Phytotaxa 404 (1): 001–011
https://www.mapress.com/j/pt/

Article

ISSN 1179-3155 (print edition)
PHYTOTAXA
ISSN 1179-3163 (online edition)

https://doi.org/10.11646/phytotaxa.404.1.1

Zamia brasiliensis, a new species of *Zamia* (Zamiaceae, Cycadales) from Mato Grosso and Rondônia, Brazil

ROSANE SEGALLA[1*] & MICHAEL CALONJE[2]
[1]*Instituto Federal de Educação, Ciência e Tecnologia de Mato Grosso – Campus Cáceres, Mato Grosso, Brazil. biosegalla@gmail.com*
[2]*Montgomery Botanical Center, Coral Gables, FL, U.S.A.*
[*]*Author for correspondence*

Abstract

Zamia brasiliensis Calonje & Segalla, a new subterranean-stemmed species of *Zamia* (Zamiaceae) from Mato Grosso and Rondônia, Brazil, is described and illustrated. It is compared to two morphologically similar species with adjacent geographic distributions: *Z. boliviana* from the Cerrado biome, and the Amazonian species *Z. ulei*. The new species shares unarmed petioles with *Z. boliviana* but is readily distinguishable by its much broader leaflets. *Z. brasiliensis* has leaflets somewhat resembling those of juvenile individuals of *Z. ulei*, but the latter species is easily differentiated by the presence of prickles on its petiole.

Keywords: Cerrado-Amazon Rainforest, Cycad, Endangered species, Endemic species, Gymnosperm, IUCN Red List

Introduction

Zamia Linnaeus (1763: 1659), a New World endemic cycad genus consisting of 79 species (Calonje *et al.* 2019), is the most speciose of the four cycad genera native to the Americas. Occurring from Florida, U.S.A. south to Bolivia, it is also the most broadly distributed genus in the New World. During the last decade there have been remarkable advances in our understanding of *Zamia* taxonomy, with 17 new species names or combinations published (Schutzman *et al.* 2008, Taylor *et al.* 2008, Calonje 2009, Calonje *et al.* 2009, Lindstrom & Idarraga 2009, Acuña 2010, Calonje *et al.* 2010, Calonje *et al.* 2011, Calonje *et al.* 2012, Pérez-Farrera *et al.* 2012, Taylor-Blake & Holzman 2012, Lindstrom *et al.* 2013, Calonje *et al.* 2018, Stevenson *et al.* 2018) and multiple papers providing additional taxonomic and/or nomenclatural clarifications (Nicolalde-Morejón *et al.* 2008, Calonje & Meerman 2009, Lindstrom 2009, Nicolalde-Morejón *et al.* 2009, Calonje *et al.* 2010, Applequist 2012, Calonje *et al.* 2012, Calonje *et al.* 2015, Pérez-Farrera *et al.* 2016, Ward 2016). Despite recent advances, *Zamia* populations occurring within the Amazon basin remain poorly understood, with the taxonomic circumscriptions of most accepted species remaining unclear, and the presence of several populations that potentially represent undescribed species. Among these poorly understood populations are ones occurring in the transition zone between the Brazilian Cerrado and Amazon biomes in Mato Grosso and Rondônia, Brazil. Several *Zamia* specimens from this region have been collected in the last few decades but often remained undetermined in herbaria or misidentified as *Zamia ulei* Dammer (1907: 117), an Amazonian species that has similarly shaped leaflets during its juvenile stage but that reaches a much larger overall size. Recent botanical surveys conducted in Mato Grosso and Rondônia states led to the discovery of two extant populations of this Cerrado-Amazon transition zone taxon, and close examination of its reproductive and vegetative morphology has produced convincing evidence that this taxon represents a species that is new to science.

The species is quite distinct from *Zamia ulei* and appears most closely related to neighboring Cerrado species, *Z. boliviana* (Brongn. 1846: 9) Candolle (1868:40) due to several similarities in vegetative and reproductive morphology. We hereafter describe and illustrate this new species and provide comparison to neighboring species *Z. ulei* and *Z. boliviana* with which it shares some morphological similarities.

