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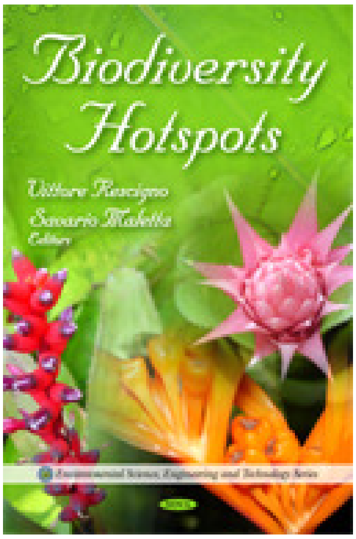

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Chapter 1

BIODIVERSITY CONSERVATION AND MANAGEMENT IN THE BRAZILIAN ATLANTIC FOREST: EVERY FRAGMENT MUST BE CONSIDERED

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ABSTRACT

The Brazilian Atlantic forest is a hotspot of biodiversity, characterized by high species richness, high level of endemism and high danger of extinction. The remnants of this biome stand in the most populated and developed region of the country and their conservation is in constant conflict with strategies of development. Our study was developed in the State of Espírito Santo, in the municipalities of Linhares and Sooretama. Located at the north of Rio Doce, it was one of the last regions of the Atlantic forest to be deforested, and forest fragmentation took place mostly after 1950. Our purpose were: 1) characterize the evolution of the forest fragmentation in this region, the present situation

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of its remnants, and the main strategies, conflicts and potentials for conservation; 2) evaluate the conservation value of the forest fragments based on a study of the community of a group of insects: the community of Blattaria; 3) integrate these information to propose guidelines to resolve potential conflicts based on positive and non conflictual conservation recommendations. The landscape of Linhares and Sooretama is dominated by plantations, among which can be found two large reserves and fragments of diverse sizes, shapes and degrees of disturbance. Only in Sooretama there are 213 fragments, which, with the Sooretama Biological Reserve, cover 44% of the municipality area. Similarly to the reserves, the fragments were preserved by the imposition of the law and due to the interest of people of keeping the forest as a reserve of value. Fragments are used for several purposes, being submittedto strong disturbances that could lead to their massive disappearance in a near future. The analysis of the community of Blattaria showed that the number of species shared among sites is very low (between 22.9% and 39.6%), with a high number of species found only in single fragments and nowhere else; the richness per area in small fragments is not smaller than in large reserves; habitat diversity is stronger than the effect of area *per se*. These results show that even after more than 50 years of fragmentation and isolation, the situation of the biodiversity in this region is not lost: small and very disturbed fragments still shelter important biodiversity of insects, and can be of extreme interest for composing a set of remnants that maximizes the number of species to be protected. Based on it, the management and conservation of the biodiversity should first of all include the fragments, and for this reason should be conceived in the landscape or regional scale. At this scale, fragments should be envisaged in a management plan, in which restrictions and possible uses are explicitly established. In such a context, the choice of priority fragments should be done taking in account the landscape diversity: it should include fragments from different hydrographic basin, soil types, vegetation *facies*, as well as the diversity of use.

INTRODUCTION

In many regions of the world the management of natural resources is at the center of never ending conflicts between the desire of keeping a part of the territory for conservation and the immediate need of using the same land for cultures, industries, cities, etc, due to cultural reasons and/or regional or national strategies of development. This situation is very common in Brazil, particularly in the region of the Brazilian Atlantic forest.

This biome is one of the richest in the world in terms of species richness and endemism: it harbors about 8.000 species of endemic plants and 567 species of endemic vertebrates. Nevertheless, the conservation of its remnants is a challenge (Gentry, 1992; Mittermeier, 1997; Myers, 1997). Originally it covered an area of about 1,400,000km^2, stretching along the Atlantic coast from 4° to 32°S, in altitudes ranging from sea level to 2,900m, covering a wide range of climatic belts and vegetation formations (Rizzini, 1992; Oliveira-Filho & Fontes, 2000). But it was by this coast that started the colonization of the country, being the first region of Brazil deforested to give place to modern civilization. Presently, the original area of the Atlantic forest has about 100 million inhabitants distributed in more than 3,000 cities, among which Rio de Janeiro and São Paulo, two of the biggest metropolis of the world. As a result, the forests are reduced to less than 8% of its original surface, distributed in scattered fragments imbedded in the most populated and developed region of the country (SOS Mata Atlântica/INPE/ISA, 1998; IBGE, 2000).

Due to its enormous surface, the land use as well as the history of deforestation/conservation can be very different from one region to another. So must be the strategies for solving the conflicts in order to establish a long-term policies of conservation. In this chapter we will focus at the north of Rio Doce, State of Espirito Santo, in the municipalities of Linhares and Sooretama, a part of the Atlantic forest considered of extreme biological importance for mammals, reptiles, invertebrates and vegetation (MMA/SBF, 2000). In this region, the deforestation and fragmentation of the ecosystems occurred mainly after 1950, and apparently most of forest remnants still harbour an important fraction of its original diversity.

This chapter was written with a triple aim: the first was to characterize the evolution of the forest fragmentation in this region, the present situation of its forest remnants, and the main strategies, conflicts and potentials for conservation. This study was based on data from geographic censuses, on our field observations , and on published researches about the conservation of biodiversity in this region. The second aim was to evaluate the importance of the forest fragments for the conservation of biodiversity. This evaluation was based on the study of the effects of disturbance, area *per se* and habitat diversity on the community of Blattaria, a group of insects with an important species richness and with diverse social behaviors, forms of feeding, and habitat requirements. Last but not least, our third aim was to integrate the results of this two-level analysis to propose guidelines to resolve potential conflicts based on positive and non conflictual conservation recommendations.

A Brief Characterization of the Landscape in the State of Espírito Santo in the 20th Century

When compared to Rio de Janeiro, São Paulo and Minas Gerais, the three other States of the southeast region of Brazil, Espírito Santo is very peculiar in several aspects. It stayed out of the main development of Brazil, which was always more intense in the southeast region, until very recently, being the last one to be included in this process (Becker, 1969); its population density is much lower than the mean of the region; and the density of rural population is rather high (Table 1).

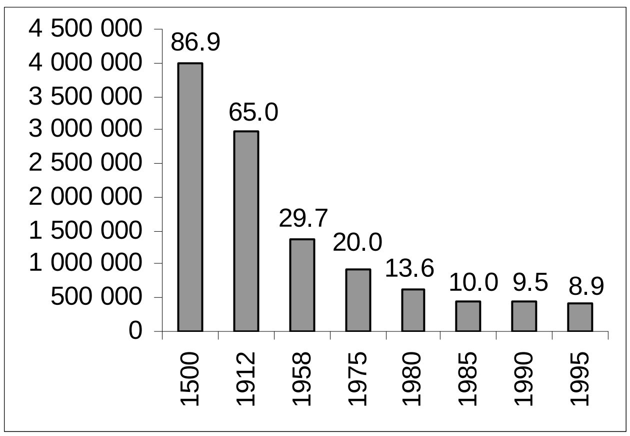

Figure 1. Area covered by vegetation (ha) in the State of Espírito Santo from 1500 to 1995. The values on top of the bars correspond to the percentage of natural forests in relation to the total area of the state. Data from SOS Mata Atlântica *et al.,* 1998.

At the beginning of the 20th century most of the surface of Espírito Santo was covered by forests, and *Botocudos* Indians from the linguistic branch of Botocudos Macro-Jê, the first inhabitants of this region, were seen until the 40's (Aguirre, 1951; Zunti, 1982; Egler, 1951; Garay, 2006). We do not pretend that the forests were intact until this date, but after the 40's and particularly during the 50's the landscape changed markedly. During this period 35% of the forests disappeared, first giving place to the culture of coffee and later to more diversified land use (Egler, 1951; Becker, 1969; SOS Mata Atlântica *et al.*, 1998; Pellens, 2002). Presently, less than 9% of the original surface of the state is covered by remnants of the Atlantic forest and its associated ecosystems (e.g., mangroves, restinga), and the land use comprise urban areas in addition to large surface of rural landscape mostly used by pastures and plantations of coffee, tropical fruits, *Eucalyptus*, *Cocoa*, *Hevea* and black pepper (Figure 1) (IBGE, 1995-96; SOS Mata Atlântica *et al.*, 1998).

Linhares and Sooretama: a Region of Beautiful Forests that Changed Very Recently

In the construction of the history of Espírito Santo, the Rio Doce, which divides the state into two portions, one austral and the other septentrional, served during a long period as a natural limit between the populated zone in the South, and the unknown zone in the North (Egler, 1951). It is in this "unknown zone" at the North of low Rio Doce that the municipality of Linhares and the recently created municipality of Sooretama[1] are located.

According to Egler (1951), the colonization of the North of lower Rio Doce was caused by a displacement of the population in the space and not by an expansion in terms of number of individuals, since it was not verified an increase of the population of the State in this period but a simple displacement to the North. The new population was mainly composed by Italians of third generation coming from the mountains of Espírito Santo, and by people from the Northeast escaping from the drought. In Egler's opinion, this displacement was caused by the need of new areas of "virgin lands", because the usual habits of slash-and-burn followed by intensive culture used to lead to the exhaustion of the soil resources, forcing the search for new lands. Searching for new lands, escaping from drought in Northeast or from many other sources of poverty and difficulties existing in Brazil at that moment, the fact is that Linhares population increased more than three times between 1950 and 1970, and more 32% between 1970 and 1980 when population growth started

[1] The municipality of Sooretama was created in March 30th, 1994 by the State Law Nº 4,593/1994. It was created as a municipality in the same area of the previous District named "Distrito de Córrego D'água" that belonged to the municipality of Linhares. Sooretama was installed as a municipality in 1997. For this reason, in this first part of our analysis we use the data of Census concerning the Municipality of Linhares, since there was not similar data by districts during all this period.

Table 1. Area and population of the municipalities of Linhares e Sooretama, the state of Espirito Santo, the southeast region, and Brazil in the year 2000.

