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Research Article

Rediscovery of *Passiflora clypeophylla* (subgenus *Decaloba*): a highly threatened and narrow endemic species found within a karstic canyon in Guatemala

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Passiflora clypeophylla, an endemic species to the Guatemalan karstic forests last seen in 1889 and deemed extinct, was rediscovered in the Department of Alta Verapaz, east of Cobán. The species was known only from a single specimen hailed from the type locality, Rubel Cruz, where it has been found again. An additional location has been identified in a similar habitat near it. The current study further presents a revised morphological description of *P. clypeophylla* based on this new material, along with notes on its ecology and preservation. Though now known from two populations, the IUCN Red List Criteria classify *P. clypeophylla* as 'Critically Endangered' (CR).

Key words: biodiversity, critically endangered, Decaloba, Passifloraceae, Verapaz



Introduction

The Passifloraceae family comprises 17 genera totalling approximately 750 species. The namesake genus is *Passiflora*, which can be found naturally throughout tropical Latin America, Indochina and Oceania, from the coastal lowland forest up to about 4200 m a.s.l. in the high Andes (Ulmer and MacDougal 2004). Many of the larger species are admired for their economic, ornamental or pharmaceutical values, whereas other species are lesser praised since they have small inconspicuous anatomy and no known medicinal properties (Yockteng et al. 2015). Yet, the *Passiflora* species are important ecological keystone species, featuring coevolutionary relationships with many organisms: including ants, herbivores including many members of *Lepidoptera*, seed dispersers consuming the fruit, pollinators including bees and birds, and surrounding plant communities (Muschner et al. 2012). Large-scale changes in land-use and agricultural development are threatening the ecological balance on which *Passiflora* depends, and many species are experiencing significant declines in population to the point of



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becoming [critically] endangered. A few species are even considered extinct by IUCN and Red List criteria, stressing the necessity for drastically increasing conservation efforts to help preserve the endangered species clinging on to the edge of survival.

Passiflora clypeophylla, a species belonging to *Passiflora* subgen. *Decaloba*, was originally described by Maxwell Masters, and published as a taxonomic novelty in the Botanical Gazette 16: 6–7 in 1891 (Killip 1938). This description was based on a single specimen collected by John Donnell Smith in April 1889, whom in the locality description with the specimen merely provided the words: ‘Barranca Rubel Cruz’, and ‘Alta Verapaz, alt. 2500 pp.’. J.D. Smith was a well-respected North American plant collector, who travelled extensively for his ‘*Enumeratio plantarum Guatemalensium*’ (1889–1907) that described 3736 plant species from Guatemala alone. He must have visited the region during the early stages of this work, and many species found within the Barranca Rubel Cruz today bear his name, e.g. *Louteridium donnell-smithii* and *Roseodendron donnell-smithii*. Rubel Cruz is the name of an indigenous Mayan community high up in the karstic regions of Alto Verapaz, perched atop a steep barranca or canyon of which rivers feed into the Rio Cahabon, ultimately leading to the city of Cobán. Cultural and geopolitical struggles between the indigenous Q’eqchi’ Maya and RENACE (the hydroelectrical scheme in the region) over land ownership has created prominent problems for accessibility and trust between the local communities and ‘extranjeros’, either Guatemalteca or foreign, making access to all nearby indigenous-owned land without local guides practically prohibited.

Comprehensive and well-curated herbarium collections play a critical role in elucidating species relationships, documenting morphological variation, identifying habitat and climatic preferences, and informing conservation status. The local socioeconomic disputes in the region preventing further botanical surveying offered a compelling case study with *Passiflora clypeophylla* highlighting the limitations of relying solely on historical specimens and sparse data. In much of Latin America, many species were initially described by foreign botanists who had restricted access to local material and these localities have not since been revisited, leaving important gaps in knowledge such as the full extent of distribution, phenological patterns or morphological variegation. Local experts are geographically positioned to fill these gaps, but a prevailing lack of interest in certain plant groups has slowed progress, perpetuating taxonomic and ecological blind spots. This is particularly pressing within karstic forest ecosystems of Guatemala, known for their high levels of endemism and species with highly restricted distributions, often housing taxa known only from a handful of specimens or locations due to its topographic and geological isolation. This is reflected by the absence of *P. clypeophylla* from the surrounding areas where more frequent ecological surveying or tourist visitation has taken place, showing this highly restricted distribution.

