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Lianas, tree ferns and understory species: indicators of conservation status in the Brazilian Atlantic Rainforest remnants, southeastern Brazil

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Abstract

Indicators are applied faster and at lower costs than conventional surveys, providing quick and efficient responses that can facilitate protected areas management. Our aim was to select indicators from vegetation to monitor protected areas. For this purpose, we analyzed understory and quantified lianas and tree ferns in protected and non-protected areas, in order to find indicator species. Our study areas are located in Vale do Ribeira, southeastern São Paulo state, Brazil. One of the areas is under two protection categories (IUCN's categories II and V), and the other is a privately owned farm. Lianas with large diameters (> 13 cm) and tree ferns with great heights (> 19 m) were considered indicators of undisturbed areas (protected areas) because their growth is directly related to forest successional stage. Indicator species within the protected area were shade tolerant species, such as *Bathysa australis* (A.St.-Hil.) K.Schum., whereas outside the protected area were pioneer species, such as *Pera glabrata* (Schott) Poepp. ex Baill. e *Nectandra oppositifolia* Ness. All of the suggested indicators can be used in management actions, especially in protected areas, to guarantee forest maintenance and ensure fulfillment of the conservation objectives of these areas.

Keywords: successional stages, indicator species, protected areas, Brazilian Atlantic Rainforest.

Lianas, fetos arborescentes e espécies de sub-bosque: indicadores do estado de conservação da Mata Atlântica brasileira

Resumo

Os indicadores são aplicados com menores custos e mais rapidez em comparação com levantamentos convencionais, fornecendo respostas rápidas e eficientes que podem facilitar a gestão das áreas protegidas. Nosso objetivo foi selecionar indicadores de vegetação para monitorar áreas protegidas. Para este fim, analisamos o sub-bosque e quantificamos as lianas e fetos arborescentes em áreas protegidas e não-protegidas em busca de espécies indicadoras. Nossas áreas de estudo estão localizadas na região do Vale do Ribeira, sudeste do Estado de São Paulo, Brasil. Uma delas é uma área protegida (categorias da IUCN II e V) e outra uma fazenda de propriedade privada. Lianas com grandes diâmetros (>13 cm) e fetos arborescentes com grandes alturas (>19 m) foram considerados indicadores de áreas não perturbadas (área protegida), pois seu crescimento está diretamente associado com o estágio sucessional das florestas. As espécies indicadoras da área protegida são não pioneiras, como *Bathysa australis* (A.St.-Hil.) K.Schum., já as da fazenda (não protegida) são pioneiras, como *Pera glabrata* (Schott) Poepp. ex Baill. e *Nectandra oppositifolia* Ness. Todos indicadores sugeridos podem ser utilizados em ações de gestão e conservação, especialmente em áreas protegidas, para garantir a manutenção dos remanescentes florestais e para assegurar o cumprimento dos objetivos destas áreas.

Palavras-chave: estágios sucessionais, espécies indicadoras, áreas protegidas, Mata Atlântica.

1. Introduction

The Atlantic rainforest is one of the world's biodiversity hotspots, because of its great diversity of species, level of endemism and threat (Myers et al., 2000). The Atlantic rainforest remnants are highly fragmented, mostly as small and isolated patches (Ribeiro et al., 2009). The largest continuous area of this domain is located in Vale do Ribeira, southeastern São Paulo State, Brazil. The remnants represent approximately 50% of what have not been ravaged (Kronka et al., 2005) and the main strategy to conserve the Atlantic Rainforest's biodiversity is via protected area establishment (Gaston et al., 2006; Le Saout et al., 2013).

Human disturbances are undesirable in highly restrictive protected areas such as IUCN categories I and II. Disturbance type and intensity – vegetation removal for agricultural land use, selective logging, selective harvesting of economically important species (e.g. Palm trees), among others – can lead to species substitution and other structural changes (e.g. decrease in height and diameter of canopy species) and to a return to an earlier successional stage (Guariguata and Ostertag, 2001). Light exposure, temperature, humidity (Denslow, 1987), canopy layer (Tabarelli et al., 1999), litter cover (Regina, 2001) are variables that change along the forest successional process, affecting structure and species composition (Guariguata and Ostertag, 2001). Intermediate disturbances (Connell, 1978) also contribute to occurrence of certain species and they even increment species richness in certain areas. Disturbances occur at forest fragments edges or in the core (or between conserved and degraded areas). In addition, they can cause heterogeneous environmental conditions, which may positively influence diversity and complexity of the system (Rodrigues et al., 2007; Vale et al., 2009).

In order to maintain the ecological integrity of a forest, it is necessary to provide information about status, condition and conservation value of protected areas (Noss, 1999). Monitoring conservation status of protected areas (PA) is a promising tool for assessing whether conservation objectives have been achieved or not. This assessment tool may help to protect the Atlantic Rainforest remnants and in decision making to minimize potential problems over time (Butchart et al., 2010). However, there are few monitoring programs of PA and many of them are focused on management and infrastructure (ICMBio, 2011) and not on conservation status, e.g., meeting biodiversity conservation goals (Le Saout et al., 2013).

In developed countries there are guidelines to monitor biodiversity (Gardner, 2010; Parrotta et al., 2012), mostly focused on certified forests outside protected areas. In developing countries, however, we lack systematic programs to monitor PA conservation effectiveness (Terborg and Davenport, 2002; Gaston et al., 2006; Le Saout et al., 2013). In addition, the complexity of biodiversity makes it virtually impossible to monitor all species (Lindenmayer et al., 2000). Therefore, the use of indicators to assess vegetation conservation status can be a useful tool for monitoring these areas (Noss, 1990). The advantage of using indicators is that they can be applied faster and at lower costs than conventional surveys, providing quick and efficient responses that can facilitate protected areas management (Carignan and Villard, 2002).

