.2	0.8
Boron (mg dm^{-3})	0.3	0.6	0.6
Manganese (mg dm^{-3})	22	25	28

Substratum analysis by the Soil Laboratory of the Faculty of Agronomy/UFRGS – a member of the Oficial Network Soil Analysis Laboratories (ROLAS) – in accordance with Tedesco *et al.* (1995) and Cqfs - Comissão de Química e Fertilidade do Solo (2004).

The species *I. campestris* afforded a quicker and more uniform recoverture of the area, leading to a reduction in drainage in the respective plot, when compared to that with *C. dactylon*. Nonetheless, as *I. campestris* is more sensitive to frosts than *C. dactylon*, from July on, it was noted that drainage was similar in both plots (Figure 3).

The peaks in sediment production occurred in March for the plot with *C. dactylon*, and in April for that with *I. campestris,* even though there was no a peak in rainfall and drainage. This probably occurred through digging up the soil to remove plants of the species (*Urochloa decumbens* Stapf, synonym *Brachiaria decumbens* - Poaceae), an exotic invader that had been used by the mining company for revegetation in the neighborhood of the study area, and whence had invaded the plots.

On an average, the production of sediments during the period analyzed was 43.5 and 43.8 kg per hectare in the plots with *I. campestris* and *C. dactylon*, respectively, thereby demonstrating that, when growth has been completely established, the potential for sediment retainment by both is similar. Nevertheless, these numbers do not represent total sediment loss during the period, since some rainfall-events were discarded from analysis, due to gutter overflowing, thus annulling correct volume readings on these occasions.

Over the same period, *I. campestris* cover dropped from 88 to 69%, but as plant decomposition in this species is quicker than in *C. dactylon*, in the collection in October, it was already possible to note an increase of 8 to 12 species, as compared to April. In February, 2011, in the plots of *C. dactylon* and *I. campestris*, there was 47 and 20% of uncovered soil, species richness was 18 and 9, and promoted cover 5 and 70%, respectively. The temporal sequence of the process of recovery over the two previous years can be seen in Figure 4.

As can be observed, between October, 2009 and February, 2011, cover in the *C. dactylon* plot dropped from 20 to 5%, which presupposes that this species was being dislocated by the rest in the succession advance, whereas in the *I. campestris* plot, cover practically remained around 70% throughout the period. Bare substratum remained around 20%. Shannon diversity indices for *C. dactylon* and *I. campestris* plots were in April, 2009 1.263 and 1.192, in October, 2009 0.791 and 1.260, and in February, 2011 1.594 and 1.227, respectively (Table 2). These results point to the greater

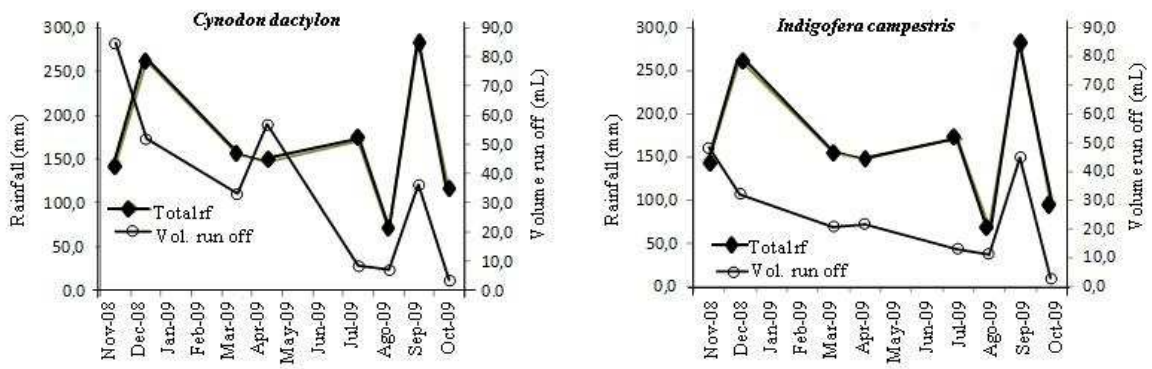

Figure 3. Data on the production of sediments in the plots for implanted recovery in the area of the coal deposit. rf = rainfall.

In April, 2009, there was 40 and 25% of uncovered soil, and species richness was 31 and 8 in the plots of *C. dactylon* and *I. campestris*, respectively (Table 2), whereas in October, 2009, uncovered soil was 44 and 25%, and species richness 19 and 12 (Table 2). In April, *I. campestris* soil coverture was around 25%, and *C. dactylon* around 40%. From April to October, 2009, although mantle cover rose from 5 to 35% in the area with *C.dactylon,* there was a drop of 31 to 19 species, and in cover from 40 to 20%, through the aerial part of many species dying during the winter. contribution by *C. dactylon* in furthering vegetal diversity throughout the period evaluated.

Table 2. Number of spontaneous vegetal species (Richness) in each of the recovery systems, and the respective Shannon Diversity indices (H').

	Period of data collection					
	2009, April		2009, October		2011, February	
Recovery plots	Species richness	Shannon Diversity H'	Species richness	Shannon Diversity H'	Species richness	Shannon Diversity H'
C. dactylon	31	1.263	19	0.791	18	1.594
I. campestris	8	1.192	12	1.260	9	1.227

Figure 4. Advance of the vegetation in the plots where *C. dactylon* and *I. campestris* were planted.

As to the substratum, on analyzing nutrients, it was noted that, over the period December, 2008 to February, 2011, there was an increase in organic matter of 0.3% to 1.9% in the plot with *C. dactylon* and to 2.6% in that with *I. campestris* (Table 1). There was also a tendency for a reduction in acidity, especially in the *I. campestris* plot, on comparing with zero moment. As to surface sediment drainage, on an average, the production of sediment from April to October was similar in both species, with 43.5 kg for the *C. dactylon* plot and 43.8 kg for that with *I. campestris.*

DISCUSSION

When considering the recovery of areas on an ecological basis, the species *C dactylon* was chosen for testing in the role of pioneer for establishing a sequential process, followed by accompaniment of diversity in other species throughout the process, as important elements in the recovery of areas impacted by the exploitation of coal. Efficiency was compared with that of another species of the family Fabaceae,

i.e., *I. campestris*, which also possesses the characteristics of pioneer plant and substratum restorer. The empirical and theoretic fundamentals of the initial phase of an ecological model for coal-refuse impacted area recovery have already been defined (1). No matter how drastic the local degradation conditions, the recovery of an area should not be understood as a simplified process, with the sole aim of recovering the area, or simply making it green.

When considering the serious physical and chemical limitations of areas impacted by coal mining, as revealed through substratum analyses, their recovery requires ample planning. The choice of appropriate vegetal species should be in accordance with criteria which facilitate the establishment of recovery on an ecological basis. Thus, further attention should be directed towards evaluating the capacity of the different vegetal species to colonize these environments and induce rapid soil coverture. This would consist of the contribution towards a reduction in surface and sub-surface drainage, and the fixing of toxic metallic elements, with an eye to phytoremediation, thence leading to an increase in local fauna and floral diversity (1,13). Thus, the species *C. dactylon*, was included in the experiments, through presenting the characteristics of tolerance to degraded terrains, as well as facilitating the entrance of new species into the community, even though it is a domesticated exotic species (17), whence its use is debatable (6). The species *I. campestris* was used as a pioneer, since, through being a Fabaceae, it possesses nitrobacterium nodules. This is an essential characteristic for substratum nitrogen enrichment, thereby, according to the degree of cover, reducing loss.

The results obtained for sediment surface drainage indicated their higher retention in the plot planted with *I. campestris*, which is characterized by lower native and spontaneous species diversity, when compared with the *C. dactylon* plot, thus placing in evidence that one vegetal species alone would hardly possess all the necessary characteristics for recovery in ecological terms. Hence, for recovery to play a complete role, it is necessary to understand the interactions between the species and the dynamics of succession, with a view to an increase in environmental diversity and local ecological complexity.

On the other hand, knowledge of the requirements for maintaining an ecosystem is not enough, but also comprehension of the methods and techniques which accelerate recovery processes in degraded areas, is essential. Among these, knowledge of facilitating species (5, 13, 9), nucleater species (13, 8), or 'nurse plants', that enhance recovery processes on an ecological basis, is essential, since these can also play a role in the natural advance of one type of vegetation over another, in a dynamic process of flower succession. These qualities, as observed in the experiment with *C. dactylon*, presuppose that this plant, even though a domesticated exotic species, is capable of exerting a facilitating role in natural sequential processes, since its substitution by other native species is possible. These characteristics contributed to higher spontaneous vegetal species richness in the plots with *C. dactylon,* than in those with *I. campestris*, as can be seen from results. Furthermore, *C. dactylon*, besides being heavy-metal tolerant and fast-growing in contaminated terrains (1), is capable of detaining substratum loss and partial fertilization, as was observed here.

The continuation of this work would make it possible to glean further invaluable information on the contribution of the vegetal species here used, when considering further sequential phases in vegetal coverture in association with bushy and arboreal species. Thus, the dynamics of the recovery process for degraded areas, applied on an ecological basis in a region where the original landscape matrix was Atlantic Forest, would be more comprehensible.

CONCLUSION

On comparing the outcome in plots of *C. dactylon* and *I. campestris*, after 32 months of planting on a bare substratum, it can be concluded that *C. dactylon* contributed more to an increase in native spontaneous species diversity and was more involved in the natural succession process, through its role in facilitating recovery on an ecological basis.

It can also be concluded that, besides substratum chemical indicators revealing a higher

contribution for fertilization on the *I. campestris* plot, there was no significant difference in surface sediment drainage between the two, a clear indication of the same capacity for substratum retainance.

RESUMO

A recuperação de uma área degradada deve aumentar a biodiversidade natural para caracterizar-se como restauração em bases ecológicas. Este estudo visou estabelecer experimentos que revelem os processos de avanço de vegetação espontânea em áreas degradadas pela exploração do carvão mineral. Inicialmente foram plantadas espécies para a cobertura primária deste substrato, formado por rejeitos de carvão, cobertos pelo horizonte B de solos regionais. A diversidade de espécies vegetais espontâneas foi monitorada em três levantamentos de abundância e cobertura, após o plantio das espécies com características de pioneira *Cynodon dactylon* (L.) Pers. e *Indigofera campestris* Bong. *ex* Benth. O experimento consistiu de uma parcela com 9 sub-parcelas para cada espécie. De abril de 2009 a fevereiro de 2011, a cobertura de *C. dactylon* reduziu-se de cerca de 40% para 5%, facilitando o estabelecimento de um maior número de espécies espontâneas nesta parcela. *I. campestris* cobriu cerca de 80% do solo em cada levantamento. O índice de Shannon diferiu significativamente entre as parcelas com as duas espécies ($f=0{,}0141$, $\alpha=0{,}05$) no período avaliado. Análises de fertilidade do substrato foram feitas no inicio e no fim dos experimentos e demonstraram que a fertilidade teve acréscimo de matéria orgânica, e redução de acidez no final do experimento. Conclui-se que ambas as espécies retém substrato, mas *I. campestris* contribui para uma maior fertilização do substrato e *C. dactylon* facilita a sucessão natural e a diversidade, sendo esta adequada à restauração.

Palavras chave: recuperação em bases ecológicas, recuperação de áreas degradadas, diversidade em espécies áreas de mineração, carvão.

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Brazilian Journal of Ecology ISSN 1516-5868

FLOWERING PHENOLOGY OF A BROMELIACEAE COMMUNITY OF AN ENVIRONMENTAL PROTECTION AREA (EPA) IN THE RESTINGA OF MARICÁ (RJ, BRAZIL) AS COMPARED TO OTHER HABITATS OF THE SOUTHEASTERN BRAZILIAN ATLANTIC RAIN FOREST

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ABSTRACT

A study was made of a community of Bromeliaceae in the EPA of a restinga in Maricá, Rio de Janeiro State, Brazil. The collected data revealed the intensity (2010-2011) and activity (2004-2011) of flowering phenology. Tests of the correlation between flowering and environmental factors, such as temperature, rainfall, relative humidity of the air and insolation, were applied, besides comparisons between these periods of the phenophase for the same species in other habitats of the Brazilian southern Atlantic Rain Forest. *Aechmea nudicaulis* (L.) Griseb., *Billbergia amoena* (Lodd.) Lindl., *Neoregelia cruenta* (Graham) L.B. Sm., *Tillandsia gardneri* Lindl., *Tillandsia stricta* Sol. ex Sims. and *Vriesea neoglutinosa* Mez., presented sequential flowering, with the peaks concentrated in the restinga rainy season. The abiotic factors tested revealed no statistically significant correlation with the periods of flowering in the majority of the species, with the exception of *T. stricta* and *B. amoena*. In the first, there was a significant positive correlation with medium and minimum temperatures, and the second, with the relative humidity of the air. Through bibliographic surveys, thereby comparing other habitats, three of the six species presented notable variations in the period and duration of flowering. There were also variations in floral visitor guilds, almost exclusively represented by hummingbirds in forested areas, but also including insects (bees and butterflies) in the area of the restinga. It was concluded that abiotic and intrinsic factors, such as phylogenetic constraints, are not the main determinants in the flowering periods of some bromeliads, thereby presupposing that biotic factors, such as pollination could be more significant.