Four targeted expeditions conducted in 2008, 2012, 2016 and 2018 tried to locate *Passiflora clypeophylla*, however. None of these attempts succeeded in getting access to the specific region, let alone the Rubel Cruz canyon or enter its

forbidden confines. Instead, these expeditions were focused on surveying the surrounding karstic and non-karstic lands or access roads between communities which evidently have a different species composition. Thanks to family ties between the second author and the Q’eqchi’ Maya, the authorial team was able to gain access into the Rubel Cruz canyon and survey the forests within leading to this rediscovery. Finding *P. clypeophylla*, which thus far was represented merely by a single specimen of which the leaves and flowers have since deteriorated significantly limiting botanical usage, showcases the extremely restricted distribution of the species that is limited to this karstic forest. The new material also allowed for a detailed analysis of the morphology, to amend and improve the original description, and understand its ecological relationship with the wider ecosystem. Finally, new herbarium material that is carefully pressed, prepared and dried has been stored at the Universidad de San Carlos (BIGU), making it digitally available to the public. This rediscovery has elevated *P. clypeophylla* from the IUCN class Extinct (EX), back to ‘Critically Endangered’ (CR), cultivating living material in local collections to preserve the species for future generations (Porter-Utley 2014, IUCN 2003, 2024).

Material and methods

There were only two known specimens of *Passiflora clypeophylla* in the world, located at the Royal Botanical Gardens Kew Herbarium (K) and at the United States National Herbarium (US). Both were from the same collection (syntypes), making the species known from just a single collection (that of 1889 by J. D. Smith). Both specimens were examined in detail to help identify the diagnostic traits of *P. clypeophylla*, enabling identification of the species in the field. Additional specimens from the major herbaria in Guatemala: Universidad del Valle de Guatemala (UVAL) and Universidad de San Carlos (BIGU), were studied, though these show no additional records corresponding with *P. clypeophylla*. In addition, online records regarding other major herbaria (e.g. B, MEXU, NY, P, TEX) show no matching material for this species, limiting the known material to just the original collection (digitized specimens examined) and the historic manuscript from 1891.

The fieldwork was organized in conjunction with local contacts of the second author. Target sites were selected using satellite imagery (ArcGIS Pro), the original collection site, and accessibility using routes or walking trails. During the rediscovery of *Passiflora clypeophylla*, high quality photographs of *in situ* plants were taken and both new herbarium material and living material were collected. This material is incorporated here to provide an improved morphological description that more accurately reflects *P. clypeophylla* based on living plants. In particular the structure and colour of the flower have been greatly improved upon, since these details were imperceptible in the older herbarium specimen. New information has been added describing the fruit and mature seeds, as well as providing additional ecological information using a closer evaluation of its habitat and coexisting species. The conservation assessment was elaborated based on

the number of individuals found in the field, following the IUCN criteria (Bachman et al. 2011; IUCN 2003, 2024).

Results and taxonomic treatment

Passiflora clypeophylla Mast. (subgenus *Decaloba*, supersection *Cieca*)

Type: Guatemala, Department of Alta Verapaz, Barranca del Rubelcruz, April 1889, John Donnell-Smith 1625 (holotype: K, No. 323141; isotype: US, No. 36858).

New specimen: Guatemala, Department of Alta Verapaz, Barranca del Rubelcruz, 882 m a.s.l., 21 Feb. 2024, J.R. Kuethe, Dennis Medina, Saban Sequen, Markus Varga, Jan Rasche, Josef Sochtingen 210224-1 (USCG 51259).

