

# Distribution and conservation of *Paepalanthus* Mart. sect. *Diphyomene* Ruhland (Eriocaulaceae) in Neotropical savannas

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## ABSTRACT

*Paepalanthus* Mart. sect. *Diphyomene* Ruhland (Eriocaulaceae) is mainly diversified in the savannas of Central Brazil (Cerrado). This is an unusual pattern regarding the highest diversity of Eriocaulaceae in Southeastern Brazil (in the Espinhaço Range). Despite this interesting contrast, the geographic distribution of these species has yet to be explored. The present work aims to detail the geographic distribution of species of *Paepalanthus* sect. *Diphyomene* in order to discuss biogeographical patterns. The species are also categorized according

**KEY WORDS**  
Biogeography,  
Cerrado,  
Endemism,  
Extent of occurrence,  
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to their risk of extinction, based on the IUCN criteria, establishing their conservation status and implications for the conservation of the Cerrado domain. Distribution maps were constructed for each species based on geographical coordinates obtained in the field or from herbarium specimens. All eighteen species occur in the Cerrado domain, with sixteen species exclusive to it, whilst *Paepalanthus erectifolius* Silveira and *P. chiquitensis* Herzog also occur in the Caatinga and Amazonian domains, respectively. We hereby confirm that the center of diversity of the section is situated in Central Brazil, more precisely in the Chapada dos Veadeiros, where eight species occur. Thirteen species are restricted to a single locality, and are categorized as critically endangered. Four species are regionally restricted, two of them are vulnerable, one is endangered, and the other one is considered of least concern, together with *P. chiquitensis*, a widely distributed species. The extension of occurrence of each species is used as a basis for their assessed conservation status. Our results reinforce the importance of the preservation of the Cerrado as a whole. The distribution patterns in association with the conservation status revealed important areas for conservation of the Cerrado, and corroborate the importance of previously established areas for conserving biodiversity.

## RÉSUMÉ

*Distribution et conservation de Paepalanthus sect. Diphyomene (Eriocaulaceae) dans les savanes néotropicales.*

Les savanes du Brésil central (Cerrado) hébergent le centre de diversité du genre *Paepalanthus* Mart. sect. *Diphyomene* Ruhland (Eriocaulaceae). Ce modèle est inhabituel en comparaison du reste de la famille dont la plus grande diversité est concentrée au sud-est du Brésil dans la chaîne de l'Espinhaço. Malgré cette différence notable, la répartition des espèces de cette section n'a pas encore fait l'objet d'investigations détaillées. Afin de mieux la comprendre, notre travail a pour objectif d'étudier cette répartition afin d'en déduire des modèles biogéographiques. Les espèces ont été classées selon leur menace d'extinction, selon les catégories et critères de la Liste Rouge de l'UICN, afin de définir leurs statuts de conservation et analyser leur implication dans la stratégie de conservation du Cerrado. Des cartes de répartition ont été élaborées pour chaque espèce en utilisant des coordonnées géographiques obtenues sur le terrain ou à partir des informations figurant sur les spécimens d'herbier. Les dix-huit espèces se rencontrent dans le Cerrado et seize y sont exclusives. Les deux autres espèces, *Paepalanthus erectifolius* Silveira et *P. chiquitensis* Herzog se retrouvent aussi dans l'Amazonie pour la première et dans la Caatinga pour la seconde. Nos résultats confirment que le centre de diversité de cette section est le Brésil central, en particulier la Chapada dos Veadeiros où huit espèces sont présentes. Treize espèces sont limitées à une seule localité, et sont classées en danger critique d'extinction. Quatre autres ont une distribution régionale : deux sont vulnérables, une est en danger et la quatrième est en préoccupation mineure. La dernière espèce, *P. chiquitensis*, est très répandue et aussi classée en préoccupation mineure. L'extension d'occurrence de chaque espèce est en rapport direct avec leurs statuts de conservation, due à l'application des critères de l'UICN. Nos résultats renforcent l'importance de la préservation du Cerrado entier. Les patterns de distribution que nous proposons, en association avec le statut de conservation, ont mis en évidence des régions prioritaires pour la conservation du Cerrado. Ils corroborent aussi l'importance d'autres régions déjà établies comme prioritaires pour la conservation de la biodiversité en général.

