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Zamia paucifoliolata, a new species of *Zamia* (Zamiaceae, Cycadales) from Valle del Cauca, Colombia

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Abstract

Zamia paucifoliolata, a new cycad species from the Pacific lowlands of Valle del Cauca, Colombia, is described and illustrated. It is distinguished from other species of *Zamia* by having an underground stem typically bearing large solitary leaves with eighteen or fewer leaflets, villous strobilar axes, microsporangia borne on both the abaxial and adaxial side of microsporophylls, and seeds that are longer than 18 mm. It is compared to *Z. pyrophylla, Z. cunaria,* and *Z. ipetiensis*, species which it most closely resembles.

Keywords: Chocó biogeographic region, systematics, taxonomy

Resumen

Se describe y se ilustra *Zamia paucifoliolata*, una nueva especie de cícada de las tierras bajas del Pacífico Colombiano del Valle del Cauca. Se distingue de otras especies de *Zamia* por su tallo subterráneo típicamente cargando hojas solitarias con 18 folíolos o menos, ejes estrobilares vellosos, presencia de microesporangios en el lado abaxial y adaxial de los microesporofilos, y semillas de mas de 18 mm de longitud. Se compara con *Z. pyrophylla*, *Z. cunaria*, y *Z. ipetiensis*, las especies a las que más se asemeja.

Palabras clave: Chocó biogeográfico, sistemática, taxonomía

Introduction

With 78 species, the neotropical genus *Zamia* Linnaeus (1763: 1659) is the most speciose and broadly distributed genus in the New World (Calonje *et al*. 2018). Colombia hosts over a quarter of all *Zamia* species, making it the most species-rich country for the genus. A considerable amount of academic and taxonomic research on Colombian zamias has taken place over the last decade, including several new species descriptions (Lindstrom & Idarraga 2009, Calonje *et al.* 2010, Calonje *et al.* 2011, Calonje *et al*. 2012a, Stevenson *et al.* 2018) as well as taxonomic revisions (Lindstrom 2009, Calonje *et al*. 2012b, Calonje *et al*. 2015). Despite these recent and significant advances in Colombian *Zamia* systematics, additional research is still required, because several species remain undescribed or poorly understood, especially in the Amazonian region.

A visit in 2009 by the first author to the CUVC herbarium (Cali, Colombia) revealed an enigmatic *Zamia* specimen (*Gil Cardona et al. 577*) collected in 2002 in coastal forests of the Buenaventura municipality in Valle del Cauca, Colombia. The specimen consisted of a mature seed strobilus without any accompanying vegetative material. The strobilus had an extremely long peduncle unlike any other species known in the Valle del Cauca, but somewhat resembled that of Chocoan endemic species *Z. pyrophylla* Calonje *et al*. (2010: 80), albeit with much larger seeds. Recent expeditions to this region has revealed this enigmatic taxon to be an undescribed species, which we formally describe below. The new species has morphological affinities with *Z. pyrophylla*, *Z. cunaria* Dressler & Stevenson (in Stevenson 1993: 5), and *Z. ipetiensis* Stevenson (1993: 7).

