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Endangered flora in protected areas of Rio de Janeiro municipality – Rio de Janeiro State, Brazil

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ABSTRACT. This study presents a qualitative analysis of endangered species occurrences in conservation units of Rio de Janeiro, one of the largest Brazilian municipalities in population size. Increasing human activities trigger changes in biodiversity, promote fragmentation, and reduce species distribution ranges, which can ultimately lead to declines in population sizes. One of the main goals of protected areas (PAs), such as conservation units, is to protect and conserve biodiversity. Here, we compiled all vascular plant species recorded within Rio de Janeiro PAs by consulting the Reference Center for Environmental Information (SpeciesLink), Flora do Brasil (2020), and primary data records contained in management plans. We compared this compilation with the list of Brazilian endangered plant species, verifying whether the management plans presented specific programs for these species. Of the 60 surveyed PAs, 24 had records of endangered species and only 17 had management plans, 14 of which had a specific program that contemplated the monitoring and/or conservation of endangered species. A total of 70 endangered species were recorded. The highest numbers of endangered species were found in the Tijuca National Park (41) and the Pedra Branca State Park (17), the two largest PAs with the two largest forest fragments. Despite the high number of endangered species and the number of protected areas that harbor them, few internal programs address endangered species conservation and management. Thus, efforts to maintain endangered species in protected areas can be aided by field data collections that confirm their occurrence and maintenance in these PAs.

Keywords: atlantic forest; biodiversity conservation; public policies; management plans; conservation units.

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Introduction

Communities of organisms may change over ecological time in three different ways: species can be lost (extinctions), added (invasions), or change in relative abundance (Hero & Ridgway, 2006). An endangered species can be described as one that experiences declining abundance in one or more of its populations (Sevegnani et al., 2013), or experiences fragmentation or isolation of small-sized populations (International Union for Conservation of Nature [IUCN] - Standards and Petitions Committee, 2022a). The number of endangered plant species has been growing since the 1990s, and today more than 23,000 plant species are threatened with extinction (International Union for Conservation of Nature (IUCN, 2022a).

Currently, compilations of endangered species in Brazil follow the Species Extinction Risk Assessment, based on criteria defined by the International Union for Conservation of Nature (Ministério do Meio Ambiente [MMA], 2014). In Brazil, the National Center for Plant Conservation (CNCFlora) has listed 2,953 threatened species (CNCFlora, 2022). The Brazilian National Biodiversity Commission (CONABIO) administrates the priority actions for the conservation and recovery of natural populations and establishes the National Action Plans for species conservation, ensuring compliance with national legislation and following the terms of the Convention on Biological Diversity (MMA, 2014).

Species extinctions can be either caused by natural processes, such as interspecific competition, diseases, and hybridization (Levin, Francisco-Ortega, & Jansen, 1996), or by human activities, through habitat destruction, overexploitation, introduction of exotic species, and extinction cascades (Diamond, 1989). Habitat destruction by land cover and land use changes leads to habitat fragmentation, reductions in species'

distribution ranges, population declines and, ultimately, species extinction (Bergallo, Rocha, Sluy, & Alves, 1999; Tilman et al., 2017; Fahrig et al., 2019; Araújo et al., 2022).

Climate change has also been linked to reductions in biodiversity and increases in vulnerability (Miles, Grainger, & Phillips, 2004; Mittermeier & Scarano, 2013; IBPES, 2018; Hoveka, van der Bank, & Davies, 2022). Other threats include the escape of genetically modified organisms and alien species invasions (Trakhtenbrot, Nathan, Perry, & Richardson, 2005; Santos & Calafate, 2018; Zenni et al., 2022). Biodiversity plays a critical role in tropical ecosystem functions, such as carbon stock and uptake, which, according to the United Nations' Reducing Emissions from Deforestation and Forest Degradation (REDD+), imputes value in biodiversity conservation (Araújo et al., 2022).

The Atlantic Forest biota is extremely diverse, and even today little is known about the biological attributes of some of its remnants. Estimations suggest that the Atlantic Forest region is home to between 1 and 8% of the world's species (Ministério do Meio Ambiente [MMA], 2000). Due to its high biodiversity, endemism rates, and human-driven habitat loss, the Atlantic Forest is considered a global priority for conservation (Myers, Mittermeier, Mittermeier, Fonseca, & Kent, 2000). In recent years, between 2017 and 2018, the biome's total vegetation cover has been estimated as 16,269,972 hectares. In the state of Rio de Janeiro, the vegetation cover of the Atlantic Forest and associated ecosystems has been estimated as 917,196 ha (Fundação SOS Mata Atlântica, 2019).

The need to preserve natural areas threatened by habitat fragmentation and habitat reduction has advanced the protection of natural resources (Gaston, Jackson, Cantú-Salazar, & Cruz-Piñón, 2008; Qin et al., 2019). The legal framework for the creation of areas to protect biodiversity and natural resources in Brazil began with the creation of National Parks, by Federal Decree 23.793 of 23 January 1934, (Brasil, 1934) established through the Forest Code of 1934. In 2000, the National System of Conservation Units (SNUC - *Sistema Nacional de Unidades de Conservação*) was established through Federal Law 9,985 to standardize and systematize the management of conservation units in Brazil, which are divided into two groups: full protection and sustainable use (Brasil, 2000). These conservation units are protected areas (PAs) that play a crucial role in biodiversity conservation (Fonseca & Venticinque, 2018). Their categories correspond to those defined by the IUCN (Rylands & Brandon, 2005a).

