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Gradsects – a new approach on plant biodiversity assessment in vegetation growing on coastal sandy plains from Southeastern Brazil§

Gradsects – uma nova abordagem de avaliação da biodiversidade de plantas em vegetação de planícies arenosas costeiras no sudeste do Brasil

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Abstract *Restingas*, a geomorphological local name for the sandy coastal plains, are a type of coastal tropical and subtropical ecosystem that occur on sandy, acidic, and nutrient-poor soils of eastern Brazil. It is within the Atlantic Forest, one of the hottest hotspots due to its fragmentation and for being constantly pressured by anthropic forces. We have assessed the open shrubby vegetation located in the Paulo Cesar Vinha State Park (20°33'-20°38'S e 40°26'-40°23'W) in order to know whether past sand extraction mining affects biological diversity and species richness locally or in a broader scale. We used Gradsect technique in order to determine if this approach is efficient in assessing biodiversity changes in impacted tropical ecosystems. Gradsect assesses plant functional types (PFT) without quantifying the occurrence of each PFT. Gradsect sampled 994 PFTs in a total area of 4200 m², distributed in 168 sampling unities, to find 151 species in 285 different *modi*. The diversity index of Shannon-Wiener (*H'*) was 4.65, evenness index (*J*) was 0.97, and Whittaker's Index for taxa richness was 21.88. Among 121 plant genera, 93 corresponded to monospecific ones, as well as 34 among the 64 plant families were monospecific, suggesting high diversity levels. The biodiversity in the deep of the hole created by sand mining and in its slope was only significantly lower than the intermediate zone, about 300 m far from the impact point, but both of them did not differ significantly from the blocks from an adjacent area, no more than 50 m far from the impact point; from the boundaries of a marsh, and from a distant zone that was about 500 m far from the impact point.

Keywords: gradient, salt marsh, sandbank, evenness, Pielou Index, Shannon-Wiener Index, Simpson Index, species richness, transect, VegClass, Whittaker Index.

Resumo Restingas, uma denominação geomorfológica local para as planícies arenosas costeiras, são um tipo de ecossistema costeiro tropical e subtropical que ocorrem e solos arenosos, ácidos e pobres em nutrientes do leste do Brasil. São consideradas associadas Mata Atlântica, um dos mais diversos hotspots devido à sua fragmentação e por ser constantemente pressionado por forças antrópicas. Nós avaliamos a vegetação arbustiva aberta localizado no Parque Estadual Paulo César Vinha (PEPCV), que sofreu impacto da extração de areia e suas adjacências, são distintas considerando tipos funcionais de plantas. Utilizamos a técnica Gradsect, a fim de determinar se esta abordagem é eficiente para avaliar as alterações da biodiversidade em ecossistemas tropicais impactados. Gradsect avalia de tipos funcionais de plantas (TFP) sem quantificar a ocorrência de cada PFT. Gradsect amostrou 994 TFP em uma área total de 4.200 m², distribuídos em 168 unidades amostrais, para encontrar as 151 espécies em 285 *modi* diferentes. O índice de diversidade de Shannon-Wiener (*H'*) foi de 4,65, o índice de uniformidade (*J*) foi de 0,97, e o Índice de Whittaker para riqueza de táxons foi de 21,88. Entre 121 gêneros de plantas, 93 correponderam a gêneros monoespecíficos, bem como 34 entre as 64 famílias botânicas eram monoespecíficas, sugerindo altos níveis de diversidade. A biodiversidade no fundo do buraco gerado pela mineração de areia e seu talude foram significativamente menores apenas que a encontrada na zona intermediária, cerca de 300m de distância do ponto de impacto, mas ambos não diferiram significativamente dos blocos adjacentes, a não mais que 50 m do local de impacto; da região contato com o brejo e de uma zona mais distante, há cerca de 500 m do ponto de impacto.

Palavras-chaves: equitabilidade, gradiente, Índice de Pielou, Índice de Simpson, Índice de Whittaker, Índice de Shannon-Wiener, marisma, restinga, riqueza de espécies.

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Introduction

The Atlantic Forest is a biosphere reserve that has been dramatically fragmented, loosing more than 70% of its original cover and was considered one of the hottest Hotspots, most-devastated places in the world. It has remarkable high levels of endemism and is a place where the world is capable of preserving more species per dollar invested (Myers 2000). Between ecosystems associated with the Atlantic Forest, is a salt marsh vegetation that covers the entire range of the tropical Atlantic coast of South America and features 10 distinct vegetation types in mosaics of different vegetation communities. (Suguio and Tessler 1984, Suguio and Martin 1990, Waechter 1990, Fundação SOS Mata Atlântica 1998, Pereira 2003).

As geological formation, the salt marshes comprise sandy ridges and coastal plains, formed by tertiary and quaternary sediments deposited predominantly in marine, continental or transitional environments (Villwock 1994). The plant formations in salt marshes occur on a sandy loam substrate and strongly leached, where temperatures at ground level can exceed 60 ° C during the day. It is believed that low resilience marks these ecosystems. In the case of suppression this vegetation trends to suffer a slow replacement, usually smaller in size and diversity, where some species come to predominate, especially when subjected to impacts incurred in the removal of vegetation (Henriques 1986, Araújo *et al.* 2004, Guedes *et al.* 2006).

Although legally protected, the sandbank formations lose annually considerable part of the area due to the increase of anthropic activities along Brazilian coast, leading to continued destruction and degradation of biological and landscape components (Santos and Medeiros 2003). Part of the removal of vegetation can be explained by the phenomenon of the metropolization, which happened in Brazil after the World War II. This metropolization contributed to the mass migration from the countryside to the cities and to the intensification of the environmental impacts of the coastal zone, degrading coastal ecosystems (Souza 2004, Santos and Medeiros 2003).

Real estate speculation have been sometimes joining and sometimes replacing the search for agricultural soils as a cause for that devastation. The sandbank is one of Brazilian tropical vegetation types that have suffered most with that, since sand is an essential raw material to society, for its large-scale use in construction and industry, which requires a large volume of production. With metropolization process, the sand mining had grown and has expanded the impact on the sandbanks. According to data compiled by the National Department of Mineral Research, in Brazil there are about 2,000 companies engaged in sand mining (DNPM 2002), which produced about 236 million tons in 2001 (Almeida and Sánchez 2005). It represents an environmental impact that should be considered as far beyond that expressed in environmental laws, if one wants to understand the processes of changing in biophysical, economic, social or cultural dimensions, whether or not arising from polluting activities (Sánchez 1998).

The growth of the metropolitan region of Vitória, the capital of Espírito Santo, was no exception as the pressure on coastal ecosystems. The area in Guarapari, which today comprises the APA Setiba is a large region of sandbank of easy extraction of sand with bulldozers. This activity continued, even after the creation of the Setiba State Park, by State Decree No 2993-N of June 5, 1990. It is difficult to precise the date when sand extraction finished. However, it is possible that the benchmark year was 1994, when the Conservation Unit was renamed to Paulo Cesar Vinha State Park – PEPCV. That was a homage to the eponymous biologist and environmentalist who was murdered inside the park, after investigating and catching the shoal sand mining (CEPEMAR 2007).

The PEPCV protects an area considered as of high ecological significance by the Brazilian Federal Government. The park has nine of the ten plant communities described for the sandbanks (MMA 2008) in only 1.574,85 ha. This study aimed to use the methodology of sampling with transects oriented through ecological gradients – Gradsect (Gillison and Brewer 1985), taking Plant Functional Types – PFTs – as biodiversity units to biodiversity assessment.

Methods

The studied area

The Paulo Cesar Vinha State Park – PEPCV is a Conservation Unity managed by the State Institute for Environment Affairs and Water Resources – IEMA. The park is in Setiba in Guarapari, ES (20 ° 33'-20 ° 38'S and 40 ° 26'-40 ° 23'W), and assumes an important role in conservation because it has a land area of 1574.85 ha (Figure 1).