	Área (km^2)	Population	Demographic density (inhabitant/km^2)	Rural population	% of rural population	Urban Population	% of urban population
Linhares	6,885.90	250,300	32.6	58,469	23.4	191,831	76.6
Sooretama	585.6	18,269	31.2	6,850	37.5	11,419	62.5
Espírito Santo	46,047.30	3, 097,232	67.2	634,183	20.5	2,463,049	79.5
Southeast	924,573.80	72, 412,411	78.2	6,863,217	9.5	65,549,194	90.5
Brazil	8,514,204.90	169,799,170	19.9	31,845,211	18.8	137,953,959	81.2

Data from IBGE – Population count 2000.

to stabilize (Data of the Census of Linhares). In the same period, the number and the area of agricultural establishments doubled (Figure 2).

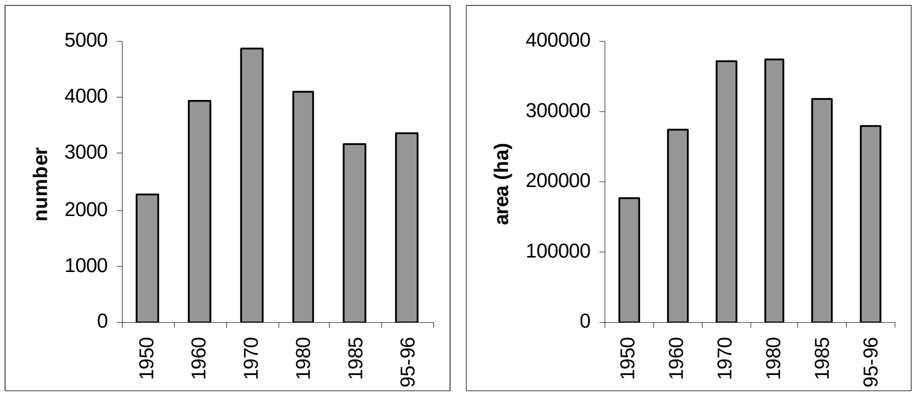

Figure 2. Number and area occupied by agricultural establishments in Linhares between 1950 and 1996. Data from IBGE, Census of Agriculture (1950, 1960, 1970, 1980, 1985, 1995-96). These data include the municipality of Sooretama, which became independent of Linhares only in 1997.

The major attractor of the first inhabitants was the wood of very high quality from the Atlantic forest on the table-lands, and the available lands that allowed the survival of the families with peasant farming. This first structure was followed by the production of coffee stimulated by the federal government, which failed at the end of 60's leading this population to a strong poverty. In her study about the transformation of this region, Becker (1969) showed that the colonization was marked by strong patchiness. The landscape was characterized by the small size of the coffee plantations due to the restrictions imposed by the topography and the small dimension of the properties. This situation remained until the beginning of the 70's, when "the settlements used to occur in small encroachments interrupted by large areas of forests, areas recently deforested, and decadent coffee plantations".

When we look at the dynamic of the area occupied by agricultural establishments, we see that if in a first moment there was an appropriation of the territory by the population, marked by a significant increase in number and size of their area in the municipality of Linhares. In a second period started in 1970 the transformations are mainly associated to shifts in the new forms of land use. Between 1970 and 1980 the area of agricultural establishments remained the same but their number was reduced, showing an expansion of the size of rural properties. Finally, between 1980 and 1995 both the number and the total area occupied by rural establishments were markedly reduced, now indicating the reduction of the rural area, or in other words, the expansion of urban areas in the municipality (Figure 2).

From the eight categories of land use considered in the Agricultural Census, only native forests, permanent cultures, natural and artificial pastures occupied a significant surface of the agricultural establishments in Linhares between 1950 and 1995-96 (Figure 3).

As expected in a context of occupation of the territory, the main transformation in this landscape during the last 50 years corresponds to the reduction of native forests. From 1950 to 1995-96, the area of forest in the totality of agricultural establishments of Linhares was reduced in 58%, and this reduction was sharp between 1960 and 1985 (47%). At the same time there was a slow expansion of the area used to permanent cultures (23% of the total area of agricultural establishments in 1995-96), and a more intense expansion of the area for artificial pastures (45% of the total area of agricultural establishments in 1995-96) (Figure 3).

Presently, the landscape of Linhares and Sooretama is marked by the presence of an important area of continuous forest protected in the Sooretama Biological Reserve, in Natural Reserve of Companhia Vale do Rio Doce, commonly known as Linhares Reserve, and in some private properties linking them (IBDF & FBCN, 1981; Jesus, 1987; SOS Mata Atlântica/ISA, 2002; Garay & Rizzini, 2004). This green heart of about 50,000ha is surrounded by pastures and plantations of coffee, *Eucalyptus*, papaya and black pepper within which a multitude of forest fragments of diverse size, shape and distance to the reserves can be found (Figure 4).

In a characterization of these fragments in the municipality of Sooretama, Agarez *et al.,* 2004 showed that there are 213 forest fragments with area between 1 and 200ha making a total of 3,000ha of forest (Figure 5). These fragments with the Sooretama Biological Reserve cover a total of 44% of the municipality surface. Unfortunately, we do not have similar data for the municipality of Linhares.

The forests protected in Linhares and Sooretama constitute the biggest remnant of Atlantic forest on lowlands. The greatest part of it is represented by the table-land Atlantic forest, a semideciduous forest located on the table-lands. This geomorphological unit is characterized by a gently rolling relief with table columns with mean altitude of about 70-80m formed by deposits of sediments during the high Tertiary and beginning of the Quaternary period

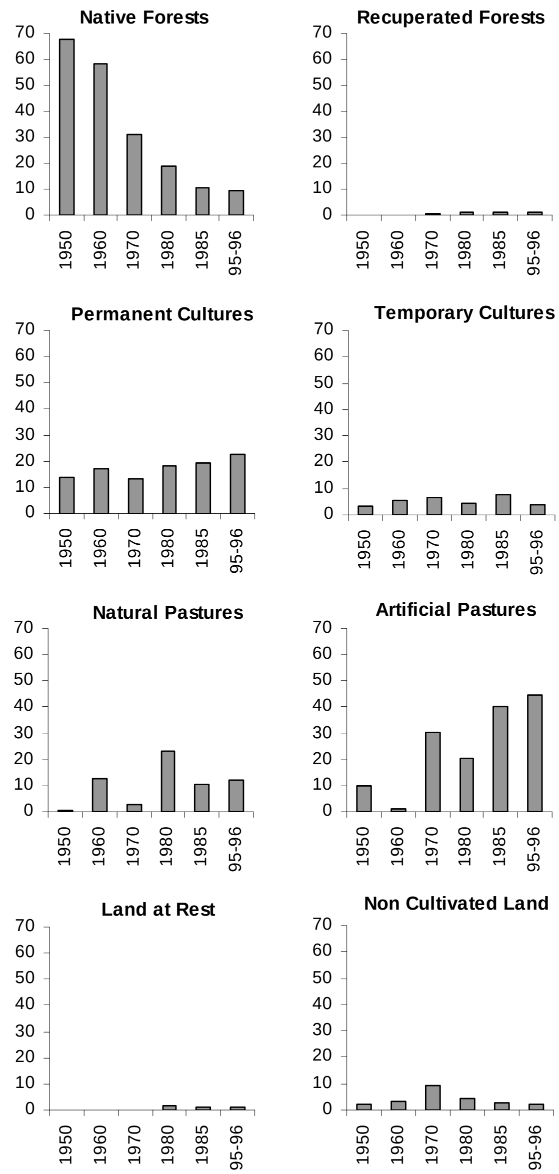

Figure 3. Area (in percentage) of agricultural establishments in Linhares – ES occupied by eight main land uses from 1950 to 1995-96. Data from IBGE Census of Agriculture (1950, 1960, 1970, 1980, 1985, 1995-96). These data include the municipality of Sooretama, which became independent of Linhares only in 1997.

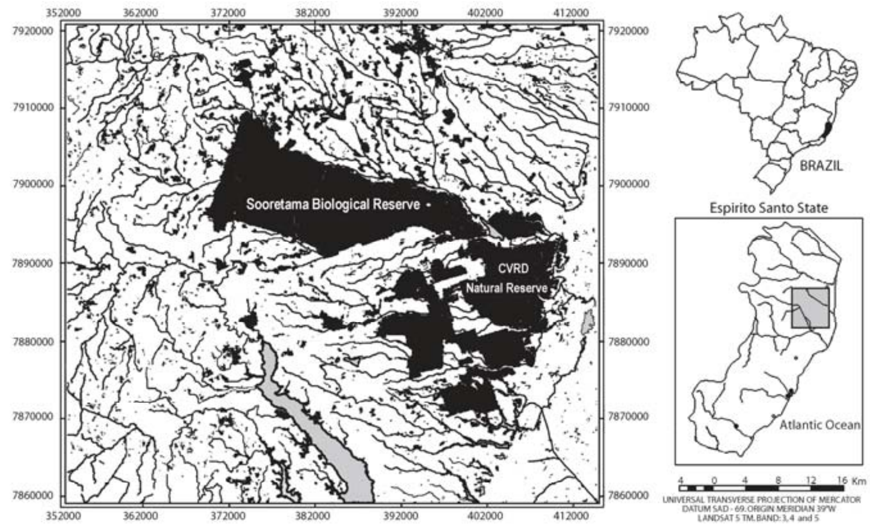

Figure 4. Localization of the remnants of Atlantic forest in the municipalities of Sooretama and Linhares, with the main water bodies. The Sooretama Biological Reserve is formed by a continuous forest, while the Linhares Reserve (CVRD Natural Reserve) is formed by multiple lots of forests not always contiguous. Around the two reserves one can see the multiple forest fragments, most of them very small.

