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Floristic and structure of a secondary urban forest with a long history of man-made disturbances in Espírito Santo state, Brazil

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ABSTRACT

This study aimed to describe the floristic composition and the structure, indicate the successional stage, and provide proposals for conservation and management of a secondary urban forest in Vitória Island, Espírito Santo state, which grew after about 400 years of man-made disturbances. In a 0.5 ha plot all tree and shrub individuals with dbh > 3.2 cm were sampled. Additional vouchers were collected outside of the plot in order to increase the list of local flora. In total, 91 species were recorded (within the plot and by additional collects), distributed in 73 genera and 35 botanic families. Within the plot, 1083 living individuals were recorded (plus 27 standing dead) belonging to 81 species. The estimated basal area and the Shannon diversity index were 32.54 $m^2.ha^{-1}$ and 3.52, respectively. The most important species in community were *Gallesia integrifolia* and *Ocotea diospyrifolia*, which dominate the upper and middle storeys. In the understorey, shrub species of Rubiaceae dominate, mainly *Rudgea umbrosa*. The advanced successional stage of

the forest was confirmed by the values of basal area and diversity index, the vertical structure divided into three storeys, well developed understorey, small number of larger trees, and dominance of late secondary species. However, the absence of timber species and palms, and the small number of species of families such as Lauraceae and Myrtaceae indicates a possible loss of species due to the long history of man-made disturbances and the fragment isolation within an urban matrix. The enrichment with regional species and restoration of abandoned pastures and plantations are appropriate strategies for conservation of this forest.

PALAVRAS-CHAVES:
Fitossociologia
Riqueza florística
Fragmento florestal
Mata Atlântica
Perda de espécies

RESUMO – FLORÍSTICA E ESTRUTURA DE UMA FLORESTA SECUNDÁRIA URBANA COM LONGA HISTÓRIA DE DISTÚRBIOS ANTRÓPICOS NO ESTADO DO ESPÍRITO SANTO, BRASIL. Este estudo objetivou descrever a composição florística e a estrutura, indicar o estádio sucessional e sugerir propostas de manejo e conservação de uma floresta secundária urbana na ilha de Vitória, Estado do Espírito Santo, sob regeneração após cerca de 400 nos de distúrbios antrópicos. Em uma parcela de 0,5 ha todos os arbustos e árvores com DAP ≥ 3,2 cm foram amostrados. Coletas adicionais de material botânico foram realizadas fora da parcela a fim de incrementar a lista da flora local. Ao todo foram registradas 91 espécies (na parcela e em coletas adicionais), distribuídas em 73 gêneros e 35 famílias. Na parcela foram registrados 1083 indivíduos vivos pertencentes a 81 espécies, além de 27 indivíduos mortos. A área basal estimada e o Índice de Shannon foram de 32.54 $m^2.ha^{-1}$ e 3,52, respectivamente. As espécies mais importantes da comunidade foram *Gallesia integrifolia* e *Ocotea diospyrifolia*, as quais dominaram os estratos superior e médio. No sub-bosque, arbustos de espécies de Rubiaceae foram dominantes, principalmente *Rudgea umbrosa*. O estágio sucessional avançado da floresta foi confirmado por valores de área basal e índice de diversidade, estrutura vertical dividida em três estratos, sub-bosque bem desenvolvido, pequeno número de grandes árvores e dominância de espécies secundárias tardias. Entretanto, a ausência de espécies de madeiras nobres e palmeiras e o pequeno número de espécies de famílias como Lauraceae e Myrtaceae indica uma possível perda de espécies devido à longa história de distúrbios antrópicos e ao isolamento do fragmento na matriz urbana. O enriquecimento com espécies regionais e a restauração de pastagens e áreas de plantio abandonadas são estratégias apropriadas para a conservação dessa floresta.

PALABRAS-CLAVES:
Fitosociología
Riqueza florística
Fragmento forestal
Mata Atlántica
Pérdida de especies

RESUMEN – FLORÍSTICA Y ESTRUCTURA DE UNA FLORESTA SECUNDARIA URBANA COM ANCHA HISTORIA DE DISTURBIOS ANTROPICOS EM EL ESTADO DEL ESPÍRITO SANTO, BRASIL. Este estudio objetivó describir la composición florística y la estructura, indicar el ciclo sucesional y añadir propuestas de manejo y conservación de una floresta secundaria urbana en la isla de Vitória, provincia de Espírito Santo, bajo regeneración después de cerca de 400 años de disturbios antrópicos. En una cuota de 0,5 ha todos los arbustos y árboles con DAP ≥ 3,2 cm fueron amostrados. Colectas adicionales de material botánico fueron realizadas fuera de la cuota, con el fin de incrementar la lista de la flora local. En total, fueron registradas 91 especies (en la cuota y en colectas adicionales), distribuidas en 73 géneros y 35 familias. En la

cuota fueron registrados 1083 individuos vivos pertenecientes a 81 especies, además de 27 individuos muertos. El área basal estimada y el Índice de Shannon fueron de 32.54 $m^2.ha^{-1}$ y 3,52, respectivamente. Las especies más importantes de la comunidad fueron *Gallesia integrifolia* y *Ocotea diospyrifolia*, las cuales dominaron los estratos superior y medio. En el sub-bosque, arbustos de especies de Rubiaceae fueron dominantes, principalmente *Rudgea umbrosa*. El ciclo sucesional avanzado de la floresta fue confirmado por valores de área basal e índice de diversidad, estructura vertical fraccionada en tres estratos, sub-bosque bien desarrollado, pequeño número de grandes árboles y dominancia de especies secundarias tardías. Sin embargo, la ausencia de especies de maderas nobles y palmeras y la pequeña cantidad de especies de familias como Lauraceae y Myrtaceae indica una posible pérdida de especies debido a la larga historia de disturbios entrópicos y al aislamiento del fragmento en la matriz urbana. El enriquecimiento con especies regionales y el restablecimiento de pastizales y áreas de plantío abandonadas son estrategias apropiadas para la conservación de esa floresta.

1. Introduction

The Brazilian Atlantic Forest is one of the world's biodiversity hotspots because it has high levels of diversity and endemism, and is extremely threatened (Mittermeier et al., 2004). Its destruction began in the 16th century, when the first cities were founded in the Brazilian coast. With the population growth, the demand for food, firewood and timber increased. This led to intense deforestation, leaving a few remaining forests. Many of these forests are small in size (<50 ha), with mean isolation 1440 m, highly influenced by edge effect, with its secondary forests arising from the abandonment of deforested areas with low agricultural suitability (Ribeiro et al., 2009).

