




Tovomita cornuta (Clusiaceae): a new and threatened species from the Amazonian *campinaranas* revealed by ecological field research

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ABSTRACT

High species diversity, large area, and taxonomically under-studied groups are some of the explanations for the frequent discovery of new species of plants during ecological field campaigns in the Amazon region. Some of these new species are already being threatened from unplanned urban expansion associated with deforestation and habitat loss. Here we describe *Tovomita cornuta*, a new species discovered during ecological studies in the white-sand *campinaranas* of the Amazon, which is also threatened. The species is endemic to the state of Amazonas, Brazil, where it occurs in the understory of forested *campinaranas* physiognomies and is easily recognized by its narrowly obovoid fruits with dilated free styles. We provide a description, taxonomic and ecological comments, assessment of conservation status, geographic distribution, phenology, and illustrations for the new species.

Keywords: Central Amazonia, conservation, IUCN Red List, new species, sampling gaps, threatened species, *Tovomita*, white-sand vegetation

Introduction

The demand to solve the main issues that deal with environmental degradation and the conservation of biodiversity is hampered by a lack of knowledge in relation to biodiversity. This paradox is partly caused by the demand to produce general environmental standards and related solutions, which require large data sets. As a result, the proportion of ecological investigations based on field research has declined in recent decades. For example, Ríos-Saldaña *et al.* (2018) analyzed the related environmental literature between the 1980s and 2014 and found a 20 % decrease in publications based on fieldwork and an increase of 600 % and 800 % in modeling and meta-analysis studies, respectively, for the same period. On the other hand, new species are still being found

almost every day, indicating that the diversity of animal and plant species is still poorly known due to sampling gaps in large areas (Hopkins 2007) and this diversity is underestimated even for well-studied taxa (Ceballos & Ehrlich 2009).

In the Amazon region, the large area, the high diversity of species and, in some cases, taxonomically understudied groups are some of the reasons for the frequent discovery of new species of plants (Sobral & Stehmann 2009; Cardoso *et al.* 2017; Hopkins 2019). In this sense, long-term ecological studies are important because they generally conduct frequent field campaigns and collaborate in the discovery of new species (Lindenmayer *et al.* 2012). A good example is the genus *Tovomita*, for which most of the new specimens collected in the Amazon have come from research in ecology (*e.g.*, Marinho *et al.* 2016a; 2019a). The large trees, which are common to the genus, usually have small, greenish flowers and are hardly seen during rapid

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collection expeditions, but will likely be found during collections in systematic monitoring studies (Marinho & Beech 2019).

Tovomita comprises 53 exclusively Neotropical species belonging to the Clusiaceae family (Marinho *et al.* 2020). These species occur more frequently in humid forests, with only a few representatives in areas of seasonal semi-deciduous forest in eastern Brazil (Marinho *et al.* 2016b). In the Amazon region, they occupy areas of upland forests (*terra-firme*), white- and black-water floodplain forests (*várzea* and *igapó* respectively) and white-sand forests (*campinaranas*). In the Brazilian Amazon, *Tovomita* is sympatric to *Arawakia* and *Chrysochlamys*, two other genera of the Clusiaceae tribe that are commonly confused with each other. *Tovomita* can be distinguished by the acute or cuneate to attenuate leaf base (*vs.* leaf base gradually narrowed, ultimately shortly truncate or abruptly rounded in *Arawakia*) and its floral buds enclosed by the outer sepals (*vs.* floral buds not enclosed by the outer sepals in *Chrysochlamys*) (Marinho *et al.* 2019b).

The present study describes a new species of *Tovomita* collected within the scope of the PELD-MAUA project (Brazilian Long-term Ecological Research Network - Ecology, monitoring and sustainable use of wetlands). Illustrations, a distribution map and an assessment of the conservation status of the new species are provided. Taxonomic characters are discussed and compared with those of other closely related species.

