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Richness, geographic distribution and ecological aspects of the fern community within the Murici Ecological Station in the state of Alagoas, Brazil

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ABSTRACT

We conducted a floristic survey of ferns within the Murici Ecological Station (remnant of the northeastern Atlantic Forest), located near the municipalities of Messias and Murici, in the state of Alagoas, Brazil. To increase knowledge of the ferns of Alagoas, we evaluated the species occurring in the study area in terms of richness, composition, geographic distribution, similarities with species in other Brazilian biomes, regional conservation status and ecological aspects. Data were obtained from field work conducted between March 2009 and September 2010. We identified 107 species of ferns, of which 19 represent new records for Alagoas. The richest families were Pteridaceae (29 species) and Polypodiaceae (22 species). The richest genera were *Adiantum* (15 species) and *Thelypteris* (9 species). Most of the species sampled are widely distributed throughout Brazil and the Americas. Within the context of the northeastern Atlantic Forest, 12 species were considered endangered. Concerning the ecological aspects, 88.8% of the species identified were herbaceous, 57.9% were terrestrial and 70.0% occurred in the forest interior.

Key words: Atlantic Forest, conservation, floristic composition, seedless vascular plants

Introduction

Ferns form a monophyletic group (Smith *et al.* 2006; 2008) of seedless vascular plants that are characterized mainly by the lateral origin of their roots from the endoderm, the mesarch protoxylem in the stem axis, the pseudoendospore, the plasmodial tapetum and the antherozoids with 30-1000 flagella (Schneider *et al.* 2002).

These plants are cosmopolitan; however, despite occurring worldwide (Tryon & Tryon 1982; Windisch 1990), ferns exemplify the dominance of the pattern known as the latitudinal gradient of biological diversity: the number of species per unit of area increases from both poles toward the equator (Moran 2008). Tropical forests have the highest species richness, as well the widest variety of habitats and life forms (Tryon & Tryon 1982; Moran 2008).

Approximately 9000 species of ferns are currently known (Smith *et al.* 2006; 2008). Of those species, approximately 12% may be found in Brazil. However, there is still a large gap in the knowledge of those species in the country. The destruction and fragmentation of their natural habitats have threatened a large number of fern species (Windisch 2002). According to Menini Neto *et al.* (2007), knowledge of the biodiversity, obtained via floristic surveys, constitutes important support for conservation, as well as for a potential rational exploration of the resources and natural areas that remain.

Studies on this theme are especially important for the Atlantic Forest biome, because of the low integrity and conservation of its remnants (Tonhasca Jr. 2005; Galindo-Leal & Câmara 2005), in contrast with its high levels of diversity and endemism (Myers *et al.* 2000; Tabarelli *et al.* 2006). Over the years, the processes of fragmentation and loss of habitat that affected the Atlantic Forest have reduced its area to only 11.4% of its original extent. In addition, the remnants of this biome are represented by small, isolated forest fragments (80% of them of less than 50 ha), often unviable for maintaining biological diversity (Ribeiro *et al.* 2009). Although the fern group has high representativeness in the Atlantic Forest, further studies of the northern portion of this biome are needed in order to gain a deeper understanding of the flora of this group.

Among the states in northeastern Brazil, Alagoas is one of the states in which the fewest surveys of the fern flora have been conducted. In a search of the literature, we identified only four such studies: Pontual (1971), Barros *et al.* (1989),

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Pietrobom & Barros (2006) and Barros *et al.* (2006). A few species for the state have been cited in nationwide studies (Prado & Sylvestre 2010) and in studies of the northeastern region (Pietrobom & Barros 2003a; Fernandes 2003). All of these studies collectively list approximately 140 species of ferns for Alagoas. Therefore, the aim of this study was to survey the fern flora in the Murici Ecological Station, which is in Alagoas and is one of the major complexes of Atlantic Forest in the northeastern region, as well as to collect information on the geographic distribution, occurrence in other biomes of Brazil, conservation status within the regional context and ecological aspects of the species found.

Material and methods

Study area

According to Tabarelli *et al.* (2006), the Atlantic Forest to the north of the São Francisco river corresponds to all portions of Atlantic Forest located in the Brazilian states of Alagoas and Rio Grande do Norte, in addition to the enclaves in the state of Ceará. This region of the Atlantic Forest possesses two known centers of endemism: the Brejos Nordestinos and the Pernambuco Endemism Center (Silva & Casteleti 2003). The latter is the location of our study site, the Murici Ecological Station (09°11'05"S to 09°16'48"S; 35°45'20"W to 35°55'12"W), which is near the municipalities of Murici and Messias, in Alagoas (ICMBio 2011). The Murici Ecological Station occupies a total area of 6116 ha (Silva & Pôrto 2009), of which approximately 83% are covered by forest, at elevations of 100-650 m (IBGE 1985).

The vegetation is classified as submontane open rain forest (Veloso *et al.* 1991). The climate is mesothermal with a mean annual temperature of 24°C and mean annual rainfall of approximately 2000 mm (INMET 2012, data for 1961-1990). The study site is located in a non-differentiated pre-Cambrian geological formation and is within the region of the Borborema plateau, with soil types of dystrophic yellow latosol and dystrophic red-yellow spodosol (podzol) (IBGE 1985).

The Murici Ecological Station was created by federal decree on May 28, 2001, and is considered of extreme biological importance as one of the largest complexes of remnants of the Atlantic Forest in the northeast region of Brazil (ICMBio 2011). The Station comprises approximately 19 forest fragments that vary in size and conservation status. The fragments have been regenerating for at least 20 years, are restricted to the tops of hills and are within a matrix of sugarcane and pasture (Silva & Pôrto 2009; ICMBio 2011).

Sampling and data analysis

The surveys were performed in 11 forest fragments within the Murici Ecological Station between March 2009 and September 2010. Field work consisted of five excursions to the Station, for six days each. In each fragment studied, the floristic survey was carried out on foot and priority was given to the habitats where ferns are most representative (Ambrósio & Barros 1997).

Specimens were collected and prepared using the standard techniques for vascular plants (Mori *et al.* 1989). Voucher specimens were deposited at the Herbarium of the Department of Botany of the Federal University of Pernambuco (code, UFP).

