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ORIGINAL PAPER

Bromeliaceae diversity and conservation in Minas Gerais state, Brazil

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Abstract Field work and data from herbaria collections (2686 records) representing 283 taxa (265 species and 18 infraspecific taxa) of Bromeliaceae occurring at Minas Gerais state, southeastern Brazil, were analyzed in order to obtain distribution and diversity information, and to determine IUCN (The World Conservation Union) conservation status for each taxon. A map containing $1^\circ \times 1^\circ$ grid cells was used to identify priority areas for new research collections, areas of high species diversity, and Bromeliaceae conservation status. A clear decrease in Bromeliaceae diversity is observed between the eastern and the western portions of Minas Gerais, and low floristic similarities were found between neighboring grid cells. The rocky mountains of Cadeia do Espinhaço are considered the most important area for Bromeliaceae endemics. From the 283 taxa of Bromeliaceae that occur at Minas Gerais, 118 (42%) are considered threatened, and 124 taxa (44% of the total) do not occur inside any protected area. The region of the Quadrilátero Ferrífero in the southern portion of the Cadeia do Espinhaço is the most threatened, and urgent strategies for conservation of this rich Bromeliaceae flora are needed. Northeastern Minas Gerais, particularly the rocky outcrops or inselbergs located in the Jequitinhonha and Mucuri rivers drainage basins need additional collection efforts and conservation actions focused on these saxicolous taxa.

Keywords Brazil · Bromeliaceae · Conservation · Cadeia do Espinhaço · Endemism · Epiphytes · Minas Gerais · Serra da Mantiqueira · Species richness

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Introduction

The monocot family Bromeliaceae Juss. is among the most characteristic of the Neotropical region. It is wholly American except for a single species of west tropical Africa, and contains about 56 genera and 3000 species of generally herbaceous and rhizomatozous plants, with lanceolate leaves that are often spirally arranged with tightly overlapping basal sheathes that form free-water tanks, or phytotelma, and both blades and sheathes often bear scale-like water-absorbing trichomes (Dahlgren et al. 1985; Luther 2004). The distinct adaptations for a wide variety of terrestrial and epiphytic life forms have enabled Bromeliaceae to colonize and diversify within the Neotropics, and the family constitutes a noteworthy case of adaptive radiation (Benzing 2000; Givnish et al. 2004). Being widely distributed and frequent in Neotropical habitats, bromeliads act as an important ecological element in many communities, contributing to structural complexity of the environment, which is directly reflected on richness and diversity of associate fauna and flora (Benzing 2000).

Bromeliaceae is also world renowned for its horticultural value. Over the last two decades, the family has become more popular in Brazil, as home and garden ornamental plants, and this has promoted increased collecting pressures on natural populations. Although it is broadly accepted that Brazil is the richest country for Bromeliaceae species, a precise and updated inventory for use in conservation efforts and to drive environmental agency decisions and actions, is lacking. The present work is the first to employ grid cell analysis with respect to diversity and conservation data on Minas Gerais (MG) Bromeliaceae species. One degree grid cells have been employed in research addressing phytogeography, species richness, and endemism analyses for conservationist purposes (e.g. Kress et al. 1998; Serrato et al. 2004). Benzing (2000) notes that studies of Bromeliaceae phytogeography are rare, usually restricted to areas continental in scale (e.g. Smith 1934), and that important information on Bromeliaceae evolution would arise from analyses combining taxonomic, floristic and life-form data.

Due to the great ecological importance and horticultural interest in the family, versus the current, alarming status of human interference in natural bromeliad habitats in MG, we present this work, which aims (1) to determine current knowledge on Bromeliaceae distribution and their habitats within MG; (2) analyze the diversity and collection efforts for the family within $1° \times 1°$ grid cells; (3) establish the conservation status of each taxon, and list those that are not protected; (4) indicate areas where more scientific collections, or special conservation are needed.

Study sites

The state of MG is located in the southeastern region of Brazil (Fig. 1) contains 586,528 km^2 of area, 853 municipalities, and a rich Bromeliaceae flora, characterized by high numbers of genera and species, and elevated levels of endemism (Versieux and Wendt 2006). Unfortunately, the history of MG is rich with massive deforestation due to expansions of agricultural, cattle rising and urban areas, and also by mining activities. Minas Gerais is characterized by a hilly relief with elevation ranging from 79 to 2,890 m (Drummond et al. 2005). The state has a complex vegetation that ranges from xerophytic dry forest to tropical evergreen forests, that can generally be divided into three different biomes: Atlantic Forest in the eastern and southern

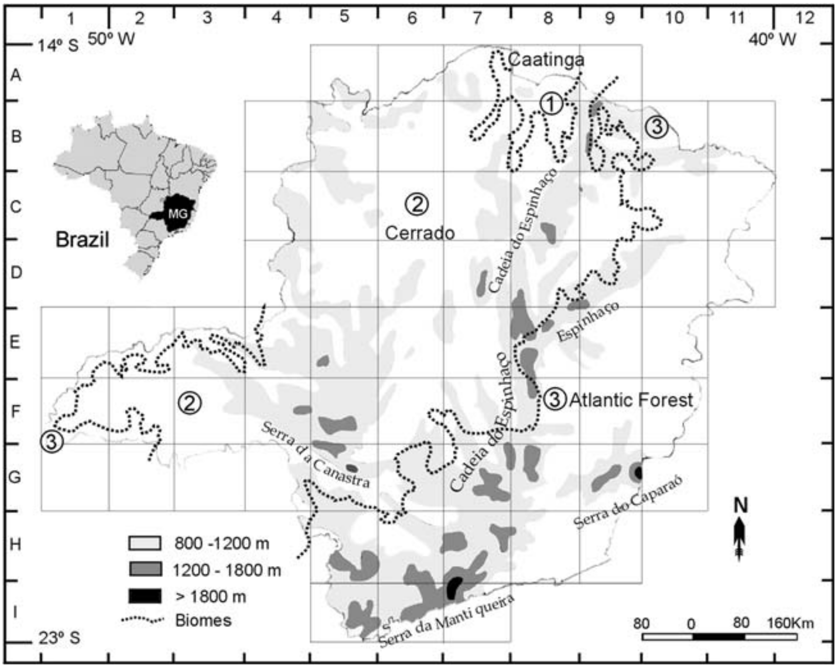

Fig. 1 Map of Minas Gerais showing the main mountain ranges and the biomes

portions of the state; cerrado (savanna) in the central-western and northwestern areas; and caatinga (low drought-decidous forest) in the extreme north of MG (Drummond et al. 2005).

The highlands region formed by the Cadeia do Espinhaço and the Serra da Mantiqueira have great importance as habitat for endemic flora and fauna (Fig. 1). The Cadeia do Espinhaço extends for ca. 1,100 km from MG (Ouro Preto municipality) to Chapada Diamantina in Bahia state, its northernmost limit (Harley 1995). A particular vegetation type known as campo rupestre (rocky field) is characteristic of the more elevated areas along the Cadeia do Espinhaço. This grassland vegetation usually appears above 800 m where soils are shallow, and sandstones and quartzite outcrops are very frequent, providing different habitats for saxicolous plants (Giulietti et al. 1987; Harley 1995). Robust vegetation with twisted low trees appears wherever the soil is deeper and gallery forest and forest patches known as *capões* occur along watercourses, ravines and hillsides, or even on hill tops (Pirani et al. 1994). The extreme southern part of Cadeia do Espinhaço is called 'Quadrilátero Ferrífero' and differs from most of the remaining mountain range, due to exposed iron oxide deposits which are known as 'canga' and provide habitat for many saxicolous species (Rizzini 1997). Lying close to boundaries of Rio de Janeiro and São Paulo states is another important mountain range, Serra da Mantiqueira. In this range the forest resembles the most exuberant and rich vegetation that is found along the southeastern Brazilian coast, called Atlantic Forest *sensu stricto*. As the altitude increases, small areas of *Araucaria* forest, also called cloud forest, appear and high humidity within the forest supports abundant epiphytic vegetation. Above

1,200 m in Serra da Mantiqueira, the forest gives way to campo de altitude, or high altitude grassland. This open habitat provides only a thin soil layer and vegetation is scattered in small islands and adapted to high levels of humidity, winds, solar exposure, and low winter temperatures (< 12°C) (Martinelli 1989; Safford 1999).

Methods

Data were obtained from field work carried out from 2002–2005 and from collections located at 14 herbaria that were examined between years 2002–2004 (BHCB, BHZB, CESJ, HB, HBR, MBM, R, RB, RFA, SEL, SP, SPF, US, VIC, acronyms according to Holmgren et al. (1990) except BHZB = Fundação Zoobotânica de Belo Horizonte). All herbarium specimens from MG were photographed and databased using Brahms software (Botanical Research and Herbarium Management System, version 5.55, Oxford University). The recent checklist of Minas Gerais Bromeliaceae (Versieux and Wendt 2006) was used as the main taxonomic framework. Data on the type of vegetation in which Bromeliaceae taxa occurred were mostly taken from specimen labels, but for some cases a vegetation map was consulted (Drummond et al., 2005). Municipalities were grouped inside 74 grid cells of 1 per 1° and those that were not totally confined within a single grid cell were assigned as belonging to the cell that hosts their administration center. The presence or absence of each taxon of Bromeliaceae in each cell was recorded. The Jaccard's measure of similarity and the UPGMA clustering method were employed in order to identify floristic similarities among grid cells, using BiodiversityPro software (ver. 2/1997). The IUCN (2001) methodology was used to establish conservation status of each taxon, except for the genus *Encholirium* that was previously defined by Forzza et al. (2003). Bromeliaceae taxa occurrence within parks or natural reserves were verified with the list of protected areas of MG (Camargos 2001).