Accepted by Daniela Zappi: 6 May 2019; published: 16 May 2019

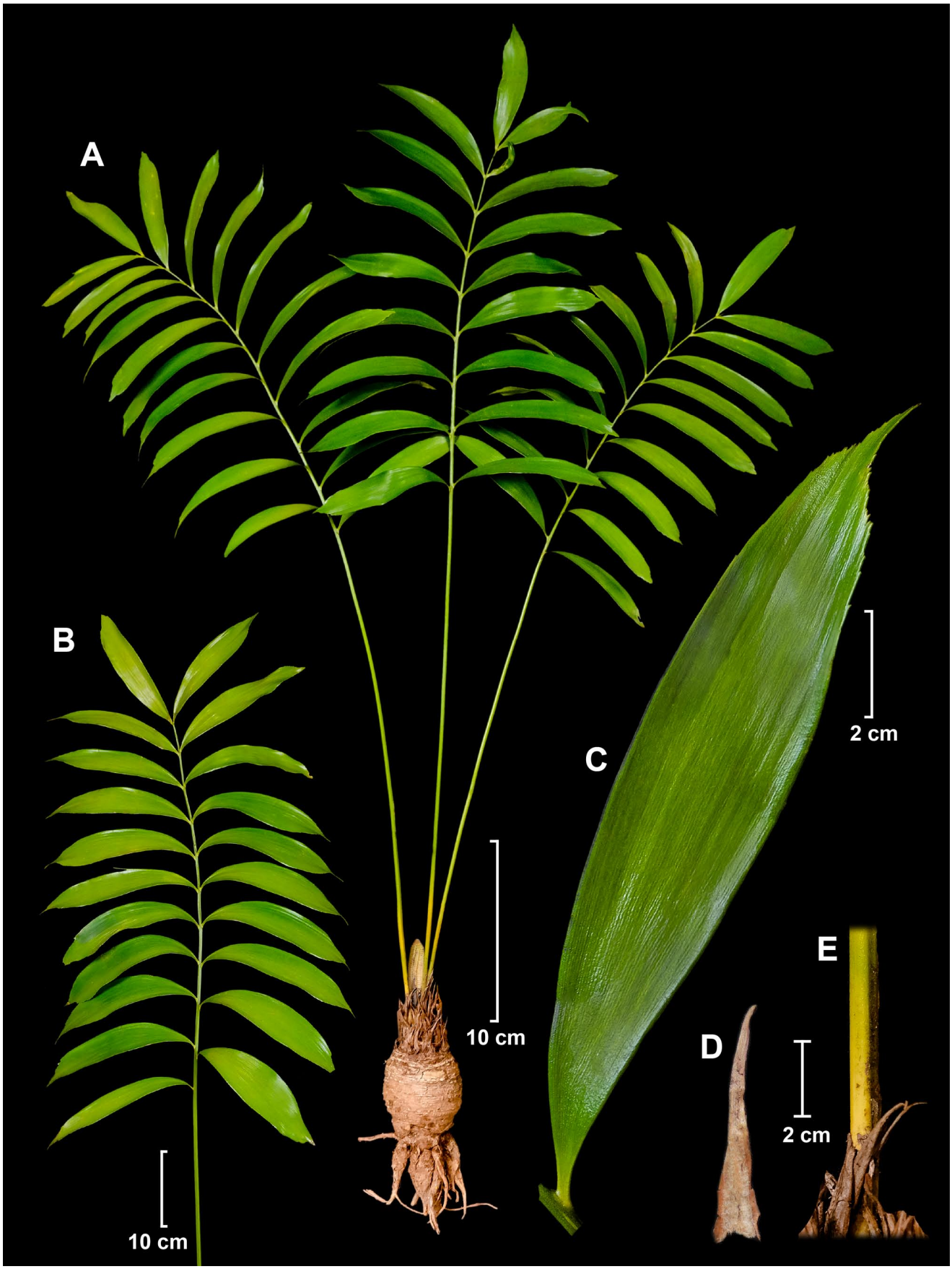

FIGURE 1. Vegetative characteristics of *Zamia brasiliensis*. A. Adult individual. B. Leaf, C. Middle leaflet. D. Cataphyll. E. Base of unarmed petiole.

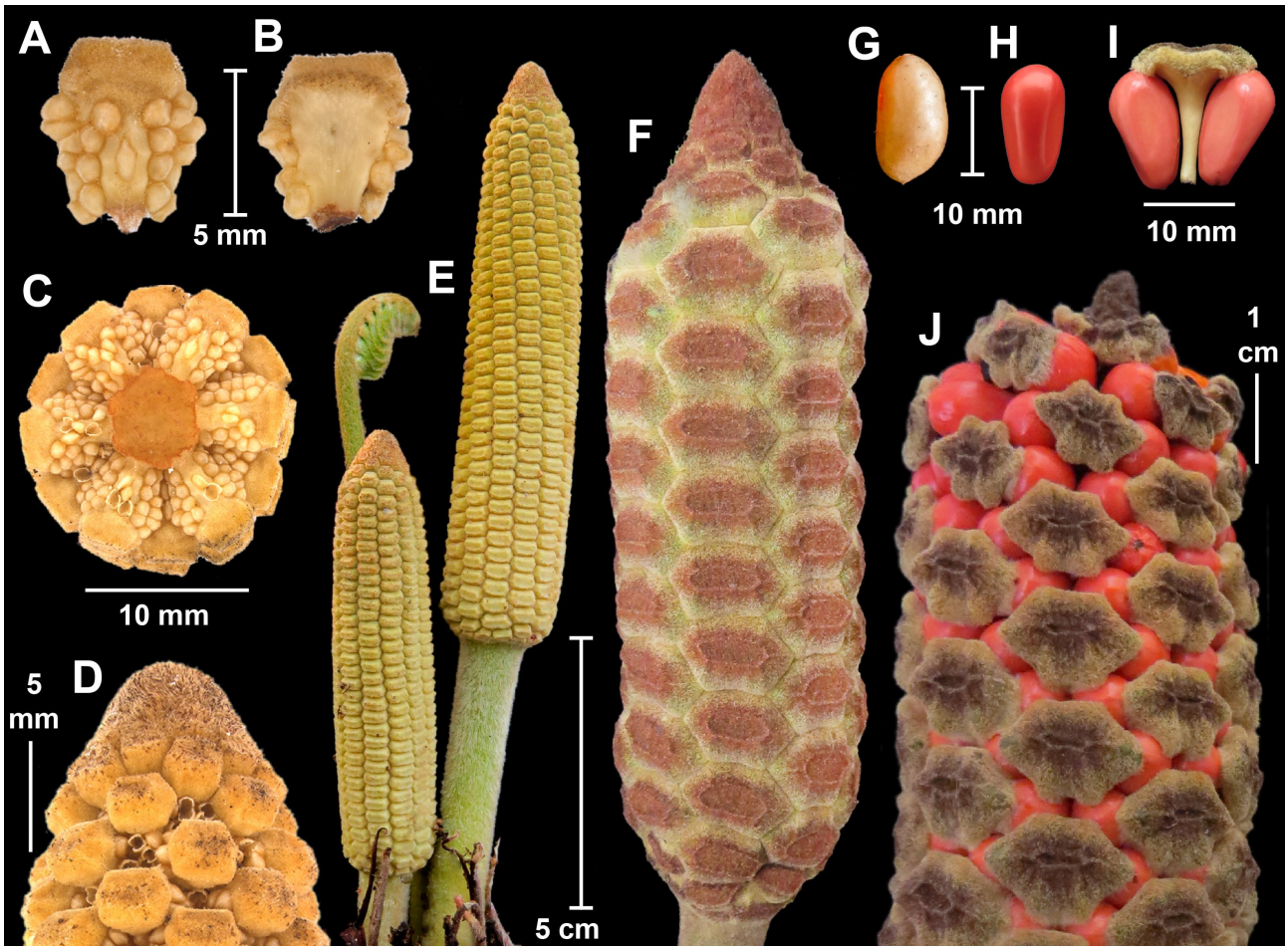

FIGURE 2. Reproductive characteristics of *Zamia brasiliensis*. A. Abaxial side of microsporophyll. B. Adaxial side of microsporophyll. C. Cross section of pollen strobilus, abaxial side. D. Apex of pollen strobilus showing characteristic orange-brown tomentum E. Pollen strobili, near mature and immature, and new leaf showing inflexed ptyxis. F. Seed strobilus shortly after receptivity phase. G. Mature seed sclerotesta. H. Mature seed with sarcotesta. I. Mature seed strobilus, adaxial side. J. Distal half of mature seed strobilus. A–G based on material from Itaúba, Mato Grosso, H–J from Cacoal, Rondônia.

