

## ECOLOGICAL ATTRIBUTES, GEOGRAPHIC DISTRIBUTION AND ENDEMISM OF CACTI FROM THE SÃO FRANCISCO WATERSHED

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**ABSTRACT** – The purpose of this study is to assess the ecological attributes, geographic distribution, conservation status and endemism of cactus species in the São Francisco River Watershed (SFRW). In order to gather information on the cactus species found in the SFRW, three sources of information were used: collections from Brazilian herbaria, bibliographic references and online collections. The ecological attributes were related to (1) habitat specificity, (2) species habit, (3) pollination syndrome, and (4) groups of primary and secondary dispersers. Moreover, data from the three information sources cited above were used to assess geographic distribution of the cacti found in the SFRW. Species were divided into three categories according to the number of populations sampled: (1) widespread species: over 30 populations, (2) species with intermediate distribution: 11 to 30 populations, (3) locally distributed species: up to 10 populations. Conservation status of the cacti found in the SFRW was determined according to the classification of the International Union for Conservation of Nature and Natural Resources Red List. There were 108 cacti taxa scattered throughout the SFRW and 32.4% of the taxa are endemic. Species may be present in more than one ecosystem; most were found in areas of Caatinga (59.5%). The most common microhabitat was soil (62.5%). The globose habit (21.2%), columnar habit (29.8%) and shrubby habit (36.5%) are more frequent. The main pollination syndrome is chiropterophily (34.5%). All Cactaceae found in the SFRW produce fruits that are dispersed by animals and vertebrates are the main agents of zoochoric dispersal. The conservation status of these cacti is cause for worry, because many species are classified as vulnerable or critically endangered.

**KEYWORDS:** *Conservation status, habitat specificity, species habit, pollination syndrome, seed dispersers.*

### ATRIBUTOS ECOLÓGICOS, DISTRIBUIÇÃO GEOGRÁFICA E ENDEMISMO DE CACTOS DA BACIA HIDROGRÁFICA DO SÃO FRANCISCO

**RESUMO** – O objetivo deste estudo é avaliar os atributos ecológicos, a distribuição geográfica, o status de conservação e o endemismo dos cactos da Bacia Hidrográfica do Rio São Francisco (BHSF). A fim de reunir informações sobre os cactos encontrados na BHSF, foram utilizadas três fontes de informação: coleções de herbários brasileiros, referências bibliográficas e coleções on-line. Os atributos ecológicos estavam relacionados com (1) especificidade de habitat, (2) hábito da espécie, (3) síndrome de polinização, e (4) grupos de dispersores primários e secundários. Além disso, dados das três fontes de informação citadas acima foram utilizadas para avaliar a distribuição geográfica dos cactos encontrados na BHSF. As espécies foram divididas em três categorias de acordo com o número de populações amostradas: (1) espécies amplamente distribuídas: mais de 30 populações, (2) espécies com distribuição intermediária: 11 a 30 populações e (3) espécies com distribuição local: até 10 populações. O status de conservação dos cactos encontrada na BHSF foi determinado de acordo com a classificação da Lista Vermelha da União Internacional para a Conservação da Natureza e dos Recursos Naturais. Foram encontrados 108 táxons de cactos espalhados por toda BHSF e 32,4% dos táxons são endêmicos. As espécies podem estar presentes em mais de um ecossistema; e a maioria foi encontrada em diferentes áreas da Caatinga (59,5%). O microhabitat mais comum foi o solo (62,5%). O hábito globoso (21,2%), colunar (29,8%) e arbustivo (36,5%) são os mais frequentes. A síndrome de polinização principal é quiropterofilia (34,5%). Todas as Cactaceae encontradas na BHSF produzem frutos que são dispersos por animais e os vertebrados são os principais agentes de dispersão zoocórica. O status de conservação desses cactos é preocupante, porque muitas espécies são classificadas como vulneráveis ou criticamente em perigo.

**PALAVRAS-CHAVE:** *Status de conservação, especificidade de habitat, hábito de espécies, síndrome de polinização, dispersores de sementes.*

### ATRIBUTOS ECOLÓGICOS, DISTRIBUCIÓN GEOGRÁFICA Y ENDEMISMO DE LOS CACTUS DE LA CUENCA HIDROGRÁFICA DEL SÃO FRANCISCO

**RESUMEN** – El objetivo de este estudio es evaluar los atributos ecológicos, la distribución geográfica y el estado de conservación de cactus endémicos de la Cuenca Hidrográfica del Río São Francisco (CHSF). Con el fin de obtener información sobre los cactus que se encuentran en la CHSF, se utilizaron tres fuentes de información: las colecciones de los herbarios de Brasil, las referencias y las colecciones *on line*. Se relacionaron los atributos ecológicos con (1) la especificidad del hábitat, (2) el hábito de la especie, (3) el síndrome de polinización, y (4) grupos de dispersores primarios y secundarios de semillas. Además, se utilizaron los datos de las tres fuentes de información mencionadas anteriormente para evaluar la distribución geográfica de los cactus que se encuentran en la CHSF. Las especies se dividieron en tres categorías de acuerdo con el número de poblaciones muestreadas: (1) las especies ampliamente distribuidas: más de 30 poblaciones, (2) las especies con distribución intermedia: 11 a 30 poblaciones y (3) las especies con distribución local: hasta 10 poblaciones. Se determinó el estado de conservación de los cactus que se encuentran en CHSF de acuerdo a la clasificación de la Lista Roja de la Unión Internacional para la Conservación de la Naturaleza y de los Recursos Naturales. En la CHSF se encontraron 108 taxones de cactus y el 32,4% de los taxones son endémicos. Las especies se pueden encontrar en más de un tipo de ecosistema; y la mayoría se encuentran en las diferentes áreas de la Caatinga (59,5%). El suelo es el microhabitat más común (62,5%). El hábito observado fue; globular (21,2%), colunar (29,8%) y con mayor frecuencia los arbustos (36,5%). El principal síndrome de polinización es la quiropterofilia (34,5%). Todos los cactus de la CHSF producen frutos que son dispersados por animales, los vertebrados son los principales dispersores. El estado de conservación de estos cactus es preocupante debido a que muchas especies están clasificadas como vulnerables o en peligro crítico de extinción.

**PALABRAS CLAVE:** *Estado de conservación, especificidad de hábitat, hábito de las especies, síndrome de polinización, dispersores de semillas.*

## INTRODUCTION

Cacti are among the most typical and conspicuous species of arid and semi-arid environments in the New World. The phylogenetic relationships of basal lineages within this family were recently studied and elucidated (Edwards *et al.*, 2005; Hernández-Hernández *et al.*, 2011). These species are found from southeastern Patagonia, in Argentina, to southern Canada. They grow in a variety of habitats including warm deserts, coastal areas, dry forests, and tropical rain forests, as well as montane habitats, and at altitudes from sea level to 5000 meters (Anderson, 2001). The centres of diversity and distribution of cacti are located in arid regions of North and South America, especially in the southwestern United States, Mexico, the Andes and eastern Brazil (Taylor and Zappi, 2004). Only the genus *Rhipsalis* Gaertn. has a distribution ranging from the Neotropics to Africa and southern Asia (Barthlott and Hunt, 1993; Anderson, 2001).

These plants are characterized by great diversity of growth forms. Some species are trees or shrubs with conspicuous, persistent leaves, as seen in the genus *Pereskia* Mill. (Taylor and Zappi, 2004). Most other cacti have succulent stems, which may be globose, columnar or flattened, and are sometimes branched (Salgado and Mauseth, 2002; Taylor and Zappi, 2004). They are scandent or epiphytic, or grow on the ground and/or on rocks (Taylor and Zappi, 2004). The unusual vegetative morphology of these plants is the result of structural modifications such as leaf reduction or loss, leaves converted to spines to reduce water loss, stems that actively participate in photosynthesis, and aquiferous parenchyma with large cells and vacuoles that store water (Nobel and Bobich, 2002). These ecophysiological traits allow members of the family to be perennial and evergreen, even during drought periods (Nobel and Bobich, 2002).