In the last decades, the expansion of urban areas on nearby forests created a new scenario (then called urban forests), increasing disturbances such as fire, hunting, firewood extraction, air pollution, and introduction of exotic species (Silva Matos; Santos; Chevalier, 2002; Solórzano; Oliveira; Guedes-Bruni, 2005; Melo et al., 2011).

However, the disturbed urban forests provide important environmental and social services such as climatic regulation, erosion contention, hydric regulation, protection of native fauna and flora, recreation, ecotourism, scientific research and environmental education (Porto et al., 2005; Oleyar et al., 2008; Melo et al., 2011).

The history of deforestation in Vitória Island, southeastern Brazil, is old and coincides with the period of founding of Vitória city (in year 1551). Since then, the disturbances were recurrent, resulting in secondary forest remnants. In recent decades the unplanned growth of the city caused a significant transformation of the landscape and occurrence of several disturbances in the forest fragments. The conservation units created in the central portion of the island by the government since the 1980s, as the Fonte Grande State Park (FGSP) and the Environmental Protection Area of the Maciço Central (EPAMC), have served to control the expansion of the city.

In the FGSP, researches with small mammals (Santos; Loss; Leite, 2004; Caldara Junior; Leite, 2007), birds (Simon; Lima; Cardinali, 2007), and parasite wasps (Azevedo et al., 2002) have been conducted in the last years. Regarding the vegetation only preliminary floristic surveys and vegetation characterizations were performed as part of the management plan (Secretaria Municipal de Meio Ambiente;

Secretaria de Estado da Agricultura, 1996) as well as floristic data collected by O. J. Pereira (unpublished data). Nonetheless, no detailed information about floristic, structure and successional stage of the FGSP forest is available. Such data are useful to determine the forest conservation status and necessary management actions for the maintenance of ecological processes that occur there.

In this context, the study purpose was to describe the floristic and the structure of a secondary forest of the FGSP aiming to answer the following questions: (1) in the face of a long history of man-made disturbances, what tree and shrub species remain in this forest? (2) what is the successional stage of the forest? (3) what management actions should be taken for its conservation?

2. Methods

Study area - The FGSP (20º18'11"; 20º04'00" S and 40º20'02"; 40º20'39" W; 218 ha) is located at the central portion of Vitória Island, Southeastern Brazil (Figure 1). It is surrounded by the EPAMC and by urban areas of Vitória city, the capital of Espírito Santo state, which has in its metropolitan area nearly 1.7 million inhabitants. The FGSP ranges from 50 up to 310 m.a.s.l., with soils classified as Eutrophic and Distrophic Red-yellow Argisoil, Cambisoil, and Litholic Neosoil. The climate of this region is classified as Aw - tropical rainy, with absence of a typical cold season *sensu* Köppen. The mean temperature is 24 ºC and the annual rainfall is between 1200-1400 mm (Secretaria Municipal de Meio Ambiente; Secretaria de Estado da Agricultura, 1996).

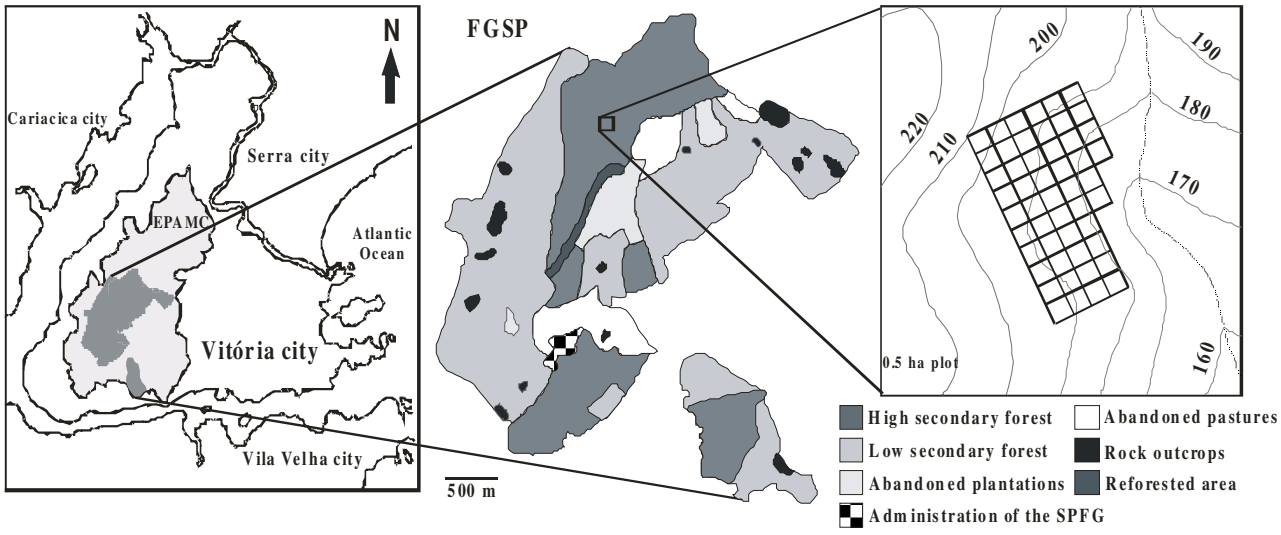

Figure 1. Location of the 0.5 ha plot in the Fonte Grande State Park (FGSP), within the Environmental Protection Area of the Maciço Central (EPAMC), in Vitória Island downtown. Modified from Secretaria Municipal de Meio Ambiente; Secretaria de Estado da Agricultura (1996).

Prior to the colonization of Vitória Island the area of FGSP used to be covered by an exuberant Atlantic Forest classified as Submontane Dense Ombrophilous Forest (*sensu* Instituto Brasileiro de Geografia e Estatística, 1992). The colonization started in 1537 when the first farm was installed. In subsequent periods the necessity of firewood and timber for constructions and repair of ships, houses, forts, churches and tools were increasing and the farmland occupation (mainly cotton, sugar cane

and manihot) was striking. In 1590 Vitória had 150 houses and extensive plantations that occupied both the lowlands and slopes of the island (Derenzi, 1965).

