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Original Paper

Floristic composition, structure and species-area relationships on a neotropical inselberg in southeastern Brazil

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Abstract

The inselberg vegetation, in general, occurs in patches that vary in size, shape, number of plant species and are surrounded by a bare rock. The present study evaluated the species composition, structural analysis, and species-area relationships of vegetation patches on a neotropical inselberg in Rio de Janeiro state, southeastern Brazil. A total of 69 vascular plant species, from 31 families, were sampled in 84 vegetation patches varying in area from 0.02 to 500 m^2, totaling 0.33 ha. Fabaceae and Cactaceae were the most representative families. *Vellozia plicata* and *Selaginella sellowii* presented the highest relative frequencies, relative dominances and importance values and were the most successful in the colonization of the studied rocky outcrop. A linear regression showed a positive correlation between patch size and species richness. Phanerophytes were the predominant life-form, with small patches being less rich in species and dominated by *Selaginella* mats. Our results suggest that the vegetation patches on the "Morro do Itaoca" inselberg currently represent a refuge against fire and other anthropogenic disturbances for many typical species of the surrounding matrix. In addition, the locality is home to endemic and endangered species, which reinforces its importance for conservation actions.
Key words: Atlantic Forest, conservation, endangered species, life forms, rock outcrops.

Resumo

A vegetação de inselbergs, em geral, ocorre em manchas que variam em tamanho, forma e número de espécies e são cercadas por uma matriz de rocha nua. O presente estudo avaliou a composição de espécies, estrutura e a relação espécie-área em um inselberg neotropical no Estado do Rio de Janeiro, sudeste do Brasil. Foram amostradas 69 espécies de plantas vasculares, de 31 famílias, em 84 manchas de vegetação com área variando de 0,02 a 500 m², totalizando 0,33 ha. Fabaceae e Bromeliaceae foram as famílias mais representativas. *Vellozia plicata* e *Selaginella sellowii* apresentaram as maiores frequências relativas, dominâncias relativas e valores de importância e foram as mais bem sucedidas na colonização do afloramento rochoso estudado. A regressão linear mostrou uma correlação positiva entre o tamanho da mancha e a riqueza de espécies, e fanerófito foi a forma de vida predominante, com pequenas manchas apresentando menor riqueza de espécies e dominadas pelos tapetes de *Selaginella*. Nossos resultados sugerem que os trechos de vegetação no inselberg Morro do Itaoca representam atualmente um refúgio contra incêndios e outros distúrbios antropogênicos para muitas espécies típicas da matriz circundante. Além disso, a localidade abriga espécies endêmicas e ameaçadas de extinção, o que reforça sua importância para as ações de conservação.
Palavras-chave: Mata Atlântica, conservação, espécies em perigo, formas de vida, afloramentos rochosos.

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Introduction

Precambrian rocky outcrops are hotspots of plant diversity around the world supporting plant communities that are distinctive, both structurally and floristically, from the surrounding vegetation (Safford & Martinelli 2000; Porembski 2007; Hopper 2009; Sarthou *et al.* 2017; de Paula *et al.* 2017). In Brazil, rupicolous vegetation grows on a range of underlying substrates, including quartzite-sandstone (Conceição & Pirani 2005; Alves *et al.* 2014;), ironstone (Jacobi *et al.* 2007; Lima *et al.* 2019), carbonate or karstic outcrops (Bystriakova *et al*. 2019) and granite and/or gneiss outcrops (Porembski *et al.* 1998; Meirelles *et al.* 1999; Couto *et al.* 2016, 2017; de Paula *et al.* 2017; Pereira *et al.* 2018). In the Atlantic Forest Domain in southeastern Brazil, rocky outcrops of granite and/ or gneiss predominate, with different degrees of insulation, sizes, and elevations, ecologically known as inselbergs (Safford & Martinelli 2000; de Paula *et al*. 2020). Inselbergs represent isolated terrestrial islands that rise above from their surrounding natural ecosystems, mainly tropical forests (Barthlott & Porembski 2000; Sarthou *et al*. 2017).