Indicators are defined as a signature or sign of a biodiversity feature, with quantitative and/or qualitative features that translate in a simplified and useful way the biodiversity aspects (Duelli and Obrist, 2003). The indicators choice should be based on criteria such as aptitude and response to environmental characteristics, and they should allow hypotheses tests (McGeoch, 1998; Duelli and Obrist, 2003). To be effective, an indicator must: (1) be sensitive and respond to changes in the ecosystem caused by human disturbance, (2) allow easy and reliable identification, (3) be viable and have low implementation costs (Carignan and Villard, 2002; Pearce and Venier, 2006). Lindenmayer et al. (2000) also suggest that indicators are identified as: (1) taxon-based biodiversity indicators - indicator species that can be used as proxies for other biodiversity components or for changes in the ecosystem; or (2) structure-based indicators - forest structure features that can be used as proxies for changes in the ecosystem.

An ecological monitoring program aims to detect changes in the ecosystem, usually those of anthropogenic origin, which can degrade environmental quality. In forest ecosystems it is difficult to detect indicator species capable of signaling those changes, especially plant species, because they can resist to disturbances and maintain structure and function relatively intact (Walker and Salt, 2006). In this context, our aim was to select vegetation indicators to monitor protected areas in the Atlantic Rainforest. We analyzed the understory and quantified lianas and tree ferns in protected and non-protected areas, in order to search for indicator species. We also evaluated the influence of environmental characters (i.e., light, canopy cover, humidity and litter cover) on vegetation (i.e., lianas, tree ferns and understory species). We selected areas based on the assumption that vegetation remnants located within protected areas would be more conserved, and in an advanced successional stage (i.e. high levels of canopy cover, litter cover and humidity and low levels of light available) compared to vegetation outside protected areas.

2. Material and Methods

2.1. Study areas

This study was conducted in two different areas – a protected area (PA) and a non-protected area (NPA) – which were approximately 65 kilometers apart, both in the Vale do Ribeira, southeastern of São Paulo State, Brazil (Figure 1). In this region, the predominant vegetation types are "Tropical Atlantic Forest Lowland, Submontane and Montane" which belong to the Atlantic Rainforest domain (IBGE, 2012); climate is characterized as warm and humid, with temperatures ranging from 18 °C to 22 °C (Barroso et al., 2010) and annual average precipitation is approximately 1500 mm (Gonçalves et al., 2000). In the PA soil type is mainly Alic Cambisol and in the NPA "GleizadoTiomorfico" (Dalmas, 2013).

The PA (24º 20' to 24° 46' S, 48º 03' to 48º 40' W) comprises Caverna do Diabo State Park (corresponding to category II of IUCN) with 40,000 hectares of total area and Quilombos do Médio Ribeira Environmental Protection Area (corresponding to category V of IUCN)

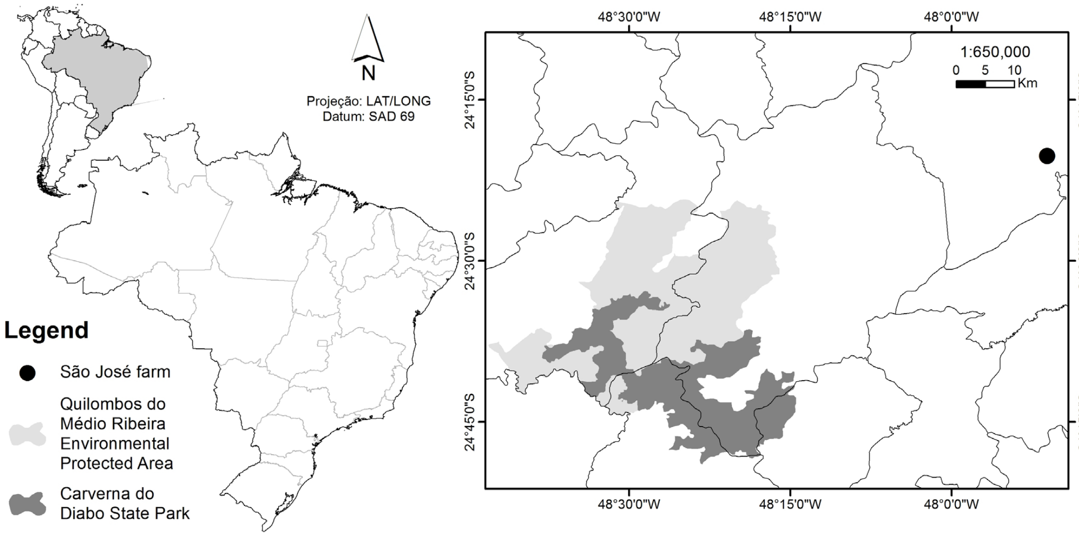

Figure 1. Location of the study areas in São Paulo State, Brazil. Protected area: PA - Caverna do Diabo State Park and Quilombos do Médio Ribeira Environmental Protected Area (dark and light gray); Non-protected area: NPA - São José Farm, Sete Barras, SP (black dot).

with 65,000 hectares of total area. These areas are mostly covered by continuous forests.

NPA - São José Farm (24° 20' 1.74" S and 47° 51' 31.66" W) – has 995.82 hectares and it is privately owned, not legally protected area. About 80% of the total area is economically explores with pasture for cattle and buffalos. The remaining area consists of native vegetation. Some remnants are abandoned plantations of *Hevea brasiliensis*, where native vegetation has regenerated over the past 25 years. In other forest areas there is no direct use by the owner. However, due to the lack of surveillance, there are selective logging and *Euterpe edulis* (palmito-jussara) harvest for palm heart.