Description

Herbaceous tendrillate vine, 3–5 m long, glaucous throughout. Stems flattened, very wiry, becoming slightly woody at base, green to reddish, becoming deep red when exposed to direct sunlight; internodal distance 7–16 cm. Stipules narrowly ovate-triangular, acute, 2.9–5.2(–6.4) mm long, 0.6–1.1 mm wide, glabrous, light green. Petioles terete, 3.3–3.8(–5.6) cm long, green to slightly reddish, with two opposite to subopposite nectaries borne near the middle but in proximal half of the petiole; glands sessile to discoid, 0.8–1.2 mm wide, 0.5–1.0 mm high. Laminas deltoidal, subrotund to obscurely three-lobed, 6.0–8.7(–9.4) cm long, 6.7–10.8(–12.2) cm wide, membranaceous to subcoriaceous, distinctly peltate at base, with distance from leaf base to point of petiole insertion 7.6–15.1 mm; lateral lobes (when present) somewhat elliptic, obtuse to rounded or marginally emarginate at apex, 4.0–7.1 cm long, 3.2–5.8 cm wide; margins entire, hyaline; primary veins 3, diverging and branching above base, 5.0–7.6 cm long; lateral veins 4.0–6.4 cm long; laminar nectaries absent; adaxial surface a deep shiny green, abaxial surface silverish green to grey. Inflorescence axillary with flowers borne in pairs in the leaf axils. Peduncles 4.5–12.3 cm long, terete; bract(s) absent. Flowers 23.2–26.3 mm in diameter, green with brown-purple, upright oriented; hypanthium discoidal, 6.8–7.2 mm in diameter, green, glabrous; sepals narrow to ovate triangular, 9.1–10.3 mm long, 4.3–5.2 mm wide, acute to narrowly rounded at apex, ecoriaceous, light green at both sides; petals absent; coronal filaments in 2 series, the outer 5.2–6.0 mm long, linear, spreading, brown-purplish to reddish in basal half, turning greenish-yellow to yellow in apical half, stout, the inner 2.4–2.7 mm long, linear, capitate, erect, purplish-brown to reddish, with a distinct greenish swollen knob at apex that is ca 0.9–1.0 mm in diameter; operculum 1.32–1.52 mm long, plicate, purplish to reddish at base with whitish-yellow apex, at margin with narrow, minutely fimbriate teeth; limen floor 2.7 mm in diameter, greenish yellow with purplish to reddish spots; androgynophore 4.0–5.2 mm tall, green with few reddish spots in basal half; ovary globose to ellipsoid, 1.8–2.2 mm long, 1.5–1.8 mm wide, green, glabrous. Stamens five; filaments 1.9–2.3 mm long, green; anthers 1.5–1.6 mm, greenish yellow. Pistils three; styles 3.1–3.4 mm, green; stigma globular, 1.0–1.1

mm, slightly darker green. Fruit a deep purple to blackish berry, globose to subglobose, 18–27 mm wide; pericarp whitish. Seeds foveolate, 5.2–5.6 mm long, 2.10–2.23 mm wide, dark brown, with irregular blackish pits. (Fig. 1)

Phenology

Passiflora clypeophylla was found flowering in February (the 2024 collection) and April (the 1889 collection), with both young and [few] mature fruits seen during the February collection. This phenology corresponds to the beginning of the local dry season.

Distribution

Passiflora clypeophylla is shown to be an extremely rare, narrow endemic found only in the karstic cliff exposures of Rubel Cruz, Department of Alta Verapaz. It was noted that the specimens grow only in partial shade, where it is anchored directly within near vertical crevasses of limestone outcrops (Fig. 2). Among the four plants sighted, two separate populations could be assigned based on presence and abundance within their habitat. Based on this new georeferenced data, the Area of Occupancy (AOO) is calculated to be less than 4 km², with an Extent of Occurrence (EOO) of 0.022 km². The forest within the canyon is distinct tropical calcareous wet forest, the dry periods compensated with moisture and fog remaining within the canyon structure providing a ‘wet climate’ year-round. Average rainfall (based on nearby Cobán) is about 2000–2500 mm annually. The forest is primary in composition and distinctly layered, showing a canopy of Piperaceae, Malvaceae, Bignoniaceae and Bixaceae, with understory composed of Begoniaceae, *Louteridium* Watson, Solanaceae and Melastomataceae. Epiphytes of Bromeliaceae, *Anthurium* Schott and Orchidaceae aligning the tree trunks and major branches. The river running through is spring-sourced and clear (non-polluted), showing some evidence of rain-induced flash floods that eradicates bank-vegetation which is thus mostly composed of pioneering species. Rare Orchid species, including *Anathallis* spp. Barb. Rodr., *Acianthera* spp. Scheidw. and *Scaphosepalum* spp. Pfitzer. were seen as epiphytic vegetation on higher- and medium canopy trees, with vines including of *Philodendron* Schott, *Monstera* Adans and *Camonea* Raf. showing prominent presence along its trunks (Fig. 3).