Inselbergs are ecosystems characterized by strong ecological isolation due to severe environmental filters, including high exposure to radiation, high evaporation, total or partial absence of soil, low water and nutrient availability and exposure to constant wind (Porembski & Barthlott 2000a). This environmental filters are responsible for the high richness and endemism in these environments (Safford & Martinelli 2000; Porembski 2007; de Paula *et al*. 2017), that present a floristic composition clearly distinguished from their surrounding matrices (Porembski 2007; de Paula *et al*. 2015). However, despite the ecological importance of this ecosystem (Hopper 2009; Porembski *et al*. 2016) inselbergs are threatened, mainly by mining activities (Hopper 2009).

In Brazil, the number of studies on inselberg vegetation has been increasing, especially in the last decades (Araújo *et al.* 2008; Gomes & Alves 2009, 2010; Couto *et al.* 2017; de Paula *et al.* 2017; Pena & Alves-Araújo 2017; Francisco *et al.* 2018; Paulino *et al.* 2018; Pereira *et al.* 2018). However, ecological and phytosociological studies of plants communities are still scarce (Porembski *et al.* 1998; Safford & Martinelli 2000; Meirelles *et al.* 1999; Medina *et al.* 2006; Caiafa & Silva 2007). The difficulty in establishing replicable samples in different topographies and habitat heterogeneity on rocky outcrops helps to explain this scarcity of studies (Caiafa & Silva 2007).

Rupicolous vegetation on inselbergs is generally distributed in isolated patches of different sizes, shapes and limited on all sides by the rocky surface (Meirelles *et al.* 1999; Ribeiro *et al.* 2007; Conceição *et al.* 2007a, 2007b; de Paula *et al.* 2015, 2019) and these patches contain aggregates of a few to many species. The increase in species richness in the patches over time can be attributed to an increase in area as emphasized the Island Biogeography Theory (MacArthur & Wilson 1967). Large patches may have greater resource availability, mainly due to deeper soils (Houle 1990; Meirelles *et al.* 1999; Michelangelli 2000; Gram *et al.* 2004; de Paula *et al.* 2015, 2019; Villa *et al.* 2018).

In the northern region of Rio de Janeiro state, southeastern Brazil, inselbergs are distributed in an anthropized matrix, and are very isolated in the landscape. The biodiversity of these environments is directly threatened by the mining and extractivism of plants (Pessanha *et al*. 2014). Furthermore, inselbergs in this region have been neglected in scientific studies, with few publications on their biodiversity (Aguiar & Gaglianone 2011; Pessanha *et al*. 2014; Mauad *et al*. 2014; Marques *et al*. 2018), and this prevents conservation actions for inselbergs in this area.

In this context, we studied the structure of vascular plant communities in vegetation patches, of different sizes, on an inselberg in the northern region of Rio de Janeiro state, due to the importance of the inselberg vegetation for the floristic diversity of Rio de Janeiro (Werneck *et al.* 2011) and the pressure from the mining industry in the region. Our expectations were that the flora of Morro do Itaoca inselberg harbors a number of endemic plant species and rupicolous species richness increases with patch size. Thus, we hope to contribute positively to the knowledge of rupicolous flora in southeastern Brazil, and our data will serve as a basis for conservation and restoration actions of these unique rock outcrop systems.

Material and Methods

Study site

The study was conducted on an inselberg in the Atlantic Forest Domain (21°48'S, 41°26'W), known as Morro do Itaoca, located in the

municipality of Campos dos Goytacazes, in the northern region of Rio de Janeiro state (Fig. 1). The climate in the region has been classified as AW (*sensu* Köppen 1948), characterized by tropical hot and humid with a dry winter (April to September) and wet summer (October to March). The Morro do Itaoca stands amidst the surrounding flat landscape and flooded areas that can be characterized by a vegetation mosaic, represented mostly by Seasonal Semidecidual Forest (*sensu* Vellozo *et al.* 1991). Aside from the natural communities, the inselberg is in an anthropogenic matrix of livestock and sugarcane plantations and rock mining activity (Pessanha *et al.* 2014; Marques *et al.* 2018).

The area sampled is located on the west face of Morro do Itaoca and covers approximately 20 ha. It is situated along an elevation gradient ranging from 8 to 266 m a.s.l., extending 900 m from the base to the top of the inselberg. This area was selected because of its accessibility without the need for rock climbing equipment (Fig. 2).