The specimens were identified in accordance with a specialized bibliography for each family. The classification system adopted followed Smith *et al.* (2006; 2008), with modifications by Rothfels *et al.* (2012) for the treatment of family Athyriaceae and by Moran *et al.* (2010) for the genus *Mickelia*. The species of the genus *Pleopeltis* were considered according to Prado & Sylvestre (2012). The names of the authors of species were abbreviated following Pichi-Sermolli (1996).

The verification of the geographic distribution of the taxa was based on data from the literature (mainly Moran & Riba 1995 and Mickel & Smith 2004) and on consultations with Brazilian specialists. The analysis of the worldwide distribution of the taxa followed Tryon & Tryon (1982), Moran & Smith (2001) and Parris (2001), with adaptations for the present study. The species were classified into the following categories: introduced (species from the Old World introduced into the Americas and currently with subspontaneous occurrence); endemic to Brazil (occurrence restricted to Brazil); tropical American (occurring from the south of Florida to the south of Uruguay); South American (restricted to the countries of South America), pantropical (occurring at the tropical regions of all continents) and cosmopolitan (widespread throughout the world).

For the analysis of the geographic distribution in Brazil, we considered the following phytogeographic domains, according to the "Lista de Espécies da Flora do Brasil" (Prado & Sylvestre 2012): Amazon rain forest; Atlantic Forest; *cerrado* (savanna); *caatinga* (shrublands); *pantanal* (swampland); and pampa (grassland). However, the Atlantic Forest biome was further divided into the northeastern Atlantic Forest (Atlantic Forest located north of the São Francisco river) and the southern-southeastern Atlantic Forest (including the south of the state of Bahia). This subdivision was based on the studies of Prance (1982) and Silva & Casteleti (2003), which indicate that the Atlantic Forest does not form a single natural region. These studies also provide evidence that the Atlantic Forest north of the São Francisco river is an important center of endemism for this biome and is characterized by the occurrence of unique biological phenomena, particularly in the area referred to as the Pernambuco Endemism Center.

According to Andrade-Lima (1953; 1982), the flora of the Pernambuco Endemism Center is more related to the flora of the Amazon rain forest than to that of the southern-southeastern Atlantic Forest. To test the applicability of this

hypothesis for the fern flora at the study site, we used a t-test with the program Statistica 7.0 (Statsoft 2012), setting the level of significance at $p \leq 0.05$.

Ecological aspects

Form (herbaceous, arborescent and climbing) and habit (terricolous, rupicolous, epiphytic and hemiepiphytic) were evaluated based on the methodology of Santiago & Barros (2003) and Santiago *et al.* (2004), with some modifications. The evaluation of the preferred substrates followed Ambrósio & Barros (1997) with adaptations for the present study. We defined the "forest edge" as the area from the edge line adjacent to the matrix of the landscape to 60 m into the forest, a criterion established in the specialized literature (Paciencia & Prado 2004; 2005a; 2005b).

Conservation status

For the analysis of the conservation status of the ferns in a regional context, we analyzed the distribution and the collection points of each species only in the northeastern Atlantic Forest, disregarding their distribution in the remaining areas of the country. Of the criteria used by the International Union for Conservation of Nature (IUCN 2008), the following were applied in the present study: the degree of conservation of the natural habitats where the species are found; the number of localities of occurrence or number of subpopulations; and the real or potential levels of exploration. The species were divided into categories of threat level, as follows: critically endangered (risk of extinction for the species in the immediate future is extremely high); endangered (risk of extinction in the near future is high); and vulnerable (risk of extinction in the medium term). Data-deficient and non-endangered species were not considered. For the identification of the collection points and additional information of the species studied we used the database of the Laboratory of Pteridophytes of the Federal University of Pernambuco, as well as a pertinent bibliographic review.

Results and discussion

Species richness

Within the Murici Ecological Station, we recorded 107 species of ferns, distributed in 48 genera and 19 families, of which 19 species represented new records for the fern flora of Alagoas (Tab. 1). According to floristic and taxonomic studies, 140 species of ferns are currently recorded for the state of Alagoas (Pontual 1971; Barros *et al.* 1989; Pietrobom & Barros 2006; Barros *et al.* 2006; Prado & Sylvestre 2010; Pietrobom & Barros 2003a). Consequently, the species richness of the study site can be considered significant, because it includes 88 (62.9%) of the 140 species of ferns already cited for the state (Tab. 1). Therefore, the areas of northeastern Atlantic Forest in the state of Alagoas, although not sufficiently sampled, possess considerable richness for the fern group, with 159 species, corresponding to 46% of the fern species recorded for the northeastern Atlantic Forest.

In comparing the Murici Ecological Station to areas evaluated in other surveys of the northeastern Atlantic Forest (Tab. 2), we found the former to be the second richest locality in the region. The highest species richness in the region was reported by Lopes (2003), who identified 138 species of ferns in a survey performed in the Urubu mountain range (near the municipalities of Jaqueira and Lagoas dos Gatos, in the state of Pernambuco).

The most representative families at our study site were Pteridaceae, with 29 species and Polypodiaceae, with 22 (Tab. 1). Those families were also the richest in terms of the number of genera—11 for Polypodiaceae and 10 for Pteridaceae (Tab. 1). The genera with the highest number of species were *Adiantum*, with 15 species, and *Thelypteris*, with nine (Tab. 1).

The most representative families accounted for 47% of the species of ferns recorded for the study site. The families Pteridaceae and Polypodiaceae are frequently highlighted in floristic surveys in the northeastern Atlantic Forest, such as those conducted by Santiago & Barros (2003), Santiago *et al.* (2004), Xavier & Barros (2005), Pietrobom & Barros (2007), Pereira *et al.* (2007) and Pereira *et al.* (2011). Smith *et al.* (2006) commented that Pteridaceae consists of a typically tropical group, whereas Polypodiaceae is defined by Tryon & Tryon (1982) as comprising plants that commonly occur in the neotropics. Both families are phylogenetically recent in the evolution of the fern group (Rothwell & Stockey 2008), and have been adaptively distributed in tropical biomes, which display recent geological alterations (Morley 2000).

