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Original article

What is being published on floristics? an overview of floristic studies carried out in the Espinhaço Range

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ABSTRACT

The campo rupestre in the Espinhaço Range is subject of many floristic studies due to its high rates of species diversity and endemism. These studies are made up of critical, easily accessible data about local richness and biodiversity, which are essential for subsidizing new studies in the fields of conservation, ecology, and systematics. This study describes the results of a survey of floristic studies carried out in the Espinhaço Range and provides a checklist of the plant species listed in them. We found that 294 floristic studies were conducted in the Espinhaço Range, but they were focused only on a few areas. Likewise, we detected sampling gaps in some areas. The Floras studied provide information on 3,191 plants or 6,3% Brazilian flora, of which 2,879 are angiosperms, 247 bryophytes, and 65 lycophytes and ferns. Finally, we observed a lack of standardization regarding the habits reported for angiosperms shrubs and subshrubs which is more problematic for Espinhaço's flora because of its grasslands or shrublands vegetation. Thereby, we reaffirm the importance and need to encourage new floristic studies in the Espinhaço Range as a means to train new taxonomists and to provide new studies and projects.

Keywords: Bahia, Checklist, Conservation, Flora, Minas Gerais and Iron Quadrangle.

Introduction

Campo rupestre, a rocky phytophysiognomy inserted in the Cerrado biome, has 5,344 species of angiosperms distributed in 124 families, 78 species of bryophytes distributed in 17 families, and 77 species of lycophytes and ferns distributed in 16 families (Flora do Brasil 2020). This vegetation harbors high rates of species endemism proportionately to the total number of species (BFG 2015), with ca. 1,748 endemic species (Colli-Silva *et al*. 2019a), of which at least 1,123 are endemic to the *campo rupestre* of Espinhaço Range (Rapini *et al.* 2021). This impressive diversity of species represents c. 15% of all Brazilian angiosperms and they are distributed in less than 1% of the Brazilian territory (Silveira *et al.* 2016; Vasconcelos *et al*. 2020). The high rates of diversity and endemism in *campo rupestre* may be the result of of old strains, with low diversification rates of diversification which survived

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due to climatic stability (OCBIL's theory) or, alternatively, the result of high diversification rates caused by climatic fluctuations in the Pleistocene (Vasconcelos *et al.* 2020). A third explanation is the "escape to radiate" model, which combines the fragmentation of the *campo rupestre* along the Espinhaço Range with high extinction rates and adaptive radiation events (Rapini *et al.* 2021). However, Rapini *et al.* (2021) pointed out that the diversification and evolution of this flora cannot be explained fully by a single mechanism.

The high rates of species richness and endemism in the Espinhaço Range's *campo rupestre* generates a unique vegetation that has attracted much interest from botanists and naturalists throughout history, such as von Martius, St. Hilaire, Spix, and Pohl (Lopes *et al.* 2011). Consequently, several floristic studies and projects have been elaborated to the Espinhaço Range region, including the *Flora da Serra do Cipó* (Giulietti *et al.* 1987), *Flórula de Mucugê* (Harley & Simmons 1986), *Flora dos Picos das Almas* (Stannard 1995), and *Flora de Grão Mogol* (Pirani *et al.* 2003). Furthermore, Floras are essential tools in the professional training of new botanists (Rapini *et al.* 2008), and other fields of biology, such as systematics and ecology, make extensive use of these studies (Funk 2006; Rapini *et al.* 2008).

Despite the importance of classical taxonomic studies, i.e., Floras and other botanical works, these have faced difficulty to be published in high-impact journals (Crisci *et al.* 2020; Zeppelini *et al.* 2021). Here we provide a detailed compilation of the floristic studies carried out in the Espinhaço Range and aim to demonstrate the importance of these studies and why they still need to be encouraged. Additionally, we provide a checklist of the plant species listed in the floristic studies we have surveyed. Thus, we aim to demonstrate that such studies carry valuable information for understanding vegetation and, therefore, must be continuously encouraged.

Materials and methods

Bibliometric research

We searched two databases: Scopus and SciELO. The bibliometric survey was conducted by searching at Scopus' and SciELO's "topic" field (i.e., title, abstract or keyword) with terms relating to both floristic diversity and Espinhaço Range location. The complete set of keywords used in the survey is available in Table S1. We performed searches with and without the term "espinhaço", as not all studies in the Espinhaço Range area have "espinhaço" in the title, abstract or keyword. The search performed without the "espinhaço" term was limited to journals that could publish this kind of work; notwithstanding, the search returned a list of floristic papers from both Minas Gerais and Bahia states, reason why we had to screen these results to keep only studies from Espinhaço Range. The selection of the Espinhaço Range floristic studies was carried out in two stages: i) reading both the title and abstract of each article, and ii) examining every article to confirm the adequacy of the definition adopted. We combined the results from the two databases and deleted duplicated data.

Finally, we also searched the collection of the *Boletim de Botânica da Universidade de São Paulo*. This journal has a long-recognized relevance for publishing floristic studies, but the journal's content is not currently available in other databases. This search was carried out directly on the journal's website (http://www.revistas.usp.br/bolbot/issue/archive), checking all articles available, including accepted ones published until 2/01/2022. We double-checked all searches. To ensure the accessibility of all data cited here, we conducted our research only in scientific journals, not investigating Ph.D. theses, master's dissertations, and books.

Checklist

After screening the floristic articles, we used the species addressed in them to compile a checklist. The species names follow Flora do Brasil 2020 and to check it, we used the R package "Flora" (Carvalho 2017; R Core Team 2020). Species whose names are not present in Flora do Brasil 2020 were checked manually using the IPNI (2020), Tropicos (2020), and The Plant List (2013). The taxa identified as *affinis* (aff.), *species incerta* (sp.), *confer* (cf.), and the taxa indicated as new species, were treated according to the original floristic publication.

In addition, for angiosperms we provided a figure detailing the habit of each species, based on the information supplied by the authors in the original floristic study. When authors did not indicate the habit of a species, we treated the case as "missing data". For Monocots, an exception was adopted: when the habit of a species was not indicated, the species was classified as either palm (for all Palmae) or herb (for all other Monocots). When the authors of the floristic study indicate more than one habit for a species, for example "shrub or subshrub" we count all habits in the analysis. Also we treat all lianas as vines, because when the floristic studies were published, there was no standardization.

Map elaboration

The distribution map of floristic studies by geological region in the Espinhaço Range was made in QGIS version 3.12.1 (QGIS Development Team 2018) by superimposing the coordinates of the floristic studies on the shapefiles of Espinhaço Range.