Only three species of *Passiflora* were seen within the canyon, though it is possible several more were hidden out of reach. *Passiflora choconiana* Watson and *Passiflora* aff. *biflora* Lam. were found growing near the river, whereas *Passiflora clypeophylla* was seen growing only along the canyon’s flanks. It was noted that *P. clypeophylla* grows solely on pure limestone, exploiting cracks or crevasses where it is rooted directly into the highly alkaline bedrock. Within *Passifloraceae*, this is a trait seen only in the Jamaican endemic *P. calcicola* Proctor (Kay 2001, 2003, Kuethe pers. observ. 2023). In addition, *P. clypeophylla* appears to be restricted to the partial shade of the understory, where it grows solely in the presence of rivers indicating that a continual humidity is required for the species to survive. Aridification, or the changing or draining of the local waterways would therefore be highly detrimental for

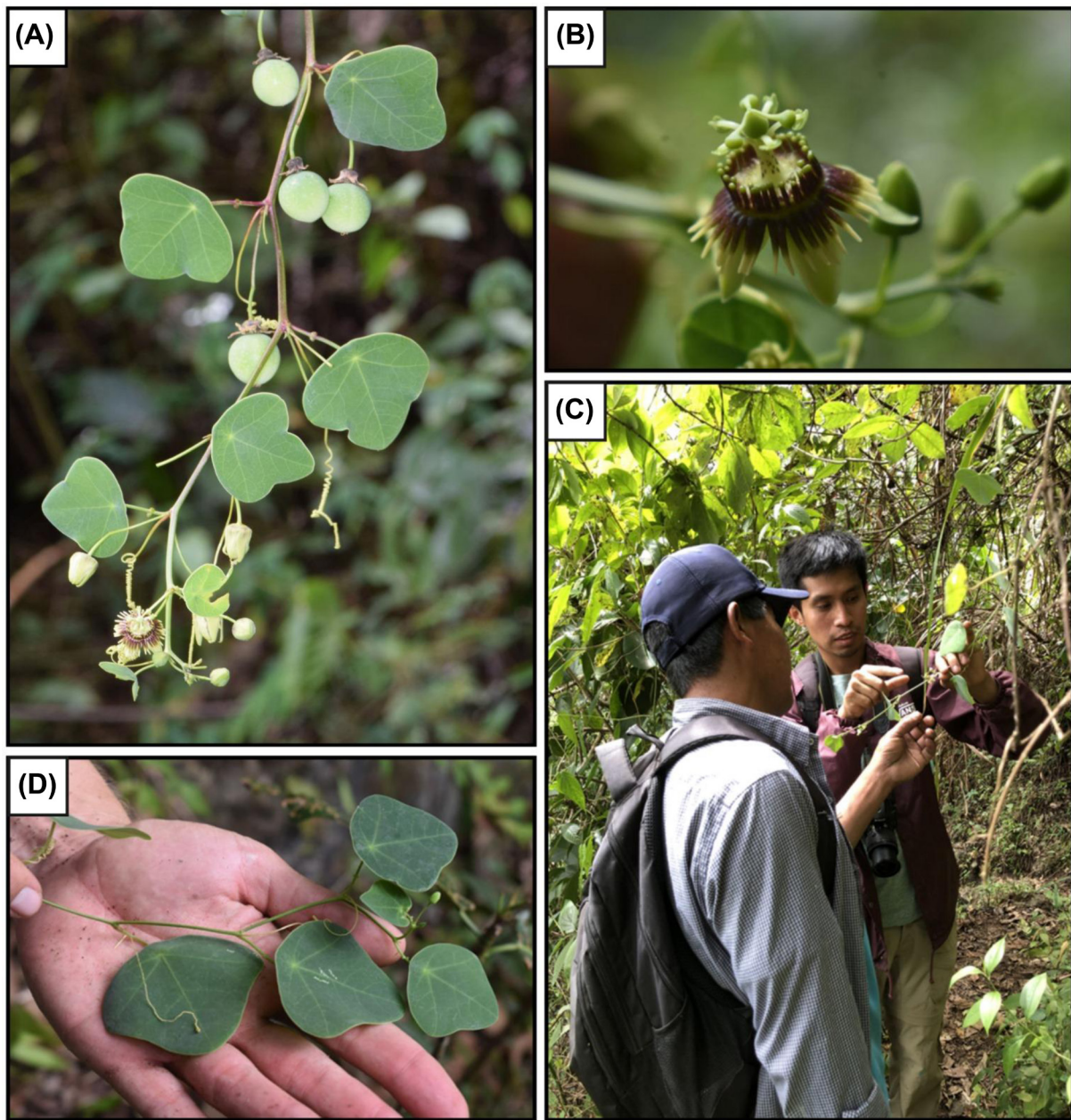


Figure 1. *Passiflora clypeophylla* in the field at the time of its rediscovery. (A) showing the habit, flower and maturing fruit, (B) detail of the flower (note the small capitate knobs on the internal corona series). (C) Saban Sequen with our local guide Alfredo, showing the intricacies of *Passiflora* morphology, (D) detail of the leaves and their peltate blade. Photographs taken by J.R. Kuethe.

its future prospect and conservation. In addition to expanding agriculture within the region and the ongoing activity by RENACE, which is visible higher up in the barranca, could pose a significant risk to the long-term survival of *Passiflora clypeophylla* in the wild (Fig. 4).

Discussion

Passiflora clypeophylla belongs to *P. supersect. Cieca* (Feuillet and MacDougal 2003, Ulmer and MacDougal 2004), recognized for its apetalous flowers and mostly (sub-)coriaceous foliage. The members of *P. supersect. Cieca* are well-versed

across both Central and Southern America, exhibiting some of the most common entities in the genus, e.g. *P. suberosa*, *P. coriacea* Juss. and *P. sexocellata* Schltdl. Other species, such as *P. mcvaughiana* MacDougal and *P. lancifolia* Ham., are more specialized, featuring a geochemical dependence or an intimate relation to a specific pollinator or disperser restricting these species to very small regions. Internal floral morphology is generally simple in comparison, allowing easy pollination by a wide range of small insects both flying and crawling. This does suggest however, that geochemical and habitational factors are key in the success of its survival, rendering