Other noteworthy families are Hymenophyllaceae (seven species) and Cyatheaceae (six species), which had a considerable number of taxa. In the northeast of Brazil, these families are more representative in localities with high humidity that are more preserved, establishing themselves only in specific microhabitats (Santiago *et al.* 2004). Therefore, the occurrence of these taxa might indicate that the Murici Ecological Station still possesses conserved areas capable of supporting species that are sensitive and more demanding in terms of environmental conditions.

The plants belonging to the abovementioned families play an important role in the maintenance of the microfauna and microflora of the substrate (Smith 1972), which are extremely important for the ecological equilibrium of the environment (Brade 1940). Most species of Hymenophyllaceae are small plants composed of a single layer of cells (Tryon & Tryon 1982), which preferably inhabit the trunks and branches of trees and less frequently rocks. Because they quickly absorb humidity (Hietz 2010) and form small "carpets", these species are often used as residence and shelter for the spawning of small invertebrates. The family Cyatheaceae is composed

Table 1. Species richness, ecological aspects and geographic distribution of the ferns recorded in the Murici Ecological Station (Alagoas, Brazil).

Family	Ecological Aspects			Geographic distribution		Sampled Material
Species	Form	Growth habit	Preferred habitats	World	Phytogeographic domain	
Anemiaceae						
Anemia hirta (L.) Sw.	Herbaceous	Terricolous	GA FI FE RO	Tropical America	NAF SAF	Pereira & Silva 1274
Anemia villosa Humb. & Bonpl. *ex* Kunth	Herbaceous	Terricolous	RA TS FE	South America	ARF NAF SAF	Pereira & Silva 1071
Aspleniaceae						
Asplenium auritum Sw.	Herbaceous	Rupicolous	FI RO	Pantropical	ARF NAF SAF CE	Pereira & Silva 1312
Asplenium formosum Willd.	Herbaceous	Rupicolous	FI RO	Pantropical	ARF NAF SAF CE PA	Pereira & Silva 1050
Asplenium salicifolium L.	Herbaceous	Epiphytic	FI	Tropical America	ARF NAF CE	Pereira & Silva 1068
Asplenium serratum L.	Herbaceous	Epiphytic	FI	Tropical America	ARF NAF SAF	Pereira & Silva 1052
Athyriaceae						
Diplazium cristatum (Desv.) Aslton	Herbaceous	Terricolous	RA FI	Tropical America	NAF SAF PA	Pereira & Silva 1403
Blechnaceae						
Blechnum brasiliense Desv.	Herbaceous	Terricolous	MA FI	Tropical America	NAF SAF CE PA	Pereira & Silva 1020
Blechnum occidentale L.	Herbaceous	Terricolous	TS GA FE FI	Tropical America	ARF NAF SAF CA CE PA	Pereira & Silva 1076
Blechnum serrulatum Rich.	Herbaceous	Terricolous	MA FE	Tropical America	ARF NAF SAF CA CE	Pereira & Silva 1053
Salpichlaena volubilis (Kaulf.) J. Sm.	Climbing	Hemiepiphytic	BB; FI	Tropical America	ARF NAF SAF CE	Pereira & Silva 1126
Cyatheaceae						
Cyathea abreviata I.Fern.	Arborescent	Terricolous	FI BB	Endemic to Brazil	NAF SAF	Pereira & Silva 1022
Cyathea corcovadensis (Raddi) Domin	Arborescent	Terricolous	RA FI	Endemic to Brazil	NAF SAF	Pereira & Silva 1078
Cyathea microdonta (Desv.) Domin	Arborescent	Terricolous	TS GA RA FI	Tropical America	ARF NAF SAF CE PA	Pereira & Silva 1060
Cyathea phalerata Mart.	Arborescent	Terricolous	FI BB	Endemic to Brazil	ARF NAF SAF CE	Pereira & Silva 1251
Cyathea praecincta (Kunze) Domin	Arborescent	Terricolous	FI BB	Endemic to Brazil	ARF NAF SAF	Pereira & Silva 1172
Cyathea pungens (Willd.) Domin*	Arborescent	Terricolous	FI BB	Tropical America	ARF NAF SAF CE	Pereira & Silva 1175
Dennstaedtiaceae						
Pteridium arachnoideum (Kaulf.) Maxon	Herbaceous	Terricolous	FE	Tropical America	ARF NAF SAF CA CE PA PM	Pereira & Silva 1077
Dryopteridaceae						
Ctenitis distans (Brack.) Ching	Herbaceous	Terricolous	TS RA FI	Endemic to Brazil	NAF SAF	Pereira & Silva 1070
Ctenitis submarginalis (Langsd. & Fisch.) Ching	Herbaceous	Terricolous	FI RA MA	Tropical America	ARF NAF SAF CE PA	Pereira & Silva 1063
Cyclodium heterodon var. *abreviatum* (C.Presl) A.R.Sm.	Herbaceous	Terricolous	RA TS FI	Endemic to Brazil	NAF SAF	Pereira & Silva 1066
Cyclodium meniscioides (Willd.) C. Presl var. *meniscioides*	Herbaceous	Terricolous	MA BB FI	South America	ARF NAF SAF CE PA	Pereira & Silva 1121
Elaphoglossum burchellii (Baker) C.Chr.*	Herbaceous	Epiphytic	FI	Tropical America	NAF SAF	Pereira & Silva 1138
Elaphoglossum sp.	Herbaceous	Epiphytic	FI			Pereira & Silva 1189
Megalastrum sp.	Herbaceous	Terricolous	FI RA			Pereira & Silva 1400
Mickelia guianensis (Aubl.) Ching	Climbing	Hemiepiphytic	FI BB	Tropical America	ARF NAF SAF	Pereira & Silva 1203
Polybotrya cylindrica Kaulf.	Climbing	Hemiepiphytic	FI	Endemic to Brazil	NAF SAF	Pereira & Silva 1061

Continues

Table 1. Continuation.