Results and discussion

Survey of floristic studies

The search performed in SciELO returned 59 articles using "espinhaço" as a keyword and 350 in Scopus databases. The search performed without the "espinhaço" keyword returned 575 articles from SciELO and 2124 from Scopus.

The screening step kept 294 floristic studies carried out in the Espinhaço Range (Table S2). In terms of number of publications, the three main journals were Boletim de Botânica (253 articles), Rodriguésia (17), and Hoehnea (10). Publication of floristic studies was not limited to scientific journals (ex. Harley & Simmons 1986), but these studies were more accessible.

The distribution of articles published over time is shown in Figure 1. The first publication on the topic dates from 1987; since then, there was constant production until the late 20th century. Publications returned to a significant amount in 2003, when the first volume of *Flora de Grão-Mogol* was published (Pirani *et al*. 2003). After 2003 the maximum number of studies published in a single year occurred in 2004 (46), and the minimum, in 2018 (4). However, in 2021 there was only a single article, but it possibly reflects the Covid-19 pandemic and how its restrictions affect herbarium and field works.

The projects *Flora da Serra do Cipó* (Giulietti *et al*. 1987) and *Flora de Grão-Mogol* (Pirani *et al*. 2003), both published

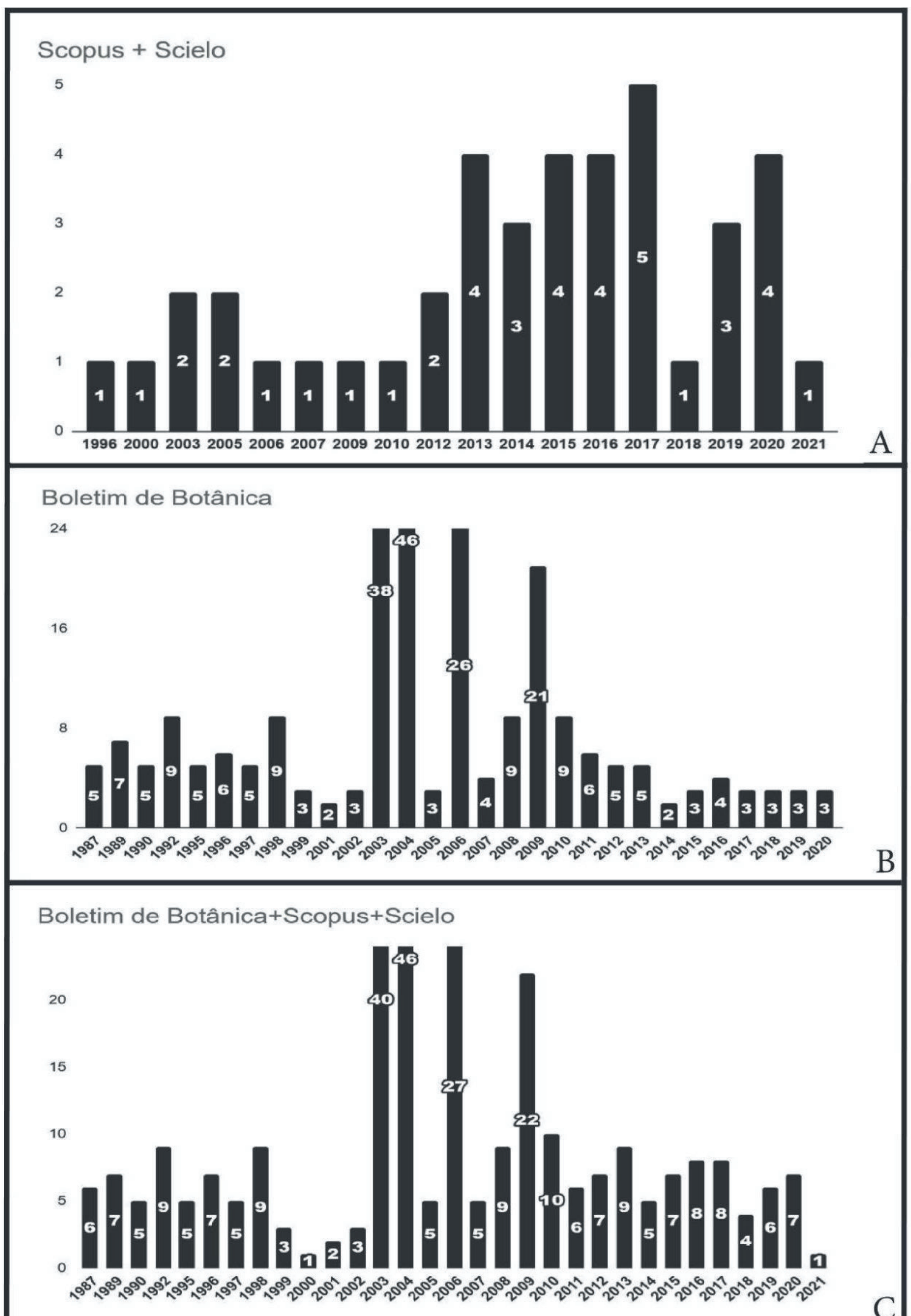

Figure 1. Temporal distribution of floristic studies carried out in the Espinhaço Range, according to the SciELO and Scopus databases; Boletim de Botânica; Scopus, SciELO and Boletim de Botânica.

in Boletim de Botânica, are iconic examples of floristics studies in the Espinhaço Range. These projects have had continuity since then due to the effort and commitment of researchers, graduate, and undergraduate students, to maintain the projects running in the long-term. Other Floras and journals typify this continuity, for example, *Flora das Serras de Carajas* published in Rodriguésia (Viana *et al.* 2016). Flora do Brasil is a shining example of a Flora -979 taxonomists participated in the project, which monographed the world›s most diverse flora (Flora do Brasil 2020). We regard Flora do Brasil as a fine example for future floristic studies. Indeed, we predict a key role of this project in encouraging new floristic projects in Brazil, as we understand that the project does not overlap or avoid new floristic studies.