Materials and Methods

Several specimens belonging to a potentially undescribed species from northern Mato Grosso and Rondônia states were identified in Brazilian herbaria by the authors in the course of conducting general systematics research on the genus *Zamia*, and additional specimen records were accessed online via the speciesLink network (http://splink.cria.org.br/). Field surveys were conducted in northern Mato Grosso and Rondônia in search of this taxon, and two extant populations over 650 km distant from each other were located and surveyed. One population was located in semideciduous forest within Itaúba Municipality in northern Mato Grosso, the other was found in woodland savanna (cerradão) within the Cacoal Municipality in Rondônia. Fieldwork at these surveyed localities included the collection of herbarium specimens, detailed morphometric data, photographs, and soil samples. Comparative field data and photographs were obtained for *Zamia boliviana* in Chapada dos Guimarães, Cáceres, and Glória do Oeste Municipalities in Mato Grosso, Brazil and for *Z. ulei* in Marechal Thaumaturgo Municipality in Acre, Brazil. Specimen data was georeferenced and analyzed in ArcGIS v. 10.5.1 (ESRI 2018) in order to (a) estimate the area of occupancy (AOO) and extent of occurrence (EOO) for the species as well as the amount of deforestation within the EOO in order to prepare an IUCN Red List assessment, and to (b) evaluate climate characteristics within the EOO. The AOO was calculated using a circular buffer around each occurrence point with an area of 4 km^2, as suggested by Breiner & Bergamini (2018). The EOO was calculated by drawing a minimum convex hull around the buffered occurrence points. Historical land use and deforestation over the last three decades within the EOO was visualized utilizing land use layers for 1987 and 2017 from MapBiomas

v 3.0 collection (Mapbiomas 2018). Climate within the EOO according to the Koppen-Geiger climate classification system (Köppen 1918, Geiger 1954) was visualized in GIS using maps produced by Kottek *et al.* (2006). Estimates for annual temperature and rainfall ranges within the AOO were obtained by extracting values at occurrence points using CHELSA bioclimactic variables (Karger *et al.* 2016). Monthly precipitation estimates were obtained using Worldclim 2 bioclimactic variables (Fick & Hijmans 2017).

Specific locality information associated with herbarium specimen collections cited below is omitted from this paper to minimize the risk of illegal extraction of this species from the wild.

FIGURE 3. *Zamia brasiliensis* in habitat. A. Submontane semideciduous forest habitat during the dry season (September 2018) at the type locality in Itaúba, Mato Grosso. Photographed with Rosane Segalla. B. Habit of plant at type locality. C. Woodland savanna (Cerradão) habitat in Cacoal (Rondônia) at the beginning of the rainy season (November 2018). Plants most common at boundaries of Cerradão and more open 'campo cerrado' habitats. D. Plant growing among grasses in woodland savanna. Photo credits: A, C, D—Rosane Segalla; B—Márcio Cassiano de Jesus.

Taxonomic Treatment

Zamia brasiliensis Calonje & Segalla *sp. nov.* (Figs. 1–3)

Diagnosis:—*Zamia brasiliensis* is distinguishable from *Z. boliviana* in having much broader leaflets and from *Z. ulei* in having unarmed petioles.

Type:—BRAZIL. Mato Grosso: Itaúba: 295m, 18 Sep 2018, *R. Segalla & M.C. Jesus ITA01* (holotype UFMT!, isotype INPA!).

Additional specimens examined:—BRAZIL. Mato Grosso: Alta Floresta, *J.A. Lombardi s.n.* (HRCB 64169); Aripuanã: *R.A. Rosa 183* (IAN 145897!), ex Aripuanã, cultivated at INPA in Manaus, Amazonas, *W. Rodrigues 9713* (INPA 68496!); Guarantã do Norte: *M.A. Carmello & F.J. Sonara s.n.* (UFMT 3311!); Itaúba, 380 m, 26 Jun 2015, *S.A. Antoniazzi S.A. 3630* (HERBAM 19899), 280 m, 21 Oct 2015, *M.E. Engels 3737* (MBM 403994), 279 m, 13 May 2015, *M.E. Engels 3825* (CNMT 497, MBM 403046, TANG 3338), 289 m, 26 May 2017, *M.E. Engels & L.S. Silva 95295517 Copel9* (HERBAM 20686), 374 m, 26 Oct 2015, *M.E. Engels & A.S. Bezerra 3724* (MBM 403995), 289 m,

26 May 2017, *M.E. Engels 5517* (HCF 24572), 295m, 12 Oct 2018, *R. Segalla & E.A. Soares ITA02* (UFMT!); Novo Mundo: 30 Jul 2006, *D. Sasaki et al. 167* (HERBAM 0411), 21 July 2006, *D. Sasaki et al. 512* (HERBAM 0614); Rondônia: Alvorada do Oeste: 1 May 1987, *C.A. Cid Ferreira et al. 9000* (INPA 153653!); Cacoal: 22 Jun 1984, *C.A. Cid Ferreira et al. 4701* (INPA 121074!); 185 m, 24 November 2018. *R. Segalla & S.C. Freitas ROD05* (INPA!), *ROD06* (UFMT!), *ROD08* (IAN!), *ROD09* (JBRJ!), *ROD10* (SP!); Campo Novo de Rondônia, 245 m, 8 Sep 2017, *I. Mendes-Silva et al. 249* (RON 15629!); Pimenta Bueno: *P. Lisboa et al. 2924* (MG 95972!); Presidente Médici: 169 m, 21 Nov 2013, *A. Petini-Benelli & S.C. Freitas APB920* (UFMT 41202!).