Family / Species	Ecological Aspects: Form	Growth habit	Preferred habitats	Geographic distribution: World	Phytogeographic domain	Sampled Material
Gleicheniaceae						
Dicranopteris flexuosa (Schrad.) Underw.	Herbaceous	Terricolous	FE	Tropical America	ARF NAF SAF CE PA	Pereira & Silva 1004
Gleichenella pectinata (Willd.) Ching	Herbaceous	Terricolous	FE	Tropical America	ARF NAF SAF CE	Pereira & Silva 1081
Hymenophyllaceae						
Didymoglossum angustifrons Fée	Herbaceous	Rupicolous	FI RO	Tropical America	ARF NAF SAF	Pereira & Silva 1169
Didymoglossum hymenoides (Hedw.) Desv.	Herbaceous	Epiphytic rupicolous	FI RO	Tropical America	NAF SAF CE	Pereira & Silva 1263
Didymoglossum krausii (Hook. & Grev) C. Presl	Herbaceous	Epiphytic rupicolous	FI RO	Tropical America	ARF NAF SAF	Pereira & Silva 1262
Hymenophyllum hirsutum (L.) Sw.*	Herbaceous	Epiphytic	FI	Tropical America	ARF NAF SAF	Pereira & Silva 1401
Hymenophyllum polyanthos (Sw.) Sw.*	Herbaceous	Epiphytic	FI	Pantropical	ARF NAF SAF CE	Pereira & Silva 1212
Trichomanes pedicellatum Desv.*	Herbaceous	Epiphytic	FI	South America	ARF NAF SAF	Pereira & Silva 1211
Trichomanes pinnatum Hedw.	Herbaceous	Terricolous	TS RA FI	Tropical America	ARF NAF SAF CE	Pereira & Silva 1073
Lindsaeaceae						
Lindsaea lancea (L.) Bedd. var. *lancea*	Herbaceous	Terricolous	TS FE FI	Tropical America	ARF NAF SAF	Pereira & Silva 1056
Lindsaea quadrangularis Raddi*	Herbaceous	Terricolous	FI RA	Tropical America	NAF SAF CE	Pereira & Silva 1208
Lomariopsidaceae						
Lomariopsis japurensis (Mart.) J. Sm.	Climbing	Hemiepiphytic	FI BB	Tropical America	ARF NAF	Pereira & Silva 1064
Nephrolepis biserrata (Sw.) Schott	Herbaceous	Terricolous	FE FI GA	Cosmopolitan	ARF NAF SAF	Pereira & Silva 1327
Lygodiaceae						
Lygodium venustum Sw.	Climbing	Terricolous	TS GA FE FI	Tropical America	ARF NAF SAF PA	Pereira & Silva 1093
Lygodium volubile Sw.	Climbing	Terricolous	TS GA FE FI	Tropical America	ARF NAF SAF	Pereira & Silva 1001
Marattiaceae						
Danaea leprieurii Kunze	Herbaceous	Terricolous	RA BB FI	Tropical America	ARF NAF	Pereira & Silva 1029
Polypodiaceae						
Campyloneurum phyllitidis (L.) C. Presl	Herbaceous	Epiphytic	FI	Tropical America	ARF NAF CE PA	Pereira & Silva 1105
Campyloneurum repens (Aubl.) C. Presl	Herbaceous	Epiphytic	FI	Tropical America	ARF NAF	Pereira & Silva 1245
Cochlidium serrulatum (Sw.) L.E. Bishop*	Herbaceous	Epiphytic	FI	Pantropical	ARF NAF SAF CA CE	Pereira & Silva 1195
Dicranoglossum desvauxii (Klotzsch) Proctor	Herbaceous	Epiphytic	GA FE FI	South America	ARF NAF SAF	Pereira & Silva 1064
Dicranoglossum furcatum (L.) J. Sm.	Herbaceous	Epiphytic	GA FE FI	Tropical America	NAF SAF	Pereira & Silva 1157
Microgramma geminata (Schrad.) R.M.Tryon & A.F.Tryon	Herbaceous	Epiphytic	FI	Tropical America	NAF SAF	Pereira & Silva 1313
Microgramma lycopodioides (L.) Copel.	Herbaceous	Epiphytic	FI GA	Tropical America	ARF NAF SAF	Pereira & Silva 1200
Microgramma vacciniifolia (Langsd. & Fisch.) Copel.	Herbaceous	Epiphytic	GA FE FI	South America	ARF NAF SAF CE PA	Pereira & Silva 1019
Micropolypodium nanum (Fée) A.R.Sm.	Herbaceous	Epiphytic	FI	Tropical America	ARF NAF SAF CE	Pereira & Silva 1194
Niphidium crassifolium (L.) Lellinger	Herbaceous	Epiphytic	FI	Tropical America	ARF NAF SAF CE PA	Pereira & Silva 1337

Continues

Table 1. Continuation.