Key words: Bromeliaceae, phenology, sequential flowering, restinga, phylogenetic constraints

INTRODUCTION

Even though phenological studies of Bromeliaceae have been included in those involving the Atlantic Rain Forest (15, 12, 14), caatinga (19), upland swamps (23), Amazon Forest (17) and rocky ground (21), these are scarce for the restinga (15, 3, 6).

Hummingbirds have been shown to be the main pollen vectors for around 85% of the Bromeliaceae species investigated (24). Many authors have indicated that sequential flowering is common among sympatric bromeliads of the same floral syndrome. This could arise from pollinator competitive activity, as a selective force, thereby

giving rise to divergence in species flowering peaks in the same locality throughout the evolutive process (3, 12, 14).

It has been said of the family Bromeliaceae, that rainy and dry season periodicity has a strong influence on the flowering pattern (5), with peak predominance in the rainy season, as registered in the Atlantic Rain Forest (12, 14) and the Caatinga (19). However, in upland swampy environments, bromeliad community behavior has proven to be otherwise, with the peak occurring predominantly in the dry season (23). Differences in the beginning and extension of the flowering period of the same species, although in different localities, could indicate that environmental factors are more important for phenology in tropical areas than intrinsic factors, such as phylogenetic constraint and evolutive history (11, 12).

OBJECTIVES

The aim was to characterize the flowering phenology of a bromeliad community in the EPA (Environmental Protection Area) of a restinga in Maricá, Rio de Janeiro State, Brazil, by investigating the occurrence of species sequential flowering, as well as the correlation between environmental factors, such as rainfall, temperature, relative humidity and insolation, with the flowering periods registered. Furthermore, attention was given to comparing the periods of flowering and floral visitors of these species in different ecosystems of the Brazilian southeastern Atlantic Rain Forest, through the use of the available bibliographic records. The intention was to contribute towards clarifying the question of which factors exert a greater influence on Bromelaceae phenology, intrinsic, i.e., phylogenetic relations or group evolutive history, or environmental, i.e., rainfall, temperature, photoperiod, relative humidity, pollinator availability and competitiveness.

METHODOLOGY

The study was carried out in an EPA in the restinga of Maricá, Rio de Janeiro State (22°52' to 22°54'S and 42°48' to 42°54'W), along a transect (320m) on an inner sandy cordon, parallel to the beach, and passing through two vegetal formations, an open bushy (shrublike) and closed bushy (22) areas, both not liable to flooding. According to Köeppen (1948) classification, the climate of the region is Aw tropical rainy, with the rains concentrated in the summer, and reduced in the winter. According to data from INMET (National Institute of Metereology), the average temperature during the year of studies (from May, 2010 to April, 2011) was 23,5°C, with a maximum average of 34,4°C and minimum 16,1°C. The total annual rainfall was 1.251,6 mm, with 65,6% occurring from October, 2010 to April, 2011.

Fortnightly one-or-two-day field visits took place between May, 2010 and April, 2011, during one year of observation. Considering each inflorescence as a single individual, bromeliads in flower and up to 1 meter on each side of the transect were marked. Records of each of the six bromeliad populations studied were of the absence or presence of the flowering phenophase (activity – 4). The intensity of the event was estimated by the number of individuals in flower, taking into consideration the three classes, low, medium and high, in accordance with the minimum and maximum number of individuals in flower (9 with modifications). Floral visitors were observed with the naked eye at various distances from the plant, during 5 to 15 minutes each visit, in sessions between 6 a.m. and 7 p.m. Visitors were identified only at the genus or family level.

Monthly rainfall (mm), maximum, minimum and average temperatures (ºC), relative humidity of the air (%), and total monthly insolation (hours) were taken into account, when checking correlations with the intensity of flowering of each species. The two latter parameters refer to historic averages for Maricá between 1986 and 2008 (Station n. 83089). The Spearmen correlation test, considering $p<0,01$, and with the STATISTICA version 7 program, was applied for testing the correlations of average temperature and rainfall, taking into account 1 and 2 months prior to the event (7).

Use was made of data collected during the study, as well as data on flowering phenological activity in bromeliads collected between 2004 and 2010 by Rodarte (2008 – and unpublished data), in the same area and for the same species, for testing flowering period

regularity. Bibliographic references containing data on the species in question (15, 12, 14) were also consulted, in order to compare flowering periods and bromeliad floral visitors in the restinga with other habitats in the Atlantic Rain Forest in the Brazilian southeast. After analyzing the areas of the reference studies, the following habitats of the Atlantic Rain Forest were considered: 1) granitic outcrops at sea level, known as rocky shores (15); 2) upland plains at over 1.400 m, this including two habitats proposed by Marques and Lemos Filho (2008), altitudinal mesic and stoney xeric; 3) forest mesic between 1.200 and 1.300 m; and 4) mixed ombrophilous forest, an ecotonal zone between Araucaria forest and the forest environment itself (12).

RESULTS

The bromeliad community studied included all the species found in the transect, *Aechmea nudicaulis* (n= 260), *Billbergia amoena* (n= 20) and *Neoregelia cruenta* (n= 61), of the subfamily Bromelioideae, and *Tillandsia gardneri*, during the years 2005, 2007 and 2010. In accordance with the data on flowering intensity, obtained for the years 2010-2011, although the bromeliads of the Maricá restinga presented sequential flowering peaks (Table 2), these were concentrated from the end of the rainy season during transition to the sub-dry (January to May). During the study period, there was a long period (July to December), in which Bromeliaceae species intensity and activity were low, with no register of flowering in October and November, 2010 (Table 2; Figure 1). The intensity of flowering (Figure 1) presented no significant correlation with the factors total rainfall, average, minimum and maximum temperature, relative humidity of the air, and total insolation for most of the species, except for *T. stricta*, whose peak of flowering was positively and significantly correlated with the average (Spearman coefficient = 0,76, for p=0,0039) and minimum (Spearman coefficient = 0,74, for p=0,0054) temperatures, and *B. amoena* with the relative humidity of the air (Spearman coefficient = 0,83, for p=0,0008).

Table 1. Records of the flowering phenophase in six bromeliad species of the EPA in the restinga of Maricá, RJ, during the period January, 2004 to April, 2011.

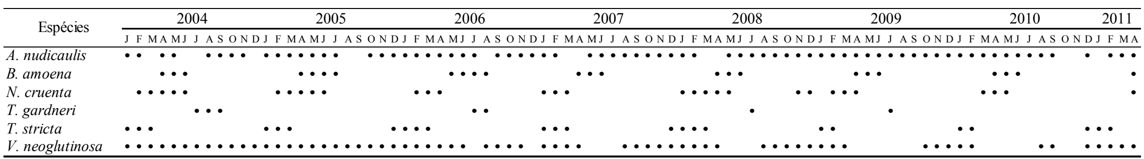
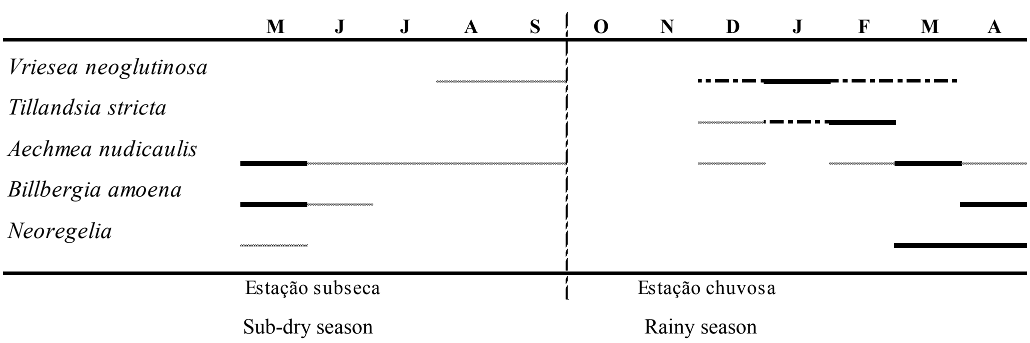


Table 2. Flowering intensity in five bromeliad species of the EPA in the restinga of Maricá, RJ (May, 2010 to April, 2011) Intensities - Low ...... Medium -.-.- High ——



T. stricta. (n= 54) and *Vriesea neoglutinosa* (n= 25), of the subfamily Tillandsioideae. Since 2004, species annual flowering periods have been relatively regular, varying from short to long (Table 1). The exception was *T. gardneri*, which presented a supra-annual pattern, through failing to flower

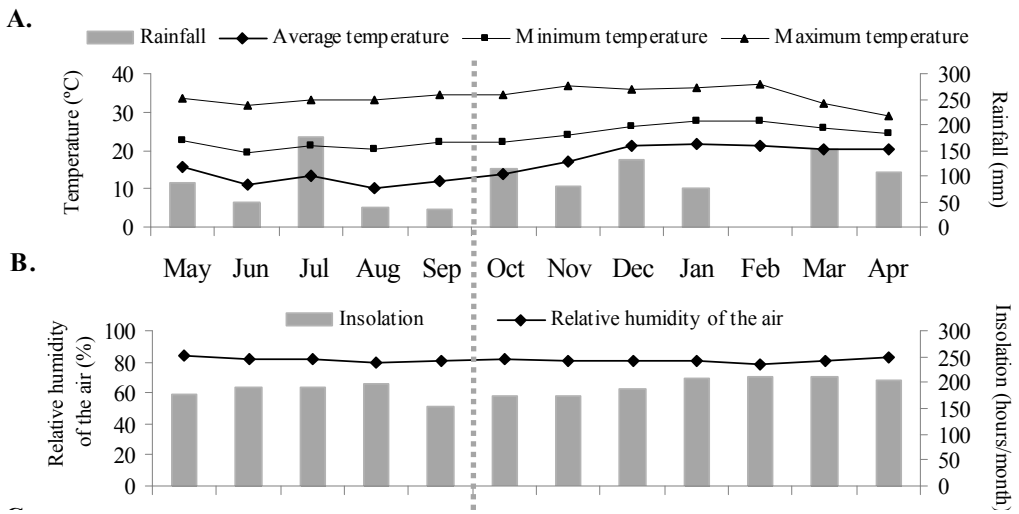
In three of the six species studied, there was appreciable variation in the period and duration of flowering, which very often took place in different seasons, when compared to occurrence in other habitats in the Atlantic Rain Forest (Table 3). The rainy (October to March) and dry (April to September)

periods are the same in all the areas studied. In the restinga, *Tillandsia stricta* flowers between December and March, hot and rainy months, whereas in up-lands and mixed ombrophylous forests, this occurs between May and September, colder months and with less rainfall. *Aechmea nudicaulis* also presents in uplands and mixed ombrophylous forests flowering period from November to February, when it is also hot and rainy (Table 3). This period is relatively short compared to the restinga, where the event extends throughout practically the entire year, with the peak in April and May (Table 2; Figure 1), which are months of transition to the colder and less rainy season. Apart from differences in the flowering period among the habitats compared (Table 3), *T. gardneri* also presented differences in the flowering pattern, by appearing as annual in the uplands and supra-annual in the restinga (Table 1 and 2). The only species that presented coinciding flowering periods in all the habitats of occurrence were *Billbergia amoena,* between April and June in the restinga and ombrophyilous forest, and *Vriesea neoglutinosa,* between August and March, in the restinga and rocky shores (Table 3). No records of *Neoregelia cruenta* were encountered in comparative studies.

Although hummingbirds (Throchilidae) were observed visiting all the bromeliads that flowered throughout this study, visits by butterflies were also recorded (Nymphalidae, Lycaenidae and Pieridae) in *A. nudicaulis* and *V. neoglutinosa*, as well as bees. *Euglossa* sp. and *Xylocopa* sp. in *A. nudicaulis*, and *Euglossa* sp. and *Trigona* sp. in *N. cruenta*.