In Brazil, the Caatinga has high cactus-species diversity with about 90 species (Taylor *et al.*, 2015). According to Giulietti *et al.* (2004a), the Caatinga is, botanically, the most unappreciated and poorly known Brazilian ecosystem, a fact that may be related to the erroneous belief that this ecosystem resulted from the modification of other plant formations. It is often associated with low plant-species diversity, lack of endemic species, and widespread modification by man's activities. However, the Caatinga has a variety of well-represented vegetation types that include a substantial number of rare and endemic taxa (Giulietti *et al.*, 2002; Giulietti *et al.*, 2004b) such as, for example, several members of the Cactaceae family (Taylor and Zappi, 2004).

This semi-arid ecosystem is found only in Brazil and is characterized by a high degree of floristic endemism (Giulietti *et al.*, 2002; Giulietti *et al.*, 2004b), low rainfall (240 to 900 mm.yr<sup>-1</sup>) and high mean annual temperatures (> 27°C), as well as considerable variation in the edaphic characteristics of the environment (Sampaio, 1995; Prado, 2003). Part of one of Brazil's main watersheds is located in the Caatinga. The São Francisco River Watershed, hereafter denoted as SFRW, has a permanent water flow that traverses areas of various plant formations in the Brazilian Southeast, Center-West and

Northeast regions. Beginning at the headwaters and along tributaries, the watershed is undergoing a degradation process with serious impact on the river and on the surrounding vegetation [for further information on the history and utilization of the SFRW, see Kury (2012) and Leão (2012)]. Several different species of cactus are found in these areas and some are believed to occur only in the SFRW (Taylor and Zappi, 2004). Therefore, the purpose of this study is to assess the ecological attributes, geographic distribution, conservation status and endemism of cacti species in the SFRW, and to define areas where the Cactaceae have not been studied, and that will be given priority in future floristic surveys of the family.

## MATERIAL AND METHODS

### *Characterization of the study area*

The SFRW covers an area with 506 towns in seven Brazilian states, located in the Southeast region (Minas Gerais), the Center-West region (Federal District and Goiás) and the Northeast region (Alagoas, Bahia, Pernambuco and Sergipe) (Figueiredo *et al.*, 2011). The main water course in this watershed is the São Francisco River, c. 2,863 km long, with over 168 tributaries (Figueiredo *et al.*, 2011). The São Francisco River has its source in the Serra da Canastra, a mountain range in the south-central part of Minas Gerais state, near the municipality of São Roque de Minas. The waters of the São Francisco run through parts of various Brazilian ecosystems, such as the Atlantic Rain Forest, near its source, and the Cerrado in parts of Minas Gerais state and southwestern Bahia. But the Caatinga is the main ecosystem through which this river flows. It is very important economically and culturally for the riverine communities on its banks [for more information on the cultural and economic relevance of the SFRW, see Siqueira Filho (2012)]. The SFRW is divided into four regions: the "Upper São Francisco", from the source to Pirapora (Minas Gerais), the "Middle São Francisco", between Pirapora and Remanso (Bahia), the "Lower-middle São Francisco", between Remanso and Paulo Afonso (both in the state of Bahia) and the "Lower São Francisco", from Paulo Afonso to the river's mouth in the Atlantic Ocean, on the border between the states of Alagoas and Sergipe (Figueiredo *et al.*, 2011).

### *Gathering information on the occurrence of Cactaceae*

In order to gather information on the cacti species found in the SFRW, three sources of information were used: collections from Brazilian herbaria, bibliographic references and *on line* collections. Initially, the Cactaceae collections of 30 of the most important herbaria in Northeast Brazil were assessed from September to December 2010 (**Table 1**). All of the herbarium specimens of this family were examined and the names updated according to the *Lista de Espécies da Flora do Brasil* [Flora of Brazil Species List] (Taylor *et al.*, 2015). In addition, references with information on the occurrence of cactus species in Brazilian ecosystems were consulted (Taylor and Zappi, 2004), as well as five *on line* collections (*speciesLink*) from herbaria that could contribute to this study, whether due to proximity to the SFRW or because of important Cactaceae

**TABLE 1.** Number of specimens, genera, species (number of endemic species of the Caatinga) and endangered species (IUCN, 2001) of the Cactaceae consulted at the 30 main herbaria of Northeast Brazil. (+) presence and (-) absence.

Herbarium Name	City (State)	Voucher (Type)	Genus	Species (Endemic)	Endangered	
01	Herbário da Universidade Estadual de Feira de Santana	Feira de Santana (BA)	1409 (+)	34	135 (35)	57
02	Herbário André Maurício Vieira de Carvalho	Ilhéus (BA)	538 (+)	27	90 (34)	41
03	Herbário Dárdano de Andrade Lima	Recife (PE)	476 (+)	24	57 (21)	20
04	Herbário Vale do São Francisco	Petrolina (PE)	574 (-)	20	40 (22)	10
05	Herbário Geraldo Mariz	Recife (PE)	319 (-)	18	38 (11)	8
06	Herbário Lauro Pires Xavier	João Pessoa (PB)	373 (-)	12	26 (11)	6
07	Herbário da Universidade Estadual de Santa Cruz	Ilhéus (BA)	257 (-)	16	45 (15)	15
08	Herbário Professor Vasconcelos Sobrinho	Recife (PE)	210 (-)	15	34 (13)	9
09	Herbário Prisco Bezerra	Fortaleza (CE)	278 (+)	14	30 (12)	9
10	Herbário do Instituto do Meio Ambiente	Maceió (AL)	145 (-)	13	31 (11)	9
11	Herbário da Universidade Federal de Sergipe	Aracaju (SE)	189 (+)	13	28 (12)	8
12	Herbário Alexandre Leal Costa	Salvador (BA)	89 (-)	14	33 (8)	7
13	Herbário Sérgio Tavares	Recife (PE)	68 (-)	14	31 (12)	8
14	Herbário Jayme Coêlho de Moraes	Areia (PB)	59 (-)	12	22 (8)	6
15	Herbário Graziela Barroso	Teresina (PI)	52 (-)	8	13 (7)	3
16	Herbário da Universidade Federal do Rio Grande do Norte	Natal (RN)	204 (-)	10	15 (3)	4
17	Herbário do Trópico Semiárido	Petrolina (PE)	35 (-)	11	18 (9)	5
18	Herbário Dárdano de Andrade Lima	Mossoró (RN)	31 (-)	8	10 (3)	3
19	Herbário Professor Honório Monteiro	Maceió (AL)	22 (-)	5	9 (7)	3
20	Herbário Francisco José de Abreu Matos	Sobral (CE)	20 (-)	11	12 (6)	4
21	Herbário Caririense Dárdano de Andrade Lima	Crato (CE)	20 (-)	10	12 (6)	4
22	Herbário da Universidade Estadual do Sudoeste da Bahia	Jequié (BA)	19 (-)	9	15 (5)	6
23	Herbário Antônio Nonato Marques	Salvador (BA)	14 (-)	7	8 (6)	3
24	Herbário Afrânio Gomes Fernandes	Teresina (PI)	2 (-)	2	2 (-)	1
25	Herbário Parque das Dunas	Natal (RN)	2 (-)	2	2 (-)	1
26	Herbário Rosa Mochel	São Luiz (MA)	2 (-)	2	2 (-)	-
27	Herbário Ático Seabra	São Luiz (MA)	-	-	-	-
28	Herbário Manoel de Arruda Câmara	Campina Grande (PB)	-	-	-	-
29	Herbário Rodolfo Teófilo	Fortaleza (CE)	-	-	-	-
30	Herbário da Universidade Católica de Pernambuco	Recife (PE)	-	-	-	-

collections. These were as follows: Herbarium Dimitri Sucre Benjamim of the Rio de Janeiro Botanical Garden (RB), Universidade Federal de Goiás Herbarium (UFG), Universidade de São Paulo Herbarium (SPF), Universidade Federal de Minas Gerais Herbarium (BHCB) and Universidade de Brasília Herbarium (UB). Data such as species name, collection locality and geographic coordinates were recorded for the consulted material. From the *on line* consultation, only those specimens identified to species, with the above information, were included.