Family	Ecological Aspects			Geographic distribution		Sampled Material
Species	Form	Growth habit	Preferred habitats	World	Phytogeographic domain	
Pecluma camptophyllaria (Fée) M.G. Price*	Herbaceous	Epiphytic	FI	Tropical America	NAF SAF	Pereira & Silva 1199
Pecluma pectinatiformis (Lindm.) M.G.Price*	Herbaceous	Epiphytic	FI	South America	NAF SAF	Pereira & Silva 1018
Pecluma pilosa (A.M.Evans) M.Kessler & A.R.Sm.	Herbaceous	Epiphytic	FI	South America	NAF SAF	Pereira & Silva 1271
Phlebodium decumanum (Willd.) J.Sm.	Herbaceous	Epiphytic	FE	Tropical America	ARF NAF SAF CE CA PA	Pereira & Silva 1351
Phlebodium pseudoaureum (Cav.) Lellinger	Herbaceous	Epiphytic	FI	Tropical America	ARF NAF SAF CE PA	Pereira & Silva 1402
Pleopeltis astrolepis (Liebm.) E. Fourn.	Herbaceous	Epiphytic	GA FE FI	Tropical America	NAF SAF PA	Pereira & Silva 1108
Pleopeltis macrocarpa (Bory *ex* Willd.) Kaulf.	Herbaceous	Epiphytic	FI	Pantropical	ARF NAF SAF CA	Pereira & Silva 1109
Polypodium dulce Poir.	Herbaceous	Epiphytic	FI	Tropical America	NAF SAF	Pereira & Silva 1242
Serpocaulon catharinae (Langsd. & Fisch.) A.R.Sm.	Herbaceous	Epiphytic	FI	Endemic to Brazil	NAF SAF	Pereira & Silva 1198
Serpocaulon fraxinifolium (Jacq.) A.R.Sm.	Herbaceous	Epiphytic	FI	Tropical America	ARF NAF SAF CE	Pereira & Silva 1086
Serpocaulon meniscifolium (Langsd. & Fisch.) A.R.Sm.*	Herbaceous	Epiphytic	FI GA	Endemic to Brazil	NAF SAF	Pereira & Silva 1235
Serpocaulon triseriale (Sw.) A.R.Sm.	Herbaceous	Epiphytic	GA FI	Tropical America	ARF NAF SAF CA CE PA	Pereira & Silva 1102
Pteridaceae						
Adiantopsis radiata (L.) Fée	Herbaceous	Terricolous	FI	Tropical America	ARF NAF SAF CE	Pereira & Silva 1204
Adiantum abscissum Schrad.	Herbaceous	Terricolous	FI TS GA	Endemic to Brazil	ARF NAF SAF PA	Pereira & Silva 1097
Adiantum cajennense Willd. *ex* Klotzsch*	Herbaceous	Terricolous	TS FI GA	South America	ARF NAF	Pereira & Silva 1305
Adiantum diogoanum Glaz. *ex* Baker	Herbaceous	Terricolous	FI FE TS	South America	ARF NAF SAF PA	Pereira & Silva 1062
Adiantum dolosum Kunze	Herbaceous	Terricolous	TS GA FE FI	South America	ARF NAF SAF	Pereira & Silva 1222
Adiantum glaucescens Klotzsch	Herbaceous	Terricolous	FE TS	South America	ARF NAF SAF	Pereira & Silva 1035
Adiantum humile Kunze	Herbaceous	Terricolous	FE TS	Tropical America	ARF NAF SAF	Pereira & Silva 1091
Adiantum intermedium Sw.	Herbaceous	Terricolous	FI TS	Endemic to Brazil	NAF SAF CE	Pereira & Silva 1027
Adiantum latifolium Lam.	Herbaceous	Terricolous	FI GA FE TS	Tropical America	ARF NAF SAF PA	Pereira & Silva 1045
Adiantum lucidum (Cav.) Sw.	Herbaceous	Terricolous	TS GA FE FI	Tropical America	ARF NAF SAF	Pereira & Silva 1123
Adiantum obliquum Willd.	Herbaceous	Terricolous	FI GA TS	Tropical America	ARF NAF SAF	Pereira & Silva 1036
Adiantum petiolatum Desv.*	Herbaceous	Terricolous	TS GA FE	Tropical America	ARF NAF SAF	Pereira & Silva 1229
Adiantum pulverulentum L.	Herbaceous	Terricolous	TS GA FE FI	Tropical America	ARF NAF SAF	Pereira & Silva 1101
Adiantum serratodentatum Willd.	Herbaceous	Terricolous	FE FI TS GA	Tropical America	ARF NAF SAF CE PA	Pereira & Silva 1293
Adiantum terminatum Kunze *ex* Miq.	Herbaceous	Terricolous	TS GA FE FI	Tropical America	ARF NAF SAF	Pereira & Silva 1033
Adiantum tetraphyllum (Humb. & Bonpl.) Willd.*	Herbaceous	Terricolous	TS GA FE FI	Tropical America	ARF NAF SAF CE	Pereira & Silva 1079
Anetium citrifolium (L.) Splitg.	Herbaceous	Epiphytic	FI	Tropical America	ARF NAF SAF	Pereira & Silva 1264

Continues

Table 1. Continuation.

Family / Species	Ecological Aspects: Form	Growth habit	Preferred habitats	Geographic distribution: World	Phytogeographic domain	Sampled Material
Ceratopteris thalictroides (L.) Brong*	Herbaceous	Terricolous	FE BB	Cosmopolitan	ARF NAF SAF CE PA	Pereira & Silva 1374
Doryopteris pentagona Pic.Serm.*	Herbaceous	Rupicolous	FE RO	South America	NAF SAF	Pereira & Silva 1322
Hemionitis palmata L.	Herbaceous	Rupicolous	GA FI RO	Tropical America	ARF NAF	Pereira & Silva 1007
Hemionitis tomentosa (Lam.) Raddi	Herbaceous	Terricolous	FI FE	South America	NAF SAF CA CE PA	Pereira & Silva 1292
Pityrogramma calomelanos (L.) Link var. *calomelanos*	Herbaceous	Terricolous	FE	Tropical America	ARF NAF SAF CA CE PA	Pereira & Silva 1003
Polytaenium cajenense (Desv.) Benedict	Herbaceous	Epiphytic	FI	Tropical America	ARF NAF SAF CE	Pereira & Silva 1186
Polytaenium guayanense (Hieron.) Alston*	Herbaceous	Epiphytic	FI	South America	ARF NAF	Pereira & Silva 1167
Pteris biaurita L.	Herbaceous	Terricolous	FI BB	Pantropical	ARF NAF SAF	Pereira & Silva 1302
Pteris denticulata Sw.	Herbaceous	Terricolous	RA BB FI	Tropical America	ARF NAF SAF PA	Pereira & Silva 1223
Pteris vittata L.	Herbaceous	Terricolous	FI GA	Introduced	ARF NAF SAF PA	Pereira & Silva 1404
Vittaria costata Kunze*	Herbaceous	Epiphytic	FI GA	Tropical America	ARF NAF SAF	Pereira & Silva 1011
Vittaria lineata (L.) J.E. Smith	Herbaceous	Epiphytic	FI	Tropical America	ARF NAF SAF PA	Pereira & Silva 1220
Saccolomataceae						
Saccoloma elegans Kaulf.	Herbaceous	Terricolous	RA BB FI	Tropical America	ARF NAF SAF	Pereira & Silva 1065
Schizaeaceae						
Schizaea elegans (Vahl.) Sw.*	Herbaceous	Terricolous	FI	Tropical America	ARF NAF SAF	Pereira & Silva 1158
Tectariaceae						
Tectaria incisa Cav.	Herbaceous	Terricolous	RA BB FI	Tropical America	ARF NAF SAF	Pereira & Silva 1115
Triplophyllum boliviensis J. Prado & R.C. Moran	Herbaceous	Terricolous	TS RA FI	South America	ARF NAF	Pereira & Silva 1042
Thelypteridaceae						
Thelypteris abrupta (Desv.) Proctor	Herbaceous	Terricolous	RA FI	Tropical America	ARF NAF	Pereira & Silva 1119
Thelypteris crysodioides (Fée) C.V.Morton	Herbaceous	Terricolous	FI RA	South America	ARF NAF SAF CE	Pereira & Silva 1301
Thelypteris hispidula (Decne.) C.F. Reed	Herbaceous	Terricolous	MA FE	Cosmopolitan	CE NAF SAF PA	Pereira & Silva 1030
Thelypteris interrupta (Willd.) K. Iwats	Herbaceous	Terricolous	MA FE	Cosmopolitan	ARF NAF SAF CA CE PA	Pereira & Silva 1090
Thelypteris jamesonii (Hook.) R.M.Tryon	Herbaceous	Terricolous	FI RA	South America	NAF SAF CE PA	Pereira & Silva 1244
Thelypteris leprieurii (Hook.) R.M.Tryon var. *leprieurii**	Herbaceous	Terricolous	FI MA	Tropical America	NAF SAF CE	Pereira & Silva 1210
Thelypteris macrophylla (Kunze) C.V. Morton	Herbaceous	Terricolous	MA FI	South America	ARF NAF SAF	Pereira & Silva 1099
Thelypteris polypodiodes (Raddi) C.F. Reed	Herbaceous	Terricolous	RA FI	Endemic to Brazil	NAF SAF	Pereira & Silva 1069
Thelypteris serrata (Cav.) Alston	Herbaceous	Terricolous	MA FI	Tropical America	ARF NAF SAF CE PA	Pereira & Silva 1038