**MOTS CLÉS**  
Biogéographie,  
Cerrado,  
endémisme,  
extension d'occurrence,  
liste rouge de l'UICN.

## INTRODUCTION

The original area covered by savannas in the Neotropics surpasses two million km<sup>2</sup>, being mainly distributed in Central Brazil, throughout the Cerrado domain. Beyond Brazil, the area occupied by savannas extends southward, into Paraguay, westward into Bolivia, and northward reaching Colombia and Venezuela (Joly *et al.* 1999; Pennington *et al.* 2006; Fiaschi & Pirani 2009). Differing from past claims (e.g., Rizzini 1963, 1971; Leitão-Filho 1992), the Cerrado revealed a highly diversified flora, comprising more than 10 000 angiosperm species, and being considered a hotspot for biodiversity conservation (Castro *et al.* 1999; Myers *et al.* 2000; Ratter *et al.* 2006; Fiaschi & Pirani 2009). This domain encompasses a mosaic of vegetational formations, varying from the predominant open grassy fields to the seasonally dry forests (Joly *et al.* 1999; Ratter *et al.* 2006; Fiaschi & Pirani 2009). However, despite the preponderance of herbaceous plants, the majority of the floristic and phytogeographic studies involving the Cerrado are focused on trees and shrubs (e.g., Rizzini 1971; Castro *et al.* 1999; Ratter *et al.* 2003; Ratter *et al.* 2006).

Eriocaulaceae are herbs easily distinguished by their capituliform inflorescence, which is a unique feature among Monocotyledons. The family diversity is concentrated in tropical savannas, in the Cerrado region, usually inhabiting open grass fields over 900 m above sea level. In the Neotropic, the family comprises 10 genera and *c.* 900 species. The main diversity centers are located in the rocky outcrops of the Espinhaço Range and in the Venezuelan Tepuis and adjacent savannas (Giulietti & Hensold 1990; Hensold 1991, 1999; Stützel 1998; Sano 2004; Parra *et al.* 2010; Trovó & Sano 2010, 2011; Trovó *et al.* 2013). *Paepalanthus* sect. *Diphyomene* Ruhland, as well as the other Eriocaulaceae, include many narrowly distributed species, usually restricted to a single locality or even a single mountaintop (Giulietti & Hensold 1990; Giulietti *et al.* 2005; Trovó & Sano 2010, 2011). However, the morphological and taxonomic diversity of *P.* sect. *Diphyomene* is not concentrated in the Brazilian and Venezuelan highlands, but in the savannas of South America, mainly in central Brazil.

This work intends to discuss the patterns of geographic distribution of *P.* sect. *Diphyomene* species. It is also intended to relate these patterns to previously described patterns of other angiosperms, giving special attention to the species distributed in the savannas of central Brazil, thus providing fundamental information to the conservation of one of the most rich and endangered regions in South America (Myers *et al.* 2000; Silva & Bates 2002; Fiaschi & Pirani 2009). In this context, the conservation *status* of each species is also established. Allied with the geographic distribution, it may develop to be a significant tool to ground conservation strategies for the Cerrado (Silva & Bates 2002; Pennington *et al.* 2006).

## MATERIAL AND METHODS

The dataset of *P.* sect. *Diphyomene* geographic distribution is based on herbarium collections deposited in the following herbaria (acronyms according to Thiers continuously updated): ALCB, B, BHC, BOCH, BR, C, CEPEC, CEN, CVRD, ESA, G, GFJP, HBG, HEPH, HRCB, HUEFS, IBGE, K, LE, M, OUPR, P, R, RB, S, SP, SPF, UB, UEC, UPS, W, WU. Specific literature, fieldwork, and data from virtual herbaria were used to complement the database.

Maps were constructed using ARCVIEW-GIS 3.2 (ESRI 1999) based on geographic coordinates extracted from the herbarium sheets. Locations of specimens lacking exact coordinates were estimated using Google Earth ([www.earth.google.com](http://www.earth.google.com)). The final dataset is available upon request from the first author. We adopted the domain classification proposed by Ab'Saber (1967), revised by Joly *et al.* (1999) and Fiaschi & Pirani (2009). The conservation *status* of each species was achieved using IUCN (2001) criteria.

## RESULTS AND DISCUSSION

The 18 species of *P.* sect. *Diphyomene* are restricted to South America (Fig. 1A). Seventeen are restricted to Brazil, while *P. chiquitensis* Her-

Table 1. — *Paepalanthus* sect. *Diphyomene* species and their respective geographic distribution (Brazilian states or countries\*), domain, habitat, and conservation status (criteria between parenthesis). Abbreviations: **AM**, Amazon domain; **CA**, Caatinga domain; **CE**, Cerrado domain; **BOL**, Bolivia; **COL**, Colombia; **VEN**, Venezuela; **CR**, critically endangered; **EN**, endangered; **LC**, least concern; **VU**, vulnerable.