Materials and methods

The descriptions and photos of the species in its habitat were carried out in the field within the scope of the doctoral thesis of the first author, and collections were made monthly from July 2017 to March 2020. Specimens were collected and processed following the usual procedures for botanical samplings (Fidalgo & Bononi 1989). The description of dried material was complemented by collections from the INPA herbarium (acronym according to Thiers 2021, continuously updated) and their respective duplicates. Flower measurements were taken from rehydrated flowers and floral buds; colors of all the structures described were recorded in the field and on the herbarium labels. Leaf terminology follows Ellis *et al.* (2009), and flower and fruit terminology follows Radford *et al.* (1974). The geographic distribution map was created using the website SimpleMapp (Shorthouse 2010) with subsequent style modifications. The conservation status of the new species was assessed using the software GeoCAT (Bachman *et al.* 2011) and discussed based on the IUCN (2012) criteria.

Results and discussion

Taxonomic treatment

***Tovomita cornuta* Demarchi & L. Marinho, sp. nov. Type:** BRAZIL. Amazonas: São Sebastião do Uatumã,

Uatumã Sustainable Development Reserve (SDR), PELD-MAUA plots, understory of white-sand forest *campinarana* with high groundwater level, 2°11'47" S, 59°00'53" W, 35 m a.s.l., 10/III/2020, fr., L.O. Demarchi 1674 (holotype: INPA; isotype: MAR; RB).

(Figs. 1, 2, 3, 4).

Tovomita cornuta can be differentiated from *T. umbellata* Benth. by the number of secondary veins (25–28 pairs *vs.* 10–15 in *T. umbellata*) and by the narrowly obovoid fruit with dilated styles (*vs.* pyriform with non-dilated styles in *T. umbellata*), from *T. amazonica* (Poepp.) Walp. by the number of secondary veins (25–28 *vs.* 13–18 in *T. amazonica*), floral bud length (3–4.3 *vs.* 5–7 mm long in *T. amazonica*), and fruit epicarp (smooth *vs.* rugose in *T. amazonica*).

Trees or treelets 3–8 m alt., dbh < 9 cm, prop roots inconspicuous, not exceeding 30 cm in height; outer bark gray, smooth, inner bark reddish; exudate yellow, orangish when oxidized, scarce; proximal internodes 3–11 cm long, distal internodes 3–20.5 mm long. Petioles 8.6–17.2 mm long, green, slightly canaliculate, not striated, lenticels absent. Leaf blades 3.4–15.1 × 1.4–6.1 cm, greenish adaxially and light brownish abaxially *in sicco*, black dots absent, subcoriaceous, brittle, shiny, oblong to obovate, base convex to rounded, apex acute to cuneate, margin entire and slightly revolute, exudate canals conspicuous, parallel to secondary veins, visible only abaxially *in sicco*. Venation brochidodromous, midvein prominent on both surfaces, more so abaxially, secondary veins in 25–28 pairs, 1.5–3.5 mm apart, forming an angle 75–80° to the midvein, slightly prominent adaxially, prominent abaxially; intersecondary veins present, one or rarely two per intercostal area, similar to the secondary veins, parallel to major secondaries and reticulating near the margin, visible only abaxially *in sicco*; tertiary veins percurrent sinuous to reticulate; intramarginal vein present. Staminate inflorescences a lax 5–6-branched pleiochasial cyme, ranging from 20–47 flowers, with primary flower, sometimes with reduced dichasia lacking the central flower. Pistillate inflorescences a lax 5-branched pleiochasial cyme or a dichasia cyme, ranging from 7–8 flowers, usually with reduced dichasia lacking the central flower. Pedicel 3–5.5 mm long on the flower and strongly dilated and elongated on the fruit with 7.1–10 mm long, whitish green, proximally articulated in the lateral flowers of the dichasia; lenticels present when in fruit; bracteoles 2, non-calyptrate, apex rounded to acute. Floral buds 3–4.3 mm long, ovoid to oblong, apex rounded, slightly apiculate, lenticels absent. Sepals 2, 3.3–4.1 × 1.7–1.9 mm, oblong to ovate, apex rounded, greenish to white; petals 4, 6.2–6.7 × 2.5–2.6 mm, oblong, reflexed, apex acute, greenish to white. Staminate flowers with 23–28 stamens, 1.5–3.5 mm long, heterodynamous; filaments terete, white becoming yellowish when senescent; anthers 0.3–0.4 mm long, slightly wider than filaments, connective not exceeding the thecae; pistillode white, diminute. Pistillate flowers with 20–26 staminodes, 1–1.6 mm long, rudimentary anther present,