The starting point of the chosen gradient was a near 3.25 m deep hole (Figure 2) that was probably opened by a backhoe, in which the sand extraction exposed a clayish substrate. The open shrubland vegetation

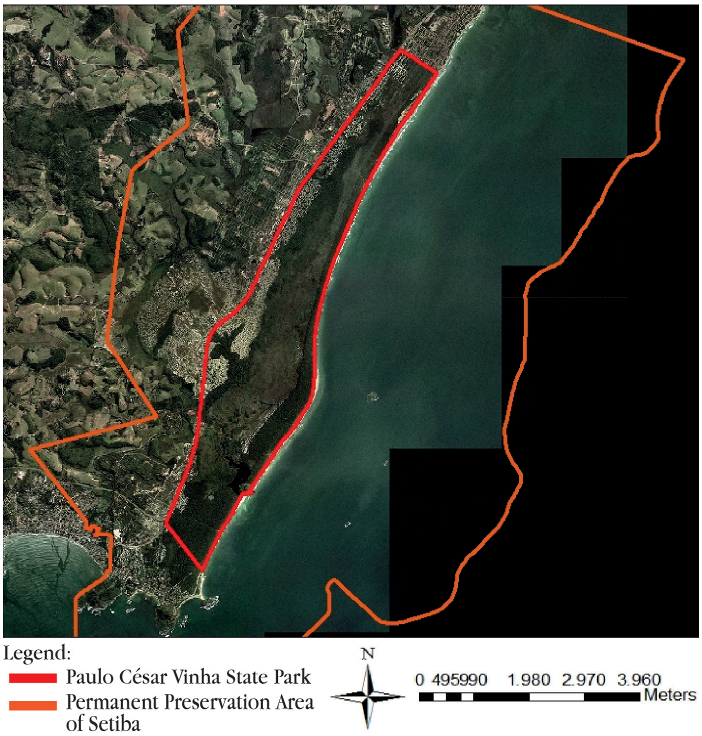

Figure 1 Limits of Paulo César Vinha State Park - PEPCV, and of the Permanent Protection Area of Setiba - APA-Setiba, in Gurapari, ES, Brazil. Source: Integrated Geospatial Bases of the State of Espírito Santo (Geobases), and the Orthophoto Mosaic images sponsored by IEMA. Datum WGS 84

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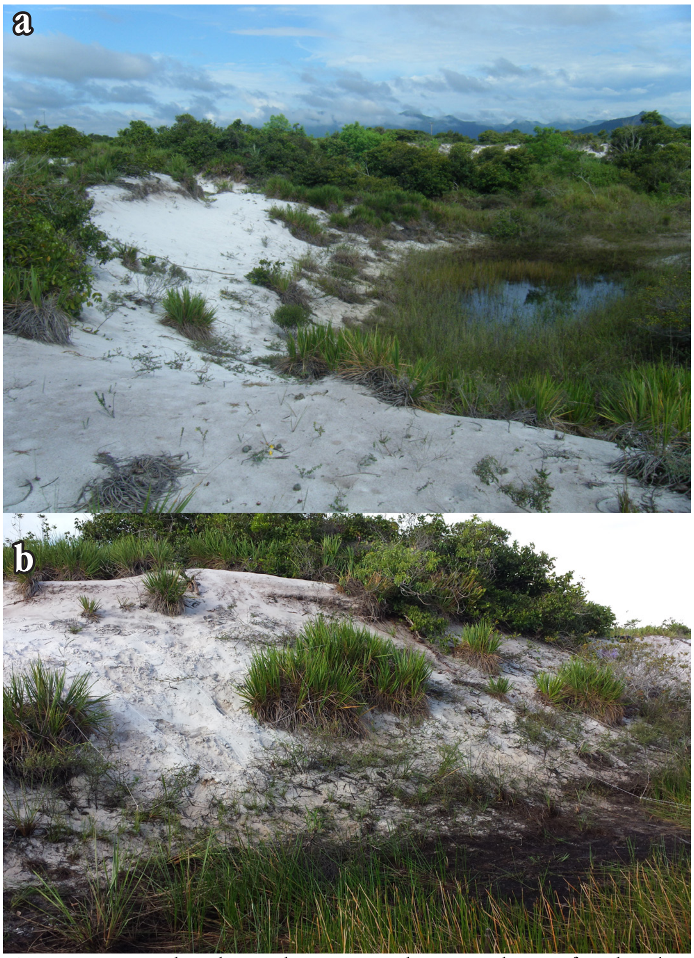

Figure 2 Impacted are by sand mining inside current limits of Paulo César Vinha State Park - PEPCV. **a**: view from the top, at the sandy plain; **b**:view from the bottom, at 3.25 m depth from the top, evidencing the sandy slope.

area in the neighborhood of the gradient starting point was chosen a passage amidst the nearest to the area for this study, to evaluate the effect of such perturbation on the biodiversity of the studied area. Transects were georeferenced by the UTM coordinate system WGS 84 datum. All maps were made using ArcGIS, release 10 (ESRI 2011).

In the characterization of the studied area, it was used maps of the Brazilian Institute of Geography and Statistics (IBGE), satellite images, shapes of the Integrated Geospatial Bases of the State of Espírito Santo (Geobases), and the Orthophoto Mosaic images sponsored by IEMA. A description of the vegetation physiognomies was made following the nomenclature proposed by Pereira (2003), based on the life habits of plant species components, using photographs in the natural scale of the studied plant formations.

Biodiversity Assessment

The biodiversity assessment was carried out through gradient oriented transects – Gradsects (Gillison 1984, Gillison and Brewer 1985), beginning at the bottom of the impacted hole towards the sandy coastal plain. Each transect had 40m x 5m, and was composed of eight squares of 5m x 5m, totalizing. 21 transects were installed, totaling 168 sampling units in 4200m².

The transects were arranged in six blocks with at least three transects each: three at the deepest point of the impacted area; three transects below the level of the sandy plain, at 3,25 m deep in the impacted hole; three on the sandy slope with a declivity of approximately 45 degrees; four in the area adjacent to the impact; seven in the intermediate zone, 300 m from mining impact; three in the boundaries of marsh area, and the sandy plain; four in the 500 m far from the impacted area (Figure 3).

The assessment of biodiversity was made by recording the plant functional types - PFT (Gillison and Carpenter 1997,Gillison 2002) that are constructed by a combination of the species with a set of 35 functional vegetative attributes taken as adaptations that vascular plants can display. It allows that the same species can be registered as many times as necessary for its adaptive behavior be fully inventoried. However, repeated functional types found are not reported in the same transect (Gillison and Carpenter 1997, Gillison 2013). Every non-seedling individual that was rooted in a trasnsect was registered concerning its PFT in the bushes and in opened areas among the bushes, comprised by the this open shrubland vegetation physiognomy.

For plant species records that were not identified in field collections, samples of preferably fertile branches were taken and sent to the University of Vila Velha (UVV) where they were herborized. Exsicates specimens of the species were then determined by comparison method in Central Herbarium of the Federal University of Espírito Santo - UFES (VIES), where the testimony deposited material. Duplicates of the material are also deposited in the Herbarium UVV ES, located in University of Vila Velha (UVV). The Angiosperms Phylogenetic Group - APG III (Bremer *et al*. 2009) was adopted as the classification system. The scientific binomials and their authors and plant families were available in two nomenclatural databases: Tropicos®, headquartered in Missouri Botanical Garden, available in http://www.tropicos.org; and The International Plant Names Index, available in http://www.ipni.org/index.html.

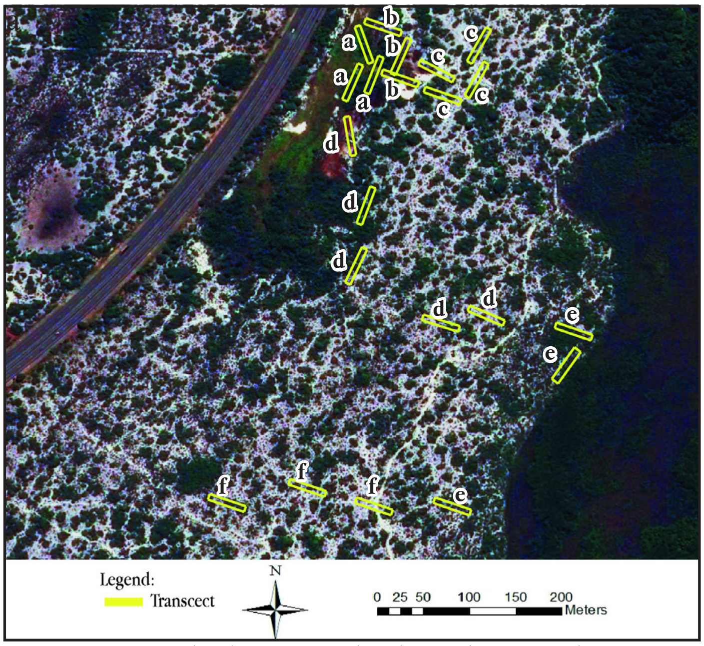

Figure 3 Transects distribution in Paulo César Vinha State Park - PEPCV, in Gurapari, ES, Brazil. **a**: wet bottom of the impacted hole; **b**: sandy slope; **c**: sandy pain area adjacent to the impact; **d**: sandy plain intermediate zone; **e**: boundaries of marsh area and sandy plain; **f**: sandy plain 500m far from impacted area. Source: Integrated Geospatial Bases of the State of Espírito Santo (Geobases), and the Orthophoto Mosaic images sponsored by IEMA. Datum WGS 84.

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Data analysis

The biological richness was estimated by Whittaker Index of taxa richness (Whitakker 1975). Biological diversity was estimated by Simpson's and Shannon-Wiener's Indices, and evenness index was estimated by the Pielou-*J* Index (Ludwig and Reynalds 1988). For all estimated indices, the number of individuals was replaced by the number of PFTs records since plant individuals are not registered in this way of sampling by Gradsect. Registering and management of PFTs, as well as the calculations of the diversity indices cited were run in VegClass, release 2.0 (Gillison and Carpenter 2006).

Significant differences in species richness and diversity indices were detected through Analysis of Variance - ANVOVA, and were discriminated through *post hoc* Tuckey's test (Zar 2010). Statistical analysis and graphs were run in Systat, release 11.0 (Wikinson 2004).

