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Brazilian Flora 2020: Innovation and collaboration to meet Target 1 of the Global Strategy for Plant Conservation (GSPC)

The Brazil Flora Group

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Resumo

A Estratégia Global para a Conservação das Plantas (GSPC) foi estabelecida pela Conferência das Partes em 2002 para diminuir a perda da diversidade vegetal, reduzir a pobreza e contribuir para o desenvolvimento sustentável. Para atingir um objetivo tão abrangente, a GSPC estabeleceu uma série de tarefas, uma das quais é assegurar um bom conhecimento da diversidade vegetal para que a mesma possa ser conservada de forma efetiva e utilizada de maneira sustentável. O Brasil possui mais de 46 mil espécies de plantas, algas e fungos, representando um dos países com maior biodiversidade no planeta, sendo um participante chave na GSPC. Para atingir os objetivos da GSPC e possibilitar o acesso à diversidade de plantas, o Brasil se comprometeu em preparar a Lista de Espécies da Flora do Brasil (2008-2015) e a Flora do Brasil 2020 (2016 até o presente). Gerenciar todas as informações relacionadas a esta enorme biodiversidade provou ser uma tarefa extremamente desafiadora. Neste artigo, sintetizamos a história destes projetos e a abordagem multidisciplinar e colaborativa adotada para desenvolver e gerenciar a inclusão de todo o conhecimento gerado em sistemas de informação digitais. Apresentamos ainda os métodos utilizados, desafios enfrentados, e estratégias adotadas, bem como sintetizamos os avanços até o momento e perspectivas para completar a flora do Brasil em 2020.

Palavras-chave: banco de dados, diversidade, *hotspots*, taxonomia.

Abstract

The Global Strategy for Plant Conservation (GSPC) was established by the Conference of Parties in 2002 to decrease the loss of plant diversity, reduce poverty and contribute to sustainable development. To achieve this overarching goal, the GSPC has established a series of targets, one of which is to ensure that plant diversity is well understood, so that it can be effectively conserved and used in a sustainable manner. Brazil hosts more than 46,000 species of plants, algae and fungi, representing one of the most biodiverse countries on Earth, and playing a key role in the GSPC. To meet the GSPC goals of Target 1 and facilitate access to plant diversity, Brazil committed to preparing the List of Species of the Brazilian Flora (2008–2015) and the Brazilian Flora 2020 (2016–present). Managing all the information associated with such great biodiversity has proven to be an extremely challenging task. Here, we synthesize the history of these projects, focusing on the multidisciplinary and collaborative approach adopted to develop and manage the inclusion of all the knowledge generated though digital information systems. We further describe the methods used, challenges faced, and strategies adopted, as well as summarize advances to date and prospects for completing the Brazilian flora in 2020.

Key words: database, diversity, hotspots, taxonomy.

Introduction

Increasing global concern about current threats to biodiversity led to the establishment of the Convention on Biological Diversity (CBD), an international forum to discuss the most effective means by which countries with significant biodiversity could participate effectively in conservation actions. This forum was created during the United Nations Conference on Environment and Development (popularly known as the "Rio Summit," "Rio-92" or "Eco-92"), held in Brazil in 1992. Among the commitments of all CBD signatories is the Global Strategy for Plant Conservation (GSPC), which aims to facilitate consensus and synergy between the generation of knowledge and plant conservation at local, regional and global levels (CBD 2010a, 2010b).

To meet the 2010 and 2020 goals of Target 1 of the GSPC, Brazil committed to produce a comprehensive list of all plants, algae and fungi found in the country, plus morphological descriptions of all of these taxa, as a means for accurate species identification. These goals were implemented through two successive projects coordinated by the Jardim Botânico do Rio de Janeiro (JBRJ), namely the: (i) List of Species of the Brazilian Flora (Lista de Espécies da Flora do Brasil, 2008–2015), and (ii) Brazilian Flora 2020 (Flora do Brasil 2020, 2016–present). Considering the pioneering nature of this initiative, as well as the vast amount of biological data involved, collaborative efforts and innovative approaches, especially concerning bioinformatics, were greatly needed for data archiving and dissemination.