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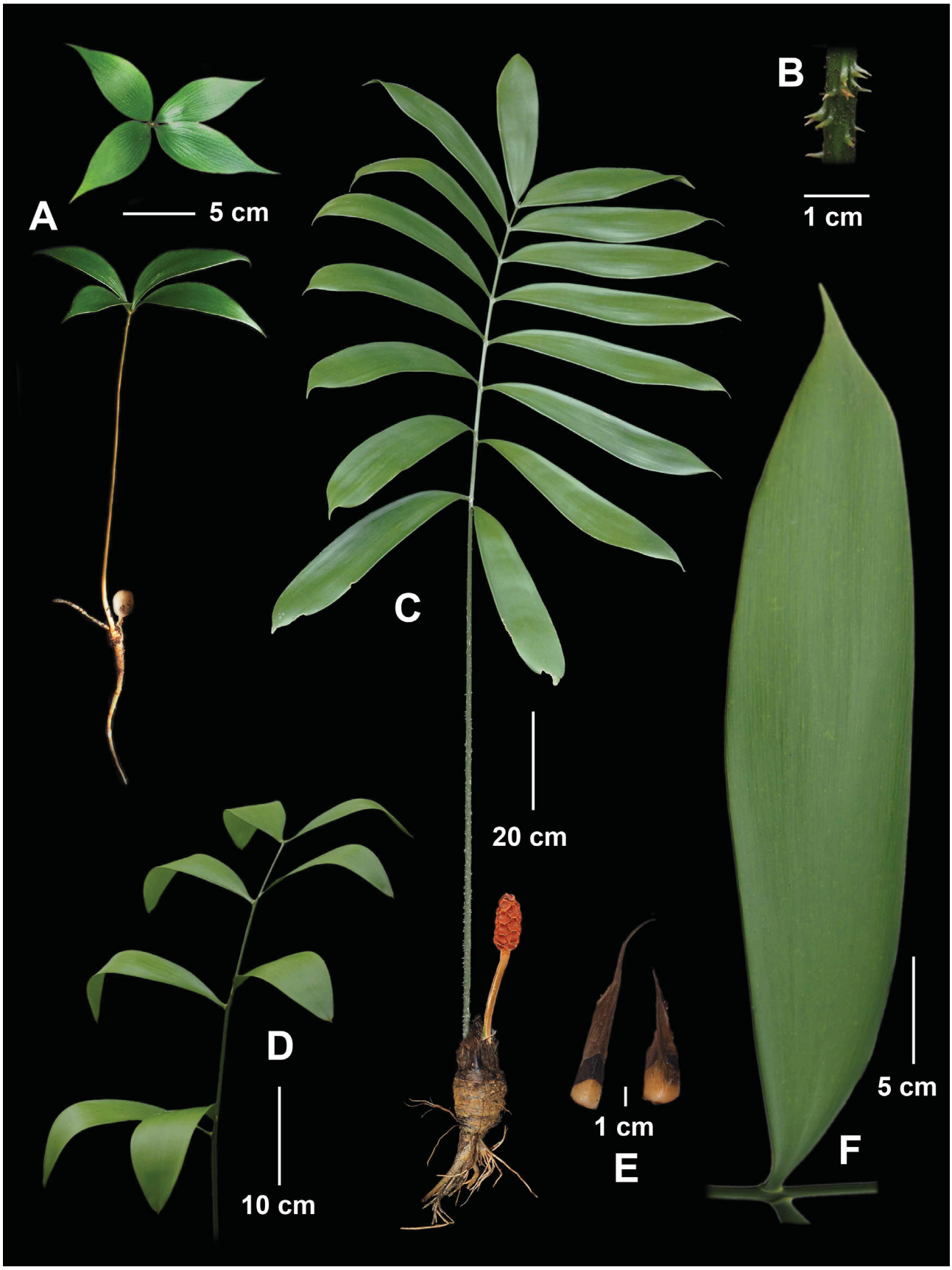

FIGURE 1. Vegetative characteristics of *Zamia paucifoliolata*. A. Seedling with eophyll, top and side view. B. Center of petiole showing prickles. C. Adult plant with immature seed strobilus. D. New leaf flush. E. Cataphylls. F. Middle leaflet of adult plant.