Sampling sufficiency was assessed through two different ways: the collector's curve, plotting the cumulative number of species as a function of the cumulative number of sampling unities (Pielou 1975), and the sampling saturation curve which plots the cumulative Whittaker Index as a function of the cumulative number of sampling unities (Loss and Silva 2005, Christo *et al.* 2009).

The ecological importance (Müller-Dombois and Ellenberg 1974) of plant species was assessed as the number of their records, since they weighed all the different *modi* for a single species, and therefore include not only the occurrence of a species in different sampling units, but all the different PFTs the species may assume. For the plant families, ecological importance was assessed as an arithmetic mean of their number of species, genera and *modi*, that was named as Index of Ecological Importance of Plant Functional Types - IPFT.

Results

A total of 151 plant species, distributed in 121 genera and 64 families identified (Table 1). Among them, 121 genera occurred with

Table 1 Plant species according their site of occurence, ranging from the bottom of the hole originated from sand mining, up to the sandy costal plain, in microenvironments at the open shrubby vegetation at Paulo César Vinha State Park, Gurapari, ES, Brazil.

Family	Species	Wet bottom	Slope	Bushes	Among bushes	Diameter <1.5cm
Anacardiaceae	*Schinus terebinthifolia* Raddi			X		
Apocynaceae	*Ditassa arianeae* Fontella & E.A. Schwarz		X	X	X	X
	Mandevilla funiformis (Vell.) K. Schum.				X	X
	Mandevilla moricandiana (A. DC.) Woodson[1]				X	X
	Oxypetalum banksii R. Br. ex Schult			X	X	X
Aquifoliaceae	*Ilex integerrima* Reissek				X	
Araceae	*Anthurium cleistanthum* G. M. Barroso				X	
	Anthurium parasiticum (Vell.) Stellfeld				X	
Arecaceae	*Allagoptera arenaria* (Gomes) Kuntze			X	X	X
Aspleniaceae	*Asplenium laciniatum* D. Don[1]				X	X
Asteraceae	*Achyrocline satureioides* (Lam.) DC.*			X	X	X
	Baccharis bahiensis Baker				X	
	Baccharis genistelloides (Lam.) Pers.[1]	X	X	X	X	
	Baccharis trinervis Pers.			X	X	
	Bahianthus viscosus (Spreng.) R. M. King & H. Rob.					
	Vernonia fruticulosa Mart. ex DC.	X	X	X	X	
	Vernonia scorpioides (Lam.) Pers.			X	X	
Blechnaceae	*Blechnum serrulatum* Rich[1]		X	X		
Bonnetiaceae	*Bonnetia stricta* (Nees) Nees ex Mart.			X		
Boraginaceae	*Varronia verbenacea* (DC.) Borhidi		X	X		
Brassicaceae	*Lepidium virginicum* L.*	X	X			
Bromeliaceae	*Aechmea lingulata* (L.) Baker			X		
	Aechmea nudicaulis (L.) Griseb.			X		
	Neoregelia pascoaliana L. B. Sm.			X		
	Tillandsia gardneri Lindl.			X		X
	Tillandsia stricta Sol. ex Sims[1]			X		X
	Tillandsia usneoides (L.) L.[1]			X		X
	Vriesea neoglutinosa Mez			X	X	
	Vriesea procera (Mart. ex Schult.f.) Wittm.			X	X	
Burseraceae	*Protium heptaphyllum* (Aubl.) Marchand[1]			X		
	Protium icicariba (DC.) Marchand			X	X	
Cactaceae	*Cereus fernambucensis* Lem.		X	X	X	
	Hylocereus setaceus (Salm-Dyck) Ralf Bauer			X		
	Melocactus violaceus Pfeiff.				X	
	Pilosocereus arrabidae (Lem.) Byles & G.D. Rowley			X	X	
Calophyllaceae	*Kielmeyera albopunctata* Saddi			X	X	
Celastraceae	*Maytenus obtusifolia* Mart.			X		
	Maytenus schumanniana Loes.			X		
Chrysobalanaceae	*Chrysobalanus ovalifolius* Schott[1]			X	X	
Cleomaceae	*Dactylaena microphylla* Eichler				X	
Clusiaceae	*Clusia hilariana* Schltdt.			X		
	Garcinia brasiliensis Mart.			X	X	
Combretaceae	*Buchenavia capitata* (Vahl) Eichler			X		
Convolvulaceae	*Evolvulus genistoides* Ooststr.		X	X	X	
	Evolvulus maximiliani Mart. ex. Choisy		X	X	X	

1. Occurrence in a single transect; * Exotic and invasive species

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Family	Species	Wet bottom	Slope	Bushes	Among bushes	Diameter <1.5cm
Cyperaceae	*Cyperus ligularis* L.	X	X	X		X
	Eleocharis geniculata (L.) Roem. & Schult.	X	X	X		X
	Fimbristylis bahiensis Steud.	X	X			X
	Fuirena umbellata Rottb.	X	X	X		X
	Lagenocarpus rigidus (Kunth) Nees			X	X	X
	Rhynchospora tenuis Link.	X	X	X		X
	Scleria hirtella Sw.	X		X		X
Dennstaedtiaceae	*Pteridium aquilinum* (L.) Kuhn[1]*			X	X	X
Ericaceae	*Agarista revoluta* (Spreng.) Hook f. ex Nied			X	X	
	Gaylussacia brasiliensis (Spreng.) Meisn.			X	X	
Eriocaulaceae	*Paepalanthus ramosus* (Wikstr.) Kunth				X	
	Paepalanthus tortilis (Bong.) Koern. [1]	X		X		
	Syngonanthus imbricatus Ruhland		X	X	X	
	Syngonanthus gracilis (Bong.) Ruhland	X				X
Erythroxylaceae	*Erythroxylum lucidum* Kunth			X	X	
	Erythroxylum subsessile (Mart.) O.E. Schulz			X		
Euphorbiaceae	*Chaetocarpus myrsinites* Baill.			X	X	
	Jatropha urens L[1]*		X	X		
	Sapium glandulatum (Vell.) Pax				X	
	Sebastiania glandulosa (Sw.) Müll. Arg.	X	X	X	X	
Fabaceae	*Acacia mangium* Willd*	X		X	X	
	Acosmium bijugum (Vogel) Yakovlev[1]			X	X	
	Andira legalis (Vell.) Toledo				X	
	Andira nitida Mart. ex Benth.			X	X	
	Centrosema virginianum (L.) Benth.		X		X	X
	Chamaecrista cytisoides (DC. ex Collad.) H.S. Irwin & Barneby			X	X	
	Chamaecrista flexuosa (L.) Greene*	X	X		X	
	Chamaecrista ramosa (Vogel) H. S. Irwin & Barneby	X	X		X	
	Stylosanthes guianensis (Aubl.) Sw.*		X		X	X
	Stylosanthes viscosa (L.) Sw.*		X		X	X
Gentianaceae	*Schultesia crenuliflora* Mart.	X				X
	Schultesia stenophylla Mart. [1]	X				X
Haloragaceae	*Laurembergia tetrandra* (Schott) Kanitz	X				X
Humiriaceae	*Humiria balsamifera* Aublet. [1]			X		
Icacinaceae	*Emmotum nitens* (Benth.) Miers			X		
Lamiaceae	*Hyptis brevipes* Poit.	X	X			X
Lauraceae	*Cassytha filiformis* L.			X		X
	Ocotea notata (Nees & Mart.) Mez		X	X	X	
Loranthaceae	*Struthantus polyrrhizos* (Mart. ex Roem. & Schult.) Martius ex G. Don			X		X
Lythraceae	*Cuphea flava* Spreng.		X	X	X	
Malpighiaceae	*Byrsonima sericea* DC.	X	X	X	X	
	Peixotoa hispidula A. Juss.			X		
	Stigmaphyllon paralias A. Juss.		X	X	X	
Malvaceae	*Pseudobombax grandiflorum* (Cav.) A. Robyns			X		
	Waltheria aspera K. Schum.			X		
Melastomataceae	*Comolia ovalifolia* Triana[1]				X	
	Marcetia taxifolia (A. St.-Hil.) DC.				X	
	Pterolepis glomerata (Rottb.) Miq.	X	X			
	Tibouchina trichopoda (DC.) Baill.				X	
	Tibouchina urceolaris Cogn.	X	X	X		
Molluginaceae	*Mollugo verticilata* L.		X		X	X
Myrtaceae	*Eugenia rotundifolia* Casar.			X		
	Marlierea neuwiedeana (O. Berg) Nied.			X		
	Myrciaria floribunda (H. West ex Willd.) O. Berg			X	X	
	Neomitranthes obscura (DC.) N. Silveira			X		
	Neomitranthes obtusa Sobral & Zambom			X	X	
Nyctaginaceae	*Guapira opposita* (Vell.) Reitz			X	X	
	Guapira pernambucensis (Casar.) Lundell			X	X	
Ochnaceae	*Ouratea cuspidata* Tiegh.			X	X	
	Sauvagesia erecta L.	X	X			X
Onagraceae	*Ludwigia longifolia* (DC.) H. Hara[1]	X	X			X
Orchidaceae	*Catasetum discolor* (Lindl.) Lindl.			X	X	
	Cattleya guttata Lindl[1]			X		
	Cyrtopodium holstii L.C. Menezes			X	X	
	Epidendrum denticulatum Barb. Rodr.			X	X	
	Habenaria leptoceras Hook. [1]			X		
	Vanilla bahiana Hoehne			X		
	Vanilla chamissonis Klotzsch			X		
Orobanchaceae	*Esterhazya splendida* J. C. Mikan			X	X	
Passifloraceae	*Passiflora galbana* Mast.			X	X	X
	Passiflora mucronata Lam.			X	X	X
	Passiflora pentagona Mast.			X	X	
	Turnera angustifolia Mill.[1]*	X	X	X		X

1. Occurrence in a single transect; * Exotic and invasive species

Table 1 - cont Plant species according their site of occurence, ranging from the bottom of the hole originated from sand mining, up to the sandy costal plain, in microenvironments at the open shrubby vegetation at Paulo César Vinha State Park, Gurapari, ES, Brazil.