Species	Distribution	Domain/Habitat	Conservation status
<i>P. acanthophyllus</i> Ruhland	GO, DF	CE; savanna & campo rupestre	VU (B1a, B1b, B2a)
<i>P. amoenus</i> (Bong.) Koern.	MG	CE; campo rupestre	EN (B1a, B1b, B2a)
<i>P. arcuatus</i> Trovó	MG	CE; campo rupestre	CR (B1a)
<i>P. brevis</i> Trovó	DF	CE; savanna	CR (B1a)
<i>P. chiquitensis</i> Herzog	AM, GO, MG, MT, MS, TO, RO; BOL*, COL*, VEN*	CE, AM; savanna, campo rupestre & lowland	LC
<i>P. cordatus</i> Ruhland	GO	CE; savanna & campo rupestre	CR (B1a, B1b, B2a)
<i>P. decussus</i> Koern.	MG	CE; campo rupestre	CR (B1a)
<i>P. erectifolius</i> Silveira	MG, BA	CE, CA; campo rupestre	LC
<i>P. flexuosus</i> Trovó	GO	CE; savanna	CR (B1a)
<i>P. koernickei</i> (Ruhland) Trovó	GO, DF	CE; savanna & campo rupestre	VU (B1a, B1b, B2a)
<i>P. linearis</i> Trovó	MG	CE; campo rupestre	CR (B1a)
<i>P. longiciliatus</i> Trovó	GO	CE; campo rupestre	CR (B1a, B1b, B2a)
<i>P. macer</i> Trovó	GO	CE; savanna & campo rupestre	CR (B1a, B1b, B2a)
<i>P. polycladus</i> Silveira	MG	CE; campo rupestre	CR (B1a, B1b, B2a)
<i>P. sericiscapus</i> Trovó	MG	CE; campo rupestre	CR (B1a)
<i>P. stellatus</i> Trovó	GO	CE; savanna	CR (B1a, B1b, B2a)
<i>P. urbanianus</i> Ruhland	GO	CE; savanna	CR (B1a, B1b, B2a)
<i>P. weddellianus</i> Koern.	GO	CE; savanna	CR (B1a)

zoc occurs in Bolivia, Brazil, Colombia and Venezuela. Species richness is higher in Goiás state with ten species, followed by Minas Gerais state with seven species. The diversity center is situated in the Chapada dos Veadeiros (Goiás), where eight species occur. All species occur in the Cerrado domain; *P. chiquitensis* also occurs in the Amazonian domain, and *Paepalanthus erectifolius* Silveira also occurs in the Caatinga domain. Thirteen species occur in campos rupestres (typical rocky outcrops), while ten species occur in typical savannas (cerrado *sensu stricto*) or open fields. Five species occur both in campos rupestres and open fields. *Paepalanthus erectifolius* and *P. chiquitensis* do not suffer risk of extinction. *Paepalanthus acanthophyllus* Ruhland and *Paepalanthus koernickei* (Ruhland) Trovó are considered vulnerable, *Paepalanthus amoenus* (Bong.) Koern. is considered endangered, while the remaining 13 species fit the critically endangered criteria. Detailed results are given in Table 1.

#### PATTERNS OF GEOGRAPHIC DISTRIBUTION

Based on the spatial distribution, the *P.* sect. *Diphyomene* species are disposed in the following three patterns, detailed below: I) widely distributed in South America; II) regionally restricted; and III) narrowly distributed. Species occurrence corresponding to patterns I and II are depicted in Figure 1 and pattern III is represented in Figure 2.

#### Pattern I

Species widely distributed in South America. This pattern has been recorded only for *P. chiquitensis* (Fig. 1B). This species distribution is highly coincident with the section distribution, except for the north and extreme southern portions of the Espinhaço Range. This is the only species distributed in the Amazon domain, occurring in open lowlands (200-400 m) in the southern portion of the Amazon Forest. In the Cerrado domain, the species occurs in campos rupestres, open fields and typical savannas. In Minas Gerais and Goiás, the