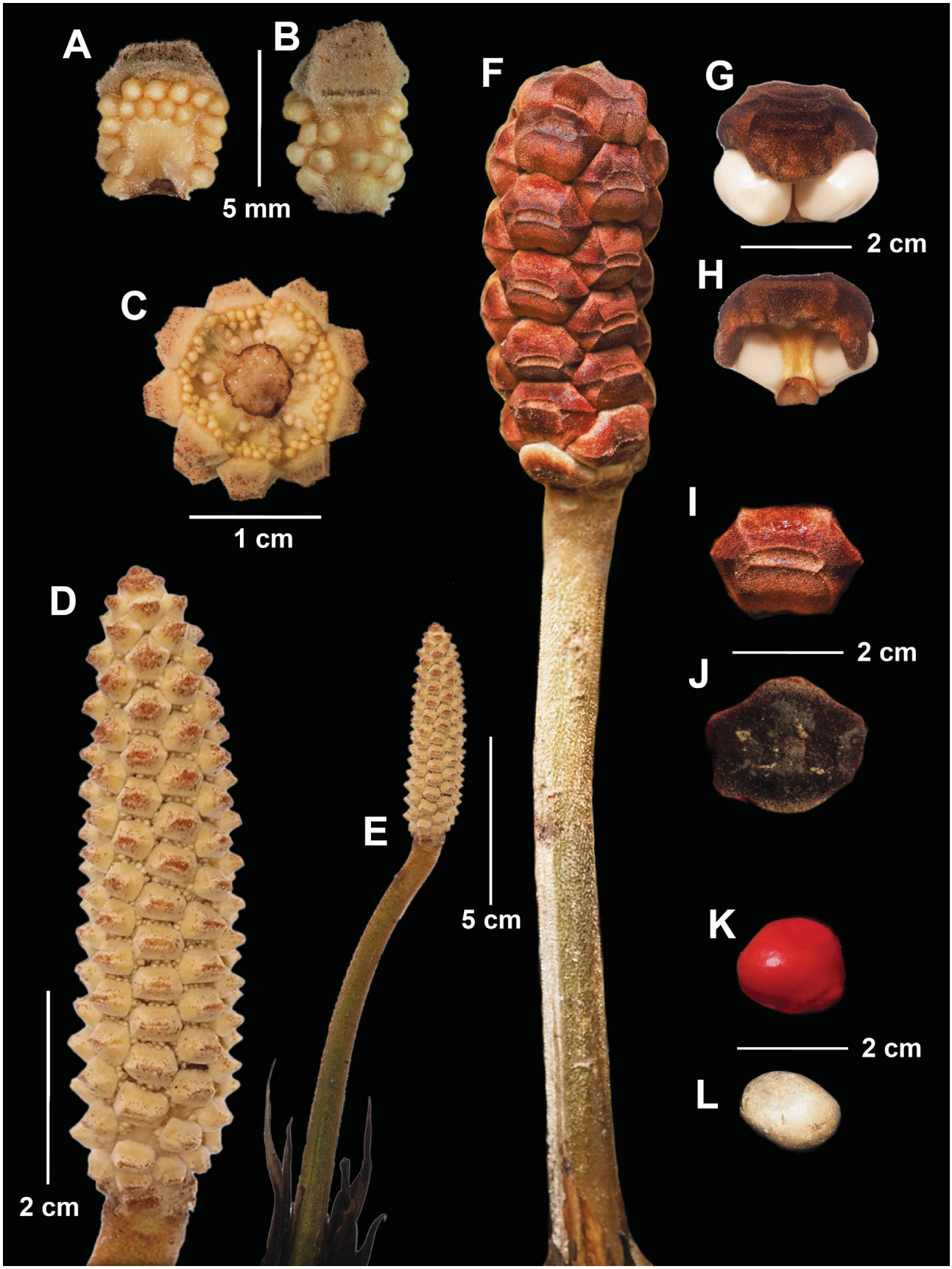

FIGURE 2. Reproductive characteristics of *Zamia paucifoliolata*. A. Microsporophyll, adaxial side. B. Microsporophyll, abaxial side. C. Cross section of pollen strobilus, adaxial side. D. Closeup of pollen strobilus near pollen release stage. E. Pollen strobilus with peduncle near pollen release stage. F. Immature seed strobilus. G. Megasporophyll with immature seeds, adaxial side. H. Megasporophyll with immature seeds, abaxial side. I. Megasporophyll face, immature. J. Megasporophyll face, mature. K. Seed with ripe sarcotesta. L. Seed sclerotesta. A–I based on collection *López-Gallego et al. 68–69* (HUA), J–K based on *Castro et al. 1118–1119* (HUA), L based on *Castro et al. 1289* (holotype HUA; isotypes COL, CUVC, FMB, JAUM, MEDEL, TOLI).