Family	Species	Wet bottom	Slope	Bushes	Among bushes	Diameter <1.5cm
Pentaphylacaceae	*Ternstroemia brasiliensis* Cambess.			X	X	
Phyllanthaceae	*Phyllanthus klotzschianus* Müll. Arg.		X		X	
Phytolaccaceae	*Microtea paniculata* Poq.		X		X	
Poaceae	*Andropogon leucostachyus* Kunth[1]*	X			X	X
	Axonopus aureus P. Beauv.	X	X		X	X
	Brachiaria decumbens Stapf.[1]*		X		X	X
	Dactyloctenium aegyptium (L.) Willd.		X		X	X
	Panicum trinii Kunth	X	X		X	X
Polygalaceae	*Polygala tenella* Wild[1]	X				X
Polygonaceae	*Coccoloba alnifolia* Casar.			X		
	Coccoloba arborescens R. A. Howard			X	X	
Polypodiaceae	*Microgramma persicariifolia* (Schrad.) C. Presl.			X		X
	Microgramma vacciniifolia (Langsd. & Fisch.) Copel.			X		X
Primulaceae	*Myrsine guianensis* (Aubl.) Kuntze[1]			X		
Pteridaceae	*Pityrogramma calomelanos* (L.) Link			X		X
Rubiaceae	*Melanopsidium nigrum* Colla			X	X	
	Mitracarpus frigidus (Willd. ex Roem. & Schult.) K. Schum.			X	X	
	Salzmannia nitida DC[1]				X	
	Spermacoce capitata Ruiz & Pav.		X	X		
	Spermacoce verticillata L.	X	X		X	
	Tocoyena bullata (Vell.) Mart.			X	X	
Sapindaceae	*Cupania emarginata* Cambess[1]			X		
	Dodonaea viscosa Jacq.*	X	X		X	
	Paullinia weinmanniaefolia Mart.		X	X	X	
	Serjania salzmanniana Schltr.		X		X	
Sapotaceae	*Manilkara subsericea* (Mart.) Dubard			X	X	
Schoepfiaceae	*Schoepfia brasiliensis* A. DC.			X	X	
Smilacaceae	*Smilax rufescens* Griseb.	X	X	X		X
Verbenaceae	*Lantana camara* L.[1]*		X	X	X	
	Lantana pohliana Schauer			X		
	Stachytarpheta cayennensis (Rich.) Vahl		X	X	X	
Violaceae	*Hybanthus calceolaria* (L.) Oken	X	X			X
Xyridaceae	*Xyris jupicai* Rich.	X				X

1. Occurrence in a single transect; * Exotic and invasive species

only one species and 34 families were also monospecific (Table 2).

Considering the nature of the records and the sampling effort to assess biodiversity, the gradsect sampled 994 PFTs to find the 151 species in 285 different *modi*. The diversity index of Shannon-Wiener (H') was 4.65, evenness index (J) was 0.96, and Whittaker Index for taxa richness was 21.88 (Table 3).

Both the collector's and the sampling saturation curves point to the sampling sufficiency. The collector's curve was asymptotically stabilized after sampling 145 unities, while sampling saturation occurred from the 129 quadrat on, with 40 points of fall in the cumulative Whittaker Index curve (Figure 4). Considering all the sampled species, 36 usually have diameters at the ground level that are smaller than 1.5 cm (Table 1) which is a current criterion to

Table 2 Ecological importance of Plant Functional Types - IPFT - of plant families from the open shrubby vegetation at Paulo César Vinha State Park, Gurapari, ES, Brazil.

Families	Species	Genera	Modus	IPFT
Fabaceae	10	6	18	11.33
Bromeliaceae	8	4	19	10.33
Cyperaceae	7	7	14	9.33
Asteraceae	7	4	16	9.00
Myrtaceae	5	4	17	8.67
Rubiaceae	6	5	12	7.67
Orchidaceae	7	5	7	6.33
Malpighiaceae	3	3	11	5.67
Poaceae	5	5	7	5.67
Euphorbiaceae	4	4	8	5.33
Melastomataceae	5	4	7	5.33
Apocynaceae	4	3	8	5.00
Cactaceae	4	4	7	5.00
Sapindaceae	4	4	6	4.67
Eriocaulaceae	4	2	5	3.67
Araceae	2	1	7	3.33

Table 2 - cont Ecological importance of Plant Functional Types - IPFT - of plant families from the open shrubby vegetation at Paulo César Vinha State Park, Gurapari, ES, Brazil.

Families	Species	Genera	Modus	IPFT
Clusiaceae	2	2	6	3.33
Lauraceae	2	2	6	3.33
Passifloraceae	4	2	4	3.33
Verbenaceae	3	2	5	3.33
Convolvulaceae	2	2	5	3.00
Ochnaceae	2	2	5	3.00
Polygonaceae	2	1	6	3.00
Calophyllaceae	1	1	5	2.33
Celastraceae	2	1	4	2.33
Ericaceae	2	2	3	2.33
Nyctaginaceae	2	1	4	2.33
Arecaceae	1	1	4	2.00
Burseraceae	2	1	3	2.00
Erythroxylaceae	2	1	3	2.00
Gentianaceae	2	1	3	2.00
Malvaceae	2	2	2	2.00

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Table 2 - cont Ecological importance of Plant Functional Types - IPFT - of plant families from the open shrubby vegetation at Paulo César Vinha State Park, Gurapari, ES, Brazil.

Families	Species	Genera	Modus	IPFT
Polypodiaceae	2	1	3	2.00
Smilacaceae	1	1	4	2.00
Lamiaceae	1	1	3	1.67
Lythraceae	1	1	3	1.67
Primulaceae	1	1	3	1.67
Sapotaceae	1	1	3	1.67
Aquifoliaceae	1	1	2	1.33
Boraginaceae	1	1	2	1.33
Combretaceae	1	1	2	1.33
Haloragaceae	1	1	2	1.33
Molluginaceae	1	1	2	1.33
Xyridaceae	1	1	2	1.33
Anacardiaceae	1	1	1	1.00
Aspleniaceae	1	1	1	1.00
Blechnaceae	1	1	1	1.00
Bonnetiaceae	1	1	1	1.00
Brassicaceae	1	1	1	1.00
Chrysobalanaceae	1	1	1	1.00
Cleomaceae	1	1	1	1.00
Dennstaedtiaceae	1	1	1	1.00
Humiriaceae	1	1	1	1.00
Icacinaceae	1	1	1	1.00
Loranthaceae	1	1	1	1.00
Onagraceae	1	1	1	1.00
Orobanchaceae	1	1	1	1.00
Pentaphylacaceae	1	1	1	1.00
Phyllanthaceae	1	1	1	1.00
Phytolaccaceae	1	1	1	1.00
Polygalaceae	1	1	1	1.00
Pteridaceae	1	1	1	1.00
Schoepfiaceae	1	1	1	1.00
Violaceae	1	1	1	1.00

Table 3 Global and mean biological diversity parameters from the open shrubby vegetation at Paulo César Vinha State Park, Gurapari, ES, Brazil.

Parameters	Gloval values / area	Mean values / transect ± Confidence Interval
Records (N)	994	46.95± 7.65
Species (N)	151	43.33 ± 6.68
Whittaker's Index of Species Reachness	21.88	11.19 ± 1.29
Shannon-Wiener's Diversity Index - *H'*	4.65	3.48 ± 0.15
Simpson's Diversity Index	0.97	0.96 ± 0.01
Pielou's Evenness Index - J	0.96	0.94 ± 0.10

exclude their entry in a structural description of plant community.

Among the identified species, the higher number of registers belonged to *Allagoptera arenaria*, *Cuphea flava*, *Guapira opposita, Ocotea notata, Chamaecrista ramosa, Smilax rufescens, Clusia hilariana, Evolvulus maximiliani, Myrciaria floribunda, Panicum trini, Protium icicariba*, and *Stigmaphylon paralias* (Figure 5). When the number of different *modi* for a single species is considered, the species which showed higher values were *Byrsonima sericea*, *Kielmeyera albopunctata*, *Myrciaria floribunda*, *Neomitranthes obscura*, *Ocotea notata*, *Vriesea neoglutinosa*, *Allagoptera arenaria*, *Anthurium parasiticum*, *Bahianthus viscosus*, *Clusia hilariana*, *Coccoloba arborescens*, *Neomitranthes obtusa*, *Ouratea cuspidata*, *Smilax rufescens*, *Stygmaphyllon paralias*, and *Vriesea procera* (Figure 6).