ca. 0.2 mm long; ovary ca. 1 mm long, not costate or lobed, 4-locular, white-yellowish; styles 0.8–1 mm long, free from each other, curved in the floral bud, erect on anthesis; stigmas 4, 0.5–0.8 mm width, capitate, white. Capsules fleshy, 1.5–2 × 0.8–1.1 cm, 4-septate, narrowly obovoid

when closed, not costate, not lobed, epicarp smooth, green when immature; when mature green with visible yellowish resin canals, mesocarp purplish-red; pedicel dilated, styles strongly dilated; sepals, petals and staminodes caducous, styles and stigmas persistent; free styles 6.3–8.3 × 1.6–2.8

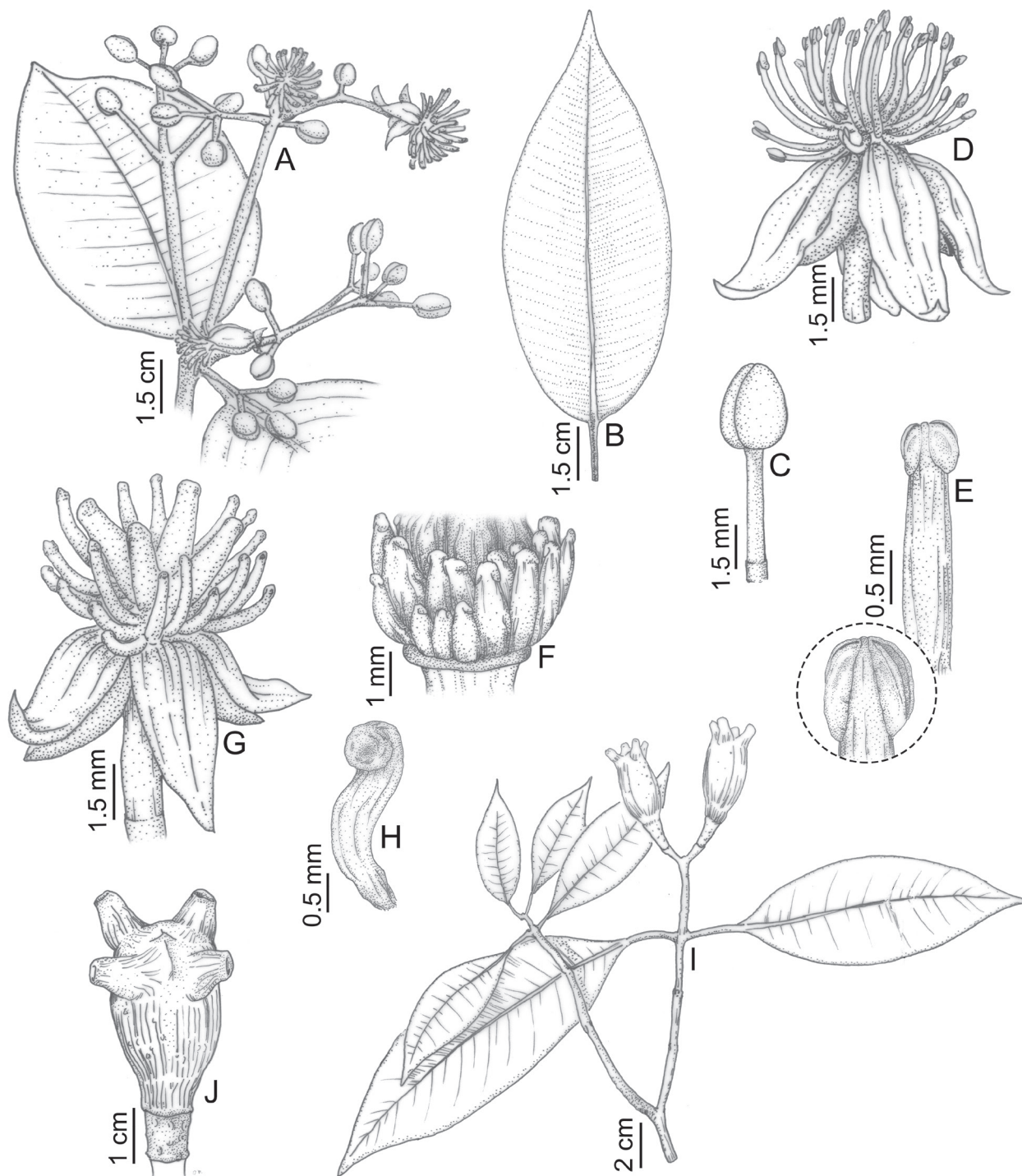


Figure 1. *Tovomita cornuta*. **A.** Branch with staminate inflorescence. **B.** Leaf abaxial surface. **C.** Staminate floral bud. **D.** Staminate flower. **E.** Stamen with detail of anther. **F.** Stamines detail in the pistillate flower (from floral bud), sepals and petals removed. **G.** Pistillate flower. **H.** Style (from pistillate floral bud). **I.** Branch with closed fruits. **J.** Closed fruit. (**A–E** from L.O. Demarchi 1558; **F–G** from W. Thomas et al. 5330; **H** from L.O. Demarchi & Andriolli 1691; **I–J** from L.O. Demarchi 1674). Illustration by Marcos Melo Corrêa.

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mm, conical to oblong. Seeds ca. 12.5×6 mm, ellipsoid, aril bright orange.

Paratypes: BRAZIL: Amazonas, Manaus, Rio Negro, Ponta Negra, 11–14/IV/1972, fr., R.E. Schultes & W. Rodrigues 26191A (GH, INPA, NY); Tupé Sustainable Development Reserve, Comunidade Agrovila, *campinarana* forest on sand-soil, $02^{\circ}58'55''$ S, $60^{\circ}14'26''$ W, 9/VI/2013, fb. ♂, L.O. Demarchi et al. 192 (EAFM, INPA); 9/VI/2013, fb. ♂, L.O. Demarchi et al. 193 (EAFM, INPA); 28/IX/2013, fb. ♂, L.O. Demarchi et