The families with more floristic studies in Espinhaço Range were Asteraceae, Myrtaceae, Orchidaceae, Vochysiaceae, and Xyridaceae, all with four publications each. However, when we looked at infra family taxonomic categories, this scenario changes. In this context, the families with more studies were Asteraceae (11) and Fabaceae (10). Asteraceae's studies include four conducted at the family level (Hind 2003; Moura & Roque 2014; Roque *et al.* 2016; Staudt *et al.* 2017), and seven conducted at lower taxonomic levels: tribe, Senecioneae (Teles & Stehmann 2011), Eupatorieae (Contro & Nakajima 2017), Barnadesieae and Mutisieae (Roque & Pirani 1997), Gnaphalieae and Inulae (Loeuille *et al.* 2013), Heliantheae (Marques & Nakajima 2015), Vernonieae and Eupatorieae (Staudt & Roque 2020); and genera, *Richterago* Kuntze (Franco *et al.* 2014). Fabaceae had a single study at the family level (Queiroz 2004), with the remaining studies representing classical subfamilies, Caesalpinioideae (Rando *et al.* 2013), Papilionoideae (Silva & Martins 2013), Mimosoideae (Borges & Pirani 2013); tribe, Dalbergieae s.l. (Ferreira *et al.* 2019) and Phaseoleae s.l. (Teixeira *et al.* 2021); or genera, *Chamaecrista* Moench (Zeferino *et al.* 2019; Cota *et al.* 2020) and *Senna* Mill (Azevedo & Conceição 2017; Santos *et al.* 2020).

Families such as Apocynaceae, Bromeliaceae, Eriocaulaceae, Malvaceae, and Melastomataceae, had few studies at the family level. These groups of plants are very diverse in the *campo rupestre* of Espinhaço Range, with high rates of endemism (Colli-Silva *et al.* 2019a) what could encourage the elaboration of floras. Despite that, these taxa were treated in floristic studies in the Espinhaço Range due to the publication of Floras with other taxonomic categories (Table 1). We believe that this can also be related to the fact that these families show a high diversity in the Espinhaço Range and present a complex taxonomic history, which may make it difficult to complete a monography at once. Some situations than can corroborate this is 1) Apocynaceae studies in Grão Mogol's flora are divided in Apocynaceae without Asclepiadoideae (Oliveira & Pirani 2003) and Apocynaceae only Asclepiadoideae (Rapini *et al.* 2003); for example 2) Eriocaulaceae's studies in Serra do Cipó were treated by genera or infrageneric categorical *Paepalanthus* subg. *Xeractis* (Hensold 1998) and *Paepalanthus* sect. *Actinocephalus* (Sano 1998), and *Syngonanthus* (Parra 1998), the same situation occured at *Paepalanthus* in the Parque Estadual do Biribiri (Andrino *et al.* 2015); 3) Malvaceae's studies in Serra do Cipó are also divided as subfamilies (Colli-Silva *et al.* 2019b; Yoshikawa *et al.* 2019; Yoshikawa *et al.* 2020).

Our results showed that floristic studies use taxonomic categories to delimit the plants in a study. Also, its suggests the presence of a specialist in these taxonomic categories in most floristic studies from the Espinhaço Range. Floras promote essential tools for the specialist's professional development (Rapini *et al.* 2008), and the formation of specialists may promote more flora in the future. That highlights the importance of floras for a continued formation of specialists and therefore its continued necessity.

The knowledge on botanical diversity in the Espinhaço Range keeps growing. For example, between 2005 and 2014, 12 new plant species were described yearly, on average (Fernandes *et al.* 2018). In the last ten years, 20 species of Eriocaulaceae were described (Echternacht *et al.* 2011; Echternacht & Sano 2012; Trovó *et al.* 2013; Echternacht 2014; Echternacht & Trovó 2015; Andrino *et al.* 2016; Costa *et al.* 2016; Giulietti *et al.* 2016; Pereira *et al.* 2016; De Oliveira Chagas *et al.* 2019; Andrino *et al.* 2020; Echternacht *et al.* 2021), seven of which are endangered, 12 critically endangered, and one is data deficient, according to authors. The endemic and microendemic species of the *campo rupestre* are extremely vulnerable to extinction (Rapini *et al.* 2021), a fact that reinforces the need of continuous conservation efforts targeting this flora. It is predicted that areas of *campo rupestre* suitable for conservation will be lost to an extent of up to 82% over the next 50 years if climate change is not reversed (Fernandes *et al.* 2018). Other factors could be cited as a threathed for the biodiversity of the *campo rupestre*, such as urban growth, disorderly mining, forestry industry, lack of governance and animal farming (Fernandes *et al.* 2020).

Another significant result of our research is the confirmation of the overlap between floristic studies and protected areas. The floristic studies mapped were carried out in or close too national and state parks, or other categories of conservation areas. This result attests the importance of protected areas for floristic research in the Espinhaço Range. In fact, to promote and facilitate research is one of the core objectives of creating a protected area (Brasil 2000). In addition, surveys are an important ally for conservation areas, as they can provide important data to decision makers and also present more information about the biodiversity in protected areas, and their conservation. These data can shed light on the biodiversity that is not being watched, and on how to act for its conservation. Thus, floristic studies are relevant for the conservation of the Espinhaço Range as these studies map the local and regional flora, discover, and describe new species, and help

Table 1. List of floristic studies in the Espinhaço Range and the number of studies carried out in each locality according to the articles.*Only for Espinhaço Mineiro.