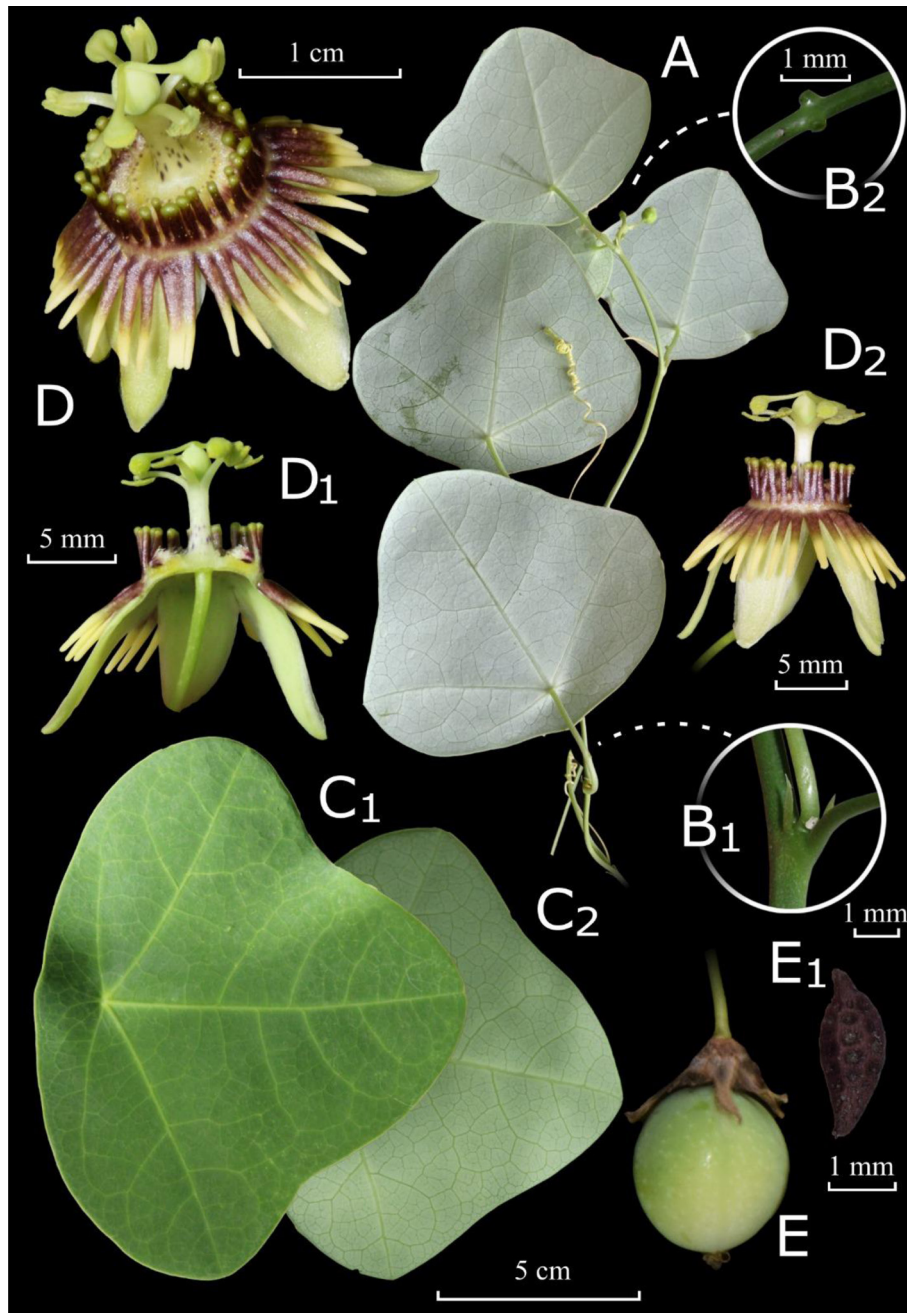


Figure 2. Lankaster Composite Dissection Plate (LCDP) of *Passiflora clypeophylla*. (A) Habit of the plant showing the silvery abaxial side of the leaves, (B1) stipules, (B2) detail of the petiolar nectaries, (C1) adaxial side of the leaf, (C2) abaxial side of the leaf, (D) detail of the flower, (D1) longitudinal section, (D2) lateral view of the flower, (E) a maturing fruit, (E1) mature seed. Made from photos taken by J.R. Kuethe and Marcus Varga.

conservative action to the maintenance of soil chemistry or its directly associated aquifers.

Similar to other species in *P. supersect. Cieca*, the structure of the flower suggests pollination by small insects, and visitation by a species of small bee (*Trigona fulviventr* Guérin-Ménéville) was captured on camera. The green-yellow flowers are typical for the species of this taxonomic alliance, completely lacking petals reducing the flower to simply five sepal organs, with a stubby 2-serial corona of which

the outer radiate and the inner erect. The apices of the inner series are complimented by contrasting green, knobular projections emitting a faint herbaceous scent inevitably to attract its effective pollinator. Several fruits, although few containing mature seeds, were seen on two of the four plants sighted, indicating successful unaided pollination by natural means. The limen floor is green and lustrous, with little nectar hidden beneath a softly plicate opercular structure as reward for pollination.