One of the most important tools for the administration of PAs is their management plan. This document outlines strategies and programs set to achieve the conservation goals of a PA (Santana, Santos, & Barbosa, 2020). However, many PAs lack a management plan or a management council, which jeopardizes effective administration and highlights the challenges faced by management agencies (Medeiros & Pereira, 2011; Santana et al., 2020).

In this study, we aimed to analyze how species threatened with extinction (according to the Brazilian Ministry of the Environment) are distributed in PAs within the municipality of Rio de Janeiro and to assess whether and how these endangered species are presented in PA management plans. We also aimed to identify which PAs have specific programs for the protection of endangered plant species and, therefore, to assist decision-making in PA management and planning processes. The surveys in this study were conducted by consulting databases of scientific collections and the lists presented in the respective management plans of the protected areas when they existed.

Material and methods

Study area

The municipality of Rio de Janeiro has a total area of 1,200,255 km² with an estimated population of 6,320,446 inhabitants (Instituto Brasileiro de Geografia e Estatística [IBGE], 2019). According to the Municipal Plan for Atlantic Forest Conservation and Restoration (*Plano Municipal De Conservação e Recuperação da Mata Atlântica* [PPMA], 2015), Rio de Janeiro has important Atlantic Forest remnants. Among non-urban areas of Rio de Janeiro municipality, PAs comprise 408 km² and reforested Atlantic Forest areas sum up 35 km² (Data Rio, 2022).

We surveyed and identified PAs in the municipality of Rio de Janeiro through the National Register of Conservation Units (CNUC – *Cadastro Nacional de Unidade de Conservação*) on the Ministry of the Environment website (MMA – *Ministério do Meio Ambiente*; http://www.mma.gov.br/areas-protegidas/cadastro-nacional-de-ucs.html) and in municipal and state agencies responsible for managing

municipal and state PAs, respectively. Only the PAs categories recognized by SNUC were considered in the survey. Private Natural Heritage Reserves (RPPN – *Reserva Particular do Patrimônio Natural*) were not included, due to different creation mechanisms and difficulty of access to data provided by their owners. We identified the PAs that had a management plan and verified whether they contained specific programs for the management and conservation of threatened plant species. The respective management plans were obtained from the official websites of the environmental agencies responsible for managing the PA. We also assessed which PAs had a management council (another tool for administrating protected areas) through CNUC and PA management agencies.

Data collection

To compile the list of species recorded in the conservation units, we consulted three sources: i) the PA management plans, ii) the records comprised in the database of the Reference Center for Environmental Information – SpeciesLink (www.splink.cria.org.br), and iii) the Reflora Virtual Herbarium (http://reflora.jbrj.gov.br). In the management plans, we analyzed the items that described the PA vegetation ("vegetation diagnosis") in the characterization chapters. We compiled a list of species present in the PA using only the records indicated as primary data, disregarding the records based on secondary data sources and records for which the source was not presented.

In the two websites consulted (SpeciesLink and Reflora), the data were collected through their respective search engines by filling the fields "municipality" as Rio de Janeiro and "locality" as the full and abbreviated names of each conservation unit. Thus, no records were added that did not mention the name of a researched PA in the collection site description (i.e., only occurrences recorded within the limits of the referred PA were added to the species list). This means that, even though there may have existed a record for the same site where a PA exists today, we assumed that the collection was made before the creation of the PA. Only vascular plants were included in the list.

Data analysis

We manipulated the collected data in the environment R version 4.1.2 (https://www.rproject.org) with R Studio interface (https://www.rstudio.com). We used the package *flora* (https://github.com/gustavobio/flora) (install_github ("gustavobio/flora"), developed by Gustavo Carvalho (web interface: *Plantminer*) to correct the species' scientific names and to collect information on their conservation status, endemism, phytogeographic domain, and establishment. All the data generated by the package *flora* were based on Flora do Brasil (2020) (accessed in January 2021). The species' conservation statuses were based on IUCN criteria (https://www.iucnredlist.org) and followed CNCFlora (*Centro Nacional de Conservação da Flora*) (http://cncflora.jbrj.gov.br/portal). Incorrectly spelled names for which automatic verification failed were individually consulted on the Flora do Brasil (2020) website, as well as the International Plant Name Index website (https://www.ipni.org). We consulted the conservation statuses of these species individually on the CNCFlora website (http://cncflora.jbrj.gov.br/portal), which follows the CONABIO Ordinance of 2014, in force at the time of consultation.

Species can be categorized according to the following classification criteria: population reduction, restricted geographic range, fragmentation, declines or fluctuations, small population, very small population, or very restricted range (IUCN, 2022b). Quantitative analysis of extinction risk groups species into nine possible categories: not assessed (NE), insufficient data (DD), least concern (LC), near threatened (NT), vulnerable (VU), endangered (EN), critically endangered (CR), extinct in the wild (EW) and extinct (EX) (IUCN, 2012). In this study, we listed the species classified in the threatened categories of IUCN (2012): VU, EN, and CR.

Results

We identified 60 protected areas (PAs) in the municipality of Rio de Janeiro, most of which belong to the sustainable use group (Figure 1). The PAs that lacked georeferenced limits in the databases provided by the managing agencies were not presented in Figure 1 and were indicated in Supplementary Table 1, which also displays information about their administrative sphere, area, the existence of a management council, management plan, and information about endangered species within their limits. Of the 60 PAs identified, 19 had a management council and 17 had a management plan, but none had a specific program for the conservation of endangered plant species (Supplementary Table I). Most management plans (about 80%)

mentioned some kind of activity, such as monitoring or study, targeted at endangered species in vegetation conservation programs, but none of them referred to actions such as management and recovery of endangered species populations. The Marapendi Environmental Protection Area (EPA) was the only sustainable use PA with a management plan; all other PAs with a management plan belonged to the full protection group. The conservation units of Rio de Janeiro belong to the following full protection categories: Biological Reserve (BR), National Park (NP), State Park (SP), Municipal Natural Park (MNP), and Natural Monument (NM). The sustainable use categories identified were: Environmental Protection Area (EPA) and Area of Relevant Ecological Interest (AREI).