Here, we synthesize the history of the List of Species of the Brazilian Flora and the Brazilian Flora 2020, and summarize the methods used to develop and manage those projects, especially the ongoing Brazilian Flora 2020. We present results to date, as well as prospects for meeting Target 1 in 2020.

History

The List of Species of the Brazilian Flora

The first step to achieve the goal of Target 1 of the GSPC for 2010 was to develop a functional list of all known plant species for each CBD signatory country (CBD 2010a). In order to achieve this goal, in 2008 the Brazilian Ministry of the Environment (Ministério do Meio Ambiente, MMA, Brazil) designated JBRJ to coordinate the List of Species of the Brazilian Flora project (hereafter "Brazilian List"). In that same year, a meeting was held at JBRJ including 17 taxonomists and information systems specialists, representing around 20 research institutions and all Brazilian regions (see Forzza *et al.* 2010a). Several important decisions were made during that meeting: a broad definition of the focal taxa (encompassing algae, fungi, bryophytes, and vascular plants), the composition of the project coordination committee, and the designation of scientific coordinators for each taxonomic group. Furthermore, a strategy was established to produce the "Brazilian List" in two main phases. During the first phase, all names published in *Flora brasiliensis* (Martius *et al.* 1840–1906), regional species lists, and also names published for Brazilian taxa in the International Plant Name Index (IPNI 2009) and in the World Checklist of Selected Plant Families (2009) would be combined in a comprehensive list that would be thoroughly evaluated by specialists during the second phase. Work conducted during the first phase of the project resulted in an initial database (see Forzza *et al*. 2010a) that included ca. 90,000 names. To expedite the completion of the "Brazilian List" an online information system was developed by the Reference Center on Environmental Information (Centro de Referência em Informação Ambiental, CRIA) to enable online collaboration among researchers from different parts of the country and abroad. This information system allowed taxonomists to edit species lists simultaneously, and almost 80% of the names included in this database were reviewed by 413 taxonomists.

Between April 7th and December 31st 2009, specialists indicated the taxonomic status of each name (*i.e.*, accepted *vs*. synonym) and cited at least one voucher (*i.e.*, herbarium specimen) or literature attesting to the occurrence of individual species (or infraspecific taxon) in Brazil (Forzza *et al.* 2010b). During this phase, geographic distribution data (federal states, and phytogeographic domains or biomes *sensu* IBGE 2004) were also recorded for each taxon, and specialists either indicated whether or not each species or infraspecific taxon was endemic to Brazil (Forzza *et al.* 2010b). Over the first two years, the National Center for Plant Conservation (Centro Nacional de Conservação da Flora, CNCFlora) provided important support for the "Brazilian List" because this list represented a key source of names to meet Target 2 of the GSPC through the preparation of the Red List of the Brazilian Flora (Livro Vermelho da Flora do Brasil; Martinelli & Moraes 2013). During this first phase, specialists checked 78,723 names (Forzza *et al.* 2010b). The evaluation of such an unprecedented amount of data by multiple specialists, based in different regions, using a unified online platform, was only possible due to technological advances and increased internet speed, in a continental country with regional infrastructure differences.

The "Brazilian List" was finalized and made available online on the 21st May 2010, meeting Target 1 of the GSPC. In addition, the decision to publish a printed catalog led to a detailed revision of all the information compiled until that point by an editorial board composed of taxonomists that were members of the project coordination committee. This publication included all accepted names of native plants and non-native plants (except cultivated) recorded for Brazil, as well as species endemisms. Furthermore, distribution data indicating presence or absence across Brazilian states and phytogeographic domains (biomes), as well as vouchers and/or literature were also included (Forzza *et al.* 2010b).

