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Morpho-ecological characterization and composition of rocky fields bryophytes in Brazilian Cerrado

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Resumen: Caracterización morfo-ecológica y composición de briofitos en pastizales rocosos en el Cerrado Brasileño. El objetivo de este estudio es proporcionar información sobre las relaciones ecológicas y la composición florística de la comunidad de briofitos en los pastizales rocosos del Cerrado brasileño en el estado de Minas Gerais. Hay pocos estudios de comunidad de briofitos y su relación con el ambiente para Cerrado brasileño, además de esto, estos ambientes son sometidos a presiones intensas. Para este estudio se seleccionaron al azar nueve transectos de 50 m con un total de 45 parcelas para analizar la composición y las características morfo-ecológicos de las comunidades de briófitos. Las medidas de diversidad se realizaron utilizando el software PAST y EstimateS para realizar el agrupamiento de las especies encontradas entre las tres diferentes áreas de pastizales rocosos. Se encontraron 176 ocurrencias de 47 especies de briofitos en el área de rocas. La familia más rica de musgos fue Leucobryaceae (Bryophyta) con siete especies y Lepidoziaceae (Marchantiophyta) para hepáticas con nueve especies. Antóceros no fueron encontrados. De acuerdo con PCoA (Análisis de Coordenadas Principales), la composición florística de la comunidad de briofitos en los pastizales rocosos es homogénea, sin diferencias entre las parcelas estudiadas. La comunidad tiene predominio de especies terrestres, colonizadoras de largo plazo, tolerantes a la luz directa del sol y la desecación. Esas características están relacionadas con su ciclo de vida.

Palabras clave: Ambientes secos, composición de comunidades, ecología, hepáticas, musgos, riqueza.

Summary: The aim of this study is to provide information about ecological relations and floristic composition of bryophytes community in Brazilian Cerrado rocky fields in Minas Gerais state. There are few works of bryophyte communities and their relation with this environment for Brazilian Cerrado, besides this, these environments are submitted to several intense treats. For this study nine transects of 50 m with total of 45 plots were randomly sampled in order to analyze the composition and morpho-ecological traits of bryophytes communities. The diversity measures were performed using the PAST and EstimateS software to perform the clustering of the species found between the tree different areas of rocky fields. We found 176 occurrences of 47 bryophytes species in the area of rock fields. The richest family for mosses was Leucobryaceae (Bryophyta) with seven species and Lepidoziaceae (Marchantiophyta) for liverworts with nine species. Hornworts were not found. According to PCoA (Principal Coordinates Analysis), the floristic composition of bryophytes community in rocky fields is homogeneous, without differences between studied plots. The community has predominance of terrestrial and longtime colonizer species tolerant to direct sunlight and desiccation. These characteristics are related to their life cycle.

Key words: Community composition, dry environments, ecology, liverworts, mosses, richness.

Introduction

The Cerrado consists a mosaic of environments and forest formations (Batalha, 2011), among the several vegetation types present in this domain there are the rocky fields (*campos rupestres*), rocky cerrado (*cerrado rupestre*), grasslands, mixed fields (*campos sujos*), cerrado *sensu stricto*, gallery forests (*matas de galerias*), slope forests (*matas de encosta*), moist fields (*campos úmidos*) and waterfalls areas (Couto Junior *et al*., 2010). Despite this great landscape diversity, its original area has been destroyed for the pastures and monoculture installation, also with climate change,

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population growth, overexploitation, pollution and introduction of invasive species, now it is considered the Brazilian domain with the highest deforestation rate and lowest conservation effort (Klink & Machado, 2005; Faleiro *et al.,* 2013).

The dominant vegetation formation in Cerrado is represented by grasslands and rocky fields (Carvalho-Silva & Guimarães, 2009), which presents a high number of endemic species since they range in areas with specific ecological conditions influenced by geographic isolation and biotic and abiotic factors (Harley & Simmons, 1986; Giulietti *et al.,* 1987; Pirani *et al.,* 1994; Stannard, 1995). The rock fields have herbaceous and shrub formations associated with lithic soils, predominantly quartz being found in areas of Cerrado and Caatinga, often interspersed with riparian forests and isolated groups of trees (Rapini *et al*., 2008).