The management plans of some PAs did not present primary data, while some did not describe how the PA vegetation was characterized (e.g., Ilhas Cagarras Natural Monument, Guaratiba Biological Reserve, and Serra do Mendanha Municipal Natural Park). The species surveys reported in the management plan of Morros do Pão de Açúcar and Urca Natural Monument relied only on SpeciesLink data. The vegetation diagnosis contained in this PAs management plan used only satellite images and remote sensing, therefore using species records that occur in each vegetation type, and not collected *in situ*. The field effort described in the management plan did not provide information on the identified species.

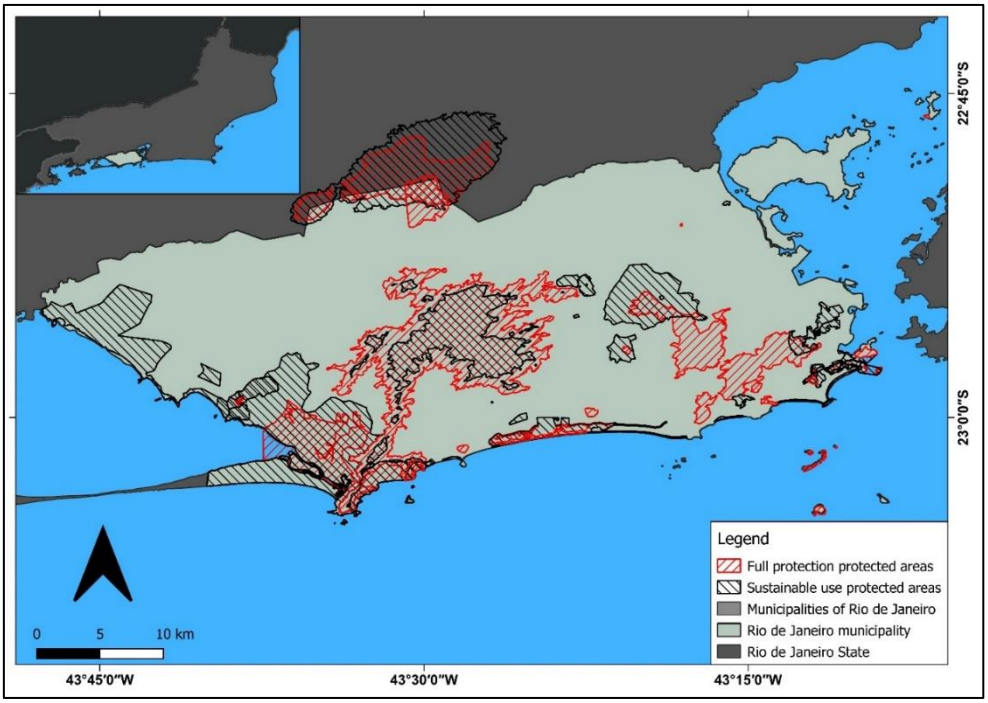

Figure 1. Location of the protected areas, of the full protection and sustainable use groups, inserted totally or partially in the territory of the municipality of Rio de Janeiro.

Only the management plans of two conservation units (Chacrinha State Park and Grajaú State Park) contained no records of threatened species. However, consulting the databases, we found occurrence records of threatened species in these areas.

All the PAs without a management plan have exceeded the deadline established in SNUC's article 27, item III (Federal Law 9.985 of 2000), which demands the creation of these plans within a maximum of five years after establishing the PA.

Most of the PAs (~64%) with records of threatened species belong to the full protection group, whereas only ~18% belong to the sustainable use group. The category "Park" had the highest number of PAs with threatened species records, and the largest number of records *per* PA.

The units with the highest number of threatened species were Tijuca National Park (40), Pedra Branca State Park (17), Prainha Municipal Natural Park (13), and Grumari Municipal Natural Park (11). However, the Pedra Branca State Park, Grumari Municipal Natural Park, Prainha Municipal Natural Park, Grumari Environmental Protection Area, and Prainha Environmental Protection Area, have overlapping boundaries and their areas encompass a relatively continuous fragment. Thus, if this large block of conservation units is considered, the number of threatened species in this region rises to 33.

With the results of the analyses, we listed about 3,200 collection records of plant species within protected areas in the municipality of Rio de Janeiro. Combining the records drawn from the management plans, SpeciesLink, and Reflora, we found 70 species that fit into one of the three categories of threatened species: Vulnerable (24), Endangered (36), and Critically Endangered (10) (Table 1).

Of the 70 threatened plant species, 65 were angiosperms distributed in 34 families, and five were fern species distributed in three families. No records of threatened lycophytes or gymnosperms were found. These two groups, which appeared scarcely in the surveys, have the lowest diversity and representativity in the flora of Rio de Janeiro State (Coelho et al., 2017). The highest species richness was attained by Bromeliaceae (9 species), followed by Myrtaceae (6), Orchidaceae (5), and Rubiaceae (4). Most species are endemic to Brazil.