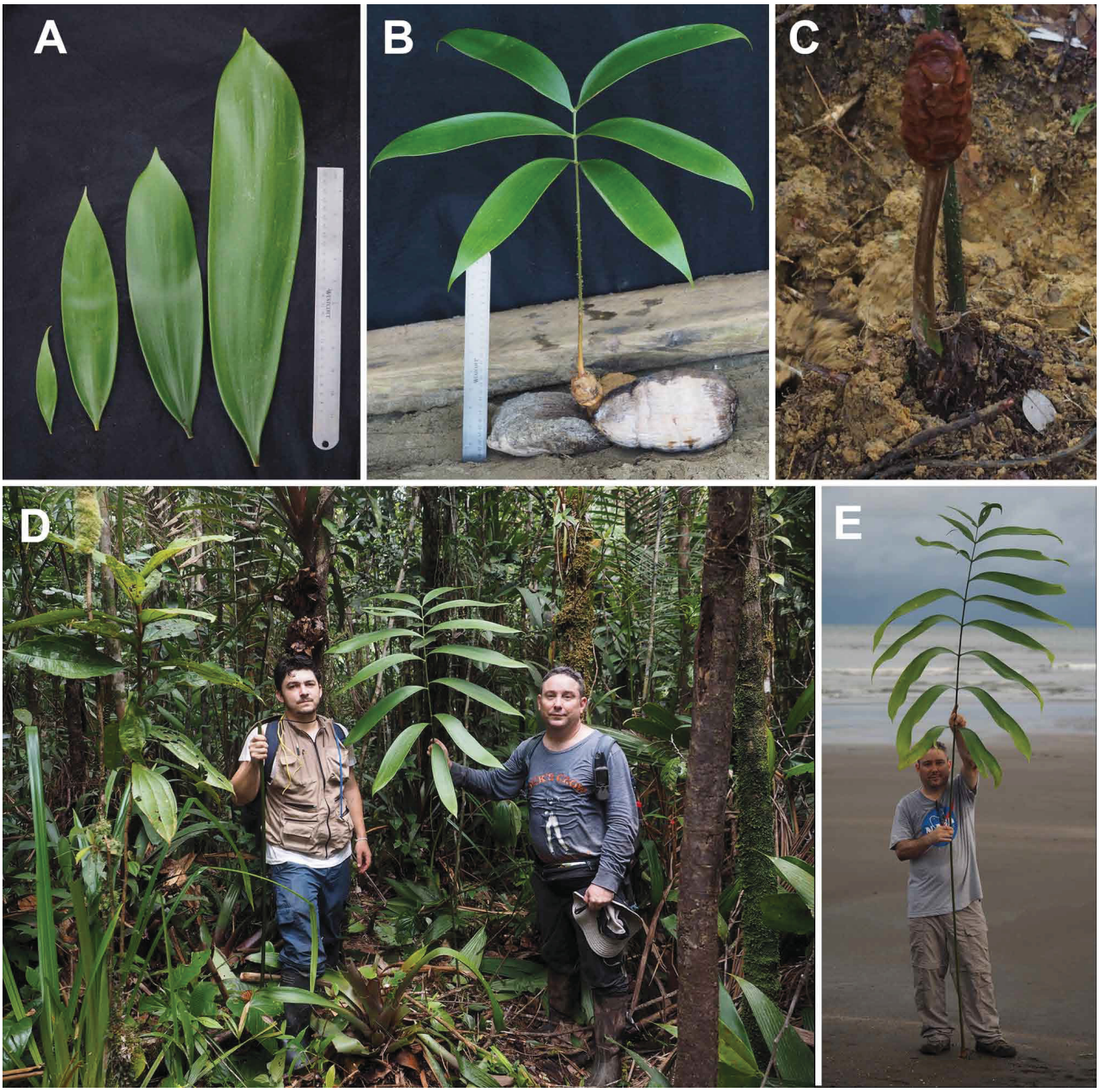

FIGURE 3. *Zamia paucifoliolata* in its natural habitat at the type locality. A. Middle leaflets collected from plants at different stages of development. B. Juvenile plant. C. Adult plant with seed strobilus, showing yellow clay soils in which the species grows. D. Adult plant in habitat with Jonatan Castro (left) and Michael Calonje (right). E. The largest leaf yet observed for this species, measuring 285 cm long and carrying 18 leaflets.