Results and discussion

Phytogeographical analysis

Species richness and endemism

Bromeliaceae is represented within MG by 27 genera, 265 species, and 18 infraspecific taxa (Fig. 2). The areas with highest species richness are concentrated along the southern Cadeia do Espinhaço and in southeastern MG, and generally correspond to well-known and historical collection localities (e.g. Diamantina, Serra da Piedade, Ouro Preto, Serra de Ibitipoca). Some grid cells with numerous bromeliad taxa are also important because they are among the floristically richest areas for other plant groups. For example, cell F8 is the richest cell for Bromeliaceae and corresponds to a very rich area for Xyridaceae and *Mimosa* (Wanderley 1992; Simon and Proença 2000). High generic-level diversity is related to the geographic position occupied by MG, where many different climatic types exist, allowing the development of distinct vegetation forms and, consequently, distinct taxa of Bromeliaceae. Bromeliaceae species diversity within MG is high, corresponding to almost 9% of the total number of species for the entire family. Once again, this is related to unique sets of habitat

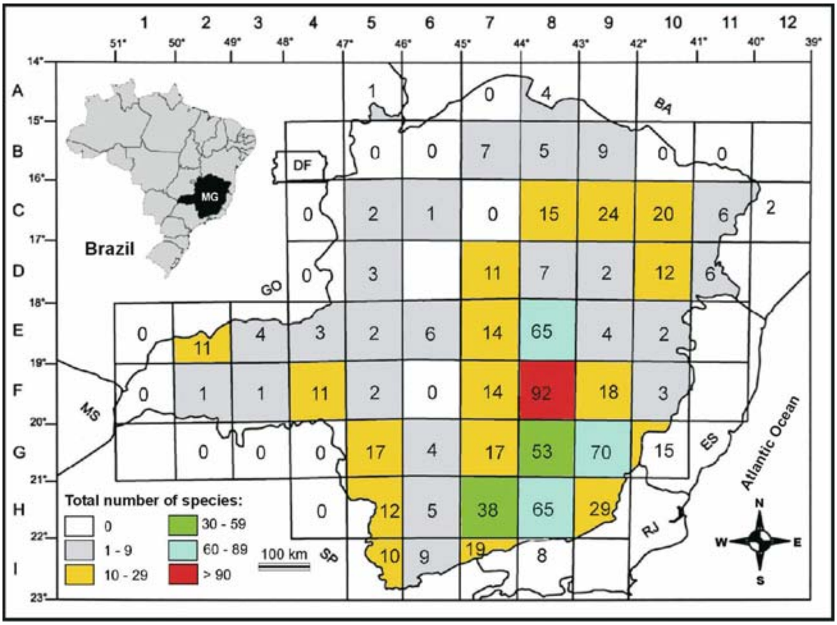

Fig. 2 Species richness within 1° × 1° grid cells for Bromeliaceae of Minas Gerais, Brazil

attributes, local climates, and to the biogeographical affinities among eastern Brazilian areas, where Bromeliaceae has profoundly diversified (Versieux and Wendt 2006). One genus (*Andrea*) and 98 species (37% of total) are endemic to MG. Sixty two percent of all the endemic taxa are restricted to the Espinhaço, while 12% are only known to occur in the Mantiqueira. Only one percent of Bromeliaceae endemic species have general, broad distributions within MG.

The importance of the campo rupestre habitat of the Cadeia do Espinhaço for flora diversity and endemism has been observed by many authors while working with different plant families and is confirmed here for MG Bromeliaceae (Fig. 2). As observed by Pirani et al. (1994), many species from the Cadeia do Espinhaço rocky fields probably aroused *in situ* in response to specific environmental conditions due to the isolation from nearby mountains. Morton (1972) explained the higher levels of endemism in montane habitats of west African mountains by a rapid speciation following extinctions of many grassland species resulting from repeated climatic oscillations (i.e. either temperature and rain fall increase or decrease) that promoted advances of the forest during climatic optima, when many of the savanna habitats were reduced or eliminated. However, open habitat species rested confined to suitable refuge such as cliffs and rock outcrops where hybridization provided a sufficient genetic variation for the evolution of new species during the next expansion of grasslands (Morton 1972). Similar processes could have occurred in elevated areas of MG, such as the Cadeia do Espinhaço and the Serra da Mantiqueira, allowing their notable floristic diversity and endemism. Even endemic genera inhabit these mountains, as the monotypic *Andrea*, from the Espinhaço. Considering only dispersal capacity, higher endemism rates for the Bromeliaceae of the Espinhaço campo

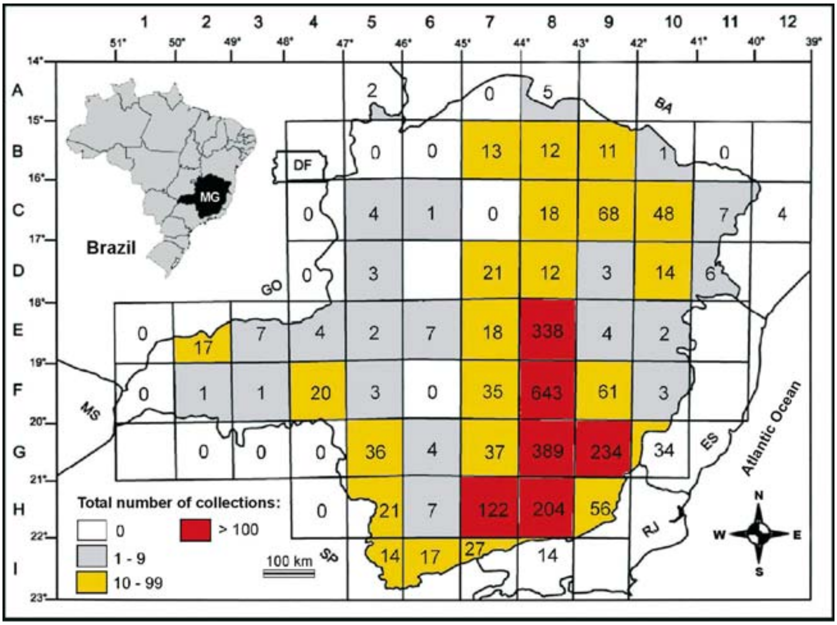

Fig. 3 Total number of Bromeliaceae taxa collections within 1° × 1° grid cells, in Minas Gerais, Brazil

rupestre may be attributed to lower dispersal ability for many saxicolous taxa (e.g. *Dyckia*, *Encholirium*) and perhaps to an efficient isolation from nearby mountains by lower elevated forested valleys, where similar rock outcrops, or other environmental factors required for seed germination and seedling growth are unavailable.

Collection efforts

The most collected grid cell are located along the Cadeia do Espinhaço, particularly in its southernmost portion, i.e. grid cells E8, F8, and G8 (Fig. 3) and three are in the southeastern portion of MG (G9, H7, H8). Almost 26% of the Bromeliaceae listed for MG are represented in herbaria by a single specimen (Table 1). Spiny and succulent leaves, the large dimensions of many of its species, and their occurrence in locations difficult to access seem to be the cause of these low numbers. A clear decrease in collection numbers is observed toward the central-western and northwestern portions of the 45° meridian. The 45° of longitude roughly corresponds to the western border of the Espinhaço, limiting the campo rupestre and the Atlantic forest to the east, and the savanna and part of the caatinga at the western and northern portions of MG, respectively. Thus this mountain chain seems to act as barrier for the inland distribution of many Bromeliaceae species of the Atlantic domain, influencing diversity and sampling. Sampling also decreases toward northeastern (e.g. B10, B11, C10, C11, D9, D11, E9, E10, F10) and the extreme southern (e.g. H6, I5, I6) portions. Seventeen grid cells did not presented any voucher of Bromeliaceae. Those undercollected areas should be considered priorities in future collections and field work research.