Table 3: Flowering periods of six bromeliad species in various habitats in the Brazilian southeast Atlantic Rain Forest

	Restinga (sea level)	Granitic outcrops (sea level)	Upland plains (over 1.400m)	Forest mesic (1.200m)	Mixed ombrophilous forest (900m)
Aechmea nudicaulis	Jan - Dec (all seasons)		Nov - Feb (hot and rainy season)		Nov - Dec (hot and rainy season)
Billbergia amoena	Apr - Jun (cold and dry season)			Mar - May (transition)	Apr - May (cold and dry season)
Neoregelia cruenta	Feb - May (transition)				
Tillandsia gardneri	Jul - Aug (cold and dry season)		Feb - May (transition)		
Tillandsia stricta	Dec - Mar (hot and rainy season)		May - Sep (cold and dry season)		Aug - Sep (cold and dry season)
Vriesea neoglutinosa	Aug - Mar (transition / hot and rainy season)	Jan - Mar (hot and rainy season)			



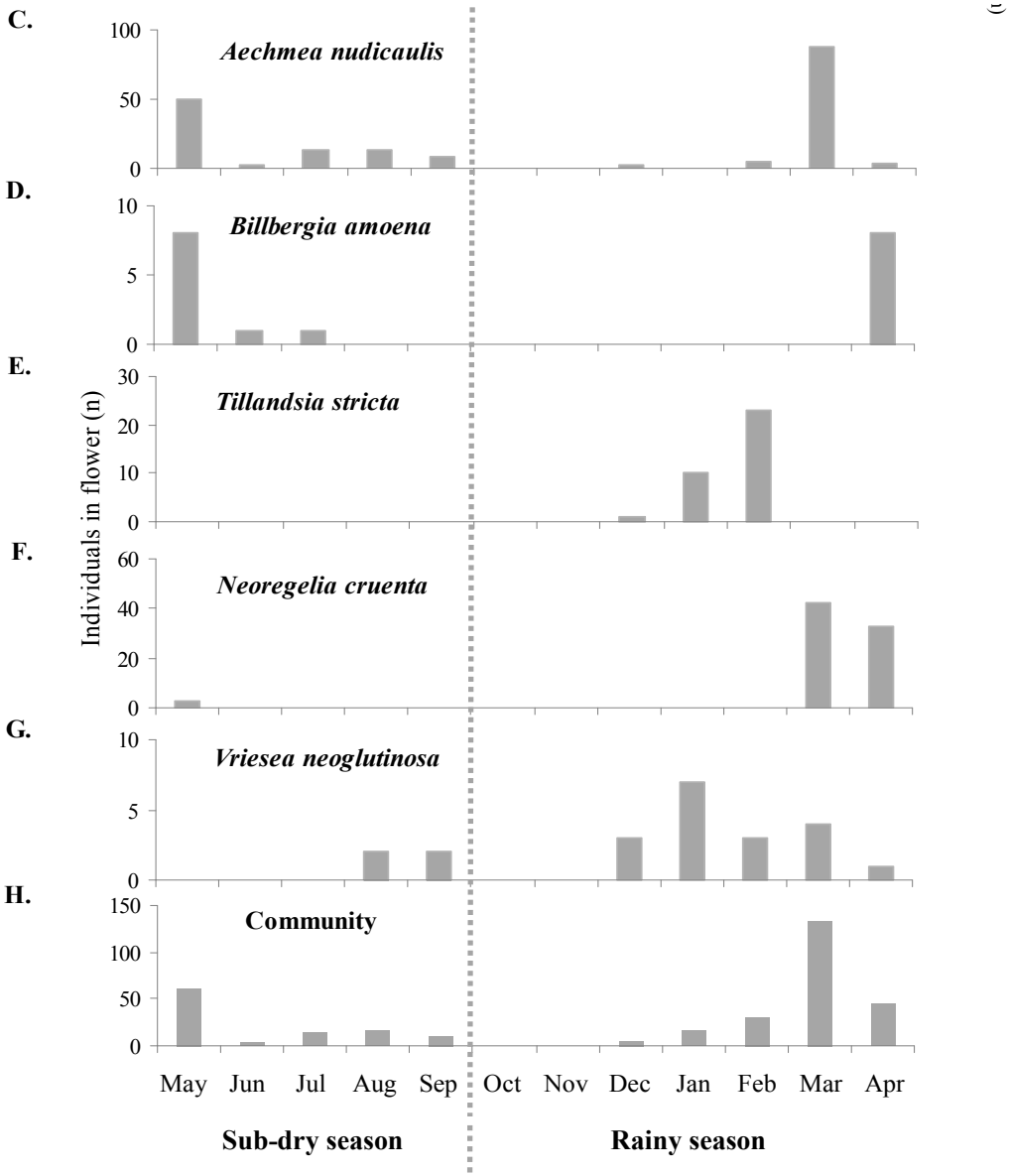


Figure 1. Records of abiotic factors and flowering periods of bromeliads species in an area of the EPA in the restinga of Maricá, during the period May 2010 to April 2011. A. Graph of average minimum and maximum temperatures (ºC) and rainfall (mm); B. Graph of relative humidity of the air (%) and insolation (hours/month); C-H. Distribution of the number of bromeliads individuals in flowers by species and community.

DISCUSSION

On comparing various habitats in the Atlantic Rain Forest, all in the southeast of Brazil, bromeliad species flowering phenology was found to be considerably variable. Kochmer and Handel (1986) attribute the regulation of flowering in temperate regions mainly to intrinsic factors, which they denominate phylogenetic constraints, and affirm that competition by pollinators would be responsible for only small and temporary adjustments during flowering periods. From the present study, it was possible to indicate that, in tropical areas, these constraints are possibly less important in determining phenological patterns than local selective pressure.

In all the bibliographies used for comparative studies (15, 12, 14), the six species studied presented ornithophylic characteristics, such as exposed inflorescences, with attractive bracts tubular and inodorous flowers with contrasting colors and daily anthesis (7), with records of hummingbirds as their main pollen vectors. Sequential and continuous flowering of species with the same floral syndrome has been pointed out as being an important strategy

in the maintenance of pollinators throughout the year, thereby maximizing the reproduction of these vegetal species (2, 12, 14). Nonetheless, the records of bromeliad flowering in the Maricá restinga have shown a period of the year with very low intensity, or even the total absence of floral activity, with the consequential lack of available nectar for hummingbirds. Notably, bromeliad species represented around 60% of the ornithophyles within the study area (18). In other words, they represent the main resource for these birds. Notwithstanding, there are records of low throchili diversity, with only *Amazilia fimbriata* Elliot and *Eupetomena macroura* Gmelin as floral visitors in the Maricá (13) and Jurubatiba (8) restingas. Possibly this diversification in the guild of bromeliad pollinators, this including insects, in the restinga, may have favored the successful reproducibility of these plants.

In the Maricá restinga, by presenting a high fruit|flower ratio (around 90%), *A. nudicaulis* is not self-compatible (Suizani, unpublished data). In other words, fruit production depends on the pollinator. This could be the consequence of the large number of visits by at least four species of butterflies and two species of bees supplanting the number of visits by hummingbirds. Schmid *et al.* (2011) reported that both bees and hummingbirds are responsible for the pollination of *A. nudicaulis* in an area of the restinga in Santa Catarina State. Besides hummingbirds, Almeida *et al*. (2004) also registered bees as the most frequent visitors (93,3%) of *Tillandsia stricta* in the Jurubatiba restinga. Apparently, hummingbirds were the only, or at least always the most frequent, floral visitors of the species studied in other habitats of the Atlantic Rain Forest (15, 12, 14). These data presuppose that, in the restinga environment, the pollination of some bromeliad species tends to be more generalist. As the restingas are geologically recent and their fauna mainly composed of species that have migrated from adjacent, humid forests (3), possibly more generalist pollination systems selectively arose, thus guaranteeing more successful reproducibility, as it is improbable that specialized pollinators migrated together with specific vegetal species (1). Thus, it is presupposed that pollinator competition was possibly different in the two areas, thereby giving rise to flowering period variation.

CONCLUSIONS

Divergence in flowering periods between the areas compared, and the rare cases of significant correlations between flowering and factors, such as temperature, rainfall, photoperiod and relative humidity of the air in the restinga, indicate that phylogenetic constraints and abiotic environmental factors are possibly not the main determinants of this phenophase in some bromeliad species. This presupposes that biotic factors, as variations in the pollinating scenario, could possibly be related to variations in the distribution and extent of flowering periods in species of this family, whose occurrence includes restinga and forest areas.

RESUMO

O estudo foi feito na APA da restinga de Maricá, RJ, Brasil, em uma comunidade de Bromeliaceae. Os dados coletados focaram a intensidade (2010-2011) e atividade (2004-2011) da fenologia da floração. Foram aplicados testes de correlação entre floração e os fatores ambientais temperatura, precipitação, umidade relativa do ar e insolação, além de comparações entre os períodos dessa fenofase para as mesmas espécies em outros habitats da Mata Atlântica do sudeste brasileiro. *Aechmea nudicaulis* (L.) Griseb., *Billbergia amoena* (Lodd.) Lindl., *Neoregelia cruenta* (Graham) L.B. Sm., *Tillandsia gardneri* Lindl., *Tillandsia stricta* Sol. ex Sims. e *Vriesea neoglutinosa* Mez. apresentaram floração sequencial, com picos concentrados na estação chuvosa da restinga. Os fatores abióticos testados não mostraram correlação estatística significativa com os períodos de floração da maioria das espécies. As exceções foram *T. stricta* e *B. amoena*, onde a primeira apresentou correlação positiva significativa com a temperatura média e mínima, e a segunda com a umidade relativa do ar. Três das seis espécies apresentaram variações notáveis no período e duração da floração quando comparadas a outros habitats, através dos levantamentos bibliográficos. Também foram observadas variações na guilda de visitantes florais, quase que exclusivamente representada por beija-flores em áreas de mata, mas incluindo insetos (abelhas e borboletas) em

área de restinga. Concluímos que fatores abióticos e intrínsecos (como restrições filogenéticas) não sejam os principais determinantes nos períodos de floração de algumas bromélias, sugerindo que fatores bióticos como a polinização possam ser mais significativos.

Palavras chave: Bromeliaceae, fenologia, floração sequencial, restinga, restrições filogenéticas

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Brazilian Journal of Ecology ISSN 1516-5868

FLORAL BIOLOGY AND POLLINATION ECOLOGY OF CHRYSOBALANUS ICACO L. (CHRYSOBALANACEAE) IN AN ENVIRONMENTAL PROTECTION AREA (EPA) WITHIN THE RESTINGA OF BARRA DO RIO MAMANGUAPE, PARAÍBA, BRAZIL.

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ABSTRACT

(Floral Biology and Pollination Ecology of *Chrysobalanus icaco* (Chrysobalanaceae) in an Environmental Protection Area (EPA) within the Restinga of Barra do Rio Mamanguape, Paraíba, Brazil). The aim was to investigate floral biology and pollination ecology of *Chrysobalanus icaco* (Chrysobalanaceae) in an EPA of Barra do Rio Mamanguape - Rio Tinto (6º 70'72''S and 34º 90'21''W). Data was obtained during the period July 30th, 2009 to September 30th, 2010. 10 individuals, distributed among dunes in the study area inside the open restinga, were selected. *Chrysobalanus icaco* presents continuous flowering, daily anthesis, clear-colored flowers, and a small amount of nectar, viz., 1-5µl with an average concentration of 20 to 55%. The flowers were visited by 11 insect species, belonging to the orders Hymenoptera, Lepdotera and Coleoptera. The most common visitors were wasps of the family Crabonidae. The bee *Apis mellifera* was also another. Although only 3,3% of fruit formation was obtained in spontaneous self-pollination treatments (n=1.452), the test control (n=1.064) was more successful with 9,5%. As the species is a generalist, hence visited by various groups of insects, it is important as a resource for the local fauna.

Key words: Restinga; *Chrysobalanus icaco*; pollination.

INTRODUCTION

The Atlantic Rain Forest biome formerly consisted of an area of 1.306.000 km², or around 15% of what is now known as, Brazilian territory. After 500 years of continuous exploitation, less than 4% of the original primary forest, plus 4% of secondary forest, still remain. Apart from this widespread devastation, the forest harbors one of the most important assemblages of plants and animals worldwide (45, 44).

Ecologically, the restinga is considered a mosaic of various vegetal formations belonging to the Atlantic Rain Forest, located on the Brazilian coastal plateau (35). According to Suguio & Tessler (1984), the denomination 'restinga', as employed in the Brazilian literature, has several meanings, and can be used as much for designating various types of coastal deposits, as well as other coastal, and even vegetal, features. According to Azevedo (2005), the adaptability of the species encountered in coastal ecosystems demonstrates their importance in the maintenance of dune relief, which is constantly undergoing modifications, mainly wind induced.

The family Chrysobalanaceae, distributed throughout tropical and subtropical regions, is comprised of 20 genera and 500 species, form shrublike to arboreal (29). The species

Chrysobalanus icaco L., a shrub, is essential for fixing dunes in areas of the restinga. In Brazil, this species is also used in the treatment of diabetes, its hypoglycemic and diuretic effects having been pharmacologically proven (13, 7, 2).

As, to date, there are few studies of floral biology and pollination ecology of the Chrysobalanaceae family, and with the aim of obtaining additional information, an investigation of these specific aspects in *Chrysobalanus icaco* was undertaken, in an Environmental Protection Area (EPA) in Barra do Rio Mamanguape, in Rio Tinto county, Paraíba State, one of the most important conservation units in the Brazilian northeast.

METHODOLOGY

Study area

The study was carried out in the EPA of Barra do Rio Mamanguape (6º46'55,814" S and 35º03'46,732'' W), in Rio Tinto county, Paraíba State. The EPA perimeter is around 80 km, encompassing a total area of 14.460 ha (34). According to Köppen, the climate of the region is tropical rainy (Aw), and the average annual temperature varies between 24ºC and 27ºC. The average annual rainfall along the north Paraiba coast is around 1.500mm, with the rains concentrated in the trimester April to June (28).

Sampling planning

Data were obtained during the period July 30th, 2009 to September 30th, 2010, during monthly visits to a natural population of *C. icaco*. In the study area, 10 individuals, 5 to 10 meters, apart were selected. These were distributed in an area of dunes in an open part of the restinga at about 50 meters from the beach (6º 70'72''S and 34º 90'21''W Datum SAD-69).

The flowers collected from five individuals were conserved in alcohol 70% for subsequent analysis and morphometry of floral structures (n=20) through stereomicroscopy. The average number of flowers per inflorescence was estimated (n=40), and the number of open flowers in three randomly chosen individuals counted. Floral anthesis and resources offered to visitors were verified in the field. For the former, buds in the pre-anthesis stage were marked for posterior accompaniment until floral senescence. Stygma receptivity was tested in the field using H_2O_2, and with the aid of a magnifying glass (18). Sugar concentration in the nectar was noted with the aid of a pocket refractometer (0 - 90% Atago®), and the volume measured with micro-syringes of 5 µl and 10 µl (Microliter®) from buds which had been previously bagged during pre-anthesis. In order to check the rate of floral nectar production in six groups of inflorescences, each group containing four flowers, use was made of cloth-bagged inflorescences, thereby impeding floral-visitor contact.