Nowadays, lowlands and many slopes are urbanized and there are only forest remnants in the central portion of the island. These remnants are dominated by high ('capoeira alta') and low ('capoeira baixa') secondary forests and were derived mainly from abandoned agricultural areas in different periods of the last century (see figure 1). Due to its proximity to urban areas, these remnants are impacted by fire, hunting, firewood extraction and air pollution (Secretaria Municipal de Meio Ambiente; Secretaria de Estado da Agricultura, 1996).

Floristic and structure survey - Between February and October of 2004 a detailed floristic and structural survey was undertaken in a 0.5 ha plot composed of 50 continuous 10 x 10 m quadrats (Figure 1). This plot was located in the 'Gruta do Morcego' site, where there is a slope (175–205 m.a.s.l) covered by secondary forest that raised after the abandonment of coffee plantation and cattle raising 50-60 years ago. This is considered the best preserved forest of the FGSP. The plot has the irregular shape due to the presence of some rocks, which made impossible the establishment of squares.

All tree and shrub individuals with diameter at breast height (dbh) $\geq$ 3.2 cm where sampled, labeled and measured. The height of all individuals was estimated with the use of 12 m telescoping pole. For individuals with multiple stems the dbh was converted on a unique dbh through square root of sum of stems square diameter. The standing dead individuals were only quantified.

Vouchers were collected within the plot and in its vicinity for species determination. The families were determined according to the APG III (2009) classification system and the vouchers were deposited in the Central Herbarium of the Universidade Federal do Espírito Santo (VIES).

The species were classified on the following ecological groups: pioneer, early secondary and late secondary. Exotic species formed the 'no classified group'. According Gandolfi; Leitão-Filho; Bezerra (1995), pioneer species are clearly dependent on light, which did not occur in understorey and occupy gaps or edges of forests. Early secondary species tolerate intermediate levels of shade, occurring in gaps, forest edges and understorey little shading. Late secondary species grow in the understorey under conditions of shade and may remain in the understorey throughout their life or then reach the upper storey or an emergent condition.

For the purpose of such classification, work notes (e.g. the high of individuals, the occurrence in other neighbor forest formations and timber and leaves features) and ecological data of species reported in literature reviews (Gandolfi; Leitão-Filho; Bezerra, 1995; Lorenzi, 2002a; Lorenzi, 2002b; Carvalho; Nascimento; Braga, 2007; Dan; Braga; Nascimento, 2010) were used.

The data were used to quantify the species diversity (Shannon Index, H') according to Brower; Zar (1984). Species frequency, density, basal area, dominance, coverage value (CV) and importance value (IV) were determined *sensu* Mueller-Dombois; Ellenberg (1974). In addition, the vertical and horizontal structure of the community and from some populations were analyzed based on dbh classes (3.2-5, 5-10, 10-20, 20-40, 40-80, 80-100 cm) and estimates of height. The classes had increasing intervals in order to compensate the small number of trees which had dbh > 30 cm.

3. Results

Floristic composition – In total, 91 species (71 tree and 20 shrub species) were recorded within the plot and in vicinity of 'Gruta do Morcego', distributed in 73 genera and 35 botanic families (see Table 1). The taxa incompletely identified scores 14.3% of the species. Three exotic species were recorded: *Coffea robusta*, *Citrus*

nobilis, and *Artocarpus heterophyllus*. Their occurrence can be explained through the use of the area for agriculture in the past.

Table 1. Tree (T) and shrub (S) species recorded in a high secondary forest in the Fonte Grande State Park, Southeastern Brazil. LF = life form; EG = ecological group; LS = late secondary; ES = early secondary; PI = pioneer; * Exotic species.

Family	Species	Popular name	LF	EG
Achariaceae	*Carpotroche brasiliensis* Endl.	sapucainha	T	LS
Anacardiaceae	*Astronium gracile* Engl.	aderne	T	LS
Annonaceae	*Annona acutiflora* Mart.	araticum	T	LS
	Annona laurifolia Dunal	pinha-da-mata	T	LS
	Guatteria glabrescens R.E.Fr.		T	LS
	Xylopia sericea A.St.-Hil.	pindaíba-branca	T	PI
Apocynaceae	*Tabernaemontana laeta* Mart.	leiteiro	T	PI
Asteraceae	*Gochnatia polymorpha* (Less.) Cabrera	camará	T	PI
Bignoniaceae	*Adenocalymma macrophyllum* DC.		S	LS
	Sparattosperma leucanthum K.Schum.	cinco-folhas	T	PI
	Tabebuia chrysotricha (Mart. ex DC.) Standl.	ipê-amarelo	T	PI
	Zeyheria tuberculosa Bureau ex B.Verl.	ipê-felpudo	T	PI
Boraginaceae	*Cordia trachyphylla* Mart.	louro-branco	T	ES
	Cordia trichotoma (Vell.) Steud.	louro-pardo	T	PI
Cactaceae	*Brasiliopuntia brasiliensis* (Willd.) A.Berger	palma-da-mata	S	PI
Capparaceae	*Crateva tapia* L.	pau-cebola	T	LS
Celastraceae	*Maytenus ardisiifolia* Reissek	vinhal	S	LS
Euphorbiaceae	*Alchornea triplinervia* (Spreng.) Müll. Arg.	tapiá	T	ES
	Croton floribundus Spreng.	capixingui	T	ES
	Sapium glandulatum (Vell.) Pax	pau-de-leite	T	ES
	Sebastiania klotzschiana (Müll. Arg.) Müll. Arg.		S	LS
Fabaceae	*Albizia polycephala* (Benth.) Killip ex Record	angico-monjolo	T	ES
	Bauhinia cf. *angulosa* Vogel	pata-de-vaca	T	LS
	Bauhinia forficata Link	pata-de-vaca	T	ES
	Inga subnuda Salzm. ex Benth.	ingá-peludo	T	ES
	Lonchocarpus sericeus (Poir.) Kunth ex DC.	cabelouro	T	ES
	Machaerium hirtum (Vell) Stellfeld	bico-de-pato	T	PI
	Machaerium nyctitans (Vell.) Benth.	bico-de-pato	T	PI
	Parapiptadenia pterosperma (Bojer) Brenan	angico-vermelho	T	ES
	Piptadenia gonoacantha (Mart.) J. F. Macbr.	pau-jacaré	T	PI
	Pterocarpus rohrii Vahl	pau-sangue	T	ES
	Swartzia myrtifolia Sm.	pau-teimoso	T	LS
	Vataireopsis araroba (Aguiar) Ducke	angelim-amargoso	T	LS
Lauraceae	*Ocotea diospyrifolia* (Meisn.) Mez	canela	T	LS
Loganiaceae	*Strychnos* SP		T	LS
Melastomataceae	*Miconia nervosa* (Sm.) Triana	quaresma-da-mata	S	LS
Meliaceae	*Cedrela odorata* L.	cedro	T	LS
	Guarea guidonia (L.) Sleumer	peloteira	T	ES
	Trichilia casaretti C. DC.	catiguá	T	LS
	Trichilia hirta L.	carrapeta	T	ES
	Trichilia lepidota Mart.	catiguá-pardo	T	LS
	Trichilia pseudostipularis (A. Juss.) C. DC.	óleo-de-	T	ES