2.2. Selection of indicators

In this study we selected two types of indicators, according to Lindenmayer et al. (2000): structure-based biodiversity indicators and conservation status or management indicator species. As structure-based biodiversity indicators we selected lianas and tree ferns, using diameter and height class for assessment, respectively. As conservation status or management indicator species we selected understory species composition. Lianas, tree ferns and understory species seem to be more sensitive to habitat changes than canopy species, considering the following features:

The abundance of lianas may be associated with changes caused by natural or anthropogenic disturbances (Engel et al., 1998; Laurance et al., 2001). Therefore, they may serve as indicators of disturbance (Medeiros and Torezan, 2013). In mature forests, it is expected to find individuals with a diameter greater than 10 cm (Hora and Soares, 2002). Additionally, abundance of lianas tends to decrease in undisturbed forest (Putz, 1984).

Tree ferns (mainly those belonging to the Cyatheaceae and Dicksoniaceae families) are representative in tropical forests (e.g. Atlantic Rainforest), sometimes reaching the canopy (Schmitt and Windisch, 2006). Their trunks can measure up to 30 cm in circumference and reach 15 m in height. Their growth rate is very slow and it has been related to forests successional stage (Schmitt and Windisch, 2012). Consequently, we expected to find more tree ferns with greater diameters and heights in mature forests, because they are positively influenced by higher canopy cover, humidity and lower light exposure found in advanced successional stages. In addition, commercially valuable tree ferns may be missing in some mature forests as a result of harvesting or even poaching (Schmitt and Windisch, 2006).

According to Milledge et al. (1991) an indicator must reflect the effects of a disturbance regime and it can be used to draw efforts to mitigate them. Understory species are involved in community maintenance processes (Guariguata and Ostertag, 2001). Consequently, understanding understory dynamics may provide valuable information regarding ecological integrity (Salles and Schiavini, 2007). Thus, composition of the understory can function as an indicator of the successional stage and guide management actions in a protected area.

2.3. Data collection

Data collection was carried out using plots (Müller-Dombois and Ellenberg, 1974). In each study site (PA - Caverna do Diabo State Park and Environmental Protection Area Quilombos do Médio Ribeira; and NPA - São José Farm) seven 20×20 m plots were randomly allocated. In the center of each plot we allocated one 2×20 m subplot. The understory was sampled in the subplots, and the lianas and tree ferns were sampled in the plots. All plots in PA were distributed at a minimum distance of 50 m and a maximum of 400 m apart from each other, and plots in NPA, at a minimum distance of 50 m to 200 m apart.

The understory vegetation was sampled in the subplot of 2x20 m and included all woody plants with a height ≥150 cm and a circumference at breast height (CBH) <15 cm. The specimens were collected in reproductive or vegetative phase and the material was pressed and dried for taxonomic identification. The specimens were later deposited in the SORO herbarium (Thiers, 2015).

In this study, we considered lianas as all climbing plants with woody stem that germinate in the soil, remain rooted throughout their lives and climb a support (Müller-Dombois and Ellenberg, 1974; Simpson, 2006). Lianas were sampled in plots of 20x20 m by counting all individuals and we measured the DBH (diameter at breast height) of the stem, but we have not performed the botanical identification. Tree ferns were sampled in plots of 20×20 m by counting all individuals with height greater than one meter, without performing botanical identification. We also measured the total height of the individuals.

2.4. Data analysis

An environmental characterization of the plots was carried out measuring the following parameters: light, canopy cover, relative humidity, and height of the litter layer. Those variables were chosen because they influence forest structure and understory composition (Medeiros and Torezan, 2013; Cardoso-Leite et al., 2013). Twenty measurements for each variable were taken at sampling points randomly assigned within each of the 20×20 m plots. The depth of the litter layer was measured with a 30 cm ruler, perpendicular to the ground surface; luminosity and relative humidity were measured in the morning to avoid bias, with the thermo-hydro anemometer *Termohigro Digital Lutron LM-8000* (Suganuma et al., 2008). Measures were always taken when the values were stabilized. Canopy cover was measured with a canopy densiometer (Lemmon, 1957).

We also characterized the plots according to the successional stage using resolution CONAMA 1/94 (Brasil, 1994), a Brazilian national legislation that defines the concept of successional stages in the Atlantic Rainforest domain. The CONAMA resolution is based on Budowski (1965) and it considers: (1) early successional stage - canopy cover ranging from open to closed, species from 1.5 m to 8.0 m high, diameter at breast height - DBH - (130 cm above the ground) up to 10 cm and low plant species richness (approximately 10 species); (2) intermediate successional stage - presence of strata at different heights, the upper stratum may have emergent trees, species from 4 to 12 m high, DBH up to 20 cm and significant plant richness (among 11 to 30 species), and might have dominance of some species; (3) advanced successional stage - large number of strata, with trees, shrubs, herbs, vines, epiphytes, etc., the upper canopy is generally horizontally wide, with maximum heights exceeding 10 m, average DBH is always greater than 20 cm and high plant species richness (more than 30 species).

Hereafter the plots are called: U-PA: undisturbed plots within protected area (advanced successional stage); D-PA: disturbed plots within protected area (early successional stage); and ID-NPA: intermediate disturbance plots outside protected area (intermediate successional stage).

The tree ferns and lianas measured within the plots were divided into height and diameter classes, respectively, using the Sturges' Rule (Vieira, 1991). As a result, tree ferns were distributed into five classes of height, each of them with an amplitude of 3.1 cm while the lianas were distributed into 11 classes of DBH, each with an amplitude of 1.3 cm. Tree ferns height classes were: class 1: 1m to <4.1 m; class 2: 4.1 m to <7.2 m; class 3: 7.2 m to <10.3 m; class 4: 10.3 to <13.4 m; class 5: 13.4 m to <16.5 m; class 6: 16.5 m to 19.6 m; class 7: >19.6 m. Lianas DBH classes were: class 1: 0.1 cm to <1.4 cm; class 2: 1.4 cm to <2.7 cm; class 3: 2.7 cm to <4.0 cm; class 4: 4.0 cm to <5.3 cm; class 5: 5.3 cm to <6.6 cm; class 6: 6.6 cm to <7.9 cm; class 7: 7.9 cm to <9.2 cm; class 8: 9.2 cm to <10.5 cm; class 9: 10.5 cm to <11.8 cm; class 10: 11.8 to <13.1 cm; class 11: >13.1 cm.