Bryophytes floristic characterization for rocky fields in Brazil are reported by Yano & Carvalho (1995) who found 46 species of bryophytes in Serra da Piedade; Yano & Peralta (2009) with 42 species in the mountains of Serra de Grão-Mogol; Yano & Peralta (2011a) with 114 species in Serra de São José at the city of Tiradentes; Yano & Peralta (2011b) with 237 species in different vegetation types of Serra do Cipó; Luizi-Ponzo *et al*. (2013) who found 209 species for Ibitipoca State Park and recently Carmo & Peralta (2016) published the floristic survey of 289 species found in Serra da Canastra National Park, all these works were carried out for Minas Gerais state. Besides these, we also found Bastos *et al*. (2000) who presented a list of 65 taxa and Valente *et al*. (2013) found 212 species, both in Chapada Diamantina, in the Bahia state. All these works were carried out using floristic surveys methodology and included species of other vegetation types, such as gallery forest, mixed ombrophilous rain forests, slope forests and waterfalls areas.

The spatial heterogeneity among different areas affect the structure and diversity of population plants (Ricklefs, 1996), therefore some parameters as density and richness are related to conditions and characteristics present in the environment (Austrheim *et al*., 2005; Corrales *et al*., 2010). The bryophyte works which present ecological approaches for Brazilian Cerrado are scarce and presents great importance once this phytogeographic domain has a high rate of extinction threat, beside this, this plant group plays several ecological functions for the ecosystems that still remains unknown for the Brazilian Cerrado (Klink & Machado, 2005; Costa *et al*., 2011; Faleiro *et al*., 2013).

Some examples that exist in the bibliography for Brazilian Cerrado are found at Egunyomi & Vital (1984), which the mosses communities among Cerrado (Brazil) and Savannah (Nigeria) vegetation types were compared in order to establish taxonomic affinities and explain the reasons for their distribution. Twenty years later, Visnadi (2004) analyzed the bryophytes distribution in relation to the host phorophytes and the vegetation types from the Mogi Guaçu Biological Reserve of São Paulo state. Meanwhile for ecological studies in rocky outcrops, only one work composes this vegetation formation for Brazil found in Silva *et al*. (2014), who analyzed the influence of some abiotic factors in the distribution patterns of bryophytes species in Brazilian northeastern, thirty years after the first bryophytes ecological study in Cerrado. However, in recent years, Peralta *et al*. (2015) and Rios *et al*. (2016) worked in a Brazilian Cerrado of Goiás state and found and provide great results about the bryophytes community of this environment, such as the description of the new species *Archidium oblongifolium* Peralta *et al.* and ecological approaches showing new occurences and the most colonized substrate.

The rock fields environments were chosen for bryophytes community analysis mainly due to their large representation in the Serra da Canastra National Park (PARNA) area and by the few ecological works existing of bryophytes occurring in Brazilian Cerrado. It is also important to highlight that this work evaluate the specific bryophytes community composition of rocky fields in Brazilian Cerrado of Minas Gerais state, which represents a new study for this important conservation area.

This study aimed to know the specific contribution of rocky fields for bryophytes flora in Cerrado *sensu lato* and to characterize the community analyzing the parameters of richness, abundance, frequency, composition and morpho-ecological adaptive characteristics of bryophytes species occurring in these environments.

Materials and methods

Study area – Were selected three rocky fields areas: Curral das Pedras (CP), Rocky fields I (R1) and Rocky fields II (R2), where temporary transects were set as way for standardize the collections among these different areas. The study was carried out in areas of Cerrado *sensu lato* at Serra da Canastra National Park (PARNA), where is characterized by a mountain range located in southwestern Minas Gerais in the municipalities of Sacramento, São Roque de Minas and Delfinópolis (20°00'-20°30'S e 46°15'- 47°00'W) (Fig. 1). It contains 71,525 ha with an average altitude ranging between 800-1,200 m, with the highest point of the park being Serra Brava at 1,496m. The average temperature is around 17°C in the winter and 23°C in the summer, but varies between higher and lower regions. In general, the average annual rainfall being concentrated from December to February, which is the moistest period for all the country (IBDF, 1981).