#### *Ecological attributes of cacti*

The ecological attributes of all species collected in SFRW areas were determined. These were related to (1) habitat specificity, classified as “macrohabitat” (number of ecosystems where the species is found, *i.e.*, Caatinga, Campo Rupestre, Cerrado, Atlantic Forest, Restinga), “mesohabitat” (preference for certain habitats, *i.e.*, forest or inselberg) or “microhabitat” (a specific habitat in the environment, *i.e.*, soil, rock or phorophyte) (adapted from Siqueira Filho and Tabarelli, 2006); (2) species habit [*i.e.*, shrub, columnar, epiphyte or globose, according to Gibson and Nobel (1986)]; (3) pollination syndrome [*i.e.*, sphingophily, melittophily, ornithophily and chiropterophily, according to Locatelli and Machado (1999), Rocha (2007) and Rocha *et al.* (2007)]; and (4) groups of

primary and secondary dispersers [*i.e.*, birds, ants, lizards, small land mammals and bats (Taylor and Zappi, 2004; Leal *et al.*, 2007)].

#### *Geographic distribution of cacti*

Data from the three information sources cited above were used to assess geographic distribution of the cacti found in the SFRW. Specimens were initially grouped according to the municipality where they were collected and this information was used to assess the distribution pattern. Species found only in SFRW areas were defined as “exclusive to SFRW” and those that were also collected in other areas outside the SFRW were designated “widely distributed species”. Exotic and/or cultivated cacti were not included in the analysis. Distribution maps of the cacti exclusive to SFRW were produced to update information on areas of occurrence of these species.

#### *Number of populations and conservation status of cacti*

Estimates of the number of cactus populations in the SFRW were also based on the three information sources cited above. Each sample at a specific collection site was used to indicate the existence of a population and collections from one study area were treated as belonging to the same population (Siqueira Filho and Tabarelli, 2006). Samples consulted in herbaria and cited in publications on the family were counted

only once in the analyses. Species were divided into three categories according to the number of populations sampled: (1) widespread species: over 30 populations; (2) species with intermediate distribution: 11 to 30 populations; (3) locally distributed species: up to 10 populations.

Conservation status of the cacti found in the SFRW was determined according to the classification of the International Union for Conservation of Nature and Natural Resources Red List (IUCN, 2001). The categories are as follows: critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), data deficient (DD) and least concern (LC). In addition, CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) was consulted in order to draw up a list of the cacti in the SFRW that are endangered by the international wildlife trade.

## Results and Discussion

Information from the completed survey was gathered from 6,436 cactus collections, representing herbaria collections (68.3%), bibliographic references on the Cactaceae family (25.1%), and *on line* collections consulted via *speciesLink* (6.6%). There were 108 cacti taxa scattered throughout the SFRW, in areas of all ecosystems that are present in this region. The genera with the most species in the SFRW areas were *Pilosocereus* Byles & Rowley (15 species), *Melocactus* Link & Otto (16 species) and *Micranthocereus* Backeb. (8 species) (**Figure 1**). Species may be present in more than one ecosystem; most were found in areas of Caatinga (59.5%), followed by Campo Rupestre (42.1%), Atlantic Forest (18.2%), Cerrado (17.5%) and Restinga (6.4%). Cactus species are not commonly found on inselbergs; only 21.1% of the species were seen on rocky outcrops. The most common microhabitats were soil (62.5%) and rocks (25.0%); only a few members of the family were collected on phorophytes (12.5%). This pattern of microhabitat specificity reflects the habit of most cactus species found in the SFRW, since epiphytes are less common (12.5%). The globose habit (21.2%), columnar habit (29.8%) and shrubby habit (36.5%) are more frequent.

The cactus species found in the SFRW produce flowers with traits that favor pollination by animals such as, for example, the production of large amounts of floral resources to be used as food (*i.e.*, pollen grains and nectar). However, this issue is little assessed, and only 20 species that occur in areas of SFRW were used in studies of pollination systems. The main pollination syndrome here is chiropterophily (34.5%), followed by ornithophily (24.1%), sphingophily (20.7%) and melittophily (20.7%). These pollination syndromes are associated with biotic agents (animals) that promote gene flow between populations, thus increasing the genetic variability of the plants (Machado and Lopes, 2003). Some of these pollinators, bats for instance, are capable of visiting many flowers in one night and of flying long distances in search of food resources (Rocha, 2007). Furthermore, all Cactaceae found in the SFRW produce fruits that are dispersed by animals, and the vertebrates (*i.e.*, birds, bats and lizards) are the main agents of zoochoric dispersal. In most cases, this type of

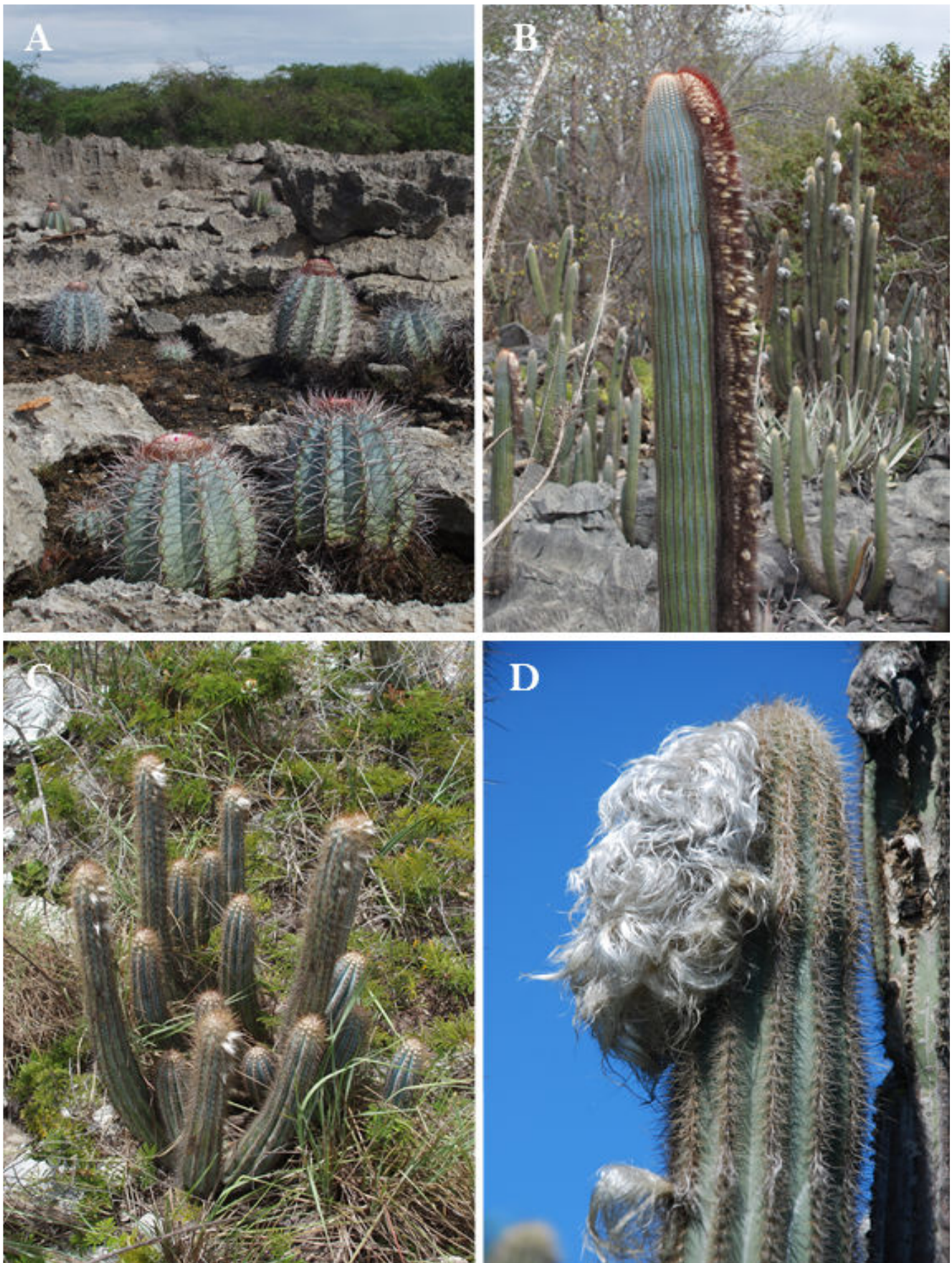
dispersal involves eating the seeds (endozoochory) that are subsequently released in the feces. However, some invertebrates, like ants, for example, act as primary dispersers of species of the genus *Discoactus* Pfeiff. [M.V. Meiado, personal observation; Taylor and Zappi (2004) and Oliveira (2009)] and as secondary dispersers by cleaning the seed when eating the funicular pulp (Leal *et al.*, 2007). Regardless of the type of zoochory observed, removal of the funicular pulp may increase reproductive success of the cactus species because some species, such as members of the genus *Pilosocereus*, produce pulp with chemical substances that inhibit germination. So pulp removal during dispersal favours seed germination and seedling establishment, thus increasing reproductive success of species (Meiado, 2012). For other examples of reproductive strategies related to seed production in cactus species that inhabit areas of Caatinga, see Meiado *et al.* (2012).