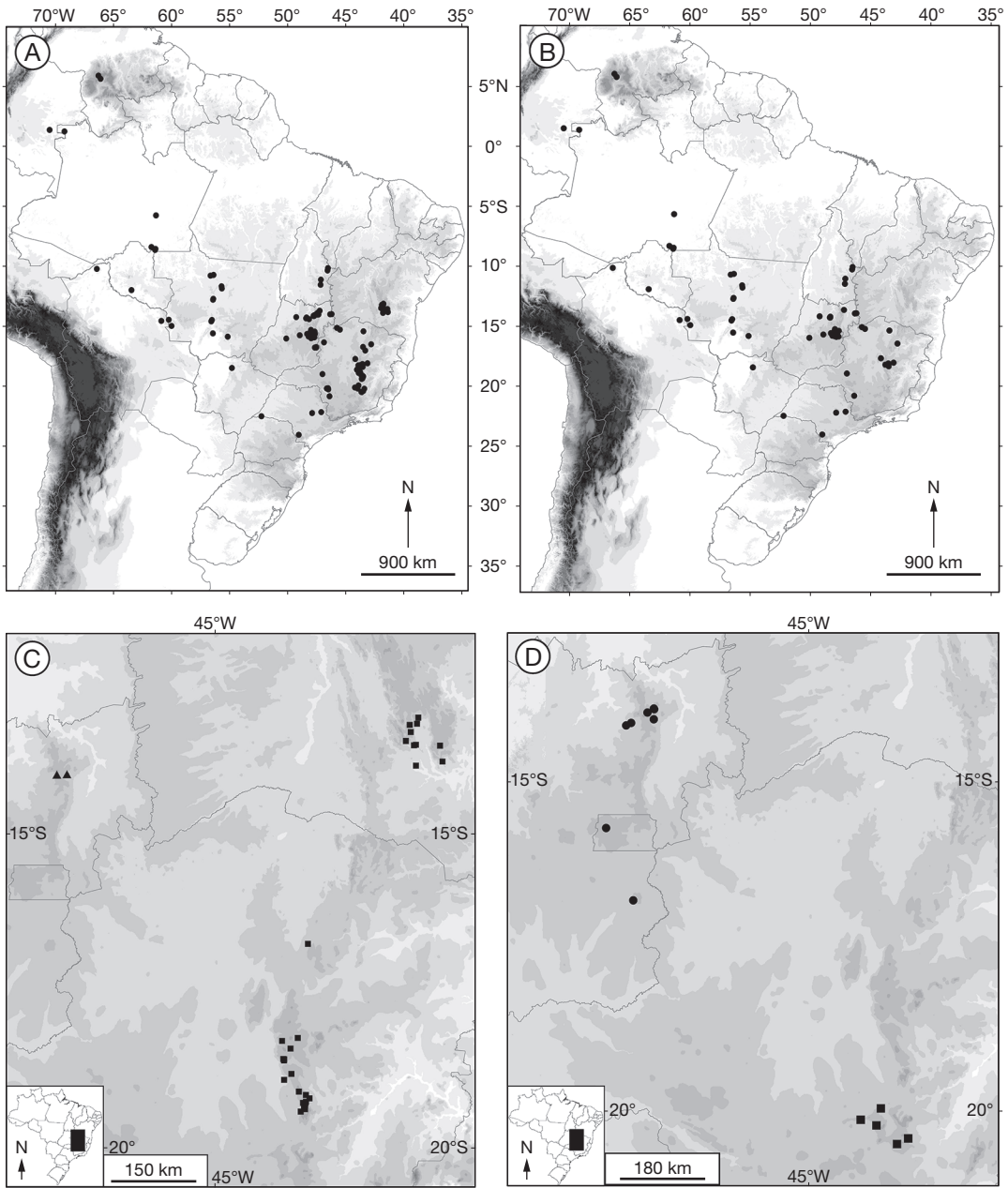


FIG. 1. — Geographic distribution of: **A**, *Paepalanthus* sect. *Diphymene* (●); **B**, *P. chiquitensis* Herzog (●); **C**, *P. erectifolius* Silveira (■) and *P. stellatus* Trovó (▲); **D**, *P. acanthophyllus* Ruhland (●) and *P. amoenus* (Bong.) Koern. (■).

species is mostly distributed in the campos rupes- tres and open fields of the Espinhaço Range, Serra da Canastra, and Chapada dos Veadeiros. In the

states of the Mato Grosso, Mato Grosso do Sul and Tocantins, the species occurs in typical savannas and open fields. Outside of Brazil, the species oc-



curs in typical savannas in Bolivia and Colombia, and rocky fields at high altitudes (1000-2000 m) of Venezuela. Associated with these different habitats, the species possesses different morphological variants. This explains why different authors have described many different species and infra-specific taxa. This variation is now understood as part of a continuum, as proposed by Trovó & Sano (2010).

Although this pattern is cited for only one species of *P.* sect. *Diphyomene*, it has also been reported for other species pertaining to different families, such as: *Froelichia procera* (Seub.) Pedersen and *Pfaffia acutifolia* (Moq.) Stützer (Amaranthaceae), distributed throughout Brazilian savannas, extending to the South (Marchioretto *et al.* 2004, 2009), and *Diplusodon virgatus* Pohl (Lythraceae), distributed throughout South American savannas (Cavalcanti 2007).