Data collection

Vegetation patches were sampled between October and November 2007, along three parallel linear transects of 900 m in length distributed systematically in intervals of 40 m. This arrangement allowed us to maximize environmental variation in the sampling. All vegetation patches (from now on, patches) intercepted along the transections were examined and the composition and abundance of vascular plants in each patch was recorded and quantified. The surface area of each patch was estimated through the maximum width and length of each patch, measured with a tape measure, and subsequently applying the equation for calculating an ellipse, according to de Paula *et al*. (2019). The cover of each species in each patch was estimated using the mean value of a six-point scale (modified from Daubenmire 1959): 2.5 (0–5%), 7.5 (5–10%), 17.5 (10–25%), 37.5 (25–50%), 62.5 (50–75%) and 87.5 (75–100%).

Taxonomic identification was done using specialized taxonomic literature, herbarium data and

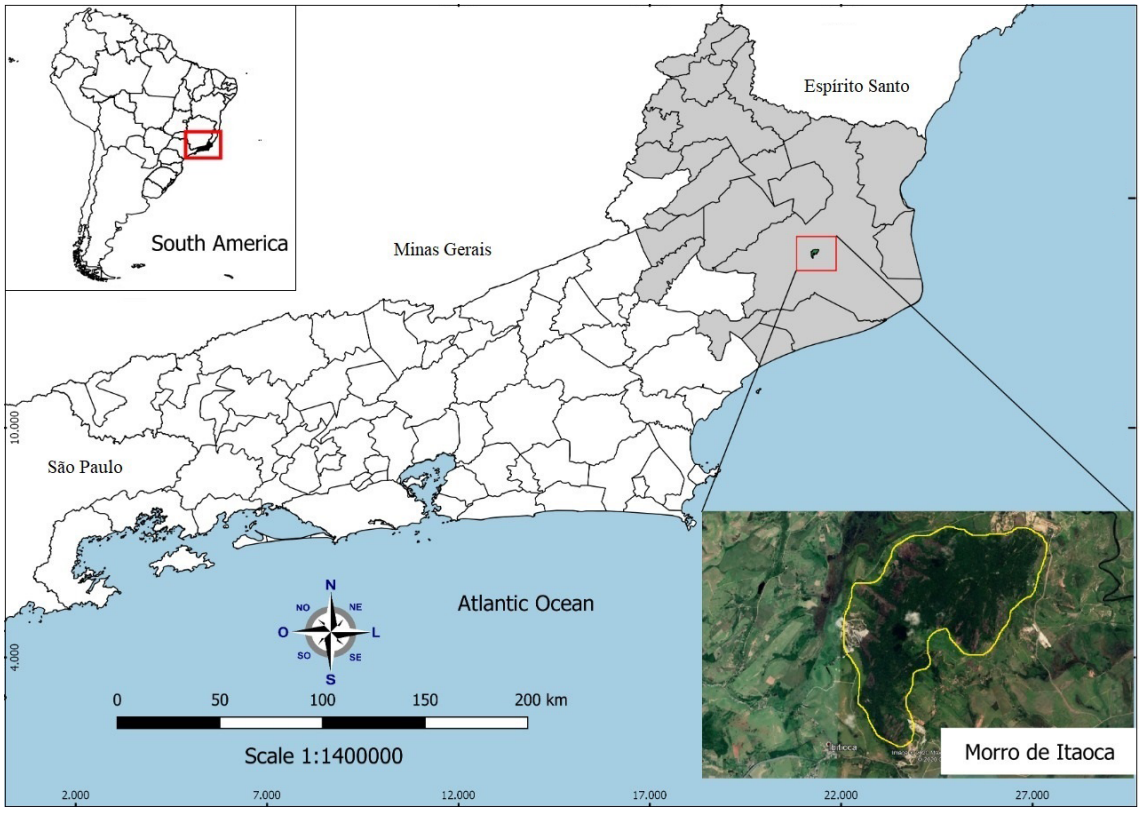

Figure 1 – Location of the Morro do Itaoca inselberg, with emphasis on the north/northwest Fluminense region, highlighted (in gray), Rio de Janeiro state, southeastern Brazil.