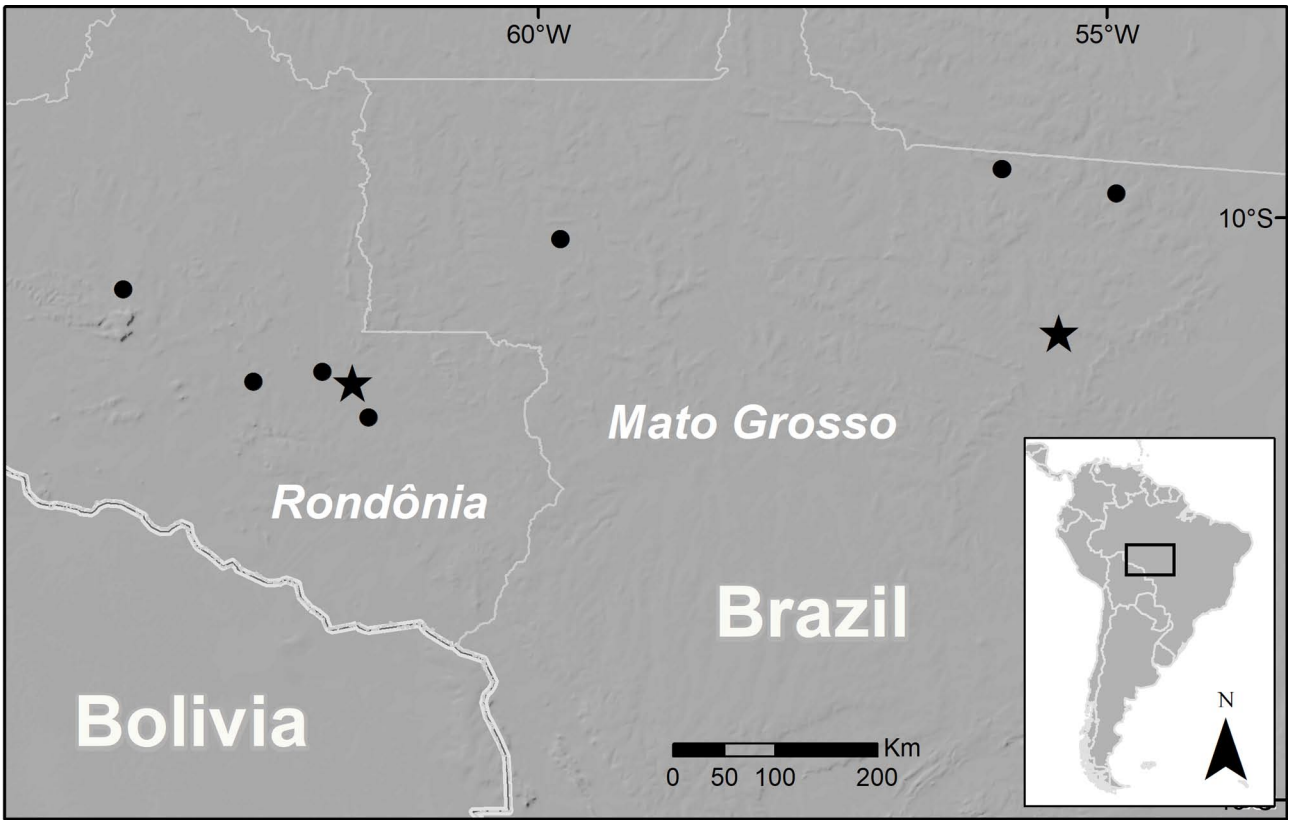

FIGURE 4. Geographic distribution of *Zamia brasiliensis* in Mato Grosso and Rondônia. Locations marked with stars indicate the populations studied in Itaúba (Mato Grosso) and Cacoal (Rondônia).

Description:—*Stem* hypogeous, solitary or clustering, globose to cylindrical, 6.4–25 × 6.2–8.4 cm. *Cataphylls* caducous, triangular to narrowly triangular, 6.5–8.5 cm long and 1.2–1.8 cm wide at base, margins glabrous and orange, central abaxial surface densely cream-orange tomentose, gradually loosing tomentum as cataphyll dries and turns tan-brown. *Leaves* 1–6 per crown, spreading, 10–112 cm long, longitudinal ptyxis inflexed. *Petiole* 10.5–61.2 cm long and 3.8–6.0 mm thick, slightly grooved adaxially, with abruptly swollen base to 13.5 mm wide, unarmed. *Rachis* 0.1–54.5 cm long, unarmed. *Leaflets* 2–24 (10+ on adults), chartaceous to subcoriaceous, oppositely to sub-oppositely arranged, articulate insertion on rachis 5.0–5.5 mm wide, spaced to 1.5 to 4.7 cm apart at leaf center, lanceolate to obovate with acuminate apex, margins strongly serrated in distal 1/4 to 1/3, basal leaflets 16–22 cm × 1.9–3.5 cm, middle leaflets 16.7–21 cm × 2.4–3.5 cm, apical leaflets 12.7–17.0 cm × 2.2–3.2 cm, light green on new leaf flushes, turning dull greyish green to bright green at maturity. *Eophylls* to 10.5 cm long, rachis 1–2 mm long, carrying two to four leaflets 4.8 × 1.7 cm. *Pollen strobili* 1–3 per crown, yellow-cream tomentose, conical-cylindrical, at pollen shedding 12.8 × 1.9 cm, sterile apex obtuse and tan-brown tomentose to 8 mm long, strobilar axis densely villous with white to orange trichomes, peduncles cream colored and villous with mixed yellow and orange-brown tomentum, 3.8–4.0 × 0.8 cm. *Microsporophylls* spirally arranged in 9–12 orthostichies of 20–30 sporophylls each, obtrullate, 5.2–6.4 × 4.0–4.8 mm at pollen shedding, villous in proximal section and near sterile apex transition, sterile apex encompassing 30–45 % of the total microsporophyll length, cream-yellow tomentose with brown speckles on distal section, face hexagonal to oblong hexagonal, 2.7–3.2 mm tall × 3.4–3.8 mm wide with shallowly indented terminal facet, abaxial surface of microsporophyll with 19–21 microsporangia concentrated mostly along the margins but with a few on the central area, adaxial surface glabrous, without microsporangia. *Ovulate strobili* 8–11.5 × 3.5–4.8 cm, typically solitary but up to five per apex, erect at maturity, cylindrical with pronounced acute or obtuse sterile apex encompassing 1/5 to

1/12 of the strobilus length, beige-green when first emerging, turning to solid orange-brown at receptivity, and at maturity the margins of megasporophylls becoming a markedly lighter tan-cream. Strobilar axes and megasporophyll pedicels glabrous on mature strobili, peduncles 10–26 × 0.5–0.6 cm, maturing from tan to brown tomentose with green undertones. *Megasporophylls* spirally arranged in in 9–10 orthostichies of 6–13 sporophylls each, pedicel 13.5–15.0 mm long, sterile apex 2.5–5.5 mm thick with hexagonal to oblong-hexagonal distal face 13.4–16.2 mm wide and 9.3–12.0 mm tall, roundly extruded to a narrow, shallowly depressed reddish-brown terminal facet. Seeds ovoid to ovoid-pyramidal, at maturity 11.9–16.6 × 7.1–9.3 mm with paper thin orange-red sarcotesta, sclerotesta 11.3–15.3 × 6.7–8.6 mm.