Locality: Number of Floristcs Work
Chapada Diamantina: 5 Floristics Works: *Bulbophyllum* (Orchidaceae); *Ichnanthus* (Poaceae); *Paspalum* (Poaceae), *Phyllanthus* (Euphorbiaceae) and Schizaeales
Central Portion of Espinhaço Range: 2 Floristic Works: *Paepalanthus* subg. *Xeractis* (Eriocaulaceae) and *Richterago* (Asteraceae)
Diamantina Plateau: 2 Floristic Work *Chamaecrista* (Legminosae); Vochysiaceae
Espinhaço Range: 8 Floristics Works: Asclepiadoideae (Apocynaceae)*; *Croton* (Euphorbiaceae)*; Dioscoreaceae; Gesneriaceae; *Habranthus* (Amaryllidaceae); Polygonaceae, Revisiting Asclepiadoideae (Apocynaceae) and Tecomeae (Bignoniaceae)
Grão-Mogol:119 Floristics Works: Acanthaceae; Alismataceae; Alstroemeriaceae; Amaranthaceae; Amaryllidaceae; Anacardinaceae; Annonaceae; Apocynaceae s.l. (exeto Asclepiadoideae); Apocynaceae s.l.-Asclepiadideae; Aquifoliaceae; Araceae; Araliaceae; Aristolochiaceae; Begoniaceae; Bignoniaceae; Bombacaceae; Boraginaceae; “Briófitas”; Bromeliaceae; Burmanniaceae; Burseraceae; Cactaceae; Campanulaceae; Capparaceae; Caryocaraceae; Celastraceae; Chloranthaceae; Chrysobalanaceae; Combretaceae; Commelinaceae; Compositae (Asteraceae); Connaraceae; Convolvulaceae; Cunonaceae; Cyperaceae; Dileniaceeae; Dioscoreaceae; Droseraceae; Ebenaceae; Ericaceae; Eriocaulaceae; Erythroxylaceae; Euphorbiaceae; Flacourtiaceae; Gentianaceae; Gesneriaceae; Gramineae; Guttiferae (Clusiaceae); Herreriaceae; Hippocrateaceae; Humiriaceae; Icacinaceae; Iridaceae; Juncaceae; Krameriaceae; Labiate; Lauraceae; Leguminosae; Lentibulariaceae; Loganiaceae; Loranthaceae; Lythraceae; Malpighiaceae; Malvaceae; Marcgraviaceae; Melastomataceae; Meliaceae; Memecylaceae; Molluginaceae; Monimiaceae; Moraceae; Myrsinaceae; Myrtaceae; Nyctaginaceae; Ochnaceae; Olacaceae; Oleaceae; Onagraceae; Opiliaceae; Orchidaceae; Oxalidaceae; Palmae; Passifloraceae; Pentaphylacaceae; Phytolaccaceae; Piperaceae; Podocarpaceae; Polygalaceae; Polygonaceae; Portulaceae; Proteaceae; “Pteridófitas”; Rapataceae; Rhamnaceae; Rosaceae; Rubiaceae; Rutaceae; Santalaceae; Sapindaceae; Sapotaceae; Scrophulariaceae; Smilacaceae; Solanaceae; Sterculiaceae; Styracaceae; Symplocaceae; Symplocaceae- Adendo; Tiliaceae; Trigoniaceae; Turneraceae; Ulmaceae; Umbeliferae(Apiaceea); Urticaceae s.l.; Velloziaceae; Verbenaceae; Violaceae; Vitaceae; Vochysiaceae and Xyridaceae
Municipality of Caetité: 4 Floristics Works Vochysiaceae; *Dalbergia* (Leguminosae); Phaseoleae s.l. (Leguminosae-Papilionoideae) and *Senna* (Leguminosae)
Municipality of Morro do Chapéu: 4 Floristics Works Asteraceae; *Evolvulus* (Convolvulaceae); Orchidaceae and Vernonieae and Eupatorieae
Municipality of Mucugê: 3 Floristic Works: Asteraceae; Microliceae (Melastomataceae) and Xyridaceae
Municipality of Jacobina: 3 Floristics Works Orchidaceae; Asteraceae and Myrtaceae
Parque Estadual do Biribiri: 3 Floristics Works Heliantheae (Asteraceae); *Paepalanthus* and Miconiae (Melastomataceae)
Parque Estadual do Rio Preto: 1 Floristic Work: *Chamaecrista* (Leguminosae)
Parque Municipal de Mucugê: 2 Floristics works: Orchidaceae and Apocynaceae
Pico do Itambé: 1 Floristics works: Verbenaceae
Serra do Cipó 130 Floristic Works: Acanthaceae; Alstroemeriaceae; Amaranthaceae; Amaryllidaceae; Anacardiaceae; Annonaceae; Apocynaceae s. str. (Rauvolfoideae e Apocynoideae); Apodanthaceae (Rafflesiaceae s.l.) ; Aquifoliaceae; Araceae; Araliaceae; Aristolochiaceae; Asclepiadaceae; Asteraceae- Eupatoriae; Asteraceae- Senecioneae; Balanophoraceae; Begoniaceae; Bignoniaceae; Bixaceae; Bombacaceaeae; Bombacoideae (Malvaceae); Boraginaceae; “Briófitas” (Anthocerotophyta Bryophyta e Marchantiophyta); Bromeliaceae- Bromelioodeae; Bromeliaceae- Pitcairnioideae; Bromeliaceae-Tillandsioideae; Burmanniaceae; Burseraceae; Byttnerioideae Helicterioideae e Sterculioideae (Malvaceae); Cactaceae; Campanulaceae; Cannabaceae; Carpiopteridaceae; Caryocaraceae; Celastraceae Sensu Lato; Chlorantaceae; Chrysobalanaceae; Cleomaceae; Clethraceae; Combretaceae; Commelinaceae; Compositae- Gnaphalieae and Inulae; Compositae- Barnadesieae e Mutisieae; Connaraceae; Convolvulaceae; Costaceae; Cunonaceae; Cyatheaceae; Dennstaedtiaceae; Dileniaceae; Droseraceae; Ebenaceae; Ericaceae; Erythroxylaceae; Euphorbiaceae; Flacourtiaceae; Gentianaceae; Gesneriaceae; Gramineae I; Grewioideae (Malvaceae); Haloragaceae; Herreriaceae; Hippocrateaceae; Humiriaceae; Hymenophyllaceae; Hypoxidaceae; Iridaceae; Jucaceae; Lamiaceae; Leguminosae- “Cesalpinoideae”; Leguminosae- Mimosoidae; Lentibulariaceae; Loganiaceae; Loranthaceae; Lythraceae; Macgravinaceae; Magnoliaceae; Malphigiaceae; Marcetieae (Melastomataceae); Mayacaceae; Meliaceae; Menyanthaceae; Microlicieae (Melastomataceae); Monimiaceae; Moraceae; Myrsinaceae; Myrtaceae; Nyctaginaceae; Oleaceae; Onagraceae; Oxalidaceae; *Paepalanthus* subg *Actinocephalus* (Eriocaulaceae); *Paepalanthus* subg. *Xeractis* (Eriocaulaceae); Palmae; Passifloraceae; Pentalhylaceae; Phytolacaceae; Piperaceae; Polygonaceae; Pontederiaceae; Portulacaceae; Potamogetonaceae; Proteaceae; Pteridaceae- Adiantoideae e Taenitidoideae; Pteridaceae- Cheilanthoideae; Rapataceae; Rhamnaceae; Rosaceae; Rubiaceae; Rutaceae; Santalaceae; Sapindaceae; Sapotaceae; Scrophulariaceae; Simaroubaceae; Smilacaceae; Styracaceae; *Syngonanthus* (Eriocaulaceae); Thaceae; Tilaceae; Trigonaceae; Turneraceae; Umbeliferae (Apiaceae); Urticaceae; Verbenaceae; Violaceae; Vitaceae; Vochysiaceae; Winteraceae and Xyridaceae
Serra do Cabral: 2 Floristic Work: Leguminosae- Papilonoidae and Xyridaceae
Serra Geral de Licínio de Almeida 4 Floristic works: Euphorbiaceae; Myrtaceae; Rubiaceae and *Senna* (Leguminosae)
Serra da Fumaça: 1 Floristic Work Rubiaceae

to identify and monitor priority areas for conservation. The relationship between Parque Nacional da Serra do Cipó and the project Flora da Serra do Cipó (Giulietti *et al.* 1987) are a shining example for that.