However, some of those species, in a way or another are ecologically important as expressions of biological diversity, such as *A. parasiticum*, *C. flava*, *C. ramosa*, *E. maximiliani*, *P. trini*, *S.*

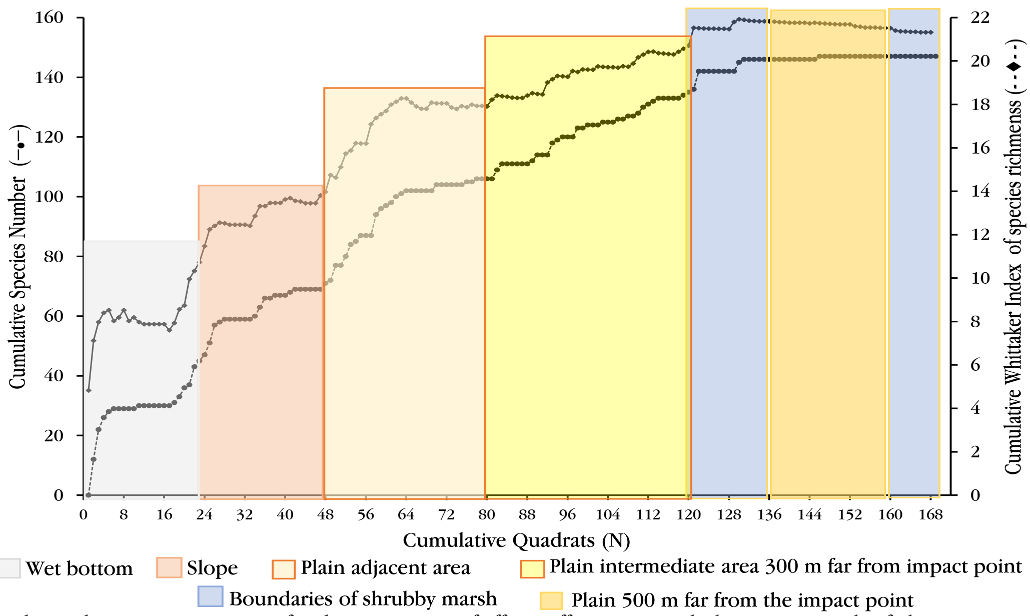

Figure 4 Collector's and sampling saturation curves for the assessment of effort sufficiency in including new records of Plant Functional Types at the distance gradient starting at the bottom of the hole created by sand mining at Paulo César Vinha State Park, Guarapari, ES, Brasil.

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rufescens, *V. neogutinosa*, and *V. procera* may never appear in a plant community inventory, due to their usually low diameter at the ground level (Table 1) or because they are herbs.

Families with higher values of IPFT were Fabaceae, Bromeliaceae, Cyperaceae, Asteraceae, Myrtaceae, Rubiaceae, Orchidaceae, Poaceae, Malpighiaceae, Melastomataceae, and Euphorbiaceae (Table 2). As the same way that happened at the species level, some of these families of high ecological importance as sources of diversity, such as Bromeliaceae, Cyperaceae, Orchidaceae, Poaceae may never appear in current plant community inventory, because they are herbs.

The distribution of species and PFTs along the distance gradient that were sampled (Table 4) showed high evenness levels, with *J*-values ranging from 0.85-1.00. The number of species in each transect varied from 15-64, and the lowest value (14) occurred in one of the transects placed at the wet bottom in the deep of the hole of the mining impact (Table 3). This transect also comprised the species which are more restricted to flooded areas in the sandy plains and did not happen in other vegetation physiognomies (Figure 2, Table 1).

The diversity assessment through the Simpson's diversity index could not discriminate expressive variations, ranging from 0.92-0.98. In the other hand, the Shannon-Wiener's Diversity Index ranged from 2.85-3.96 and reflected better the Whittaker's Species Richness Index that varied from 5.88-15.01 (Table 3).

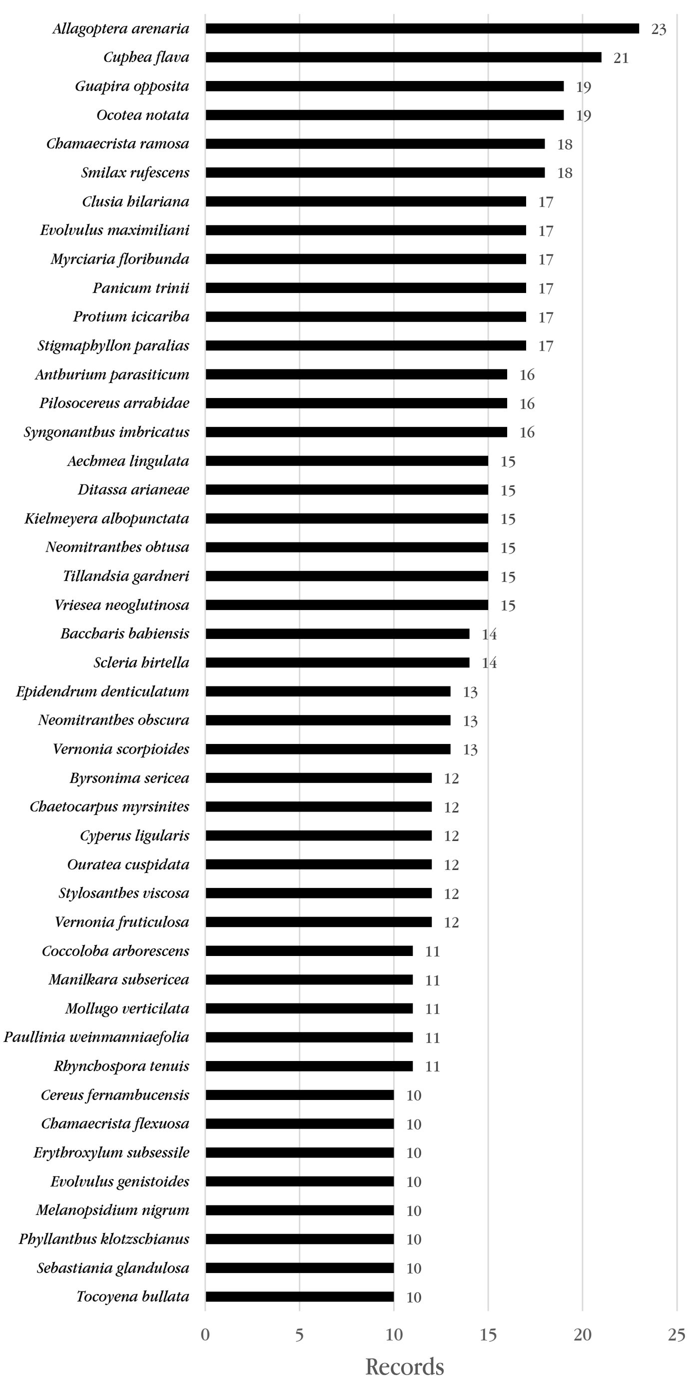

Figure 5 Ecological importance of plant species, considering their occurence as well as the different Plant Funcitonal Type - PFT - which they expressed in the studied area.