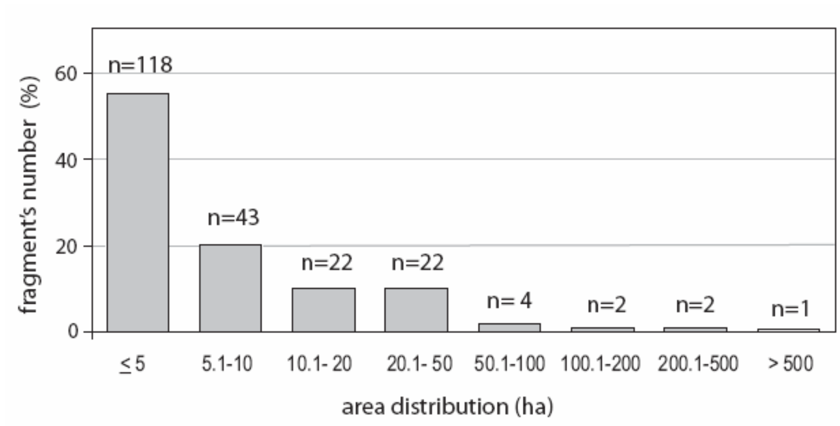

Figure 5. Number of forest fragments in different classes of sizes in the municipality of Sooretama (modified from Agarez *et al.*, 2004). The fragment with more than 500 ha corresponds to the Sooretama Biological Reserve.

(Suguio *et al.*, 1987). The vegetation is exuberant, distributed in three superposed strata, with emergent trees of about 40m (Figure 6). The forest is exceptionally marked by the richness and endemism of plants, as well as for mammals, reptiles and invertebrates (Thomas *et al.*, 1998; MMA/SBF, 2000) being for this reason one priority area for conservation within Atlantic forest (MMA/SBF, 2000). Only in Linhares Reserve about 650 tree species were already identified (Linhares Reserve, 2004; Jesus & Rolim, 2005). Agarez (2002) studying tree species with DBA ≥ 5cm found 202 species in one hectare of forest in Sooretama Biological Reserve, and between 168 and 197 species in one hectare of forest within fragments. In addition to that, the forests of this region are also characterized by the richness and density of woody vines as well as by the rarity or absence of epiphytes (Jesus, 1987; Gentry, 1992; Peixoto *et al.*, 1995; Peixoto & Gentry, 1990; Rizzini, 1992). The forests in the large reserves shelter a very diverse fauna, and important populations of big mammals were recently observed (Chiarello, 2000).

Figure 6. A picture of the understory of the table-land Atlantic forest taken at the site named Mata Alta in Linhares Reserve.

The Conservation of the Forests: its Main Historical Reasons and Present Conflicts

In the same period of large scale deforestation, there were some efforts on the opposite way, resulting in the creation of the present Sooretama Biological

Reserve and Linhares Reserve. A brief context of the creation and aims of these two reserves are presented in Box 1. We will not further detail their history here because it was carefully done elsewhere (see Aguirre, 1951; IBDF & FBCN, 1981; Jesus, 1987; Pellens, 2002; Garay, 2004; Garay, 2006).

Box 1

Characterization of the reserves.

The Sooretama Biological Reserve is a national reserve, protected by determination of the Ministry of Environment under the responsibility of IBAMA - The Brazilian Institute of Environment and Renewable Natural Resources. The creation of this reserve started in 1940 with the creation of the Parque de Reserva, Refúgio e Criação de Animais Silvestres Sooretama (with 12,000ha) and the contiguous Reserva Florestal de Barra Seca (with 10,200 ha). The Parque de Reserva, Refúgio e Criação de Animais Silvestres Sooretama was created with the aim of preserving fauna, flora and geological formations, rasing wild animals, facilitating studies and knowledge about the nature, and stimulatingf touristic excursions. We have no information about the explicit objectives of the creation of the Reserva Florestal Barra Seca. In 1971, these two reserves were merged, giving origin to the Sooretama Biological Reserve, with an area of 22,168 ha (IBDF & FBCN, 1981). Since 1982, this reserve has the aim of integral protection of the fauna and flora. Nowadays, only scientific research on its biodiversity and educational programs are allowed.

The Linhares Reserve is private. It belongs to Companhia Vale do Rio Doce, and has its origin in a program of buying land in several parts endeavoured by this company from the beginning of 1950’s, mostly in 1951. According to Jesus (1987) the aims of buying this forest is not explicit in any document. But his analysis of reports and forestry inventories always bring significant information about forestry production and the quantity of wood to be used in railroad structure, which suggests that this forest was envisaged as a reserve of wood to be used in the construction of the railroad Vitória-Minas. The decision of maintaining this forest was based on the result of studies and on the increased about the potential of wood production and the sustainable use of the property. Even though, at that moment none of these programs of wood extraction and of sustainable use of the forest were implemented and the present vegetation cover is practically the same existing when the property was acquired. Presently the Natural Reserve of Linhares protects an area of 21,780 ha of Atlantic forest and associated ecosystems. Its main uses are: ecological tourism and seedling production of Atlantic forest trees to be used in programs of forest restoration all over the country. See http://www.vale.com/hot_sites/linhares/reserva.htm.

Nevertheless, it is important to remark that in spite of the efforts of some well-dedicated conservationists, the main reason of the present existence of the forest protected in these two reserves was the high quantity of wood they had.

These forests represented reserves of values to be used in a near future mostly by Companhia Vale do Rio Doce, the greatest Brazilian miner that, at that time, needed wood to build railroads to transport the ore from the inlands of the state of Minas Gerais to the port in Vitória, state of Espírito Santo, to be exported. In fact, as indicated Jesus (1987) (Box 1) the aim of making reserves of wood for using in the construction of the Railroad Vitória-Minas is easily seen when reading the documents of acquisition of the land of Linhares Reserve.

The case of Sooretama Biological Reserve is more complex. On the one hand, the Parque de Reserva, Refúgio e Criação de Animais Silvestres Sooretama was created with the aim of preservation and associated objectives such as education and scientific knowledge. On the other hand, the Reserva Barra Seca seems to have been created with the aim of preserving a forest that contained an important reserve of wood. It came to the point that in 1968 the government of the State of Espírito Santo demanded the repeal of the donation of the lands of Reserva Barra Seca, previously donated by this State to the National Government in order to create a national reserve. This repeal aimed the used of the lands to exploit the forest (Aguirre, 1951; IBDF & FBCN, 1981). In 1971, Sooretama Biological Reserve was finally created in the form it exists nowadays. About 30 or 40 families used to live within the limits of the Parque de Reserva, Refúgio e Criação de Animais Silvestres Sooretama at the moment of its creation. With the creation of the Park, logging, hunting, and raising domestic animals became forbidden. Apparently these prohibitions lead the families that lived within the park to search for new areas of forest still existing in the region (Aguirre, 1951). In the Linhares Reserve there was a small settlement named community São João Batista, from which remained a bandstand that was recently destroyed and a cemetery. Their history was recently studied by Machado-Guimarães (1998) (see also Garay, 2004).

Presently the Sooretama Biological Reserve is protected by IBAMA[2], and the main problems for its conservation are fire and hunters. The Linhares Reserve is a private property used for education, ecological tourism, and production of seedlings of forestry species used for reforestation.

The history of preservation of the small forest fragments is probably more complex than that of the two large reserves, particularly due to their high number, to the fact that they belong to different owners, and to that the land use around them can be quite different from one property to another and can

[2] IBAMA - The Brazilian Institute of Environment and Renewable Natural Resource.

change along time. Nevertheless, at least two main reasons are at the basis of their conservation.

One is the obligation by the law, first formalized in the Forest Code, the law n^{o} 4,771 from 15.IX.1965. This law limited the right of property concerning the native vegetation existing in the national territory. It qualified the forest as wells of common interest to every inhabitant of the country subordinating its exploitation to the interest of the population. The Forest Code created the status of Permanent Preservation Area[3] and Legal Reserve[4], two kinds of situation in which the forests must be protected in rural properties or possessions. In 1993, with the Decree 750 from 10.II.1993, deforestation, forest logging, and exploitation of the vegetation became very restrict. In addition to that, since 1998 the remnants of the Brazilian Atlantic forest are protected by the Federal Constitution that established the Atlantic forest a national patrimony, and settled that its utilisation must be done in conditions that assure the preservation of the environment, including the utilization of natural resources. Presently tree cutting is mostly forbidden, and the only cases permitted need the specific authorization of the relevant environmental institutions.

In spite of the importance of the legal apparatus for avoiding the total deforestation, a close look to the distribution of the fragments in the landscape indicates that, although the law obviously contributed to its maintenance, it was not sufficient. The majority of the properties do not have 20% of forest that should constitute the Legal Reserve, and many Permanent Preservation Areas (margins of rivers, lagoons and lakes, springs, hilltops, and slopes greater than 45°) are not covered by native vegetation.

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[3] The Permanent Preservation Area is the area covered or not by native vegetation, with the environmental function of preserving the hydric resources, the landscape, the geologic stability, the biodiversity, the gene flow of the fauna and flora, of protecting the soil and of assuring the well-being of human populations. It is considered of Permanent Preservation, a) the forests and any other form of vegetation located along the rivers and any body of water from its highest level in a marginal strip of width varying between 30m and 500m according to the width of the water body; b) in the edges of lagoons, lakes and natural or artificial water reservoir; c) in springs, independently of their topographic situation, in a radius of 50m of width; d) in hilltops; e) in slopes greater than 45°; and in a few other situations that do not concern this region (Forestry code – federal law n^{o} 4,771/1965; Art. 2°).

[4] The Legal Reserve is an area localized in a rural property or possession, except the Area of Permanent Preservation, necessary to the sustainable use of natural resources, to the conservation and recuperation of ecological processes, to the conservation of the biodiversity, and to shelter and protect the native flora and fauna. In the Atlantic forest 20% of the area of the rural property or possession must be kept as Legal Reserve (Forestry code – federal law n^{o} 4,771/1965; Art. 1°; Paragraph III).