Overall, the Catalog of Brazililan Plants and Fungi (Catálogo de Plantas e Fungos do Brasil) contains information about 40,989 native (incl. endemic) and non-native (except cultivated) species of plants, algae, and fungi, distributed as follows: algae 3,496 species (1.5% endemic) (Bicudo & Menezes 2010); angiosperms 31,162 species (56.6% endemic) (Forzza *et al.* 2010c); bryophytes 1,521 species (18.1% endemic) (Costa & Luizi-Ponzo 2010); fungi 3,608 species (14.5% endemic) (Maia & Carvalho Jr. 2010); gymnosperms 26 species (7.7% endemic) (Souza 2010); and ferns and lycophytes 1,176 species (38.3% endemic) (Prado & Sylvestre 2010). These results indicated that Brazil is the country with the highest number of species of plants in the world, and considering the richness of vascular plants alone (32,364 species), Brazil ranks first among the 10 most megadiverse countries (Forzza *et al.* 2012).

In order to achieve the goal of the Target 1 for 2020, we maintained the same structural collaboration network and computational technology, while incorporating new fields and functionalities into the online system so that species descriptions, identification keys, photographs, illustrations and additional distribution data could be included in this database.

Integration and collaboration between the "Brazilian List" and Reflora

Biological collections are key to meeting the goals established by the GSPC for 2020. More specifically, digitization of biological collection data is critical for understanding and documenting of plant diversity. By making biological collection data available online, studies on biodiversity are facilitated, especially the preparation of taxonomic and monographic work.

As such, the Brazilian National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico, CNPq) launched, in December of 2010, the project "Plants of Brazil: Historic Rescue and a Virtual Herbarium for Knowledge and Conservation of the Brazilian Flora – Reflora" (Plantas do Brasil: Resgate Histórico e Herbário Virtual para o Conhecimento e Conservação da Flora Brasileira – Reflora). The primary goal of Reflora was to make high-resolution images of Brazilian botanical specimens freely available to scientists and the general public through an online platform. Attention was focused on herbarium specimens collected during the XVIII and XIX centuries, deposited in the National Museum of Natural History, in France, and in the Royal Botanic Gardens, Kew, in England.

JBRJ was designated by CNPq to coordinate this project and to host the equipment needed to receive, store, and disseminate the specimen images obtained. In addition, it was established that the collections deposited at the JBRJ herbarium, a major reference for Brazilian botanical studies (*e.g.*, Gasper & Vieira 2015), would also be digitized and published online. In order to handle such hundreds of thousands of high quality images, a new online platform was needed. Considering that botanical taxonomy and nomenclature are directly linked to herbarium specimens, the new online system housing the images from P, K and RB (Thiers continuously updated) had to be integrated with the "Brazilian List". Thus, Reflora resources were also used to maintain and develop the "Brazilian List", in order to meet Target 1 of the GSPC in 2020.

At the beginning of 2012, JBRJ firmed a partnership with the Systems and Computation Engineering Program of the Institute for Graduate Studies and Research in Engineering of the Federal University of Rio de Janeiro (Programa de Engenharia de Sistemas e Computação do Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia, COPPE - UFRJ) to jointly develop the new information system. This system would be subsequently used by Reflora as well as would house the existing online system hosting the "Brazilian List", in order to ensure that both information systems would be compatible. It took over one year to conclude the updated information system that would host all data obtained through the "Brazilian List" and serve as basis for the next project, the Brazilian Flora 2020 which would include all the monographic work required to meet Target 1 of GSPC by 2020. This new system was released to the public on the 8th March 2013, while the Reflora Virtual Herbarium was released on the 30th September 2013, including approximately 420,000 images of specimens deposited at P, K and RB.

The Reflora Virtual Herbarium is not only an image and data repository but also includes a series of tools aiming at assisting taxonomists by streamlining the daily routine of herbaria and plant identification. These tools allow the inclusion of updated specimen identifications, the designation and categorization of type materials, corrections of locality data, and measurements of morphological structures from images, among others. In sum, this system aims at expediting the work of taxonomists and monographic work.