GA – gaps; RA – ravines; MA – marshes; TS – trail-side; BB – banks of a brook; RO – rocky outcrops; FI – forest interior; FE – forest edge; ARF – Amazon rain forest; NAF – northeastern Atlantic Forest (Atlantic Forest located north of the São Francisco river); SAF – southern-southeastern Atlantic Forest (including the south of Bahia); CE – *cerrado*; CA – *caatinga*; PA – *pantanal*; PM – pampa.
*New record for the state of Alagoas.

Table 2. Main surveys of ferns performed in areas of the northeastern Atlantic Forest of Brazil in order by number of species identified.

Authors	Year of Publication	Study site/state	Size of the forest area	Number of species
Lopes	2003	Urubu Montain Range/Pernambuco	360 ha	138
Pereira *et al.*	This study	Murici Ecological Station/Alagoas	6.116 ha	107
Santiago *et al.*	2004	Macacos Mountain Range/Pernambuco	150 ha	91
Pietrobom & Barros	2003b	Mascarenhas Mountain Range/Pernambuco	600 ha	90
Barros *et al.*	2006	Frei Caneca Private Reserve of the Natural Heritage/Pernambuco	900 ha	89
Barros *et al.*	2006	Serra Grande Mill/Alagoas	3.814 ha	85
Pietrobom & Barros	2007	Água Azul Mill/Pernambuco	600 ha	83
Pereira *et al.*	2011	Gurjaú Ecological Reserve/Pernambuco	1.362 ha	75
Pietrobom & Barros	2006	Maria Maior Forest/Alagoas	600 ha	72
Xavier & Barros	2005	João Vasconcelos Sobrinhos Ecological Park/Pernambuco	359 ha	66

of arborescent plants that, in the northeastern region, can reach a height of 12 m (Santiago *et al.* 2004). Their caudices are frequently used both as shelter by small invertebrates and as substrate (phorophyte) by other plants (bryophytes, ferns and angiosperms). In both cases, the species of this family develop the ecological interaction of commensalism, enabling part of the functioning of the net of ecological interactions in the environments they inhabit (Barros *et al.* 2006).

During field work, we observed that the genus *Adiantum* was found more frequently in the smallest forest fragments, with fewer shaded and protected areas as a clear result of human activity (presence of several trails, intensive logging and plant extraction). This observation corroborates those of Xavier & Barros (2005), who commented that this genus is more representative in areas of secondary forest and is species-poor in areas of primary forest. Salino (1996) correlated the species richness of the genus *Thelypteris* with the diversity of microhabitats available in the vegetation. The *Thelypteris* species occur in varied environments, from open localities outside forest fragments to marshes and well-shaded areas in the forest interior.

Patterns of geographic distribution

Most species of ferns recorded in the Murici Ecological Station occur in tropical America (64 species). The species that occur in South America had lower representativeness (18 species), followed by those endemic to Brazil (12 species), those that are pantropical (six species) and those that are cosmopolitan (four species). Only one introduced species, *Pteris vittata*, was recorded (Tab. 1).

The predominance of species that occur in tropical America was expected, because, as is already known, species of ferns are more common in tropical and subtropical humid forests (Tryon & Tryon 1982; Windisch 1990; Moran 2008). According to Tryon & Tryon (1982), tropical America represents one of the two regions with the highest species richness for this group of plants, with 33% of all species of ferns.

The Murici Ecological Station had a low number of species endemic to Brazil (11% of the species recorded in the study site), in comparison with studies evaluating the geographic distribution of ferns in the south and southeast regions of Brazil. For example, Lima *et al.* (1997) reported that species endemic to Brazil accounted for 24% of the fern species in the Macaé de Cima Ecological Station (in the state of Rio de Janeiro), within the Atlantic Forest. Labiak & Prado (1998) recorded a value of 25% for epiphytes in the Volta Velha Reserve (state of Santa Catarina), and Senna & Waechter (1997) recorded a value of 27% for the Araucaria forest. This difference in the representativeness of endemic taxa might be explained by the fact that the southern and southeastern regions of Brazil share one of the centers of endemism and diversity of ferns for the American continent, mainly because of the presence of montane forests. These forests possess high ecological diversity with the presence of an environmental mosaic, in contrast to lowland regions, which typically possess habitats with greater area but lower ecological diversity (Tryon & Tryon 1982).