We performed a Canonical Correspondence Analysis - CCA (Borcard et al., 2011) (ANOVA permutation test, using 999 random permutations) in order to analyze relationships among understory species (filter to five individual, or more, per species), tree fern height classes, lianas DBH classes, studied areas, and the environmental characterization (Table 1). We also analyzed understory species using IndVal method (Dufrene and Legendre, 1997), which examines the relationship between species occurrence from the sampled sites, and according to classification of these sites considering characteristics of these areas (Dufrene and Legendre, 1997). In this study, we grouped our sampled areas by their successional stages. We expected to find more tree ferns with greater heights and lianas with greater diameters in undisturbed forests. To check that, ANOVA and Tukey's test were performed to compare the average height of tree ferns and average DBH of lianas. All the analyses were performed using R "vegan" and "indicspecies" packages (R Core Team, 2014).

3. Results

The majority of plots in PA (1, 2, 3, 5, 6 and 7) were classified as advanced successional stage, except plot 4, which that was classified as in early successional stage. All plots allocated in NPA were classified as intermediate successional stage.

In PA's understory, we sampled 195 individuals belonging to 75 species, 46 genera and 28 families. In NPA, 238 individuals belonging to 75 species, 44 genera and 31 families were sampled (Appendix A). From the total number of species sampled in both areas, 25 were sampled with more than five individuals, including the dead individuals, considered as one species. Considering IndVal analysis, *Bathysa australis* (Figure 2A) was considered an indicator of undisturbed areas (U-PA) ($p<0.001$; IndVal=1), *Piper arboreum* (Figure 2B) was considered an indicator of disturbed areas (D-PA) ($p<0.05$; IndVal=0.837), and none of the species could be related to intermediate disturbance areas (ID-NPA).

Table 1. Environmental characteristics of the studied sites: undisturbed protected area (U-PA) and intermediately disturbed non-protected area (ID-NPA).

Plots	Litter layer (cm)	Canopy cover (%)	Light (lux)	Humidity (%)
U-PA (1)	6.9	99.5	252.04	72.3
U-PA (2)	4.8	99.9	526.6	68.11
U-PA (3)	6.2	99.3	626.8	69.2
D-PA (4)	7	99.6	1149.2	68.8
U-PA (5)	7.9	99.9	3309.9	64.2
U-PA (6)	5.2	100	256.9	66.6
U-PA (7)	7.6	99.6	663.8	64.2
ID-NPA (8)	3.1	99	272.6	78.6
ID-NPA (9)	4	99.6	166.3	73.6
ID-NPA (10)	3.2	99.1	484.9	75.1
ID-NPA (11)	3.5	98	1050.4	72
ID-NPA (12)	3.6	99.4	452.6	74.1
ID-NPA (13)	2.85	99.5	340.9	70.1
ID-NPA (14)	3.3	99.4	285.5	71.6

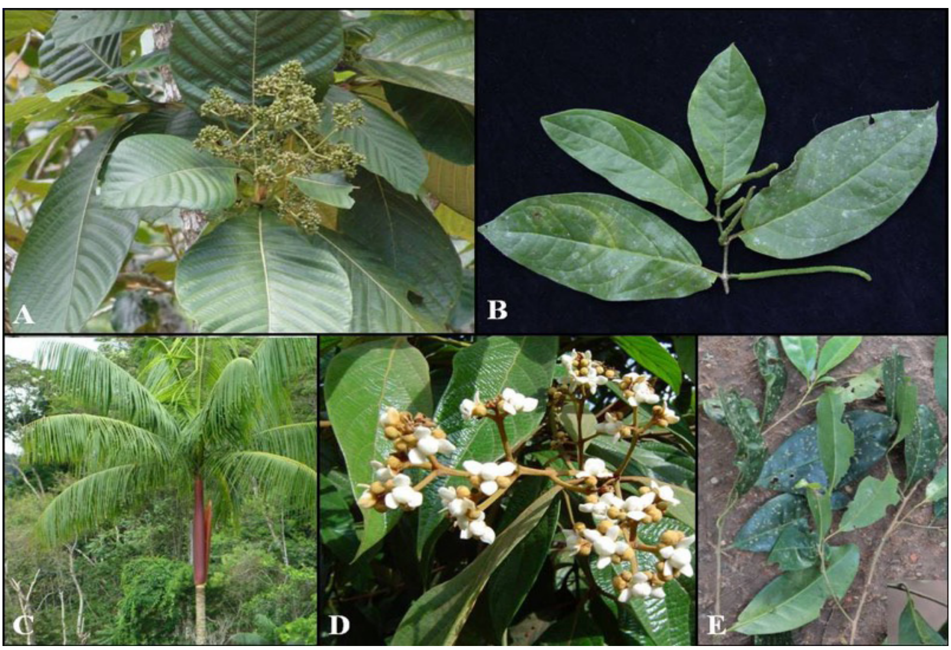

Figure 2. Species considered indicators in the two sites studied (undisturbed protected area (U-PA) and intermediately disturbed non-protected area (ID-NPA): (A) *Bathysa australis* (A.St.-Hil.) K.Schum. (Photo: Eugênio A. Melo); (B) *Piper arboreum* Aubl. (Photo: Rolando Perez); (C) *Euterpe edulis* Mart. (Photo: Eugênio A. Melo); (D) *Nectandra oppositifolia* Nees (Photo: Eugênio A. Melo); (E) *Pera glabrata* (Schott) Poepp. ex Baill. (Photo: Ana C.D. Castello).