In total, we found 13 records of the 10 Critically Endangered species, distributed in the following PAs: Tijuca National Park (6 records/5 species), Pedra Branca State Park (2 records/2 species), Prainha Municipal Natural Park (3 records/2 species), and Serra do Mendanha Municipal Natural Park (2 records/1 species). The threatened species with the broadest distribution range, recorded in seven protected areas, was *Terminalia acuminata* (Allemão) Eichler (EN), followed by *Inga maritima* Benth., recorded in six PAs, and *Hippeastrum striatum* (Lam.) Moore and *Tabebuia cassinoides* (Lam.) DC., both recorded in five PAs. Three species were only recorded in the management plans (and not in the consulted databases).

Table 1. List of threatened species according to the National Center for Plant Conservation (CNCFlora), whether they occur within protected areas, and the source of the data. (Biological Reserve - BR; National Park - NP; State Park - SP, Municipal Natural Park - MNP; Natural Monument - NM; Environmental Protection Area - EPA; Area of Relevant Ecological Interest - AREI; a – Management Plan; b – SpeciesLink; c – Reflora; *Species with at least one synonym categorized as a threatened species in the official list).

Family	Species	Status	Endemic from Brazil	Conservation unit and data source
Ferns				
Anemiaceae	*Anemia blechnoides* Sm.	VU	Endemic	Tijuca NP [c]
Anemiaceae	*Anemia gardneri* Hook.	VU	Endemic	Chacrinha SP [c]; Pedra Branca SP [c]
Hymenophyllaceae	*Hymenophyllum elegans* Spreng.	CR	Not endemic	Tijuca NP [c]
Pteridaceae	*Lytoneuron tijucanum* (Brade & Rosenst.) Yesilyurt	EN	Endemic	Tijuca NP [c]
Pteridaceae	*Pteris congesta* J. Prado	EN	Endemic	Tijuca NP [c]
Angiosperms				
Acanthaceae	*Justicia tijucensis* V.A.W.Graham	VU	Endemic	Tijuca NP [c]; Pedra Branca SP [c]
Amaryllidaceae	*Hippeastrum striatum* (Lam.) Moore	EN	Not endemic	Ilhas Cagarras NM [c]; Prainha MNP [a]; Grumari MNP [a,c]; Grumari EPA [b]; Prainha EPA [a,c];
Annonaceae	*Annona parviflora* (A.St.-Hil.) H.Rainer	EN	Endemic	Tijuca NP [c]; Pedra Branca SP [b,c]
Annonaceae	*Trigynaea axilliflora* D.M.Johnson & N.A.Murray	CR	Endemic	Pedra Branca SP [c]
Araceae	*Anthurium lucidum* Kunth	EN	Endemic	Tijuca NP [b,c]
Araceae	*Anthurium luschnathianum* Kunth	EN	Endemic	Grumari MNP [b]; Grumari EPA [b]
Arecaceae	*Euterpe edulis* Mart.	VU	Not endemic	Tijuca NP [c]; Chico Mendes MNP [a]; Prainha MNP [c]
Asteraceae	*Cololobus rupestris* (Gardner) H.Rob.	EN	Endemic	Chacrinha SP [c]
Asteraceae	*Mikania argyreiae* DC.	VU	Endemic	Tijuca NP [c]
Bignoniaceae	*Tabebuia cassinoides* (Lam.) DC.	EN	Endemic	Bosque da Barra MNP [a]; Chico Mendes MNP [a,c]; Marapendi MNP [a]; Nelson Mandela MNP [a]; Marapendi EPA [a]
Bromeliaceae	*Aechmea cariocae* L.B.Sm.	EN	Endemic	Tijuca NP [c]
Bromeliaceae	*Alcantarea geniculata* (Wawra) J.R.Grant	EN	Endemic	Prainha MNP [a]
Bromeliaceae	*Alcantarea glaziouana* (Leme) J.R.Grant	EN	Endemic	Ilhas Cagarras NM [a]; Pão de Açucar NM [a]; Grumari MNP [a]; Prainha MNP [a]
Bromeliaceae	*Pitcairnia albiflos* Herb.	EN	Endemic	Tijuca NP [b,c]; Chacrinha SP [c]
Bromeliaceae	*Stigmatodon brassicoides* (Baker) Leme, G.K.Br. & Barfuss	EN	Endemic	Tijuca NP [c]
Bromeliaceae	*Tillandsia araujei* Mez	EN	Endemic	Tijuca NP [a,c]; Pedra Branca SP [b,c]; Catacumba MNP [a]; Prainha MNP [b,c]; Prainha EPA [b,c]
Bromeliaceae	*Tillandsia brachyphylla* Baker	EN	Endemic	Tijuca NP [c]
Bromeliaceae	*Tillandsia sucrei* E.Pereira	CR	Endemic	Tijuca NP [c]
Bromeliaceae	*Vriesea amethystina* E.Morren	CR	Endemic	Tijuca NP [b]
Cactaceae	*Coleocephalocereus fluminensis* (Miq.)	EN	Endemic	Ilhas Cagarras MN [a]; Pão de Açucar MN [a];