Table 1 List of Bromeliaceae of Minas Gerais state, Brazil, followed by total number of records, occurrence within protected areas, and IUCN conservation status

Taxon	No. of records	Occurrence within parks	IUCN Category
1. ***Acanthostachys strobilacea*** (Schult. & Schult. f.) Klotzsch	44	y	Least Concern (LC)
2. ***Aechmea alba*** Mez	3	n	Vulnerable (VU)
3. *A. alopecurus* Mez	1	n	Endangered (EN)
4. *A. bambusoides* L.B. Sm. & Reitz	6	n	Vulnerable (VU)
5.1. *A. bromeliifolia* (Rudge) Baker var. *bromeliifolia*	104	y	Least Concern (LC)
5.2. *A. bromeliifolia* var. *albobracteata* Philcox	1	y	Least Concern (LC)
6. *A. brueggeri* Leme	5	n	Critically Endangered (CR)
7. *A. burle-marxii* E. Pereira	1	n	Data Deficient (DD)
8.1. *A. distichantha* Lem. var. *distichanta*	22	y	Least Concern (LC)
8.2. *A. distichantha* var. *glaziovii* (Baker) L.B. Sm.	3	n	Least Concern (LC)
8.3. *A. distichantha* var. *schlumbergeri* E. Morren ex Mez	7	y	Least Concern (LC)
9. *A. gamosepala* Wittm.	1	n	Not Evaluated (NE)
10. *A. lamarchei* Mez	40	y	Least Concern (LC)
11. *A. maculata* L.B. Sm.	3	y	Vulnerable (VU)
12.1. *A. nudicaulis* (L.) Griseb. var. *nudicaulis*	59	y	Least Concern (LC)
12.2. *A. nudicaulis* var. *aureorosea* (Antoine) L.B. Sm.	13	y	Least Concern (LC)
12.3. *A. nudicaulis* var. *cuspidata* Baker	9	y	Least Concern (LC)
13. *A. organensis* Wawra	3	y	Least Concern (LC)
14. *A. phanerophlebia* Baker	42	y	Least Concern (LC)
15. *A. pineliana* (Brongn. ex Planch.) Baker	4	y	Least Concern (LC)
16. *A. purpureorosea* (Hook. f.) Wawra	1	n	Endangered (EN)
17. *A. ramosa* Mart. ex Schult. & Schult. f.	22	y	Least Concern (LC)
18. *A. vanhoutteana* (Van Houtte) Mez	4	y	Least Concern (LC)
19. *A. weilbachii* Didr.	1	y*	Vulnerable (VU)
20. ***Alcantarea burle-marxii***(Leme) J.R. Grant	3	n	Endangered (EN)
21. *A. duarteana* (L.B. Sm.) J.R. Grant	9	n	Endangered (EN)
22. *A. extensa* (L.B. Sm.) J.R. Grant	8	y	Least Concern (LC)
23. *A. hatschbachii* (L.B. Sm. & Read) Leme	2	n	Critically Endangered (CR)
24. *A. imperialis* (Carrière) Harms	6	y	Vulnerable (VU)
25. *A. odorata* (Leme) J.R. Grant	1	n	Data Deficient (DD)
26. *A. turgida* Versieux & Wand.	2	y	Not Evaluated (NE)
27. *A.* sp. 1.	2	n	Not Evaluated (NE)
28. ***Ananas ananassoides*** (Baker) L.B. Sm.	46	y	Least Concern (LC)
29. *A. bracteatus* (Lindl.) Schult. & Schult. f.	5	y	Least Concern (LC)
30. *A. comosus* (L.) Merr.	1	y	Least Concern (LC)
31. *A. nanus* (L.B. Sm.) L.B. Sm.	2	y	Vulnerable (VU)
32. ***Andrea selloana*** Baker	11	y	Endangered (EN)
33.1. ***Billbergia amoena*** (G. Lodd.) Lindl. var. ***amoena***	46	y	Least Concern (LC)
33.2. *B. amoena* var. *carnea* E. Pereira	3	n	Vulnerable (VU)
33.3. *B. amoena* var. *minor* (Antoine & Beer) L.B. Sm.	4	y*	Endangered (EN)
34. *B. distachia* (Vell.) Mez	26	y	Least Concern (LC)
35. *B. elegans* Mart. ex Schult. & Schult. f.	54	y	Least Concern (LC)

Table 1 continued

Taxon	No. of records	Occurrence within parks	IUCN Category
36. *B. euphemiae* E. Morren	15	y	Least Concern (LC)
37. *B. horrida* Regel	13	y	Least Concern (LC)
38. *B. iridifolia* (Nees & Mart.) Lindl.	12	y	Least Concern (LC)
39. *B. leptopoda* L.B. Sm.	5	y*	Endangered (EN)
40. *B. lymanii* E. Pereira & Leme	7	y	Least Concern (LC)
41. *B. macrocalyx* Hook. f.	1	n	Not Evaluated (NE)
42. *B. meyeri* Mez	3	n	Vulnerable (VU)
43. *B. minarum* L.B. Sm.	3	y	Not Evaluated (NE)
44. *B. nutans* H. Wendl. ex Regel	3	y	Least Concern (LC)
45. *B. pohliana* Mez	1	n	Data Deficient (DD)
46. *B. porteana* Brongn. ex Beer	9	y	Least Concern (LC)
47. *B. reichardtii* Wawra	4	n	Endangered (EN)
48. *B. sanderiana* E. Morren	1	n	Data Deficient (DD)
49. *B. saundersii* W. Bull	1	n	Data Deficient (DD)
50. *B. tweedieana* Baker	3	n	Vulnerable (VU)
51. *B. vittata* Brongn.	50	y	Least Concern (LC)
52. *B. zebrina* (Herb.) Lindl.	18	y	Least Concern (LC)
53. ***Bromelia antiacantha*** Bertol.	4	y	Least Concern (LC)
54. *B. balansae* Mez	20	y	Least Concern (LC)
55. *B. glaziovii* Mez	2	y	Vulnerable (VU)
56. *B. interior* L.B. Sm.	4	n	Least Concern (LC)
57. *B. regnellii* Mez	3	y	Least Concern (LC)
58. *B. serra* Griseb.	5	n	Vulnerable (VU)
59. *B. villosa* Mez	1	n	Data Deficient (DD)
60. ***Canistrum auratum*** Leme	1	n	Vulnerable (VU)
61. ***Cryptanthus. caracensis*** Leme & E. Gross	9	y*	Critically Endangered (CR)
62. *C. glaziovii* Mez	4	y*	Critically Endangered (CR)
63. *C. leopoldo-horstii* Rauh	6	n	Critically Endangered (CR)
64. *C. minarum* L.B. Sm.	2	n	Critically Endangered (CR)
65. *C. schwackeanus* Mez	47	y	Vulnerable (VU)
66. *C. warasii* E. Pereira	1	n	Critically Endangered (CR)
67. ***Dyckia argentea*** Mez	2	n	Vulnerable (VU)
68. *D. brachyphylla* L.B. Sm.	14	n	Vulnerable (VU)
69. *D. bracteata* (Wittm.) Mez	21	y	Vulnerable (VU)
70. *D. brevifolia* Baker	2	n	Not Evaluated (NE)
71. *D. cinerea* Mez	12	y	Vulnerable (VU)
72. *D. consimilis* Mez	8	n	Endangered (EN)
73. *D. densiflora* Schult. & Schult. f.	4	y	Vulnerable (VU)
74. *D. dissitiflora* Schult. & Schult. f.	5	n	Least Concern (LC)
75. *D. elata* Mez	1	n	Data Deficient (DD)
76. *D. glandulosa* L.B. Sm. & Reitz	1	y	Data Deficient (DD)
77. *D. goehringii* Rauh	1	n	Data Deficient (DD)
78. *D. granmogulensis* Rauh	2	n	Data Deficient (DD)
79. *D. lagoensis* Mez	11	y	Least Concern (LC)
80. *D. leptostachya* Baker	3	n	Least Concern (LC)
81. *D. linearifolia* Baker	2	n	Data Deficient (DD)
82. *D. macedoi* L.B. Sm.	14	y	Vulnerable (VU)
83. *D. macropoda* L.B. Sm.	1	n	Data Deficient (DD)
84. *D. marnier-lapostollei* L.B. Sm.	2	n	Critically Endangered (CR)
85. *D. mello-barretoi* L.B. Sm.	3	y	Vulnerable (VU)
86. *D. minarum* Mez	27	y	Least Concern (LC)