Zamia paucifoliolata Calonje *sp. nov.* (Figs. 1–3)

Diagnosis:—*Zamia paucifoliolata most closely resembles Z. pyrophylla from which it is distinguished by the light green leaf flushes, the leaflets that are broader and less numerous, the fewer and larger* mature *megasporophylls and seeds, and the lighter colored pollen strobili.*

Type:—COLOMBIA. Valle del Cauca: Municipio de Buenaventura, 15–50 m, 25 June 2018. *J. Castro et al. 1289* (holotype HUA; isotypes COL, CUVC, FMB, MEDEL, TOLI).

Additional specimens examined:—COLOMBIA. Valle del Cauca: Municipio de Buenaventura: *Castro et al. 1118–1119* (HUA), *Gil Cardona et al. 577* (CUVC), *López-Gallego et al. 68–69* (HUA).

Description:—*Stem* hypogeous, unbranched, globose to cylindrical, 8–21 × 1–11 cm. *Cataphylls* caducous, triangular to narrowly triangular, 4–11 cm long and 0.6–2 cm wide at base, proximally carnose and glabrous,

transitioning to chartaceous and dull distally, with separate cream, black, and brown colored sections proceeding acropetally. *Ptyxis* inflexed. *Leaves* typically solitary, rarely in pairs, erect, 20–285 cm long. *Petiole* 15–176 cm long with abruptly swollen base to 4 cm wide, moderately to densely covered with stout, sometimes branching prickles to 5 mm long. *Rachis* 0.2–109 cm long, slightly recurved, typically unarmed or very sparsely armed with prickles in proximal quarter. *Leaflets* 2–18, chartaceous to coriaceous, oppositely or sub-oppositely arranged, articulate insertion on rachis 2–7 mm wide, spaced to 17 cm apart at leaf center, lanceolate and with acute apex on smaller plants, becoming more obovate and with an abruptly acuminate apex on older plants, margins entire, basal leaflets 6.5–60 cm × 2.7–9.5 cm, middle leaflets 28–61 cm × 6.0–11.5 cm, apical leaflets 6.5–53.5 cm × 2.7–10 cm, light green on new leaf flushes, turning dark green at maturity. *Eophylls* with unarmed petioles 15–26 cm long, rachis 2–3 mm long, carrying two to four leaflets 6.5–12.5 × 1.7–2.5 cm. *Pollen strobili* 4–6, conical-cylindrical, spreading or decumbent with fertile section held vertically, at pollen shedding 6.5–6.8 × 1.8–2.0 cm, strobilar axis and proximal section of microsporophyll villous with white hairs, peduncles light green covered with orange tomentum, 17.5–20 × 0.6–0.8 cm. *Microsporophylls* spirally arranged in 8–9 orthostichies of 12–13 sporophylls each, obtrullate, 6.5–8 × 4.5–5 mm at pollen shedding, sterile apex encompassing 1/4 to 1/3 of the total microsporophyll length, tomentose, cream colored in proximal half, speckled with reddish-brown hairs in distal half, face hexagonal to oblong hexagonal, 3.5–5.0 × 4.0–5.0 mm, extruded downward to a narrow indented horizontal facet, abaxial surface of microsporophyll with 15–20 microsporangia limited to the proximal half and along the margins, adaxial surface with 8–11 microsporangia limited to the distal half. *Ovulate strobili* cylindrical, solitary, erect at maturity, 10–13 × 5–6 cm, reddish-brown tomentose when young, gradually becoming black at maturity, sterile apex acute, 0.3–1.0 cm, strobilar axis and megasporophyll pedicel villous with white hairs, peduncles 20–29 × 1.5–2.5 cm, maturing from light cream tomentose to tan tomentose with green undertones. *Megasporophylls* spirally arranged in 6 orthostichies of 3–5 sporophylls each, pedicel 14–16 mm long, villous with white hairs, sterile apex 19–20 mm deep with hexagonal to oblong-hexagonal distal face 23–25 × 28–34 mm, roundly extruded to a narrow, shallowly depressed terminal facet. Megasporophyll face tomentose. Seeds ovoid, at maturity 20–24 mm × 14–17 mm with red sarcotesta, sclerotesta 18–22 × 12–15 mm.