The Espinhaço Range

Espinhaço Range can be recognized in two portions, based on the geopolitical Brazilian states in which they occur: *Espinhaço Mineiro* and *Espinhaço Baiano*, this division used to be adopted in botanical studies in the past. (Giulietti *et al.* 1987; Lohmann & Pirani 1996; Pirani *et al.* 2003; Rapini *et al.* 2008; Versieux *et al.* 2008). However, it is also possible recognize four portion in Espinhaço Range, based on local geology: Espinhaço Meridional, Serra do Cabral, Espinhaço Septentrional, and Chapada Diamantina (Chemale Jr *et al.* 2011). Nevertheless, we found that some studies carried out in *Espinhaço Baiano* do not mention Espinhaço Range in the "topic field"; these studies were made in Chapada Diamantina (see Torres *et al.* 2003; Pataro *et al.* 2017) and Espinhaço Setentrional (see Azevedo *et al.* 2015; Ferreira *et al* 2019; Santos *et al.* 2020).

In the geopolitical classification, the Iron Quadrangle, a unique Pre-Cambrian structure and one of the richest mineral-bearings regions in the world (Almeida *et al.* 2011) is commonly viewed as part of the Espinhaço Range (Rapini *et al*. 2008; Almeida *et al.* 2014; Silveira *et al*. 2016). The UNESCO (2005) accepted this delimitation in the proposal of Espinhaço Range as a Biosphere Reserve. The inclusion of the Iron Quadrangle into the Espinhaço Range limits is opportune as it intends to provide greater protection to the area (Gontijo 2008), as well as to other *campo rupestre* areas (Fernandes *et al.* 2018), given that the region faces strong mining pressure.

A total of 16 floristic studies from the Iron Quadrangle appeared in our search, which were conducted at the following locations: Serra do Ouro Branco (Santos & Sano 2012; Longhi-Wagner & Araújo 2014; Vieira & Barros 2017), Pico do Itacolomi (Dutra *et al.* 2005; Lima *et al.* 2007; Dutra *et al.* 2008a; Dutra *et al.* 2008b; Rolim & Salino 2008; Casarino *et al.* 2009; Dutra *et al.* 2009; Lima *et al.* 2010; Coser *et al.* 2010; Bünger *et al.* 2012; Almeida *et al.* 2014), Serra da Caraça (Morais & Lombardi 2006) and Serra do Rola-Moça (Guarçoni *et al.* 2010). Together, these studies highlight the diversity of plants in this region, reinforcing the need of conservation actions.

The spatial distribution of floristic studies in the Espinhaço Range is presented in Figure 2. In total, Floras are distributed in 13 points: five in Espinhaço Meridional + Serra do Cabral, three in Espinhaço meridional, and five in Chapada Diamantina. There are four unplaced local in the map, because they are regions and not only a locality: Central Portion of Espinhaço Range (Andrino & Costa 2013), Chapada Diamantina (Torres *et al.* 2003; Oliveira *et al.* 2003; Ribeiro *et al.* 2005; Ferreira *et al.* 2012; Pimenta *et al.* 2019), Diamantina Plateau (Shimizu & Yamamoto 2012), and Espinhaço Range (Lohmann & Pirani 1996; Melo 2000; Rapini 2001; Lima & Pirani 2003; Araujo *et al.* 2005; Oliveira *et al.* 2010; Rapini 2010). In some cases, the locality indicated in the article's title differ from that wherein the floristic study took place (ex: Staudt *et al.* 2017); we advise against that.

Our results revealed a concentration of floristic studies in Espinhaço Mineiro – 260 works, and only 26 in Espinhaço Baiano. Chapada Diamantina province has 381 endemic species (sensu Colli-Silva *et al* 2019a), but had only 18 floristic studies. Therefore, it is essential to develop additional floristic studies about this vegetation. The area does not have any study project published in article or monograph formats, such as *Flora da Serra do Cipó*, in Espinhaço Meridional, and *Flora de Grão-Mogol*, in Espinhaço Setentrional of Minas Gerais. The two major floristic studies in Chapada Diamantina are *Flórula de Mucugê* (Harley & Simmons 1986) and *Flora dos Picos das Almas* (Stannard 1995), both of which are published in book format and did not enter our survey. Additionally, we identified five regions with sampling gaps regarding floristic studies: the areas 1) between Serra do Cipó and Biribiri State Park; 2) between Grão-Mogol and Caetité municipalities; 3) between Serras de Licínio de Almeida and the municipality of Mucugê, 4) west of Chapada Diamantina, and 5) north of Chapada Diamantina. Some of these regions had already been identified as areas of low sampling effort for Asteraceae (Campos *et al.* 2019). These areas need news studies and collecting efforts because these gaps could reflect a lack of knowledge about the geographical distribution of species -Wallacean Shortfall and it can help to promote the discovery of new species- Linnean Shortfall (Hortal *et al.* 2015) and floristic studies are useful to face these shortfall. Table 1 shows the relationships between sampling points and the number of floristics studies.

Checklist

Table S3 presents the checklist of plant names compiled from the floristic studies of the Espinhaço Range. We assembled 3,191 plant species belonging to 214 families and 949 genera; of these, 2,879 are angiosperms, 247 bryophytes, and 75 lycophytes and ferns. We highlight that *all* bryophytes are from *Flora da Serra do Cipó* (Yano & Peralta 2011) and *Flora do Grão-Mogol* (Yano & Peralta 2009), whilst all Lycophytes and Ferns are from one of three localities: Serra do Cipó, Grão-Mogol, or Chapada Diamantina (Windisch & Prado 1990; Prado 1992; Windisch 1992; Prado & Windisch 1996; Prado 1997; Prado & Labiak 2003; Ferreira *et al.* 2012). The Flora do Brasil (2020) indicates 49,992 plant species in Brazil; therefore, at least 6,3% of the Brazilian flora was sampled in floristic studies carried out in the Espinhaço Range. This fact highlights the importance of floristic studies in high biodiversity areas.