Tree ferns in NPA were not found in four of the seven plots and height average in D-PA was 6.7 m, in ID-NPA was 2.2 m ± 1.16 and in U-PA was 10.54 m ± 5.47 (Figure 3). We found significant differences ($p<0.01$) between ID-NPA and U-PA, but not between D-PA and ID-NPA ($p = 0.362$) and D-PA and U-PA ($p = 0.628$). D-PA was represented only by one plot and that might be the reason there were no differences between D-PA and the other successional stages (ID-PA and U-PA). Lianas were sampled in all plots and the DBH average in D-PA was 1.0 cm, in ID-NPA was 1.5 cm ± 0.37 and in U-PA was 1.4 cm ± 0.47 (Figure 4). There were no significant differences ($p = 0.346$) in the DBH average of the lianas among the successional stages (D-PA, ID-NPA and U-PA).

Only one axis of CCA was significant (axis 1 = $p<0.001$; axis 2 = $p>0.1$), and explained 18.11% of the total variation in species composition (Figure 5). Two groupsformed: group 1 - all plots from PA except 1, all tree ferns height classes except class 1, liana DBH class 11, light, canopy cover, litter cover, and species *Allophylus edulis*, *Bathysa*

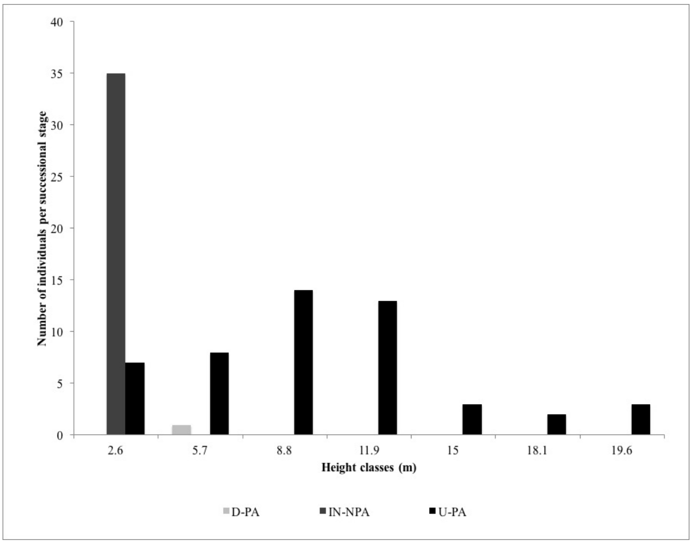

Figure 3. Abundance of tree ferns in height classes sampled in the two sites studied - undisturbed protected area (U-PA) and intermediately disturbed non-protected area (ID-NPA) - in Vale do Ribeira region in Atlantic rainforest domain. D-PA: disturbed plots within protected area (early successional stage); ID-NPA: intermediate disturbance plots outside protected area (intermediate successional stage); and U-PA: undisturbed plots within protected area (advanced successional stage).

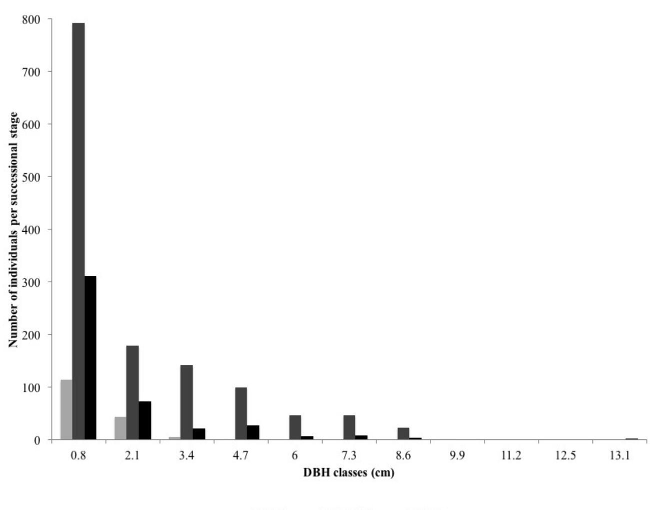

Figure 4. Abundance of lianas in diameter at breast height (DBH) classes sampled in the two sites studied - undisturbed protected area (U-PA) and intermediately disturbed non-protected area (ID-NPA) - in Vale do Ribeira region in Atlantic rainforest domain. D-PA: disturbed plots within protected area (early successional stage); and ID-NPA: intermediate disturbance plots outside protected area (intermediate successional stage).

australis, *Bactris* sp., *Dahlstedtia pinnata*, *Euterpe edulis*, *Guapira opposita*, *Mollinedia schottiana*, *Nectandra leucantha*, *Ocotea teleiandra* and *Piper gaudichaudianum*; group 2–PA's plot 1, all plots from NPA, tree fern height class 1, all the remaining liana DBH classes, humidity and species *Cabralea canjerana*, *Eugenia florida, Guarea macrophylla, Guatteria australis*, *Hevea brasiliensis*, *Eugenia cuprea*, *Myrcia spectabilis*, *Nectandra oppositifolia*, *Ouratea parviflora*, Rubiaceae sp.3, Rubiaceae sp.5, *Pera glabrata*, *Psychotria leiocarpa, Psychotria* cf. *suterella* and *Virola gardneri*. We found significant differences ($p < 0.001$; $F = 21.84$) in litter cover between U-PA and ID-NPA and D-PA and ID-NPA, with the highest values found in U-PA and D-PA (Table 1). Humidity was also significantly different ($p < 0.01$; $F = 7.27$) between U-PA and ID-NPA, with the highest values found in ID-NPA.