		marceneiro		
Monimiaceae	*Macrotorus utriculatus* (Mart.) Perkins		S	LS
Moraceae	*Artocarpus heterophyllus* Lam.	jaqueira*	T	NC
	Ficus gomelleira Kunth & C.D. Bouché	figueira	T	ES
	Maclura tinctoria (L.) D. Don ex Steud.	amarelinho	T	PI
	Sorocea hilarii Gaudich.	folha-de-serra	T	ES
Myrsinaceae	*Cybianthus* SP		S	LS
Myrtacee	*Campomanesia laurifolia* Gardner	guabiroba	T	ES
	Eugenia melanogyna (D. Legrand) Sobral	batinga-goiaba	T	LS
Nyctaginaceae	*Guapira cafferiana* (Casar.) Lundell	maria-mole	T	ES
	Guapira opposita (Vell.) Reitz	maria-mole	T	ES
	Guapira SP		S	LS
	Pisonia cf. *ambigua* Heimerl	maria-mole	T	ES
	Ramisia brasiliensis Oliv.	taipa	T	PI
Phytolacaceae	*Gallesia integrifolia* (Spreng.) Harms	pau-d'alho	T	LS
Rhamnaceae	*Ziziphus platyphyllus* Reissek	juá	T	PI
Rubiaceae	*Coffea robusta* Linden	café-conilon*	S	NC
	Coussarea graciliflora (Mart.) Benth. & Hook. f.		S	LS
	Coussarea nodosa (Benth.) Müll. Arg.		T	LS
	Melanopsidium nigrum Colla	coroa-de-sapo	T	LS
	Posoqueria latifolia (Rudge) Roem et Schlt	fruta-de-macaco	S	LS
	Psychotria carthagenensis Jacq.	gumana	S	LS
	Psychotria sp1		S	LS
	Psychotria sp2		S	LS
	Randia armata (Sw.) DC.	ponteiro	T	ES
	Rudgea coronata (Vell.) Müll. Arg.	cravo-liso	S	LS
	Rudgea umbrosa Müll. Arg.		S	LS
Rutaceae	*Citrus nobilis* Lour.	mexerica*	S	NC
Salicaceae	*Casearia arborea* (Rich.) Urb.	guaçatunga	T	ES
	Casearia decandra Jacq.	cafezeiro-do-mato	T	ES
Sapindaceae	*Allophylus puberulus* Radlk.	fruta-de-saíra	T	ES
	Cupania oblongifolia Mart.	pau-magro	T	ES
	Cupania racemosa (Vell.) Radlk.	camboatá-mirim	T	LS
	Sapindus saponaria L.	pau-sabão	T	ES
Sapotaceae	*Chrysophyllum splendens* Spreng.	bapeba	T	LS
	Chrysophyllum sp1		T	LS
	Chrysophyllum sp2		T	LS
	Micropholis SP		T	LS
Simaroubaceae	*Picramnia bahiensis* Turcz.	caxeta-preta	T	LS
	Simaba cedron Planch.	caxeta-amargosa	T	LS
Solanaceae	*Cyphomandra sycocarpa* (Mart. & Sendtn.) Sendtn.		S	PI
	Solanum SP		S	PI
Sterculiaceae	*Guazuma crinita* Mart.	moço-branco	T	PI
	Pterygota brasiliensis Allemão	farinha-seca	T	ES
Cannabaceae	*Trema micrantha* L. Blume	candiúba	T	PI
Urticaceae	*Urera nitida* (Vell.) Brack	urtigão	T	PI
Verbenaceae	*Citharexylum myrianthum* Cham.	pau-viola	T	ES
Violaceae	*Amphirrhox longifolia* (A. St.-Hil.) Spreng.	capitão-branco	S	LS
Indetermined	Indetermined sp1		T	LS
	Indetermined sp2		T	ES

The families with higher number of species were Rubiaceae (11), Fabaceae (8), Meliaceae (6), Nyctaginaceae (5), Sapotaceae and Annonaceae (4). Myrtaceae and Lauraceae were represented by only two and one species, respectively. Others 18 families were represented by only one species. Palms (Arecaceae) were not found. Rubiaceae was predominantly shrub, with only two tree species (*Randia armata* and *Coussarea nodosa*).

Structure and diversity - In the plot we recorded 1083 living trees and shrubs (plus 27 standing dead) with dbh $\geq$ 3.2 cm, belonging to 81 different species. The total estimated density was 2,166 ind.ha^{-1} and the estimated basal area was 32.54 m^2.ha^{-1}. The phytosociological parameters for each species are detailed in Table 2. At dbh $\geq$ 3.2 cm the diversity index was 3.52. Considering only trees with dbh $\geq$ 10 cm the diversity index was 2.96. This difference in diversity emphasizes the great importance of shrub species (often of smaller diameters) for the community diversity.

In respect to vertical structure individuals were distributed into three layers or storeys (upper-, middle- and understorey). The upper storey forms a discontinuous canopy and is composed by few individuals of species that reached between 18 and 26 meters height (only *Gallesia integrifolia*, *Albizia polycephala*, *Parapiptadenia pterosperma*, *Sparattosperma leucanthum* and *Astronium gracile*).

The middle storey is more populated and intercepts the light, reducing the brightness on the forest floor and ensuring the retention of humidity in the soil. The height of the trees was between 6 and 18 meters, and the species *Ocotea diospyrifolia*, *Gallesia. integrifolia* and *Bauhinia* cf. *angulosa* dominated this storey. Bellow middle storey there were many treelets and shrubs composing a well developed understorey. Among the shrubs the Rubiaceae family dominates.

Some herbs were found in places of higher humidity, highlighting up species of Alstroemeriaceae, Araceae, Marantaceae, Piperaceae, Rutaceae and Solanaceae. Epiphytes were scarce in all layers, being represented mainly by *Tillandsia stricta* Sol. ex Sims (Bromeliaceae).