#### *Pattern II*

Species regionally restricted. This pattern encompasses four species with restricted distribution, but occurring in more than one place. Among these species, *P. erectifolius* presents the widest distribution, occurring disjunctive in the campos rupestres of the Espinhaço Range in Minas Gerais and Bahia (Fig. 1C). This is the only species occurring in Bahia state, in the Caatinga domain. In Minas Gerais the distribution is concentrated in the Diamantina Plateau, Serra do Cabral, and Serra do Cipó. In Bahia, the distribution is restricted to the southern portion of the Chapada Diamantina, in the vicinities of Rio de Contas and Abaíra. This disjunction also bears a morphological differentiation. The populations from Minas Gerais are usually composed of more robust individuals and with patent leaves, while the populations from Bahia are composed of individuals with more gracile form and reflexed leaves.

The pattern exhibited by *P. erectifolius* deserves attention due to discontinuity between the northern and southern sectors of the Espinhaço Range. Few species have distribution restricted to both sectors, and this pattern is very rare within Eriocaulaceae (Harley 1988; Giuliatti & Pirani 1988; Fiaschi & Pirani 2008). In other families, some species exhibiting this disjunctive pattern are:

*Declieuxia asphalathoides* Muell. Arg., *Declieuxia saturejoides* Mart. & Zucc. (Rubiaceae) (Kirkbride 1976; Giuliatti & Pirani 1988) and *Gomphrena scapigera* Mart. (Amaranthaceae) (Giuliatti & Pirani 1988).

The species *P. acanthophyllus* and *P. koernickei* are restricted to the states of Goiás and Distrito Federal (Figs 1D; 2A). Both occur in campos rupestres and savannas in the Chapada dos Veadeiros and in the vicinities of Brasília. *Paepalanthus acanthophyllus* is also distributed to the south in the savannas of Cristalina. This species also presents a morphological variation, in this case associated with the soil type: individuals of the populations occurring in rocky soils are smaller than the individuals of populations occurring in argillaceous soils.

The pattern exhibited by *P. acanthophyllus* and *P. koernickei* are contrary to some expectations of floristic regions proposed for the Cerrado based on trees and shrubs (Ratter *et al.* 2003). According to Ratter *et al.* (2003), the Chapada dos Veadeiros is related to areas in Tocantins and Mato Grosso do Sul states, whereas Distrito Federal would be related to the southeast of Goiás and northwest of Minas Gerais states. However, the species studied here, as well as for *Picramnia oreadica* subsp. *oreadica* Pirani, are distributed in open fields from the Chapada dos Veadeiros until the Distrito Federal (Pirani 1990). The connection between these areas is coincident with the relations of the provinces designated by Simon & Proença (2000) based on the distribution of *Mimosa* (Fabaceae). The explanation for such a pattern may be related to the habitat restriction of these species, which occurs mostly in high altitude quartzitic soils.

*Paepalanthus amoenus* is restricted to Minas Gerais state, distributed in the extreme south of the Espinhaço Range (Fig. 1D), in a place known as “Quadrilátero Ferrífero” a region with iron-rich soils. *Paepalanthus amoenus* occurs in mountains between the cities of Belo Horizonte and Ouro Preto. Due to their distinct geologic origin, some authors do not consider the Quadrilátero Ferrífero as part of the Espinhaço Range. Indeed, the Quadrilátero forms an area of endemism independent from the Espinhaço Range (Renger *et al.* 1994; Knauer 2007; Echternacht *et al.* 2011). Other species restricted