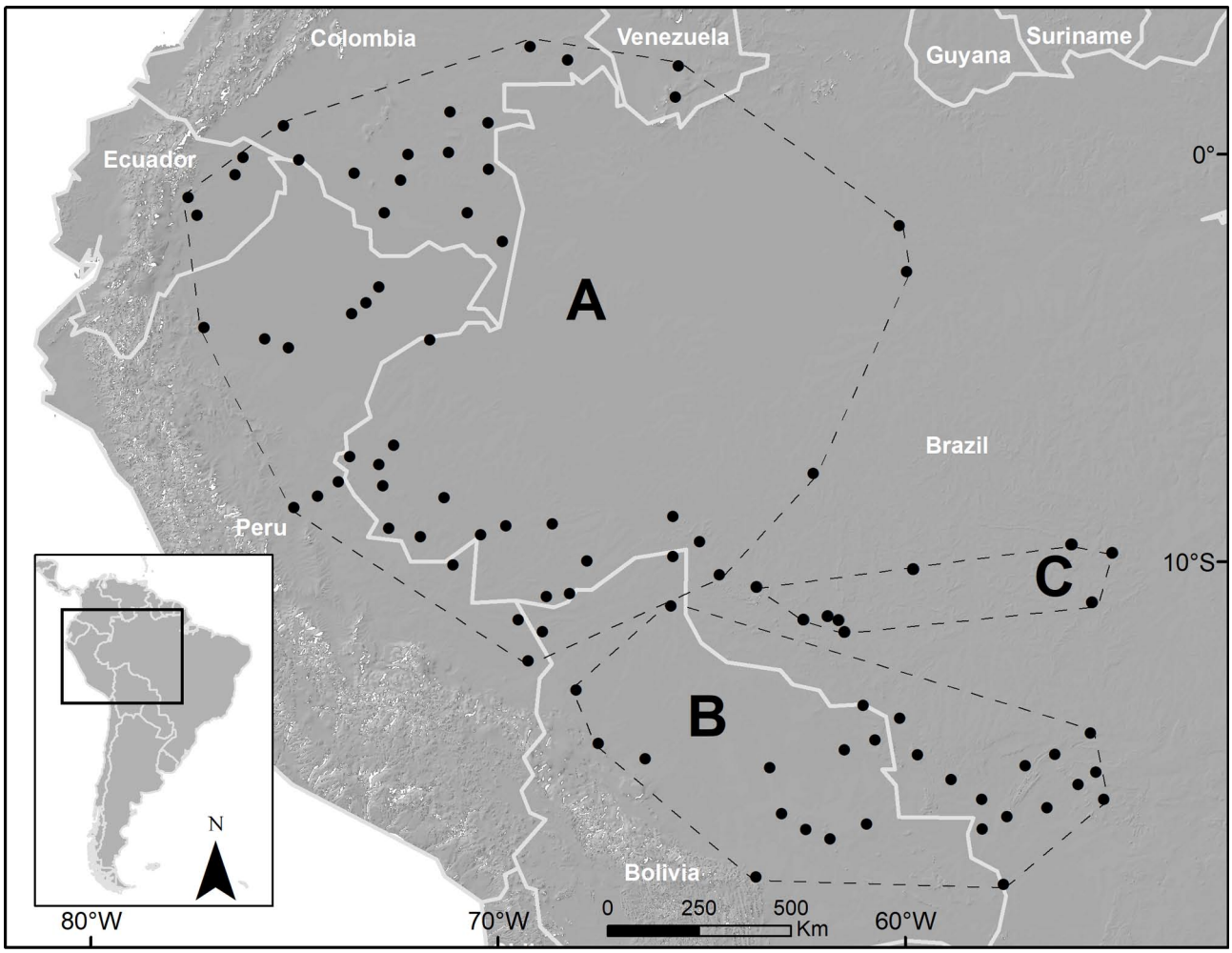

FIGURE 5. Extents of occurrence of a) *Zamia ulei*, b) *Z. boliviana*, and c) *Z. brasiliensis.* Note non-overlapping geographic distributions of the three species.

Etymology:—*Zamia brasiliensis* is the only species of *Zamia* endemic to Brazil. The specific epithet refers to its distribution which is restricted to this country.

Climate:—The climate within the area of occupancy of *Zamia brasiliensis* is classified as equatorial savanna with dry winter (Aw) by the Koppen-Geiger classification system (Köppen 1918, Geiger 1954, Kottek *et al.* 2006). It is characterized by an average temperature of 18° C or higher, the dry season occurring in the winter, and the driest month having less than 60 mm precipitation and contributing less than 4% of the total annual precipitation. The climate is considered hot and humid, with temperatures relatively constant year round. Mean annual temperature ranges from 24.7° to 25.2° C, low temperatures from 18.9° to 20.6° C and high temperatures between 30.4° and 32.2° C (Data derived from GIS analysis using bioclimactic variables from CHELSA (Karger *et al.* 2016). Annual rainfall ranges from 1400 to 2500 mm per year with a distinct dry season (< 100 mm per month) occurring from May through September. The driest months are June through August, receiving less than 30 mm per month, while the wettest months are December through March, receiving over 300 mm.

Ecology:—Strobili emerge from September to December, the seed strobili becoming receptive and the pollen strobili becoming dehiscent from October to December. Pollinated seed strobili develop from November through

August, with seed dehiscence occurring from June to September. New leaves are produced from August to November. In Itaúba, we observed colonies of an unidentified species of *Pharaxonotha* Reitter (Coleoptera: Erotylidae), a potential pollinating agent, within dehiscent pollen strobili and in the soil around the adult plants. In the Cacoal population, larvae of a butterfly species of the genus *Eumaeus* Hübner (1819: 17) were observed feeding on new leaves of *Z. brasiliensis.*

Habitat, geology and soils:—*Zamia brasiliensis* occurs in various habitats within the transition zone between the Brazilian Cerrado and the Amazon forest in upland areas of northern Mato Grosso and Rondônia states (Rondônia and North Mato Grosso Uplands Landscape Region, *sensu* Volkoff *et al.* (2012), including submontane dense and open ombrophilous forests, semideciduous and deciduous seasonal forests, and woodland savannas, also known as Cerradão (IBGE 2012).

The Itaúba (Mato Grosso) population studied occurred in submontane semideciduous forest transitioning to an open ombrophilous forest at the margins of the Teles Pires River (Figs. 3a, 3b). Semideciduous forest is characterized by two well-demarcated climatic seasons, a rainy season followed by a long biologically dry period during which 20% to 50% of all trees lose their foliage (IBGE 2012). The forest has high biomass with lianas and epiphytes common, and a 25–30 m high canopy with a few emergents. The community structure includes trees that range from 2 to 30 m in height and from 3.18 to 92 cm diameter at breast height (1.30 m). Within the semideciduous forest, the distribution pattern of *Zamia brasiliensis* follows the edaphic features of the habitat, with plants appearing to be more common in the drier, sandier areas. The soil is a slightly acidic sandy clay loam (Table 1) with a rocky substratum consisting of arcosean sandstones, medium to coarse grained, with lenses of argillite conglomerates, siltstones and sandstones of the Dardanelos Formation, with the main soil types in the area being Litolic Neosols and Red-Yellow Oxisols. (SEPLAN, 2000).