Data sampling – For each rocky fields area (CP, R1 and R2) was sampled three transects of 50 m long, with at least 100 m distance between them, each transects was divided into 10 subplots (SU - Sampling units) with five m each (5 m). Five subplots (SU) were randomly selected, totaling 50 m^2 analyzed per transect (5 m long and 2 m wide), (adapted from Vanderpoorten *et al*., 2010). In overall were analyzed nine transects, 45 sampling units (SU) and 450 m^2 of rocky fields area.

Data collection and identification – In each raffled subplot (SU), all bryophytes species occurring were sampled and identified; the percentage of coverage was performed by visual estimation (Mantovani & Martins, 1990) and noted the available types of substrates. The methodology for collecting, herborization and preservation of material followed Gradstein *et al*. (2001) and the samples collected were deposited in the herbarium SP.

For identification of the species were used the following bibliographies: Frahm (1991), Sharp *et*

Fig. 1. Sampling rocky fields area. CR – Curral de Pedras (A), R1 – Rocky field I (B) and R2 – Rocky field II (C). (Google Earth taken 01/13/2017).

al. (1994), Yano & Carvalho (1995), Buck (1998), Vilas Bôas-Bastos & Bastos (1998), Bastos *et al*. (2000), Gradstein *et al*. (2001), Castro *et al*. (2002), Gradstein & Costa (2003), Yano & Peralta (2009), Valente *et al*. (2011), Yano & Peralta (2011a; b), Bordin & Yano (2013) and Valente *et al*. (2013). The classification systems follow Crandall -Stotler *et al*. (2009) for Marchantiophyta and Goffinet *et al*. (2009) for Bryophyta.

The species morpho-ecological characterization (Table 1) followed the classification proposed by Fulford (1966; 1968; 1976), Smith (1978), Nyholm (1987; 1989), Dull (1991), Ellenberg *et al*. (1991), Frahm (1991), During (1992), Nyholm (1993),Reese (1993), Gradstein (1994), Sharp *et al*. (1994), Frisvoll (1997), Nyholm (1998), Schuster (1999), Vevle (1999), Schuster (2000), Gradstein *et al*. (2001), Damsholt (2002), Schuster (2002), Gradstein & Costa (2003), Austrheim *et al*. (2005) and Ireland & Buck (2009).

The absolute frequency (FR) related the occurrences number of a kind species by the total sampling units in rocky fields (45), while the relative frequency (FCP, FR1, FR2) is the occurrences number of kind species in relation to total sample units in each rocky fields area (15). The species showing absolute frequency (FR) greater or equal than 20% were considered frequent.

The software PAST version 3.01 (Hammer *et al*., 2001) were used for the following analysis: univariate statistics (average and standard deviation), Principal Coordinates Analysis (PCoA) and EstimateS version 9.1 (Colwell, 2013) for richness estimated by the accumulative curve of collector rarefaction from permutation Jackknife method. With the PCoA analysis we intend to figure out how bryophytes communities at the rocky fields relates themselves, and with the EstimateS software we can affirm if our collect of samples was well represented for the area.

Results And Discussion

Species richness - The community found in rocky fields is characterized by the predominance of acrocarpous mosses (47%) and for the liverworts family Lepidoziaceae (43%) (Table 1). Were observed 176 occurences of 47 species in the three areas of rocky fields (Table 2). The mosses division (Bryophyta) showed greater richness in relation to liverworts (Marchantiophyta), with 27 and 20 species respectively.

The number of species found is 16% of the 289 species cited for Serra da Canastra National Park (Carmo & Peralta, 2016), 6% of 773 bryophytes cited for Minas Gerais state and 12% of 397 bryophytes cited for Brazilian Cerrado (Flora do Brasil, 2020 *em construção*).

Leucobryaceae (Bryophyta) was the mosses family with the highest diversity, with seven species found, four of them considered frequently (Table 2). Among the areas of high altitudes for Minas Gerais state, this family is cited in literature as high richness (Yano & Carvalho, 1995; Yano & Peralta, 2009; Yano & Peralta, 2011a; b; Carmo & Peralta, 2016) and constantly found in mountainous regions (Gradstein *et al*., 2001).