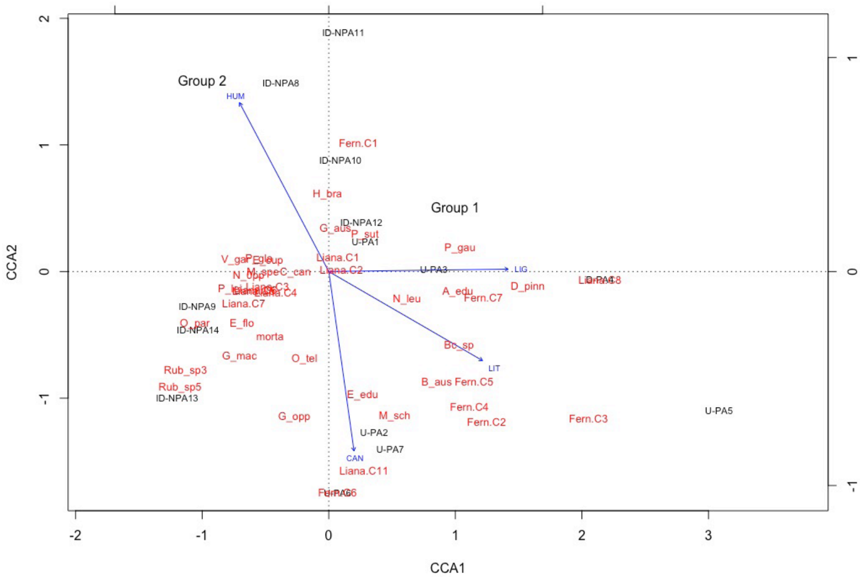

Figure 5. Canonical Correspondence Analysis of the understory species (with more than five individuals), tree ferns and lianas and its association with annual environmental variables sampled in the two sites studied - undisturbed protected area (U-PA) and intermediately disturbed non-protected area (ID-NPA) - in Vale do Ribeira region in Atlantic rainforest domain CAN: canopy cover; HUM: humidity; LIT: litter cover; LIG: light. A_edu = *Allophylu sedulis*; Bc_sp. = *Bactris* sp.; B_aus = *Bathysa australis*; C_can = *Cabralea canjerana*; D_pinn = *Dahlstedtia pinnata*; E_cup = *Eugenia cuprea*; E_flo = *Eugenia florida*; E_edu = *Euterpe edulis*; G_opp = *Guapira opposita*; G_mac = *Guarea macrophylla*; G_aus = *Guatteria australis*; H_bra = *Hevea brasiliensis*; M_sch = *Mollinedia schottiana*; "morta" = Deadtrees; M_spe = *Myrcia spectabilis*; N_leu = *Nectandra leucantha*; N_opp = *Nectandra oppositifolia*; O_tel = *Ocotea teleiandra*; O_par = *Ouratea parviflora*; P_gla = *Pera glabrata*; P_gau = *Piper gaudichaudianum*; P_sut = *Psychotria* cf. *suterella*; P_lei = *Psychotria leiocarpa*; Rub_sp3 = Rubiaceaesp.3; Rub_sp5 = Rubiaceae sp.5; V_gar = *Virola gardneri*.

Canopy cover ($p = 0.177$; $F = 2.627$) and light ($p = 0.488$; $F = 0.766$) showed no significant differences.

4. Discussion

Our study identified indicator species of (i) disturbed areas, (e.g., *Piper arboreum* Aubl.); (ii) intermediated disturbed areas, (e.g., *Nectandra oppositifolia* Nees (Figure 2D) and *Pera glabrata* (Schott) Poepp.); and (iii) undisturbed areas (e.g., *Bathysa australis* (A.St.-Hil.) K.Schum and *Euterpe edulis* Mart.). These species and the large lianas and tree ferns can be useful tools to monitor protected areas in the Atlantic rainforest.

Nutrient cycling, productivity and ecosystem stability differ according to the degree of forest maturity. Species require particular conditions for development, such as pioneer species that depend on light to germinate and grow (Swaine and Whitmore, 1988) leading to poor establishment in late succession stages (van Breugel et al., 2013). Shade tolerant species can germinate and grow under forest shade (Swaine and Whitmore, 1988), consequently found mainly in late successional stages (Liebsch et al., 2008). Besides species successional groups, structural features also relates to forest conditions, as pointed out in our study.

Bathysa australis - a shade tolerant species - is usually recorded among those with the highest importance value in undisturbed areas (Guilherme et al., 2004; Cardoso-Leite et al., 2013) or areas where disturbance occurred in the past, but with shaded understory (Bosa et al., 2015). *Euterpe edulis* (Figure 2C) is a shade tolerant species, typically occurring in undisturbed forest (Aidar et al., 2001; Moreno et al., 2003). *E. edulis* plays an important role in forest succession because it is an abundant species and has a strong interaction with fauna (Reis and Kageyama, 2000); produces large number of flowers and fruits, which serve as food source for insects, birds and mammals (Reis and Kageyama, 2000). Pioneer species such as *Piper arboreum* (Figure 2B), *Nectandra oppositifolia* (Figure 2D) and *Pera glabrata* (Figure 2E) plays an important role in forest regeneration (Denslow, 1980), because they establish in forests gaps (Tabarelli and Mantovani, 1999) and also facilitate establishment of other species during successional advancement (Connell and Slatyer, 1977).

Despite no differences in lianas DBH average, almost all lianas DBH classes were related to the ID-NPA plots and only the largest liana DBH class (class 11) was related to U-PA plots. The same pattern was observed by Letcher and Chazdon (2009) in vegetation areas, in different successional stages, and found an increase in the mean diameter of lianas according to forest ageing, i.e., with successional advancement. In early successional stages it is common to find higher abundance of lianas with smaller diameters (Dewalt et al., 2000; Medeiros and Torezan, 2013). Carvalho et al. (2011) highlighted that, usually, lianas with large diameters are found mostly in areas with low levels of disturbance.

Our study showed that disturbance conditions seem to influence tree fern growth. This pattern was already found in the literature (Bittner and Breckle, 1995; Arens and Sánchez-Baracaldo, 1998), but the relationship between height growth in different levels of disturbance and/or successional stages was not found in the literature. Instead, Bittner and Breckle (1995) and Schmitt and Windisch (2012) highlighted that trunk growth in secondary forest is three times faster than in primary forest. On the other hand, disturbance can affected richness and abundance of ferns (Silva et al., 2011), as observed ID-NPA, with low density of tree ferns in this area.