As Reflora progressed, it became apparent that the project could benefit substantially from the participation of additional Herbaria. As such, Reflora firmed partnerships with the Information System on Brazilian Biodiversity (Sistema de Informação sobre a Biodiversidade Brasileira, SiBBr) and the National Forest Inventory (Inventário Florestal Nacional, IFN/SFB) in 2014. These partnerships allowed the participation of eight additional foreign herbaria (*i.e.*, B, E, GH, MO, NY, S, US, W), as well as dozens of national collections. This initiative allowed continuous databasing and digitizing Brazilian specimens, with the resulting data being constantly published and updated in the Reflora Virtual Herbarium (see <http://reflora.jbrj.gov.

br/reflora/herbarioVirtual/> for a complete list of participating herbaria). The integration with smaller Brazilian herbaria allowed advances in the identifications of these collections, which generally receive a smaller number of specialists to update the identification of their specimens due to their location outside of the major economic centers of the country (*e.g.,* Versieux *et al.* 2017). These partnerships were also fundamental for the development of the "Brazilian List" system by allowing the inclusion of new functionalities and maintenance of a management team.

The "Brazilian List" was concluded in November 2015, with the publication of a series of articles synthesizing all the data on algae, angiosperms, bryophytes, fungi, gymnosperms, ferns and lycophytes of Brazil compiled during the eight years of duration of this project (see papers published in Rodriguésia 66[4]: 2015, respective databases and supplements at <http://ckan.jbrj.gov.br/dataset/floradobrasil>). The "Brazilian List" quickly became a key tool for the scientific community, the general public, and the government, by enabling rapid generation of species lists in various formats, as well as faster recognition of new species and new occurrence records. Furthermore, the "Brazilian List" also became an essential tool for curating botanical collections and for taxonomical harmonization, as well as constituted the taxonomic base for risk evaluations and the publication of two reference books: (i) Livro Vermelho da Flora do Brasil (Martinelli & Moraes 2013) and (ii) Livro Vermelho da Flora do Brasil – Plantas Raras do Cerrado (Martinelli *et al.* 2014), both of which are freely available at <http://cncflora.jbrj.gov.br/portal>.

Material and Methods

The Brazilian Flora 2020

With the end of the "Brazilian List" it was time to move forward with the GSPC's Target 1 for 2020 and start the second project entitled Brazilian Flora 2020 which entailed the preparation of descriptions for all taxa listed in the "Brazilian List". On 10th March 2015, a call for proposals to prepare monographs for the Brazilian Flora 2020 was sent to all the taxonomists that contributed to the "Brazilian List". This call for proposals was open until the 30th June 2015. In October 2015, a meeting was held at JBRJ with members of the project coordination committee to make decisions on the proposals submitted, review the updated online platform that would be used to prepare the monographs, and finalize the project guidelines and management plan.

One major change from the practices employed in the preparation of the "Brazilian List" was the exclusion of coordinators for different taxonomic groups in the Brazilian Flora 2020 so that all taxonomists involved with a particular proposal would be equally responsible for the monographic work on that group. Differently from the authorship system adopted for the "Brazilian List", authorship of the Brazilian Flora 2020 will be attributed after the completion of monographs, with the order of authors being proportional to the work contributed by each participant. The authorship string will be generated by the online system and will reflect the completeness of the morphological descriptions available for each taxon (*e.g.,* genus or family). However, if there is consensus among the authors of a particular group, the order of authors can also be changed manually. Because not all of the contributors to the "Brazilian List" submitted proposals for the Brazilian Flora 2020, authorship of the information published up to 2015 was fixed in a non-editable "Reference" field, along with citations for the syntheses papers published in November 2015.

The new working online platform for the Brazilian Flora 2020 and its public home page (http://floradobrasil.jbrj.gov.br) were launched on the 17th February 2016. By that point, the monograph proposals included 100% of the native and naturalized species of gymnosperms, 78% of the angiosperms, 74% of the ferns and lycophytes, 36% of the bryophytes, 17% of the fungi, and 2% of the algae. An open call for new proposals was launched at that point, with new proposals being continuously evaluated by the coordination committee. The Brazilian Flora 2020 currently includes 770 taxonomists (Brazilians and foreigners) affiliated to 203 institutions, representing the largest biodiversity research network in Brazil.