Table 1 continued

Taxon	No. of records	Occurrence within parks	IUCN Category
87. *D. monticola* L.B. Sm. & Reitz	1	n	Not Evaluated (NE)
88. *D. orobanchoides* Mez	1	n	Data Deficient (DD)
89. *D. pectinata* L.B. Sm. & Reitz	2	n	Critically Endangered (CR)
90. *D. princeps* Lem.	1	n	Data Deficient (DD)
91. *D. rariflora* Schultes f.	9	y	Vulnerable (VU)
92. *D. remotiflora* Otto & A. Dietr.	3	n	Vulnerable (VU)
93. *D. saxatilis* Mez	52	y	Least Concern (LC)
94. *D. schwackeana* Mez	3	n	Endangered (EN)
95. *D. simulans* L.B. Sm.	4	y	Endangered (EN)
96. *D. sordida* Baker	28	y	Endangered (EN)
97. *D.* sp. 1.	17	n	Not Evaluated (NE)
98. *D.* sp. 2.	2	y	Not Evaluated (NE)
99. *D.* sp. 3.	2	y	Not Evaluated (NE)
100. *D.* sp. 4.	1	n	Not Evaluated (NE)
101. *D.* sp. 5.	29	n	Not Evaluated (NE)
102. *D. spinulosa* L.B. Sm. & Reitz	1	n	Data Deficient (DD)
103. *D. tenebrosa* Leme & H. Luther	2	n	Data Deficient (DD)
104. *D. trichostachya* Baker	5	y	Endangered (EN)
105. *D. tuberosa* (Vell.) Beer	4	n	Not Evaluated (NE)
106. *D. ursina* L.B. Sm.	13	y	Critically Endangered (CR)
107. *D. warmingii* Mez	1	n	Data Deficient (DD)
108. *D. weddelliana* Baker	2	n	Data Deficient (DD)
109. ***Edmundoa lindenii*** var. ***rosea*** (E. Morren) Leme	2	n	Vulnerable (VU)
110. ***Encholirium belemii*** L.B. Sm. &Read	1	n	Data Deficient (DD)
111. *E. biflorum* (Mez) Forzza	4	n	Endangered (EN)
112. *E. bradeanum* L.B. Sm.	1	n	Data Deficient (DD)
113. *E. gracile* L.B. Sm.	1	n	Critically Endangered (CR)
114. *E. heloisae* (L.B. Sm.) Forzza & Wand.	39	y	Vulnerable (VU)
115. *E. horridum* L.B. Sm.	1	n	Critically Endangered (CR)
116. *E. irwinii* L.B. Sm.	10	y	Vulnerable (VU)
117. *E. longiflorum* Leme	2	n	Critically Endangered (CR)
118. *E. luxor* L.B. Sm. & Read	8	n	Critically Endangered (CR)
119. *E. magalhaesii* L.B. Sm.	25	y	Vulnerable (VU)
120. *E. pedicellatum* (Mez) Rauh	4	n	Critically Endangered (CR)
121. *E. reflexum* Forzza & Wand.	4	n	Vulnerable (VU)
122. *E. scrutor* (L.B. Sm.) Rauh	7	n	Endangered (EN)
123. *E. subsecundum* (Baker) Mez	69	y	Vulnerable (VU)
124. *E. vogelii* Rauh	5	y	Vulnerable (VU)
125. ***Fernseea itatiaiae*** (Wawra) Baker	4	y	Critically Endangered (CR)
126. ***Hohenbergia augusta*** (Vell.) E. Morren	1	n	Data Deficient (DD)
127. *H. catingae* Ule	2	n	Vulnerable (VU)
128. *H. pabstii* L.B. Sm. & Read	1	n	Vulnerable (VU)
129. *H. ramageana* Mez	2	n	Vulnerable (VU)
130. ***Neoglaziovia variegata*** (Arruda) Mez	16	y	Least Concern (LC)
131. ***Neoregelia bahiana*** (Ule) L.B. Sm.	40	y	Least Concern (LC)
132. *N. brigadeirensis* Paula & Leme	2	y*	Vulnerable (VU)
133. *N. brownii* Leme	4	y	Vulnerable (VU)
134. *N. chlorosticta* (Baker) L.B. Sm.	1	y	Data Deficient (DD)
135. *N. cyanea* (Beer) L.B. Sm.	2	n	Data Deficient (DD)
136. *N. farinosa* (Ule) L.B. Sm.	1	y	Data Deficient (DD)
137. *N. ibitipocensis* (Leme) Leme	3	y	Vulnerable (VU)
138. *N. leprosa* L.B. Sm.	1	n	Data Deficient (DD)
139. *N. lymaniana* R. Braga & Sucre	4	y	Vulnerable (VU)

Table 1 continued

Taxon	No. of records	Occurrence within parks	IUCN Category
140. *N. oligantha* L.B. Sm.	1	y*	Data Deficient (DD)
141. *N. sarmentosa* (Regel) L.B. Sm.	5	y	Least Concern (LC)
142. *N. simulans* L.B. Sm.	1	y	Vulnerable (VU)
143. ***Nidularium antoineanum*** Wawra	8	y	Least Concern (LC)
144. *N. azureum* (L.B. Sm.) Leme	2	n	Critically Endangered (CR)
145. *N. bicolor* (E. Pereira) Leme	9	y	Vulnerable (VU)
146. *N. ferdinando-coburgii* Wawra	4	y	Vulnerable (VU)
147. *N. linehamii* Leme	1	y	Critically Endangered (CR)
148. *N. longiflorum* Ule	3	y	Vulnerable (VU)
149. *N. marigoi* Leme	9	y	Least Concern (LC)
150. *N. purpureum* Beer	1	n	Data Deficient (DD)
151. *N. meeanum* Leme	1	n	Data Deficient (DD)
152. *N. rutilans* E. Morren	2	y	Endangered (EN)
153. ***Orthophytum benzingii*** Leme & H. Luther	1	n	Endangered (EN)
154. *O. compactum* L.B. Sm.	4	n	Vulnerable (VU)
155.1. *O. disjunctum* L.B. Sm. var. *disjunctum*	3	n	Not Evaluated (NE)
155.2. *O. disjunctum* var. *angustobracteatum* Rauh	1	n	Data Deficient (DD)
155.3. *O. disjunctum* var. *variegatum* Rauh	1	n	Data Deficient (DD)
155.4. *O. disjunctum* var. *viridiflorum* Rauh	1	n	Data Deficient (DD)
156. *O. duartei* L.B. Sm.	1	n	Data Deficient (DD)
157. *O. eddie-estevesii* Leme	1	n	Endangered (EN)
158. *O. estevesii* (Rauh) Leme	1	n	Data Deficient (DD)
159. *O. foliosum* L.B. Sm.	1	n	Vulnerable (VU)
160. *O. glabrum* (Mez) Mez	7	n	Vulnerable (VU)
161. *O. grossiorum* Leme & Paula	1	n	Vulnerable (VU)
162. *O. gurkenii* Hutchison	1	n	Critically Endangered (CR)
163. *O. horridum* Leme	1	n	Endangered (EN)
164. *O. humile* L.B. Sm.	3	y	Vulnerable (VU)
165. *O. itambense* Versieux & Leme	1	y	Critically Endangered (CR)
166. *O. leprosum* (Mez) Mez	10	n	Vulnerable (VU)
167. *O. lucidum* Leme & H. Luther	2	n	Endangered (EN)
168. *O. magalhaesii* L.B. Sm.	4	n	Vulnerable (VU)
169. *O. maracasense* L.B. Sm.	3	n	Vulnerable (VU)
170. *O. mello-barretoi* L.B. Sm.	32	y	Vulnerable (VU)
171. *O. supthutii* E. Gross & Barthlott	3	n	Critically Endangered (CR)
172. ***Pepinia bradei*** (Markgr.) G.S. Varad. & Gilmartin	3	y	Vulnerable (VU)
173. ***Pitcairnia carinata***Mez	9	y	Least Concern (LC)
174. *P. curvidens* L.B. Sm. & Read	5	y	Vulnerable (VU)
175. *P. decidua* L.B. Sm.	9	y	Vulnerable (VU)
176.1. *P. flammea* Lindl. var. *flammea*	25	y	Least Concern (LC)
176.2. *P. flammea* var. *floccosa* L. B. Sm.	6	y	Least Concern (LC)
176.3. *P. flammea* var. *glabrior* L.B. Sm.	4	y	Least Concern (LC)
176.4. *P. flammea* var. *macropoda* L.B. Sm. & Reitz	4	n	Endangered (EN)
177. *P. lanuginosa* Ruiz & Pav.	13	y	Least Concern (LC)
178.1. ***Portea petropolitana*** (Wawra) Mez var.***petropolitana***	7	y	Least Concern (LC)
178.2. *P. petropolitana* var. *noettigii* (Wawra) L.B. Sm.	4	y	Vulnerable (VU)
179. *P. silveirae* Mez	8	y	Least Concern (LC)

Table 1 continued

Taxon	No. of records	Occurrence within parks	IUCN Category
180. ***Pseudananas sagenarius*** (Arruda) Camargo	13	y	Least Concern (LC)
181. ***Quesnelia arvensis*** (Vell.) Mez	1	y	Data Deficient (DD)
182. *Q. augusto-coburgii* Wawra	4	y	Vulnerable (VU)
183. *Q. indecora* Mez	18	y	Least Concern (LC)
184. *Q. kautskyi* C.M. Vieira	7	y	Vulnerable (VU)
185. *Q. liboniana* (De Jonghe) Mez	3	y	Least Concern (LC)
186. *Q. quesneliana* (Brongn.) L.B. Sm.	3	n	Not Evaluated (NE)
187. *Q. strobilispica* Wawra	7	y	Least Concern (LC)
188. ***Racinaea aerisincola*** (Mez) M.A. Spencer & L.B. Sm.	6	y	Least Concern (LC)
189. ***Tillandsia arhiza*** Mez	1	y	Least Concern (LC)
190. *T. chapeuensis* Rauh	1	y	Not Evaluated (NE)
191. *T. copynii* Gouda	2	n	Data Deficient (DD)
192. *T. gardneri* Lindl.	46	y	Least Concern (LC)
193. *T. geminiflora* Brongn.	42	y	Least Concern (LC)
194. *T. globosa* Wawra	6	n	Least Concern (LC)
195. *T. graomogolensis* Silveira	7	y	Least Concern (LC)
196. *T. horstii* Rauh	1	n	Data Deficient (DD)
197. *T. leonamiana* E. Pereira	1	n	Data Deficient (DD)
198. *T. loliacea* Mart. ex Schult. & Schult. f.	20	y	Least Concern (LC)
199. *T. mallemontii* Glaziou ex Mez	1	n	Least Concern (LC)
200. *T. parvispica* Baker	5	y	Least Concern (LC)
201. *T. pohliana* Mez	19	y	Least Concern (LC)
202. *T. polystachia* (L.) L.	12	n	Least Concern (LC)
203. *T. pruinosa* Sw.	3	n	Data Deficient (DD)
204. *T. recurvata* (L.) L.	82	y	Least Concern (LC)
205. *T.* sp. 1.	1	n	Not Evaluated (NE)
206. *T.* aff. *sprengeliana* Klotzsch ex Mez	1	n	Not Evaluated (NE)
207. *T. streptocarpa* Baker	45	y	Least Concern (LC)
208. *T. stricta* Sol.	115	y	Least Concern (LC)
209.1. *T. tenuifolia* L. var. *tenuifolia*	38	y	Least Concern (LC)
209.2. *T. tenuifolia* var. *surinamensis* (Mez) L.B. Sm.	7	y	Least Concern (LC)
209.3. *T. tenuifolia* var. *vaginata* (Wawra) L. B. Sm.	18	y	Least Concern (LC)
210. *T. tricholepis* Baker	8	y	Least Concern (LC)
211. *T. usneoides* (L.) L.	31	y	Least Concern (LC)
212. ***Vriesea arachnoidea*** And. Costa	2	y	Endangered (EN)
213. *V. atropurpurea* Silveira	4	y	Critically Endangered (CR)
214. *V. billbergioides* E. Morren ex Mez	6	y	Least Concern (LC)
215. *V. bituminosa* Wawra	8	y	Least Concern (LC)
216. *V. cacuminis* L.B. Sm.	6	y*	Vulnerable (VU)
217. *V. carinata* Wawra	3	y	Least Concern (LC)
218. *V. clausseniana* (Baker) Mez	21	y	Vulnerable (VU)
219. *V. crassa* Mez	14	y	Vulnerable (VU)
220. *V. densiflora* Mez	3	y	Endangered (EN)
221. *V. diamantinensis* Leme	6	n	Vulnerable (VU)
222. *V. ensiformis* (Vell.) Beer	14	y	Least Concern (LC)
223.1. *V. friburgensis* Mez var. *friburgensis*	22	y	Least Concern (LC)
223.2. *V. friburgensis* var. *tucumanensis* (Mez) L.B. Sm.	1	n	Data Deficient (DD)
224. *V. gigantea* Gaudich.	1	y	Vulnerable (VU)