Figure 2 – a. General view of the Morro do Itaoca inselberg, Campos dos Goytacazes, Rio de Janeiro state, and its surrounding matrix. b. monospecific community of the poikilohydric fern *Selaginella sellowii* in small patches. c. typical landscapes of the north Fluminense region, with flat and flooded areas, livestock activities and Desengano State Park mountains in the back. d. view of a large vegetation patch, with occurrence of *Vellozia plicata*, *Coleocephalocereus fluminensis*, *Anthurium minarum* and *Selaginella sellowii*, restricted to the edge of a large patch. e. rock mining in Morro do Itaoca, the greatest threat to its flora. Photos by D.R. Couto.

by sending specimens to specialists. An exception was for the Poaceae family, because in addition to the difficulties in taxonomic identification, it was not easy to recognize individuals in the field, which in many cases formed dense clusters that made it difficult to assess unless we pulled and separated the material. Thus, to ensure better data quality, we lumped all morphospecies of Poaceae (ca. three) into one group denominated Grass.

Species names and authors followed the Flora do Brasil 2020 on-line (<http://floradobrasil.jbrj.gov.br/>) and endangered species were cited according to the official list of endangered species of Centro Nacional de Conservação da Flora (CNC Flora 2019 - <http://floradobrasil.jbrj.gov.br/>). The classification of angiosperm families follows the recommendations of APG IV (2016) for magnoliids, monocotyledons (monocots), and eudicotyledons (eudicots), and PPG I (2016) for lycophytes and monilophytes (grouped together as ferns). Species life forms were classified according to Raunkiaer (1934), with adaptations: Ch = chamaephyte, Cr = cryptophyte (including geophytes), Hc = hemicryptophyte, Ph = phanerophyte, Th = therophyte and Epi = epiphyte. Voucher specimens were deposited in the herbaria HUENF and RB (herbaria acronyms follow Thiers, continuously updated).

Data analysis

The phytosociological parameters calculated for the species were: absolute and relative frequency (AF; RF), absolute and relative dominance (ADo; RDo) based on species cover value, and importance value index (IV) (Müller-Dombois & Ellenberg 1974). We calculated the importance value index (VI) by the sum of the relative values of frequency (RF) and dominance (RDo) (Müller-Dombois & Ellenberg 1974 modified by Caifa & Silva 2007) and expressed it as a percentage (%VI = RF+RDo/2).

We used linear regression to test the relationship between species richness and patch size, species richness was used as the dependent variable and patch size as the independent variable. Both variables were log-transformed before analysis. The transformed data followed the assumptions of normality and homoscedasticity of the residuals.

Differences in species richness by patch size class were evaluated using the non-parametric Kruskal-Wallis test (Zar 2010), since Shapiro-Wilk and Levene's tests showed non-normality and non-homoscedasticity of the data. *A posteriori* comparisons were conducted using Dunn's post hoc test. Differences were considered significant at $p < 0.05$. All analyses were performed using the R software (R Development Core Team 2019).

Results

We sampled 84 vegetation patches with a total area of 3,344 m² (0.33 ha). The patches varied in size from 0.02 to 500 m² and were distributed in 31 small (≤ 5 m²), 24 medium (5–25 m²), and 29 large (> 25 m²), with an average match size (m²) of 1.09 ± 1.18 (small), 12.56 ± 5.50 (medium) and 103.74 ± 114.09 (larger).

A total of 69 species (considering grass group as a species), 59 genera and 31 families, were sampled in the 84 patches (Tab. S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.16864600.v1>). The most representative families were Fabaceae (8 spp.), Cactaceae (7 spp.), Asteraceae (6 spp.), Orchidaceae and Bromeliaceae (5 spp. each), Malvaceae and Cyperaceae (4 spp. each). These families accounted for 57% of the total species richness recorded in the patches. The contribution of the most representative families according to the size classes of the patches showed that only Cactaceae and Malvaceae had representation in the small patches (Fig. 3). The species with the highest relative frequency in the sample were represented by two poikilohydric species, *Selaginella sellowii* Hieron. (13.42%) and *Vellozia plicata* Mart. (9.27%), followed by the cacti *Coleocephalocereus fluminensis* (Miq.) Backeb. (9.27%) (Tab. S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.16864600.v1>).

When we compared the relative frequency of the main species between the different patch size classes (Tab. S2, available on supplementary material <https://doi.org/10.6084/m9.figshare.16864600.v1>), the results were similar to the pattern found for the general sampling, with these three species occurring as the most representative in all patch size classes. *Selaginella sellowii* was by far the most frequent species in all the patch size classes, forming mats in 100% of the patches.