The online information system developed for the Brazilian Flora 2020 was constructed using the MDArte (Model Driven Architecture) framework. The new system represents an additional module within the previously available system developed for the "Brazilian List". New functions were included with minimal impact to the running system and seamless integration. The new module allowed the inclusion of morphological descriptions for the various taxa, as well as allowed new authorship rules, and the inclusion

of additional fields within the working area (*e.g.*, keys, free text plant descriptions). This new module was developed in plain Java using no frameworks, open source common libraries exclusively, and an interface that was completely decoupled from the core system, using the concept of rich clients and interface components. This methodology enabled the morphological description functionality to be easily added to any other system that uses a taxonomic hierarchical tree. For systems built in Java, such as the Taxonomic Catalog of the Brazilian Fauna (<http://fauna.jbrj.gov.br/>), the integration is seamless.

PostgreSQL was the chosen database, with the PostgreSQL JSON native support being used to accommodate the complex characters and respective character states in three different languages, *i.e.*, English, Portuguese and Spanish. The whole database structure follows the Common Data Model (<http://dev.e-taxonomy.eu/trac/wiki/CommonDataModel>), ensuring that the data can be easily exported to other systems that use Darwin-Core standards (Berendsohn *et al*. 1999; Müller *et al*. 2017).

Furthermore, all data included in the system (*i.e*., nomenclature, life form, and distribution) are stored in a Darwin Core Archive dataset (<http://tools.gbif.org/dwca-assistant/>) that can be easily exported and integrated into other systems (Wieczorek *et al.* 2012). These data are available through the Integrated Publishing Toolkit (IPT), which is updated weekly (http://ipt.jbrj.gov.br/), using a web service that is updated on a daily basis (<http://servicos.jbrj.gov.br/flora>).

In the Brazilian Flora 2020 system, groups are structured within a taxonomic tree that includes six main branches representing the highest taxonomic ranks, each of which includes different subdivisions, as follows: (i) algae includes class, genus, species and infraspecific taxa; (ii) angiosperms, (iii) gymnosperms and (iv) ferns plus lycophytes include family, genus, species and infraspecific taxa; (v) bryophytes, divided into hornworts, liverworts and mosses, each of which includes family, genus, species and infraspecific taxa; and, (vi) fungi, divided into *sensu lato* and *sensu stricto*, each of which includes division, order, genus, species and infraspecific taxa. While registered users can see all branches of the taxonomic tree within the working area, users only have permission to edit taxa included in their study groups. Taxonomists are responsible for monographing families or genera, depending on the taxon size. A maximum limit of 300 species was established per taxonomist. On the other hand, families with 60 species or fewer must be treated by the same group of taxonomists.

The authors of each monograph start their treatment with the information that was already entered into the "Brazilian List" (*i.e*., species list, nomenclature, life form, substrate, voucher, endemism, and distribution). The author is then able to accept, add or change this information accordingly, as well as to associate herbarium images to the individual species and infraspecific taxa. For that, the author can use images available from the Reflora Virtual Herbarium (<http://reflora.jbrj.gov.br/>), images from the Herbário Virtual da Flora e dos Fungos (HVFF/INCT) (<http://inct.florabrasil.net/>), any other images available to them (*e.g.*, photos of specimens and living plants), or botanical illustrations (*e.g.*, line drawings and watercolors). In addition, the authors of each monograph are also in charge of filling out "free text" fields that allow the inclusion of taxonomic descriptions and general comments at different hierarchical levels (*i.e.*, families, genera, species, and infraspecific taxa). The "free text" fields can also be used to include keys for different hierarchical levels (*i.e.*, genera, species, and infraspecific categories). Identification keys can also be included through links to interactive keys stored in other online systems.