Table 1 continued

Taxon	No. of records	Occurrence within parks	IUCN Category
225. *V. gradata* (Baker) Mez	9	y	Least Concern (LC)
226. *V. guttata* Linden & André	6	y	Least Concern (LC)
227. *V. heterostachys* (Baker) L.B. Sm.	11	y	Least Concern (LC)
228. *V.* aff. *hieroglyphica* (Carrière) E. Morren	1	n	Not Evaluated (NE)
229. *V. hoehneana* L.B. Sm.	2	y	Data Deficient (DD)
230. *V. itatiaiae* Wawra	1	n	Endangered (EN)
231. *V. jonghei* (K. Koch) E. Morren	1	n	Not Evaluated (NE)
232. *V. longicaulis* (Baker) Mez	12	y	Least Concern (LC)
233. *V. longistaminea* Paula & Leme	2	n	Vulnerable (VU)
234. *V. lubbersii* (Baker) E. Morren ex Mez	2	y	Least Concern (LC)
235. *V. minarum* L.B. Smith	36	y	Endangered (EN)
236. *V. minor* (L.B. Sm.) Leme	25	y	Least Concern (LC)
237. *V. modesta* Mez	1	n	Data Deficient (DD)
238. *V. monacorum* L.B. Sm.	4	y	Endangered (EN)
239. *V. morrenii* Wawra	2	y	Endangered (EN)
240. *V. nanuzae* Leme	1	n	Endangered (EN)
241. *V. neoglutinosa* Mez	1	n	Data Deficient (DD)
242. *V. oligantha* (Baker) Mez	55	y	Least Concern (LC)
243.1. *V. paraibica* Wawra var. *paraibica*	3	n	Data Deficient (DD)
243.2. *V. paraibica* var. *interrogatoria* (L.B. Sm.) And. Costa	3	n	Vulnerable (VU)
244. *V. pauperrima* E. Pereira	3	y	Least Concern (LC)
245. *V. pardalina* Mez	6	y	Least Concern (LC)
246. *V. penduliflora* L.B. Sm.	1	y	Vulnerable (VU)
247. *V. procera* (Mart. ex Schult. & Schult. f.) Wittm.	5	y	Least Concern (LC)
248. *V. racinae* L.B. Sm.	1	y	Data Deficient (DD)
249. *V. rafaelii* Leme	2	n	Critically Endangered (CR)
250. *V. regnellii* Mez	1	n	Data Deficient (DD)
251. *V. ruschii* subsp. *leonii* Leme	6	y	Least Concern (LC)
252. *V. sazimae* Leme	1	n	Data Deficient (DD)
253. *V. saxicola* L.B. Sm.	3	n	Endangered (EN)
254. *V. scalaris* E. Morren	3	y	Least Concern (LC)
255. *V. sceptrum* Mez	5	n	Least Concern (LC)
256. *V. schwackeana* Mez	4	y	Vulnerable (VU)
257. *V. segadas-viannae* L.B. Sm.	2	n	Data Deficient (DD)
258. *V. simulans* Leme	1	n	Vulnerable (VU)
259. *V.* sp. 1.	3	y	Not Evaluated (NE)
260. *V. stricta* L.B. Sm.	11	y	Vulnerable (VU)
261. *V. vagans* (L.B. Sm.) L.B. Sm.	5	y	Least Concern (LC)
262. ***Wittrockia cyathiformis*** (Vell.) Leme	4	n	Least Concern (LC)
263. *W. gigantea* (Baker) Leme	10	y	Least Concern (LC)
264. *W. tenuisepala* (Leme) Leme	2	n	Data Deficient (DD)
265. *W.* sp. 1.	1	y	Not Evaluated (NE)

Different genera are separated by bold face. y = occur in protected area(s), y* = restricted and only known to occur in one protected area, n = do not occur in any protected area

Floristic inventories concentrated in small areas have produced significant contributions to the knowledge of the Brazilian flora (Prance 2001; Giulietti et al. 2005). We observed that the existence of protected areas or reserves raise many grid cell collection totals, and these numbers are higher if such areas have undergoing detailed floristic work (e.g. Flora da Serra do Cipó, grid cell F8). Decreased collections toward northeastern MG (e.g. cells E9, E10, B10, B11), may be related to the lower number of protected areas, or to the highly fragmented original vegetation (cf. IEF-MG 1994), rather than to unsuitable natural environmental conditions for Bromeliaceae occurrence. Greater collecting efforts within parks/reserves were also observed by Calvente et al. 2005 while working with the Cactaceae of Rio de Janeiro. Thus we conclude that Brazilian botanists are becoming more highly dependent on officially protected areas due to the lack of original vegetation outside of these areas, or due to poor access to private lands. Greater efforts are needed to establish more preserved areas, and to develop a more efficient system of permitting to allow for needed scientific collecting and study in these parks and reserves.

Uneven sampling can bias or influence floristic analyses, but the data presented here and our personal observations indicate that within the savanna and caatinga the Bromeliaceae tend to be rarer and have lower species diversity than in the Atlantic forest. Rizzini (1997) observed that the epiphytic life form is uncommon for plants in the savanna, and that is certainly reflected in Bromeliaceae diversity in western MG. The greater richness of epiphytic Bromeliaceae in eastern MG Atlantic forest is concordant with Gentry and Dodson (1987) observation that epiphytes are most diverse in wet, middle elevation, rich-soil, tropical American forests. Reitz (1983) observed in Santa Catarina state a drastic decrease in the total number of Bromeliaceae species while going from east to west and attributed this pattern to the decreasing inland temperature. Lower temperatures, particularly frost, were also recognized as a factor influencing Bromeliaceae species richness in Bolivia (Kessler 2002). In MG other climatic factors, such as the distribution of rain fall, seems to be more important than temperature in influencing Bromeliaceae taxa occurrence in the eastern and western sides of the state, and also toward the north portion of the Espinhaço range. As shown by Harley (1995) rainfall regime changes in the Espinhaço, becoming progressively sparser, the dry season is longer, and temperatures are generally greater northward. Bromeliaceae diversity is known to peak in humid montane forests (Ibisch 1996 apud Kessler 2002). In MG, reduced humidity could affect Bromeliaceae distribution patterns since in the cerrado and caatinga few genera, usually terrestrial, are observed (e.g. *Aechmea, Ananas, Bromelia, Dyckia, Neoglaziovia* and *Pseudananas*).

We identify as priorities for future scientific research the southern portion of the state, as well as the Jequitinhonha, Mucuri, and Doce rivers drainage basin (e.g. B10, B11, C11, D9, D11, E9, E10, F10) all being under collected areas that should potentially present much higher Bromeliaceae diversity. The northwestern portion (A5, B4, B5, B6, C4, C5, C6, C7, D4, D5, D6) and the Triângulo Mineiro region (E1, E2, E3, F1, F2, F3) are also relevant for future floristic surveys with the family.

Bromeliaceae habitat and life form

Of the total number (283) of Bromeliaceae species known from MG, 97 (34%) are exclusive of the Atlantic forest, 65 (23%) of the campo rupestre, and 32 (11%) can be found in these both habitats. Thirteen taxa (4.6%) are exclusive of the cerrado, and twelve (4.2%) inhabit both cerrado and campo rupestre (Fig. 4). Habitats combinations involving the caatinga, Atlantic forest, cerrado, high altitude grasslands, and campo rupestre are less frequent and vary from one to five taxa (Fig. 4).