At 7 a.m., nectar was extracted from the first group, at 9:00 a.m., from the second, and so on, the final extraction from the sixth group beginning at 5:00 p.m. The pollen grains from each anther were colored with safranine and counted directly (14) with the aid of a squared laminator and stereomicroscope (16x magnification). Pollinic viability was estimated using acetic carmine 2% (33). Ten buds in the pre-anthesis stage from three specimens were used throughout the whole process. The ovary wall was cut open to facilitate ovule counting.

For obtaining phenological data, ten individuals were observed by monthly accompaniment over the period July, 2009 to Sepetember, 2010, whereby data referring to flowering and fruition were collected (17). The flowering pattern was classified according to Newstrom *et al.* (1994). Normality testing of data was through Shapiro – wilk, followed by Pearson linear correlation testing of the relationship of the flowering and fruition phenophases with precipitation.

During the study period, 85 hours of observation, distributed throughout seven consecutive days from 5:00 a.m. to 5:00 p.m., were exclusively dedicated to recording and observing visitors, as to visiting time, frequency and duration, and their behavior towards the flowers. During this period, visitors were classified as rare (0 to 5% of the visits), common (6 to 15% of the visits), and very common (16 to 45% of the visits), as well as effective pollinator (eP) – all those that contacted the stigmatic area and the anthers -, and occasional pollinators (oP) –stigmas and anthers only rarely or not contacted - . The spot of pollen placement on the visitor's body was analyzed according to visiting

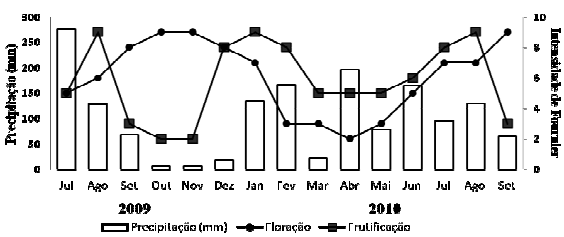
behavior. Some visitors from each visiting species were collected and dry-mounted for structure analysis and identification, prior to depositing in the Laboratory of Vegetal Ecology – LABEV – of the Federal University of Paraíba, campus IV.

For defining reproductive strategy, *C.icaco* flowers were subjected to experiments involving manual self-pollination, spontaneous pollination, xenogamy, natural pollination and apomixis. Buds, previously randomly selected among the ten individuals under study, were marked with a colored tape, to be so identified as test controls. The exsiccates produced from sample specimens were deposited in the Laboratory of Vegetal Ecology – LABEV – of the Federal University of Paraíba, campus IV.

RESULTS

Chrysobalanus icaco is a shrublike species, from 1,5 to 3 meters high, and generally placed 2 to 10 meters apart, one from the other.

Flowering occurs throughout the year (27), the peak of highest concentration of inflorescences and flowers per individual occurring in the dry season, from September to December, with little rain (66 mm), and an average temperature of 27°C (Figure 1). Generally speaking, when compared to other species, *C. icaco* flowering and fruition is extremely irregular, with the regular occurrence of individuals presenting all the different stages at the same time, thereby generating mutual asynchronism. Whereas some individuals presented flowers, others, which had already ceased to flower, had reached the fruit maturation stage, and some even presented overlapping cycles of flowering-production of fruits-seeds in one and the same plant.



Rainfall Flowering Fruition

Figure 1. Fournier Intensity of the flowering and fruition phenophases, as well as precipitation, of the ten *Chrysobalanus icaco* individuals during the period July, 2009 to September, 2010.

The production and development of *C. icaco* fruits occurs throughout the year with a peak of release from December to February (Figure 1). As regards size, this attained around 7 mm (N=50) in a fortnight, thereon varying between 12,8 and 19,6 mm (DP 2,13, N=44), until reaching maturation, ready for dispersion, at the end of 45 days, with sizes varying between 26,8 and 29,3 mm (DP 1,33, N=20).

Data on flowering (p= 0.1026), fruition (p=0.6722) and precipitation (p=0.41497) were considered normal. There was a significant negative correlation between flowering and precipitation ($r = -2.1611$, $p < 0,005$), contrary to fruition and precipitation where the correlation was significantly positive ($r = 1.4265$, $p > 0,005$).

C. icaco inflorescences are terminal cymoid. The number of flowers that open every day, per inflorescence, varied between five and eight (DP 1,41, N=40), there being a certain variation in the number among individuals. The 7 to 11 mm long (DP 1,4 – N=20) flowers are hermaphroditic and urceolate, whose floral parts are arranged in whorls (cyclic). The 10 mm-long gynoecium, which possesses a pilose semi-detached ovarium and is unilocular, uniovular and stileto-like, positions the stygma over and opposed to the stamina. The androecium, formed by 22 four-to-six mm long (DP 1,2, N=20), polystem, heterodynamic and external stamina, possesses yellow-colored anthers and a longitudinal opening. The fruit is berrylike, 5 cm in diameter and red and orange colored with a soft white pulp.

Anthesis lasts three days. On the first day, the flowers are light colored and attractive. On the second and during the morning, the petals, which have acquired an orange tone, drop off. The opening of the buds is asynchronous, the production of nectar initiating even before the petals are fully open. Some flowers already begin to open at around 8:00 a.m. Protogyny occurs in the first two hours of opening, and when the flower is in the feminine phase. Spontaneous opening of the anthers begins gradually and asynchronously from 10 o'clock on, thereby initiating the bisexual phase of the flower. At both instants, the petals are attractive and there is the production of nectar, with average viability reaching 95% (± 2,0).

C. icaco flowers begin to produce nectar at 7:00 a.m., with an average volume of 2,5± 2,0 µl

per flower. In other words, even before the flower is totally open, production has already begun, only dropping off at the end of the afternoon. However, although the production of nectar takes place in the first ten hours of anthesis, there is only an increase in the concentration of sugar towards the end of the afternoon.

The small amount of nectar produced (1-5 µl) is stored on the nectariferous disc at the filament insertion, and is limited to the first day of anthesis. In the present case, nectar sugar concentration was 15-55%. The production of nectar of the last group of flowers tested reached 5,4 ± 5,2 µl, 55% of the total volume of nectar accumulated (Table 1). The extraction of nectar did not affect its production. With a constant daily production of nectar for visitors, the number of these per flower was naturally higher. Keeping in mind that the plant is a generalist, the production of nectar was consequentially higher.

The average production of nectar was around 1.0 ± 1.5 µl. For extraction at the six times indicated, there must have been re-absorption, notable through the similar quantities of nectar momentarily available. The first group began with a concentration of 15%, this reaching 55% towards the end. In the second group, this began with 32%, had already reached 42% until 11: a.m., and gradually dropped until 1:00 p.m. Oscillations in production possibly occurred throughout.

The *C. icaco* flowers were visited by 11 insect species belonging to the orders Hymenoptera (8), Lepidoptera (2) and Coleoptera (1). The visitors, their behavior and the resource sought appear in Table 2. The first visits began at 7:00 a.m., even before the flowers were completely open. The most common visitor was a species of wasp of the family Crabronidae. When on the flowers, these wasps were shown to be extremely territorial. After initially flying over the plant, they then alighted on a flower, even when not completely open, whereupon they introduced the buccal apparatus to suck out nectar. On passing through the inflorescences, the ventral part of the abdomen entered in contact with the anthers and stigma. Although the visit to each flower lasted around 2-3 seconds, permanence among the inflorescences themselves depended on the number of open flowers. The wasps of this family can be considered as the effective pollinators, since, through seasonal independence, their behavior and frequency was stable throughout the year.

Bees of the species *Apis mellifera* L. entered in contact with the reproductive structures when collecting nectar. During the rainy season, their visiting peak was between 10:00 and 11:00 a.m. in the morning, and 2:00 to 3:00 p.m. in the afternoon. The duration of each visit was extremely variable, extending to 9 seconds per flower, during which there were short and continuous flights among the inflorescences.

Table 1. Volume and concentration of nectar in *Chrysobalanus icaco*, measured by group of flowers subjected to extraction.

		Time of extraction of nectar					
Group		**07:00**	**09:00**	**11:00**	**13:00**	**15:00**	**17:00**
1	µl	2,5± 2,0	1,5 ± 1,3	1,0 ± 0,7	1,5 ± 1,0	1,0 ±0,7	0,7 ±0,5
	%	15	15	32	35	42	55
2	µl		4,0 ± 3,9	1,3 ± 1,2	1,4 ± 1,2	0,9 ± 0,8	0,7 ± 0,6
	%		32	42	34	55	55
3	µl			4,5 ± 4,2	1,9 ± 1,6	1,3 ± 1,2	1,3 ± 1,1
	%			42	42	55	55
4	µl				5,1 ± 5,0	1,5 ± 1,2	2,3 ± 2,2
	%				42	42	55
5	µl					4,7 ± 4,4	3,3 ± 3,4
	%					42	55
6	µl						5,4 ± 5,2
	%						55

Bees of the species *Trigona spinipes* Fabricius were often observed collecting nectar. In this case, the bee perforated the chalice, thereby harming the flower, since some lepidoptera, which before collected legitimately, began to introduce their apparatus through the hole thus made.

In the reproductive experiments (Table 3), it could be observed that, whereas spontaneous self-pollination treatment was successful in 3,3% of the cases, in the test control this reached 9,5%. Although the fecundation obtained by self-pollination indicated species compatibility, this was inexpressive, due to the small number of fruits formed (3,3%). Low fruit productivity was characterized through reproductive testing.

Table 2. Visitors to *Chrysobalanus icaco* flowers. Ep – Effective pollinator, Op – Occasional pollinator, N – Nectar; P – Pollen. R = rare (till 5% of the visits); C = common (6% to 15% of the visits) and VC = very common (16% to 45% of the visits).

Order|Family	Genus|species	Frequency of visits	Behavior	Substance collected
Hymenoptera/Crabronidae	Morfoespécie I	VC	Ep	N
Hymenoptera/Apidae	*Centris nitens* Lepeletier, 1841	C	Op	N/P
Hymenoptera/Apidae	*Apis mellifera* Linnaeus, 1758	VC	Op	N/P
Hymenoptera/Apidae	*Xylocopa frontalis* Olivier, 1789	R	Op	N/P
Hymenoptera/Vespidae	*Polistes canadensis* Linnaeus, 1758	R	Op	N
Hymenoptera	*Pepsis* sp.	C	Ep	N/P
Hymenoptera	Vespa sp.	C	Op	N
Hymenoptera/Apidae	*Trigona spinipes* Fabricius, 1793	VC	Op	N/P
Coleoptera/Coccinellidae	Não identificado	R	Op	N
Lepidóptera 1	Não identificada	R	Op	N
Lepidóptera 2	Não identificada	R	Op	N

Table 3. Formation of fruits from controlled pollination.

Treatment	N. of flowers Tested	N. of Fruits Obtained	Success (%)
Control	1064	101	9,5
Spontaneous autogamy	1452	47	3,3
Manual autogamy	43	0	0
Xenogamy	36	0	0
Apomixis	25	0	0
Total	2620	148	5,9

DISCUSSION

The floral attributes presented by *Chrysobalanus icaco*, such as diurnal anthesis, a short corola, light color, low production of nectar (2.5± 2.0 µl), several flowers per inflorescence and sweet odor, are all associated to the syndrome of entomophily (15). Morphological analysis of the flowers indicated hermaphroditism, the most common type of sexual system among the angiosperms (31).

The concentration of sugar in nectar is also associated with the type of floral visitor (6, 15, 31). Flowers visited by bees and wasps present a high concentration (13-50%), which was the case of *C. icaco* in the present study, with an even higher concentration (55%) than the interval established by Baker (1975).

C. icaco visitors used nectar as the main foraging resource, possibly due to its high concentration. Besides being the most important floral reward offered to pollen biotic vectors (23), nectar is easily metabolized by all classes of floral visitors, without requiring high energetic expenditure from the plant for its production (38). The reduced production of nectar could be related to a species strategy, thereby forcing visitors to carry out the search among several flowers to satisfy their wants, with the consequential cross pollination (26, 37). The association of low production with high concentration is essential for a plant to benefit by pollination. Whereas the high concentration of nectar sugar serves in attracting pollinators, its constant availability throughout the day maintains their presence.

Various patterns of nectar secretion during anthesis can occur in vegetal species; on the one side, only one secretion occurs throughout the entire anthesis, whereas on the other, secretion can continue after each removal by a visitor, with the consequential replacement of volume (19). This is what occurred with *C. icaco*, whose continuous secretion guarantees a constant flow and larger number of visitors per flower, also the case of Couepia uiti (Chrysobalanaceae), as noted by Paulino Neto (2007).

The concentration of nectar in C. icaco flowers is high and similar to that of other generalist entomophylous plant-species (8, 24, 29, 35), which makes this resource a very attractive energy source for visitors. According to Baker (1975), flowers visited by wasps and bees present high nectar sugar concentration (16-50%). Furthermore, the increase in this concentration could be related to changes in temperature and relative humidity (12). Although the volume of nectar produced per flower in *C. icaco* is low, this is compensated by the high concentration of sugar, which, in this case, reached its peak at the end of the afternoon.

C. icaco presents generalist entomophylous pollination. The most frequent visitors were wasps of the family Crabronidae and bees of the species *Apis mellifera* and *Centris nitens*. Flowers adapted to pollination by bees and wasps are denominated entomophylous (15, 9, 31).