The other reason for the present existence of the forest fragments in the landscape is that they have good quality wood and other natural resources, representing for their owners a reserve of values that continue to be exploited until our days. In several of them one can easily see tracks, trails, traces of logging, traps, and many other indicators of an active use (Pellens *et al*., *in prep*.) (Table 2).

Table 2. Present uses of the forest fragments in Linhares and Sooretama, based on observations of the authors of this chapter, and on reports of workers of IBAMA acting on the region.

Uses	Some Details	Indicators
Hunting	Birds, lizards, small mammals, big mammals	Traps Riffles Guards of the reserves aggressed and shot by hunters Techniques of hunting, recipes and techniques of preparation of the meat of wild animals common in the speech of the population
Wood extraction	Hardwood trees, softwood trees, bushes, young trees, etc.	Piles of trunks recently cut on the ground of the forest Firewood oven/stove Coffee dried with firewood Fences made with wood of forest species Houses/stables joists made with wood Tool's handles made with wood of forest species
Herbs extraction	Medicinal Decorative	Traditional use of medicinal plants that are found in the forests – seen by people's indications when you are sick. Forest species observed in gardens (bromeliads, orchids, ferns, palms, short trees, etc)
Protection of springs, ponds and rivers		Location of the fragment in relation to the water body Fishing Washing clothes
Protection against the wind		Long fragments usually left as a barrier against the dominant wind and the house of the property or the plantation
Protection for cattle		Cows resting at the shadow in small fragments during the sunny hours of the day
Leisure		People walking for doing exercises Dating Hunting
Scientific research		Tracks, tags on trees, ropes used to delimit stands, cameras for filming mammal's movements, holes for studying the soil, thesis sustained, scientific results published.

Forest is part of people's everyday life. It provides wood for drying the coffee, for the structure of the houses, and many other resources and services (Table 2). Although these resources and services were factors that contributed to the protection of the forest fragments, its continuation in time without a planning for the entire landscape can be dangerous to the preservation of the biodiversity. As a matter of example we show the study of Agarez *et al*., (2004), in which they compared the density of the most common tree families in Sooretama Biological Reserve and in fragments submitted to different logging intensity. Their results show that the density of the families with higher wood quality, as is the case of the species of Myrtaceae, Sapotaceae, Leguminosae and Lecythidaceae, is markedly reduced in sites with higher logging intensity. Conversely, the density of the families of fast growing trees with low quality wood, such as Anacardiaceae, Moraceae and Euphorbiaceae, tends to increase in fragments with higher logging intensity (Figure 7).

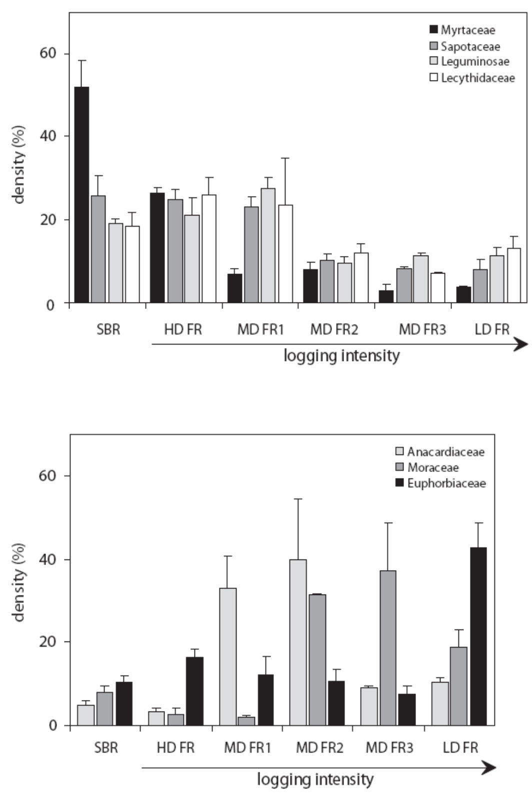

Figure 7. Density of the most abundant tree families in Sooretama Biological Reserve and in four fragments with different logging intensity (SBR: Sooretama Biological Reserve; HD FR: fragments of high density; MD FR: fragments of medium density; LD FR: fragment of low density). Modified from Agarez *et al.,* 2004.

New Perspectives for Conservation: PROBIO and Ecological Corridor of Atlantic Forest

During the last twenty years, many demands of political and social character related to the management of natural resources were developed in Brazil. These demands were deeply rooted in the political priorities of the country and materialized in several governmental programs. Among them was the National Program of Biological Diversity (PRONABIO-PROBIO), created in 1994 to answer the commitments of the country to the Convention of Biological Diversity. One of its main integrative subprojects was developed in Linhares and Sooretama: the demonstrative subproject *"Conservation and Recuperation of Atlantic forest in Linhares – ES, based on the functional evaluation of the biodiversity"*. This subproject represented a study case. Its implementation constituted a search of methodologies aiming the construction of an interinstitutional and participative model of conservation that includes the transfer of technologies of forest recuperation and environmental education for conservation to the table-land Atlantic forest (Garay, 2006). The aims, methodologies, results and details of the implementation of this main subproject were carefully presented in Garay (2006). In the present chapter we simply want to characterize its existence and to show a few results related to the recuperation of the forest. However, the most significant result of this interdisciplinary research was the change of perception of the conservation value of the local biodiversity, reversing the tendency of indiscriminate deforestation of the forest remnants existing outside the reserves.

In this perspective, the central strategy consisted in relating the problems of maintenance of hydric resources necessary to the local agriculture and of controlling the soil erosion of the edges of numerous streams whose waters are essential to the agriculture as well as to the forest vegetation (an ecosystem service). It is important to remark the existence of periodic cycles of drought that not only facilitate fire in the forest remnants being also catastrophic to the local agriculture.

The sites for the implementation of the subproject were chosen based on the interdisciplinary approach shown in Figure 8. Following this interdisciplinary approach, the areas for future plantation of forests were located in the buffer zone of the reserves (nuclear areas). As far as possible they linked fragments with the aim to constitute micro-corridors, and surrounded springs and the edges of the streams, sites protected by law (Permanent Preservation areas). The socio-economic diagnostic showed the importance of small and medium properties in the productive rural system of the region, once more putting in evidence the need of restoration of the edges of water bodies (service of the forest cover). Parallel studies about the status of the biodiversity and the diffusion of part of these results were instruments of valorisation of native ecosystems. These results are presently used to evaluate the efficiency of the restoration concerning the recuperation of the biodiversity.

The project was developed in two main phases: first with local leadership and after with rural producers and other members of the community. Regarding the restored areas, a total 110ha was planted with 270,000 seedlings in a basis of 40 native species/ha; 38 rural producers were involved and about 150 people were trained; the strategy adopted lead to 90% cost reduction when compared to the costs of forest recuperation in the market.

In the first phase the project was developed in seven rural properties and comprised a total of 120,000 seedlings planted in 48ha. The restoration was efficient, and in practically every site planted plants grew efficiently in way that in nine years the plantations had the general aspect of a young forest (Figure 9). This phase was characterised by significant demonstrative areas (several hectares planted in each property). The main action was the transfer of technology of maintenance of the forest plantations. The positive aspects were: higher exemplar and demonstrative value; massive participation of local workforce, training *in locus* and seedlings' production for replacement in farms. The limits were: high-cost of implementation, centralized social responsibility, limited number of social agents involved, restricted benefits to the community.

The second phase was characterized by the creation of a community NGO, named Bionativa, born from a partnership between government and society (MMA[5]/UFRJ[6], Municipality, and Community). The exemplar value given by the participation of local leaders and by the creation of a local space of public access that centralized the production of low cost seedlings facilitated the diffusion of the actions of restoration to the low and medium producers (Garay, 2006). The positive results of this second phase were: dissemination of technology across the land and also in other countries (dispersion pole), shared social responsibility, broad spectrum of social agents involved, significant decrease of costs (90 %). The aims and results of conservation of the ONG Bionativa are synthesized in Box 2. In the process of creating this ONG a forest fragment was acquired with the aim of creating a park for the

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[5] Ministério do Meio Ambiente = Ministry of Environment.
[6] Federal University of Rio de Janeiro.

community. It represents the last Atlantic forest fragment in periurban zone of this region and is destinated to research and environmental education.

The results obtained with the implementation of this subproject shows up the need of: 1) a change of perception of the social agents aiming to develop an active attitude concerning the conservation of the biodiversity; 2) the establishment of partnerships to develop consensual solutions that reconcile productive activities and conservation; 3) the capacity of social intervention of non governmental organization as facilitators of conservation actions, including the intervention in the reduction of costs of conservation and in exemplar demonstrative actions; and, finally, 4) the importance of developing scientific research about the status of the biodiversity, with the main objective of evaluating the sustainability of experiments of forest restoration and the values of remnants as reservoirs of biodiversity and source of species in areas of restoration.

Box 2

Results obtained and objectives relative to the transfer of technology and environmental education for conservation with the creation of the NGO Bionativa.

technological transfer for conservation purposes

Developing and assessing new technologies of sustainable use of biological resources (*research*)

Centralizing local wisdom and scientific-technical knowledge (*forest restoration activities*)

Making the new technologies of the native germoplasm use accessible to the community (*relationship between transfer and education*)

Contributing to the equilibrium between the rural development (direct and indirect benefits of biodiversity) and forest conservation (*landscape management and public policies*)

ONG education goals for conservation of biodiversity

Institutionalization of the diffuse participation of the social agents and landers in conservation processes (*organization*)

Transfer of technologies of sustainable use of biodiversity in the socio-bio-cultural context (*adapting transfer*)

Public access to the restoration technologies for permanent conservation areas (degraded riparian forests) (*transfer facility*)

Field support and regional diffusion for research on forest biodiversity (*linking restoration activities and biodiversity knowledge*)

Possibility of the continuity of conservation actions/use/management (*integrating conservation purposes and future needs*)

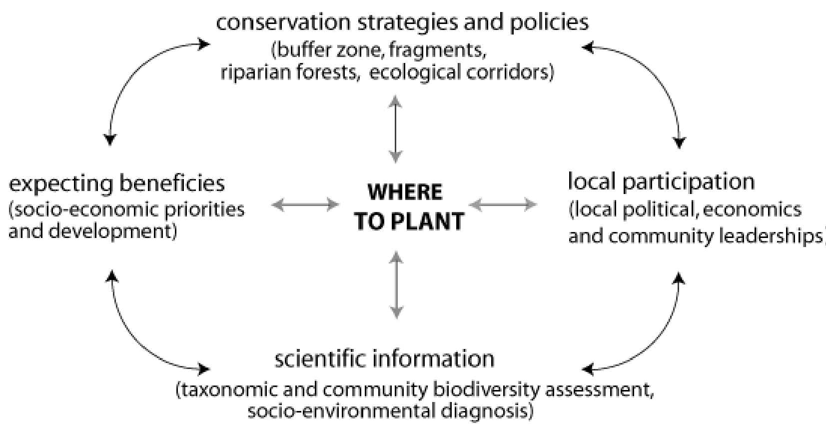

Figure 8. Interdisciplinary approach for choosing restoration areas.