TABLE 1. Soil analysis results for submontane semideciduous forest habitat in Itaúba (Mato Grosso) and woodland savannah (cerradão) in Cacoal (Rondônia) localities of *Zamia brasiliensis.* Soil analysis conducted by Agroanálise Labs, Cuiabá, Mato Grosso, Brazil.

	pH		P	K	Ca+Mg	Ca	Mg	Al	H
	H_2O	$CaCl_2$	mg/dm^3		$cmol_c/dm^3$				
Itaúba	6.6	5.8	8.3	143.4	6.53	4.95	1.58	0	2.83
Cacoal	4.6	3.9	0.6	81.8	0.6	0.35	0.25	1.4	5.97

	Org. Mat.	Sand	Silt	Clay	Sum of bases (S)	CEC	Saturation by bases (V)
	g/dm^3	g/Kg			$cmol_c/dm^3$		%
Itaúba	34.9	540	116	344	6.9	9.72	70.99
Cacoal	32.1	540	116	344	0.81	8.19	9.89

	Relationships			Saturation %				Sat. Al.
	Ca/Mg	Ca/K	Mg/K	Ca	Mg	K	H	
Itaúba	3.13	13.27	4.24	50.93	16.26	3.84	29.06	0
Cacoal	1.4	1.65	1.18	4.27	3.05	2.6	72.95	63.35

The Cacoal (Rondônia) population studied occurred in a woodland savanna (cerradão) in an area of rolling hills characterized (Figs. 3c, 3d) by a lithology of basement rocks and Paleozoic sediments (Central Rondônia hills *sensu* Volkoff *et al.*, 2012). The soil is a slightly acidic sandy clay loam (Table 1) with a rocky substratum consisting of arcosean sandstones and ortho-quartzites with lenses of coal and gypsum (Pimenta Bueno formation, CPRM 1999). Plants appeared most common along the edges of the cerradão at is interface with the more open 'campo cerrado'. Here the plants grew interspersed among grasses, shrubs and trees.

Distribution and conservation status:—*Zamia brasiliensis* has an extent of occurrence (EOO) of 139,453 km^2 and has been collected in at least ten different locations (Fig. 4). Although the geographic distribution range for this species is broad, the species occurs within the "Arc of Deforestation", the Brazilian agricultural frontier in south-southeastern Amazonia where the highest rate of deforestation in the Amazon basin occurs (Coe *et al.* 2013). In the last 30 years (1987 to 2017), forest cover within the EOO has decreased by 32.45%, and only approximately 60%

of the EOO remains forested. As is the case for the Amazon as a whole (Tyukavina *et al.* 2017), by far the primary cause for deforestation within the EOO has been agro-industrial forest clearing for cattle pasture, with 34% of the area currently converted to pasture. The area of occupancy (AOO) for *Z. brasiliensis* is estimated to be 53.3 km^2. Most of the historic collections of this species occurred in areas that have been severely deforested, and only a few disjoint populations are known to persist. Only a single protected area is known to harbor this species, the Parque Estadual Cristalino, in the state of Mato Grosso (Sasaki *et al.* 2010, Zappi *et al.* 2011). Based on the AOO smaller than 500 km^2, severe fragmentation of the remaining populations, and a projected decline in EOO, AOO, and habitat quality due to continued land transformation in the region, we recommend this species be listed as Endangered (EN) based on IUCN Red List criteria B2ab(i-v) (IUCN Standards and Petitions Subcommittee, 2017).

TABLE 2. Distinguishing traits of *Zamia brasiliensis*, *Z. boliviana*, and *Z.ulei*.

Species	*Zamia brasiliensis*	*Zamia boliviana*	*Zamia ulei*
Petiole	Unarmed	Unarmed	Armed
Leaves per apex	1–4	1–3	1–2
Leaf length (max)	112 cm	119 cm	400 cm
Seed strobilus color (mature)	Cream-yellow to tan, with sporophyll centers dark brown	Solid cream-tan with green undertones, or Cream-yellow to tan, with sporophyll centers dark brown.	Brownish red (solid)
Megasporophyll row number	6–13	5–16	20–22
Megasporophyll orthostichies number	8–14	6–7	12–13
Megasporophyll face dimensions (mm)	13.4–16.2 × 9.3–12.0	18.1–21.9 × 10.6–14.6	19.0–20.5 × 18.0–18.5
Seed sclerotesta size (mm)	11.3–15.3 × 6.7–8.6	11.1–15.3 × 7.2–10.2	18–19 × 8–10
Pollen strobilus color	Yellow-cream tomentose, with dark orange-brown tomentum on apex of strobilus	Yellow-cream tomentose throughout	Tan-tomentose throughout
Microsporangia arrangement	Abaxial, 20–22 microsporangia arranged in single group or slightly separated at center of sporophyll	Abaxial, 17–22 microsporangia arranged in single group or slightly separated at center of sporophyll	Abaxial, 14–18 microsporangia arranged in two widely separated groups aligned along sporophyll margins
Leaflet length (cm)	16.7–21	19–29	16–50
Leaflet width (cm)	2.4–3.5	1.1–2.0	3.0–7.0
Number of leaflets per leaf on adult plants	10–24	16–40	8–50

Morphological affinities:—*Zamia brasiliensis* shares morphological similarities with *Z. ulei* and *Z. boliviana*, three subterranean-stemmed species with adjacent but non-overlapping geographic distributions (Fig. 5). *Zamia ulei* is broadly distributed in the Amazon basin, *Z. boliviana* occurs in the Cerrado biome of Brazil and Bolivia, and *Z. brasiliensis* inhabits various habitats within the Cerrado-Amazon transition zone. Collections of *Z. brasiliensis* in herbaria have often been misidentified as *Z. ulei*, most likely because the leaf size and leaflet shape of *Z. brasiliensis* are similar to those of young plants of *Z. ulei*. However, adult individuals of *Z. ulei* produce much larger leaves and leaflets that far exceed the dimensions of those of *Z. brasiliensis*. Even at a young age, the species are easily diagnosable, because *Z. ulei* has petioles armed with robust prickles, whereas *Z. brasiliensis* has unarmed petioles. Unarmed petioles are very rare in mainland American *Zamia*, and in South America, they are only associated with *Z. encephalartoides* Stevenson (2001: 40), *Z. boliviana*, and *Z. brasiliensis*. The unarmed petioles, relative geographic proximity, and broad similarities in reproductive structures suggest that *Z. boliviana* is the closest relative of *Z. brasiliensis*. However,

the two species are readily distinguishable based on differences in both vegetative and reproductive morphology. *Z. brasiliensis* has leaflets that are considerably broader (2.4–3.5 cm) than those of *Z. boliviana* (0.8–2 cm). The faces of the mature megasporophylls of *Z. boliviana* are much wider (18.1–21.9 cm) than those of *Z. brasiliensis* (14.1–15.0 cm). Additionally, fewer sporophyll orthostichies are found in *Z. boliviana* seed strobili (6–7) than in those of *Z. brasiliensis* (8–14). The pollen strobili in both species is yellow-cream tomentose, but in *Z. boliviana,* the color is solid, whereas in *Z. brasiliensis*, the sterile apex is covered with orange-brown tomentum (Fig. 2c). The three species are readily distinguishable based on quantitative and qualitative characters (Table 2). A taxonomic key to aid in the identification of these species is provided below.