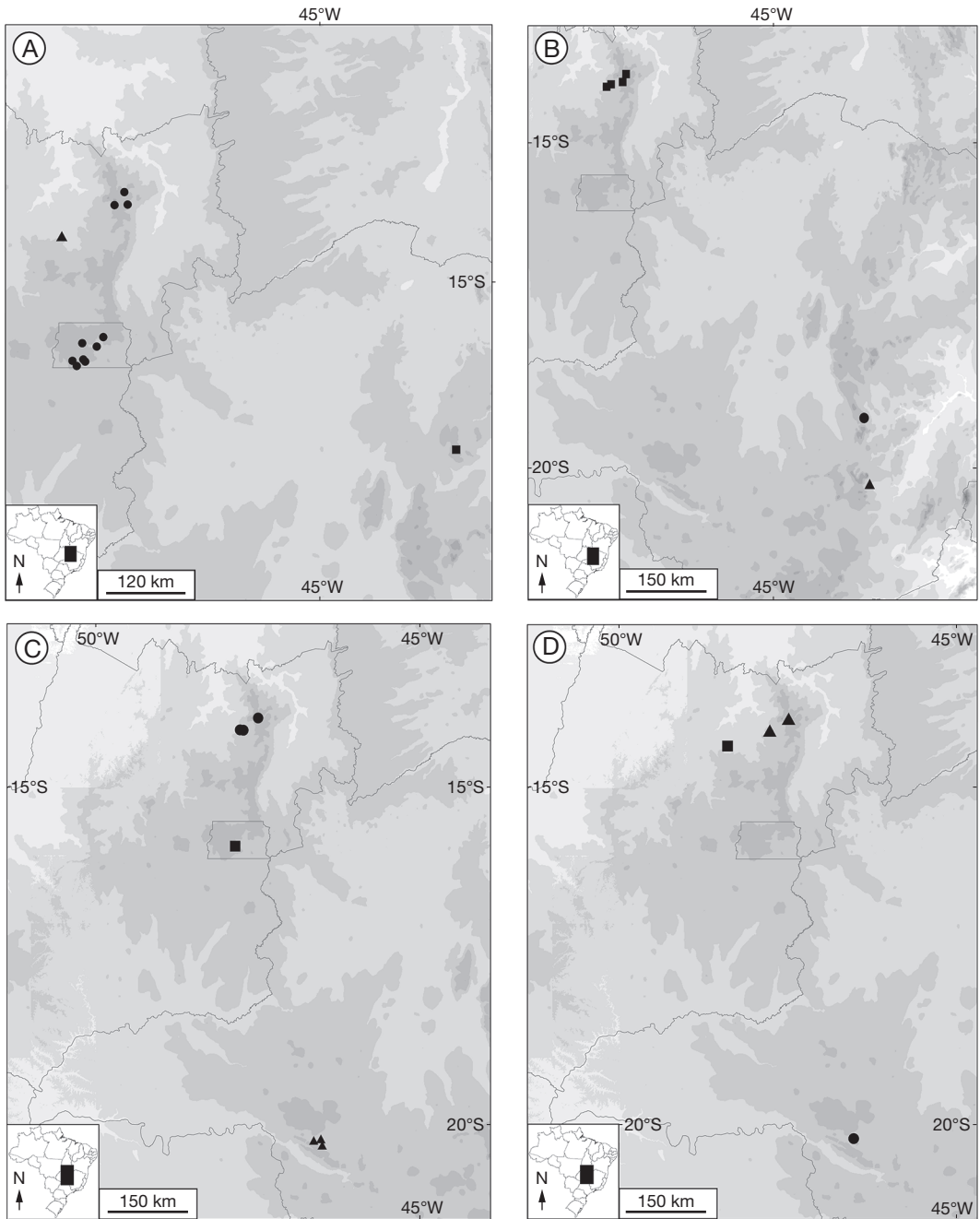


FIG. 2. — Geographic distributions of: **A**, *P. koernickei* (Ruhland) Trovó (●), *P. linearis* Trovó (■), and *P. longiciliatus* Trovó (▲); **B**, *P. arcuatus* Trovó (●), *P. cordatus* Ruhland (■), and *P. decussus* Koern. (▲); **C**, *P. macer* Trovó (●), *P. brevis* (■), and *P. polycladus* Silveira (▲); **D**, *P. sericiscapus* Trovó (●), *P. flexuosus* Trovó (■), and *P. urbanianus* Ruhland (▲).

to this region are: *Ditassa conceptionis* Fontella, *Ditassa laevis* Mart., *Ditassa pedunculata* Malme (Apocynaceae) (Rapini *et al.* 2002), and *Schefflera lucumoides* (Decne. & Planch. ex Marchal) Frodin & Fiaschi (Fiaschi & Pirani 2008).

### Pattern III

Species narrowly distributed. This is the most common pattern within the section, comprising 13 species restricted to one locality or known only by the type collection. It is also the most frequent pattern in Eriocaulaceae, in which most of the species are restricted only to one locality (Giulietti & Pirani 1988; Giulietti & Hensold 1990; Giulietti *et al.* 2005; Costa *et al.* 2008). In Apocynaceae, Araliaceae, Fabaceae, Lamiaceae, Rubiaceae, Velloziaceae, among other families, this pattern is also recurrent and usually associated with high-elevation rocky fields (Kirkbride 1976; Harley 1988; Mello-Silva 1995; Rapini *et al.* 2002; Fiaschi & Pirani 2008; Flores & Tozzi 2008). Harley (1995) and Simon & Proença (2000) suggest that the high degree of endemism in these areas must be related to their relative isolation. These high areas are surrounded by lowlands, which may represent adverse ecological conditions, restricting the dispersion events and resulting in an “insular” condition (Harley 1988, 1995; Simon & Proença 2000; Ratter *et al.* 2006).