For the liverworts, the most representative family in parameters of richness, frequency and abundance was Lepidoziaceae. The species *Kurzia brasiliensis* (Steph.) Grolle, *Kurzia capillaris* (Sw.) Grolle, *Zoopsidella integrifolia* (Spruce) R.M. Schust., *Arachniopsis monodactyla* R.M. Schust., and *Pteropsiella frondiformis* Spruce are representatives of this family and characteristics of mountainous regions, where they can colonize exposed sandy soils or rocky surfaces, generally found in rocky fields areas (Gradstein *et al.* 2001; Yano & Peralta 2011b).

The bryophytes species considered exclusive of the rock fields represent approximately 16% of species found for the total area of the Park (Carmo & Peralta, 2016). In other words, due to a drier and exposed environment (Rapini *et al*., 2008) the rock fields do not have a high richness if compared to wetter environments of Cerrado *sensu lato* as gallery forests areas, slope forests, areas of waterfalls and ombrophilous rain forests. Moreover, physical and climatic conditions of the rocky fields also favor the mosses growth instead of liverworts, as observed in this study and other studies published in similar areas (Yano & Carvalho, 1995; Yano & Peralta, 2009; Yano & Peralta, 2011a, b; Luizi-Ponzo *et al*., 2013 and Carmo & Peralta, 2016).

The sampling sufficiency obtained from Jackknife estimate (with 65 species which were estimated) was established within the confidence interval of standard deviations (ranging in 12 species for plus or minus), in other words, the

Table 1. Classification of morpho-ecological characteristics according Austrheim et al. (2005) of species found in Serra da Canastra National Park based on Smith (1978), Nyholm (1987), Nyholm (1989) Dull (1991), Ellenberg et al. (1991), During (1992), Nyholm (1993), Frisvoll (1997), Nyholm (1998), Vevle (1999), Gradstein et al. (2001), Damsholt (2002) and Gradstein & Costa (2003). Total - refers about the species number found. % - Percentage of the number species found represents in relation the total richness in rocky fields areas.

Group	Characteristics	Total	%
Morphological groups (GF)	Liverworts (1)	20	43
	Acrocarpous mosses (2)	22	47
	Pleurocarpous mosses (3)	4	9
	Mosses type - *Sphagnum* (4)	1	1
Sexuality (SE)	Monoicous (1)	20	43
	Dioicous (2)	27	57
Sexual Reproduction (SR)	Sexual reproduction rare (1)	15	32
	Sexual reproduction commom (2)	32	68
Longevity (LO)	Shorter life cycle (1)	12	26
	Longer life cycle (2)	35	74
Spore size (SS)	Small (up to 25 μm) (1)	44	94
	Median (between 26 and 50 μm) (2)	3	6
Papillae (PA)	Absent (0)	38	81
	Present (1)	9	19
Gemmae (GE)	Absent (0)	27	57
	Present (1)	20	43
Life-history strategies (LH)	Colonists (1)	16	34
	Pioneer (2)	2	4
	Perennial stayer (3)	11	23
	Perennial reviving (4)	15	32
	Perennial permanent (5)	3	7
Luminosity (LI)	Dark (1)	7	15
	Shade (2)	18	38
	Solar direct exposition (3)	22	47
Moisture (MI)	Lower rates (1)	9	20
	Intermediate rates (2)	19	40
	Higher rates (3)	19	40
Substrate PH (BI)	Acid (1)	8	17
	Neuter (2)	2	4
	Basic (3)	37	79

Table 2. List of species and their relative frequency of each rocky fields sampled in Serra da Canastra National Park (%). Relative Frequency of Curral de Pedras - FRP; Relative Frequency of Rocky fields I - FR1; Relative Frequency of Rocky fields II - FR2. The absolute frequency (RF) and morpho-ecological characteristics (GF - Morphological groups; LH - Life-history strategies; SE - Sexuality, PA - Papillae; LO - Longevity SS - Spores size; SR - Sexual reproduction; GE - Gemmae, LI - Luminosity, MI - Moisture; BI - Substrate pH) with subtitles according Table 1 of this work.