These species are just a part of the total richness of Espinhaço Range, as the Serra do Cipó checklist has 3,229

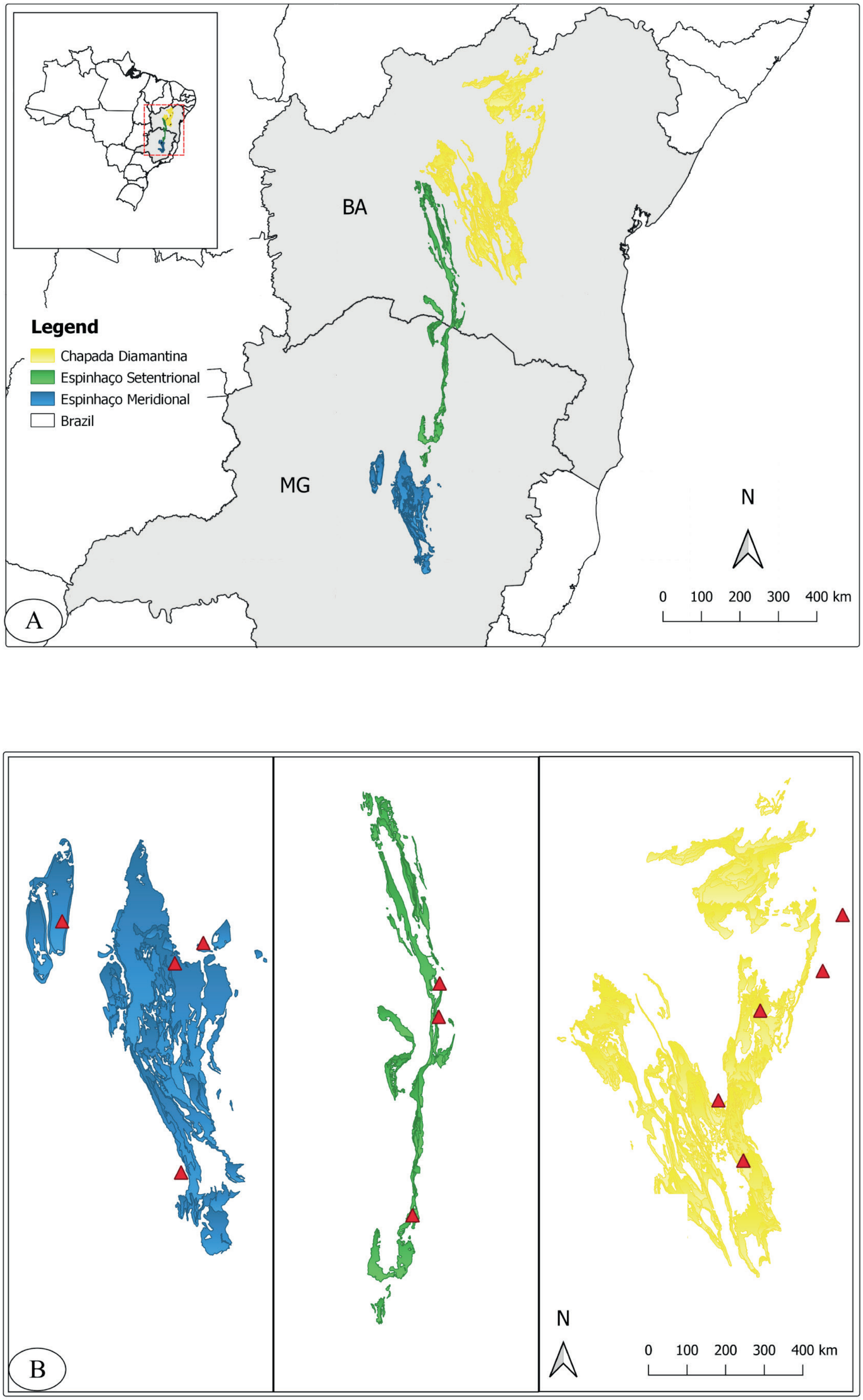

Figure 2. 2-A Geological regions in the Espinhaço Range: Espinhaço Meridional; Espinhaço Setentrional, and Chapada Diamantina, in different colors. 2-B Distribution of floristic studies by geological region in the Espinhaço Range.

species (Pirani *et al*. 2015) and the checklist for Catolés, in the Chapada Diamantina, has 1,710 species (Zappi *et al.* 2003). Both the Serra do Cipó and Chapada Diamantina areas are within the Espinhaço Range, therefore, the species richness in these mountains is higher than that reported herein (i.e., 3,191 species). Consequently, additional floristic studies in this region are much needed to improve data for all plant species of Espinhaço Range and suppress the gaps reported in "Espinhaço Range" topic.

The most species-rich families and genera found in the survey of floristic studies are shown in Figure 3. The Asteraceae and Fabaceae families present the highest numbers of plant species in the Espinhaço Range so far. Other families, including Apocynaceae, Melastomataceae, Rubiaceae, Orchidaceae, Poaceae, Eriocaulaceae, Xyridaceae, and Myrtaceae, also have a high sampling effort in the Espinhaço Range (Figure 3A). The most species-rich genera in the checklist are presented in Figure 3B and may have appeared due to four conditions: 1) Floristic studies exclusive for *Paepalanthus* (Hensold 1998; Andrino & Costa 2013; Andrino *et al*. 2015), *Chamaecrista* (Zeferino *et al.* 2019; Cota *et al*. 2020), and *Paspalum* (Pimenta *et al*. 2019); 2)