Presently, the project Ecological Corridors of the Ministry of Environment centralizes its activities in the central corridor of Atlantic forest that goes from the South of Espírito Santo to the South of Bahia with more than 1,000km of large. It is a corridor of management in an integrated perspective of management of the territory that considers the problems related both to forest conservation and the human activities, favouring the sustainability of these activities in the interstitial areas.

Linhares and Sooretama are located in this corridor, composing the micro-corridor Linhares-Sooretama-Comboios. Our previous experience on conservation and research in this focus area enabled us to take part in this project. The interdisciplinary research and solidary restoration of the Atlantic forest program to be developed considers the implementation of experiements of forest restoration, associating the existing fragments with strong community participation aiming the dissemination of techniques of reforestation. Presently the focus is at the potential utilization of the chemical diversity of the arboreous species. However, natural resources exploitation is totally forbidden in Sooretama Biological Reserve, and is made in Linhares Reserve with the structure of a big national company, both not representing the dominant structure of land use in the region (Box 1).

In this context, the conservation of fragments gains a new dimension. Being the only remnants capable of being used, they represent the source of genes and species that can assure the sustainability of the arboreous plantations that will emerge, protecting the forest and amplifying the ecological services that they do to the territorial management and to the economic and social development.

Figure 9. Pictures of an experimental site of forest restored using 40 native species/ha and its development in nine years. Top: the site recently planted (1998); center: three years later (2001); bottom: nine years later the plantation had already the aspect of a young forest.

Evaluating the Conservation Value of the Fragments with the Community of Blattaria

The conservation and management of the biodiversity requires an integration of the human dimensions, such as the ones we described above, with the knowledge of the ecology of populations, communities and ecosystems that compose that landscape. Tropical forests are characterised by the enormous diversity of species, by a great complexity of community organization and by a multitude of ways ecosystems function. In such a context the impact of deforestation, fragmentation as well as of the different uses made in forest fragments can be very high. Deforestation can create enormous disturbances on populations, communities and ecosystems. Immediate extinctions can occur if the habitats of species are eliminated. One can imagine that it can be mostly the case of short range endemics, but at the present rates of deforestation all over the world it can be also the case of species with much wider range of distribution. In this context, the survival of a great part of species becomes highly dependent on their ability of surviving in a landscape mainly formed by fragments. But the long term persistence of the populations and communities depends on factors associated to the demography of the populations, on the possibility of rescue effects among sets of fragments, on the ability to resist shifts in the environment, or on the capacity to live in an environment affected by disturbances. Above all, it depends on the long term existence of the forest fragments, on the possibility of flow of individuals among them, and on the existence of a nuclear area that can contribute to enrich the small fragments with individuals in a way to assure gene flow (Saunders *et al.*, 1991; Laurance & Bierregaard Jr., 1997; Thomas, 2000).

The study of the community of Blattaria that we will show right away was developed with the aim to evaluate the value of these fragments to the conservation of biodiversity (Turner, & Corlett, 1996; Pellens & Grandcolas, 2007). In tropical forests, insects constitute one of the richest groups in terms of number of species and diversity of roles they play in the ecosystem (Hammond, 1995). They represent an important fraction of the diversity of any tropical forest, and contribute crucially to several functions essential to the functioning of the ecosystem, such as pollination, dispersion of microorganisms, fragmentation of organic debris, etc. For that reason, insects can be good indicators of the status of the ecosystem, and the analysis of their community can give basic information about the management of an important fraction of the biodiversity in a given region.

Blattaria is a worldwide distributed insect order, but with diversity and abundance much higher in tropical forests. It comprises more than 4,000 species described (Princis, 1962-1971, and later studies), and the total number of extant cockroach species in the world is up to 20.000 (Grandcolas & Pellens, 2009). In a recent evaluation, we showed that there are 644 species of cockroaches recorded in Brazil. Nevertheless, the analysis of the number of species accumulated along time showed that the accumulation curve is still in its ascending part, indicating that the total number of species in this wide country can be at least five or six times higher than presently known (Pellens & Grandcolas, 2008). The local richness of Blattaria in a forest ecosystem can vary from a few tens to more than one hundred (Fisk, 1983; Grandcolas, 1991, 1994a; Pellens, 2002), and, as a rule, a high number of new species is found in each new region prospected (Grandcolas, 1991; 1997a; Grandcolas & Pellens, pers. obs.).

Individuals of Blattaria are involved in the decomposition of organic matter. Most of the species are saprophagous *sensu lato*, feeding on dead leaves, dead wood, carcasses, and any sort of organic debris, which are probably enriched by algae, fungi and bacteria normally found in natural ecosystems. In the case of wood-eating cockroaches, the dead wood that is poor in nutrients is transformed in the digestive tube sometimes with the help of commensal or symbiotic protista (see for example, Pellens *et al.*, 2002; 2007a). Cockroaches live in a very wide and complex set of microhabitats from the soil to the canopy with a multitude of ways of exploring space and resources (Grandcolas, 1993a). For example, in the Brazilian Atlantic forest, in a same dead trunk laying on the ground one can find *Parasphaeria boleiriana* living in galleries they make in the wood, *Petasodes dominicana* under the bark, *Monastria biguttata* on the bark at the underside, and *Minablatta bipustulata* in the dust under the dead trunk (Pellens *et al*., 2002, 2007b; Pellens & Grandcolas, 2003, 2007).

Obviously, the community of Blattaria is only one of the components of the tropical forest biodiversity, and of insect diversity as well. Nevertheless, it is a group sufficiently rich for allowing comparisons of several parameters of the community composition and structure, but not exaggeratedly rich, permitting to anchor the ecological analysis on a clear taxonomy, since it is possible to identify every individual sampled. In addition, individuals of Blattaria are sampled directly (i.e., without use of traps), which permits to include observations of their habitats and some elements of their biology (e.g.

long wings *vs* short wings) or behaviour in the analysis of community. We designed this study with the main aim of evaluating the conservation value of small and disturbed fragments to the conservation. The questions we asked were: 1) Do the disturbances associated to forest fragmentation lead to differences in the richness and composition Blattaria community? 2) What is the contribution of the effects of area *per se* and of habitat diversity to the richness of cockroach community?

A methodological note

Six study sites were selected to develop this research: three in the large reserves and three in small forest fragments. They were carefully chosen to be on similar type of soil and in forests with similar kind of vegetation. Sampling was done in two seasons, in March-April 2000 and November 2000. Each study site had one hectare and was selected in the less disturbed areas within the forest, where canopy had three strata, avoiding the edges and paths or trails commonly found in the interior of forest fragments.

Individuals of Blattaria from the understory were collected by direct sampling in the forest understory from 6:00 PM to midnight. The search was made in the forest understory, on the ground (litter, dead trunks, rocks), on standing trunks, aerial litter, on leaves of plants until 2m high. Each sample corresponds to one hour per person of observation and collection. The following analysis are based on 3351 individuals corresponding to 48 species, 25 genera and four families of Blattaria collected during 131 hours of study (for more details, see Table 3 and Table 4). We also made similar collection in sites within the matrix near to the reserves and to each fragment studied. Only seven of the 48 species collected were observed in the matrix, and only one of these species (*Pycnoscelus surinamensis*) is typically from the matrix, being taken to the fragments by man (Pellens & Grandcolas, 2002). These species are indicated in Table 4.

Do The Disturbances Associated to Forest Fragmentation Lead to Differences in the Composition and Structure of Blattaria Community?

One of the main characteristic of forest fragments is that they are more exposed to disturbances than large reserves. Their small size expose organisms to any sort of edge effects, such as augmentation of dryness, higher exposition to the sun, to the wind, to invasive species, and to the penetration of man that by itself can also promote other disturbances (Murcia, 1995). A simple way to evaluate the effect of disturbances of fragmentation in a community is by comparing certain parameters of the community composition and structure in a standard area of their habitat in sets of sites within small fragments and large reserves. Here the questions we asked were: a) is the species *richness* of sites from fragments different of those from the reserves? b) is the species *composition* of the sites within the fragments different of that from the reserves?

Table 3. Characterization of the study sites with the total area of the reserve or fragment, distance of the fragments to the nearest reserve, and number of hours sampled in each season. BRS: Sooretama Biological Reserve; LR – MA: Linhares Reserve, Mata Alta; LR – E: Linhares Reserve, Entrance; FPN: Pasto Novo Fragment; FBB: Bioparque Bionativa Fragment; FSP: São Pedro fragment.

			Number of sampling hours		
Site	Area	Distance to the nearest reserve	March-April 2000	November 2000	Total
BRS	21,780		14	12	26
LR – MA	22,168		15	12	27
LR – E	22,168		-	12	12
FPN	66.7	3.47 km	-	12	12
FBB	32.7	4.0 km	15	12	27
FSP	2.4	7.0 km	15	12	27
					131

A) Is the species richness of sites from fragments different of those from the reserves?