The forest showed low density at dbh $\geq$ 10 cm. Few individuals of larger diameter and many individuals of smaller diameter were recorded (73.6% had dbh < 10 cm, see Figure 2). Despite this, 88.1% of basal area (14.71 m^2) was concentrated on few individuals over dbh $\geq$ 10 cm.

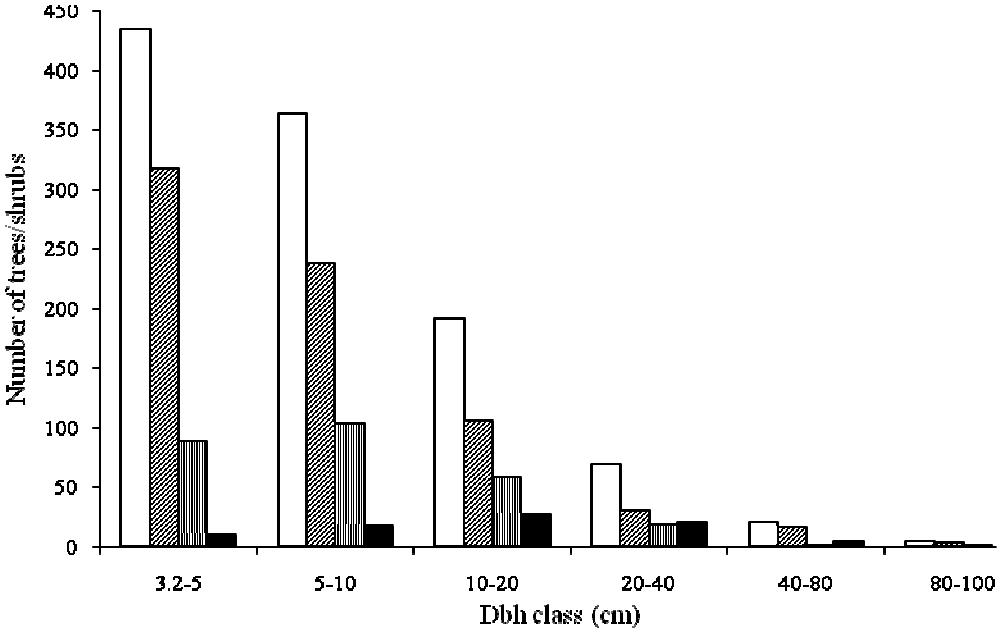

Figure 2. Distribution of tree/shrub individuals on diameter classes in a secondary forest in the Fonte Grande State Park, Southeastern Brazil. Adding, the individuals also were distributed in diameter classes for ecological groups. ☐ All groups; ▨ Late secondary; ▥ Early secondary; ■ Pioneer.

The ten most abundant species grouped 57.7% of individuals, while 29 species were represented by only one or two individuals. *Ocotea diospyrifolia* was the most abundant species in the plot adding 14.6% of the total recorded individuals. However, *Gallesia integrifolia* (with 7.8% of the individuals) showed the higher IV and CV due to its elevated basal area (see Table 2). Other abundant species were *Bauhinia* cf. *angulosa* and *Rudgea umbrosa*. Especially their densities and frequencies were responsible for the third and fourth IV, respectively. *Bauhinia* cf. *angulosa* is the most important species of Fabaceae and apparently grows under the shadow of other species of the middles storey (mainly *O. diospyrifolia)* because its maximum height is about 12 meters. *Rudgea umbrosa* is a shrub species that dominates the understorey. The exotic species (*Coffea robusta*, *Citrus nobilis*, and *Artocarpus heterophyllus*) reached low IV and CV because they were represented by only a few adults.

Table 2. Phytosociological parameters of tree and shrub species with dbh ≥ 3.2 cm sampled in 0.5 ha of secondary forest in the Fonte Grande State Park, Southeastern Brazil. NI = number of individuals; BA = basal area (m²); RD = relative density (%); RDo = relative dominance (%); RF = relative frequency (%); CV = coverage value (%); IV = importance value (%).

Species	NI	BA	RD	RDo	RF	CV	IV
Gallesia integrifolia	87	5.446	8.03	33.468	5.99	41.50	47.49
Ocotea diospyrifolia	162	1.591	14.96	9.778	6.96	24.74	31.69
Bauhinia cf. *angulosa*	79	0.480	7.29	2.948	5.50	10.24	15.74
Rudgea umbrosa	75	0.144	6.93	0.883	5.34	7.81	13.15
Casearia arborea	47	0.405	4.34	2.490	4.37	6.83	11.20
Lonchocarpus sericeus	33	0.579	3.05	3.556	3.24	6.60	9.84
Guarea guidonia	43	0.148	3.97	0.910	4.05	4.88	8.93
Tabernaemontana laeta	24	0.711	2.22	4.371	1.78	6.59	8.37