al. 194 (EAFM, INPA); 4/X/2020, fl. ♀, fr., L.O. Demarchi & F. Andriolli 1691, 1692, 1693 (INPA); 04/X/2020, fl. ♂, L.O. Demarchi & F. Andriolli 1694, 1695 (INPA); Presidente Figueiredo, represa de Balbina on Rio Uatumã, ca. 4 km NW of dam on D-1 road, *campinarana* on sand-soil, $1^{\circ}50'$ S, $59^{\circ}32'$ W, 4/VII/1986, fb. ♀, fr., W. Thomas et al. 5330 (INPA, NY); São Sebastião do Uatumã, Uatumã Sustainable Development Reserve, PELD-MAUA plots, understory of forested *campinarana* on sand-soil, $2^{\circ}11'47''$ S, $59^{\circ}00'53''$ W, 35 m a.s.l., 4/IX/2018, fb. ♂, L.O. Demarchi 1300 (INPA); 11/VIII/2019, fl. ♂, L.O. Demarchi 1558 (INPA); 10/X/2019, fl. ♂, L.O. Demarchi 1599 (INPA).

Distribution: *Tovomita cornuta* is presumably endemic to the state of Amazonas, Brazil, with occurrence records in the region of Manaus and the neighboring municipalities of Presidente Figueiredo and São Sebastião do Uatumã (Fig. 3A).

Habitat and ecology: All known specimens were collected in white-sand forests (*campinarana*) (Fig. 3C). The species occurs in the understory in dense phytophysiognomies with a shallow water table that forms small “puddles” during the wet season (Fig. 3D), and does not occur in open areas with direct sunlight.

Phenology: *Tovomita cornuta* can be seen with flowers from June to October and with fruits in March, April, and July. In the specific case of the Sustainable Development Reserve (SDR) Uatumã, phenological monitoring over 24 months showed the species with flower buds in August; flowers from September to October, which is the middle of the dry season; and immature fruits from November to February and the dehiscence of fruits and release of seeds in March, which is the wet season (Demarchi et al. unpublished data).