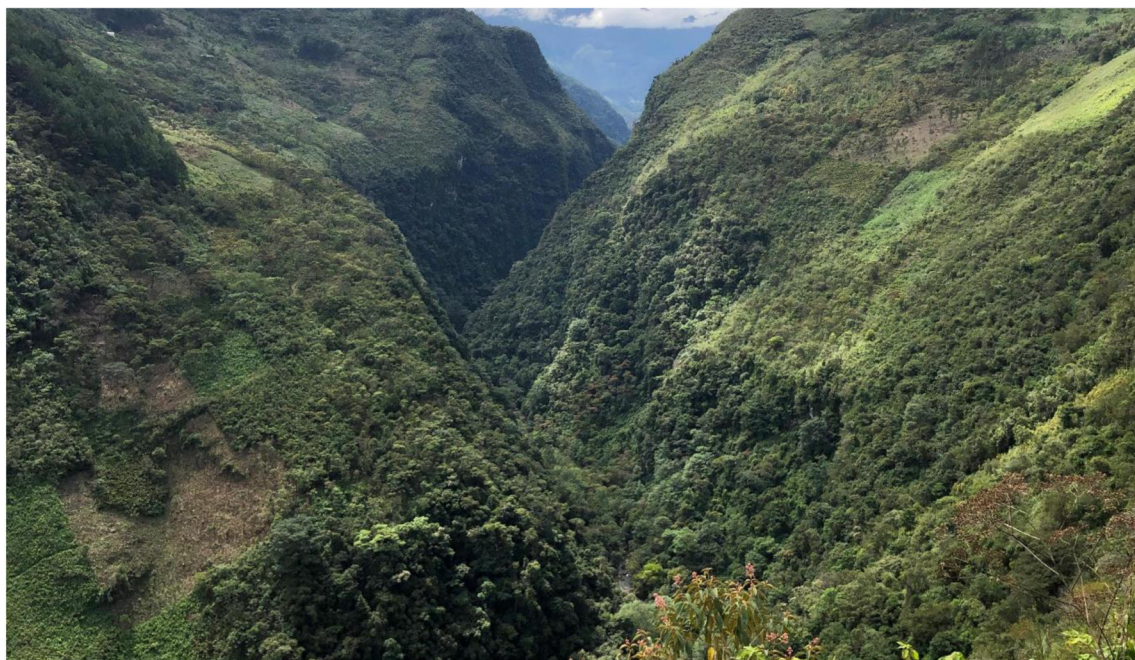
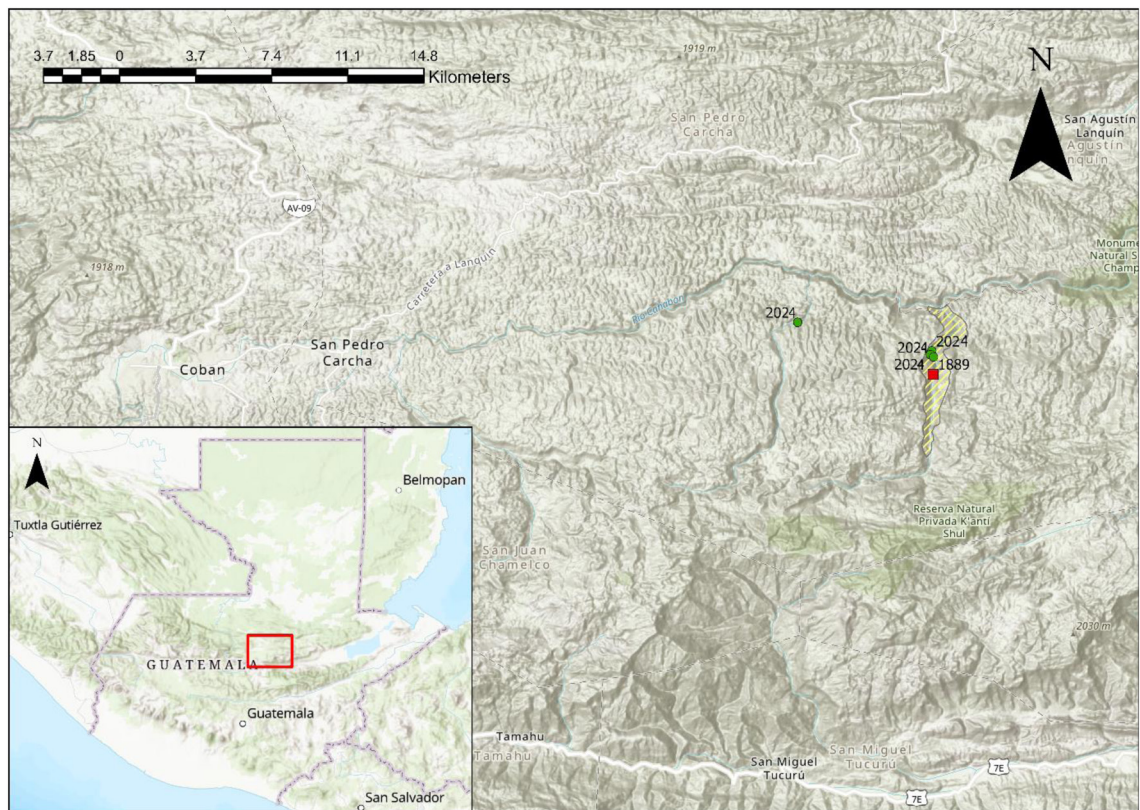


Figure 3. Distribution and habitat of *Passiflora clypeophylla*. Below a picture of the Rubel Cruz canyon in which the species was rediscovered. Note the pristine virgin forest on its steep flanks, below which the specimens were found. The original 1889 collection (red square) and new collections (green circles) in Guatemala are mapped above. Photo taken by J.R. Kuethe.



Figure 4. Comparison of herbarium specimens of *Passiflora clypeophylla*. The original 1889 collection by John Donnell-Smith (left); and the new 2024 collection by J.R. Kuethe *et al.* (right).