Parapiptadenia pterosperma	10	0.913	0.92	5.610	1.46	6.53	7.99
Trichilia casaretti	34	0.146	3.14	0.895	3.56	4.03	7.59
Psychotria sp1	38	0.046	3.51	0.284	3.72	3.79	7.51
Sparattosperma leucanthum	12	0.788	1.11	4.841	1.46	5.95	7.41
Chrysophyllum splendens	27	0.396	2.49	2.433	1.13	4.93	6.06
Astronium gracile	6	0.717	0.55	4.408	0.97	4.96	5.93
Psychotria carthagenensis	26	0.049	2.40	0.300	3.07	2.70	5.78
Picramnia bahiensis	22	0.063	2.03	0.387	2.91	2.42	5.33
Rudgea coronata	25	0.034	2.31	0.207	2.75	2.52	5.27
Guapira cafferiana	20	0.083	1.85	0.509	2.27	2.36	4.62
Randia armata	18	0.088	1.66	0.540	2.10	2.20	4.31
Cupania racemosa	13	0.247	1.20	1.519	1.29	2.72	4.01
Albizia polycephala	9	0.272	0.83	1.674	1.46	2.51	3.96
Allophylus puberulus	12	0.134	1.11	0.826	1.78	1.93	3.71
Chrysophyllum sp2	14	0.127	1.29	0.781	1.46	2.07	3.53
Crateva tapia	4	0.430	0.37	2.644	0.49	3.01	3.50
Coffea robusta	21	0.029	1.94	0.181	1.13	2.12	3.25
Machaerium nyctitans	10	0.142	0.92	0.874	1.29	1.80	3.09
Psychotria sp2	16	0.019	1.48	0.115	1.29	1.59	2.89
Eugenia melanogyna	11	0.038	1.02	0.231	1.62	1.25	2.87
Trichilia pseudostipularis	13	0.016	1.20	0.098	1.46	1.30	2.76
Chrysophyllum sp1	13	0.042	1.20	0.256	1.29	1.46	2.75
Sorocea hilarii	13	0.015	1.20	0.094	1.29	1.29	2.59
Swartzia myrtifolia	10	0.015	0.92	0.094	1.46	1.02	2.47
Bauhinia forficata	7	0.135	0.65	0.830	0.97	1.48	2.45
Urera nitida	10	0.053	0.92	0.324	1.13	1.25	2.38
Ramisia brasiliensis	3	0.237	0.28	1.456	0.49	1.73	2.22
Guazuma crinita	3	0.221	0.28	1.358	0.49	1.63	2.12
Cordia trichotoma	6	0.097	0.55	0.593	0.97	1.15	2.12
Campomanesia laurifolia	8	0.032	0.74	0.195	1.13	0.93	2.07
Guapira opposita	6	0.058	0.55	0.356	0.97	0.91	1.88
Annona acutiflora	8	0.013	0.74	0.082	0.97	0.82	1.79
Citharexylum myrianthum	2	0.207	0.18	1.269	0.32	1.45	1.78
Machaerium hirtum	4	0.116	0.37	0.711	0.65	1.08	1.73
Coussarea graciliflora	7	0.010	0.65	0.063	0.97	0.71	1.68
Pterocarpus rohrii	6	0.041	0.55	0.254	0.81	0.81	1.62
Adenocalymna macrophyllum	6	0.011	0.55	0.069	0.65	0.62	1.27
Trichilia hirta	4	0.023	0.37	0.142	0.65	0.51	1.16
Cupania oblongifolia	3	0.088	0.28	0.538	0.32	0.82	1.14
Inga subnuda	4	0.007	0.37	0.044	0.65	0.41	1.06
Miconia nervosa	4	0.007	0.37	0.040	0.65	0.41	1.06
Coussarea nodosa	4	0.020	0.37	0.123	0.49	0.49	0.98
Sapium glandulatum	3	0.030	0.28	0.182	0.49	0.46	0.94
Rollinia laurifolia	1	0.107	0.09	0.659	0.16	0.75	0.91
Xylopia sericea	2	0.062	0.18	0.379	0.32	0.56	0.89
Piptadenia gonoacantha	1	0.098	0.09	0.603	0.16	0.70	0.86
Cedrela odorata	3	0.009	0.28	0.055	0.49	0.33	0.82
Cordia trachyphylla	3	0.003	0.28	0.021	0.49	0.30	0.78
Tabebuia chrysotricha	1	0.052	0.09	0.317	0.16	0.41	0.57
Trichilia lepidota	2	0.007	0.18	0.045	0.32	0.23	0.55
Citrus nobilis	2	0.007	0.18	0.045	0.32	0.23	0.55
Carpotroche brasiliensis	2	0.004	0.18	0.025	0.32	0.21	0.53
Alchornea triplinervia	1	0.035	0.09	0.213	0.16	0.31	0.47
Pisonia cf. *ambigua*	1	0.034	0.09	0.209	0.16	0.30	0.46

Amphirrhox longifolia	1	0.003	0.09	0.018	0.32	0.11	0.43
Artocarpus heterophyllus	1	0.026	0.09	0.162	0.16	0.25	0.42
Indetermined sp2	1	0.013	0.09	0.082	0.16	0.17	0.34
Casearia decandra	1	0.013	0.09	0.080	0.16	0.17	0.33
Guatteria glabrescens	1	0.010	0.09	0.063	0.16	0.16	0.32
Indetermined sp1	1	0.005	0.09	0.028	0.16	0.12	0.28
Maytenus ardisiaefolia	1	0.004	0.09	0.024	0.16	0.12	0.28
Cybianthus sp	1	0.003	0.09	0.018	0.16	0.11	0.27
Vataireopsis araroba	1	0.003	0.09	0.018	0.16	0.11	0.27
Pterygota brasiliensis	1	0.002	0.09	0.015	0.16	0.11	0.27
Ziziphus platyphyllus	1	0.002	0.09	0.014	0.16	0.11	0.27
Cyphomandra sycocarpa	1	0.002	0.09	0.014	0.16	0.11	0.27
Melanopsidium nigrum	1	0.002	0.09	0.011	0.16	0.10	0.27
Micropholis sp	1	0.002	0.09	0.011	0.16	0.10	0.27
Simaba cedron	1	0.002	0.09	0.010	0.16	0.10	0.26
Guapira sp	1	0.001	0.09	0.008	0.16	0.10	0.26
Opuntia brasiliensis	1	0.001	0.09	0.008	0.16	0.10	0.26
Sebastiania klotzschiana	1	0.001	0.09	0.005	0.16	0.10	0.26
Strychnos sp	1	0.001	0.09	0.005	0.16	0.10	0.26

Ecological groups - In total, 41 late secondary (45%), 28 early secondary (30.8%) and 19 pioneer species (20.9%) were recorded. Regarding the number of individuals, a dominance of late secondary species was found in the forest. The late secondary species accounted 711 individuals (65.7%), while pioneers accounted only 79 individuals (7.3%) and early secondary grouped 269 individuals (24.8%). Exotic species (no classified) were represented by only 24 individuals (2.2%). The dominance of late secondary species was seen in all dbh classes, being more expressive at dbh < 20 cm (see Figure 2).

In general, late secondary species had many individuals of smaller diameters. Early secondary and pioneer species often show number of adults (with larger dbh) greater than that of the young ones (with smaller dbh). This situation is illustrated in Figure 3, in which the diameter distribution of populations of three important species of the community is shown. *Ocotea diospyrifolia* is a late secondary species and his individuals are concentrated in dbh classes < 20 cm. *Casearia arborea* is a early secondary species and his population has a little number of young individuals (with dbh between 3.2 and 5 cm). *Tabernaemontana laeta* is a pioneer species that does not have individuals in 3.2-5 cm class. It is represented mostly by trees with dbh > 10 cm.