Division/Family/Species	Frequency				Morpho-ecological characteristics										
	RP	R1	R2	FR%	GF	LH	SE	PA	LO	SS	SR	GE	LI	MI	BI
BRYOPHYTA															
BRYACEAE															
Bryum acuminatum Harv.	0.07	0.00	0.00	0.02	2	3	2	0	2	1	2	1	3	2	3
Bryum arachnoideum Müll. Hal.	0.00	0.00	0.07	0.02	2	3	2	0	2	1	2	1	3	2	3
Bryum argenteum Hedw.	0.07	0.00	0.00	0.02	2	3	2	0	2	1	2	1	3	2	3
Bryum exile Dozy & Molk.	0.33	0.00	0.20	0.18	2	3	2	0	2	1	2	1	3	2	3
Bryum subapiculatum Hampe	0.33	0.13	0.07	0.18	2	3	2	0	2	1	2	1	3	2	1
Ptychostomum capillare (Hedw.) Holyoak & N. Pedersen	0.13	0.00	0.00	0.04	2	3	2	0	2	1	2	1	3	2	3
CALYMPERACEAE															
Syrrhopodon gardneri (Hook.) Schwägr.	0.00	0.00	0.13	0.04	2	4	1	1	2	1	1	1	2	1	3
Syrrhopodon parasiticus (Brid.) Besch.	0.07	0.00	0.00	0.02	2	4	1	1	2	1	2	1	2	2	1
Syrrhopodon prolifer Schwägr.	0.07	0.07	0.33	0.16	2	4	1	1	2	1	2	1	2	2	3
Syrrhopodon tortilis Hampe	0.00	0.07	0.00	0.02	2	4	1	1	2	1	1	1	2	3	3
Octoblepharum albidum Hedw.	0.00	0.13	0.20	0.11	2	3	1	0	2	1	2	1	3	2	2
DICRANACEAE															
Atractylocarpus brasiliensis (Müll. Hal.) R.S. Williams	0.00	0.13	0.00	0.04	2	4	2	0	2	1	2	1	3	2	3
Dicranella longirostris (Schwägr.) Mitt.	0.07	0.00	0.00	0.02	2	3	2	0	2	1	2	0	3	2	3
FISSIDENTACEAE	0.00	0.27	0.00	0.09	1	2	2	0	1	1	2	0	1	3	3
Fissidens pellucidus Hornsch.	0.07	0.00	0.00	0.02	2	3	1	0	1	1	2	0	2	3	3
Fissidens serratus Müll. Hal.	0.27	0.00	0.00	0.09	2	3	1	1	1	1	2	0	2	3	3
HYPNACEAE															
Crysohypnum diminutivum (Hampe) Buck	0.07	0.00	0.00	0.02	3	1	1	1	2	1	2	0	2	2	2
LEUCOBRYACEAE															
Campylopus aemulans (Hampe) A. Jaeger	0.00	0.13	0.00	0.04	2	4	2	0	2	1	1	1	3	1	3
Campylopus angustiretis (Austin) Lesq. & James	0.20	0.27	0.20	0.22	2	4	2	0	2	1	2	0	3	1	3
Campylopus dichrostis (Müll. Hal.) Paris	0.27	0.40	0.33	0.33	2	4	2	0	2	1	2	0	3	1	3
Campylopus heterostachys (Hampe) A. Jaeger	0.07	0.67	0.20	0.31	2	4	2	0	2	1	2	0	3	1	3
Campylopus julicaulis Broth.	0.00	0.07	0.00	0.02	2	4	2	0	2	1	2	0	3	1	3
Campylopus pilifer Brid.	0.07	0.47	0.00	0.18	2	4	2	0	2	1	2	0	3	1	3