Wasps of the family Crabronidae, even though less frequent, are considered legitimate visitors, by their constant pollination throughout the year, independent of the season, thus different from the bees *Apis mellifera* and *Centris nitens*, which are seasonal. According to Proctor *et al*. (1996) and Heithaus (1979), flowers pollinated by wasps are open, small and opaque-colored, with a shallow corola, hence facilitating access to the nectarines, whereas in flowers where corollas are deep and narrow, access is restricted (1). To date, there are no studies or citations of floral visits by species of the family Crabronidae.

Wasps are cited as effective pollinators in various studies (32, 46, 25, 22, 1).

Flowering in *C. icaco* is continuous and abundant, thus offering a high availability of resources for the anthophilous fauna of the area. Plants with massive flowering, the case of *C. icaco*, attract opportunist visitors, capable of quickly responding to the ephemeral availability of resources (20, 11, 10). Furthermore, according to Augspurger (1980 and 1981), abundant flowering not only attracts a large number of floral visitors, but also increases the rate of visits and transportation of pollen among plants, thus elevating pollination levels.

Chrysobalanus icaco is characterized by low fruit production (Fruits|Flowers=9,5% reproductive success). A certain amount of the formed fruits drop off while still in the green stage, without reaching maturity, when the fruit is purple-reddish. As expressed by the average Fruit|Flower proportion of 42.1% (42), hermaphrodite plants produce an excess of flowers which do not reach the fruit stage. Hypotheses have been presented, in the attempt to clarify this pattern of low fruit production, among which, limitation in the amount of pollen, number of pollinators, or amount of maternal nutrients, or even selective abortion, are outstanding (40, 41). In the species under study, there appears to be no limitation in the amount of pollen or pollinators, since the occurrence of flower visits is intense. Furthermore, the gradual release of pollen grains favors their availability throughout anthesis.

The reproductive success of spontaneous self-pollination (3.3%) was less than that under natural conditions (9.5%), or rather, even though self-fecundatory, cross pollination in *C. icaco* places in evidence the extreme importance of pollinating agents for the species and its genic flow. In species of the family Chrysobalanaceae, such as *Couepia uiti* (30) and *Couepia bracteosa*, self-incompatibility was evident (16). Work on the reproductive system of this family is, as yet, scarce, whereby the urgent necessity for further pertinent studies.

As regards the pollen|ovulum rate, the more efficient the transference of pollen, the lower is the rate (14). In *C. icaco*, xenogamy is obligatory, thus the pollen|ovulum rate is very high. Hence, on analyzing self-pollination test data, the extremely high dependency on pollinators for accomplishing reproductive efficiency becomes evident.

Continuous flowering in *C. icaco*, added to its floral characteristics, makes this a key species, due

to its ecological role as a source of trophic resources throughout the year, both for its own pollinators, as well as other insect species, which, in turn, act in pollinating numerous other plants in the ecosystem.

ACKNOWLEDGEMENT

Thanks are extended to Dr. Celso Feitosa for the identification of the wasps and bees (UFPB); to MSc. Maria do Céo R. Pessoa (UFPB) for identification of the vegetal species studied; to the Instituto Chico Mendes de Conservação da Biodiversidade – ICMBio, and to CNPq for the Scientific Initiation grant for the first author, and for the grant Productivity in Research for the second.

RESUMO

(Biologia Floral e Ecologia da Polinização de *Chrysobalanus icaco* (Chrysobalanaceae) em uma área de Restinga na Área de Proteção Ambiental (APA) da Barra do Rio Mamanguape, Paraíba, Brasil). O presente estudo teve como objetivo investigar a biologia floral e ecologia da polinização de *Chrysobalanus icaco* (Chrysobalanaceae) na APA da Barra do Rio Mamanguape - Rio Tinto (6º 70'72''S e 34º 90'21''W). Os dados foram obtidos no período de 30 de julho de 2009 a 30 de setembro de 2010. Na área de estudo foram selecionados 10 indivíduos distribuídos em área de duna na formação aberta de restinga. *Chrysobalanus icaco* apresenta uma floração contínua, antese diurna, flores claras e uma pequena quantidade de néctar, 1-5µl com concentração média 20 a 55 %. As flores foram visitadas por 11 espécies de insetos pertencentes às ordens Hymenóptera, Lepdóptera e Coleoptera. Os visitantes mais comuns foram vespas da família Crabronidae e a abelha *Apis mellifera*. Nos tratamento de autopolinização espontânea (n=1452) obteve-se 3,3% de formação de frutos, mas no teste controle (n=1064) obteve-se um maior sucesso com 9,5%. Por ser uma espécie visitada por vários grupos de insetos, possuindo, portanto, um sistema de polinização generalista, a espécie é importante como fonte de recursos para fauna local.

Palavras chave: Restinga; *Chrysobalanus icaco*; polinização.

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ANALYSIS OF THE LANDSCAPE STRUCTURE OF THE COQUEIRAL ENVIRONMENTAL PROTECTED AREA, COQUEIRAL, MG

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ABSTRACT

This study analyzed the landscape structure of the Coqueiral Protected Area, located in southern Minas Gerais. We aimed to evaluate the landscape structure in the study area, based on landscape metrics and indicate priority areas for conservation. We use Geographic Information Systems and Remote Sensing tools to construct a land use map from a HCR SPOT 5 satellite image. Landscape structure analysis was carried out through Fragstats software and used landscape metrics. Results showed pasture class was considered as the landscape matrix and occupied almost half of the protected area. Landscape structure analysis showed the landscape is dominated by agropastoral activities. The landscape presented 704 units. Mean patch size area was higher for pasture than semideciduous forest, while semideciduous forest presented higher patch density. Land use classes showed complex shapes indicating higher edge effects. Pasture had the lower patch isolation. Data obtained in this study are relevant for decision making and environmental planning of the Coqueiral Protected Area, allowing suggest priority areas for conservation.

Keywords: Landscape ecology, Landscape metrics, Geographic Information Systems.

INTRODUCTION

Over the past years, there have been profound technological, social, economic, and mainly, environmental modifications worldwide. Man-made modifications in the landscape have given rise to intense habitat fragmentation. The fragmentation of natural habitats has been defined by Metzger (1999), as a process of rupture in the spatial continuity of natural areas, thereby representing a serious threat to the maintenance of biological diversity. The transformation of these continuous areas has generated a landscape composed of natural vegetal remnants, split up into various patches that vary in size, shape, degree of isolation, and types of connectivity and environmental matrix (29).

The fragmentation process in Brazil gained momentum from 1970 on, with essentially negative impacts on biodiversity, as confirmed by several authors, such as Primack & Rodrigues (2001) and Tabarelli & Gascon (2005). According to Metzger (2009), with the reduction into small, spaced out fragments, degradation in the Atlantic Rainforest biome has reached such a high degree,

that, according to Tabarelli and Gascon (2005), the consequential alteration in natural ecosystems can be considered as the greatest threat to biodiversity.

As has been shown by several authors, the deforestation of tropical forests has caused profound modifications in their respective ecosystems. The main consequences of fragmentation are increased edge-effects, habitat loss, alterations in ecological interactions and reproductive processes of various species, the isolation of vegetal formations, increased predation and competition, the loss of micro-habitats, the extinction of species, and the loss in biodiversity (3, 27, 30, 14).

Within this context, landscape ecology could offer a contribution, since, according to Metzger (2001), the proposal of dealing with anthropic mosaics would be a way of understanding the occurrent human-induced structural and functional modifications in the landscape, as a whole.

By way of landscape structure analysis and interpretation, it is possible to compile efficient information for the planning of an area, thereby making it possible to identify probable negative impacts, as well as seek solutions compatible with the ecological, socio-economical and cultural spheres (31).

Information regarding the effects on landscape structure in tropical communities is still scarce, accounting for only 14% of published works (20) Therefore, it is of crucial importance, not only for developing the appropriate research, but also to better understand the fundamental patterns and processes of certain organisms. This would enable working on a local scale, since each area presents different landscape characteristics, whereby the need for ample knowledge on regional ecological relationships, contriving to facilitate a more efficient action for its gestation and conservation.

In view of this need for understanding landscape structure, as a means of undertaking adequate measures for biodiversity conservation, the Coqueiral Environment Protection Area (EPA Coqueiral) was chosen for the study, since, as it deals with an established conservation unit, there is the required management structure to make the use, protection, conservation and monitoring of natural and socio-economic resources of the area, feasible.

OBJECTIVE

The aim of this study was to analyze landscape structure and fragmentation in the Coqueiral Environmental Protection Area, as a means of supplying subsidies for the management of natural vegetal remnants, and to point out priority conservation areas.

METHODOLOGY

Study area

The Environmental Protection Area (EPA) of Coqueiral is located in Coqueiral county, in the south of Minas Gerais State. Comprising 6.836,21 hectares in the Rio Grande basin in the micro-region of Lavras, it is partly surrounded by the lake formed by the Furnas reservoir, and the remainder by the counties of Boa Esperança, Aguanil, Campo Belo and Nepomuceno, between the geographic coordinates 45°19'37,5" and 45°26'16,3" longitude west and 21°03'52,7" and 21°09'30,8" latitude south (11). The main productive activities are coffee, cattle raising and small farms.

The Coqueiral EPA, created on May 17th, 2002, occupies around 25% of the area of Coqueiral county. The income of the approximately 400 families that occupy the area is mainly based on coffee culture and cattle raising (8). As a large part is covered by shallow soils on a highly irregular relief, there are many restrictions to agricultural activities (13), therefore, there is a fundamental need for studies of the suitability and adequacy of land use, when attempting to conciliate an increase in the income of the population with environmental conservation.

Study Area mapping

Reconnaissance of the study area was the first step taken, followed by acquisition of a SPO5 satellite image, with 2,5m spatial resolution, encompassing the whole area of the county. The orthorectified image, acquired with radiometric pre-processing and geometric pattern (SPOTMAP), served as a base for mapping forest fragments, as well as land use and occupation.

The three image bands used for visual interpretation, viz., the two visible and the panchromatic of the electromagnetic spectrum, referred to the green (0,5 to 0,6 μm), red (0,6 to 0,7 μm) and panchromatic (0,48 to 0,71μm) wave lengths.

A false-color composite (RGB-12PAN) was used.

Thematic vector graph maps were obtained through Geo-referenced Information Processing with SPRING 5.1.5. (5). Visual interpretation was through the simultaneous observation of recognition elements, such as tone, color, texture, shape, size pattern, shade, and the association of available evidence, as described by Marchetti & Garcia (1997). Based on visual interpretation criteria, real use was mapped according to class, as follows: (*i*) *Semidecidual seasonal forest*: dense forest formations and gallery forest at the edge of streams, neglected/abandoned fields; (*ii*) *Cerrado*: cerrado formations; (*iii*) *Coffee*: cultures at the non-productive stage, i.e., under 3 years, and over three-years-old; (*iv*) *Exposed rock*: areas with visible rock formation; (*v*) *Pasture*: areas of natural and formed pasture; (*vi*) *Other cultures*: areas with annual cultures in various stages of development; (*vii*) *Other uses*: urban areas and those with improvements; (*viii*) *Reforestation*: areas set aside for planting eucalyptus; and (*ix*) *Water bodies*: water bodies, rivers, streams and reservoirs.

The true features of the land were confirmed by field visits. 50 points of each land-use-class were sampled using a GPSMAP Garmin 76CSx receiver, together with a TOPCON GPS precision receiver, *hiper* GGD model. All the geoinformation thus generated was included in a bank of geographic data. Visual interpretation hit indices were obtained by means of points collected in the field, accuracy being evaluated by the *Kappa* index. Confusion matrices were calculated by cross tabulation between the plans of matrix information of image-derived land use, and data from field sampling, according to the methodology described by Moreira (2003). *Kappa* index evaluation was with a table adapted from Landis & Koch (1977) (Table 1).

Table 1: Value for evaluating the degree of concordance, starting from the *Kappa* index

***Kappa* value**	**Concordance**
< 0,20	Poor
0,21 – 0,40	Weak
0,41 – 0,60	Moderate
0,61 – 0,80	Good
0,81 – 1,00	Very good

Source: Adapted from Landis & Koch (1977)

Landscape contion

Landscape contion, computed from the soil cover map by means of landscape indices, was calculated with FRAGSTAS 3.3 (18) software. Four metric contions were used, viz., area, density, shape and proximity/isolation (28, 6, 33) (Tables 2 and 3)

RESULTS

Table 2: Variables and abbreviations used in the metric formulas, as computed in this study

Variables	Definition
A	Total area of the landscape (ha).
a_{ij}	Area (ha) of the fragment *ij*. *I* refers to the type of fragment (class) and *j* to the number of fragments in the landscape.
a_{ijs}	Distance (m) between two fragments, based on the distance between the edges of two fragments, and calculated from the center of one pixel to the center of another.
e_{ik}	Total length of the edge (m) in the landscape between fragments type *i* and *k*.
h_{ij}	Distance (m) from fragment *ij* to the nearest fragment of the same type of habitat (class), based on the distance from edge to edge, and computed from cell-center (pixel) to cell-center (pixel).
h_{ijr}	Distance between the cells (pixels) *ijr* (located within the fragment *ij*) and the centroid of the fragment *ij*, based on the distance cell center (pixel) to cell center (pixel).
n_{ij}	Number of fragments of a determined type of habitat (class) *i* in the landscape.
P_i	Proportion of the landscape occupied by fragments of a determined class (*i*).
p_{ij}	Perimeter of the fragment *ij* measured by the number of cell (pixel) surfaces.
x_{ij}	Represents a metric that will be calculated in the formula of average, average of the area under consideration, standard deviance, and coefficient of variation.
Z	Number of cells (pixels) in the fragment *ij*.