Etymology:—The specific epithet refers to the small numbers of maximum leaflets produced by leaves of this species which are among the least numerous of any species of *Zamia*. Leaves on adult plants carry between 10 and 18 leaflets (n=135 leaves, mode=10, mean 11.6), and only a few species with broad, prominently-veined leaflets carry the same number or fewer leaflets. Namely, *Z. wallisii* Braun (1875: 376), with the broadest leaflets in the genus, has leaves with a maximum of 11 leaflets, *Z. dressleri* Stevenson (1993: 6) carries up to 14 leaflets, and *Z. imperialis* Taylor *et al*. (2008: 421) similarly carries a maximum of 18 leaflets. The small number of leaflets carried by leaves of *Z. paucifoliolata* readily distinguishes it from its putative relatives *Z. cunaria*, *Z. ipetiensis*, and *Z. pyrophylla*, all of which carry a maximum of 32 leaflets.

Distribution and habitat:—*Zamia paucifoliolata* is known only from the Buenaventura Municipality of Valle del Cauca, Colombia (Fig. 4), where it occurs in coastal forests classified as transitional between tropical wet and tropical pluvial forest (Vásquez-Vélez *et al.*, 2013). The forest in this region is characterized by having few large trees, with most being of low average diameter, height and biomass (Faber-Langendoen & Gentry 1991), and the most common families being Annonaceae, Euphorbiaceae, Fabaceae, Melastomataceae, and Myristicaceae (Vásquez-Vélez *et al*. 2013). The soils are a combination of mottled gray-yellow clays and coarse grained alluvial soils with an acidic pH that are highly saturated with aluminum and contain very low levels of nutrients, especially phosphorus, boron, and zinc (Faber-Langendoen & Gentry 1991). Despite the poor soils, the lowland forests of the Chocó biogeographic region, which include coastal Colombia and adjacent Ecuador, are among the most species-rich plant communities in the world and contain unusually high levels of plant endemism (Gentry 1986). Indeed, the area where *Z. paucifoliolata* occurs and its immediate vicinity may host the highest concentration of *Zamia* species anywhere in the world. The peninsula between Buenaventura and Malaga bays, encompassing about 400 square km, hosts five species of *Zamia*. These are *Z. amplifolia* Bull in Masters (1878: 810), *Z. chigua* Seemann (1854: 201), *Z. obliqua* Braun (1875: 376), *Z. paucifoliolata*, and *Z. roezlii* Linden (1873: 10)) as well as a hybridization zone between *Z. amplifolia* and *Z. chigua*. Single individuals of *Zamia chigua* and *Z. roezlii* have been found growing sympatrically with *Z. paucifoliolata* but no evidence of hybridization is observed.

Climate:—The Chocó biogeographic region is one of the wettest regions on earth. The average annual precipitation within this species' distribution range is 7000–7700 mm. The wettest months are October and November, and the driest ones February and March. The temperature ranges from 24° C to 28° C, with a mean temperature between 25.8 ° C and 26 ° C. Temperature data was derived from GIS analysis using Worldclim2 bioclimactic variables as described by Fick & Hijmans (2017).