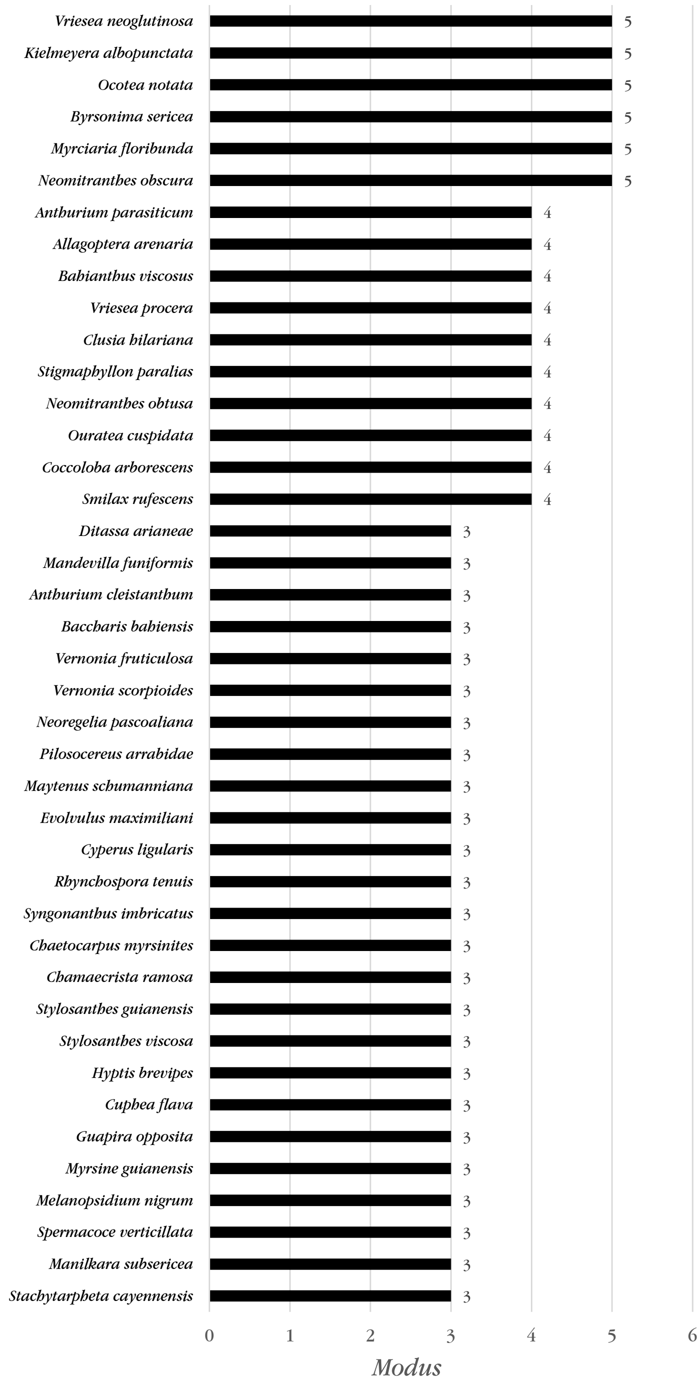

Figure 6 Number of different *modus* of combination of plant morphological atributes as a diversity indicator fot description of Plant Functional Types - PFT.

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Table 4 Species diversity and recahness parameters along the the distance gradient that begins in a hole originated after The impact of sand mining in the open shrubby vegetation at Paulo César Vinha State Park, Gurapari, ES, Brazil.

Transect	Block	Distance from impact	Species (N)	PFTs (N)	Records	*H'* Diversity	Simpson's Diversity	J	Whittaker Richness
A1	Wet bottom	0	32	28	33	3.27	0.96	0.94	9.15
A2	Wet bottom	0	17	18	18	2.89	0.94	1.02	5.88
A3	Wet bottom	0	40	38	42	3.59	0.97	0.97	10.70
B1	Sandy Slope	0	29	21	29	2.85	0.92	0.85	8.61
B2	Sandy Slope	5	32	27	33	3.20	0.95	0.92	9.15
B3	Sandy Slope	10	26	22	26	3.02	0.95	0.93	7.98
C1	Adjacent	15	36	36	42	3.51	0.97	0.98	9.63
C2	Adjacent	25	45	39	50	3.58	0.97	0.94	11.50
C3	Adjacent	35	49	42	55	3.60	0.97	0.93	12.23
C4	Adjacent	45	49	40	52	3.57	0.97	0.92	12.40
D1	Intermediate	100	61	46	66	3.69	0.97	0.90	14.56
D2	Intermediate	150	63	48	67	3.74	0.97	0.90	14.98
D3	Intermediate	200	57	47	61	3.74	0.97	0.93	13.87
D4	Intermediate	250	63	59	75	3.96	0.98	0.96	14.59
D5	Intermediate	300	64	55	71	3.90	0.98	0.94	15.01
E1	Shrubby Marsh Boundaries	350	33	27	34	3.20	0.95	0.92	9.36
E2	Shrubby Marsh Boundaries	400	50	42	56	3.65	0.97	0.93	12.42
F1	Distantant	450	22	23	25	3.11	0.95	1.01	6.83
F2	Distantant	500	47	46	51	3.79	0.98	0.98	11.95
F3	Distantant	500	47	40	50	3.60	0.97	0.94	12.01
E3	Shrubby Marsh Boundaries	500	55	45	58	3.69	0.97	0.92	13.55

PFT: Plant Functional Type; ***H'*** - Diversity Index of Shannon-Wiener; ***J***: Evenness Index of Pielou

Considering the six sampling blocks (Figure 3, Table 3), transects in the wet bottom of the hole and in the sandy slope at the impact point showed lower values than those in the sandy plain at the intermediate zone, 300 m far from the impact point for: the number of species ($F=8.31$; $p<0.01$, Figure 5a); for PFTs ($F=6.88$; $p<0.01$; Figure 5b), and for the Shannon-Wiener's Diversity Index ($F=5.40$; $p<0.01$; Figure 5c). The same happened to Whittaker's Richness Index ($F=6.91$; $p<0.01$; Figure 5d), however, the intermediate zone also showed significant higher values than the most distant zone, about 500 m far from the impact point (Figure 5d). Concerning to all parameters, there were no more significant differences among the other blocks (Figure 5a-d).

Discussion

In the study area, the proportion of monospecific families and genera in the floristic list was high (Table 1 and Table 2) and areas that behave like that suggest a characteristic pattern of high local richness level (Ratter *et al.* 2003). In this context, the global values for the total sampling area and mean values by sampling unities point to a better performance of gradsect in assessment of biodiversity in plant communities (Table 3).

Unless by the intermediate sampling blocks that were near 300 m far from the impact point, there was no significant difference on diversity or richness indices (Figure 5). Although the end of mining in

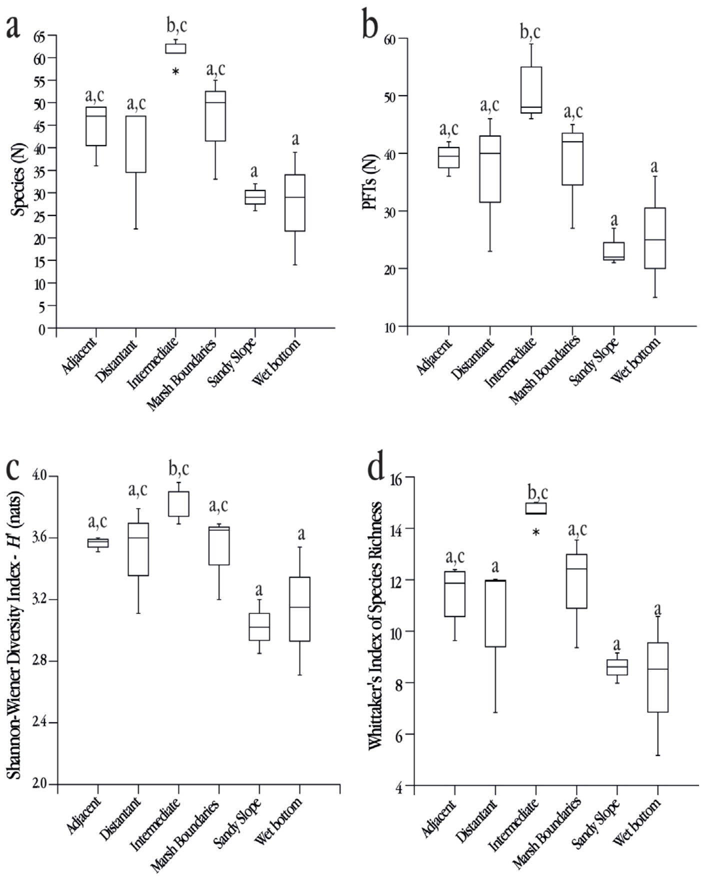

Figure 5 Biodiversity indicators in the blocks of transects at the distance gradient starting at the bottom of the hole created by sand mining at Paulo César Vinha State Park, Guarapari, ES, Brasil. **a**: number of species; **b**: number of Plant Functional Types - PFT; **c**: Shannon-Wiener's Diversity Index; **d**: Whittaker's Index of Species Richness.

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PEPCV occurred in 1996, remnant effects of that impact may be still present nowadays. One of that effects may be that immediately after sand removal, some environmental conditions changed, particularly the ability to percolation of the soil, with the exposure of the clayish substrate. Plants of open shrubland vegetation are adapted to sandy soil, but in the wet bottom of the hole in impacted area there were a colonization of a set of species tolerant to flooding (Table 1), usually list in herbal marshes or swampy areas (Valadares *et al.* 2011). Another remarkable fact was that the highest diversity and richness was found in the intermediate area, about 300 m far from the impact point, what may be supported by the intermediate disturbance theory (Connell 1978), being acceptable that this area is under the influence not only of the impact point, but the intermediate zone may be under the influence of a third area which is far from the disturbance.

Studying the same phytophysiognomy and in the same distance gradient from the point of impact sampling in and slightly smaller area than the one that was studied by Ferreira and Silva (2014) through the plots sampling method, gradsect had led to higher species richness, diversity, and evenness indices; to a number of species almost three times higher, in spite of using about a half of the total records used in plot-sampling method. The biodiversity parameters obtained in this survey were also higher than those found by Thomazi and Silva (2014) who sampled more than four times the number of records, expressed in plant individual, for a sampling area of 5,000 m² with the same phytophysiognomy.

At first sight it could be a consequence of differences in criterion of inclusion of a plant record in the sampling unit, since while in gradsect every mature and non-repeated PFT was included, in plot method used by Thomazi and Silva (2014) and Ferreira and Silva (2014) only those plant individuals with at least 1.5 cm at the ground level entered the sample. However, even if the 36 plant species that should never reach the diameter of 1.5 cm at the ground level (Table 1) were taken out, 109 species would remain in the gradsect list, what mean a value sometimes slightly lower or higher than the double of the number of species found by those authors.