Source: Adapted from McGarigal & Marks (1995)

Land use and occupation

It was possible to classify the area into nine classes of land-use. By occupying 49,19% of the total area (Figure 1), pasture was the predominant. Of the

Table 3: Indices of landscape ecology generated by FRAGSTATS (version 3.3) software for quantifying landscape structure

Indices	Formula	Sign and interval (unit)	Meaning
Class area (CA)	$CA = \sum_{j=1}^{n} a_{ij} \left(\frac{1}{10000}\right)$	CA>0 (ha)	This is a measure of landscape composition. Higher CA values indicate matrix dominance.
Percentage of the landscape in each class (PLAND)	$PLAND = P_i \frac{\sum_{j=1}^{n} a_{ij}}{A}$	PLAND>0 (%)	Quantifies the proportional abundance of each type of patch in the landscape. The interpretation of PLAND is the same as that described for CA, but expressed in percentages.
Number of patches (NP)	$NP = n_j$	NP≥1 (dimensional)	This is a simple measure of the degree of division or fragmentation. Higher values indicate higher landscape fragmentation, and lower values the union or extinction of fragments of the same class.
Patch density (PD)	$PD = \frac{n_i}{A}(10000)(100)$	PD>0 (number per 100 ha)	Represents the number of fragments of the class in 100 hectares of landscape. The interpretation of PD is the same as that described for NP.
Largest patch index (LPI)	$LPI = \frac{\max_{j=1}^{n}(a_{ij})}{A(100)}$	0<LPI<100 (%)	The highest value favors dispersers, pollinators and propagule dispersion, supplying smaller fragments.
Average area fragmentation (AREA_MN)	$MPS = \frac{\sum_{j=1}^{n} a_{ij}}{ni}\left(\frac{1}{10000}\right)$	AREA_MN>0 (ha)	Indicates the degree of fragmentation according to the number of fragments and the total area occupied by a certain class.
Index of average shape (SHAPE_MN)	$SHAPE = \frac{p_{ij}}{\min p_{ij}}, MN = \frac{}{}$	SHAPE_MN≥1 (adimensional)	Lower values indicate a simple type of fragmentation, thus beneficial for conservation.
Average distance from the nearest neighbor (ENN_MN)	$ENN = h_{ij}, \quad MN = \frac{}{}$	ENN_MN≥0 (m)	Lower values indicate fragment aggregation.

Source: Adapted from McGarigal e Marks (1995)

others, 28,95% of the area was covered by native vegetation (semidecidual seasonal forest and cerrado), 11,35% dedicated to coffee culture, 0,6% by other forms of culture, and 0,9% to reforestation, 6.836,21 ha, in total (Table 4).

A small part of the EPA corresponds to water bodies, representing 5.67% of the total area. Of this, 5% is part of the Furnas lake inside the reserve limits, with 52.37% of preserved secondary forest.

The Kappa accuracy index obtained in this classification was 95.75%.

Analysis of landscape structure

Through evaluating landscape indices, it can be seen that the four classes; pasture, coffee-culture, other cultures and reforestation occupy an area of 4273.13 ha (CA), corresponding to 62.49% (PLAND) of the total area (Table 5). The landscape percentage index (LPI) shows that, whereas the class 'pasture' occupies the largest fragment, i.e., 17.99%, the class 'semidecidual seasonal forest'

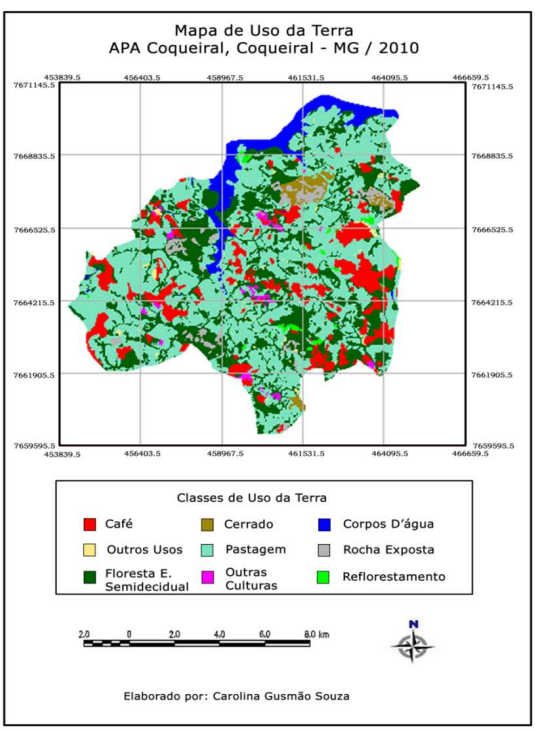

Figure 1: Map of land-use and occupation of the Coqueiral EPA, 2010

Table 4: Percentage of distribution in land-use in the Coqueiral EPA

Classes of land-use	Percentage
Coffee	11.35%
Cerrado	1.52%
Water bodies	5.67%
Semidecidual Seasonal Forest	27.46%
Other Cultures	0.6%
Other Uses	0.75%
Pasture	49.19%
Reforesting	0.9%
Exposed Rock	2.56%

Table 5: Landscape indices for the classes, land use and occupation

Classes	CA (ha)	NP	PD	LPI(%)	AREA_MN	SHAPE_MN	ENN_MN
Water bodies	387,56	26	0	2,95	14,91	1,00	545,77
Pasture	3378,96	130	1,01	17,99	25,99	16,15	21,02
Semidecidual Seasonal Forest	1844,01	265	2,06	2,45	6,96	6,11	38,24
Other cultures	50,87	102	0	0	0	1,84	280,78
Coffee	776,17	83	0	0	9,35	2,26	184,20
Other uses	52,46	25	0	0	2,1	1,88	489,12
Reforestation	67,13	26	0	0	2,58	2,37	398,8
Cerrado	103,72	13	0	0	7,98	2,92	492,84
Exposed rock	175,29	34	0	0	5,16	2,92	168,98

represents only 2.45%, much like that of the class 'water bodies', with 2.95% .

The entire landscape was composed of 704 patches distributed among the different classes of land-use. The most outstanding, with the largest number of fragments, were semidecidual seasonal forest, with 265 patches, and pasture with 130. The classes 'other cultures' and 'coffee' were also significantly represented, with 102 and 83 patches, respectively. The class 'cerrado' was almost inexpressive, with only 13 patches, adding up to 103.72 ha, throughout the entire landscape.

The classes of use that presented the smallest average sizes (AREA_MN) were those that presented the highest patch density (PD). They were: pasture (AREA_MN = 25.99; PD = 1.01 fragments|100 ha) and semidecidual seasonal forest (AREA_MN = 6.96; PD = 2.06 fragments|100 ha (Table 5).)

According to shape indices (SHAPE_MN), on a whole, landscape patches were of the most complex and irregular shapes, as clearly shown by the values for the different types of land use. Fragment irregularity in the class semidecidual seasonal forest was the highest at 2.23 (Table 5), although 'cerrado' was also high (1.95). Whereas only the classes 'water bodies' (1.0) and 'other cultures' (1.84) presented simple regular-shaped patches, the remainder were more complex-shaped, with results over 2.

The average distance from the nearest neighbor (ENN_MN) (Table 5) differed in the various classes. The lowest values were 'pasture' with 21.02 m and semidecidual seasonal forest with 38.24 m, a clear indication of intense clustering in both. On the other hand, through presenting few fragments (n=13), at 492.84, the ENN_MN for the class 'cerrado'was extremely high.

DISCUSSION

Land use and occupation

The analysis of land use and occupation indicated that, overall the landscape was mainly dedicated to agro-pastoral activities, such as pasture and coffee growing. Pasture covered the largest part of the EPA (49.19%), thus confirming cattle breeding to be the main local economic activity. Coffee culture, run on a family basis and occupying 11.35%, was another important economic source, with a large number of people depending on this activity for a livelihood. Other agricultural activities, such as 'other cultures' and reforesting, occupied smaller areas of the landscape, to a total of 1.5%. Donald (2004) stated that agricultural activities constituted the main threat towards maintaining biodiversity in the tropics.

Areas of native vegetation are distributed throughout the EPA in the form of small and middle-sized fragments. This very patchy landscape poses a grave risk for species extinction (22), through the consequential changes in both the micro-climate and fragment physical structure, and the reduction in environmental heterogeneity, thereby inducing lower local biodiversity (32).

By crossing field data, it was possible to analyze the outcome of visual classification using the *Kappa* index (16), based on the construction of error or contingency matrices. The Kappa accuracy index obtained in this classification was 95.75%, which, according to Landis & Koch, is an excellent result.

According to field observation, areas dedicated to farming are very often badly conserved, due to inadequate, and, in most cases, badly planned management, thereby posing a serious problem for populations that depend on this as their source of income. This dependency could also account for the low percentage of semidecidual seasonal forest and cerrado, since, as a means of increasing production, areas set aside for permanent preservation are very often used as a means of increasing production.

Analysis of landscape structure

According to landscape evaluation indices, agro-pastoral activities, viz., pasture, coffee culture, other cultures and reforestation, were predominant. Similar results were obtained by Tonial (2003), with 47.19% of the area with pasture, and by Valente & Vettorazzi (2005), who allocated between 2% and 4% for native vegetation in a study area in a region of São Paulo State. This further corroborates the thesis that, the predominance of agricultural activities in the EPA landscape, by hindering local forest remnant conservation, is detrimental to local biodiversity. The similar results encountered in other sustainable-use conservation units (2005), clearly show that, in a large part of these areas, consecration to agro-pastoral activities interferes with local environmental conservation.

By inference, on analyzing the number of landscape patches, and based on occupied area, although the class semidecidual seasonal forest notably presented a higher number of fragments than pasture, these were distributed in smaller-sized patches. Thus, by pasture occupying an appreciably larger area, the notion of landscape agricultural predominance was confirmed. According to Tabarelli & Gascon (2005), high forest fragmentation diminishes its biodiversity.

The average size of patches (AREA_MN) is considered a trustworthy indication of the degree of fragmentation, when considering the number of fragments and the total area occupied by natural vegetation (18, 17). When evaluated together with patch density (PD), the different aspects of a landscape, including forest fragmentation, become comprehensible, thereby facilitating the formation of a profile of the prevailing degree of this feature. Patch density values were similar to those encountered by Oliveira (2000), i.e., 3.3 fragments per 100 ha, for fragments with an average size of 1.7 ha, when evaluating a landscape with highly fragmented semidecidual seasonal forest, and by Valente & Vettorazzi (2005), in hydrographic basin landscapes. In her study area, the first author encountered the following results: sub-basins of the Mid Corumbataí (AREA_MN = 2.1 ha; PD = 3.35 fragments/100 ha); the Lower Corumbataí (AREA_MN = 3.2 ha; PD = 2.88 fragments/100ha), and the Ribeirão Claro (AREA_MN = 3.5 ha; PD = 2.48 fragments/100ha), whence the conclusion of intense landscape fragmentation.

According to land-use, shapes were very irregular, mainly so in the case of semidecidual

seasonal forest fragments. According to Forman (1997), in relation to diversity and sustainability, the analysis of forest fragment shape is as important as size, since the more irregular the fragment, the more susceptible it is to the edge-effect, especially so in the case of smaller areas, due to their higher interaction with the matrix (7). With the increase in edge-effect, there is a proportional reduction in fragment nuclear area, which, over short, medium or long term, will possibly have an effect on the structural quality of the ecosystem, as a whole. Tonial (2003) arrived at the same results, with 2.40 for the same class, whereas in the case of Calegari *et al*. (2010), the distinct results revealed more regular-shaped fragments. Apparently, higher shape-complexity indicates a higher level of disturbance, as a result of greater interaction with the matrix, through the increase in the area subject to the edge-effect (23).

According to the Almeida (2008) classification, used here for evaluating the average distance from the closest neighbor, distances between patches of 60, 120, 200 and >200 m were classified as low, medium, high, and very high isolation, respectively. Thus, for the landscape studied, isolation in the classes semidecidual seasonal forests and pasture was low, and for the remainder very high. Distinct results were encountered by Calegari *et al.* (2010), Basile (2006) and Tonial (2003) for the area 'natural vegetation, with distances of 244.5, 410 and 119 m, respectively. Valente & Vettorazzi (2005) came up with similar results for 'cerrado', with 156.65 m. Thus, the results indicate the lower commitment of the class semidecidual seasonal forest, by demonstrating the small inter-fragment distances of this class, and the higher capacity of the species for colonization towards forest patches, thus an inducement to local genic flow (32).

According to some authors, the construction or maintenance of biodiversity corridors is an important mitigatory measure for perpetuating connectivity between vegetal fragments, through facilitating the creation of a system of meta-populations (10, 24).

CONCLUSIONS

The use of geographic information systems has facilitated the generation and organization of geo-referenced information, in such a way as to enable the characterization and analysis of the structural elements of the EPA Coqueiral landscape, with its mosaic of semidecidual seasonal forest and cerrado remnants.