For vascular plant genera with two or more species, it is necessary to configure characters (at least five, up to 20) with character states that separate species or groups of species. To configure the "controlled" fields, only terms that are included into the system glossary can be used; all terms are available in Portuguese, English and Spanish. The initial system glossary was based in Radford *et al.* (1974), Font Quer (1989), Longhi-Wagner *et al.* (2001), Lellinger (2002), and Roque & Bautista (2008). Currently, the glossary contains approximately 13,000 terms. New terms can be added after consultation with the coordination committee. After configuring "controlled" fields for individual genera, the user must select the appropriate character states for each species included in that genus. Whenever the exact same character states are selected for two or more species of a single genus, the system indicates overlap and the author is required to either revise the character states entered into the "controlled" field or add additional information into the "free" field so that sufficient information is provided to distinguish each species from its congeners. The information entered into

the "controlled" fields is used to automatically generate descriptions for each taxon in Portuguese, English and Spanish. The exact language displayed for a particular description depends on the language chosen by the user navigating the system.

Results and Discussion

The Brazilian Flora 2020 and the Reflora Virtual Herbarium distribute key information for botanical systematic studies throughout the world, as well as provide important information for the general public and establishes the basis for public policies aimed at conserving biodiversity. The data within these two platforms are shared with other biological data systems around the world, such as the Global Biodiversity Information Facility - GBIF (<http://www.gbif.org>), the World Flora Online (<http://www.worldfloraonline.org>), and the SiBBr (<http://www.sibbr.gov.br>). In addition, accurate taxonomic information and species distribution data are also provided to the IFN (<http://www.florestal.gov.br/inventario-florestal-nacional>), and to the CNCFlora (<http://cncflora.jbrj.gov.br>), aiding extinction risk assessment, a key component of Target 2 of the GSCP (<https://www.cbd.int/gspc/targets.shtml>). The Brazilian Flora 2020 also provides reliable names so that different herbaria and data repositories are able to harmonize their names, as example JABOT (<http://jabot.jbrj.gov.br/>), and speciesLink (<http://www.splink.org.br/>).

To date, the Brazilian Flora 2020 includes 121,989 names of species and infraspecific categories, of which 90% were checked by specialists and are available through the home page (<http://floradobrasil.jbrj.gov.br>). Overall, the system contains information on 532 families (or classes for algae and orders for fungi), 5,823 genera, and 46,233 native and naturalized species (see supplementary material: <https://ckan.jbrj.gov.br/dataset/thebrazilfloragroup_feb2018>), of which 170 families (32%), 1,534 genera (26.3%), and 15,901 species (34.4%), now include morphological descriptions, identification keys, field images, and botanical illustrations. In addition, more than three million high-resolution images of botanical specimens are available in the Reflora Virtual Herbarium and can be linked to individual taxa.

Nomenclatural information, life-form, substrate and distribution for each taxonomic group, can be accessed through the Brazilian Flora 2020 web service (<http://servicos.jbrj.gov.br/flora/>) and also through the Integrated Publishing Toolkit (IPT) provided by GBIF (<http://ipt.jbrj.gov.br/jbrj/resource?r=lista_especies_flora_brasil>). For each taxonomic group, the following taxa are currently accepted for Brazil:

(i) Fungi: 14 divisions, 103 orders, 1,246 genera, 5,718 species, and 140 infraspecific taxa;

(ii) Algae: 30 classes, 1,018 genera, 4,754 species, and 1,455 infraspecific taxa;

(iii) Bryophytes: 118 families, 417 genera, 1,568 species, and 77 infraspecific taxa;

(iv) Ferns and lycophytes: 38 families, 153 genera, 1,330 species, and 53 infraspecific taxa;

(v) Gymnosperms: six families, seven genera, and 30 species;

(vi) Angiosperms: 237 families, 2,982 genera, 33,099 species, and 2,785 infraspecific taxa.

In February 2018, two years after its official launch, the Brazilian Flora 2020 had monograph proposals approved for families and genera as follows: 2.3% of the algae species available in the database, under the responsibility of 10 taxonomists; 81% of the angiosperm species, 662 taxonomists; 87% of the bryophyte species, 41 taxonomists; 4.2% of the fungi species, four taxonomists; 77% of the gymnosperm species, five taxonomists; and 79% of the fern and lycophyte species, 48 taxonomists (Fig. 1).