	Backeb.			Catacumba MNP [a]
Cactaceae	*Melocactus violaceus* Pfeiff.	VU	Endemic	Marapendi MNP [a]
Chrysobalanaceae	*Couepia schottii* Fritsch	EN	Endemic	Grumari MNP [a,b,c]; Prainha MNP [a]
Chrysobalanaceae	*Parinari brasiliensis* (Schott) Hook.f.	EN	Endemic	Tijuca NP [b,c]
Combretaceae	*Terminalia acuminata* (Allemão) Eichler	EN	Endemic	Tijuca NP [b,c]; Grajaú SP [c]; Pedra Branca SP [b,c]; Cidade MNP [b,c]; Grumari MNP [c]; Serra do Mendanha MNP [c]; Pedra Branca EPA [b,c]
Commelinaceae	*Siderasis fuscata* (Lodd.) H.E.Moore	EN	Endemic	Tijuca NP [c]
Cyclanthaceae	*Asplundia brachypus* (Drude) Harling	VU*	Endemic	Tijuca NP [c]; Pedra Branca SP [c]
Dilleniaceae	*Davilla glaziovii* Eichler	CR	Endemic	Serra do Mendanha MNP [b,c]
Fabaceae	*Dalbergia nigra* (Vell.) AllemÃ£o ex Benth.	VU	Endemic	Tijuca NP [a]; Catacumba MNP [a]
Fabaceae	*Inga maritima* Benth.	VU	Endemic	Bosque da Barra MNP [a]; Chico Mendes MNP [a,c]; Grumari MNP [b,c]; Marapendi MNP [a,b,c]; Nelson Mandela MNP [a]; Marapendi EPA [a]
Fabaceae	*Paubrasilia echinata* (Lam.) Gagnon, H.C.Lima & G.P.Lewis	EN	Endemic	Pão de Açucar NM [a]; Chico Mendes MNP [c]; Paisagem Carioca MNP [b,c]; Serra da Capoeira Grande EPA [c]
Gesneriaceae	*Sinningia guttata* Lindl.	EN	Endemic	Tijuca NP [c]
Gesneriaceae	*Sinningia lindleyi* Schauer	EN	Endemic	Tijuca NP [b,c]
Lauraceae	*Urbanodendron bahiense* (Meisn.) Rohwer	VU	Endemic	Mendanha SP [b]; Pedra Branca SP [b]; Gericinó/Mendanha EPA [b]
Lecythidaceae	*Cariniana legalis* (Mart.) Kuntze	EN	Endemic	Tijuca NP [a]; Pedra Branca SP [c]
Lecythidaceae	*Couratari pyramidata* (Vell.) Kunth	EN	Endemic	Tijuca NP [b,c]; Chacrinha SP [b,c]; Pão de Açucar NM [b]; Penhasco Dois Irmãos MNP [b]
Malpighiaceae	*Heteropterys ternstroemiifolia* A.Juss.	EN	Endemic	Tijuca NP [b,c]; Grumari MNP [b]
Marantaceae	*Ischnosiphon ovatus* Körn.	EN	Endemic	Tijuca NP [b,c]
Meliaceae	*Cedrela fissilis* Vell.	VU	Not endemic	Tijuca NP [a]; Catacumba MNP [a]; Prainha MNP [a]; Grumari MNP [a]
Meliaceae	*Cedrela odorata* L.	VU	Not endemic	Pedra Branca SP [c]; Prainha MNP [a,c]
Moraceae	*Ficus cyclophylla* (Miq.) Miq.	VU	Endemic	Marapendi MNP [a]; Nelson Mandela MNP [a]; Marapendi EPA [a]
Myristicaceae	*Virola bicuhyba* (Schott ex Spreng.) Warb.	EN	Endemic	Pedra Branca SP [c]
Myrtaceae	*Eugenia bunchosiifolia* Nied.	VU	Endemic	Tijuca NP [c]
Myrtaceae	*Eugenia disperma* Vell.	VU	Endemic	Tijuca NP [c]
Myrtaceae	*Eugenia repanda* O.Berg	EN	Not endemic	Grumari EPA [b]
Myrtaceae	*Eugenia vattimoana* Mattos	VU	Endemic	Pedra Branca SP [c]
Myrtaceae	*Myrcia plusiantha* Kiaersk.	CR*	Endemic	Tijuca NP [b,c]
Myrtaceae	*Plinia edulis* (Vell.) Sobral	VU	Endemic	Tijuca NP [b,c]
Oleaceae	*Chionanthus fluminensis* (Miers) P.S.Green	CR	Endemic	Prainha MNP [a]
Orchidaceae	*Cattleya guttata* Lindl.	VU	Endemic	Prainha MNP [a,b,c]; Grumari MNP [a]
Orchidaceae	*Cattleya lobata* Lindl.	EN	Endemic	Catacumba MNP [a]; Prainha MNP [c]
Orchidaceae	*Cirrhaea loddigesii* Lindl.	CR	Endemic	Prainha MNP [c]
Orchidaceae	*Gomesa uniflora* (Booth ex Lindl.) M.W.Chase & N.H.Williams	CR*	Not endemic	Pedra Branca SP [c]; Prainha MNP [c]
Orchidaceae	*Houlletia brocklehurstiana* Lindl.	EN	Endemic	Tijuca NP [c]
Phyllanthaceae	*Phyllanthus subemarginatus* Müll.Arg.	VU	Endemic	Tijuca NP [c]; Prainha EPA [c]
Plantaginaceae	*Ildefonsia bibracteata* Gardner	CR	Endemic	Tijuca NP [c]
Poaceae	*Merostachys burmanii* Send.	EN	Endemic	Tijuca NP [c]
Proteaceae	*Panopsis multiflora* (Schott ex Spreng.) Ducke	EN	Endemic	Tijuca NP [a,b,c]
Rubiaceae	*Alseis involuta* K.Schum.	VU	Endemic	Serra da Capoeira Grande EPA [c]
Rubiaceae	*Melanopsidium nigrum* Colla	VU	Endemic	Bosque da Barra MNP [b,c]
Rubiaceae	*Rudgea macrophylla* Benth.	EN	Endemic	Tijuca NP [a,b,c]; Pedra Branca SP [b,c]; Serra do Mendanha EPA [c]
Rubiaceae	*Rudgea umbrosa* MÃ¼ll.Arg.	VU	Endemic	Ilhas Cagarras NM [c]
Sapindaceae	*Cupania furfuracea* Radlk.	VU	Endemic	Pedra Branca SP [c]
Sapindaceae	*Urvillea glabra* Cambess.	VU	Endemic	Grumari MNP [b]; Grumari EPA [b,c]
Smilacaceae	*Smilax spicata* Vell.	EN	Endemic	Tijuca NP [c]; Pedra Branca SP [c]
Smilacaceae	*Smilax subsessiliflora* Duhamel	EN	Endemic	SP Pedra Branca [c]; Prainha EPA [c]