The more representative occurrence of Bromeliaceae in the Atlantic forest is concordant with the extensive diversification of the family in eastern Brazil, especially

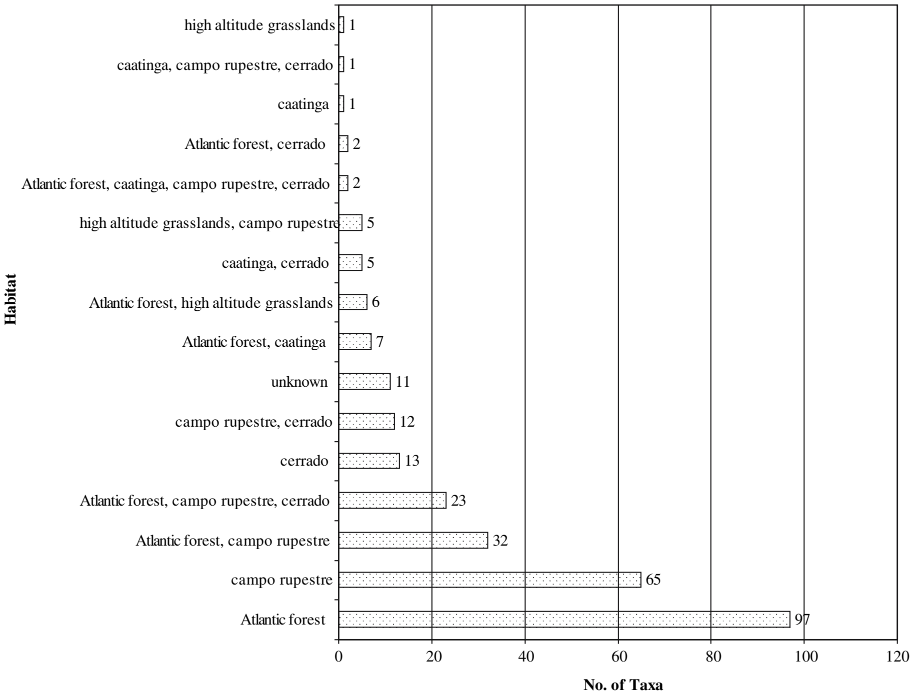

Fig. 4 Total number of Minas Gerais Bromeliaceae taxa in different habitats

for subfamily Bromelioideae (Smith 1934; Smith and Downs 1974). Many genera are endemic of this biome (Benzing 2000) and will occur in eastern MG reflecting the biogeographycal continuity. In fact, 19 of the 27 genera occurring in MG belong to subfamily Bromelioideae. Although seemingly contradictory, the Atlantic forest shares taxa with caatinga (e.g. *Alcantarea, Orthophytum*), but these are lithophytic taxa, that even while growing inside the Atlantic forest domain are exposed to totally different edaphic and microclimatic conditions.

Traditionally, the campo rupestre vegetation has been closely associated with the cerrado domain. However the data presented here shows that a greater number of Bromeliaceae taxa are shared between Atlantic forest and campo rupestre than between campo rupestre and cerrado (Fig. 4). It should be emphasized, however, that an usual view of the campo rupestre vegetation of the Espinhaço includes, as part of this habitat, the gallery forests and forest "islands" known as *capões*, which occur scattered among the grassland, and this seems to be the key to the floristic connection between the Bromeliaceae flora of the Atlantic forest and campo rupestre of the southern portion of the Espinhaço.

Most of the taxa (55%) in MG exhibit terrestrial and/or saxicolous life form. Next are those that are either ephyphytic, saxicolous and/or terrestrial (22%), followed by obligatory epiphytic (20%). The remaining 3% have unknown life forms. The predominant terrestrial/saxicolous life form reflects the existence of entire genera in each of the three subfamilies that grow only in these circumstances (e.g. *Dyckia, Alcantarea, Orthophytum*). It is notable that the open areas, characteristic of campo rupestre and cerrado are probably more conducive for the establishment of terrestrial/saxicolous bromeliad species due to the high degree of outcropping. However, even within the Atlantic forest domain there are genera (i.e. *Cryptanthus, Orthophytum*) totally restricted to rock outcrops or to the understory soils.

Grid cells clustering

To reduce uneven sampling, we used only those grid cells that presented at least 10 Bromeliaceae vouchers. Figure 5 presents a dendrogram based on 254 Bromeliaceae taxa, distributed among 28 of the 74 grid cells. The dendrogram allowed us to identify two sets of areas, subdivided into seven smaller subsets. The first set is the largest, and is subdivided into five subsets, characterizing an area of similar climatic and ecological features mainly composed by grid cells located along Atlantic forest, campo rupestre, and cerrado. The second subset includes areas of the northern portion of MG and includes subsets number six and seven, mainly covered by caatinga, campo rupestre and cerrado. We observed that the Bromeliaceae flora of the Cadeia do Espinhaço (partially represented within subset 3) is more related to the flora of southeastern MG (subset 2), which is covered by Atlantic forest. The southernmost area of the Espinhaço also corresponds to the inland western distribution limit for many characteristically Atlantic forest taxa (e.g. *Aechmea lamarchei, Quesnelia strobilispica, Vriesea pardalina*), that usually use the gallery forests as corridors for dispersion, enabling them to reach isolated forested areas inside the campo rupestre. On the other hand, the northernmost portion of the Espinhaço (subsets 5, 6, 7) is more closely related to cerrado or caatinga areas. Climatic factor seems to be the key to understand those connections, and increased sampling would likely reveal important, new information regarding this. Cell C10 appears isolated from subsets number 6 and 7. Indeed C10 presents a strong vegetation transition, hosting a peculiar mix of taxa of Atlantic forest, caatinga, and cerrado biomes. Our results show a low similarity among all the grid cells, which varied from 2 to 40%. Probably the high number of endemic species and those with very narrow ranges contribute to these low values. Simon and Proença (2000) obtained similar results while studying the genus *Mimosa* (Leguminosae). They observed that grid cells with higher number of collections were frequently close to each other, as neighbors, and occurred in mountainous areas, where endemic and narrowly distributed species were frequent, generating a low similarity among areas, regardless of their geographical proximity. This pattern repeats here for the Bromeliaceae. As an example, a similarity of only 31% was found between cells F8 and E8, in Cadeia do Espinhaço.

Conservation of Minas Gerais Bromeliaceae taxa

Of the 283 taxa of Bromeliaceae that occur in MG, 118 are considered threatened (critically endangered, endangered or vulnerable). One hundred taxa have a conservation status of least concern, 44 lack sufficient data, and 21 were not evaluated due to their doubtful taxonomic status (Table 2). Taxa that were only recently recorded for MG, with probably partially known geographic distribution or represented by few specimens from relatively under collected areas, are among those 44 taxa with deficient data (Table 2).

Half of the threatened taxa (59) belong to the subfamily Bromelioideae (12 critically endangered, 11 endangered, 36 vulnerable). Bromelioideae was followed by

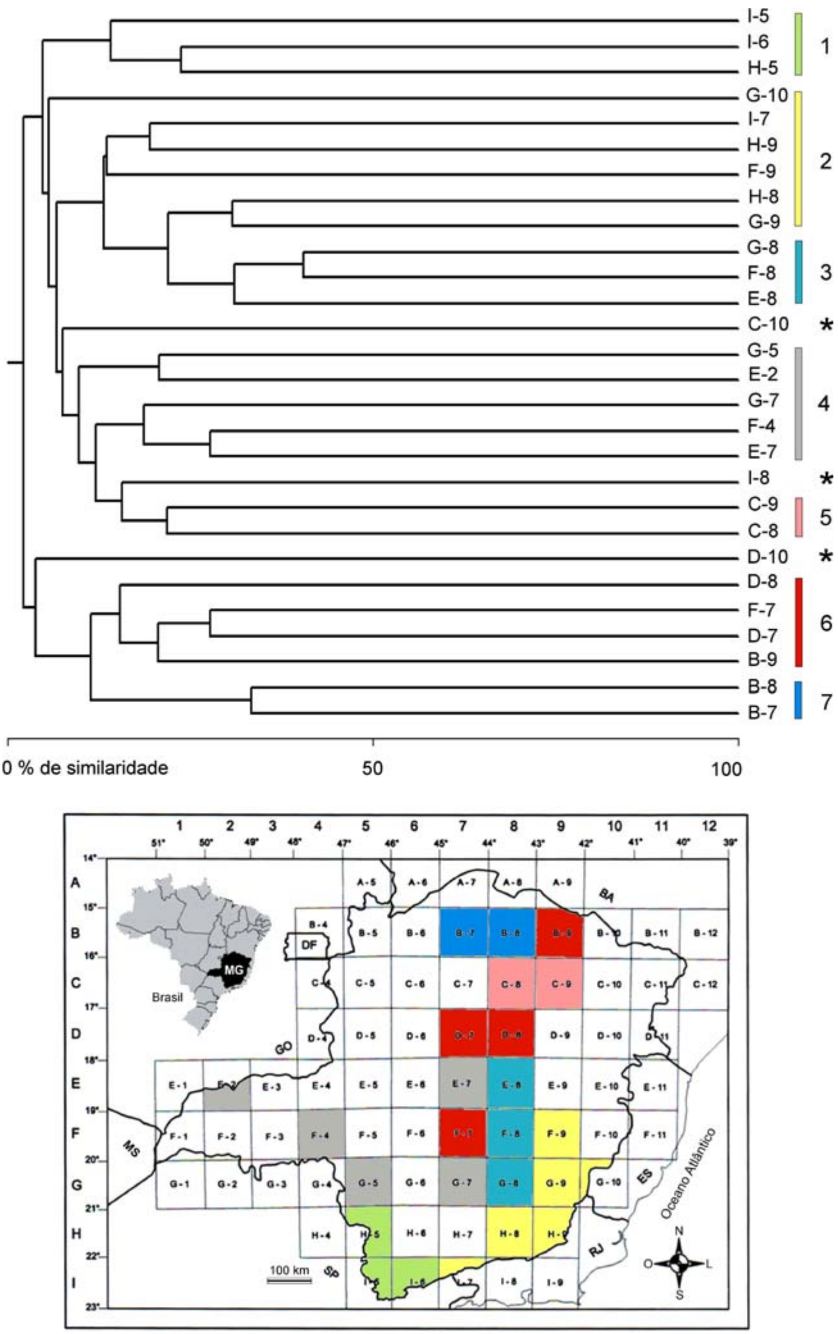

Fig. 5 Floristic similarities (Jaccard) among 28 grid cells based on Bromeliaceae taxa