Etymology: The specific epithet refers to the conspicuously prominent styles observed on the fruit. It is derived from the Latin word *cornu*, which means horn.

Conservation status: Based on the GeoCAT software (Bachman et al. 2011) *Tovomita cornuta* was classified as Endangered (EN) according to the area of occupancy (AOO, B2a) (Fig. 3A, B). However, in accordance with the IUCN criteria (2012), other factors and threats discussed herein further allow us to classify the species as critically endangered (CR). Among the four locations of known occurrence of the proposed new species, two are outside

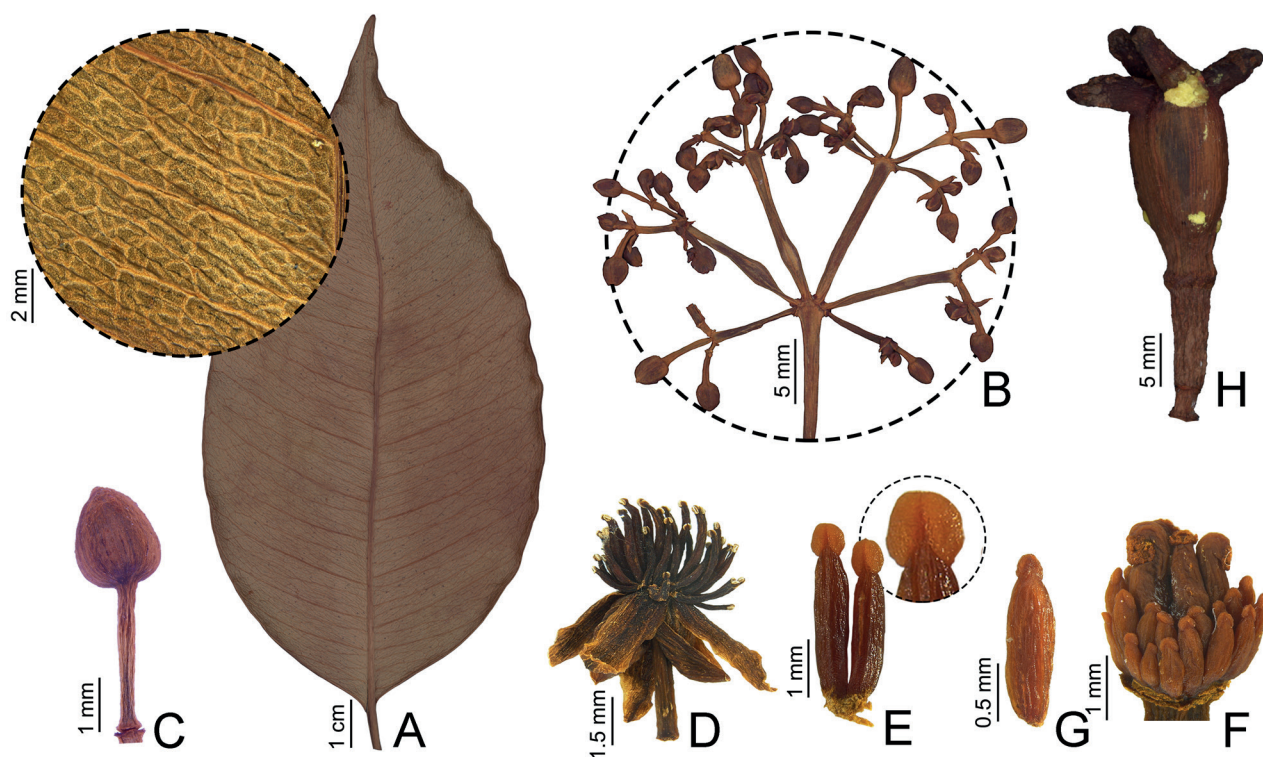


Figure 2. Details of *Tovomita cornuta* structures in sicco. **A.** Leaf abaxial surface with detail showing venation. **B.** Staminate inflorescence. **C.** Staminate floral bud. **D.** Staminate flower. **E.** Stamens with detail of anther. **F.** Pistillate floral bud, sepals and petals removed. **G.** Staminode. **H.** Closed mature fruit. (**A–E** from L.O. Demarchi 1558; **F–G** from W. Thomas et al. 5330; **H** from L.O. Demarchi 1674).