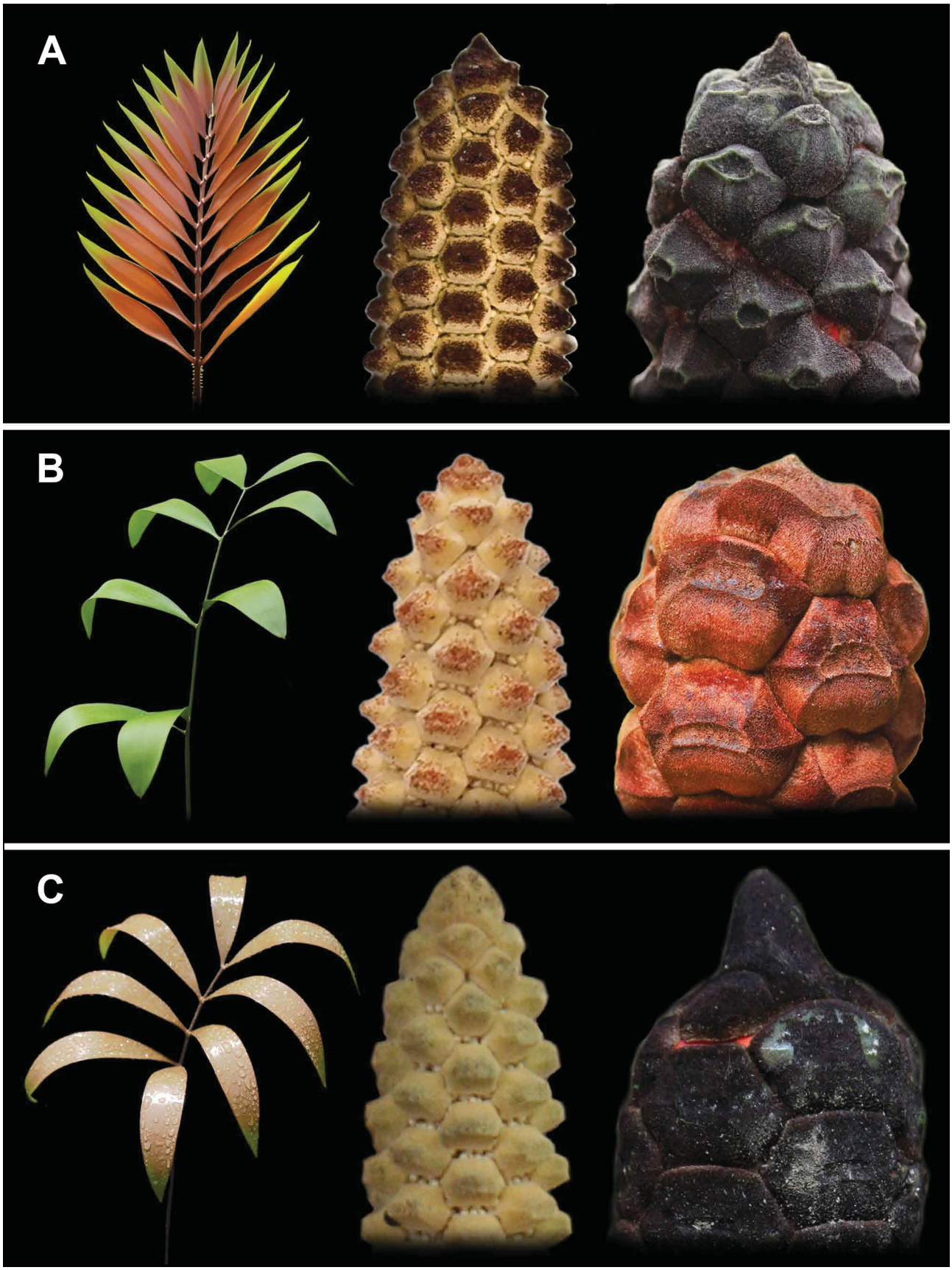

FIGURE 4. Comparison of qualitative characters of morphologically similar species of *Zamia*. From left to right, new leaf flushes, close-up view of pollen strobilus, and close-up view of seed strobilus of *Zamia pyrophylla* (A), *Zamia paucifoliolata (*B) and *Zamia ipetiensis* (C). A & B photographed at type locality, C from *Calonje et al. MAC08-089* (PMA) from Kuna de Wargandí, Panama.

Ecology:—The known populations of the species appear to be viable, with a larger proportion of juveniles compared to adults, i.e. evidence of reproduction and regeneration. Plants are distributed in highly dense patches on the understory of the forest, on moderately steep slopes and near small streams. Little is known about leaf phenology, frequency or rate of strobilus production or germination time. Mature seed strobili with ripe seeds have been observed in February and May, whereas pollen strobili have only been observed in late August. Immature seed strobili have been observed in June, August, and September. There is no information yet about microrganisms associated to roots or species interactions involved in pollination or seed dispersal, but a good proportion of viable seeds has been observed in female strobili. The typical herbivores associated to *Zamia* species, *Eumaeus* Hübner (1819: 67), have not been observed yet either, but there were signs of herbivory by leaf miners. A permanent plot has been established in one of the populations to monitor population dynamics and other ecological aspects of the species.