The Chapada dos Veadeiros in Goiás concentrates the majority of the narrowly distributed species. They are: *Paepalanthus cordatus* Ruhland (Fig. 2B), *Paepalanthus stellatus* Trovó (Fig. 1C), *Paepalanthus longiciliatus* Trovó (Fig. 2A), *Paepalanthus macer* Trovó (Fig. 2C), and *Paepalanthus urbanianus* Ruhland (Fig. 2D). Although relatively large (*c.* 70 000 ha), the Chapada dos Veadeiros is treated herein as a single locality, since the habitats where the species occur are interconnected, and the region is isolated from other elevated areas, forming a single block. In this area, the species form large populations, generally occurring in argillaceous open fields. The exception is *P. longiciliatus*, known by two small populations occurring over rocky soils on the west boundaries of the Chapada dos Veadeiros. Hundreds of species are endemic to this region, some examples are: *Froelichiella grisea* R.E.

Fries – Amaranthaceae (Marchioretto *et al.* 2004), *Diplusodon appendiculosus* Lourteig. – Lythraceae (Cavalcanti 2007), and *Crotalaria irwinii* D.R. Windler & S.G. Skinner – Fabaceae (Flores & Tozzi 2008).

One species is endemic to the states of Goiás, not occurring in the Chapada dos Veadeiros, and another species is restricted to the Distrito Federal. *Paepalanthus flexuosus* Trovó is restricted to a single mountain in the city of Niquelândia (Fig. 2D). This area has particular edaphic conditions, in which a typical savanna grows over rocky soils in a nickel-mining complex. In this same mountain, endemic species of *Paspalum* L. occur; for example, *Paspalum crispulum* Swallen – Poaceae (Oliveira & Valls 2002). *Paepalanthus brevis* Trovó is endemic to the Distrito Federal state. A single population was collected in a savanna area inside the Brasília Botanical Garden Ecological Station (Fig. 2C). *Paepalanthus weddellianus* is known exclusively by the type collection. Unfortunately, the type locality is imprecise, somewhere between the cities of Goiás and Cuiabá.

In Minas Gerais, the Serra da Canastra and the Espinhaço Range concentrate all endemic species. In the former, the species *Paepalanthus polycladus* Silveira (Fig. 2C) and *Paepalanthus sericiscapus* Trovó (Fig. 2D) occur. This area is a mountain complex isolated from other high areas. Both species occur in campos rupestres; *P. polycladus* form extensive populations and *P. sericiscapus* is known only by the type collection. A high amount of endemic species of Eriocaulaceae occurs in this area, the majority described by Silveira (1928). Species of other families endemic to this area are: *Diplusodon canastrensis* T.B. Cavalc. – Lythraceae (Cavalcanti 2007), *Ditassa insignis* Farinaccio, *Oxypetalum habrogynum* Farinaccio, and *Oxypetalum helios* Farinaccio – Apocynaceae (Farinaccio & Mello-Silva 2004).

The three species endemic to the Espinhaço Range in Minas Gerais are allopatrically distributed. *Paepalanthus decussus* Koern. is restricted to quartzitic soil sites in the Quadrilátero Ferrífero (Fig. 2B). The species is known by the type collection (imprecise locality) and a recent collection near the city of Mariana. As described above, the



unique edaphic conditions may explain the high number of endemic species in this region. *Paepalanthus linearis* Trovó is endemic to the campos rupestres of Itacambira (Fig. 2A) and is known by two collections of the same population. This location, as well as the nearby municipality of Grão Mogol, possesses several endemic species (Giulietti & Pirani 1988). Some examples are: *Schefflera botumirimensis* Fiaschi & Pirani – Araliaceae, restricted to one mountain in Botumirim (Fiaschi & Pirani 2008), *Barbacenia umbrosa* L.B. Smith and *Vellozia maxillarioides* L.B. Smith – Velloziaceae, restricted to the cities of Itacambira, Botumirim, and Grão-Mogol (Mello-Silva 1995).

Another area that concentrates endemic species of Eriocaulaceae, as species of other families as well is the Serra do Cipó (Giulietti & Pirani 1988; Giulietti & Hensold 1990). Within this area, *Paepalanthus arcuatus* Trovó is known by one individual collected in rocky soils of campos rupestres after a fire event (Fig. 2B). Examples of species from other families occurring in this area are: *Schefflera fruticosa* Fiaschi & Pirani and *S. glaziovii* (Taub.) Frodin & Fiaschi – Araliaceae (Fiaschi & Pirani 2008), *Eriope angustifolia* Epling – Lamiaceae (Harley 1988), and *Pfaffia cipoana* Marchor., Miotto & J.C. Siqueira – Amaranthaceae (Marchioreto *et al.* 2009).