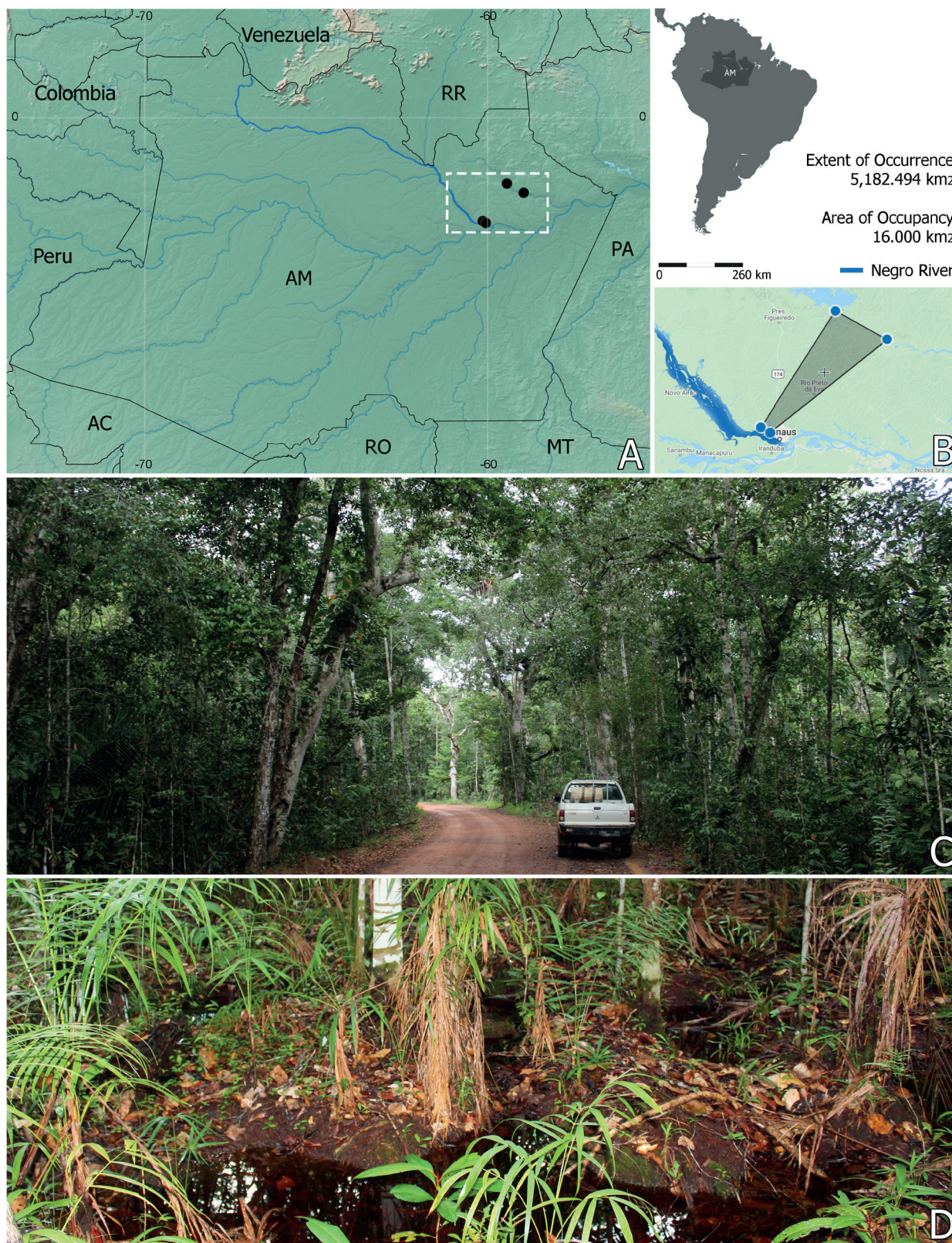


Figure 3. *Tovomita cornuta*, geographic distribution with conservation assessment and habitat. **A.** Distribution map of *T. cornuta* in the state of Amazonas, Brazil, with the detail of the state's location in South America; black circles indicate the locations where the plants were collected. **B.** The polygon represents the extent of occurrence of *T. cornuta* indicated by the GeoCAT software. **C.** Habitat of *T. cornuta* in São Sebastião do Uatumã, Amazonas, Brazil. **D.** Detail of the shallow water table forming small "puddles" during the wet season in São Sebastião do Uatumã, Amazonas, Brazil. Photos by Layon O. Demarchi