Conservation:—This species is known only from two localities approximately 5 km apart from each other within the Buenaventura Municipality of Valle del Cauca, Colombia. Plants are locally abundant at both of these locations and there is evidence of recruitment. The intervening area between these localities is forested and likely harbors additional plants. Even so, the entire known range for this species is only 3 km^2, and the combined area of the two surveyed populations (area of occupancy) is only 0.5 km^2. One locality lays within a private natural reserve, with a good level of habitat protection, but the other one is immediately adjacent to a rapidly developing beach resort town, where habitat destruction for housing development and selective logging are likely to result in habitat destruction and degradation in the near future. Approximately 300 adult individuals occur at these two places. Based on the above, we recommend this species be listed as Endangered (EN) based on IUCN Red List criteria B1ab(i-v)+2ab(i-v) (IUCN 2017). Colombia has a national conservation action plan for cycads (López-Gallego 2015), and the species will be included in this conservation plan to ensure the long-term protection of both populations and their habitats.

TABLE 1. Distinguishing traits of *Zamia paucifoliolata*, *Z. pyrophylla*, and *Z. ipetiensis*

Trait	*Zamia paucifoliolata*	*Zamia pyrophylla*	*Zamia ipetiensis*
Leaf flush color	Light green	Combination of orange, yellow and red colors	Green or rosy brown
Leaflet number	2 to 20	4 to 32	4 to 32
Leaflet size (middle)	28–61 × 6.0–11.5 cm	24.5–55 × 4–7.1 cm	22–49.7 × 3.5–7 cm
Leaflet margin	Entire throughout	Entire throughout	Finely serrulate at distal end
Microsporophyll color	Cream colored with reddish brown speckled apex	Cream colored with solid brown apex	Cream colored throughout or with tan/brown speckled apex
Megasporophyll apex	Apex blunt	Apex pungent	Apex blunt
Megasporophyll face	Strongly extruded, rounded in appearance, terminal face moderately indented	Strongly extruded, angular in appearance, terminal facet strongly indented	Flat to slightly extruded, terminal facet weakly indented
Megasporophyll number	6 orthostichies of 3–5 sporophylls each	7–10 orthostichies of 5–11 sporophylls each	7–10 orthostichies of 5–14 sporophylls each
Seed sclerotesta	18–22 × 12–15 mm	10–15.6 × 9.5–13.2 mm	12–15 mm × 8–10 mm

Morphological affinities:—*Zamia paucifoliolata* most closely resembles the Colombian species *Z. pyrophylla*, and the Panamanian species *Z. cunaria*, and *Z. ipetiensis* (Fig. 4), the latter two names treated here together as *Z. ipetiensis* due to a lack of diagnostic character separating them (pers. obs. by MC). All species within this group have unbranched subterranean stems typically carrying single leaves, microsporangia present on both the abaxial and adaxial surfaces of microsporophylls, and villous axes in both the pollen and ovulate strobili. The Colombian species are readily distinguished vegetatively by their leaflets with entire margins compared to those of the Panamanian species which have margins with fine serrations limited to the distal third of the leaflets. Furthermore, the megasporophyll faces of the Colombian species are more strongly extruded and the terminal facets more indented than those of the Panamanian species. *Zamia paucifoliolata* produces fewer and larger leaflets, sporophylls, and seeds than any of the other species. All constituent species of this group are readily distinguishable based on quantitative and qualitative characters (Fig. 5, Table 1). A taxonomic key to aid in the identification of these species is provided below.

Key to the new species and other morphologically similar species of *Zamia*

1. Leaflets with finely serrulate apex; terminal facet of mature megasporophyll face flat to slightly extruded, Panama ..... *Zamia ipetiensis*
- Leaflets with entire apex; terminal facet of mature megasporophyll face moderately to strongly extruded, Colombia 2
2. New leaf flushes solid light green, microsporophylls cream colored with reddish brown speckled apex, seeds more than 18 mm long ..... *Zamia paucifoliolata*
- New leaf flushes in various combinations of warm colors (orange, yellow, and red), microsporophylls cream colored with solid brown apex, seeds less than 12 mm long ..... *Zamia pyrophylla*

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