## DISTRIBUTIONS AND IUCN

### CONSERVATION STATUS ASSESSMENTS

Including the species in risk categories based on the criteria defined by IUCN (2001) is an arduous task. The difficulties mainly concern the lack of information on the population's size and dynamics, in addition to the lack of quantitative analyses of the species extinction probability. The only criterion applicable to these species is the geographic distribution, criterion B (IUCN 2001). This criterion is based on the species extent of occurrence and the area of occupation, as in the data obtained in this work. In this respect, for these species, the conservation *status* and the geographic distribution are directly related.

*Paepalanthus chiquitensis* and *P. erectifolius*, the two widest distributed species are the only considered of least concern (Table 1). Both occur

inside national conservation units, such as the Serra do Cipó National Park, Chapada dos Veadeiros National Park, and Campos Amazônicos National Park. The species *P. acanthophyllus* and *P. koernickei* have a restricted distribution occurring in no more than 10 localities in the Goiás and Distrito Federal states, thus both are considered vulnerable. These species occur in the Chapada dos Veadeiros National Park and in Brasília National Park. *Paepalanthus amoenus* occurs in no more than five localities within the Quadrilátero Ferrífero, occurring in the Itacolomi State Park. This species here is considered endangered.

All species narrowly distributed are considered critically endangered. However, within this category the species may be categorized into two groups. *Paepalanthus arcuatus*, *P. brevis*, *P. sericiscapus*, and *P. weddellianus* are known only by the type collection. The former occurs in the Serra do Cipó National Park, while *P. brevis* occurs in the Brasília Botanical Garden Ecological Station, and *P. sericiscapus* occurs in the Serra da Canastra National Park. The species *P. cordatus*, *P. stellatus*, *P. macer*, *P. urbanianus*, *P. polycladus*, *P. linearis*, *P. longiciliatus*, *P. decussus*, and *P. flexuosus* are known to have more than one collection in the type locality. The first four occur in the Chapada dos Veadeiros National Park, *P. polycladus* occurs in the Serra da Canastra National Park, and the other four do not occur in any conservation unit.

### IMPLICATIONS FOR CERRADO CONSERVATION

As previously stated, like the other Neotropical Eriocaulaceae, most of *Paepalanthus* sect. *Diphyomene* species are narrowly distributed (Giulietti & Hensold 1990; Giulietti *et al.* 2005). This distribution pattern is relevant to assert the species conservation *status* and also to establish key areas for biodiversity conservation (Eken *et al.* 2004; Langhammer *et al.* 2007; Rapini *et al.* 2009), because *in situ* conservation depends obligatorily on the specific conservation area. The following key areas are meaningful for the conservation of *P.* sect. *Diphyomene* in the Cerrado, as proposed by Kasecker *et al.* (2009): Brasília – CO062, Cristalina – CO063, Alto Paraíso de Goiás – CO078, Chapada dos Veadeiros – CO079, Teresina de Goiás – CO083,

Serra da Canastra – SE 051, Itacambira – SE163, Serra do Cipó – SE176, and Ouro Preto – SE204. Other areas, such as the mountain in Niquelândia and some mountains in the Quadrilátero Ferrífero, should also be designated as important areas for biodiversity conservation of the Cerrado. These areas are not only the unique habitat of some species, but shelter lineages adapted to metal-rich soils: *Paepalanthus flexuosus* occurs on nickel-rich soils, while *P. amoenus* tolerates iron-rich soils.

Besides being narrow, the distribution of these species is discontinuous in the Cerrado domain. Each different Cerrado formation may comprise different communities, and even similar formations, when isolated, may comprise different plant communities (Pennington *et al.* 2006; Ratter *et al.* 2006). The high richness of infrageneric categories in different savannic formations, also observed in other genera such as *Diplusodon* and *Mimosa* (Cavalcanti 2007; Simon & Proença 2000), illustrates the high diversity of the Cerrado domain, one of the hotspots for biodiversity conservation (Castro *et al.* 1999; Myers *et al.* 2000; Ratter *et al.* 2006).

The mosaic distribution of the vegetational formations included in the Cerrado domain is reflected in a high beta-diversity (Felfili *et al.* 2006). Therefore, precise information on species distribution is essential to support appropriate conservation management of the Cerrado. (Pennington *et al.* 2006; Ratter *et al.* 2006). The patterns of geographic distribution allied with conservation status showed to be a useful tool for conservation. The association of these data sources strengthens the necessity of preservation of previously established areas, such as the Chapada dos Veadeiros. It also highlights the necessity of conserving other areas in the Cerrado domain, which do not possess established conservation units. Some of these areas are experiencing strong anthropogenic pressure, either by soy agricultural expansion or by mining. Additionally, to achieve solid conservation strategies for the Cerrado, it remains essential to advance on floristic, phylogenetic, and population studies involving species typical of the savannas (Huber *et al.* 2006; Pennington *et al.* 2006; Ratter *et al.* 2006).

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