According to the RDo, species with the highest values in the sample were *V. plicata* (50.96%), *S. sellowii* (18.89%), Grass group (5.49%), and *C. fluminensis* (2.34%) which altogether amounted to 77.68% of the RDo (Tab.

S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.16864600.v1>). The RDo values in the different sizes patches, showed *S. sellowii* (small = 44.5%; medium = 52.5% and larger = 11.7%) and *V. plicata* (small = 39%; medium = 24.9% and larger = 53.6%) as the most dominant species (Tab. S2, available on supplementary material <https://doi.org/10.6084/m9.figshare.16864600.v1>).

Vellozia plicata had the highest importance value (30.11%), followed by *S. sellowii* (16.15%) and *C. fluminensis* (5.8%), which together represent 52% of the importance value. Ten species were responsible for 70.2% of the total importance value (Tab. S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.16864600.v1>). This pattern was observed in all three patch size classes, with *S. sellowii* and *V. plicata* having the highest importance value indices (Tab. S2, available on supplementary material <https://doi.org/10.6084/m9.figshare.16864600.v1>). In general, the 20 most abundant species in the patch size classes represented around 80% or more of the importance values (Tab. S2, available on supplementary material <https://doi.org/10.6084/m9.figshare.16864600.v1>).

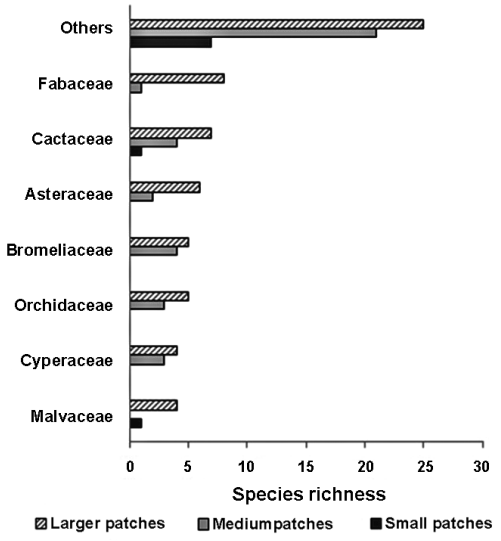

Figure 3 – Contribution of the main families of vascular plants recorded in the 84 vegetation patches sampled on the Morro do Itaoca inselberg, Campos dos Goytacazes, Rio de Janeiro state, southeastern Brazil. Vegetation patch classes: small (≤ 5 m²; n = 31), medium-sized (5–25 m²; n = 24), and large (> 25 m²; n = 29).

The total number of species per patch size class was nine (small), 38 (medium) and 64 (large). The median values of species richness per patch size class were significantly different (Kruskal-Wallis test, $x^2 = 58.44$, df = 2, $p < 0.0001$), with small patches having lower richness. There was a strong and significant positive relationship between the area of the vegetation patch and the number of vascular rupicolous species ($r^2 = 0.699$, $p < 0.001$; Fig. 4).

The predominant life-form in the patches were phanerophytes with 19 species (28%), followed by therophytes with 16 species (23.53%), hemicryptophytes with 12 species (17.65%) and chamaephytes with 11 species (16.18%). Epiphytes and cryptophytes did not occur in the small patches. However, all other life forms had an increase of representativeness in the largest patches, mainly therophytes and phanerophytes (Fig. 5).

Of the 69 species recorded on the patches, three are threatened species (*sensu* CNCFlora 2019): *Hippeastrum striatum* (Lam.) Moore, *Wunderlichia azulensis* and *Coleocephalocereus fluminensis*, all classified as Endangered (EN).