Division/Family/Species	Frequency				Morpho-ecological characteristics										
	RP	R1	R2	FR%	GF	LH	SE	PA	LO	SS	SR	GE	LI	MI	BI
Campylopus savannarum (Müll. Hal.) Mitt.	0.20	0.27	0.67	0.38	2	4	2	0	2	1	2	0	3	1	3
PYLAISIADELPHACEAE															
Isopterygium affusum Mitt.	0.07	0.00	0.00	0.02	3	1	1	0	2	1	1	0	1	2	3
Isopterygium tenerifolium Mitt.	0.00	0.00	0.07	0.02	3	1	1	0	2	1	2	0	1	2	3
SEMATOPHYLLACEAE															
Aptychopsis subpungifolia (Broth.) Broth.	0.07	0.00	0.00	0.02	3	3	1	0	2	1	2	0	3	2	3
SPHAGNACEAE															
Sphagnum ovalifolium Warnst.	0.00	0.07	0.00	0.02	4	5	2	0	2	2	1	0	3	3	1
MARCHANTIOPHYTA															
ANEURACEAE															
Riccardia regnellii (Angstr.) Hell	0.00	0.27	0.00	0.09	1	5	2	0	1	1	2	1	2	3	3
CALYPOGEIACEAE															
Calypogeia grandistipula (Steph.) Steph.	0.00	0.13	0.00	0.04	1	2	1	0	1	1	1	1	2	3	3
CEPHALOZIACEAE															
Odontoschisma denudatum (Nees) Dumort.	0.00	0.33	0.07	0.13	1	5	2	0	1	1	1	1	2	3	3
CEPHALOZIELLACEAE															
Cephaloziella granatensis (J.B. Jack) Fulford	0.00	0.13	0.13	0.09	1	1	1	0	1	1	1	0	2	3	3
FRULLANIACEAE															
Frullania caulisequa (Nees) Nees	0.00	0.07	0.20	0.09	1	4	2	0	2	2	2	0	3	2	1
JUNGERMANNIACEAE															
Jungermannia sphaerocarpa Hook.	0.00	0.13	0.00	0.04	1	1	1	0	2	1	2	1	2	3	3
LEJEUNEACEAE															
Acrolejeunea torulosa (Lehm. & Lindenb.) Schiffn.	0.00	0.00	0.07	0.02	1	4	1	0	2	2	2	1	3	1	1
Lejeunea flava (Sw.) Nees	0.00	0.13	0.00	0.04	1	1	1	1	2	1	2	0	3	3	1
Microlejeunea bullata (Taylor) Steph.	0.00	0.00	0.13	0.04	1	4	1	0	2	1	2	0	2	2	1
LEPIDOZIACEAE															
Arachniopsis monodactyla R.M. Schuster	0.00	0.27	0.00	0.09	1	2	2	0	1	1	2	0	1	3	3
Kurzia brasiliensis (Steph.) Grolle	0.00	0.40	0.00	0.13	1	1	1	0	2	1	1	0	2	3	3
Kurzia capillaris (Sw.) Grolle	0.00	0.33	0.00	0.11	1	1	1	1	2	1	2	0	2	3	3
Lepidozia inaequalis (Lehm. & Lidenb.) Lehm. & Lindenb.	0.00	0.07	0.00	0.02	1	1	2	0	2	1	2	0	2	3	3
Micropterygium campanense Spruce ex Reimers	0.00	0.07	0.00	0.02	1	1	2	1	2	1	1	0	3	2	3
Pteropsiella frondiformis Spruce	0.00	0.27	0.00	0.09	1	1	2	0	1	1	1	1	1	3	3
Telaranea diacantha (Mont.) J.J. Engel & G.L. Merril	0.00	0.20	0.00	0.07	1	1	2	0	1	1	1	0	1	3	3

Division/Family/Species	Frequency				Morpho-ecological characteristics										
	RP	R1	R2	FR%	GF	LH	SE	PA	LO	SS	SR	GE	LI	MI	BI
Telaranea nematodes (Gottsche ex Austin) M. Howe.	0.00	0.07	0.00	0.02	1	1	2	0	1	1	1	0	1	3	3
Zoopsidella integrifolia (Spruce) R.M. Schuster	0.00	0.33	0.00	0.11	1	1	2	0	1	1	1	0	1	3	3
LOPHOCOLEACEAE															
Leptoscyphus porphyrius (Nees) Grolle	0.00	0.07	0.00	0.02	1	1	2	0	1	1	2	0	2	3	3
METZGERIACEAE															
Metzgeria aurantiaca Steph.	0.07	0.00	0.00	0.02	1	1	1	0	2	1	1	1	2	2	1
Total: 47															

collection came close to the actual number of species that could be found to the area considering the means of each collection (ranging in six species for plus or minus) (Fig. 2).