Environmental variables influenced the formation of groups in CCA, and plots of PA, in most cases, there are the highest values of litter and canopy cover. Litter cover plays an important role in nutrient cycling because it is the nutrient source that accumulates in the soil (Regina, 2001), and it protects soil from erosion. Late successional stages have larger, well-developed canopy than early successional stages, which leads to deeper litter cover (Vidal et al., 2007). Canopy cover, luminosity and litter cover associates with each other, influencing species establishment and growth (Denslow, 1980). Higher canopy cover leads to low light availability and high litter production, favoring shade tolerant species. Medeiros and Torezan (2013), studying fragments of Seasonal Semideciduous Forest found a positive relationship between canopy cover and ecological integrity.

5. Conclusions

Indicator species, pointed out in this study, can be useful in monitoring programs and protocol development for long-term monitoring, in order to meet conservation objectives of protected areas, mainly because indicator species are easy to identify. For instance, the presence of indicator species of disturbed forest (e.g. *Piper arboretum*, *Nectandra oppositifolia* and *Pera glabrata*) and the absence of indicators of undisturbed forest (e.g. *Bathysa australis*, *Euterpe edulis*, large lianas and tree ferns) can be used as an alert that the area has suffered degradation. Lianas of larger diameter (above 13 cm) and tall tree ferns (above 4.1 m) can also be used as indicators of well conserved vegetation. All these information should support management practices and impact mitigation practices. Further studies are needed to clarify if the species selected in our study as indicator species of successional stages and conservation status can be replicable in other areas and vegetation types.

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Appendix A. Species sampled in the understory of PA and NPA in Vale do Ribeira Region in Atlantic rainforest domain (PA: Caverna do Diabo State Park and Quilombos do Médio Ribeira Environmental Protected Area; NPA: São José Farm, Sete Barras, SP).

Family	Species	AB	SG	Nind Area 1	Nind Area 2
Acanthaceae	*Aphelandra liboniana* Linden ex Hook.	A lib	U	4	
Annonaceae	Annonaceae sp.1	Ann sp1	U	1	
	Guatteria australis A.St.-Hil.	G aus	ST	1	4
Apocynaceae	*Malouetia cestroides* (Nees ex Mart.) Müll.Arg.	M ces	P	2	
Araliaceae	Araliaceae sp.1	Ara sp1	U	1	
	Dendropanax monogynus (Vell.) Seem.	D mon	P		3
Arecaceae	*Astrocaryum aculeatissimum* (Uhott) Burret	A acu	ST		1
	Bactris sp.	B sp	U	5	1
	Euterpe edulis Mart.	E edu	ST	15	2
	Geonoma elegans Mart.	G ele	ST	4	
Boraginaceae	*Cordia sellowiana* Cham.	C sel	P		1
Cardiopteridaceae	*Citronella megaphylla* (Miers) R.A.Howard	C meg	P	3	
Celastraceae	*Maytenus gonoclada* Mart.	M gon	ST		2
	Maytenus sp.	M sp.	U		1
	Maytenus evonymoides Reissek	M evo	ST	2	
Chrysobalanaceae	*Parinari excelsa* Sabine	P exc	ST	1	
Clusiaceae	*Garcinia gardneriana* (Planch. & Triana) Zappi	G gar	ST	1	
Elaeocarpaceae	*Sloanea guianensis* (Aubl.) Benth.	S gui	ST		3
	Sloanea hirsuta (Uhott) Planch. ex Benth.	S hir	ST	1	
Euphorbiaceae	*Actinostemon concepcionis* (Chodat & Hassl.) Hochr.	A com	ST	1	
	cf. *Sebastiania* sp.	cf.S sp	U	1	
	Croton sp.	C sp.	U	2	
	Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg.	H bra	ST		6
	Tetrorchidium rubrivenium Poepp.	T rub	P		1
	Euphorbiaceae sp.1	Eu sp1	U	1	
Fabaceae	*Andira fraxinifolia* Benth.	A fra	ST		1
	Dahlstedtia pinnata (Benth.) Malme	D pinn	ST	9	3
	Fabaceae sp.1	Fa sp1	U	3	
	Fabaceae sp.2	Fa sp2	U	1	
	Fabaceae sp.3	Fa sp3	U	2	
	Fabaceae sp.4	Fa sp4	U	1	
	Fabaceae sp.5	Fa sp5	U	1	
	Fabeceae sp.6	Fa sp6	U		1
	Inga marginata Willd.	I mar	P	2	
	Inga sp.	I sp	U	3	
	Machaerium Uleroxylon Tul.	M Ul	ST	1	
	Machaerium stipitatum Vogel	M sti	P	1	
	Myrocarpus frondosus Allemão	M fro	ST	1	
	Piptadenia gonoacantha (Mart.) J.F.Macbr.	P gon	P	1	
	Pterocarpus rohrii Vahl	P roh	ST	1	
	Zollernia ilicifolia (Brongn.) Vogel	Z ili	ST	1	
Indeterminada	Indet. 1	Indet. 1	U	1	
	Indet. 2	Indet. 2	U	2	
Lacistemataceae	*Lacistema lucidum* Uhnizl.	L luc	ST		2

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Appendix A. Continued...