The collections examined showed that only 44.9% of the municipalities in the SFRW are represented by collected specimens, that is, 234 municipalities. But these together represent a sample area of over 460,000 km<sup>2</sup>, that is, over 60% of the area of the SFRW (**Figure 2**). The states with the largest areas of the SFRW, proportionally, with collections are Pernambuco (84.7%) and Bahia (77.8%). On the other hand, Minas Gerais, the state with the greatest number of municipalities within the SFRW (258 municipalities) had the lowest proportion of collected area (**Figure 3**).

As regards the sampled ecosystems, collections in areas of Caatinga in the SFRW were the most numerous, with about 50% of collections from all of the assessed ecosystems. As seen above, these are the areas where most SFRW cactus species occur (77.8% of SFRW endemic taxa), and the geographic distribution pattern of this group confirms the need to create conservation units in these areas and to carry out floristic surveys at sites not sampled, that make up practically 30% of this ecosystem (**Figure 2**).

Around 50% of all cactus species that grow in Brazil are found in SFRW areas. The number of populations of these species may vary from one, as in *Discoactus petr-halfari* Zachar, to over 250 populations, as in *Tacinga inamoena* (K. Schum.) N.P. Taylor & Stuppy and *Tacinga palmadora* (Britton & Rose) N.P. Taylor & Stuppy. Of the 108 taxa that occur in SFRW areas, 35 are exclusive to this watershed (**Table 2**), that is, 32.4% of the taxa are endemic, a trait that reveals the very special nature of the cactus flora in this region, suggesting that it was once a refuge for species adapted to drought, in the past when humidity was higher and temperatures colder (Taylor and Zappi, 2004). The conservation status of these cacti is cause for worry, because many species are classified as vulnerable (VU), endangered (EN), or critically endangered (CR) (**Table 2**). The situation is even more worrisome when only those cactus species found exclusively in the SFRW are assessed, because all of the critically endangered species fall into this category and the number of vulnerable and endangered species is proportionally greater (**Figure 4**). Furthermore, all species found in the SFRW are part of the Cites list, which shows the potential of these cacti as a focus for international trade in wildlife species.





**FIGURE 1.** Endemic species of the São Francisco River Watershed (SFRW). (A) *Melocactus azureus* Buining & Brederoo subsp. *azureus*, (B) *Micranthocereus dolichospermaticus* (Buining & Brederoo) F. Ritter, (C) *Pilosocereus bohlei* Hofacker, and (D) *Pilosocereus densiareolatus* F. Ritter (Cactaceae). Images provided by Marlon C. Machado.



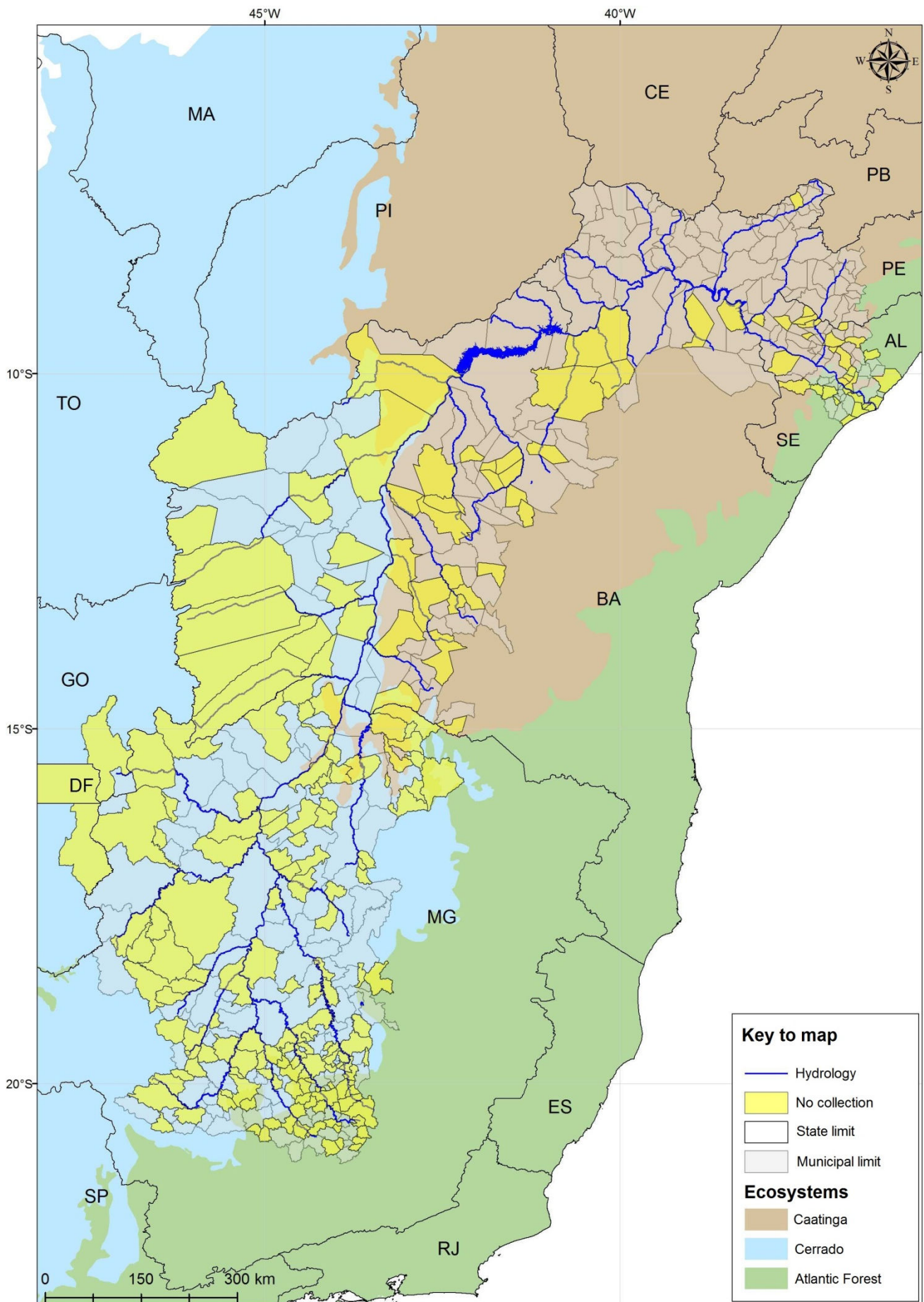
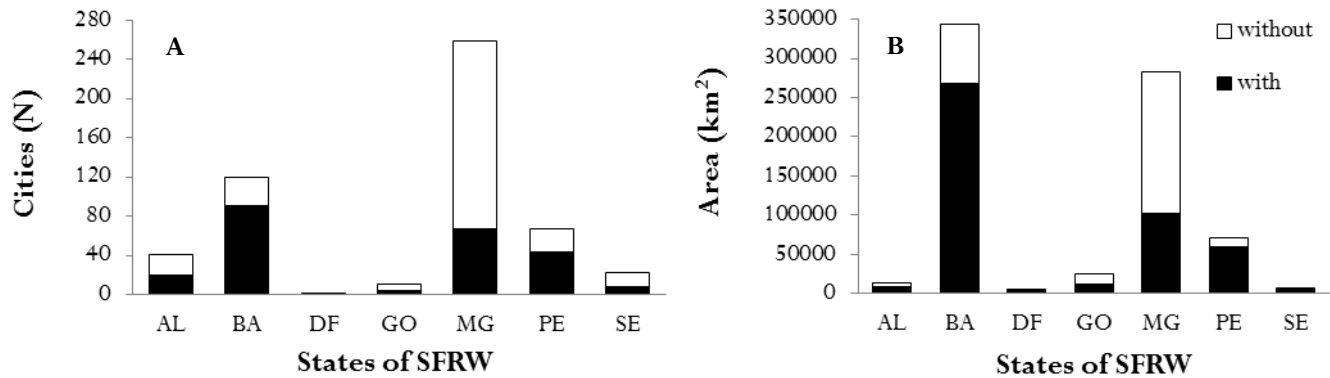


FIGURE 2. Municipalities of the São Francisco River Watershed – SFRW (in light green) where no collections were recorded of Cactaceae species.