Coverage and frequency analysis - The average cover for SU was 0.08% (wide range, with the min. 0% and max.3%) and the average species found was 3.91 (wide range, with min. 0% and max. 12).

The frequent species were *Campylopus savannarum* (Müll. Hal.) Mitt., *Campylopus dichrostis* (Müll. Hal.) Paris, *Campylopus heterostachys* (Hampe) A. Jaeger and *Campylopus angustiretis* (Austin) Lesq. & James, but none of these species found had absolute frequency above 50% (FR) (Table 2). In rocky fields of Chapada Diamantina, Bahia state, the species of this genus were also found showing greatest richness, growing often in exposed soil and on rocks (Bastos *et al*., 2000).

Morpho-ecological community characteristics - The occurrence of bryophytes species in the rocky fields areas presents distribution and floristic community composition homogeneous, in other words, when the rocky fields areas were analyzed separately (RP, R1 and R2) they showed an overlap between the sampling units (SU) (Fig. 3). This shows the type of community composition that rocky field environments select information that was unknown so far to Brazilian Cerrado bryophytes.

The acrocarpous was the main type of gametophyte growth found in mosses (Bryophyta), which is most common in open areas and exposed soils as found in rocky fields (Bastos *et al*., 2000). Therefore, the high frequency of species with acrocarpous habits in rocky fields in PARNA - Serra da Canastra can be in accordance with that statement, since the conditions and resources present in these environments influence and select this type of growth (Bastos *et al*., 2000; Bastos & Vilas Bôas-Bastos, 2008; Vanderpoorten & Goffinet, 2009).

Regarding the adaptive ecological characteristics, the species found are (34%) colonists and perennial “reviving” (32%), with direct light exposure tolerance (47%) (Table 1). This result reflects the environment found in rocky fields with temperature variations throughout the day, with exposure to wind and water restrictions. They have sandy soils, oligotrophic and acid from substrates containing quartzite-sandstone, beyond rocky outcrops and xeromorphic vegetation predominantly consists by herbs and shrubs (Giulietti *et al*., 1987; Conceição & Pirani, 2005; Rapini *et al*., 2008).

Regarding the moisture, the bryophytes resistant to desiccation percentage was lower (20%) than those that require water at intermediate levels (40%) or even excessive, typical of water satured environments (40%) (Table 1) since the rocky fields are drier environments (IBDF, 1981). This result may be related to the water need that bryophytes have to be able to reproduce sexually and diversify in the environment (Gradstein *et al*., 2001; Vanderpoorten & Goffinet, 2009), taking advantage of the water film formed during the rainy season due to low soil depth.

We can say that the species found have desiccation tolerance, seeing that 35 species (74%) had a long