The Shannon-Wiener Diversity Index (*H'*) was also higher the other four works performed in the same vegetation type (Pereira and Araújo 1995, Pereira *et al*. 2001, Castro *et al*. 2007, Montezuma and Araújo 2007). Also for evenness (*J*) this study showed higher values, but close, to that found by the authors studying the same formation (Pereira and Araújo 1995, Pereira *et al*. 2001, Castro e*t al*. 2007, Montezuma and Araújo 2007, Ferreira and Silva 2014, Thomazi and Silva 2014).

Another important finding of gradsect is that the number of species, diversity and species richness indices obtained for each sampling transect were closed to the ones that were found for the total sampling areas that were surveyed with the same phytophysiognomy (Pereira and Araújo 1995, Pereira *et al*. 2001, Castro e*t al*. 2007, Montezuma and Araújo 2007, Ferreira and Silva 2014, Thomazi and Silva 2014).

Despite of its enormous sampling efforts, the method of plots does not show higher diversity indices (H ') and evenness (J) than the gradsect. For example, Ferreira and Silva (2014) evaluated a shrubland open vegetation in this same area, registered individuals in 2320, 53 species with diversity H '= 3.27, and J = 0.82. In another study in sandbank of Maricá, in Rio de Janeiro, the plot method H'= 2.43, and J = 0.70, although they were inventoried in that area only 1450 individuals of 49 species (Pereira and Araújo 1995). When evaluating a shrubland swamp using plots, Montezuma and Araújo (2007) inventoried in 1135 individuals of 43 species, and obtained H'= 2.63 and J = 0.79. In the same direction, Thomazi and Silva (2014) using plots in an open, flooded and non-flooded shrubland areas showed the greatest sampling effort, inventorying 4224 individuals. However they found approximately the same number of species (65) and *H'*= 3.30 and *J* = 0.79. Pereira *et al*. (2001) and Castro *et al*. (2007) evaluated, respectively, a closed shrub area and a non-flooded open shrubland area using the line intercept. Those authors demonstrated that this method requires a lower sampling effort, respectively: 398 and 422 sampled individuals, identifying 42 and 30 species respectively *H'*= 2.84 and 2.67. However, those values were still much lower than the ones found using gradsect.

Among the families with the highest IPFTs in the study, the highlighting of species richness of Bromeliaceae and Myrtaceae was remarkable in the work carried out on sandbanks by Fabris and Caesar (1996). The Bromeliaceae was considered of greater species richness in the region of bushes (Pereira 2007, Ferreira and Silva 2014, Thomazi and Silva). Bromeliaceae has been cited as one of the most representative families in sandbanks (Henriques *et al*. 1986, Sá 1992, Fabris and Pereira 1998, Pereira and Zambom 1998, Cogliatti-Carvalho *et al*. 2001, Ferreira and Silva 2014). Among the Bromeliaceae raised in this paper, *Aechmea lingulata* was also mentioned by Rocha-Person *et al*. (2008). The importance of Bromeliaceae for the sandbank ecosystem was confirmed by high values of coverage, such as in the case of *Vriesea neoglutinosa* in Ilha Grande/RJ (Nunes-Freitas *et al*. 2009).

Species richness showed by the Myrtaceae is also a commonly observed fact in studies on sandbanks, as pointed out by Castro *et al*. (2007). It was also confirmed in other sandbank formations (Fabris *et al*. 1990, Assumpção and Nascimento 2000, Pereira *et al*. 2001,Thomazi and Silva 2014, and Ferreira and Silva 2014). However, what makes surprise in this study is the inclusion of usually herbaceous plant families, such as Cyperaceae, in the list of most ecologically important families (Table 2). It could be better understood by the fact that gradsect allows the sampling of non-woody plants, hence also allowed the inclusion of species of Cyperaceae, and other herbaceous families such as Poaceae, Gentianaceae, Melastomataceae, and Violaceae typical of marshes and swampy formations on the sandbank (Valadares *et al*. 2011), which are usually out of plant inventories from other phytophysiognomies from sandbanks.

Considering the sampled species, no matter if taken in count the number of registers (Figure 5) or PFTs (Figure 6), *Allagoptera arenaria* is one of the most ecologically important species , as it

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was demonstrated by Ferreira and Silva (2014), for a the same open shrubland vegetation area. In general, studies in open shrubland vegetation tend to have a concentration of structural importance in a small number of species, such as in the studies by Pereira *et al*. (2001) Castro *et al*. (2007). Rocha-Pessoa *et al*. (2008) studied the distribution of Bromeliaceae in the sandbank of Massambaba, RJ, and obtained the highest values of species richness, density, abundance, and biomass for that family at the *Clusia* open vegetation, and older nomination for a kind of open shrubland vegetation are a (Pereira 2003). In the Jurubatiba National Park that protects a sandbank vegetation area, Pereira *et al*. (2004) showed that families such as Arecaceae and Bromeliaceae showed a high ecological importance level, evidenced by their high coverage values, especially in the case of *Vriesea neoglutinosa*. However, the presence of herb species such as *Cuphea flava*, *Chamaecrista ramosa, Smilax rufescens*, and *Evolvulus maximiliani* in the list of high ecological importance presented here is a consequence of the broader inclusion criterion of gradsect.

In general, studies in open shrubland vegetation trend to have a concentration of structural importance in a small number of species, such as in the studies by Pereira *et al*. (2001) Castro *et al*. (2007), Thomazi and Silva (2014), and Ferreria and Silva (2014). Among the plant species found, *Sebastiania glandulosa*, *Chamaecrista ramosa*, *Evolvulus maximilliani*, *Syngonanthus imbricatus*, V*ernonia fruticulosa,* and *Cereus fernambucensis* were predominantly herbaceous habita. Transects located on inclined slopes produced by the sand removal by mining, exhibited lower levels of wealth than the other taxa sampled blocks. The area between bushes can present a high occurrence of species such as *Chamaecrista ramosa*, *Evolvulus maximiliani* and *Cuphea flava* (Menezes and Faria 2004), which well represented in the sampling unities.

Plant species that occupy the sloping that were created after the extraction of sand and had showed a highly significant association with the terrain slope, as *Melocactus violaceus*, *S. glandulosa*, *C. ramosa*, *E. maximilliani*, *S. imbricatus*, *V. fruticulosa*, and *C. fernambucensis*, often described in studies of the structure of the vegetation that occurs between bushes of sandbank vegetation, both in the limits of PEPCV (Pereira and Araújo 1995, Ferreira and Silva 2014), as well as in the Permanent Protection Environmental Area of Setiba – APA-Setiba (Thomazi and Silva 2014) in the neighborhood of PEPCV; or even in other geographically close regions, such as in Vitória city (Pereira and Assis 2000); or in more distant regions of the Espírito Santo State, such as in Linhares (Colodete and Pereira 2007); and even in other areas of sandbank of Brazil (Pereira et al. 2004, Sacramento et al. 2007).

In sampling blocks where there was no direct impact of sand removal, the species of bromeliads and the palm *Allagoptera arenaria* had an expressive representation in terms of dominance, abundance, and frequency. However, in the slope area in spontaneous regeneration, only *A. arenaria* was found. One detail that draws attention is that despite the ecological importance of bromeliads in the sandbank, another species, *Panicum trinii,* whose PFT would be identical to a bromeliad, except for the difference in the nature of the roots that are absorbent in *P. trinii*, but just fixing the bromeliads. However, in areas of sandy slopes, *P. trinii* was more abundant, while the bromeliads were rare. This may represent an important issue in the process of production of vegetation cover in open shrubland formation of sandbanks. In this case, Poaceae, Bromeliaceae, and some shrub species could act as facilitators species, capable of producing more favorable conditions for germination and establishment of new plant species, than the usual expected profile for the sandbank, where the highly leached and drained, sandy substrate exposed to strong sunlight, produces an environment poor in nutrients and moisture, subject to temperatures that can exceed 60° C during the day, as mentioned above (Zaluar and Sacarano 2000).

This is the first time that he method Gradsect (Gillison and Brewer 1985) is used assessment of biodiversity in vegetation of sandbanks. The premise of this method of searching through the perceived biodiversity gradients in the landscape. As an assumption, all environments respond to gradients and the sampling research through them tends to be faster and more accurate (Parker 2011). The allocation of transects resembled an active search for variations in landscape, quickly leading to the rarest species. Perhaps it is due to the fact that there are ecological responses that explain the influence of complex gradients in species composition in a community (Halvorsen 2012).

As the cost of successive trips to the field should always be taken into consideration (Strayer et al. 1986, Legg and Laszlo 2006) the sampling effort of gradsect method can be a parameter to be considered for future evaluations in sandbanks, since it had shown high sensitive to species richness and diversity, and brought information about the environmental adaptation of those species through their *modi*, and reached asymptote effort curve quickly.

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References

Assumpção J, Nascimento MT (2000) Estrutura e composição florística de quatro formações vegetais de restinga no complexo lagunar Grussuí/ Iquipari, São João da Barra, Rj, Brasil. **Acta Botanica Brasilica** 14: 301-315.