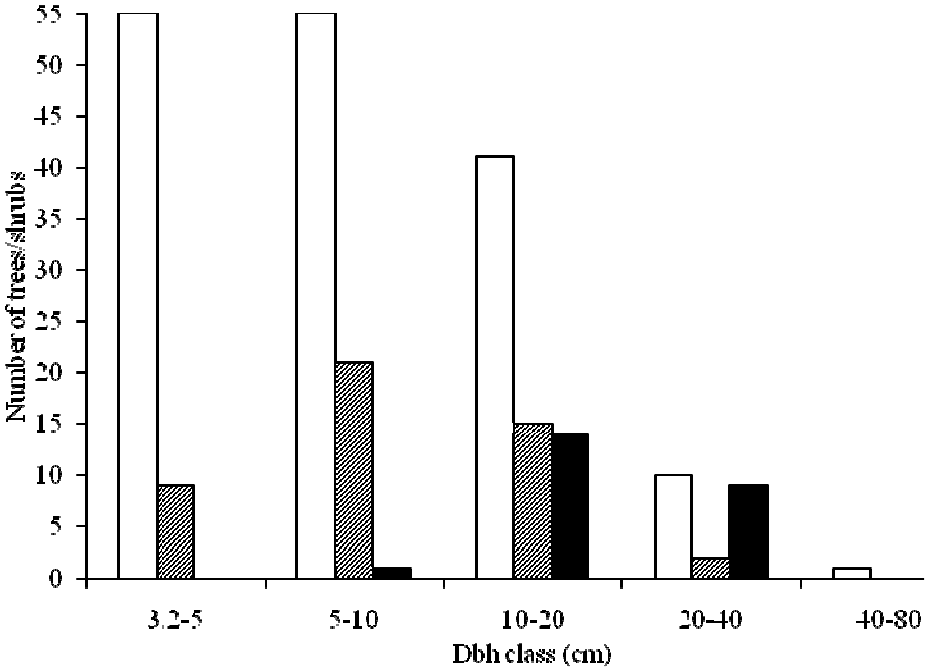

Figure 3. Distribution of individuals in diameter classes of *Ocotea diospyrifolia* (late secondary), *Casearia arborea* (early secondary) and *Tabernaemontana laeta* (pioneer) in a secondary forest in the Fonte Grande State Park, Southeastern Brazil. □ *O. diospyrifolia*; ▨ *C. arborea*; ■ *T. laeta*.

4. Discussion

Successional stage - Considering structure and diversity, characteristics such as basal area of approximately 30 $m^2.ha^{-1}$, Shannon index around to 3.0, development of three storeys (although the upper storey is still in construction), and small number of larger trees are in agreement with those often found in advanced stage secondary forests of Brazilian Atlantic Forest (see Nastri et al., 1992; Aragaki; Mantovani, 1993; Oliveira, 2002; Solórzano; Oliveira; Guedes-Bruni, 2005; Carvalho; Nascimento; Braga, 2007). These secondary forests are in a stage prior to the mature forest stage, that displays diversity indices above 3.0 and similar stratification, but bear more basal area (usually 40 $m^2.ha^{-1}$ or more) and higher number of larger trees (Oliveira, 2002; Carvalho; Nascimento; Braga, 2007; Dan; Braga; Nascimento, 2010).

In fact the low density of trees with larger diameters is common in secondary tropical forests in the building phase, because the time has not been enough for most species reach their maturity (Santos et al., 2008). In the other hand, the accumulation of individuals with smaller diameters is remarkable, forming a dense understory composed of shrubs and treelets of late secondary species. The understorey is favored by appropriate environmental conditions that are generated by the development of the upper storey (Richards, 1996).

In regard to ecological groups, although there were pioneers species typical of secondary forests in initial stage of regeneration in the 'Gruta do Morcego' (e.g. *Xylopia sericea*, *Gochnatia polymorpha*, *Sparattosperma leucanthum*, *Cordia trichotoma*, *Machaerium hirtum*, *Piptadenia gonoacantha*, *Cyphomandra sycocarpa*, *Guazuma crinita* and *Trema micrantha*), the floristic composition indicated the advanced successional stage of the forest, thus a predominance of late secondary species were recorded.

Considering the number of individuals per ecological group, the data also indicated the dominance of late secondary (shade-tolerant) individuals and low pioneer species

density, as has been reported by researchs carried in secondary forests in advanced successional stage (e.g. Lopes et al., 2002; Oliveira, 2002; Solórzano; Oliveira; Guedes-Bruni, 2005; Leite; Rodrigues, 2008).

Floristic richness - The richness of secondary forests is linked to the history of disturbance, but in general is lower than in mature forests (Pessoa; Guedes-Bruni; Kurtz, 1997; Oliveira, 2002; Solórzano; Oliveira; Guedes-Bruni, 2005). In secondary urban forests that difference may be more significant due to the higher frequency of disturbances (Dislich; Pivello, 2002).

Therefore, problably the richness of the study area (71 tree and 20 shrub species) is lower than the expected richness of coastal forests of Espírito Santo. Although the lack of floristic surveys (many unpublished) and different sampling conditions hamper detailed comparative approaches, some studies serve as a reference at least for the richness of the regional tree component. Saiter et al. (2011) recorded 203, 208 and 211 tree species (dbh ≥ 6.4 cm) in three different 0.34 plots in mature forest of the Santa Lúcia Biological Station (located 50 km away). J. M. L. Gomes (unpublished data) carried out a floristic survey in 0.64 ha of mature and secondary forests in Aricanga Natural Municipal Park (located 60 km away) and found 158 tree/shrub species (dbh ≥ 2.5 cm).

The possible loss of species in FGSP forest is the result of more than 400 years of man-made disturbances. Old records of the foundation of Vitória city (a village at that time), mention that the first buildings were made on a steep hill, with many rocks and covered with a dense forest. The forest had many timbers as 'cedro' (certainly *Cedrela odorata*) and 'pau de bálsamo' (possibly a Fabaceae from the genus *Myrocarpus*) and leaves of 'pindoba' (a palm from the genus *Attalea*) and 'taipa' (probably *Ramisia brasiliensis*, a light wood) was used for construction of rudimentary houses (Derenzi, 1965).