Discussion

Management plans contain the actions and standards necessary for ecosystem and resource use in protected areas (PAs) and, therefore, they constitute the main guidelines for agencies responsible for managing PAs around the world. In Brazil, the preparation and implementation of management plans are far from being a widespread reality. As in several other tropical countries, PA managers in Brazil face great challenges when it comes to planning and management (Medeiros & Pereira, 2011). Even when a management plan exists, most PAs struggle with lack of enforcement, deforestation, forest fires, lack of land tenure regularization, conflicting activities, and lack of human and financial resources (Barreto & Drummond, 2017). This reality reveals the problem of planning in the management of these areas, one of the challenges to be overcome by the management agencies (Medeiros & Pereira, 2011).

In the city of Rio de Janeiro, the Municipal Program for Endangered Species is regulated by Decree No. 15,793 of 4 June 1997 (Rio de Janeiro, 1997). One of the main goals of this program is for the Municipal Commission for the Conservation of Threatened Species to map and analyze the areas where threatened species occur. Recently, the Municipal Decree 49,374 of 2 September 2021 launched the new Program for the Protection and Conservation of Native Wildlife and Flora.

The municipality of Rio de Janeiro has protected areas that play an important role in the conservation of threatened plant species (Ferreira & Valdujo, 2014). According to Loyola, Machado, Ribeiro, Martins, and Martinelli (2018) in the last 50 years, most of the collection records made in PAs correspond to "Endangered" species. These species must be protected in PAs of different management spheres (municipal, state, and federal), for the sake of their protection and conservation. Despite the relevance of these protected areas for conserving these endangered species, in upcoming years, new species may be added to the current red lists (i.e., considered endangered) (Loyola et al., 2018).

It is necessary to consider all the processes that damage biodiversity, alter ecosystems, and increase the number of threatened species; therefore, protection programs need to gain strength and space. For example, the cactus species *Melocactus violaceus* Pferiff (known in Brazil as *coroa-de-frade* or "friar's-crown") is classified as Vulnerable by the IUCN and the Brazilian red lists. *M. violaceus* used to be found on sandbanks of the Baixada de Jacarepaguá, in Rio de Janeiro, but no recent record of this species was found in PAs of the region. The management plan of the Chico Mendes Municipal Natural Park specifically mentions the absence of this species (Detzel, 2014b). This cactus may be undergoing local extinction due to extensive threats, degradation, and fragmentation of its natural habitats. In the state of Rio de Janeiro, all the large forest remnants are almost entirely enclosed within conservation units (Rocha, Bergallo, Alves, & Sluys, 2003).

The most numerous PA category was "Environmental Protection Area" (EPA). EPAs are easier to establish than other types of protected areas, mainly because of their lower degree of restriction on natural resource use and for not requiring land expropriation, which facilitates the regularization of its boundaries (Rylands & Brandon, 2005b). These areas consent to a certain level of human occupation (Brasil, 2000), as seen in the Marapendi Environmental Protection Area, where numerous commercial and residential buildings are located (Arcadis, 2016a). Due to these characteristics, the Environmental Protection Areas may not contribute with the same efficiency to biodiversity conservation as other categories (Pacheco, Neves, & Fernandes, 2018).

The second most numerous PA category was "Park". This category also had the largest number of threatened species and represented most PAs with a management plan. The Tijuca National Park, for example, which had the highest number of threatened species in our survey, has broad-scale relevance for harboring the highest number of threatened species among all PAs in the state (Pougy et al., 2014).

Although the main goals of the Park category are "[...] the preservation of natural ecosystems of great ecological relevance and scenic beauty, enabling scientific research and the development of environmental education and interpretation activities, recreation in contact with nature and ecological tourism [...]" (Brasil, 2000), these PAs may eventually fail to achieve them. In some cases, most visitors are not even aware of the goals of the conservation unit, nor of its importance and representativity for biodiversity conservation (Costa, Medeiros, Avelino-Capistrano, & Santos, 2018). The creation of management councils and the implementation of management plans are essential to guarantee an understanding of belonging and identification of surrounding communities with a PA (Carregosa, Silva, & Kunhavalik, 2015). As shown in Supplementary Table 1, more than two-thirds of the PAs in the municipality of Rio de Janeiro do not have a management council or a management plan and, among those that have a management plan, some were created over ten years ago. In these cases, a revision of the document with greater input from the local

population could contribute to improve the relationship between the community and the PA, which ultimately helps achieve the proposed conservation goals.