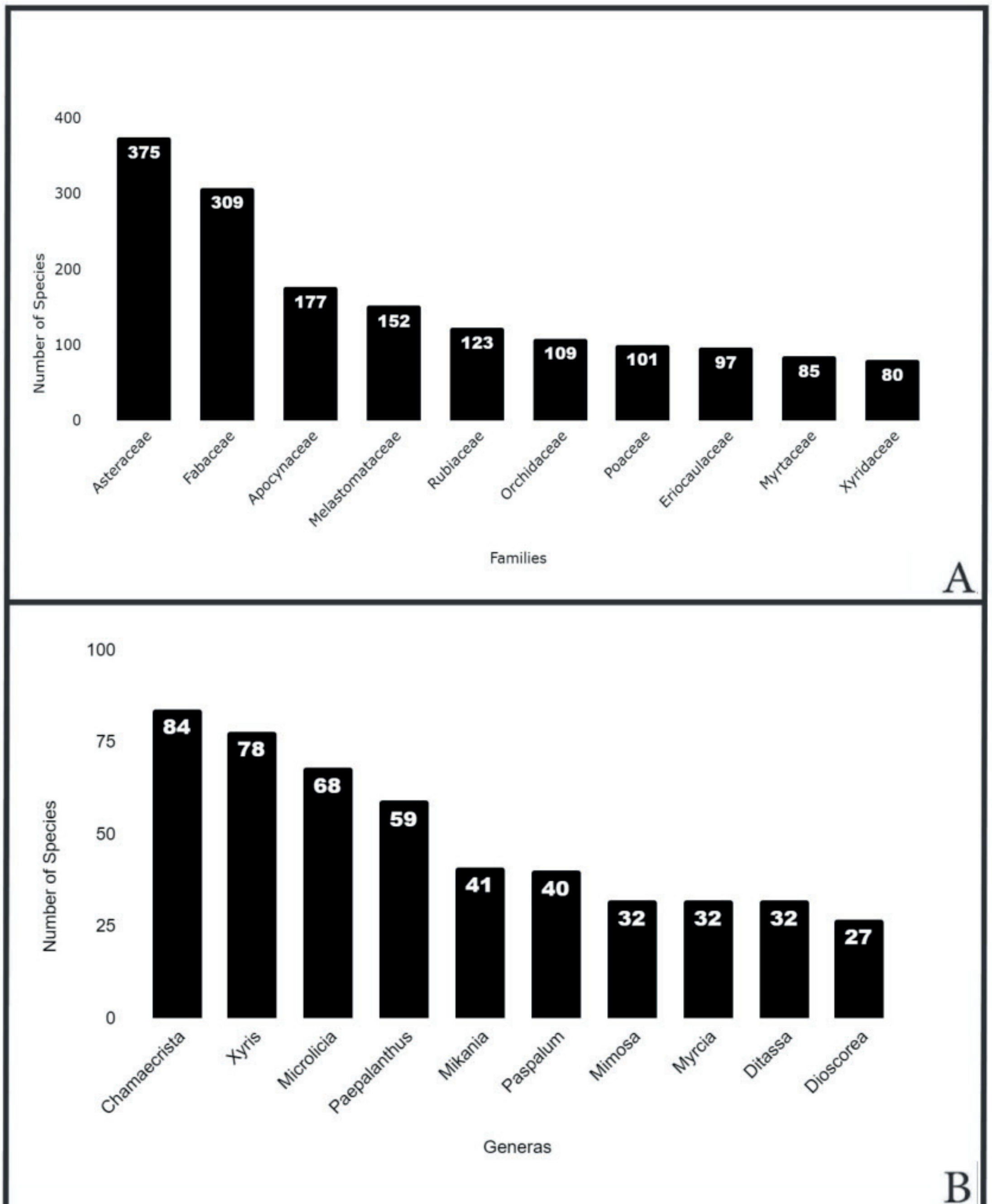

Figure 3. The most diverse taxa of the Espinhaço Range checklist. 3A- The 10 most diverse families. 3B- The most diverse genera.

Monogeneric families studies (Xyridaceae, *Xyris*) (Wanderley & Silva 2009; Wanderley 2011; Silva & Wanderley 2013); 3) Presence in the family of the richest genera know to Espinhaço Range, *Microlicia* (Melastomataceae) (Pataro *et al.* 2017; Pacifico & Fidanza 2018); and 4) Several studies on specific genera, such as *Mikania*, which appear in six of the 11 Asteraceae's Floras (Hind 2003; Moura & Roque 2014; Roque *et al.* 2016; Contro & Nakajima 2017; Staudt *et al.* 2017; Staudt & Roque 2020). These genera are rich in species endemic to the Espinhaço Range (Colli-Silva *et al.* 2019a). Furthermore, these genera cluster the highest number of species to their respective families in Espinhaço Range, as is the case of *Mikania* (Campos *et al.* 2019). Therefore, these taxa should receive special attention for conservation actions in this area.

Grasses and shrubs

Figure 4A presents a histogram of the habits of the species listed in floristic studies in the Espinhaço Range,