To answer this question we used the data of species richness obtained in each sampling hour in the field treated by models of simulation emulated by the software Estimate S 5 (Colwell, 1997) (Box 3).

The results obtained with this analysis indicate that there are sites with high and low richness in both reserves and fragments (Figure 10). The richest site is in FPN, in which we found 30 species with only 12 samples, and the poorest sites were the ones within the Linhares Reserve. Thus, the answer to our question is negative. In what concerns species richness, our data indicate that sites in forest fragments can be richer than the sites within the reserves (as

Table 4. Species of Blattaria found in the remnants of Brazilian Atlantic forest in Linhares and Sooretama. * indicates that the species was also found in the matrix. The classification follows Grandcolas (1993b; 1994b; 1996; 1997b).

Family Polyphagidae	Family Pseudophyllodromiidae
Subfamily Latindiinae	Subfamily Pseudophyllodromiinae
Latindia sp	*Cariblatta sp1*
Gen.1 sp.1	*Cariblatta sp2*
	Cariblatta sp3
Family Anaplectidae	*Dendroblatta sp1*
Anaplecta sp	*Dendroblatta sp2*
	Neoblattella sp1
Family Blattellidae	*Neoblattella sp2*
Subfamily Blattellinae	*Neoblattella sp3*
Isoldaia sp1	*Neoblattella sp4*
Isoldaia sp2	*Trioblattella sp1*
Isoldaia sp3	*Trioblattella sp2*
Isoldaia sp4 *	*Trioblattella sp3*
Isoldaia sp5 *	*Trioblattella sp4* *
Blattellidae sp1	
Blattellidae sp2	Family Blaberidae
Blattellidae sp3	Subfamily Epilamprinae
Blattellidae sp4 *	*Epilampra sp1*
Blattellidae sp5	*Epilampra sp2*
Dasyblatta sp	*Epilampra sp3*
Ischnoptera sp1	*Epilampra sp4*
Xestoblatta sp	Subfamily Blaberinae
Xestoblatta sp 1	*Minablatta sp1* *
Xestoblatta sp 2	*Minablatta sp2* *
Xestoblatta sp 3	*Monastria biguttata*
Xestoblatta sp 4	*Petasodes reflexa*
Xestoblatta sp 5	Subfamily Zetoborinae
Subfamily Nyctiborinae	*Parasphaeria boleiriana*
Nyctibora sp1	*Zetobora sp*
Nyctibora sp2	*Zetoborinae sp*
	Subfamily Pycnosceliinae
	Pycnoscelus surinamensis *

is the case of FPN), have similar number of species as the poorest sites within the reserves (as is the case of FBB that is not different of LR-MA and LR-E), or be in an intermediary situation as is the case of FSP (Table 5).

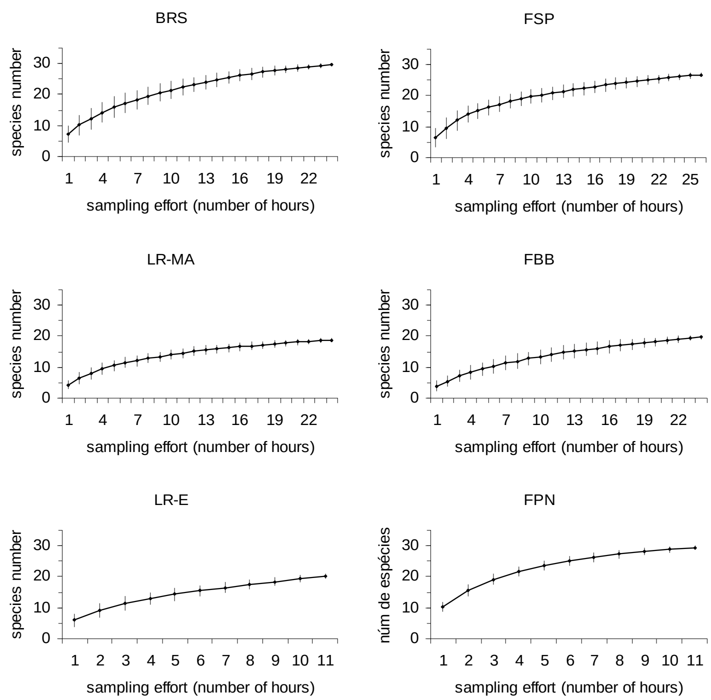

Figure 10. Cumulative curves of species number of Blattaria collected in sites within reserves (BRS, LR-MA, LR-E) and within fragments (FSP, FBB, FPN). The curves were elaborated with a method of randomization of sampling order made with the software Estimate S 5 (COLWELL, 1997). Each point of the curve is the mean and standard deviation of 100 randomizations of the sampling order without replacement.

B) Is the species composition of the sites within fragments different of those from reserves?

To answer this question we analysed some parameters of the species composition in relation to its distribution in the different study sites, and to the species shared among the sites. Besides, in the set of 48 species collected in this study (see Table 4), 12 of them had apterous adult females and 36 had winged adult females. Considering that it is the adult females that can disperse the brood, we also analysed their distribution in the different sites.

Table 5. Comparison of the maximal species richness estimated by the simulation method of Michaelis-Menten for each site from the data of richness per sample obtained for cockroaches in sites within the reserves and within forest fragments. The comparison is made with Mann-Whitney U test: ns: non significant p≥0.05; *: significant p≤0.05; **: significant p≤0.01;*: significant p≤0.001 (n =20).**

Reserves	BRS > LR-MA p=0.0000 ***	BRS > LR-E p=0.0012 ***	LR-MA < LR-E p=0.0223 *
Fragments	**FSP > FBB** p=0.0000 ***	FBB < FPN p=0.0000 ***	FSP < FPN p=0.0005 ***
Fragments *vs* BRS	FSP < BRS p=0.0337 *	**FBB < BRS** p=0.0000 ***	**FPN > BRS** p=0.0166 *
Fragments *vs* LR–MA	FSP > LR-MA P=0.0000 ***	FBB ≈ LR-MA p=0.5075 ns	FPN > LR-MA p=0.0000 ***
Fragments *vs* LR-E	FSP > LR-E P= 0.0133 *	FBB ≈ LR-E p= 0.0531 ns	FPN > LR-E p= 0.0001 ***

Box 3

Two models of simulation emulated by Estimate S 5 (Colwell, 1997) based on the data we obtained in each sampling hour

The first model was the randomization of the sampling order. "By randomizing many times, the effect of sample order can be removed by averaging over randomizations, producing a smooth species accumulation curve and allowing a comparison of estimators for your data set that does not depend on the particular order that samples were collected or added to the analysis" (Colwell, 1997). We produced the cumulative curves with the mean and standard deviation of 100 randomizations made with this method.

The second, was the Michaelis Menten (MM) richness estimator named MMRuns computed by EstimateS that permits the comparison among sites. Based on the data obtained in each sample, the data the program produces represent the estimated MM asymptote based on one, two, three...QdMax samples. The MMRuns computes estimates for values for each pooling level, for each randomization run, and then averages over randomization runs (Colwell, 1997).

Regarding the species distribution, we first verified if fragments or reserves have different numbers of species that are found in only one kind of them (Table 6; 8), and in second place we tested if sites within fragments have more ubiquitous species than sites within the reserves (Table 7; 9). These parameters can indicate if fragments have more species that are able to survive in disturbed sites, or more species that can be found everywhere, respectively.

As can be seen in table 6, the greatest part of the species studied was found in at least one site within the reserve and one in the fragments, and no species was found in every site within reserves or in every site within fragments. Five species (10.4%) were observed in up to two sites sampled in the reserves and nine (18.8%) in fragments. These figures are not significantly different of 7, the mean between 5 and 9 (χ^2 p = 0.445) (Table 6).

Table 6. Distribution of species in the sites within reserves and within forest fragments.

Study sites	Species number
The three sites within the reserves	0
Until two sites within the reserves	5
The three sites within the fragments	0
Until two sites within the fragments	9
At least one site within the reserves and one within the fragments	34

A similar trend was observed in the analysis of the number of species of the different categories of ubiquity. As a whole, a similar number of species of the different categories of ubiquity was found in every study site, independently if they were within reserves or within fragments (Table 7). These values were not significantly different (Kruskal-Wallis H=5.32 ; P>0.05. df = 5). Thus, concerning the species distribution, our analyses indicate that the sites within fragments do not have different number of particular species or of ubiquitous species than the sites within the reserves. It signifies that the fauna of the fragments has as many species that are peculiar as the sites within the large reserves, and that these species are not particularly restrict to one site, nor especially ubiquitous.

Table 7. Number of species belonging to six categories of ubiquity found in each study sites. The categories of ubiquity were defined according to the number of sites the species were found (1 to 6).

	1	**2**	**3**	**4**	**5**	**6**
BRS	2	6	8	4	5	5
LR-MA	1	1	4	3	5	5
LR-E	0	4	5	4	4	5
FPN	3	4	7	5	6	5
FBB	1	3	3	4	5	5
FSP	2	6	3	4	5	5

Species with apterous and winged adult females

The analysis of the distribution of the species with adult females winged or apterous showed that most of the species in both groups can be found in at least one within fragments or within the reserves (Table 8). Winged species are found in every site, and only 3 species are restricted to until sites in the reserves while 7 species are found in until 2 sites within fragments. Conversely, 2 apterous species are restrict to two fragments and 1 to two sites within the reserves.

Table 8. Distribution of species with apterous and winged adult females in the sites within reserves and within forest fragments.

Study sites	Number of apterous species	Number of winged species
The three sites within the reserves	0	0
Until two sites within the reserves	1	3
The three sites within the fragments	0	0
Until two sites within the fragments	2	7
At least one site within the reserves and one within the fragments	9	26

Concerning the ubiquity of species with adult females apterous and winged, we verified that our sample comprised apterous species with every degree of distribution, with no difference between species in the categories of ubiquity 1,2,3 *vs* 4,5,6 (Mann-Whitney U test $p > 0.05$). Conversely, winged species tend to be more restrict in their distribution, and from the 36 species with winged adult females, 26 (72%) are present in until three study sites (Mann-Whitney U test p ≤0.05). In sum, these results show that the presence and absence of species in the studied sites do not depend on the ability of the adult females to fly for recolonizing the fragments.