Regarding the species distribution in the Brazilian territory, most of the species found also occur in the southern-southeastern Atlantic Forest and in the Amazon rain forest—95 and 78 taxa, respectively. As can be seen in Tab. 1, other species also occur in the biomes of the *cerrado* (42 species), *pantanal* (29 species), *caatinga* (nine species) and pampa (two species). Of the 13 species endemic to Brazil, eight occur only in the Atlantic Forest (northeastern and southern-southeastern): *Cyathea abreviata, Cyathea corcovadensis, Ctenitis distans, Cyclodium heterodon, Polybotrya cylindrica, Serpocaulon catharinae, Serpocaulon meniscifolium* and *Thelypteris polypodioides* (Tab. 1). *Cyathea abreviata* is endemic to the northeast region (Windisch 2010), with records only for the states of Pernambuco, Alagoas and Bahia. The remaining five species recorded as endemic to Brazil have a wider distribution, occurring also in the other biomes, mainly in the Amazon rain forest (four species).

The result of the t-test indicated a difference, in terms of the number of species in common with the study site (Fig. 1), between the Amazon rain forest and the southern-southeastern Atlantic Forest ($t = -4.31$; $p<0.01$), that number being higher for the latter.

This result did not corroborate the hypothesis proposed by Andrade-Lima (1953; 1982) who stated that the flora of areas pertaining to the Pernambuco hotspot of endemism are likely to be more closely related to that of the Amazon rain forest than to that of the southern-southeastern Atlantic Forest. The dispersal capacity of ferns is well known (Tryon 1970; Smith 1972). The geographic barrier between the Pernambuco hotspot of endemism and the Amazon rain forest consists of extensive areas dominated by *caatinga*, a biome that offers conditions for the establishment of only a restricted number of fern species—those with specific adaptations (Xavier *et al.* 2012). However, there is no such barrier between the Pernambuco hotspot of endemism and the southern-southeastern Atlantic Forest, because those two regions are divided only by the São Francisco river.

Ecological aspects

Of the 107 fern species studied, 95 (88.8%) were herbaceous, 6 (5.6%) were arborescent and another 6 (5.6%) were climbing. More than half of the species—62 (57.9%)—were terricolous, whereas 34 (31.7%) were epiphytic, 4 (3.7%) were hemiepiphytic, 5 (4.6%) were preferentially rupicolous, and 2 (1.9%) were epiphytic or rupicolous. Regarding the preferred habitats, 75 (70.1%) of the species were recorded in the forest interior and 32 (29.9%) were recorded at the forest edge. Species were also found in gaps, ravines and marshes, as well as along the edges of trails, on the banks of brooks and among rocky outcrops. The predominant ecological aspects at the study site were those commonly observed for the fern group and similar to those reported in other studies conducted in areas of northeastern Atlantic Forest (Xavier & Barros 2005; Santiago & Barros 2003; Santiago *et al.* 2004; Barros *et al.* 2006; Pietrobom & Barros 2007; Pereira *et al.* 2007).

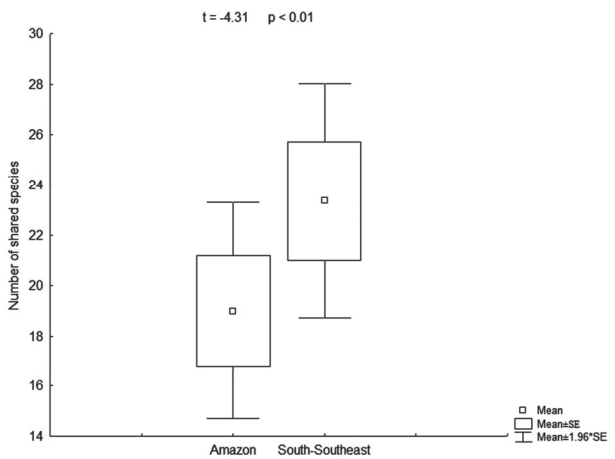

Figure 1. Results of the t-test indicating the difference between the Amazon rain forest and the southern-southeastern Atlantic Forest in terms of the number of species of ferns shared with the Murici Ecological **Station**, in the state of Alagoas, Brazil ($t = -4.31$; $p < 0.01$).

Although in the present study the ferns exhibited almost all growth forms and adaptations found for angiosperms, ferns are usually herbaceous (Xavier & Barros 2005), because they have only one meristem, which limits the growth rate and thus the architecture of sporophytes (Page 2002).

As previously mentioned, more than half of the species recorded at our study site were terricolous. According to Tuomisto & Ruokolainen (1994), the terricolous substrate is more common in this group because soils offer varied physical and chemical conditions, such as solar irradiation, temperature and humidity, in addition to a higher nutrient availability. However, the considerable representativeness of the epiphytic species should be noted, because such species are typically demanding in terms of environmental quality and therefore usually have low representativeness in forest fragments of this region (Xavier & Barros 2003, 2005; Santiago & Barros 2003; Barros *et al.* 2006; Pietrobom & Barros 2007; Pereira *et al.* 2007).

The fact that most species were observed in the forest interior may be associated with the environmental heterogeneity, because the fragments of Atlantic Forest tend to display higher complexity in their interior, with higher diversity of microhabitats and consequently a greater availability of niches (Primack & Rodrigues 2001; Ricklefs 2003; Silva *et al.* 2011). In contrast, with the process of fragmentation and habitat loss in the Atlantic Forest, forest edges tend to undergo environmental homogenization, because the climatic changes that affect these environments tend to eliminate the most sensitive species, including trees, and to favor more tolerant species that reproduce in large scale (Murcia 1995; Laurence *et al.* 1997; Laurence 1999; Primack & Rodrigues 2001; Fahrig 2003; Cagnolo *et al.* 2006; Lôbo *et al.* 2011). These aspects, which have been widely discussed in the literature, are corroborated by our study, because, during our field work, we observed that forest interiors had a higher diversity of environments, such as streams, brooks, ravines and hillsides, than did the forest edges. Similar observations were reported by Silva & Pôrto (2009) and Alvarenga *et al.* (2010), who studied the behavior of the community of bryophytes in the Murici Ecological Station. In addition, the forest interior has the capacity to retain more humidity and, as reported in the literature (Silva *et al.* 2011), environments with higher water availability are more easily colonized by ferns. Pausas & Sáez (2000) commented that water availability is indispensible for the reproduction of these plants, because their male gametes are flagellated and need to swim in the external environment in order to fertilize the oosphere. However, although forest edges are more restrictive to the occurrence of ferns, with high light intensity and low water availability, in the Murici Ecologi-

cal Station we observed a considerable number of species occurring in this habitat. A high affinity for a preferred environment is not exclusive to species of the forest interior. A major class of ferns, especially represented by the genera *Dicranopteris*, *Pityrogramma, Gleichenella* and *Pteridium*, may be considered "sun ferns" (Grime 1985; Given 1993; Mehltreter *et al.* 2010). Those plants occupy open environments especially after disturbances, acting as pioneer species, and rarely prosper in the forest interior. Additionally, although "sun ferns" seem to be tolerant to a vast array of environmental conditions, they are highly dependent on a continuous perturbation mosaic for survival. Our study supports these data, because the "sun fern" genera occurred only at the forest edges.