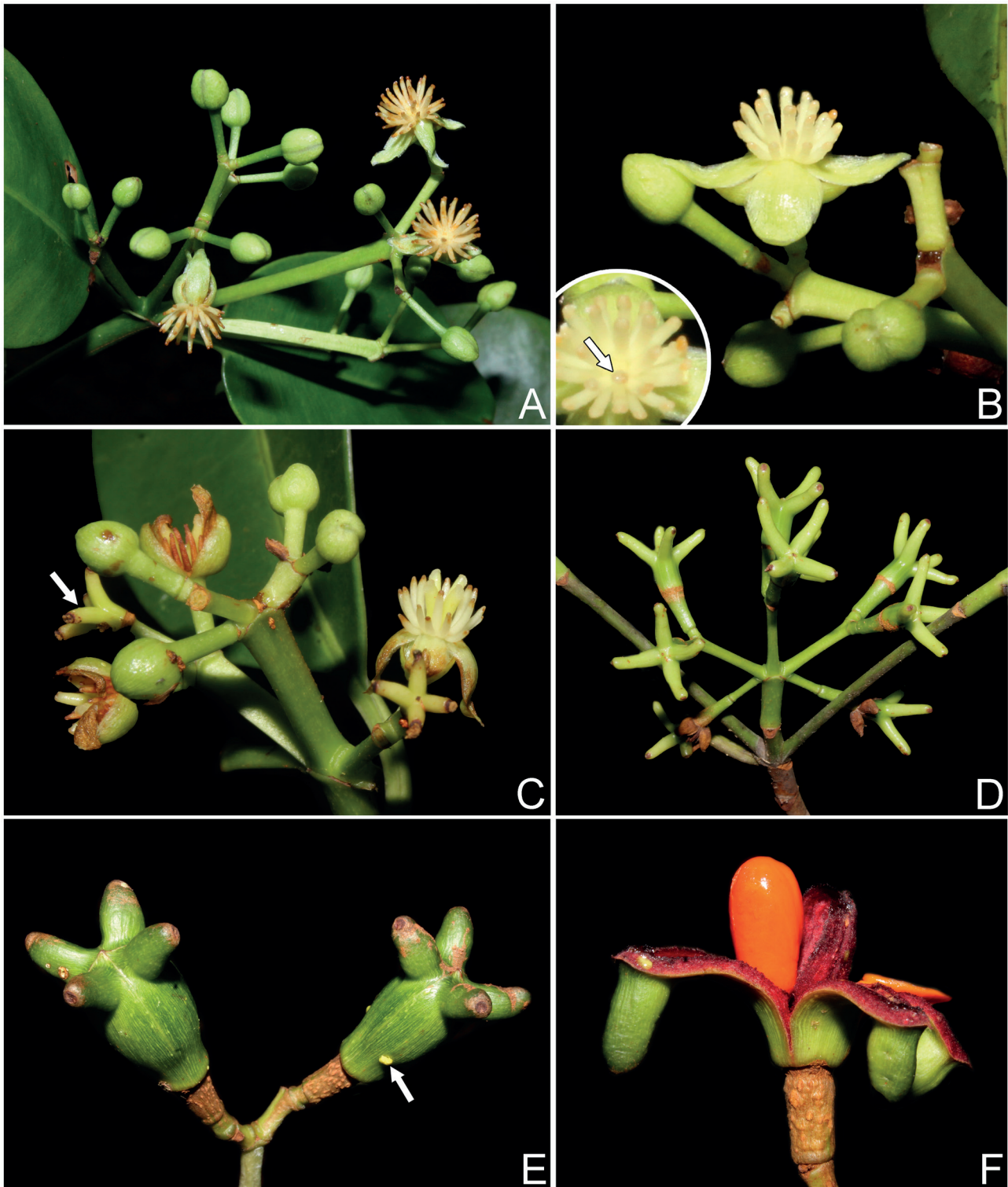


Figure 4. *Tovomita cornuta*, live plants. **A.** Staminate inflorescence with senescent stamens. **B.** Staminate flower, top view of the pistillode in detail (arrow). **C.** Pistillate inflorescence with floral buds, flower, and immature fruits (arrow). **D.** Pistillate 5-branched pleiochasium with immature fruits. **E.** Closed fruit, arrow pointing to the yellow exudate. **F.** Open fruit, lateral view. Photos by Layon O. Demarchi. (**A** from L.O. Demarchi 1558; **B** from L.O. Demarchi 1599; **C** from L.O. Demarchi 1692; **D** from L.O. Demarchi 1691; **E-F** from L.O. Demarchi 1674).



protected areas and under strong threat. The Ponta Negra district in the municipality of Manaus (*Schultes & Rodrigues 26191A*) has been strongly impacted by unplanned urban expansion associated with deforestation and habitat loss (B2bi, ii, iii); Balbina, a district in the municipality of Presidente Figueiredo (*Thomas et al. 5330*), was affected in the 1980s by the construction of the Balbina dam, which resulted in large areas being flooded in order to form a reservoir for power generation (Fearnside 1989) and has probably affected populations of this species (A1a + B2cii). The other two locations are in protected areas under the category of Sustainable Development Reserves (SDR), and some minor threats may also occur such as selective logging (Demarchi *et al.* 2019) and suppression of forest areas for small-scale agriculture and cattle ranching (IDESAM 2009) (B2biii). The species appears to be naturally rare, since, despite occurring in the surrounding areas of Manaus, one of the most sampled areas in the Amazon, only a few specimens could be found. In the two protected areas, 21 individuals were recorded in the Tupé SDR (Demarchi *et al.* 2018, supplementary material mistakenly identified as *T. acutiflora*), and less than 10 individuals were recorded in the Uatumã SDR (Demarchi pers. obs.) (C2ai). (A1a + B2a + B2bi, ii, iii, cii + C2ai).