Pitcairnioideae subfamily, with 34 taxa threatened, and by Tillandsioideae with 25 threatened taxa (Table 2). In Bromelioideae, the genus*Orthophytum* has nine vulnerable species, most of them endemic of inselbergs in northeastern MG.

Table 2 IUCN categories totals for Minas Gerais Bromeliaceae taxa in each subfamily

Subfamily	Threatened			Least Concern	Data Deficient	Not Evaluated
	Critically Endangered	Endangered	Vulnerable			
Bromelioideae	12	11	36	51	16	5
Pitcairnioideae	8	8	18	10	14	8
Tillandsioideae	3	10	12	39	14	8
Total	23	29	66	100	44	21

A similar situation is observed for many *Aechmea, Hohenbergia*, and *Neoregelia* species characteristic of the Atlantic forest, with taxa occurring within few forest fragments or, in some cases, restricted to only one protected area. The situation for *Cryptanthus* species is the most critical with five of its six species critically endangered, mainly because they form very small populations with reduced ranges in rocky field. For example, *Cryptanthus warasii* is only known from the type collection, whereas *C. leopoldo-horstii*, only from two populations, both at road side localities.

The subfamily Pitcairnioideae has eight taxa critically endangered, eight endangered, and 18 vulnerable (Table 2). Many Pitcairnioideae species presents small appendaged seeds, unable to disperse long distances, thus favoring narrowly endemic species (Holst 1994). The genus *Dyckia* deserves special attention because of the elevate number of species, many of them poorly known, and usually with overlapping diagnostic features, and frequently represented in herbaria by only a single leaf and part of the inflorescence. In addition, species from the Quadrilátero Ferrífero (e.g. *Dyckia densiflora*, *D. elata*, *D. schwackeana, D. simulans*) have very restricted distributions that are currently exposed to habitat destruction by gold and iron ore mining.

The subfamily Tillandsioideae contains three critically endangered, 10 endangered, 12 vulnerable taxa. This subfamily holds the fewest critically endangered species, and the highest percentage of least concern taxa (Table 2). Plumose appendaged seeds allow a broader dispersion for many species of *Vriesea*. However, some species like *Alcantarea hatschbachii* and *Vriesea segadas-viannae*, both endemic to the Espinhaço and only known from two collections, exemplify that even inside well collected areas there are overlooked species that deserve attention regarding conservation. Special attention should be given to those species that form large/colorful rosettes, such as *Vriesea atropurpurea, V. bituminosa, V. crassa, V. minor* and *Alcantarea* spp., because these are the ones preferred by landscape designers for use in private gardens and are frequently extracted from the wild for this type of commercial use. Dry inflorescences and fruits of *Vriesea diamantinensis, V. nanuzae* and *V. simulans* are also locally sold in dry flowers bouquets, compromising seed production, and thus dispersion. Study is needed to evaluate the effects of this kind of extractive activity on population structure. For *Tillandsia* species the conservation statuses are less critical, because many of its species have a broad distribution within the state and, in many cases, are indigenous to other Neotropical countries.

The published red list for the flora of MG (Mendonça and Lins 2000) lists 27 threatened Bromeliaceae species (19 endangered and 8 vulnerable). The numbers reported in this study are greater due to the current, better knowledge about Bromeliaceae distribution. However, as more data are generated, especially for poorly known taxa, and habitat disturbance broadens, it is expected that the frequency-level in status categories presented here will change. According to Martinelli (2000), 74% of Bromeliaceae species within the Brazilian Atlantic forest are endemic. This vegetation is considered the diversity center of subfamily Bromelioideae (Smith and Downs 1974; Benzing 2000) and also for many other plant groups (Mori et al. 1981). To ensure the preservation of this biodiversity, creation of more protected areas within the Atlantic forest should be encouraged, as this biome has been reduced to 4 % of its original coverage area within MG (Costa et al. 1998). Similar actions should apply to the cerrado, also considered to be one of the richest floristic regions in the world, and treated as the second Brazilian biodiversity hotspot with high levels of endemism (Mittermeier et al. 2000). Currently, the cerrado is reduced to 25% of its original area in MG (Mendonça and Lins 2000) and is suffering from increasing human pressure, mainly from the expansion of soy bean plantations. This destruction of cerrado vegetation will likely include loss of the few recorded populations of *Billbergia meyeri* and *Bromelia glaziovii*.

The campo rupestre, which has long provided natural grazing areas for livestock, has special relevancy for endemic lithophytic taxa, such as the genera *Cryptanthus, Dyckia, Encholirium*, and *Orthophytum* (Versieux and Wendt 2006). The long-held belief that the fire does not compromise grassland vegetation because many of its species are adapted to this disturbance, does not seem to be true for many rocky field bromeliads. During our field work we have returned to several places where fires were so intense that entire populations disappeared within a few years, regardless of their saxicolous life form.

Rapini et al. (2002) observed that many taxa endemic to the Espinhaço are rare in herbaria collections due to limited blooming periods for many species, and uneven collecting efforts. These authors considered that few taxa would be severely threatened, but many would be considered vulnerable, due to the destruction of their limited habitat. Our results seem to be concordant with those of Rapini et al. (2002), since most Bromeliaceae considered threatened here are grouped in the vulnerable category (Table 2). Under collecting can bias results on species distributions. However, we consider ongoing fire disturbance associated with urban development, road construction, and mining activities to be major hazards for small populations, and also an impediment in gaining improved knowledge of Bromeliaceae distributions in the Espinhaço. In regards to the Espinhaço, special attention should be directed to taxa endemic of the Quadrilátero Ferrífero because of the accelerated loss of habitats by urban growth and mining. Many mining companies create private reserves as a compensatory measure for the destructive mining activities. This practice, while commendable, should be carefully managed and monitored by environmental agencies so that these reserve plots are selected to better reflect the size and vegetation type that is being consumed by mine activity. For example, selecting an area of semi-deciduous forest for protection in compensation for *canga* destruction has no equivalent value because their biotic compositions are distinct. A conservation procedure that could be employed sometimes is to remove individuals of Bromeliaceae and transplant them from the mining area to a similar and protected place in the nearby or to botanic gardens. As shown by Cavallari et al. (2006), great part of the genetic difference of rare rupiculous species of *Encholirium* is found among individuals. Thus, every effort to preserve individuals and their populations are significant to conserve the whole genetic variation for some species.

Forty four percent (124 spp.) of Bromeliaceae taxa of MG do not occur inside any protected area (Table 1). Among these, 56 that are threatened (16 critically endangered, 17 endangered, 23 vulnerable), some are only known from roadside localities (e.g. *Aechmea bambusoides*) and others from areas adjacent to hydroelectricpower plant impoundments (e.g. *Aechmea bruegerii, A. purpureorosea*). Nine taxa are restricted to a single protected area (Table 1), not occurring outside their limits and requiring special measurements (i.e., environmental education, isolation of exposed populations) for their effective preservation. Camargos (2001) provided a map showing the distribution of all protected areas within MG that clearly indicates that the northeastern, northwestern and the extreme western (Triângulo Mineiro) regions are less protected. The northeastern portion of MG, particularly the Jequitinhonha river basin, is rich in Cactaceae (Taylor and Zappi 1991), new occurrences of Bromeliaceae (Versieux and Wendt 2006), and other saxicolous taxa characteristic of inselberg formations (Porembski et al. 1998), yet it is still poorly protected despite the advanced fragmentation process (Camargos 2001; IEF-MG 1994) and the threat to saxicolous taxa by the granite mining companies (Forzza et al. 2003). Although setting targets for protected areas is not a trivial task because biodiversity represents a continuum of ecological organization that can not be encapsulated in a single variable (Brooks et al. 2004), we considered that these areas in northeastern MG (i.e. Jequitinhonha and Mucuri rivers basins) should be given priority-status for Bromeliaceae conservation. For MG, Drummond et al. (2005) presented an atlas that mapped areas for biodiversity preservation, taking many groups of organisms (e.g. invertebrates, mammals) into account. Nevertheless, we reiterate here that strategies for Bromeliaceae conservation in grid cell F8 are urgent, due to the high level of endemism and species richness that are threatened by mining and deforestation.