Three years after the publication of the "Brazilian List" (*i.e.*, BFG 2015; Costa & Peralta 2015; Prado *et al.* 2015) significant growth in knowledge for some important land plants groups has emerged. The most noticeable changes in the current database of the Brazilian Flora 2020 are the addition of 470 species of angiosperms, 77 species of ferns and lycophytes, and 44 species of bryophytes. It is also possible to see differences in relation to the estimated species richness of Brazilian biomes for these groups, probably due to more accurate information compiled during the preparation of monographs (Tab. 1).

Visitor metrics for the Reflora systems (*i.e.*, Brazilian Flora 2020 and Reflora Virtual Herbarium) obtained from Google Analytics, indicate an increasing number of users as well as increasing average visitation time. Indeed, more than 3,700,000 page views, including 64.1% returning visitors and 35.9% new visitors, with an average visiting time of more than 12

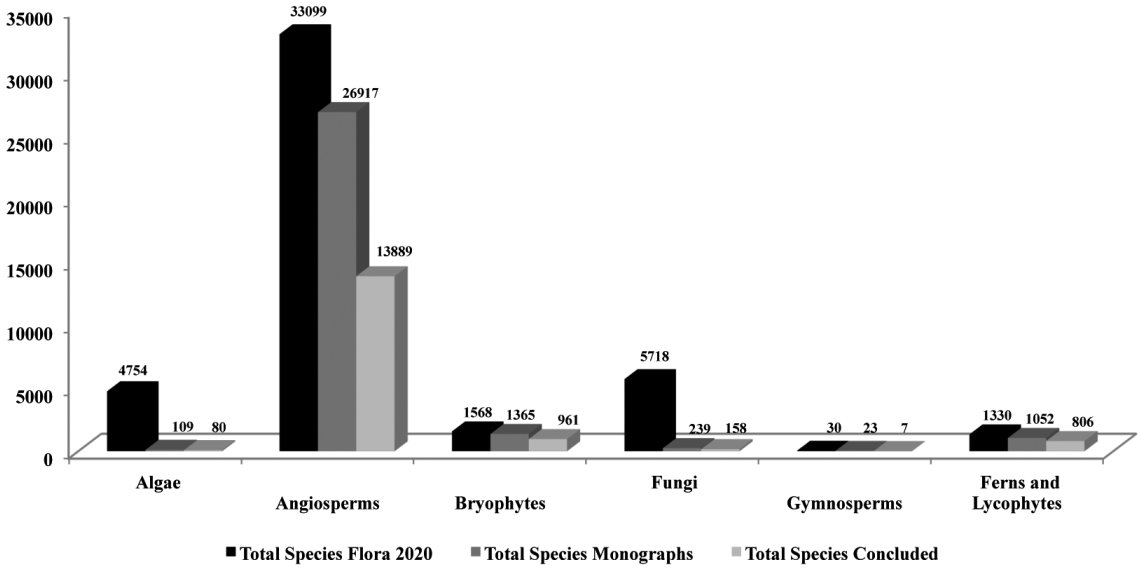

Figure 1 – Total number of species available through the database of the Brazilian Flora 2020 system, followed by the total number of monographs that are currently being prepared by taxonomists, and by total species with morphological descriptions.

Table 1 – Comparison of the taxonomic richness of different taxonomic groups found in the various Brazilian biomes.

Biomes	Taxonomic Groups							
	Angiosperms		Bryophytes		Ferns and Lycophytes		Gymnosperms	
	2015	2018	2015	2018	2015	2018	2015	2018
Amazon Rainforest	11,896	11,846	570	567	503	525	16	16
Atlantic Rainforest	15,001	15,179	1,337	1,324	883	909	3	10
Caatinga	4,657	4,702	96	104	26	35	2	2
Cerrado	12,097	12,113	478	472	269	272	6	9
Pampa	1,685	1,816	120	117	8	15	2	2
Pantanal	1,277	1,299	176	160	30	38	0	0

minutes have been observed within each of the two years of duration of this project. Apart from the obvious relevance of the Brazilian Flora 2020 for biodiversity research and conservation, this database is also extremely useful for a wide array of studies and activities, involving the Brazilian flora. The high number of visits to the online system indicates that the data contained herein are currently being extensively used by researchers from various research fields, ranging from biology, agronomy, pharmacology, and chemistry, to forestry engineering, among others.