Discussion

The most dominant species on the Morro do Itaoca inselberg (*Vellozia plicata*, *Coleocephalocereus fluminensis*, *Selaginella sellowii*, *Trilepis lhotzkiana* Nees *ex* Arn.,

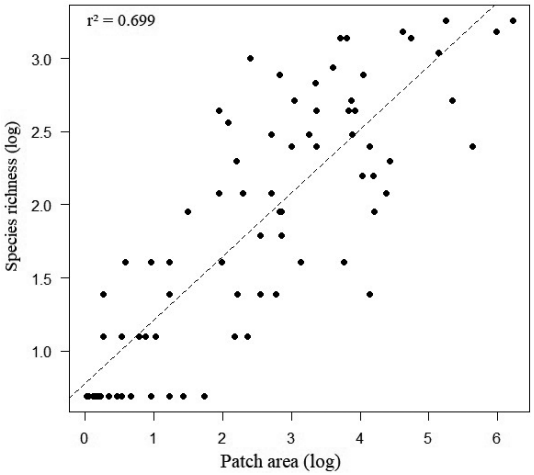

Figure 4 – Linear regression between species richness and vegetation patch size ($r^2 = 0.699$, $p < 0.001$) on Morro do Itaoca inselberg, Campos dos Goytacazes, Rio de Janeiro state, southeastern Brazil.

Cyrtopodium glutiniferum Raddi) were also recorded in other studies on inselbergs in southeastern Brazil (Porembski *et al*. 1998; Meirelles *et al*. 1999; Couto *et al*. 2017; de Paula *et al.* 2017). They were also mixed with species typical of the lowland semi-deciduous seasonal forest that surrounds the inselberg (*e.g.*, *Astronium graveolens* Jacq., *Casearia decandra* Jacq., *Passiflora alata* Curtis). However, species considered the most important (according to IVI) on the rocky outcrop were *V. plicata*, *S. sellowii* and *C. fluminensis*. *Vellozia plicata* is a rocky outcrop-specialist (it does not occur in the surrounding matrix), tolerant to desiccation, which forms mats on inselbergs in southeastern and northeastern Brazil (Porembski *et al.* 1998; Lucena *et al*. 2015). This species has been recognized as one of the most frequent species on coastal inselbergs in Rio de Janeiro state, along with *S. sellowii* and *C. fluminensis* (Meirelles *et al.* 1999).

Species richness recorded in vegetation patches on the Morro do Itaoca inselberg was higher than values found for four quartizite-sandstone rocky outcrop areas in Bahia (Conceição *et al.* 2007b), on an inselberg in the Amazon domain in Venezuela (Villa *et al*. 2018) and close to the richness recorded on eight other coastal inselbergs in Rio de Janeiro (Meirelles *et al.* 1999). The main factor that contributed to the floristic richness of the Morro do Itaoca inselberg, in addition to the rocky outcrop specialist species, was the presence of species of broad ecological value, capable of colonizing different types of habitats. Of all the species sampled, those belonging to the families Fabaceae, Salicaceae, Passifloraceae, Phyllantaceae, Clusiaceae, Euphorbiaceae and Calophyllaceae, are typical of the surrounding vegetation. Other families, like Asteraceae, Bromeliaceae, Malvaceae and Orchidaceae have species with wide distribution in different Brazilian ecosystems, and in the study area, and are represented by a few inselberg specialists (see Tab. S1, available on supplementary material <https://doi.org/10.6084/m9.figshare.16864600.v1>). Typical species of the surrounding vegetation on the rock outcrop vegetation were also registered on other tropical inselbergs (Burke 2002; Gram *et al.* 2004; Ribeiro *et al.* 2007; Couto *et al.* 2016, 2017), and questions about the inselbergs' relationship with the surrounding flora need more detailed studies (Scarano 2002). However, the number of species per sampled area was lower than values found in other studies of vegetation patches on rocky outcrops in Brazil and Venezuela (Meirelles *et al*. 1999; Ribeiro & Medina 2007; Conceição *et al*. 2007a, 2007b; Villa *et al*. 2018) (Tab. S3, available on supplementary material <https://doi.org/10.6084/m9.figshare.16864600.v1>).

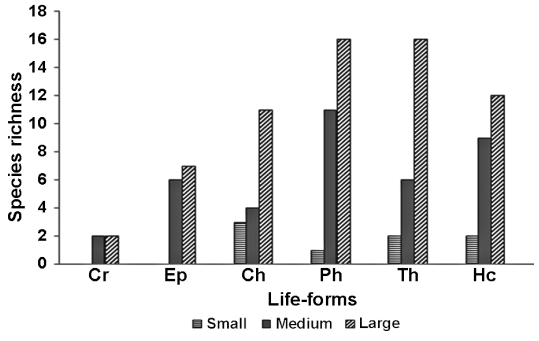

Figure 5 – Life-forms recorded in different patch size classes on the Morro do Itaoca inselberg, Campos dos Goytacazes, Rio de Janeiro state, southeastern Brazil. Cr = cryptophyte; Ep = epiphyte; Ch = chamaephyte; Ph = phanerophyte; Th = therophyte; and Hc = hemicryptophyte. Vegetation patch classes: small (≤ 5 m²; n = 31), medium (5–25 m²; n = 24), and large (> 25 m²; n = 29).