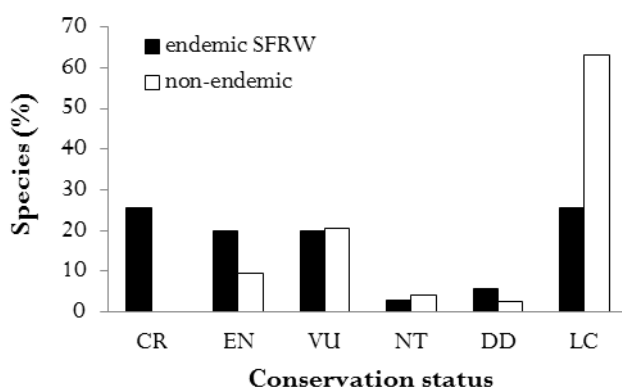


**FIGURE 3.** (A) Number and (B) area (km<sup>2</sup>) of cities in the São Francisco River Watershed – SFRW with and without collections of Cactaceae species. AL: Alagoas State, BA: Bahia State, DF: Federal District, GO: Goiás State, MG: Minas Gerais State, PE: Pernambuco State, SE: Sergipe State.

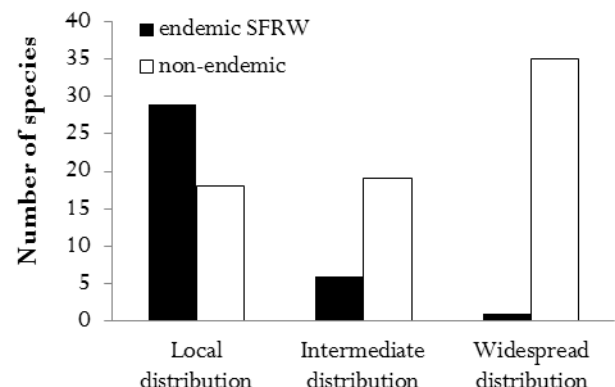
Most of the widespread cactus species (those with over 30 populations) within the SFRW are not endemic species, while species distributed locally (1 to 10 populations) have a more significant proportion of endemic SFRW species (Figure 5). This geographic distribution pattern shows that many cactus species found in the area of the watershed are not only endemic, but they are also rare, such as *Brasilicereus estevesii* (Hofacker & P.J. Braun) N.P. Taylor & M. Machado, *Discocactus petr-halfari* Zachar, *Melocactus deinacanthus* Buining & Brederoo, *Micranthocereus hofackerianus* (P.J. Braun & Esteves) M. Machado and *Pilosocereus frewenii* Zappi & N.P. Taylor (Figure 6). For this reason, in the past few years these species have been included in Brazilian conservation programmers, as seen in the “Plano de Ação Nacional de Conservação das Cactáceas” (MMA, 2011) that includes some 30% of these endemic and rare species within the aims and activities to be carried out by these programmers. Furthermore, including these species in conservation studies is justified by the fact that many of the taxa are endangered and, as shown in Table 2, very few populations of these species are known today. *Pereskia stanantha* Ritter is the only species exclusive to the watershed that is widely distributed – some 40 populations of this species have been sampled in areas of the SFRW (Figures 5 and 6).

About 20% of the exclusive taxa [*i.e.*, *Quiabentia zehntneri* (Britton & Rose) Britton & Rose] have an intermediate distribution, with 11 to 30 populations sampled (Figures 5 and 6). However, most of the taxa exclusive to the SFRW (80%) have local distributions, with a maximum of 10 populations (Figures 5 and 6). Consequently, these exclusive species with local distributions, such as *Melocactus azureus* Buining & Brederoo, *Melocactus ferreophilus* Buining & Brederoo, *Melocactus pachyacanthus* Buining & Brederoo subsp. *pachyacanthus* and *Melocactus pachyacanthus* Buining & Brederoo subsp. *viridis* N.P. Taylor, as well as all of the endemic and rare species cited above are more seriously endangered because they have fewer populations when compared to other cactus species found in the SFRW (Figure 6).

So the presence of these species should be indicative of the need to create conservation units, as is the case with the Grutas dos Brejões Environmental Protection Area, in the state of Bahia, where there are plants of *Melocactus ferreophilus* Buining & Brederoo (MMA, 2011). Furthermore, projects that aim to increase our knowledge of the biology of these species and guarantee their reproductive success should be widely encouraged to promote and maintain populations in their natural habitats.



**FIGURE 4.** Conservation status (CR: critically endangered, EN: endangered, VU: vulnerable, NT: near threatened, DD: data deficient and LC: least concern) of endemic and non-endemic Cactaceae species found in areas of the São Francisco River Watershed (SFRW).



**Figure 5.** Number of endemic and non-endemic Cactaceae species in the São Francisco River Watershed (SFRW) with local distribution (1 to 10 populations), intermediate distribution (11 to 30 populations) and widespread distribution over 30 populations).



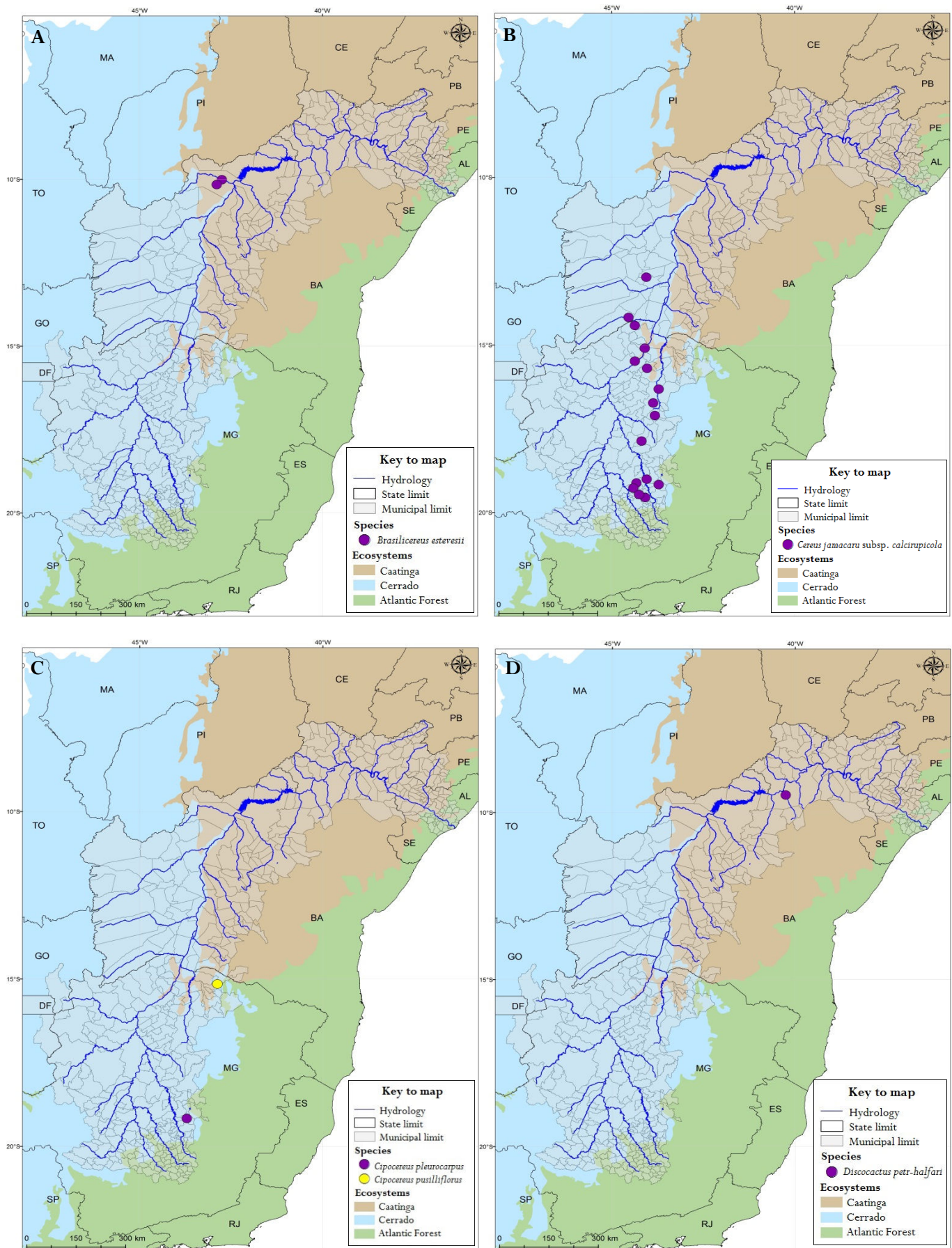


FIGURE 6. Geographic distribution of endemic cacti in areas of the São Francisco River Watershed (SFRW) from the genera (A) *Brasiliocereus* Backeb., (B) *Cereus* Mill., (C) *Cipoocereus* Ritter and (D) *Discocactus* Pfeiff.