The list of threatened species in state-level PAs located in the city of Rio de Janeiro presented by Maruenza, Bocayuva, Pougy, Martins, and Martinelli (2018) differs from the species list that we present herein. This is due to methodological differences between the two surveys, because other than searching the same databases of scientific collections used in our study, Maruenza et al. (2018) consulted researchers and taxonomic experts regarding the collections and populations known to them. However, unlike us, those authors did not use the primary data contained in management plans as a data source. Among the differences, some species were recorded in their study but were not found in our survey. For example, *Paubrasilia echinata* (Lam.) Gagnon, H.C.Lima & G.P.Lewis was not found in our study but was listed by Maruenza et al. (2018) as occurring in state-level PAs (Chacrinha State Park, Guaratiba Biological Reserve, Gericinó-Mendanha Environmental Protection Area). The opposite also took place: we found records of *Anemia gardneri* Hook in the Chacrinha State Park, but this species was not listed by Maruenza et al. (2018).

Some endangered species, such as *Rhipsalis cereoides* (Backeb. & Voll) Backeb (CR), *Pitcairnia albiflos* Herb. (EN), *Tillandsia araujei* Mez (EN), and *Vriesea botafogensis* Mez (CR), were listed in either "Morro da Urca" or "Pão de Açúcar". However, they were not found in the consulted databases as occurring in the Morros Pão de Açúcar and Urca Natural Monument (the PA which comprises both "Morro da Urca" and "Pão de Açúcar"), nor were they mentioned in its management plan. Moreover, other than the three species above, *Coleocephalocereus fluminensis* (Miq.) Backeb. (MS) is referred to in the management plan of the Paisagem Carioca Municipal Natural Park from a secondary data source (Secretaria Municipal de Meio Ambiente , 2013). In the Guaratiba State Biological Reserve, there is a record in the literature of *Anthurium luschnathianum* Kunth (Maruenza et al., 2018); however, there are no primary data records of this species in the PA management plan, nor in the online databases. Thus, it is worth noting that, eventually, the number of threatened species in PAs may be even higher than those presented here, due to the lack of primary data records in the management plans, or the lack of location and/or accurate mention of the collection sites. However, despite the conservative approach taken in this study, the number of threatened species found reinforces the relevance of PAs for conservation, especially in one of the most populated and developed regions of Brazil. Knowledge about the diversity and threatened species within Brazilian PAs is still relatively scarce (Oliveira et al., 2017).

The management flaws of these protected areas, together with the data presented herein, justify the need for an expansion of the conservation programs in Rio de Janeiro city. This expansion should include tools that allow a broadening of the concepts established and the goals set for the protected areas.

A limitation of our survey was the exclusion of Private Natural Heritage Reserves, which greatly contribute to biodiversity conservation despite their smaller sizes (Crouzeilles, Vale, Cerqueira, & Greele, 2012; Clancy et al., 2020).

Conclusion

Our study on the presence of threatened plant species in protected areas (PAs) of Rio de Janeiro revealed a lack of vegetation data in many management plans. The scarcity of specific programs targeting the protection of threatened species (e.g., only 20% of the PAs assessed presented programs of this nature) results in insufficient or inadequate monitoring of their populations. Our results stress the need for management plans to include protection and conservation actions to avoid the extinction of threatened species in PAs, especially in large cities such as Rio de Janeiro, where most forest remnants are contained within PAs.

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Supplementary material

Supplementary table I. Information about the Protected Areas (PA) fully or partially located within the municipality of Rio de Janeiro: area of the PA, whether the PA has a management plan, whether threatened species occur in the PA, and whether the PA has a program that contemplates the management and conservation of these species. (FP – full protection; SU - sustainable use; * - PA without georeferenced limits in the databases provided by managing agencies; X – It was not possible to identify the origin of the records)