The poikilohydric species *S. sellowii* together with *V. plicata*, are the most frequent species on the Morro do Itaoca, forming mats. Species of the genera *Selaginella* and *Vellozia* occur as typical constituents of mat communities on Neotropical inselbergs (Porembski *et al.* 1998) and together with *C. fluminensis*, the third most frequent species in the sampled patches, they stand out in coastal inselbergs of the Rio de Janeiro State (Meirelles *et al.* 1999).

Three species, *V. plicata*, *S. sellowii* and *C. fluminensis*, with high frequency and dominance, form the group of greatest importance in the rupicolous community of the Morro do Itaoca inselberg, with 52% of the total. This oligarchic structure with a small number of dominant species and many rare species has also been recorded on other granite rock outcrops in southeastern Brazil (Meirelles 1996; Caiafa & Silva 2007), as well as on quartzite-sandstone outcrops (Conceição 2003) and it seems to follow a pattern for vegetation on rocky outcrops.

We found that *S. sellowii* has greater dominance (coverage) and importance value in small and medium size classes, however, it loses

space to *V. plicata* in the larger patches (see Tab. S2, available on supplementary material <https://doi.org/10.6084/m9.figshare.16864600.v1>). According to some authors (see Ibish *et al.* 1995; Porembski *et al*. 2000), *Selaginella* species, mainly *S. sellowii*, represent a pioneer stage in the colonization of rocky outcrops, which are replaced by other groups in succession (mainly woody, monocots and eudicots), getting restricted to the peripheral areas of the patches (see Fig. 2e). *Selaginella sellowii* has a wide distribution in rocky environments, occurring from the Neotropics to Mexico (Heringer *et al.* 2016), is tolerant to desiccation and, in many cases, forms monospecific mats (Ibish *et al.* 1995; Porembski *et al.* 2000) as observed in the study area (see Fig. 2b). The mats formed by *S. sellowii* and *V. plicata* on the Morro do Itaoca possibly serve as a substrate, acting as nurse plants (Scarano 2002; Medina *et al.* 2006) for other plant groups, including species of the surrounding matrix, which are unable to establish directly on bare rocks.

In this study, the number of species increased significantly with increasing patch size, as predicted by the Island Biogeography Theory (MacArthur & Wilson 1967), corroborating one of the most consistent patterns in ecology (Begon 2006; Dodds 2009). This pattern is largely shown by other studies on inselberg-isolated patches (Porembski *et al*. 1996; Meirelles *et al*. 1999; Michelangeli 2000; Gram *et al*. 2004; Villa *et al*. 2018; de Paula *et al*. 2019; Henneron *et al*. 2019). Patch size includes a number of aspects that affect vascular plants richness, including mainly age (the time available for establishment of plants), surface area and microhabitats available for colonization. Also, large patches may have greater amount and depth of soil, which may promote more diverse plant communities (Houle 1990; Michelangeli 2000; Gram *et al.* 2004; Henneron *et al*. 2019). According to Houle (1990), soil availability appears to follow a gradient of depth, from the edge to center of the patches, providing different habitats for colonization of species with different ecological requirements. Thus, with the exception of epilithic species (which grow directly on the exposed rock), it can be speculated that colonization by rupicolous vegetation is more restricted where the soil is less developed (smaller patches or edges of larger patches) and constitutes a abiotic barrier for many species (Houle & Phillips 1989; Gram *et al.* 2004).

Phanerophytes were the most prevalent life form, similar to other rocky outcrops in Brazil (Meirelles *et al.* 1999; Ribeiro & Medina 2002; Conceição & Pirani 2005; França *et al.* 2005; Conceição *et al.* 2007; Gomes & Alves 2010; de Paula *et al.* 2017; Pena & Alves-Araujo 2017). In the study area, the phanerophytes (vines, cacti, subshrubs, shrubs and trees), occurred mainly in medium and increased their larger patches. In general, all life forms expanded their contribution in larger patches, probably due to soil development in these size classes, as suggested by other authors (Michelangeli 2000; Gram *et al.* 2004; de Paula *et al.* 2017).