Family	Species	AB	SG	Nind Area 1	Nind Area 2
Lauraceae	*Endlicheria paniculata* (Spreng.) J.F.Macbr.	E pan	ST		2
	Nectandra leucantha Nees	N leu	ST	5	
	Nectandra oppositifolia Nees	N opp	P		6
	Ocotea dispersa (Nees & Mart.) Mez	O dis	ST		1
	Ocotea indecora (Uhott) Mez	O ind	ST	1	
	Ocotea teleiandra (Meisn.) Mez	O tel	ST	4	4
	Lauraceae sp.1	La sp1	U	1	
	Lauraceae sp.2	La sp2	U		2
Malvaceae	Malvaceae sp.1	Ma sp1	U	1	
Melastomataceae	*Leandra* cf. *variabilis* Raddi	L var	P		1
	Miconia cabucu Hoehne	M cab	ST		1
	Miconia cf. *cineraUens* Miq.	M cin	P		2
	Miconia centrodesma Naudin	M cen	ST	1	
	Miconia cinnamomifolia (DC.) Naudin	M cin	ST	1	1
	Miconia sp.	M sp.	U	2	
	Miconia cf. *pusilliflora* (DC.) Naudin	M pus	P		4
	Tibouchina mutabilis (Vell.) Cogn.	T mut	P		3
Meliaceae	*Cabralea canjerana* (Vell.) Mart.	C can	ST	4	14
	Guarea macrophylla Vahl	G mac	ST	3	8
	Trichilia catigua A.Juss.	T cat	ST	1	
	Trichilia clausseni C.DC.	T cla	ST	2	
	Trichilia pallens C.DC.	T pal	ST	3	
Monimiaceae	*Mollinedia oligantha* Perkins	M oli	ST		1
	Mollinedia Uhottiana (Spreng.) Perkins	M Uh	ST	6	3
Moraceae	*Sorocea boSTlandii* (Baill.) W.C.Burger et al.	S bon	ST		1
	Sorocea cf. *hilarii* Gaudich.	S hil	ST		1
Mortas	Mortas		-	2	3
Myrtaceae	cf. *Calyptranthes* sp.	cfC sp	U	1	
	Eugenia cf. *bocainensis* Mattos	E boc	ST		1
	Eugenia brevistyla D.Legrand	E bre	ST		1
	Eugenia cuprea (O.Berg) Nied.	E cup	ST	3	22
	Eugenia florida DC.	E flo	ST		6
	Eugenia monosperma Vell.	E mon	ST	1	1
	Eugenia sp.2	Eu sp2	U	1	
	Myrcia anacardiifolia Gardner	M ana	ST		1
	Myrcia multiflora (Lam.) DC	M mul	ST		3
	Myrcia spectabilis DC.	M spe	ST		5
	Myrcia tijucensis Kiaersk.	M tij	ST		1
	Myrcia sp.2	M sp2	U	1	
	Myrcia sp.1	M sp1	U	1	
	Eugenia supraaxillaris Spring	E sup	ST		1
	Eugenia cf. *verticillata* (Vell.) Angely	E ver	U	1	
	Myrceugenia myrcioides (Cambess.) O.Berg	M myr	U	1	
	Eugenia sp.1	E sp1	U	1	
	Psidium cattleianum Sabine	P cat	ST		1
	Psidium sp.	P sp	U		1
	Syzygium sp.	Sy sp	U		2
	Myrtaceae sp.1	My sp1	U		3
	Myrtaceae sp.2	My sp2	U		1
	Myrtaceae sp.3	My sp3	U		1
	Myrtaceae sp.4	My sp4	U		1

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Appendix A. Continued...

Family	Species	AB	SG	Nind Area 1	Nind Area 2
Myristicaceae	*Virola gardneri* (A.DC.) Warb.	V gar	ST		6
Nyctaginaceae	*Guapira opposita* (Vell.) Reitz	G opp	ST	9	6
	Neea Uhwackeana Heimerl	N Uh	P	2	
Oleaceae	cf. *Chionanthus filiformis* (Vell.) P.S.Green	C fil	ST	1	
	Heisteria silvianii Uhwacke	H sil	ST		1
Ochnaceae	*Ouratea parviflora* (A.DC.) Baill.	O par	ST		8
Peraceae	*Pera glabrata* (Uhott) Poepp. ex Baill.	P gla	P		11
Piperaceae	*Piper* cf. *arboreum* Aubl.	P arb	P	1	3
	Piper gaudichaudianum Kunth	P gau	P	25	20
Polygonaceae	*Coccoloba latifolia* Lam.	C lat	ST		1
Phyllanthaceae	*Hieronyma alchorneoides* Allemão	H alc	ST		3
Primulaceae	*Myrsine coriacea* (Sw.) R.Br. ex Roem. & Uhult.	M cor	P		1
	Myrsine umbellata Mart.	M umb	ST	1	
Rubiaceae	*Bathysa australis* (A.St.-Hil.) K.Uhum.	B aus	ST	6	
	Faramea multiflora A.Rich. ex DC.	F mul	U		1
	Margaritopsis cymuligera (Müll.Arg.) C.M.Taylor	M cym	ST		1
	Psychotria leiocarpa Cham. & Uhltdl.	P lei	ST		5
	Psychotria mapourioides DC.	P map	ST	2	
	Psychotria cf. *suterella* Müll.Arg.	P sut	ST	2	4
	Rudgea recurva Müll.Arg.	R rec	ST	2	2
	Rubiaceae sp.1	Ru sp1	U	1	
	Rubiaceae sp.2	Ru sp2	U	1	
	Rubiaceae sp.3	Ru sp3	U		5
	Rubiaceae sp.4	Ru sp4	U		1
	Rubiaceae sp.5	Ru sp5	U		7
	Rubiaceae sp.6	Ru sp6	U		1
Rutaceae	*Zanthoxylum petiolare* A.St.-Hil. & Tul.	Z pet	P	1	
Salicaceae	*Banara parviflora* (A.Gray) Benth.	B par	ST	1	
	Casearia decandra Jacq.	C dec	ST	1	
	Casearia sylvestris Sw.	C syl	P		1
Sapindaceae	*Allophylus edulis* (A.St.-Hil. et al.) Hieron. ex Niederl.	A edu	P	12	
	Cupania oblongifolia Mart.	C obl	ST		2
	Sapindaceae sp.1	S sp1	U		1
Sapotaceae	*Diploon cuspidatum* (Hoehne) Cronquist	D cus	ST	1	1
Solanaceae	Solanaceae sp.1	So sp1	U		2
Urticaceae	*Cecropia* sp.	Ce sp	U	1	
	Pourouma guianensis Aubl.	P gui	P		2

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