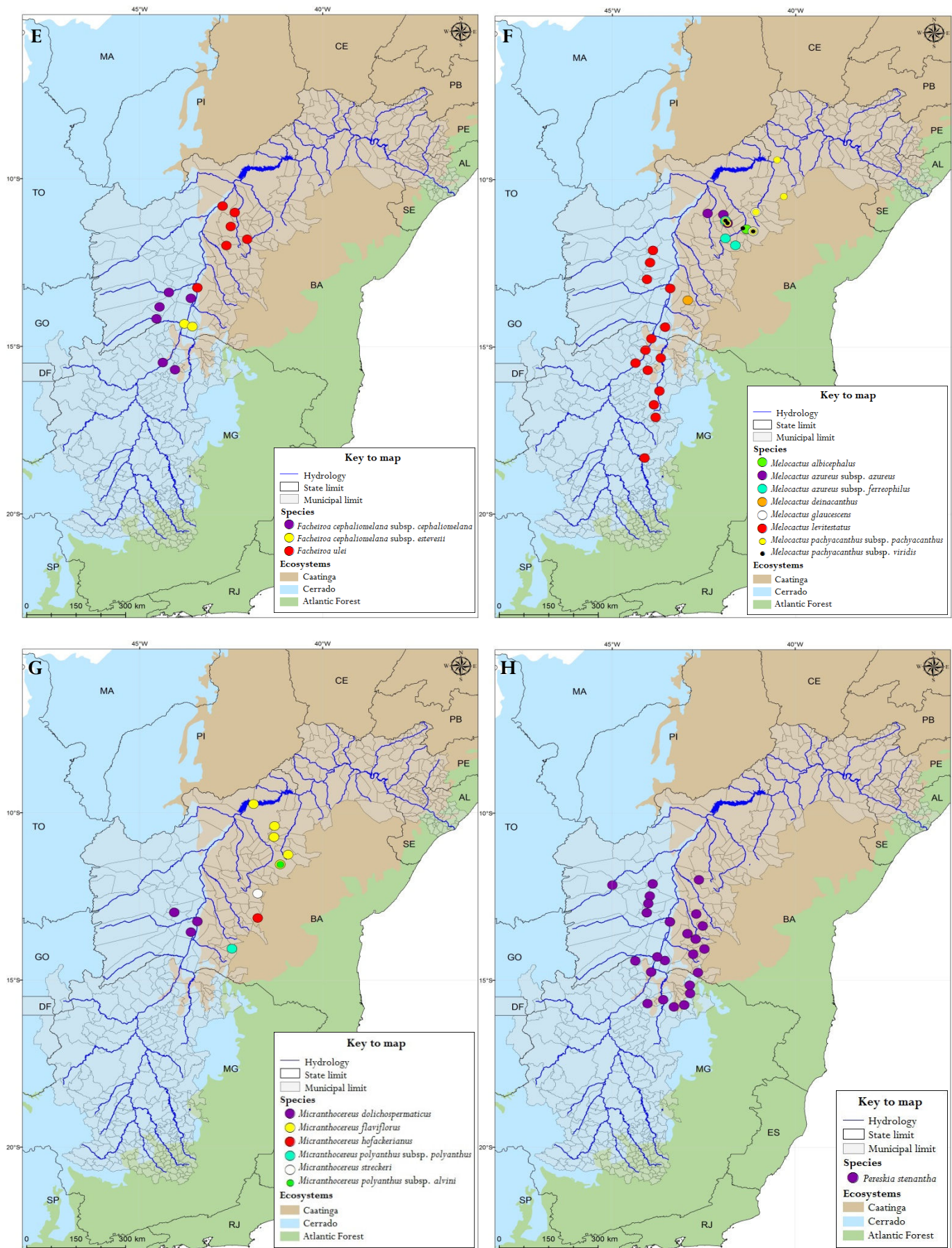


FIGURE 6. Geographic distribution of endemic cacti in areas of the São Francisco River Watershed (SFRW) from the genera (E) *Facheiroa* Britton & Rose, (F) *Melocactus* Link & Otto, (G) *Micranthocereus* Backeb. and (H) *Pereskia* Mill.



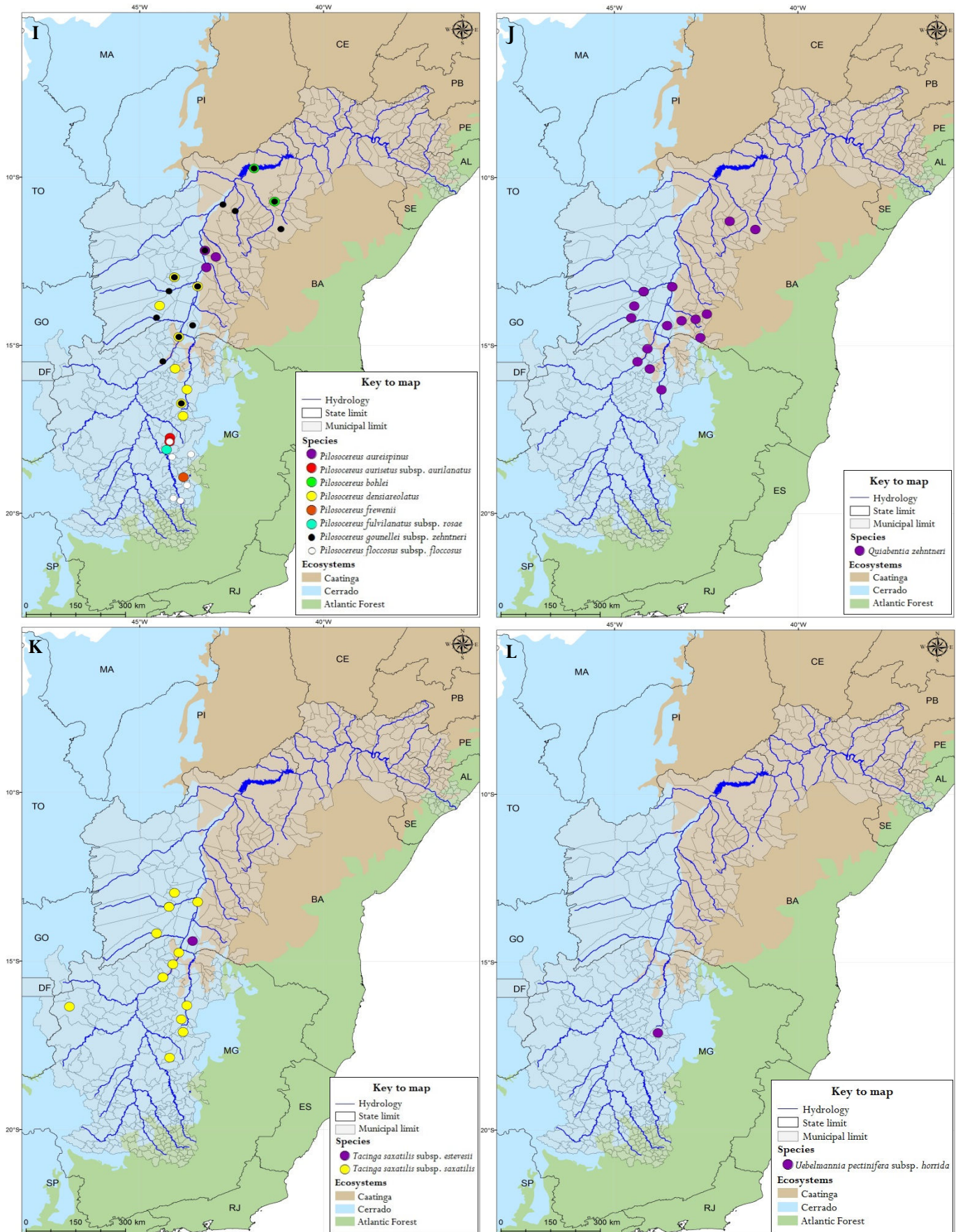


FIGURE 6. Geographic distribution of endemic cacti in areas of the São Francisco River Watershed (SFRW) from the genera (I) *Pilosocereus* Byles & Rowley, (J) *Quiabentia* Britton & Rose, (K) *Tacinga* Britton & Rose and (L) *Uebelmannia* Buining.