Conclusions

This paper provides an updated analysis of Bromeliaceae distribution within MG state, using maps containing $1° \times 1°$ grid cells. A clear decrease in Bromeliaceae diversity is observed when going from the eastern to the western sides of the state. Within MG, we observed that areas covered by the Atlantic forest present greater bromeliad diversity than areas of caatinga, and cerrado vegetation. Also, the Atlantic forest vegetation shares species with the campo rupestre of the southernmost portion of the Cadeia do Espinhaço. The most diverse grid cells are located in elevated areas in the southern Espinhaço, or in the Serra da Mantiqueira, in the southeastern portion of the state. Low floristic similarities, favored by the very narrowly distributed and endemic taxa, were found between neighboring grid cells, even for areas located along the same mountain chain. Strategic taxonomic surveys and inventories are required for many grid cells that did not present any Bromeliaceae record, or that showed low values, particularly those located along the northeastern and extreme southern portions, where new records for the state are expected, since these areas are within the Atlantic forest domain. The Cadeia do Espinhaço is considered the most important area of endemism for Bromeliaceae, sheltering 62% of all the endemic taxa. From the 283 taxa of Bromeliaceae that occur within MG, 118 were considered threatened and 124 taxa do not occur inside any protected area. Many taxa are still poorly known and therefore categorized as data deficient or were not evaluated. Changes are expected to occur in this classification, as new population and distribution data become available because taxa considered to be narrowly endemic can present broader ranges. Immediate actions to protect the Bromeliaceae flora of the Quadrilátero Ferrífero in the southern portion of the Cadeia do Espinhaço are needed, since the area suffers with accelerated urban growth and mining activities.

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References

Benzing DH (2000) Bromeliaceae: profile of an adaptive radiation. Cambridge University Press, Cambridge

Brooks TM, Fonseca GAB, Rodrigues ASL (2004) Protected areas and species. Conserv Biol 18:616–618

Calvente AM, Freitas MF, Andreata RHP (2005) Listagem, distribuição geográfica e conservação das espécies de Cactaceae no estado do Rio de Janeiro. Rodriguésia 56:141–162

Camargos RMF (2001) Unidades de conservação em Minas Gerais: levantamento e discussão. Fundação Biodiversitas, Belo Horizonte

Cavallari MM, Forzza RC, Veasey EA, Zucchi MI, Oliveira GCX (2006) Genetic variation in three endangered species of*Encholirium* (Bromeliaceae) from Cadeia do Espinhaço, Brazil, detected using RAPD markers. Biodivers Conserv 15:4357–4373

Costa CMR, Herrmann G, Martins CS, Lins LV, Lamas IR (orgs.). (1998) Biodiversidade em Minas Gerais: um atlas para sua conservação, 1ª ed. Fundação Biodiversitas, Belo Horizonte

Dahlgren RMT, Clifford HT, Yeo PF (1985) The families of the Monocotyledons: structure, evolution and taxonomy. Springer-Verlag, Berlin

Drummond GM, Martins CS, Machado ABM, Sebaio FA, Antonini Y (orgs). (2005) Biodiversidade em Minas Gerais: um atlas para sua conservação, 2ª ed. Fundação Biodiversitas, Belo Horizonte

Forzza RC, Christianini AV, Wanderley MGL, Buzato S (2003) *Encholirium* (Pitcairnioideae – Bromeliaceae): conhecimento atual e sugestões para conservação. Vidalia 1:7–20

Gentry AH, Dodson CH (1987) Diversity and biogeography of Neotropical vascular epiphytes. Ann Mo Bot Gard 74:205–233

Giulietti AM, Menezes NL, Pirani JR, Meguro M, Wanderley MGL (1987) Flora da Serra do Cipó, Minas Gerais: caracterização e lista das espécies. Boletim de Botânica da Universidade de São Paulo 9:1–151

Giulietti AM, Harley RM, Queiroz LP, Wanderley MGL, Van Den Berg C (2005) Biodiversity and conservation of plants in Brazil. Conserv Biol 19:632–639

Givnish TJ, Millam KC, Evans TM, Hall JC, Pires JC, Berrie PE, Sytsma KJ (2004) Ancient vicariance or recent long-distance dispersal? Inferences about phylogeny and South American-African disjunctions in Rapateaceae and Bromeliaceae based on *ndh*F sequence data. Int J Plant Sci 165 (4 Suppl.):S35-S54

Harley RM (1995) Introduction. In: Stannard BL (ed), Flora of Pico das Almas, Chapada Diamantina, Bahia, Brazil. Royal Botanic Gardens, Kew, pp 1–40

Holmgren PK, Holmgren NK, Barnett LC (1990) Index Herbariorum Part 1 The Herbaria of the World, 8th edn. New York Botanical Garden Bronx, New York

Holst BK (1994) Checklist of Venezuelan Bromeliaceae with notes on species distribution by state and levels of endemism. Selbyana 15:132–149

IEF-MG - Instituto Estadual de Florestas de Minas Gerais (1994) Mapa de cobertura vegetal e uso do solo do Estado de Minas Gerais. IEF-MG, Belo Horizonte, Brasil

IUCN (2001) IUCN Red list categories and criteria: Version 3.1 IUCN Species Survival Commission. IUCN, Gland Switzerland and Cambridge, UK

Kessler M (2002) Species richness and ecophysiological types among Bolivian bromeliad communities. Biodivers Conserv 11:987–1010
Kress WJ, Heyer WR, Acevedo P, Coddington J, Cole D, Erwin TL, Meggers BJ, Pogue M, Thorington RW, Vari RP, Weitzman MJ, Weitzman SH (1998) Amazonian biodiversity: assessing conservation priorities with taxonomic data. Biodivers Conserv 7:1577–1587
Luther HE (2004) An alphabetical list of bromeliad binomials, 9th edn. The Bromeliad Society International, Inc., Orlando, Florida, USA
Martinelli G (1989) Campos de Altitude. Editora Index, Rio de Janeiro
Martinelli G (2000) The bromeliads of the Atlantic forest. Scientific American, March:86–93
Mendonça MP, Lins LV (orgs) (2000) Lista vermelha das espécies ameaçadas de extinção da flora de Minas Gerais. Fundação Biodiversitas e Fundação Zoo-Botânica de Belo Horizonte, Belo Horizonte
Mittermeier RA, Gil PR, Mittermeier CG (2000) Hotspots: earth's biologically richest and most endangered terrestrial ecorregions. Cemex, México
Mori SA, Boom BM, Prance GT (1981) Distribution patterns and conservation of eastern Brazilian coastal forest tree species. Brittonia 33:233–245
Morton JK (1972) Phytogeography of the West African mountains. In: Valentine DH (ed) Taxonomy, phytogeography and evolution, Academic Press, London, pp 221–236
Pirani JR, Giulietti AM, Mello-Silva R, Meguro M (1994) Checklist and patterns of geographic distribution of the vegetation of serra do Ambrósio, Minas Gerais, Brazil. Rev Bras Bot 17:133–147
Porembski S, Martinelli G, Ohlemüller R, Barthlott W (1998) Diversity and ecology of saxicolous vegetation mats on inselbergs in the brazilian atlantic rainforest. Divers Distrib 4:107–119
Prance GT (2001) Discovering the plant world. Taxon 50: 345–359
Rapini A, Mello-Silva R, Kawasaki ML (2002) Richness and endemism in Asclepiadoideae (Apocynaceae) from the Espinhaço range of Minas Gerais, Brazil – a consevationist view. Biodivers Conserv 11:1733–1746
Reitz R (1983) Bromeliáceas e a malária-bromélia endêmica, Herbário Barbosa Rodrigues, Itajaí, Santa Catarina, Brasil
Rizzini CT (1997) Tratado de fitogeografia do Brasil. Âmbito Cultural Edições, Rio de Janeiro
Safford HD (1999) Brazilian Páramos I. An introduction to the physical environment and vegetation of the campos de altitude. J Biogeogr 26:693–712
Serrato A, Ibarra-Manríquez G, Oyama K (2004) Biogeography and conservation of the genus *Ficus* (Moraceae) in Mexico. J Biogeogr 31:475–485
Simon MF, Proença C (2000) Phytogeographyc patterns of *Mimosa* (Mimosoideae, Leguminosae) in the savanna biome of Brazil: an indicator genus of high-altitude centers of endemism? Biol Conserv 96:279–296
Smith LB (1934) Geographical evidence on the lines of evolution in the Bromeliaceae. Botanische Jahrbücher für Systematic Pflanzengeschichte und Pflanzengeographie 66:446–468
Smith LB, Downs RJ (1974) Pitcairnioideae (Bromeliaceae) Flora Neotropica Monograph No 14 Part 1. Hafner Press, New York
Taylor NP, Zappi DC (1991) Cactaceae do vale do rio Jequitinhonha. Acta Bot Brasilica 5:63–69
Versieux LM, Wendt T (2006) Checklist of Bromeliaceae of Minas Gerais, Brazil, with notes on taxonomy and endemism. Selbyana 27:107–146
Wanderley MGL (1992) Estudos taxonômicos no gênero *Xyris* L. (Xyridaceae) da Serra do Cipó, Minas Gerais, Brasil. Ph.D thesis, Universidade de São Paulo, São Paulo