Protected Area	Group	Year of establishment	Area (ha)	Management council	Management plan	Date of management plan	Species list based on primary data	List or indication of threatened species occurrence	Number of threatened species (VU; EN; CR)	Program focused on threatened species	Reference
Federal											
Ilhas Cagarras Natural Monument	FP	2010	105,9	Yes	Yes	2020	X	Yes	5	Yes	ICMBio, 2020
Tijuca National Park	FP	1961	3200	Yes	Yes	2008	Yes	Yes	41	Yes	ICMBio, 2008
State											
Chacrinha State Park*	FP	1969	13,3	-	Yes	2006	No	No	4	No	IEF, 2006a
Guaratiba Biological Reserve	FP	1974	3360	Yes	Yes	2013	X	Yes	-	Yes	PPMA, 2013b
Pedra Branca State Park	FP	1974	12500	Yes	Yes	2013	No	Yes	17	No	PPMA, 2013a
Grajaú State Park	FP	1978	55	-	Yes	2006	No	No	1	No	IEF, 2006b
Mendanha State Park	FP	2013	4,4	Yes	No	-	-	-	1	-	-
Sepetiba II Environmental Protection Area	SU	2004	171,6	Yes	No	-	-	-	-	-	-
Gericinó/Mendanha Environmental Protection Area	SU	2005	7972,4	Yes	No	-	-	-	1	-	-
Municipal											
Barra da Tijuca – Nelson Mandela Municipal Natural Park	FP	2013	450	-	Yes	2016	Yes	Yes	4	Yes	Arcadis, 2016b
Bosque da Barra Municipal Natural Park	FP	1983	50	Yes	Yes	2014	Yes	Yes	3	Yes	Detzel, 2014a
Catacumba Municipal Natural Park	FP	1979	26,5	Yes	Yes	2008	Yes	Yes	5	Yes	SMAC. 2008
Chico Mendes Municipal Natural Park	FP	1989	40,6	Yes	Yes	2014	Yes	Yes	4	Yes	Detzel, 2014b
Cidade Municipal Natural Park	FP	2008	47	Yes	No	-	-	-	2	-	-
Darke de Mattos Municipal Natural Park	FP	1976	7,2	No	No	-	-	-	-	-	-
Fazenda do Viegas Municipal Natural Park	FP	1996	8,5	No	No	-	-	-	-	-	-
Fonte da Saudade Municipal Natural Park	FP	2000	2,2	No	No	-	-	-	-	-	-
Freguesia Municipal Natural Park	FP	1992	29,9	No	No	-	-	-	-	-	-
Grumari Municipal Natural Park	FP	2001	805	Yes	Yes	2012	Yes	Yes	12	Yes	Detzel, 2012b
Jardim do Carmo Municipal Natural Park	FP	2001	2,6	No	No	-	-	-	-	-	-
José Guilherme Merquior Municipal Natural Park	FP	2016	8,3	No	No	-	-	-	-	-	-
Marapendi Municipal Natural Park	FP	1978	155	Yes	Yes	2016	Yes	Yes	5	Yes	Arcadis, 2016c
Paisagem Carioca Municipal Natural Park	FP	2013	160	No	Yes	2013	No	Yes	1	Yes	SMAC, 2013
Penhasco Dois Irmãos Municipal Natural Park	FP	1993	38	Yes	No	-	-	-	1	-	-
Prainha Municipal Natural Park	FP	1999	157,1	Yes	Yes	2012	Yes	Yes	13	Yes	Detzel, 2012b
Professor Melo Barreto Municipal Natural Park*	FP	2007	5,2	-	No	-	-	-	-	-	-
Serra da Capoeira Grande Municipal Natural Park	FP	2001	20,9	No	No	-	-	-	-	-	-
Serra do Mendanha Municipal Natural Park	FP	2001	1445	Yes	Yes	2012	X	Yes	3	Yes	Detzel, 2012c
Pau da Fome e Camorim Biological Reserve*	FP	1990	-	-	-	-	-	-	-	-	-
Morros do Pão de Açúcar e da Urca Natural Monument	FP	2006	91,5	Yes	Yes	2012	Yes	No	5	Yes	Detzel, 2012a
Bairro da Freguesia Environmental Protection Area	SU	1992	360,5	No	No	-	-	-	-	-	-
Brisas Environmental Protection Area	SU	1992	101,6	No	No	-	-	-	-	-	-
Fazenda da Taquara Environmental Protection Area	SU	2002	8,5	No	No	-	-	-	-	-	-
Fazendinha Environmental Protection Area	SU	1984	13,2	-	No				-		-
Grumari Environmental Protection Area	SU	1990	2533	No	No	-	-	-	5	-	-

Marapendi Environmental Protection Area	SU	1978	155	Yes	Yes	2016	Yes	Yes	4	Yes	Arcadis, 2016a
Morro da Saudade Environmental Protection Area	SU	1992	8,3	No	No	-	-	-	-	-	-
Morro da Viúva Environmental Protection Area*	SU	1997	16,5	-	No	-	-	-	-	-	-
Morro do Cachambi Environmental Protection Area	SU	2007	142,4	-	No				-		-
Morro do Leme Environmental Protection Area*	SU	1995	127	No	No	-	-	-	-	-	-
Morro do Silvério Environmental Protection Area	SU	1999	148,5	No	No	-	-	-	-	-	-
Morro do Valqueire Environmental Protection Area	SU	2001	166,1	No	No	-	-	-	-	-	-
Morro dos Cabritos Environmental Protection Area	SU	1992	128,1	No	No	-	-	-	-	-	-
Morros da Babilônia e de São João Environmental Protection Area	SU	1996	122,8	Yes	No	-	-	-	-	-	-
Morros do Leme e Urubu, Pedra do Anel, Praia do Anel e Ilha da Cotunduba Environmental Protection Area	SU	1990	122,2	-	No	-	-	-	-	-	-
Orla da Baía de Sepetiba Environmental Protection Area	SU	2004	172	No	No	-	-	-	-	-	-
Orla Marítima Environmental Protection Area	SU	1998	248	No	No	-	-	-	-	-	-
Paisagem Carioca Environmental Protection Area	SU	2013	204	No	No	-	-	-	-	-	-
Paisagem e Areal da Praia do Pontal Environmental Protection Area	SU	2000	22,9	No	No	-	-	-	-	-	-
Pedra Branca Environmental Protection Area	SU	1998	12,5	No	No	-	-	-	1	-	-
Pontas de Copacabana, Arpoador e seus Entornos Environmental Protection Area	SU	1994	2,6	No	No	-	-	-	-	-	-
Prainha Environmental Protection Area	SU	1990	157,1	No	No	-	-	-	5	-	-
Sacopã Environmental Protection Area	SU	1986	94,8	No	No	-	-	-	-	-	-
Santa Teresa Environmental Protection Area	SU	1984	515,7	-	No	-	-	-	-	-	-
São José Environmental Protection Area	SU	2004	108,9	No	No	-	-	-	-	-	-
Serra da Capoeira Grande Environmental Protection Area	SU	1999	80	No	No	-	-	-	2	-	-
Serra dos Pretos Forros Environmental Protection Area	SU	2000	2646	No	No	-	-	-	-	-	-
Tabebuias Environmental Protection Area	SU	1999	65	No	No	-	-	-	-	-	-
Várzea Country Clube Environmental Protection Area	SU	1991	7,8	No	No	-	-	-	-	-	-
São Conrado Area of Relevant Ecological Interest	SU	2003	83	No	No	-	-	-	-	-	-