Bremer B, Bremer K, Chase MW, Fay MF, Reveal JL, Soltis DE, Soltis PS, Stevens PF (2009) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. **Botanical Journal of the Linnean Society** 161: 105-121.

ISSN 1806–7409 - http://www.naturezaonline.com.br

Castro DN, Souza M, Menezes LFT (2007) Estrutura da formação arbustiva aberta não inundável na Restinga da Marambaia (RJ). **Revista Brasileira de Biociência** 5: 75-77

Christo AG, Guedes-Bruni RR, Sobrinho FAP, Silva AG, Peixoto AL (2009). The structure of the shrubaroreal component of an Atlantic Forest fragment on a hillock on the central lowland of Rio de Janeiro, Brazil. **Interciencia** (Caracas) 34: 232-239

Cogliatti-Carvalho L, Nunes-Freitas AF, Rocha CFD, van Sluys M (2001) Variação na estrutura e composição de Bromeliaceae em cinco zonas de vegetação no Parque Nacional da restinga de Jurubatiba, Macaé, RJ. **Revista Brasileira de Botânica** 24: 1-9.

Connel JH (1978) Diversity of tropical rainforests and coral reefs. **Science** 199: 1304-1310

DNPM (2002) **Sumário Mineral**. Brasília, Departamento Nacional de Produção Mineral.

ESRI (2011) **ArcGIS Desktop**: release 10. Redlands, Environmental Systems Research Institute.

Fabris LC, César O (1996) Estudos florísticos em uma mata litorânea no sul do estado do Espírito Santo. B**oletim do Museu de Biologia Mello Leitão (Nova Série)** 5: 15-46.

Fabris, L.C, Pereira, O.J, Araújo, D.S.D. 1990. Análise fitossociológica na formação pós- praia da restinga de Setiba, Guarapari, ES. In: ACIESP (org) **Anais do II Simpósio de Ecossistemas da Costa Sul e Sudeste Brasileira**, v.3, p. 455-466,.

Fabris LC, Pereira OJ, Araújo DSD (1990) Análise fitossociológica na formação pós-praia da restinga de Setiba, Guarapari, ES. In: ACIESP (org) **Anais do II Simpósio de Ecossistemas da Costa Sul e Sudeste Brasileir**a v.3, pp. 455-466.

Fabris LC, Pereira OJ (1998) Florística da formação póspraia na restinga do Parque Estadual Paulo César Vinhas, Guarapari (ES). In: S. Watanabe (org) A**nais do IV Simpósio de Ecossistemas Brasileiros.** São Paulo, Publicações ACIESP, pp. 165-176.

Ferreira PF, Silva AG (2014) A vegetação arbustiva aberta em regeneração espontânea dentro de uma Unidade de Conservação de Proteção Integral, numa restinga após impacto de extração de areia. **Natureza on line** 12: 51-60.

Gillison AN (1984) Gradient oriented sampling for resource surveys - the gradsect method. In: Myers KR, Margules CR, Musto I (ed) **Survey Methods for Nature Conservation** Proc. Workshop held at Adelaide University. 31 Aug. to 31 Sept. 1983. Canberra, Division of Water and Land Resources,, pp. 349-374

Gillison AN (2002). A generic, computer-assisted method for rapid vegetation classification and survey: tropical and temperate case studies. **Conservation Ecolog y** 6: 3.

Gillison AN (2013) Plant functional types and traits at the community, ecosystem and world level. In: van der Maarel E, Franklin J (ed) **Vegetation Ecolog y** 2 ed. London, Wiley- Blackwell, Publishing, U.K. pp 347-386.

Gillison AN, Brewer KRW (1985) The use of gradient-directed transects or gradsects in natural resource survey. **Journal of Environmental Management** 20: 103-127.

Gillison AN, Carpenter G (1997) A generic plant functional attribute set and grammar for dynamic vegetation description and analysis. **Functional Ecolog y** 11: 775-783.

Henriques RPB, Araújo DSD, Hay JD (1986) Descrição e classificação dos tipos de vegetação da restinga de Carapebus, Rio de Janeiro. **Revista Brasileira de Botânica** 9: 173-189.

Kollman LJC, Fontana AP, Simonelli M, Fraga CN (2007) As Angiospermas ameaçadas de extinção no Estado do Espírito Santo. In: Simonelli M, Fraga CN (org) **Espécies da Flora Ameaçada de Extinção no Estado do Espírito Santo**. Vitória, IPEMA, pp 105-137.

Loss ACC, Silva AG (2005) Comportamento de forrageio de aves nectarívoras de Santa Teresa – ES. **Natureza on line** 3: 48-52.

Ludwig JA, ReynoldS JF (1988) Statistical Ecology: a primer on methods and computing. Toronto, John Wiley & Sons.

MMA (2000) Ministério do Meio Ambiente. **Avaliação e ações prioritárias para a conservação da biodiversidade da Mata Atlântica e campos sulinos**. Brasília, Ministério do Meio Ambiente.

Montezuma RCM, Araújo DSD (2007) Estrutura da vegetação de uma restinga arbustiva inundável no Parque Nacional da Restinga de Jurubatiba, Rio de Janeiro. **Pesquisas: Botânica** 58: 157-176.

Müller-Dombois D, Ellenberg H (1974) Aims and Methods of Vegetation Ecology. New York, John Wiley & Sons.

Nunes-Freitas AF, Rocha-Pessôa TC, Dias AS, Ariani CV, Rocha CFD (2009) Bromeliaceae da Ilha Grande, RJ: revisão da lista de espécie. B**iota Neotropica** 9: 213-219.

Pielou EC (1975) **Ecological Diversity.** New York, John Willey & Sons

Pereira MCA, Cordeiro SZ, Araújo DSD (2004) Estrutura do estrato herbáceo na formação aberta de Clusia do Parque Nacional da Restinga de Jurubatiba, RJ, Brasil1. **Acta Botanica Brasilica** 18: 677-687.

Pereira OJ (1990) Caracterização fitofisionômica da restinga de Setiba/ Guarapari-ES. In: ACIESP (org.). **II Simpósio de ecossistemas da costa sul e sudeste brasileira**: estrutura, função e manejo, v. 3, pp 207-219.

Pereira OJ (2002) Restinga. In: Araújo EL, Moura AN, Sampaio ESB, Gestinari LMS, Carneiro JMT (ed) **Biodiversidade, Conservação e Uso Sustentável da Flora do Brasil**. Recife, UFRPE, imprensa Universitária, pp 38-41.

Pereira OJ (2003) Restinga: origem, estrutura e diversidade. In: Jardim MAG, Bastos MNC, Santos JUM (org) **Desafios da Botânica no Novo Milênio**: inventário, sistematização e conservação da diversidade vegetal. Belém, MPEG, UFRA: Embrapa, pp 177-179.

Pereira OJ (2007) Formações pioneiras: restinga. In: Simonelli M, Fraga CN (org) **Espécies da Flora Ameaçada de Extinção no Estado do Espírito Santo**. Vitória, IPEMA, pp 27-32.

Pereira OJ, Araújo DSD (1995) Estrutura da vegetação de entre moitas da formação aberta de Ericaceae no Parque Estadual de Setiba (ES). **Oecologia Brasiliensis** 1: 245-257.

Pereira OJ, Araújo DSD, Pereira MCA (2001) Estrutura de uma comunidade arbustiva da restinga de Barra de Marica (RJ). **Revista Brasileira de Botânica** 24: 273-281.

Pereira OJ, Assis AM (2000) Florística da restinga de Camburi, Vitória, ES. **Acta Botanica Brasilica** 14: 99-111.

Pereira OJ, Zambom O (1998) Composição florística da restinga de Interlagos, Vila Velha (ES). In: S. Watanabe (org) A**nais do IV Simpósio de Ecossistemas Brasileiros**. São Paulo, Publicações ACIESP, pp. 129-157.

Ratter JA, Bridgewater S, Ribeiro JF (2003) Analysis of the floristic composition of the brazilian cerrado vegetation III: Comparison of the woody vegetation of 376 areas. **Edinburg Journal of Botany** 60: 57-109.

Rocha-Pessoa TC, Nunes-Freitas AF, Cogliatti-Carvalho L, Rocha CFC (2008) Species composition of Bromeliaceae and their distribution at the Massambaba restinga in Arraial do Cabo, Rio de Janeiro, Brazil. **Brazilian Journal of Biolog y** 68: 251-257.

Thomazi RD, Silva AG (2014) Florística, diversidade e estrutura horizontal e vertical de uma área de vegetação arbstiva aberta numa planície arenosa costeira do Espírito Santo, sudeste do Brasil. **Natureza on line** 12: 10-18.

Valadares RT, Souza FBC, Castro NGB, Peres ALSS, Schneider SZ, Martins MLL (2011) Levantamento florístico de um brejo-herbáceo localizado na restinga de Morada do Sol, município de Vila Velha, Espírito Santo, Brasil. **Rodriguésia** 62: 827-834.

Whittaker RH (1975) **Comunities and Ecosystems**. New York, MacMillan.