**TABLE 2.** Endemism, total number of populations in Brazil, and conservation status of 108 taxa of Cactaceae found in the São Francisco River Watershed (SFRW). \*In brackets: number of populations in the SFRW.

Species	Endemic BHSF	Number of Populations*	Conservation status
<i>Arrojadoa bahiensis</i> (P.J. Braun & Esteves) N.P. Taylor & Eggli		8 (5)	VU D2
<i>Arrojadoa dinae</i> Buining & Brederoo		18 (10)	VU B1ab(iii)
<i>Arrojadoa eriocalis</i> Buining & Brederoo		6 (2)	EN B2ab(iii)
<i>Arrojadoa penicillata</i> (Gürke) Britton & Rose		99 (27)	LC
<i>Arrojadoa rhodantha</i> (Gürke) Britton & Rose		170 (149)	LC
<i>Arthroceres glaziovii</i> (K. Schum.) N.P. Taylor & Zappi		10 (10)	EN B1ab(i, ii, iii, iv, v) + 2ab(i, ii, iii, iv, iv)
<i>Arthroceres melanurus</i> (K. Schum.) Diers <i>et al.</i> subsp. <i>odorus</i> (Ritter) N.P. Taylor & Zappi		4 (3)	VU D2
<i>Arthroceres rondonianus</i> Backeb. & Voll		4 (4)	VU D2
<i>Brasilicereus estevesii</i> (Hofacker & P.J. Braun) N.P. Taylor & M. Machado	X	1 (1)	VU
<i>Brasilicereus phaeacanthus</i> (Gürke) Backeb.		41 (7)	LC
<i>Brasiliopuntia brasiliensis</i> (Willd.) A. Berger		107 (34)	LC
<i>Cereus albicaulis</i> (Britton & Rose) Luetzelb.		79 (65)	LC
<i>Cereus fernambucensis</i> Lem. subsp. <i>fernambucensis</i>		88 (4)	LC
<i>Cereus jamacaru</i> DC. subsp. <i>calcirupicola</i> (F. Ritter) N.P. Taylor & Zappi	X	17 (17)	LC
<i>Cereus jamacaru</i> DC. subsp. <i>jamacaru</i>		152 (105)	LC
<i>Cereus mirabella</i> N.P. Taylor		21 (20)	VU B2ab(iii)
<i>Cipocereus bradei</i> (Backeb. & Voll) Zappi & N.P. Taylor		6 (5)	EN B1ab(iii) + 2ab(iii)
<i>Cipocereus crassisepalus</i> (Buining & Brederoo) Zappi & N.P. Taylor		3 (1)	VU B1ab(iii) + 2ab(iii)
<i>Cipocereus minensis</i> (Werderm.) Ritter subsp. <i>leiocarpus</i> N.P. Taylor & Zappi		15 (7)	LC
<i>Cipocereus minensis</i> (Werderm.) Ritter subsp. <i>minensis</i>		26 (14)	EN B2ab(iii)
<i>Cipocereus pleurocarpus</i> Ritter	X	5 (5)	EN
<i>Cipocereus pusilliflorus</i> (Ritter) Zappi & N.P. Taylor	X	1 (1)	CR D
<i>Coleocephalocereus buxbaumianus</i> Buining subsp. <i>flavisetus</i> (Ritter) N.P. Taylor & Zappi		7 (2)	VU B2ab(iii)
<i>Coleocephalocereus goebelianus</i> (Vaupel) Buining		22 (10)	LC
<i>Discocactus bahiensis</i> Britton & Rose		18 (16)	EN B2ab(i, ii, iii, iv, v)
<i>Discocactus catingicola</i> Buining & Brederoo		18 (15)	VU B2ab(iii)
<i>Discocactus petr-halfari</i> Zachar	X	1 (1)	CR B1ab(iii, v) + 2ab(iii, v)
<i>Discocactus placentiformis</i> (Lehm.) K. Schum.		21 (14)	VU B2ab(iii, v)
<i>Discocactus zehntneri</i> Britton & Rose subsp. <i>boomianus</i> (Buining & Brederoo) N.P. Taylor & Zappi		10 (9)	VU D2
<i>Discocactus zehntneri</i> Britton & Rose subsp. <i>zehntneri</i>		10 (6)	DD
<i>Epiphyllum phyllanthus</i> (L.) Haw.		120 (22)	LC
<i>Espositoopsis dybowskii</i> (Rol.-Goss.) Buxb.		11(55)	EN B2ab(iii)
<i>Facheiroa cephalomelana</i> Buining & Brederoo subsp. <i>cephalomelana</i>	X	9 (9)	VU B1ab(iii)
<i>Facheiroa cephalomelana</i> Buining & Brederoo subsp. <i>estevesii</i> (P.J. Braun) N.P. Taylor & Zappi	X	3 (3)	VU D2
<i>Facheiroa squamosa</i> (Gürke) P.J. Braun & Esteves		46 (41)	LC
<i>Facheiroa ulei</i> (Gürke) Werderm.	X	8 (8)	DD
<i>Harrisia adscendens</i> (Gürke) Britton & Rose		155 (118)	LC
<i>Hattiora salicornioides</i> (Haw.) Britton & Rose		59 (16)	LC
<i>Hylocereus setaceus</i> (Salm-Dyck) R. Bauer		73 (16)	LC
<i>Leocereus bahiensis</i> Britton & Rose		47 (43)	LC
<i>Lepismium warmingianum</i> (K. Schum.) Barthlott		2 (2)	LC
<i>Melocactus albicephalus</i> Buining & Brederoo	X	2 (2)	CR
<i>Melocactus azureus</i> Buining & Brederoo	X	10 (10)	EN B1ab(i, ii, iii, iv) + 2ab(I, ii, iii, iv)
<i>Melocactus bahiensis</i> (Britton & Rose) Luetzelb. subsp. <i>amethystinus</i> (Buining & Brederoo) N.P. Taylor		19 (2)	LC
<i>Melocactus bahiensis</i> (Britton & Rose) Luetzelb. subsp. <i>bahiensis</i>		52 (28)	LC
<i>Melocactus concinnus</i> Buining & Brederoo		31 (20)	LC

TABLE 2. Continued.