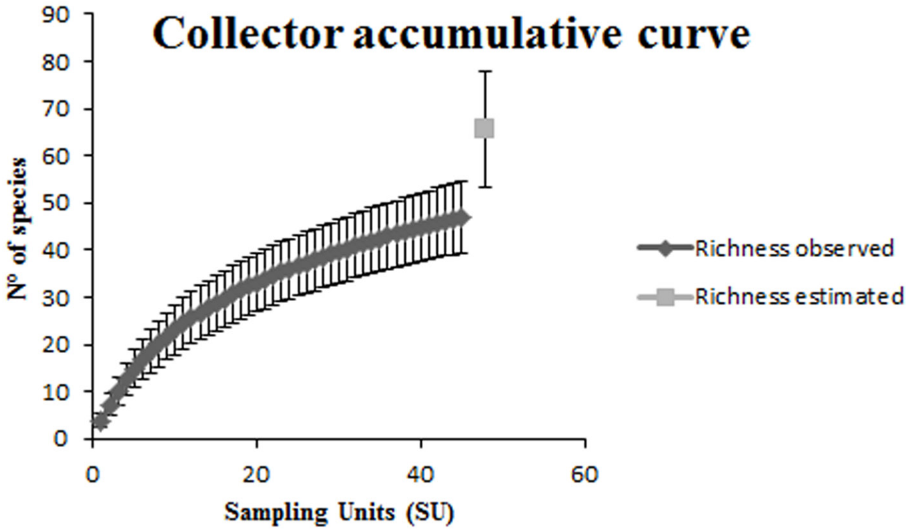

Fig. 2. Collector accumulative curve of rarefaction from Jackknife permutation method for rocky fields areas, showing the overlap and standards deviations between the samples units (SU).

life cycle (Table 1) and thus remain longer their lives in environments predominantly drier (IBDF, 1981). Furthermore, they take water to produce reproductive structures, since 32 species (68%) preferentially perform the sexual reproduction and 27 (57%) are dioicious (Table 1) revealing that most bryophytes species of rocky fields complete their life cycle in the rainy season.

The morphological characteristics show the predominance of species with small spores (94%), absence papillae on leaves cells (81%) and absence gemmaes (57%) (Table 1), highlighting the influence of bryophytes life cycle to concentrate energetic efforts to sexual reproduction. Possibly this result is in agreement with the characteristics of bryophytes be dependent on the water to achieve their sexual reproduction (Gradstein *et al*., 2001), being this type of reproduction most common in areas with higher moisture rates (Austrheim *et al*., 2005), but at this case it proved to be different, indicating other possible factors as yet unknown that must be further analyzed.

The rocky fields are oligotrophic, dry and directly exposed to solar effects environments (Rapini *et al*., 2008), thus it can compare to environments which are in initial ecological succession process as described in Raven (2001) for clearing areas. According to Vanderpoorten & Goffinet (2009) bryophytes have fundamental importance in the ecological succession process, and are considered pioneers when performing the rocks erosion, soil formations and provide microenvironments favorable to other plant species development. Based on the results found, 37 species showed

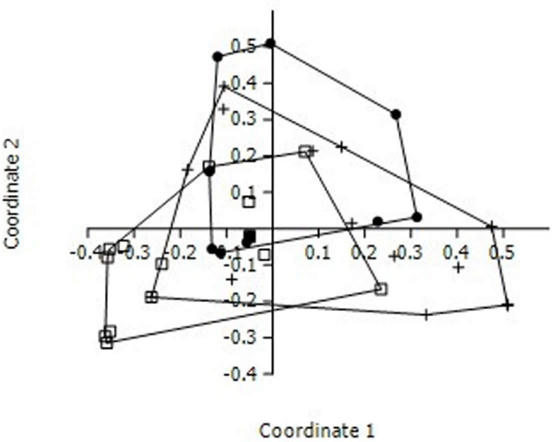

Fig. 3. Principal Coordinates Analysis (PCoA) of the rocky fields areas sampling units (SU) based on bryophytes communities floristic composition. ● - CP (Curral de Pedras), □ - R1 (Rocky fields I) and + - R2 (Rocky fields II).

tolerance to basic pH (79%) and 22 direct light exposure (47%) and are characteristics of soil and rock (Table 1), indicating an adaptation of these species for a possible environment regeneration process in rocky fields areas, which probably can be related as a result of fires that frequently occur in the region.

These results show the rocky fields areas as an important for bryophytes diversity in Cerrado *sensu lato*, since this plant formation has very specific characteristics that select the bryophyte community (Bastos *et al*., 2000). This fact was evidenced when we determined, based on the samples analysis, that the composition of bryophytes community in rocky fields of Serra da Canastra National Park is homogeneous. The characteristics such as gametophyte growth, tolerance to direct sunlight, desiccation and long life cycle allowed them to install in this type of environment, however, we emphasize the need of more bryophytes ecological studies to have a broad knowledge about the relationship between these organisms and the environment in order to explain and justify the maintenance and preservation of them.

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