The presence of few timber species in the study site (i.e. *Astronium gracile*, *Cedrela odorata*, *Parapiptadenia pterosperma* and *Vataireopsis araroba*, with low density and with major individuals of small size) points an intense exploration of forest resources in the past. In fact timber species of the regional flora as *Dalbergia nigra* (Vell.) Allemao ex Benth., *Melanoxylon brauna* Schott, *Myrocarpus frondosus* Allemão, *Peltogyne angustiflora* Ducke (all Fabaceae), *Ocotea catharinensis* Mez (Lauraceae), and *Cariniana estrellensis* (Raddi) Kuntze and *Lecythis lurida* (Miers) S.A. Mori (both Lecythidaceae) (according to database of the speciesLink Project; http://splink.cria.org.br/) were not found in the high forest of 'Gruta do Morcego'.

The absence of palms (Arecaceae) also indicates human exploration, because they are important Brazilian Atlantic Forest components (Portela; Bruna; Santos, 2010). In the Southeastern Brazil submontane forests *Euterpe edulis* Mart is usually the most representative palm (Oliveira-Filho; Fontes, 2000), but other palm species from the genera *Attalea*, *Astrocarium*, *Geonoma* and *Syagrus* also occupy prominent positions in phytosociological surveys (e.g. Pessoa; Guedes-Bruni; Kurtz, 1997; Cielo Filho; Santin, 2002; Carvalho; Braga; Nascimento, 2009; Saiter et al., 2011). As a reference for the region of the present study, about 16 species of palms were found in Duas Bocas Biological Reserve (Lima; Soares, 2003).

The past disturbances also affect the populations of Myrtaceae and Lauraceae. The small number of species of Myrtaceae and Lauraceae is an uncommon fact for the Brazilian Coastline forests, where a dominance of these families exists (Oliveira-Filho; Fontes, 2000). As an example, within 385 tree species surveyed by Saiter et al. (2011) in a mature forest in the montane range of Espírito Santo state, 79 Myrtaceae and 43 Lauraceae was reported.

Although species of Myrtaceae and Lauraceae commonly are sensitive to environment degradation, portraying a low richness in secondary forests (Pessoa; Guedes-Bruni; Kurtz, 1997), the representativeness in relation to total richness can still be high in intensively disturbed urban forests of Brazilian Coastline. The floristic

survey conducted by Porto et al. (2005) in a small fragment of urban forest in Southern Brazil resulted in 71 tree species, been 8 Myrtaceae and 5 Lauraceae. In urban forests within São Paulo city, Aragaki; Mantovani (1993) identified a total of 94 tree species, and recorded 8 Myrtaceae and 12 Lauraceae, and Nastri et al. (1992) survey 85 tree species, been 9 Myrtaceae and 6 Lauraceae. Furthermore, Solórzano; Oliveira; Guedes-Bruni (2005) identified 9 species of Myrtaceae and 3 of Lauraceae among 92 tree species reported in a secondary forest close to Rio de Janeiro city.

Management strategies - When a matrix of preserved forest is maintained around cleared areas, the original diversity is recovered through propagule rain and animal dispersal (Gotelli, 1991; Santos et al., 2008). However, habitat loss and fragmentation associated with urbanization affect landscape connectivity which creates the potential for disruption of ecological processes (Bierwagen, 2007). Thus, the arrival of pollen and seeds of native species in secondary forest surrounded by an extensive urban matrix becomes difficult and unlikely (Cielo Filho; Santin, 2002).

Whitin this forests, reproductive problems may also occur in plant populations due to lack of animal pollinators or seed dispersers, the phenomenon called defaunation (see Dirzo; Miranda, 1990). Over time, the defaunation may cause the decline these populations and promote the impoverishment of the fragments (Santos et al., 2008).

Surely in the past some species has arrived to Vitória island through the animal dispersal. However, the actual degree of forests isolation is high due to urban expansion (Secretaria Municipal de Meio Ambiente; Secretaria de Estado da Agricultura, 1996) and the dispersion of seeds from preserved forests located in mainland, such as the Mochuara Mountain, the Duas Bocas Biological Reserve and the Mestre Álvaro Mountain, becames difficult. This situation probably prevents an effective rescue of plant species, which were locally extinct because of man-made disturbances in the past.

Futhermore, the FGSP forest surely suffered high pressure of hunting in the past. This can be evidenced by various zoocoric species reported by O. J. Pereira (unpublished data) in some sites of FGSP (e.g. *Spondias monbin* L., *Swartzia apetala* Raddi, *Andira anthelmia* (Vell.) J. F. Macbr., *Ficus clusiifolia* Schott and *Syderoxylon obtusifolium* (Roem. & Schult.) Steyerm. & Kirkbr.), but absent in at study site and in its surroundings.

Although not yet exist detailed studies about the potential for dispersal exercised resident fauna, the results of recent animal studies indicate a low quality of this component in FGSP. Simon; Lima; Cardinali (2007) recorded 146 species of birds in FGSP, but found great adulteration of the original avifauna and low richness of strictly forest species, which are considered the main dispersers of tree seeds (Tabarelli; Peres, 2002). Caldara Junior; Leite (2007) found only seven species of small mammals, but these species are omnivores or seed predators (Vieira; Moraes, 2003; Ribeiro; Conde; Tabarelli, 2010).

Therefore, the enrichment of forests with seedlings of late secondary species represents an excellent strategy for management of vegetation. At this point, the choice of species for enrichment projects should consider the floristic composition of the submontane forests of the region. Moreover, species of Myrtaceae, Lauraceae and Arecaceae should be prioritized because of the pattern of diversity in the Atlantic Forest (Oliveira-Filho; Fontes, 2000).

At the same time, programmes for the restoration of abandoned pastures and plantations areas are important for increasing the forest cover of the FGSP and protection against fires (natural or man-made), which are generally started in these areas during the dry periods throughout of the year.

It is clear that programmes of reintroduction of animal species would also be valuable to restore ecological processes in the forest. However, the issue is

controversial and more detailed studies on the ecological role of wildlife in FGSP must be made to ensure the success of reintroductions.

Although there are reports about negative impacts of exotic species cultivated in dynamics of regeneration in secondary forests (see Lopes et al., 2002; Dislich; Pivello, 2002; Cielo Filho; Santin, 2002; and Abreu; Rodrigues, 2010), it seems that the presence of *Coffea robusta*, *Citrus nobilis* and *Artocarpus heterophyllus* did not have great influence in the plot, because were not reported young individuals of these species as in cases of biological invasion. Then the removal of these exotic species is not a priority.

Giving support to all management strategies, an effective surveillance system and a programme of environmental education with the surrounding residents will be valuable for the conservation of the FGSP, a place with historical and environmental importance to Vitória city.

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