Conservation status

Of the taxa found at our study site, 14 were identified as endangered for the northeastern Atlantic Forest (Tab. 3). Those taxa were classified as follows: eight as critically endangered, three as endangered and three as vulnerable (Tab. 3). On the 2008 list of endangered species within the flora of Brazil (Biodiversitas 2012), there is no record for any of the species of ferns found in the present study. This list cited only one endangered species for the state of Alagoas, *Anemia mirabilis* Brade, which was not found during our field work at the study site. Nevertheless, the publication of lists of endangered species is of great relevance, because in a country of continental dimensions such as Brazil, the "geographic division" of studies may facilitate conservation strategies. Lins *et al.* (1997) point out that national lists do not necessarily indicate the actions to be performed, because decisions are made mainly at the municipal or state level. However, in comparing the national list with lists created at the state level (for the states of São Paulo, Minas Gerais and Rio Grande do Sul), although the species composition varies widely, we found that the former shares some species with some of the latter: *Cyathea corcovadensis* (Rio Grande do Sul), *Cyathea praecincta* (Minas Gerais) and *Polytaenium cajenense* (Minas Gerais). In addition, species considered endangered in some states are better represented in the northeastern Atlantic Forest, such as: *Anemia hirta* (Minas Gerais), *Cyathea pungens* (Minas Gerais and São Paulo), *Danaea leprieurii* (Minas Gerais), *Dicranoglossum furcatum* (Minas Gerais), *Dicranopteris pectinata* (Rio Grande do Sul), *Microgramma lycopodioides* (Minas Gerais), *Thelypteris macrophylla* (Minas Gerais and São Paulo) and *Trichomanes ovale* (São Paulo). This is important because these populations that occur in distinct regions probably possess different genetic heritages, and local extinctions would lead to a loss of biodiversity.

In the present study, all endangered taxa were collected and observed only in the largest forest fragments, forming small populations. According to Ricklefs (2003), very small populations are subject to a rapid decline in number and local extinction, mainly because of stochastic phenomena and a reduction in the genetic variation within the population. The author also stated that the probability of these events increases with habitat fragmentation, as was observed in the biome studied here.

Another important aspect is the predominance of epiphytic species (64%) among the taxa classified as endangered in the present study. According to Sota (1971), epiphytes are more vulnerable because of their sensitivity

Table 3. Species of ferns recorded in the Murici Ecological Station (state of Alagoas Brazil) that are endangered in areas of the northeastern Atlantic Forest of Brazil.

Species	Criteria	Category
Adiantum cajennense Willd. *ex* Klotzsch	B2ab(iv) + C2(ai)	CR
Cochlidium serrulatum (Sw.) L.E. Bishop	B2ab(iv) + C2(ai)	EN
Cyathea corcovadensis (Raddi) Domin	A1d + B2ab(iv) + C2(ai)	CR
Cyathea praecincta (Kunze) Domin	A1d + B2ab(iv) + C2(ai)	VU
Elaphoglossum burchellii (Baker) C.Chr.	B2ab(iv) + C2(ai) + D2	CR
Hymenophyllum hirsutum (L.) Sw.	B2ab(iv) + C2(ai)	EN
Lindsaea quadrangularis Raddi	B2ab(iv) + C2(ai)	CR
Micropolypodium nanum (Fée) A.R.Sm.	B2ab(iv) + C2(ai)	EN
Pecluma camptophyllaria (Fée) M.G. Price	B2ab(iv) + C2(ai)	CR
Polypodium dulce Poir.	B2ab(iv) + C2(ai)	VU
Polytaenium cajenense (Desv.) Benedict	B2ab(iv) + C2(ai)	CR
Polytaenium guayanense (Hieron.) Alston	B2ab(iv) + C2(ai)	VU
Thelypteris leprieurii (Hook.) R.M.Tryon var. *leprieurii*	B2ab(iv) + C2(ai)	CR
Trichomanes pedicellatum Desv.	B2ab(iv) + C2(ai)	CR

B2ab(iv) – restricted and highly fragmented distribution or area of occupation with continuous decline in the number of localities or subpopulations; C2(ai) – declining population; A1d – declining population because of real or potential exploration levels; D2 – populatione reduced and restricted; CR – critically endangered; EN – endangered; VU – vulnerable.

to environmental conditions and tend to disappear when the microclimate changes because of human activity. Given (1993) also stated that after a disturbance, epiphytic ferns take a longer time to reestablish, because most are highly adapted to their habitat. Therefore, the lack or presence of a particular substrate and adequate environmental conditions are determinants of the colonization and survival of these plants. This specificity makes these species even more vulnerable.

The Murici Ecological Station belongs to one of the most diverse and threatened ecosystems on Earth. Being a designated "conservation unit" (protected area) does not guarantee the protection of its territory. During our field work, we observed intensive timber and plant extraction by the local population, as well as the use of fire in order to clear land for use as pastures or for sugarcane cultivation. These facts make the fern flora of the study site potentially vulnerable to a loss of species, whose survival is endangered by a lack of support from the government and by the human activity that continues in the area. Giudice *et al.* (2011), studying rare ferns in Argentina, and Yang *et al.* (2011), studying the ferns of Hainan Island (China), pointed out that the greatest threats to diversity in those areas are related to human activity. Fires, timber extraction, agriculture, cattle-raising and the establishment of industries are examples of such activities. According to the authors, these factors accelerate the destruction of forests and result in the loss and degradation of natural habitats, events that in turn disturb the reproduction and life cycle of ferns. All taxa identified as endangered in the present study are affected by two or more of these problems.

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