The use of a land-use and occupation map facilitated the characterization and quantification of areas of the different types of use, as well as quantification of the number of natural vegetal fragments (semidecidual seasonal forest and cerrado) of the Coqueiral EPA. Even so, landscape ecology indices were still required for characterizing their composition and contion. The groups of indices that proved to be efficient for this characterization were area, density, size, shape, proximity and isolation, and connectivity.

In the study region, there is a tendency for agropastoral activities in small rural properties. These activities account for the high regional fragmentation.

The maintenance of the small fragments in the EPA is fundamental, as they are liable for connectivity between natural vegetal remnants, and for conservation of the larger-sized fragments, thereby aiding in the persistence of local species.

Restoration of EPAs is obviously necessary, since this type of vegetation can function as ecological corridors, thereby facilitating the movement of fauna and flora. Furthermore, EPAs can also contribute towards the socio-economic potential of the community, if economically important species, such as fruit plants, are used.
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In regards to conservation, through harboring greater biodiversity, the largest-sized fragments should be considered as priority.

The construction of vegetation corridors should be considered as a means of increasing inter-fragment connectivity, as well as metapopulation auxiliary systems, within the EPA.

ACKNOWLEDGEMENT

We wish to extend our thanks to the Universidade Federal de Lavras, and the Geosoil Laboratory, Epamig/Lavras for support and

incentives, as well as to CAPES for the grant and FAPEMIG for financing the project.

RESUMO

Este trabalho analisou a estrutura da paisagem da Área de Proteção Ambiental Coqueiral, localizada na região Sul de Minas Gerais. O objetivo foi avaliar a estrutura da paisagem a partir de métricas e princípios da Ecologia da Paisagem e apontar áreas prioritárias para a conservação. Foram utilizados Sistemas de Informação Geográfica e Sensoriamento Remoto para elaborar um mapa de uso da terra a partir de uma imagem de satélite SPOT 5 HCR. A análise da estrutura da paisagem foi realizada através do software Fragstats, utilizando métricas de paisagem. Os resultados mostraram que a classe pastagem foi considerada como a matriz da paisagem e ocupou quase metade da unidade de conservação. A análise da estrutura da paisagem mostrou que a paisagem é dominada por atividades agropastoris. A paisagem apresenta 704unidades. O tamanho médio dos fragmentos foi maior para o pasto do que para a floresta estacional semidecidual, enquanto que a floresta estacional semidecidual apresentou maior densidade de fragmentos. Classes de uso da terra mostraram formas complexas indicando maiores efeitos de borda. Pastagens apresentaram menor isolamento entre os fragmentos. Os dados obtidos neste estudo são relevantes para a tomada de decisão e planejamento ambiental da Área de Proteção Ambiental de Coqueiral, permitindo sugerir áreas prioritárias para sua conservação.

Palavras-chave: Ecologia de paisagens, Métricas da paisagem, Sistemas de Informação Geográfica.

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MACROALGAE SPECIES RICHNESS IN BEACHES WITH CONSOLIDATED ARENITE SUBSTRATA AND REEF-POOLS WITH SANDY BOTTOMS IN PIAUÍ

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ABSTRACT

Sessile-organism dependence on substrate structure can drive, both the manner in which biological communities colonize new environments, as well as richness and abundance patterns. We compared the frequency of macroalgae species frequency on two beaches in Piauí (northeastern Brazil), to test the hypothesis that species richness would be higher on a rocky substrate (Barra Grande) than a sandy substrate (Coqueiro) beach. Of the 21 macroalga species recorded, most revealed low occurrence, with Hypnea spinella and H. musciformis as those predominant. Whereas all were recorded on the Coqueiro beach, only 7 were on the Barra Grande. Hence, our hypothesis remained unproven. Nonetheless, as Barra Grande beach is subject to a more intense water river and human impact than Coqueiro.

Keywords: Seaweed, macroalgae, communitie richness.

INTRODUCTION

Benthonic coastal ecosystems, which comprise one of the most productive marine environments, planet-wide, present high richness in organisms of outstanding ecological and economic importance, such as mussels, oysters, crustaceans and fishes, as well as various seaweeds which play an important ecological role by supplying oxygen, food, shelter and substratum, while at the same time functioning as nurseries for various organisms at several trophic levels in the food chain (2).

Marine algae are ephemeral or perennial benthonic organisms, which live attached, consolidated or not, to solid substrata. The richest areas in macroalgae, both in diversity and biomass, are rocky shores, rocky beaches and reefs (21).

The distribution of seaweeds along the Brazilian coast is a result of the complex interaction of factors, such as substratum availability, the presence of fresh water flows, biotic interactions, water mass characteristics, and historical and biogeographical factors (21, 20).

Brazil, considered as the country with the highest biodiversity planet-wide (3), possesses a coastline which extends from the tropics to regions of warm-temperate waters and the great challenge in countries like Brazil is the diversity

and conservation quantification.

In the case of benthonic marine algae, Oliveira Filho (1977), when compiling the first Brazilian infrageneric taxa, listed 327 Rhodophyta, 113 Chlorophyta and 64 Phaeophyta, 504 species. Subsequently, Horta *et al.* (2001), when updating the data base on Brazilian alga diversity, listed 642 taxa, distributed among 388 Rhodophyta, 166 Chlorophyta and 88 Phaeophyta. According to more recent research, there are 774 infrageneric taxa, corresponding to 482 Rhodophyta, 191 Chlorophyta and 101 Phaeophyta (10), with at least 700 species among coraline reefs alone (9).

The Brazilian southeast is the most studied region. On the other hand, whereas in the north and northeast the flora is somewhat better-known in states such as Bahia and Pernambuco, this is not the case in others, such as Sergipe, Alagoas, Piauí, Pará and Amapá. Notwithstanding, the extent of each state coastline must be taken into account, when comparing these numbers (10).

In spite of the large diversity of Brazilian marine macroalgae, most studies have mainly focused on either the morphological, biochemical or systematic aspects, or associated invertebrate fauna. To date, few studies have been dedicated to information on certain aspects of Brazilian macroalgae, such as community ecology (19, 24, 11, 29, 7, 1, 9, 18), populations (1, 13, 14, 29, 17, 18), although many of these studies have mainly dealt with communities, there is also some information on the ecology of populations, succession (8), and conservation (9) In fact, most of the cited studies of communities are botanic surveys without analysis of factors explaining the processes linked to community structure and dynamics. Published studies specifically on macroalgae population structure and dynamics are very rare in Brazil. At the same time, the Brazilian coast presents problems of pollution and the invasion by exotic species, whereby the need for further studies of marine microalgae conservation.

In the Piauí State (Northeastern Brazil), the coastline is the smallest along the Brazilian coast, with only 66 km in extent, to a large degree corresponds to a strip of recently formed sediments associated to a series of islands, basins and channels, all along the coastline, with sand bars, dunes, mangroves and some cliffs (28), all of which subject to the expressive influence of the Parnaíba delta. In these habitats there are different substrates for algae fixation like rocky formations and rocky intercalated with sandy pools and also. There is a certain degree of anthropic occupation in all habitats, which, together with biotic and abiotic attributes, exert an influence on local floral composition.

Through floristic surveys on macroalgae over the last decade along the Piauí coast, it can be assumed that this presents a characteristic tropical region flora (2), which is undergoing gradual alteration, since banks of Sargassum were encountered, and now Gracilaria have become predominant. In spite of the observed richness in biodiversity, and being an Environmental Protection Area (EPA), there are few studies of the local algae.

OBJECTIVE

The aim was to compare the number of macroalgae species on consolidated arenite substrata, as well as in sandy-bottom reef pools along the beaches of Piauí. Our hypothesis was that species richness would be higher on that with a consolidated substratum, which would be more stable for the fixing and establishment of seaweeds, as a whole.

METHODOLOGY

Study site

The algae samples came from two locations and 60km far from each other. The Barra Grande district is located in the northern part of the state of Piauí (02º55'40" S and 41º24'40" W), in Cajueiro da Praia city. The 4-km-long beach, containing the mouths of four major rivers, Timonha, Ubatuba, Camurupim and Cardoso, is mainly formed by associations of marine and continental quartz sands, together with mangroves, all part of a transition coastal ecosystem between marine and terrestrial environments. In the Barra Grande beach, there is a consolidated arenite substratum below the high tide mark (25). The climate is alternatively humid and dry tropical, with the dry period lasting six months, and an average temperature between 25º C and 32 ºC (4).

On an average, the sand contains 10-30cm-sized fragments of consolidated segment ("rocks"), water temperature is 30ºC, and salinity 35ppm. The distance between the collecting station and the water-line was 530m. Collections took place on August 19th, 2012 (0.1 tide at 11:00 am.).

Coqueiro Beach, situated in Luís Correia city (02º54'35" S and 41º32'03" O), with a high flow of tourists, is characterized by rocky outcropping and pools with fine sand at the bottom. The local climate is alternatively humid and dry tropical, with an average temperature between 25ºC and 32º, and the characteristic vegetation of dunes and restinga (5). The sand is fine and the water temperature at the time was 28ºC and salinity 35ppm. The distance between the collecting station and the water-line was 5 km. Collections took place on August 20th, 2012 (0.2 tide at 11:30 am.).

Sampling procedures

Seaweeds were first surveyed all along the reef of the two beaches and a species list was compounded.

A 10mx10m grid with 200 quadrats of 50cmx50cm was set up (Figure 1). Ten quadrats were chosen using a random-number table and the seaweed species were then recorded. Specimens were individually identified by species and in the case of doubt laboratory identification was carried out at the Piauí State University (UESPI).

To compare the two habitsts, we calculate the percentage of quadrats containing each species, as well as the Jaccard similarity index (Sj), were carried out. The species richness was estimated by the Chao1 method using the EstimateS software.

RESULTS

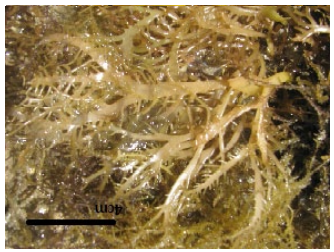
We recorded 38 seaweed species on the two beaches. In all the parcels 21 species were present on Coqueiro Beach but only 7 (33%) were on Barra Grande Beach (Table 1; Figures 2 and 3).

Table 1 – List of seaweed species recorded on Coqueiro and Barra Grande beaches.

	Barra Grande	Coqueiro
Chlorophyta		
Acetabularia calyculus	X	X
Acetabularia crenulata		X
Caulerpa mexicana	X	X
Cladophora membranacea		X
Enteromorpha muscoides		X
Ulva fasciata		X
Ulva lactuca		X
Valonia aegagropila		X
Heterokonthophyta-Phaeophyceae		
Dictyopteris delicatula		X
Dictyota menstrualis		X
Padina gymnospora		X
Rhodophyta		
Acanthophora spicifera	X	X
Gelidiella acerosa		X
Gracilaria birdiae	X	X
Gracilaria domingensis	X	X
Haloplegma duperreyi		X
Hypnea musciformis	X	X
Hypnea spinella	X	X
Jania subulata		X
Laurencia dendroidea		X
Palisada perforata		X

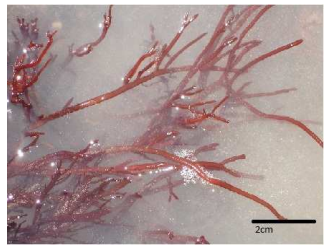
Figure 1 – Parcels, one at Barra Grande Beach with fragments of consolidated sediment (left), and the other at Coqueiro Beach with fine sand (right).

Phylum Rhodophyta

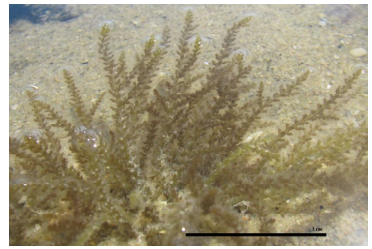


Gracilaria domingensis

Gracilaria caudata



Gracilaria birdiae



Acanthophora spicifera

Palisada perforata

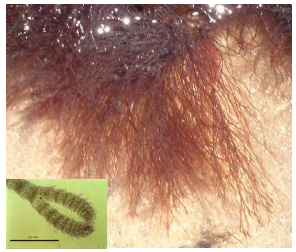
Laurencia dendroidea

Jania subulata

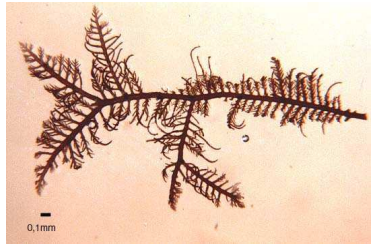
Botryocladia occidentalis

Cryptonemia crenulata

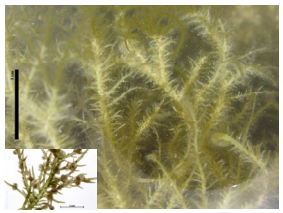
Gelidiella acerosa



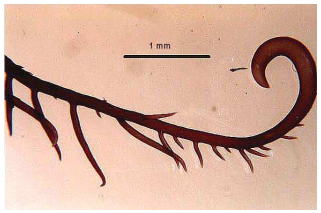
Centroceras clavulatum



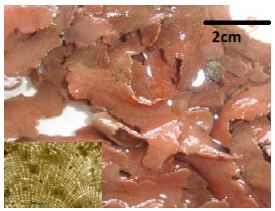
Bostrychia tenella



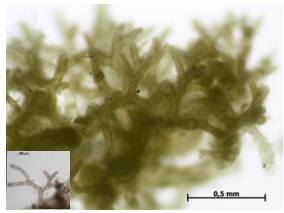
Hypnea spinella



Hypnea musciformis

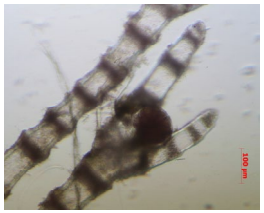


Haloplegma duperreyi



Heterosifonia crispella

Spiridia clavata



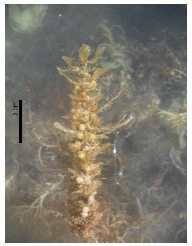
Ceramium dawsonii

Figure 1 - Seaeewd on Coqueiro Beach and Barra Grande Beach

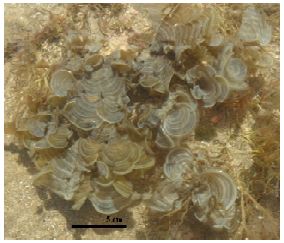
Fotos de: André Rocha Coimbra, Júlio César Voltolini, Maria Gardênia S. Batista e Edisa Nascimento.