Table 9. Number of species with apterous and winged adult females belonging to six categories of ubiquity. The categories of ubiquity were defined according to the number of sites the species were found (1 to 6).

	1	2	3	4	5	6
Apterous	3	2	1	2	1	3
Winged	6	10	9	4	4	3

The number of species shared among sites was very low. It varied between 23% (LR-E and LR-MA; FBB and LR-MA), the sites with lowest number of species, and 40% (FPN and BRS) the richest sites. As a whole, there was not higher nor lower number of species shared by sites within fragments or by sites within the reserves (Table 10).

When the number of species shared was analysed in relation to the total number of species found in each site, these percentages were much higher, but varying between 43.3% (RL-E *vs* RBS) and 78.9% (RL-MA *vs* FPN). In this case the richest sites (RBS and FPN) were the ones that have higher number of species shared with other sites. Nevertheless, this figure was rarely higher than 70%, which signifies that at least 30% of the species found in any site were not shared (Table 11). This result also shows that the fauna of the sites within very small fragments are not perfect subset of the fauna of the richest sites, putting in evidence the importance of each of these sites to the total fauna of the region.

Thus, as a conclusion, our results indicate that both the species richness and the species composition of the fauna of Blattaria from small forest fragments are not different of that from large reserves. The species richness observed in the fragments is within the range observed in the reserves. The same way, the sites within fragments have similar number of species in the different categories of distribution analysed as the sites within the reserves and do not have different number of ubiquitous species. In addition, they do not share different number of species than sites within the reserves, but as these sites, they have at least 30% of the species that are not shared. As a whole, these results show that the community of Blattaria from the sites within fragments is not particularly affected by perturbations associated to forest fragmentation.

Table 10. Number of species shared by the different sites studied (with its respective percentage values) in relation to the total number of species in the 6 sites (i.e., 48 species).

	BRS	LR-MA	LR-E	FSP	FBB	FPN
BRS		14 – 30%	13 – 27%	17 – 35%	16 – 33%	19 – 40%
LR-MA			11 – 23%	12 – 25%	11 – 23%	15 – 31%
LR-E				12 – 25%	12 – 25%	16 – 33%
FSP					14 – 30%	18 – 38%
FBB						14 – 30%
FPN						

Table 11. Number of species shared by different combinations of two study sites and respective percentages in relation to the number of species in the site.

	BRS	LR-MA	LR-E	FSP	FBB	FPN
BRS		14 –74%	13 – 62%	17 – 65%	16 – 76%	19 – 63%
LR-MA	14 – 47%		11 – 53%	12 – 46%	11 – 52%	15 – 50%
LR-E	13 – 44%	11 – 58%		12 – 46%	12 – 57%	16 – 53%
FSP	17 – 57%	12 – 64%	12 – 57%		14 – 67%	18 – 60%
FBB	16 – 53%	11 – 58%	12 – 57%	14 – 54%		14 – 47%
FPN	19 – 63%	15 – 79%	16 – 76%	18 – 69%	14 – 67%	
Total number of species in the site	30	19	21	26	21	30

What is the Contribution of the Effects of Area *Per Se* and of Habitat Diversity to the Richness of Cockroach Community?

The conceptual basis for this analysis is the well accepted theory in ecology that the number of species increase with the area sampled, which in fact is a theory that explains the scale effect for explaining the number of species (Lomolino, 2000). According to MacArthur & Wilson (1963; 1967), Connor & McCoy (1979 ; 2001), Haila (1983) and McGuiness (1984) there are four hypotheses to explain this pattern : (1) the random sampling hypothesis; (2) the habitat diversity hypothesis; (3) the area *per se* hypothesis that was better developed as the island biogeography theory; and (4) the disturbance hypothesis. In addition to that, a factor that is not related to the area but is important to the species-area relationship is the distance to a colonization source and the existence of multiple sites. Its contribution to the species-area relationship is due to the *rescue effect*, which reduces local extinctions (Brown & Kodrick Brown, 1977). We will not detail these theories here, for it is one of the most studied problems in ecology (for a good synthesis see Connor & McCoy, 1979, 2001). The important thing to remark here is that these mechanisms can act solely or in combination to determine the number of species found in a given site, and that separating the contribution of the different components allows understanding the contribution of the sets of fragments in the landscape to the totality of the regional richness.

In the previous section we came to demonstrate that there is no effect of disturbances associated to forest fragmentation on the Blattaria community. Thus we can consider that these effects are constant in the sites studied and go further to analyse the effect of area *per se* and habitat diversity. We want to remark that the effects of area *per se* and of random sampling are very intricate and not possible to separate with the methods we propose here. For this reason, we will treat them as one thing aiming to separate these mechanisms from the habitat diversity. Our interest in verifying the contribution of these two components in the species area relationship is to understand the contribution of the sets of fragments in the landscape to the totality of the regional richness, and based on that to propose strategies of conservation and management of the biodiversity.

To separate the effects of area *per se* and habitat diversity we developed the conceptual model that is synthesized in the Figure 11. In this model, the first step is the verification of effects related to the area *per se*. It is tested by the simple comparison of the richness in single sites with the richness observed in the sum of three sites within the reserves or three sites within fragments. If the sum of the richness in a set of sites is not higher than that observed in a single site, we show that there is no effect of area (we mean all the effects associated to area, area *per se*, random sampling, and habitat diversity) on the community. Conversely, if the sum of the samples of a set of sites gives a higher number of species than in each site two results are possible: the first is area *per se* effect; the second is the habitat diversity effect. To separate these two effects we propose to compare samples obtained in single sites with a mix of random and proportional samples from the set of sites (in the present case, from the set of three sites within fragments or three sites within reserves). This way, if with equal sample size, the number of species from the mix of samples is higher than for each site isolated, we verify the effect of habitat diversity. Conversely, if the number of species from the two sets of samples is not different we refute the hypothesis of habitat diversity.

These analyses were performed with simulations of increasing the sample size by adding the samples from different study sites with the model of simulation Michaelis Menten richness estimator (MMRuns) computed by Estimate S 5 (Colwell, 1997) (Box 3).

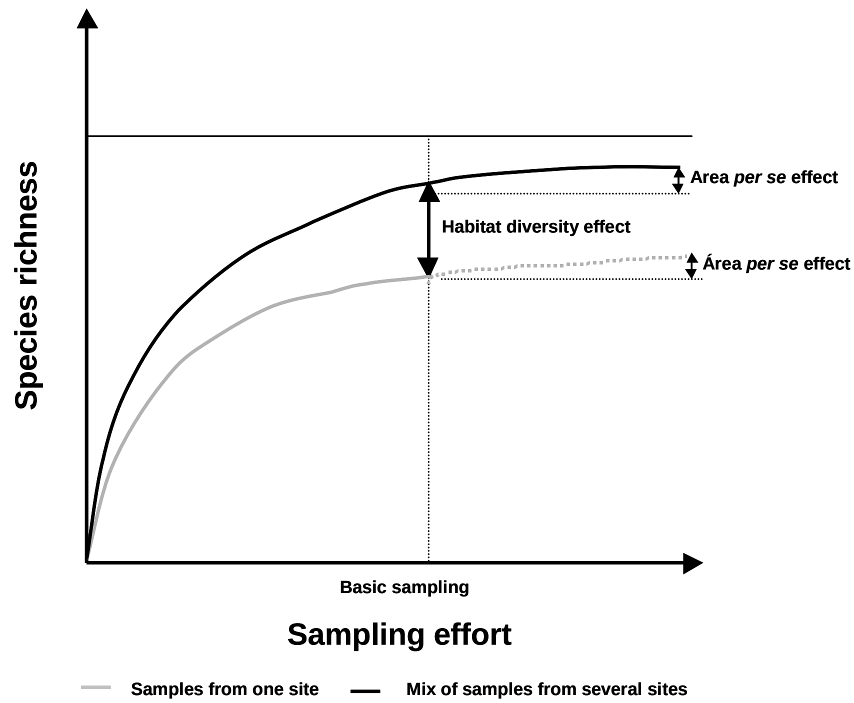

Figure 11. Conceptual model used to separate the Area *per se* effect and the habitat diversity effect.

As commonly observed in nature, the number of species increased as we increased the sampling effort: 39 species were collected in the three sites within the reserves and 43, in those from fragments (the maximum observed in a single site was 30 species in BRS and FPN). When comparing the curves concerning reserves and forest fragments, the simulation indicates differences concerning the maximum number of species, and the intensity of the sampling effort (Figure

12). In the reserves the species number increases progressively with the sample size and the 65 samples estimated for the three sites within the reserves have a higher number of species than a mix of 25 samples (Figure 12*b*) (Mann-Whitney U test, p= 0.0001). Conversely, in the set of fragments the richness estimated to the 64 samples is not significantly different than that estimated for a single site (Figure 12*a*) (Mann-Whitney U test, p=0.5074), suggesting that in the set of fragments the species richness is close to a maximum. This result suggests that the effect of area *per se* is important to explain the increase in species richness within the reserves, but not in the fragments. However, the hypothesis of habitat diversity within the reserves can not yet be refuted.