As the name suggests, the species exhibits great vegetative similarity to members of genus *Clypea* Blume (Menispermaceae), now subdivided into *Cyclea* Arn. ex. Wight and *Stephania* Lour. *Stephania* spp. are seen abundantly present within the habitat (and extended region), and these plants are generally not known to be predated by *Lepidoptera* butterflies. In fact, most species of *Stephania* contain traces of HCN, histamine, and acetylcholine, which are known to be toxic to insects and animals of any kind (Wink and Schimmer 2010, Wink 2015, 2020). Mimicry to these poisonous plants, which is good enough to fool even the most trained of eyes, can mean an effective perception technique to repel any oviposition on its fleshy leaves. No visible predation was observed on the plants of *P. clypeophylla*, indicating its ecological success as a species within the region despite the observed presence of *Lepidoptera* within the habitat.

Conservation status

With only two populations known and a total of four individual plants found, *Passiflora clypeophylla* classifies as Critically Endangered (CR), based on the two IUCN Red List guideline (IUCN 2024) assessment criteria B2a and D. Considering criterion B, *P. clypeophylla* meets category B2a, where the area of occupancy is calculated to be less than 10 km², and planimetrically fragmented permitting the species to exist at a single location. With respect to criterion D, the population size is estimated to number far fewer than 50 mature individuals, with just three plants found within Barranca del Rubel Cruz and a single plant at another (though much smaller) nearby canyon.

To help ensure its future conservation, living material of *Passiflora clypeophylla* has been collected and delivered to the Guatemala Botanical Gardens curated by the Universidad de San Carlos, in Guatemala City. Specimens have rooted successfully and are grown under protected environments to allow further study of its growth and possible reintroduction in its native habitat. A local awareness campaign of the species at the nearby indigenous village of Rubel Cruz allows for protection through understanding, and new local management of conservation through preservation efforts within the type habitat will ensure that *P. clypeophylla* continues to exist at its original location. Further *ex situ* conservation in botanical gardens and seedbanks is another strategy that will allow the species to be reproduced, and the genetic diversity of the species maintained through the reintroduction of newly grown plants from this genetically diverse seedstock.

Conclusion

The importance of comprehensive and well-curated botanical collections cannot be overstated, as they provide crucial insights into species relationships, document morphological diversity, help identify habitat, and climatic preferences that facilitates assessment of conservation potential, however. It is important for these records to be complete and comprehensive. *Passiflora clypeophylla* exemplifies the challenges arising from reliance on historical specimens that contain merely limited data, highlighting the uncertainties that impede clear

taxonomic and ecological understanding as was shown by the incomplete analyses of the species in Porter-Utley (2014). The rediscovery of *P. clypeophylla* from just within the canyon builds on the ecological uniqueness of this karstic structure, presenting the hypothesis that similar narrow endemism in families other than *Passifloraceae* are likely to be present within this remote ecosystem.

The rediscovery of *Passiflora clypeophylla* provided an excellent case study for a species formerly considered extinct and known solely from a single 1889 type collection. It underscores the value of intensive botanical expeditions and meticulous fieldwork in remote and challenging habitats, as well as the inclusion of local indigenous and cultural expertise in the conducting of field work. This rediscovery not only reestablishes the existence of the species but also opens new avenues for in-depth study of its morphology, taxonomy, and distribution within the context of both the Guatemalan karst forests and for enhancing taxonomic clarity of the species of *P. supersect. Cieca*. Based on this rediscovery, conservation strategies using non-destructive sampling of plant material for cultivation at local conservation institutions are highlighted, particularly for species inhabiting ecologically sensitive and geographically restricted environments like those of the karstic forests of rural Guatemala.

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Author contributions

J.R. Kuethe: Conceptualization (equal); Data curation (equal); Formal analysis (equal); Investigation (equal); Methodology (equal); Project administration (equal); Resources (equal); Supervision (equal); Validation (equal); Visualization (equal); Writing – original draft (equal).

Dennis I. Medina: Conceptualization (equal); Investigation (equal); Methodology (equal); Resources (equal); Visualization (equal); Writing – review and editing (equal). **Saban Sequen:** Formal analysis (equal); Investigation (equal); Methodology (equal); Resources (equal); Visualization (equal); Writing – review and editing (equal). **Maura L. Quezada:** Investigation (equal); Project administration (equal); Resources (equal).

Data availability statement

This article has no additional data.

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