Phylum Heterokonthophyta-Phaeophyceae

Colpomenia sinuosa



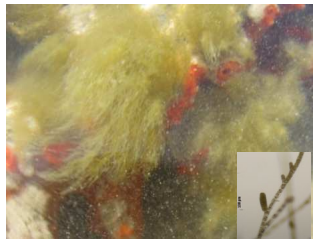
Sargassum vulgare



Padina gymnospora

Lobophora variegata

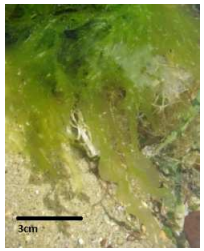
Dictyota menstrualis



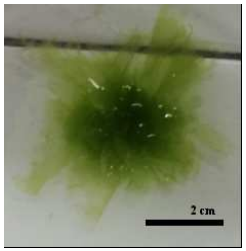
Hincksia mitchelliae

Phylum Chlorophyta

Ulva lactuca



Ulva fasciata

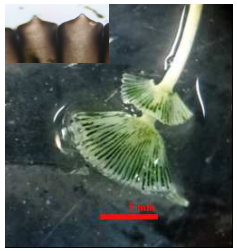


Gayralia oxysperma

Cladophora vagabunda

Enteromorpha flexuosa

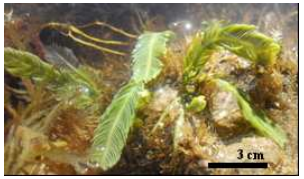
Acetabularia calyculus



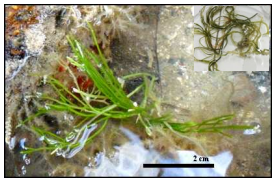
Acetabularia crenulata

Codium isthmocladum

Valonia aegagropila

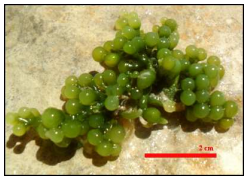


Caulerpa sertularioides



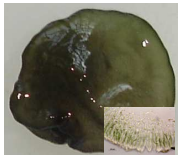
Caulerpa serrulata

Caulerpa mexicana



Caulerpa racemosa

Phylum Cyanophyta



Brachytrichia quoyi

Fotos de: André Rocha Coimbra, Júlio César Voltolini, Maria Gardênia S. Batista e Edisa Nascimento.

Figure 2 - Seaeewd on Coqueiro Beach and Barra Grande Beach

Brazilian Journal of Ecology ISSN 1516-5868

The similarity between the two communities was only 29% (Sj=0,29). ***Hypnea spinella*** was the only species present in all the ten quadrats at both sites. (3).

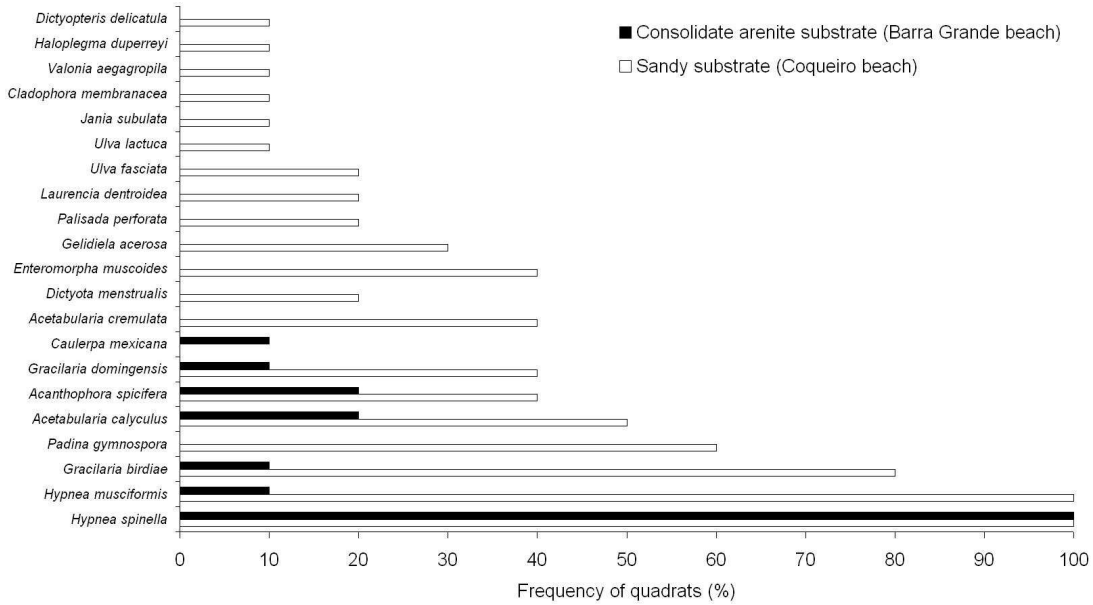


Figure 3 – Percentage of parcels containing each of the seaweed species sampled in the beaches of Coqueiro and Barra Grande in Piauí.

Most of the species were present in less than 50% of the quadrats, 16 (76% of the 21 species) in Coqueiro Beach, and 6 (86% of the 7 species) in Barra Grande.

Richness estimates showed Coqueiro Beach to be richer than Barra Grande, the latter proving to be a poorer and more homogeneous system (Figure 4). Furthermore, the number of species at both sites having already reached stabilization, with a little more than half of the sampling effort having been employed, was a clear indication that the number of parcels was sufficient for estimating richness.

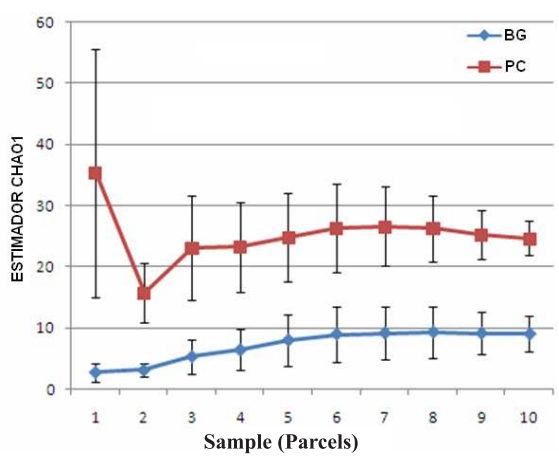


Figure 4 – Estimates of species richness (S) at the beaches of Barra Grande and Coqueiro.

DISCUSSION

Macroalga diversity is directly related to environmental conditions, especially to the type of substratum available for spore fixation, and the quality of the water. The various reproduction strategies function in combination with high spore dispersion ability, and the capacity for regeneration, as well as certain aspects of intra and inter-specific competition, thereby very often facilitating rapid substratum colonization, both organic or inorganic and natural or artificial. In reef ecosystems, seaweeds occur upon a large number of species that are fixed on the various substrata, such as shells, corals and other algae (6). Hence, reef substrata are eminently appropriate for the fixation of spores, and consequently, the efficient development of grasps.

Nonetheless, the initial hypothesis remained unproven, since a larger number of macroalga species were registered on Coqueiro Beach, where the substratum is sandy. This pattern was the contrary to those encountered by other authors. In a Papua

New Guinea study, low algae cover, richness and abundance was recorded on arenite substrata with marine monocotyledon banks (15). In the Antarctic, low seaweed cover (27) and biomass (26) was also observed on arenite substrata. In the Baltic Sea, Russia, there was accumulation on the bottom of the Neva estuary, due to human drainage and sand filling, with the consequential lessening of seaweed biomass (12). In Brazil, the patterns encountered by Aquino (2012) in Ceará, were also substratum formation in the form of sandy reefs. On comparing the beaches of Flexeiras and Manguinhos, Trairi county, it was noted that reef heterogeneity exerted an influence on seaweed distribution, with Manguinhos presenting higher species richness than Flexeiras.

Pollution, brought about by the direct release of home and industrial pollutants onto beaches via river courses and the movement of shipping along the coast, can be cited among the main factors contributing to the decrease in marine diversity (23). At Barra Grande, there is a greater flux of both people and boats throughout the year, when compared to Coqueiro, which is situated in a region where summer tourism predominates, thereby undergoing less yearly impact. Furthermore, Barra Grande is subject to the influence of four main rivers, Timonha, Ubatuba, Camurupim and Cardoso, as well as mangroves (4), with the consequential inducement of low species richness through the impact of fresh water.

At Barra Grande, there is the adverse influence of rivers and an inappropriate substratum for fixation in the case of most species. It is also possible that, depending on tide and wind conditions, those consolidated are also subject to rolling and abrasion. On the other hand, at Coqueiro Beach, salinity is probably stable and the substratum more appropriate for seaweed fixation (consolidated sandy rocks). In this case, the sandy bottom represents a sand deposit, with seaweed stems possibly being fixed below the sand on the hard substratum.

CONCLUSION

Species richness was greater at Coqueiro Beach, with more sand, than at Barra Grande Beach, which, although with more rocks, is subject to higher river water and human impact.

ACKNOWLEDGEMENT

We wish to thank the Piauí State University (UESPI) for logistic support, Dr. Sérgio Rosso (Department of Ecology, USP) for discussions on sampling methods, and Prof. Dr. Mutue Toyota Fujii (Institute of Botany, São Paulo), Dr. Estela Maria Plastino (Department of Botany, USP) and Dr. Carlos Wallace do Nascimento Moura (Department of Biological Sciences, UEFS), for helping in species identification.

RESUMO

A dependência dos organismos sésseis da estrutura do substrato pode conduzir a maneira pela qual as comunidades biológicas colonizam novos ambientes assim como os padrões de riqueza e abundância. Nós comparamos a freqüência de macroalgas em duas praias do Piauí (Nordeste do Brasil) para testar a hipótese de que a riqueza de espécies seria maior em uma praia com substrato mais rochoso (Barra Grande) do que arenoso (Coqueiro). Das 21 espécies de algas registradas, a maioria apresentou ocorrência baixa com Hypnea spinella e H. musciformis como predominantes. Enquanto todas as espécies foram registradas na Praia do Coqueiro, apenas 7 foram registradas em Barra Grande. Assim, a nossa hipótese não foi corroborada. Contudo, a praia de Barra Grande é sujeita ao maior efeito da água de rios e impacto humano do que a praia do Coqueiro.

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Conclusões – separadas ou junto do item discussão quando este estiver não estiver incluidos em resultados e discussão.

Acknowledgments.

This section is optional and follows the Discussion. It acknowledges financial and personal assistance.

References.

Arrange the references in alphabetical order, by last name of the author. All authors must be cited. Number the references consecutively. Cite each reference in the text by its number. Names of Journals names should be abbreviated according to the style of Biological Abstracts or Chemical Abstracts. All references given in the list should be cited in the text, and all references mentioned in the text must be included in the list. List references according to the style shown in the following examples.

a. Paper in a journal

Campos, L.c., Whittam, T.S., Gomes, T.AT, Andrade, 1.R.C., Trabulsi, L.R. Escherichia coli serogroup 0111 includes several clones of diarrheagenic strains with different virulence properties. lnfect. lmmun., 62: 3282¬3288, 1994.

b. Paper or chapter in a book

Salati, E., Tauk-Tomisielo, S.M. Ecology. In: Campos, F.M.; Sachs, B.; Muska, K.G. (eds.). General Ecology. Mapples Deker, Los Angeles, 1995, p.361-377.

c. Book by author(s)

Salyers, A. A., Whritt, D.D. Bacterial pathogenesis. A molecular approach. ASM, Washington, 1994, 418p.

d. Patent

Hussong, R.V., Marth, E.H., Vakaleris, D.G. Manufacture of cottage cheese. US. Pato 3,117,870. lan. 14, 1964.

e. Thesis

Soave, R.C.F. Aspectos ambientais da mineração de Caleário no município de Rio Claro. Instituto de Geociências e Ciências Exatas, Rio Claro, SP, UNESP. 1990, 237 p.

f. Publication with no identifiable author or editor

Anonymous. The economy of by-products. Álcool Alcoolquim., 2:3-40, 1985.

g. Communications in events (Symposia, conferences, and other), but not abstract as papers published ln Proceedings.

Simão. G.S.; Silva J.; Toledo. A. S.; Gontijo Filho. P.P. Microbactérias não tuberculosas isoladas de pacientes com síndrome de imunodeficiência adquirida. Anais do XVII Congresso Brasileiro de Microbiologia, Santos, SP. 1993, pAl- 50.

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