Species	Endemic BHSF	Number of Populations*	Conservation status
<i>Melocactus deinacanthus</i> Buining & Brederoo	X	2 (2)	CR B1ab(iii) + 2ab(iii)
<i>Melocactus ernestii</i> Vaupel subsp. <i>ernestii</i>		83 (35)	LC
<i>Melocactus ernestii</i> Vaupel subsp. <i>longicarpus</i> (Buining & Brederoo) N.P. Taylor		9 (7)	LC
<i>Melocactus ferreophilus</i> Buining & Brederoo	X	5 (5)	EN B1ab(iii) + 2ab(iii)
<i>Melocactus glaucescens</i> Buining & Brederoo	X	15 (15)	CR B1ab(iii) + 2ab(iii)
<i>Melocactus lanssensianus</i> P.J. Braun		2 (1)	DD
<i>Melocactus levitestatus</i> Buining & Brederoo	X	15 (15)	LC
<i>Melocactus oreas</i> Miq. subsp. <i>cremnophilus</i> (Buining & Brederoo) P.J. Braun		7 (7)	LC
<i>Melocactus pachyacanthus</i> Buining & Brederoo subsp. <i>pachyacanthus</i>	X	9 (9)	EN B1ab(I, ii, iii, iv)
<i>Melocactus pachyacanthus</i> Buining & Brederoo subsp. <i>viridis</i> N.P. Taylor	X	10 (10)	CR B2ab(I, ii, iii, iv); C2a(ii); D
<i>Melocactus paucispinus</i> Heimen & R.J. Paul		14 (13)	EN B2ab(v)
<i>Melocactus violaceus</i> Pfeiff. subsp. <i>margaritaceus</i> N.P. Taylor		16 (3)	VU A3c
<i>Melocactus zehntneri</i> (Britton & Rose) Luetzelb.		136 (112)	LC
<i>Micranthocereus albicephalus</i> (Buining & Brederoo) F. Ritter		7 (4)	NT
<i>Micranthocereus dolichospermaticus</i> (Buining & Brederoo) F. Ritter	X	6 (6)	LC
<i>Micranthocereus flaviflorus</i> Buining & Brederoo	X	5 (5)	LC
<i>Micranthocereus hofackerianus</i> (P.J. Braun & Esteves) M. Machado	X	1 (1)	EN B1ab(iii, v) + 2ab(iii, v); C2a(ii)
<i>Micranthocereus polyanthus</i> (Werderm.) Backeb. subsp. <i>alvini</i> M. Machado & Hofacker	X	2 (2)	VU B1ab(ii, iii, v) + 2ab(ii, iii, v)
<i>Micranthocereus polyanthus</i> (Werderm.) Backeb. subsp. <i>polyanthus</i>	X	1 (1)	EN B2ab(iii)
<i>Micranthocereus purpureus</i> (Gürke) F. Ritter		35 (17)	LC
<i>Micranthocereus streckeri</i> Van Heek & Van Criek.	X	1 (1)	CR B1ab(iii) + 2ab(iii); C2a(ii); D
<i>Micranthocereus violaciflorus</i> Buining		4 (1)	VU D2
<i>Pereskia aculeata</i> Mill.		94 (12)	LC
<i>Pereskia aureiflora</i> Ritter		23 (9)	VU A2c + 3c
<i>Pereskia bahiensis</i> Gürke		105 (50)	LC
<i>Pereskia grandifolia</i> Haw. subsp. <i>grandifolia</i>		59 (13)	LC
<i>Pereskia stenantha</i> Ritter	X	37 (37)	LC
<i>Pilosocereus aureispinus</i> (Buining & Brederoo) Ritter	X	3 (3)	DD
<i>Pilosocereus aurisetus</i> (Werderm.) Byles & G.D. Rowley subsp. <i>aurilanatus</i> (Ritter) Zappi	X	2 (2)	EN B1ab(iii) + 2ab(iii)
<i>Pilosocereus aurisetus</i> (Werderm.) Byles & G.D. Rowley subsp. <i>aurisetus</i>		20 (8)	LC
<i>Pilosocereus bohlei</i> Hofacker	X	2 (2)	VU B1ab(ii, iii, v) + 2ab(ii, iii, v)
<i>Pilosocereus catingicola</i> (Gürke) Byles & Rowley subsp. <i>cattingicola</i>		47 (10)	LC
<i>Pilosocereus catingicola</i> (Gürke) Byles & Rowley subsp. <i>salvadorensis</i> (Werderm.) Zappi		51 (32)	NT
<i>Pilosocereus chrysostele</i> (Vaupel) Byles & G.D. Rowley		27 (25)	LC
<i>Pilosocereus densiareolatus</i> F. Ritter	X	9 (9)	LC
<i>Pilosocereus floccosus</i> Byles & Rowley subsp. <i>floccosus</i>	X	7 (7)	NT
<i>Pilosocereus frewenii</i> Zappi & N.P. Taylor	X	1 (1)	CR D
<i>Pilosocereus fulvilanatus</i> (Buining & Brederoo) Ritter subsp. <i>rosae</i> (P.J. Braun) Zappi	X	1 (1)	CR B1ab(iii) + 2ab(iii)
<i>Pilosocereus glaucocrouns</i> (Werderm.) Byles & G.D. Rowley		23 (20)	NT
<i>Pilosocereus gounellei</i> (F.A.C. Weber) Byles & Rowley subsp. <i>gounellei</i>		149 (110)	LC
<i>Pilosocereus gounellei</i> (F.A.C. Weber) Byles & Rowley subsp. <i>zehntneri</i> (Britton & Rose) Zappi	X	20 (20)	LC
<i>Pilosocereus machrisii</i> (E.Y. Dawson) Backeb.		4 (2)	LC
<i>Pilosocereus pachycladus</i> F. Ritter subsp. <i>pachycladus</i>		74 (43)	LC
<i>Pilosocereus pachycladus</i> F. Ritter subsp. <i>pernambucoensis</i> (Ritter) Zappi		139 (113)	LC
<i>Pilosocereus pentaedrophorus</i> (Cels) Byles & Rowley subsp. <i>pentaedrophorus</i>		84 (14)	LC
<i>Pilosocereus tuberculatus</i> (Werderm.) Byles & G.D. Rowley		81 (1)	LC



TABLE 2. Continued.

Species	Endemic BHSF	Number of Populations*	Conservation status
<i>Quiabentia zehntneri</i> (Britton & Rose) Britton & Rose	X	26 (26)	LC
<i>Rhipsalis cereuscula</i> Haw.		18 (1)	LC
<i>Rhipsalis floccosa</i> Salm-Dyck ex Pfeiff. subsp. <i>floccosa</i>		107 (17)	LC
<i>Rhipsalis floccosa</i> Salm-Dyck ex Pfeiff. subsp. <i>oreophila</i> N.P. Taylor & Zappi		6 (5)	LC
<i>Rhipsalis floccosa</i> Salm-Dyck ex Pfeiff. subsp. <i>pulvinigera</i> (G. Lindb.) Barthlott & N.P. Taylor		22 (8)	LC
<i>Rhipsalis lindbergiana</i> K. Schum.		73 (17)	LC
<i>Stephanocereus leucostele</i> (Gürke) A. Berger		45 (23)	LC
<i>Stephanocereus luetzelburgii</i> (Vaupel) N.P. Taylor & Eggli		40 (18)	LC
<i>Tacinga funalis</i> Britton & Rose		61 (43)	LC
<i>Tacinga inamoena</i> (K. Schum.) N.P. Taylor & Stuppy		277 (224)	LC
<i>Tacinga palmadora</i> (Britton & Rose) N.P. Taylor & Stuppy		254 (167)	LC
<i>Tacinga saxatilis</i> (Ritter) N.P. Taylor & Stuppy subsp. <i>estesvii</i> (P.J. Braun) N.P. Taylor & Stuppy	X	1 (1)	LC
<i>Tacinga saxatilis</i> (Ritter) N.P. Taylor & Stuppy subsp. <i>saxatilis</i>	X	19 (19)	VU D2
<i>Tacinga wernerii</i> (Eggli) N.P. Taylor & Stuppy		23 (6)	VU B2ab(ii, iii, iv, v)
<i>Uebelmannia pectinifera</i> Buining subsp. <i>flavispina</i> (Buining & Brederoo) P.J. Braun & Esteves		2 (1)	VU B1ab(iii, v)
<i>Uebelmannia pectinifera</i> Buining subsp. <i>horrida</i> (P.J. Braun) P.J. Braun & Esteves	X	1 (1)	VU D2
<b>TOTAL</b>	36		

Finally, the importance of the SFRW areas for members of the family Cactaceae is obvious due to the many cactus species found there. However, floristic surveys are still nonexistent in circa 300,000 km<sup>2</sup> that represent over 280 municipalities in the watershed. Therefore, the situation of the São Francisco's cacti will be improved by including new species and/or more complete geographic distribution patterns. Due to the high degree of endemism of Cactaceae and the rarity of cactus species found in SFRW areas, many species as yet unknown to science may soon be eliminated from their natural habitats due to environmental degradation, even before they are discovered. So it is urgent that we create programs to promote the effective conservation and reduction of extinction risk of these species, efforts that must involve three segments: (1) the government, that should sponsor these programs; (2) the scientific community, that should increase basic research and floristic surveys of cactus species, as well as the development and improvement of techniques that will guarantee reproductive success, *ex situ* conservation and conservation of cactus populations in their natural habitats; (3) society, that should recognize the social, economic and environmental value of the forest and learn to use natural resources sustainably, thus avoiding destruction of new areas in the SFRW and extinction of the local flora and the fauna that use these cactus species for food.

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