Key to Southern Amazonia and Cerrado *Zamia* species

1. Petioles armed ..... *Zamia ulei*
- Petioles unarmed 2
2. Leaflets 2.4–3.5 cm wide..... *Zamia brasiliensis*
- Leaflets …0.8–2 cm wide..... *Zamia boliviana*

Acknowledgements

Funding for the fieldwork was generously provided by Lin Lougheed through the Montgomery Botanical Center Plant Exploration Fund. We thank the Instituto Federal de Educação, Ciência e Tecnologia de Mato Grosso for supporting the development of the doctoral thesis and associated research of the first author. Fernando Zagury Vaz-de-Mello of the Laboratório de Scarabaeoidologia at Universidade Federal de Mato Grosso (Cuiabá, Mato Grosso, Brazil) provided access to the laboratory facilities and equipment obtained through subproject EECBio of UFMT/Finep (agreement FINEP # 01.12.0359.00). Marcos Negrini provided some of the photographs used for developing the illustrations. Márcio Cassiano de Jesus, Onofre G. A. Caires, Rosa Maria da Silva Caires and Sebastião César de Freitas assisted with fieldwork. Joanna Tucker Lima and José Gilson Santos Lima provided habitat pictures and morphometric data of *Zamia ulei* from the Municipality of Marechal Thaumaturgo, Acre, Brazil for comparative purposes. We are grateful to Daniela Zappi for editing an early version of the manuscript, and to reviewer Sven Landrein for helpful comments and suggestions.

References

Acuña, R.H. (2010) A new species of *Zamia* (Zamiaceae) from Costa Rica. *Brenesia* 73–74: 29–33.

Applequist, W.L. (2012) Report of the Nomenclature Committee for Vascular Plants: 64. *Taxon* 61: 1108–1117. https://doi.org/10.1002/tax.615019

Breiner, F.T. & Bergamini, A. (2018) Improving the estimation of area of occupancy for IUCN Red List assessments by using a circular buffer approach. *Biodiversity and Conservation* 27: 2443–2448. https://doi.org/10.1007/s10531-018-1555-5

Brongniart, A. (1846) Sur un noveau genre de cycadées du Mexique. *Annales des sciences naturelles. Botanique* Ser. 3, 5: 7.

Calonje, M. (2009) A new cliff-dwelling species of *Zamia* (Zamiaceae) from Belize. *Journal of the Botanical Research Institute of Texas* 3: 23–29.

Calonje, M. & Meerman, J. (2009) What is *Zamia prasina* (Zamiaceae: Cycadales)? *Journal of the Botanical Research Institute of Texas* 3: 43–49.

Calonje, M., Meerman, J., Griffith, M.P. & Hoese, G. (2009) A new species of *Zamia* (Zamiaceae) from the Maya Mountains of Belize. *Journal of the Botanical Research Institute of Texas* 3: 31–41.

Calonje, M., Meerow, A.W. & Stevenson, D.W. (2010) The typification of *Zamia erosa* and the priority of that name over *Z. amblyphyllidia*. *Taxon* 59: 637–642. https://doi.org/10.1002/tax.592031

Calonje, M., Esquivel, H.E., Stevenson, D.W., Calonje, C. & Pava, D. (2011) A new arborescent species of *Zamia* from the Central Cordillera of Tolima, Colombia (Cycadales, Zamiaceae), with comments on the *Z. poeppigiana* species complex. *Brittonia* 63: 442–451. https://doi.org/10.1007/s12228-011-9190-4

Calonje, M., Esquivel, H.E., Morales, G., Mora-Lizcano, Y.A. & Stevenson, D. (2012) A new arborescent species of *Zamia* (Cycadales, Zamiaceae) from the department of Huila, Eastern Cordillera of Colombia. *Caldasia* 34: 8.

Calonje, M., Taylor-Blake, A.S., Stevenson, D., Holzman, G. & Ramos, Y.A. (2012) *Zamia lindleyi*: A misunderstood species from the highlands of western Panama. *Memoirs of the New York Botanical Garden* 106: 419–437.
https://doi.org/10.21135/893275150.026

Calonje, M., Morales, G., López-Gallego, C. & Roldán, F. (2015) A taxonomic revision of *Zamia montana* and *Zamia oligodonta*, with notes on their conservation status *Phytotaxa* 192: 279–289.
https://doi.org/10.11646/phytotaxa.192.4.5

Calonje, M., López-Gallego, C. & Castro, J. (2018) Zamia paucifoliolata, a new species of Zamia (Zamiaceae, Cycadales) from Valle del Cauca, Colombia. *phytotaxa* 385: 85–93.
https://doi.org/10.11646/phytotaxa.385.2.4

Calonje, M., Stevenson, D.W. & Stanberg, L. (2019) The World List of Cycads, online edition. Available from: http://cycadlist.org. (accessed 10 January 2019)
https://doi.org/10.21135/893275389.035

Candolle, A.L.P.d. (1868) Cycadaceae. *In: Prodromus systematis naturalis regni vegetabilis*. Candolle, A.P.D.C., A.L.P. De Ed., Paris, Treuttel & Würts., pp. 522–547.

Coe, M.T., Marthews, T.R., Costa, M.H., Galbraith, D.R., Greenglass, N.L., Imbuzeiro, H.M.A., Levine, N.M., Malhi, Y., Moorcroft, P.R., Muza, M.N., Powell, T.L., Saleska, S.R., Solorzano, L.A. & Wang, J. (2013) Deforestation and climate feedbacks threaten the ecological integrity of south–southeastern Amazonia. *Philosophical Transactions of the Royal Society B: Biological Sciences* 368: 20120155.
https://doi.org/10.1098/rstb.2012.0155

CPRM (1999) Mapa geológico do estado de Rondônia. Available from: http://www.cprm.gov.br/publique/media/geologia_basica/plgb/rondonia/rondonia_ctgeologica.pdf (accessed 1 January 2019)

Dammer, U. (1907) Cycadaceae. *In:* Ule, E. (Ed.) *Verhandlungen des Botanischen Vereins für die Provinz Brandenburg und die Angrenzenden Länder.* pp. 117–118.

ESRI (2018) *ArcGIS Desktop.* Environmental Systems Research Institute, Redlands, California.

Geiger, R. (1954) Classification of climates after W. Köppen. *In: Landolt-Börnstein—Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik und Technik.* [alte Serie]. Berlin, Springer.

Fick, S.E. & Hijmans, R.J. (2017) WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology* 37: 4302–4315.
https://doi.org/10.1002/joc.5086

Hübner, J. (1819) *Verzeichniss bekannter Schmettlinge.* Vol. 39. der Verfasser, Augsburg, pp. 17–176.