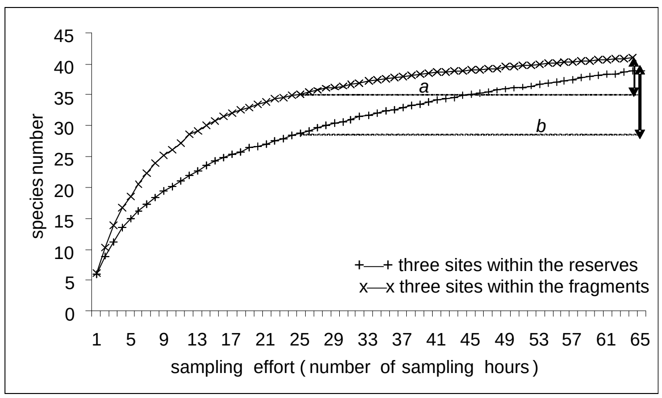

Figure 12. Verification of the effects of Area *per se* and Habitat Diversity on the species richness of Blattaria in Linhares and Sooretama, Brazil. The curves were built with the richness estimated with the simulation model Michaelis-Menten to a mix of samples from three sites of each kind. *a*) difference between the richness estimated to three sites and one site in the reserves; *b*) difference between the richness estimated to three sites and one site in the fragments.

As explained in the beginning of this section, for testing the effect of habitat diversity we compared the samples obtained in each site with a mix of random and proportional samples of the three sites within fragments and three sites within reserves (Figure 13).

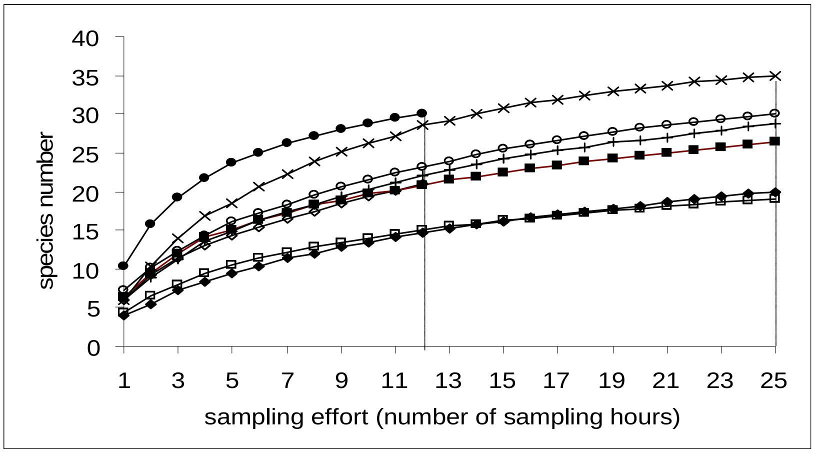

Figure 13. Verification of the effect of Habitat Diversity on the species richness of Blattaria in Linhares and Sooretama, Brazil. The richness estimated with the simulation model Michaelis-Menten to a random and proportional mix of samples obtained to the set of sites within fragments and within reserves is compared to the richness estimated to each site independently. O—O BRS; □—□ LR-MA; ◊—◊ LR-E; ●—● FPN; ■—■ FSP; ♦—♦ FBB; +—+ three sites within the reserves; x—x three sites within the fragments.

Table 12. Comparison of the richness estimated with the Michaelis-Menten method to a mix of random and proportional samples from the three sites within the reserves and the three sites within the fragments with the samples obtained to each site. In this comparison we kept the number of samples as obtained in the field (12 samples in the comparison with FPN and LR-E and 25 for the other sites). P values of Mann-Whitney U test: ns: non significant p≥0.05; *: significant at p≤0.05; **: significant at p≤0.01; *: significant at p≤0.001 (n =20).**

Mix of samples from sites within reserves ≈ RBS P= 0.3867 ns	Mix of samples from sites within reserves > RL-MA P= 0.0000 ***	Mix of samples from sites within reserves > RL-E P= 0.0071 **
Mix of samples from sites within fragments > FSP P= 0.0000 ***	Mix of samples from sites within fragments > FBB P= 0.0000 ***	Mix of samples from sites within fragments > FPN P= 0.0222 *

The comparison of the richness estimated from a mix of samples of the three study sites with the richness estimated to each study site shows different responses for reserves and fragments. The mix of samples from the reserves has higher species richness than that observed in LR-MA and LR-E, but not than that observed to BRS (Table 12). It indicates that the differences of species richness in the reserves are not strong enough to support the hypothesis of habitat diversity. This result plus the progressive and significant increase in species richness with the increase of sampling effort (Figure 12*a*) indicate that the effect of area *per se* is important to explain the species richness in the reserves. In opposition, the richness estimated with a mix of samples from the three sites within fragments is always higher than that estimated to each site within fragments. This difference indicates clearly the effect of habitat diversity on the species richness of the fragments.

CONCLUSION

In this chapter we showed that the landscape at the north of the State of Espírito Santo changed markedly during the last 50-60 years, and that this transformation had strong impact on the Atlantic forest creating a new problem, a new context for the conservation of the biodiversity. The intense deforestation gave place to a rural productive landscape in which the remaining forests were confined to two large reserves and several fragments protected in private properties. Even so these remnants represent the largest area of Atlantic forest from the south of Rio de Janeiro to the south of Bahia, and more than 50% of the forests remaining in the State of Espírito Santo. Moreover, they harbour a very high species richness and endemism, attracting the attention of the Ministry of Environment in the strategy of biodiversity conservation of this biome. For this reason, Linhares and Sooretama were chosen to be the sites of implementation of one of the main subprojects of PROBIO, in the first wave of Brazilian projects to answer the commitments to the Convention of Biological Diversity: the project *"Conservation and Recuperation of Atlantic forest in Linhares – ES, based on the functional evaluation of the biodiversity"*. As a consequence of this first endeavour, this region is presently at the centre of the project Ecological Corridor of Atlantic forest.

Our analysis of the conservation of the forest fragments showed that the most important factors were the obligations by the law and the will of putting aside a piece of forest that represented a reserve of value, due to the wood they had. However, neither the law nor the quality of wood are sufficient to assure the preservation of these fragments in the near future. The number of fragments in the landscape is below the values recommended by the law; and fragments continue to be exploited in a way that is changing the composition of their communities. The results of this exploitation can already be measured in the composition of tree families (Agarez *et al*., 2004), and if it does not stop it could lead to a biomass collapse (Laurance *et al.*, 1997), or a total impoverishment of these remnants (Cardoso da Silva & Tabarelli, 2000) in the forthcoming decades.

Nevertheless, our evaluation of the conservation value of these fragments for conservation indicates that the situation is not lost. Even small and very disturbed fragments harbor important number of species of Blattaria. Sites within fragments are not different of sites within the large reserves concerning the species richness and composition: they do not harbor higher number of species found only in fragments or of ubiquitous species, neither a lower number of species found typically in sites within large reserves. It shows that the community of fragments is not peculiar; they do not have more species of disturbed areas or less forestry species. In addition to that, habitat diversity plays an important role in the distribution of the species in the set of fragments. It indicates that fragments permit the conservation of a higher number of species by increasing the possibility of sampling those with particular types of distribution, particular habitats, thus incorporating other aspects of the regional diversity by permitting the protection of a portion of organisms not found anywhere else. In sum, the results obtained with the analysis of the community of cockroaches bring light to the importance of fragments for increasing the total number of species protected in the region, indicating thus the high value of fragments for biodiversity conservation. This result is particularly remarkable when compared to that obtained in the *Biological Dynamics of Forest Fragments Project* in Amazon. A synthesis of their study indicates that in less than 22 years after fragmentation, the fragments contain less species per area than intact forest for several groups of vertebrates and invertebrates. In addition, a high number of species disappeared even from the largest (100ha) forest fragment, and for several groups the fragmentation increased the number of species of disturbed habitats (Laurance *et al.*, 2002).

It places the fragments of this region of the Atlantic forest in a positive context, indicating the need to look at fragments through a new perspective. Fragments do not replace large reserves; they contribute to enlarge the surface of remnants of Atlantic forest in the landscape by including other aspects of the regional environment, thus contributing to the protection of a higher number of organisms. Furthermore, they can contribute to the long-term persistence of the different species by serving as step stones, increasing the probability of dispersion and/or reducing the local competition. Nevertheless, the conservation of the biodiversity including forest fragments requires an approach considering the fragility of being numerous, small, scattered in the landscape, and susceptible to be simultaneously exploited. Recent studies indicate clearly that this kind of indiscriminate exploitation might lead to the simultaneous impoverishment of their biota, which could promote a clash of the regional biodiversity (Laurance *et al.*, 1997; Agarez *et al.*, 2004; Cardoso da Silva & Tabarelli, 2000), a "tragedy of commons" (Hardin, 1968).

The conservation of the biodiversity in this perspective requires shifting the scale: it must be envisaged at the landscape or regional scale, in which fragments shall be included in the strategy of conservation. In the present case it means that the conservation of the regional biodiversity depends on the engagement of the rural producers, owners of the fragments, in the project of conservation of the Atlantic forest. In this context, a way to avoid the "tragedy of commons" would be through the elaboration of a plan of management of the forest fragments, in which uses could be defined, and results monitored along time.

Our results of the community of cockroaches are in accordance with the study of plants in the same region (Agarez, 2002), which can be taken as an indicator that that it might be the case for several other biological groups of organisms. Based in these studies we can go further and state on the definition of priority fragments for conservation. First of all, these results indicate that the set of fragments existing in the landscape are important for increasing the protection of the biological richness of this region. As a consequence, all fragments should be protected, many of them should be recuperated in order to assure its permanence in the long run, and certain disturbances common to several fragments should be immediately stopped, as for example, closing roads or trails that permit the easy movement of people through the fragments. In a second step, the management of the set of fragments should give priority to diversity: either geologic, geomorphologic, edaphic, and ecologic; or the diversity of uses, which promotes differential survival of species and could help to protect certain populations.

In conclusion, in Linhares and Sooretama the population is becoming conscientious of the fragment's importance due to the ecosystem services provided, above all by their contribution to the protection of springs and streams, assuring the availability of the so precious water for the agriculture during the years of drought. They are also beginning to recognize the fragment's potentialities in creating a system of sustainable development using forest resources, since fragments represent the only possibility of using forest resources in the region. Our study emphasizes the potential of the set of fragments remaining in this landscape for the protection of the regional biodiversity.

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