Therophytes, the second most represented group in this study, have low representivity on Atlantic Forest inselbergs (Safford & Martinelli 2000; Caiafa & Silva 2005; Ribeiro *et al.* 2007), compared to inselbergs of the Caatinga Domain (Araújo *et al.* 2008; Gomes & Alves 2010) and Africa (Porembski *et al*. 1996, Porembski & Barthlott 1997). Its representativeness is due to the presence of a high number of ruderal species, typical of pastures that occur in the surrounding area present at the base of the inselberg.

An absence of epiphytes in small patches can be explained by the low (or lack of) availability of substrates (trunk and branches of woody plants - phorophytes) for colonization. The richness of epiphytic species in rocky outcrops is related mainly to woody-plant species (Alves *et al.* 2008; Couto *et al.* 2016, 2017; Francisco *et al.* 2018; Henneron *et al.* 2019) or number of stems of *Vellozia* genus (Werneck & Espírito-Santo 2002; Porembski 2003), associated with a positive effect of rainfall and altitude (Henneron *et al.* 2019). Epiphytes represent a key group in tropical ecosystems because they provide fundamental resources for fauna such as nectar, fruit, shelter, nesting material and sites, making neotropical ecosystems the most complex in the world (Benzing 1999).

The rupicolous vegetation patches sampled on the Morro do Itaoca included 15 endemic species from rocky outcrops in southeastern Brazil. The southeastern Brazil is recognized as a worldwide center of richness and endemism of inselberg plants (de Paula *et al*. 2020), along with Madagascar and eastern Australia (Porembski 2007). In addition, the Morro do Itaoca is home to rare species, such as *Cryptanthus delicatus* Leme, a small bromeliad described in the 90's (Leme 1995) endemic to this location. Other rupicolous

taxa such as *Begonia ibitiocensis* E.L. Jacques & Mamede (Begoniaceae - Jacques & Mamede 2004), *Sinningia bragae* Chautems, M. Peixoto & Rossini (Gesneriaceae - Chautems *et al.* 2015) and *Pleroma ceciliana* P.J.F.Guim.& Oliveira da Silva (Melastomataceae - Guimarães & Silva 2015) were described from samples collected in this location. These data, together with the presence of endangered species, increasing mining activities, removal of ornamental plants and fire occurrence (Pessanha *et al.* 2014) reinforce the need for conservation actions for Morro do Itaoca.

It is important to note that inselbergs provide relevant ecosystem services (Porembski *et al*. 2016). The runoff from the rocky slopes can increase the supply of drinking water surrounding human populations and provide nutrients for surrounding agricultural areas (Schut *et al*. 2014). The inselbergs also may serve as refugia for biodiversity (Burke 2002; Couto *et al*. 2016) as well as promoting regional development through ecotourism, adventure sports and cultural activities (Porembski & Barthlott 2000b; Larson *et al*. 2000), generating financial resources and life quality for families living around these ecosystems.

However, habitat destruction generated by mining activity is surely the biggest global threat to inselberg vegetation in worldwide (Porembski *et al*. 2016), and negatively affects the people who live around them. In addition, the licensing of mining activity usually does not include the inventory of the biota associated with this environment, including its flora, probably due to its non-forest vegetation, completely disregarding the unique biota of these ecosystems (Couto *et al.* 2019).

In this study, we present information on the most abundant species (especially the nurse species, *Vellozia plicata* and *Selaginella sellowii*) that can be very useful for restoration purposes, which is highly desirable on the study area that faces serious threats because of the mining sector. Restorationists, based on our data, can select species based on their functional role (*e.g.*, nurse species) and on their abundance. However, it is necessary for public authorities to pay more attention to these environments, promoting laws that guarantee the protection of the biodiversity of these ecosystems.

The presence of threatened species and endemism is recognized as a priority indicator for the creation of protected areas worldwide (Brooks *et al.* 2006; Mittermeier & Scarano 2013). Thus, we hope that our results reinforce the urgent need to protect the Morro do Itaoca, with its rich biodiversity and its natural resources serving as guide for conservation actions in this important location in the northern region of Rio de Janeiro.

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