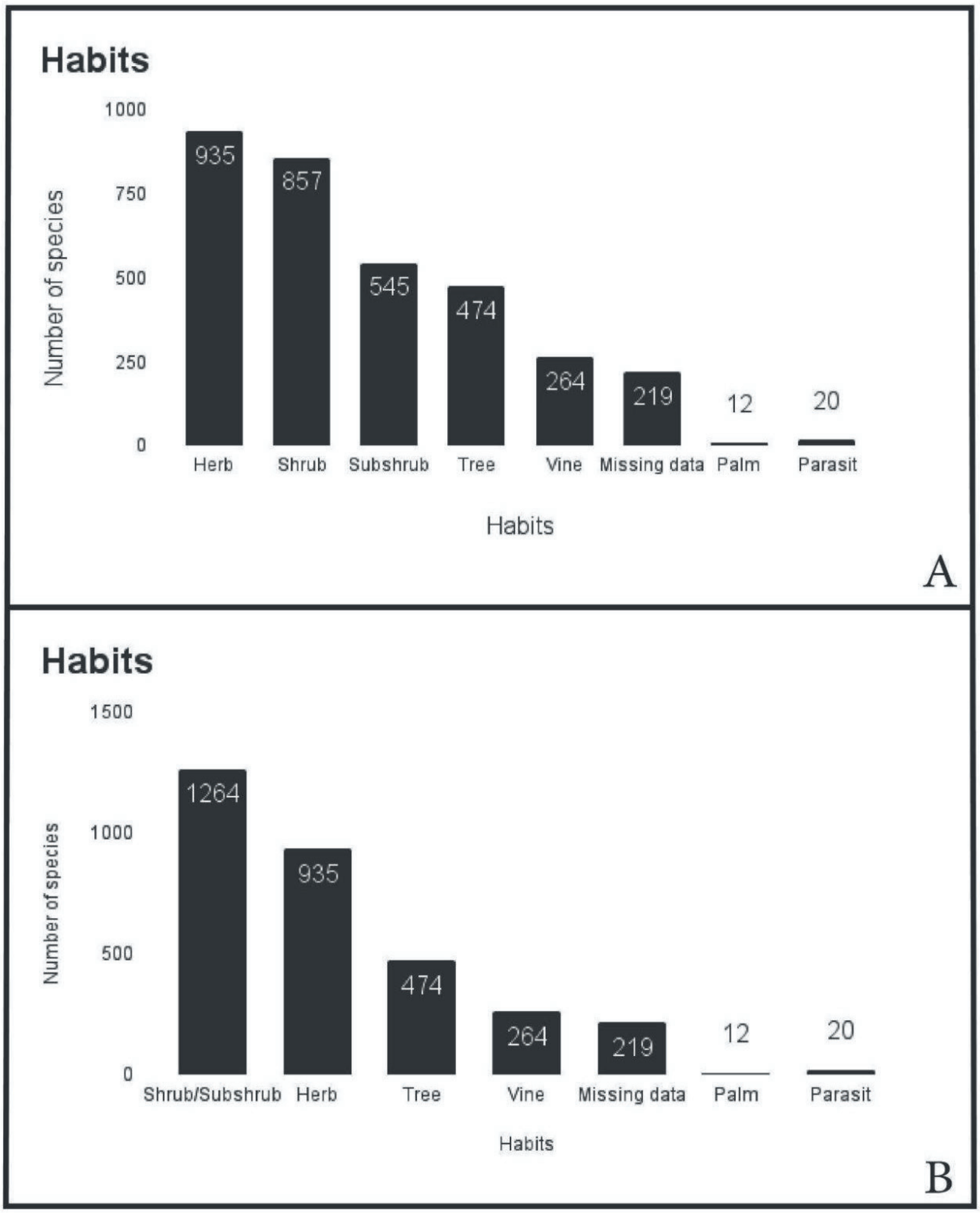

Figure 4. Habits of species of angiosperms of the Espinhaço Range checklist. 4A: Habits "Shrub"and "Subshrub" treated separately. 4B: Habits "Shrub" and "Subshrub" pooled in a single class, "Shrub/Subshrub".

using the information provided in the studies. Figure 4B presents the *shrub* and *subshrub* habits combined into a single category. We found that, in some instances, there was no clear-cutting separation supporting these habits. We believe this happens because there is no single definition that can standardize how taxonomists use these terms. Another situation detected by us is that some authors did not attribute habit to Monocot species (e.g., Longhi-Wagner & Todeschini 2004; Coffani-Nunes *et al.* 2010; Sano *et al.* 2010). We believe that the differential secondary growth in Monocots, compared to Eudicots, explain why these authors avoided defining these plants as herbs, shrubs, and subshrubs. For example, some species of *Actinocephalus* (Eriocaulaceae) have secondary growth (e.g., *Actinocephalus rigidus* (Bong.) Sano), a growth pattern that occurs due to activity of a secondary thickening meristem; this feature is likely to occur in other species of *Actinocephalus* as well (Oriani *et al.* 2008). This species does not have its habit attributed in floristic studies, though (see Sano *et al.* 2010).

In these cases, we recommend using the definitions of shrub and subshrub present in Beentje (2010). "Shrub: self-supporting woody plant branching at or near the ground or with several stems from the base. Subshrub: Small shrub with partially herbaceous stems". The definition for herbs in this study, i.e., "plant without a persistent woody stem above ground", is similar to that of Harris & Harris (2001). However, these definitions still do not suit the cases of Monocots that lack cambia but show another secondary growth. Given this scenario, we advocate that future studies should review terminology and propose clearer terms to define the habits of these plants. Sperotto *et al.* (2020), for example, promoted a similar discussion about liana terminology and suggested a standardization.

Figure 4 highlights the impressive diversity of shrubs/subshrubs and herbs in the Espinhaço Range. This is probably because most floristic studies were carried out in *campo rupestre* vegetation. Mucina (2018) discussed whether this vegetation should be classified as shrub or herbaceous, and the differences between the classification of this vegetation throughout history. He concluded that the most appropriate definition would be a "mosaic of grasslands and patches of scrub, with occasional scattered low trees". Furthermore, the *campo rupestre* vegetation changes along the Espinhaço's spatial landscape: in Chapada Diamantina the vegetation is predominantly shrub, whereas in the South the vegetation becomes predominantly herbaceous (Colli-Silva *et al.* 2019a). This also suggests that most of the plants in our checklist are from the *campo rupestre*.

Conclusion

This study highlights the published floristic studies in the Espinhaço Range. Although numerous floristic studies were found, they are concentrated in few locations. It is necessary to direct new sampling efforts to neglected areas, including some regions in the Northern Espinhaço and northwestern of the Chapada Diamantina. The Iron Quadrangle, a region with many floristic studies, is considered part of the Espinhaço Range by many authors. Floristic studies should be seen as fundamental to know and conserve the flora of Espinhaço Range and its *campo rupestre*. This floristic study of Espinhaço Range comprised a total of 3,191 plant species, or 6.3% of the Brazilian flora, highlighting the remarkable diversity of *campo rupestre*. Finally, this study also reveals a standardization problem regarding the habits of angiosperms and indicates the issues that can be revisited in future studies to bring clearer definitions about plant habits.

Heywood (2001) discussed the relevance and prospects of floristic studies in this century. Here, we intend to highlight some of Heywood's relevant thoughts and unanswered questions that remain current today: 1) The Floras will become bibliographic records of plant diversity that no longer exist. 2) Is it possible to attract young scientists to taxonomy? 3) Is it possible to persuade decision-makers to subsidize floristic studies in support of biological and conservation studies?

After more than 20 years these thoughts can be easily applied to the reality of the Espinhaço Range, in which: 1) Deforestation, mining, and uncontrolled fire can alter the flora, so that the current flora may represent a record of what once existed; 2) How can young scientists be encouraged to work with taxonomy, if this type of study is hardly accepted in impactful journals and, at the same time, the current research funding system overvalues high-impact publications to grant scholarships and financial resources?; 3) How can we convince decision-makers to support floristic studies if the academy itself has been negligent with this type of research?

Florist studies are still necessary for Espinhaço Range and other regions in Brazil. To do so, there must exist continuous effort on the part of researchers, graduate, and undergraduate students, and it is our job to encourage advisors and boost funding agencies to support these studies.

Supplementary Material

The following online material is available for this article:
Table S1 – Keywords used for the bibliometric survey in Scopus and SciELO.
Table S2 – Publications selected from Boletim de Botânica and the Scopus and SciELO databases.
Table S3 – Checklist compiled from the data present in floristic studies in the Espinhaço Range. *Species known only from typus. It was collected in this region but was not considered in the study.

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