Developing and managing the Brazilian Flora 2020 system required the development of innnovative bioinformatics tools and a crowdsourcing approach (Esteves *et al.* 2015), both of which were critical to manage the vast amount of data included in the system. Despite all the advances and possible uses of the Brazilian Flora 2020 and Reflora Virtual Herbarium, both these projects had their research funds drastically reduced due to a political and economic crisis in Brazil (Angelo 2017; Escobar 2017). It is clear, though, that we need to ensure the longevity of this

system if we are to establish effective conservation actions in Brazil. Close to USD 800,000 have been invested in the projects of the "Brazilian List" and Brazilian Flora 2020, which correspond to 0.1% of the 2014 MMA budget (Teixido *et al*. 2017). These resources come predominantly from CNPq and SiBBr (Ministério de Ciência, Tecnologia, Inovação e Comunicação, MCTIC), and were used to cover computing costs, promote biannual project meetings and, above all, maintain the technical and management team that is so critical for the maintenance of this project.

Final Remarks

Knowledge on Brazilian plant biodiversity improved substantially during the last decade (Forzza *et al.* 2010b; Forzza *et al.* 2012; BFG 2015; Costa & Peralta 2015; Morim & Nic Lughadha 2015; Prado *et al.* 2015; Cardoso *et al*. 2017; Ulloa Ulloa *et al.* 2017). This is largely due to the development of important research projects such as the ones described here (*i.e.*, "Brazilian List", Reflora and Brazilian Flora 2020), as well as due to several other key research programs created within the scope of the CNPq and/or MCTIC, including:

- Biodiversity Research Program (Programa de Pesquisa em Biodiversidade, PPBIO), established in 2004 and available at <http://cnpq.br/apresentacao-ppbio>;

- Taxonomy Training Program (Programa de Capacitação em Taxonomia, PROTAX), established in 2005 and available at <http://cnpq.br/apresentacao-proatax>;

- National Institutes of Science and Technology (Institutos Nacionais de Ciência e Tecnologia, INCTs), established in 2008 and available at <http://inct.cnpq.br/>;

- National Biodiversity Research System (Sistema Nacional de Pesquisa em Biodiversidade, SISBIOTA), established in 2010 and available at <http://cnpq.br/sisbiota/apresentacao>;

- Brazilian Biodiversity Information System (Sistema de Informação sobre a Biodiversidade Brasileira, SiBBr), established in 2014 and available at <http://www.sibbr.gov.br>;

- Taxonomic Catalog of the Brazilian Fauna (Catálogo Taxonômico da Fauna do Brasil, CTFB), established in 2015 and available at <http://fauna.jbrj.gov.br/fauna>.

Unfortunately, due to the current political and economic crisis in Brazil, all of these initiatives were discontinued or had their budgets drastically cut. The alarming reality of scientific research in Brazil represents a major threat to global biodiversity (Fernandes *et al*. 2017). Indeed, continuous government actions that act in synchrony with scientific actions are critical to improve biodiversity knowledge, to promote conservation, and control biodiversity loss (Dias 2017), all of which are essential to meeting the GSPC 2020 targets. Despite the impressive numbers provided by the Brazilian Flora 2020 and the commitment of the Brazilian botanical community to improve the system, it is critical that this project is maintained so that the information is kept up to date. It is only through a good understanding of our biodiversity that we will be able to ensure adequate knowledge of the Brazilian flora, which will result in concrete preservation and sustainable development.

The completion of Target 1 of the GSPC by 2020 will provide us with a more complete and accurate view of the knowns and unknowns on the Brazilian flora. This information will be critical to identify priority areas for Conservation and botanical exploration, both of which are critical for conservation. It is clear that a lot of work still remains to be done, including fieldwork in poorly known regions such as the Amazon, where knowledge is so fragmentary (*e.g.*, Cardoso *et al.* 2017).

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