IBGE (2012) *Manual Técnico da Vegetação Brasileira.* Série Manuais Técnicos em Geociências 1, 2ª edição revista e ampliada, Rio de Janeiro, IBGE.

IUCN Standards and Petitions Sub-committee (2017) Guidelines for using the IUCN Red List Categories and Criteria. Version 13. Available from: http://www.iucnredlist.org/documents/RedListGuidelines.pdf (accessed 15 November 2018)

Karger, D.N., Conrad, O., Böhner, J., Kawohl, T., Kreft, H., Soria-Auza, R.W., Zimmermann, N., Peter Linder, H. & Kessler, M. (2017) Climatologies at high resolution for the earth's land surface areas. *Scientific data* 4: 170122
https://doi.org/10.1038/sdata.2017.122

Köppen, W. (1918) Klassification der Klimate nach Temperatur, Niederschlag and Jahreslauf. *Petermanns Geographische Mitteilungen* 64: 193–203, 243–248.

Kottek, M., Grieser, J., Beck, C., Rudolf, B. & Rubel, F. (2006) World Map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift* 15: 259–263.
https://doi.org/10.1127/0941-2948/2006/0130

Lindstrom, A.J. (2009) Typification of some species names in *Zamia* L. (Zamiaceae), with an assessment of the status of *Chigua* D. Stev. *Taxon* 58: 265–270.
https://doi.org/10.1002/tax.581025

Lindstrom, A.J. & Idarraga, A. (2009) *Zamia incognita* (Zamiaceae): the exciting discovery of a new gymnosperm from Colombia. *Phytotaxa* 2: 29–34.
https://doi.org/10.11646/phytotaxa.2.1.5

Lindstrom, A.J., Calonje, M., Stevenson, D.W., Husby, C. & Taylor, A. (2013) Clarification of *Zamia acuminata* and a new *Zamia* species from Coclé Province, Panama. *Phytotaxa* 98: 27–42.
https://doi.org/10.11646/phytotaxa.98.2.1

Linnaeus, C. (1763) *Zamia pumila*. *Species Plantarum* 2: 1659.

Mapbiomas (2018) *Project MapBiomas - Collection 3 of Brazilian Land Cover & Use Map Series*. Available from: http://mapbiomas.org (accessed 15 December 2018)

Nicolalde-Morejón, F., Vovides, A.P., Stevenson, D.W. & Sosa, V. (2008) The identity of *Zamia katzeriana* and *Z. verschaffeltii* (Zamiaceae). *Brittonia* 60: 38–48.
https://doi.org/10.1007/s12228-008-9000-9

Nicolalde-Morejón, F., Vovides, A.P. & Stevenson, D.W. (2009) Taxonomic revision of *Zamia* in Mega-Mexico. *Brittonia* 61: 301–335.
https://doi.org/10.1007/s12228-009-9077-9

Pérez-Farrera, M.A., Vovides, A.P., Ruiz-Castillejos, C., Galicia, S., Cibrián-Jaramillo, A. & López, S. (2016) Anatomy and morphology suggest a hybrid origin of *Zamia katzeriana* (Zamiaceae). *Phytotaxa* 270: 161–181.
https://doi.org/10.11646/phytotaxa.270.3.1

Pérez-Farrera, M.Á., Vovides, A.P., Martínez-Camilo, R., Martínez-Meléndez, N., Gómez-Domínguez, H. & Galicia-Castellanos, S. (2012) *Zamia grijalvensis* sp. nov. (Zamiaceae, Cycadales) from Chiapas, Mexico with notes on hybridization and karyology. *Nordic Journal of Botany* 30: 565–570.
https://doi.org/10.1111/j.1756-1051.2012.01453.x

Sasaki, D., Zappi, D., Milliken, W., Henicka, G.S.d. & Piva, J.H. (2010) *Vegetação e Plantas do Cristalino—um manual.* Alta Floresta, Mato Grosso: Royal Botanic Gardens, Kew/Fundação Ecológica Cristalino, 128 pp.

Schutzman, B., Adams, R., Haynes, J. & Whitelock, L. (2008) A new endemic *Zamia* from Honduras (Cycadales: Zamiaceae) *The Cycad Newsletter* 31: 22–26.

SEPLAN (2000) Secretaria de Estado de Planejamento (Brasil). Aspectos geomorfológicos da folha vila Guarita –MIR-300 (SC.21-Z-B) - Memória Técnica. Portal de Dados e Metadados Geográficos do Estado de Mato Grosso. Available from: http://metadados.seplan.mt.gov.br/metadados/srv/por/catalog.search#/home (accessed 17 November 2018)

Stevenson, D.W. (2001) *Flora de Colombia.* Monografia No. 21. Orden Cycadales, Bogota D. C., Colombia, Instituto de Ciencias Natural, Univrsidad Nacional de Colombia.

Stevenson, D.W., Cárdenas López, D. & Castaño, N. (2018) A new *Zamia* (Zamiaceae) from Colombia. *Brittonia* 70 (3): 364–368.
https://doi.org/10.1007/s12228-018-9535-3

Taylor-Blake, A.S. & Holzman, G. (2012) A Nnew *Zamia* species from the Panama Canal area. *The Botanical Review* 78 (4): 335–344
https://doi.org/10.1007/s12229-012-9105-4

Taylor, A.S., Haynes, J.L. & Holzman, G. (2008) Taxonomical, nomenclatural and biogeographical revelations in the *Zamia skinneri* complex of Central America (Cycadales: Zamiaceae). *Botanical Journal of the Linnean Society* 158: 399–429.
https://doi.org/10.1111/j.1095-8339.2008.00886.x

Tyukavina, A., Hansen, M.C., Potapov, P.V., Stehman, S.V., Smith-Rodriguez, K., Okpa, C. & Aguilar, R. (2017) Types and rates of forest disturbance in Brazilian Legal Amazon, 2000–2013. *Science Advances* 3 (4): e1601047
https://doi.org/10.1126/sciadv.1601047

Volkoff, B., Mello, F., Maia, S. & Eduardo Pellegrino Cerri, C. (2012) Landscape and soil regionalization in southern Brazilian Amazon and contiguous areas: methodology and relevance for ecological studies. *Scientia Agricola* 69 (3): 217–225.
https://doi.org/10.1590/S0103-90162012000300007

Ward, D.B. (2016) Keys to the flora of Florida - 32, *Zamia* (Zamiaceae) *Phytologia* 98: 170–178.

Zappi, D., Sasaki, D. Milliken, W., Iva, J., Henicka, G.S., Biggs, N. & Frisby, S. (2011) Plantas vasculares da região do Parque Estadual Cristalino, norte de Mato Grosso, Brasil. *Acta Amazonica* 41: 29–38.
https://doi.org/10.1590/S0044-59672011000100004