Taxonomic notes and comments: Two specimens of *Tovomita cornuta* kept at the INPA herbarium were mistakenly identified as *T. acutiflora* and *T. umbellata*. In the field, *T. cornuta* can be easily differentiated from both by its inconspicuous prop roots. The prop roots are an important vegetative characteristic to differentiate it from other genera of Clusiaceae in the field, but it is not a characteristic that is shared by all species of *Tovomita*. The *T. cornuta* leaves resemble those of both related species, since they have numerous secondary veins that are close to

each other (Figs. 1B, 2A, see Table 1). Although the fruits are quite characteristic, they were initially interpreted by Marinho (2019) as possible galls or a malformation (Figs. 1J, 4E). This was mainly due to the absence of specimens with floral buds or flowers. The free and dilated style is the most striking feature for differentiating *T. cornuta*. Other species, such as *Tovomita stylosa* and *Tovomita turbinata*, share such characteristics, *T. cornuta* does not have the same geographic distribution (Colombia, Costa Rica, and Panama for *T. stylosa*; Colombia, Trinidad, and Venezuela for *T. turbinata*) and can be easily differentiated from both by the number of secondary veins (25–28 pairs *vs.* 8–9 in *T. stylosa*; 12–15 in *T. turbinata*) and epicarp texture (smooth *vs.* asperous in *T. stylosa* and *T. turbinata*).

Tovomita cornuta can be differentiated from *T. acutiflora* by its smaller floral buds (3–4.3 *vs.* 12–13 mm long in *T. acutiflora*), smaller number of stamens (23–28 *vs.* 50–70 in *T. acutiflora*) and, especially, by its four carpels and dilated styles on the fruit (*vs.* five-carpellate fruits with non-dilated styles) (Barros & Mariz 1982). In addition to the arrangement of the secondary veins, *T. cornuta* shares with *T. umbellata* the ovoid floral buds (Figs. 1C, 2C), the four-carpellate fruits with a smooth epicarp, the distal portion of the pedicel dilated in the fruit (Figs. 1J, 4F) and, finally, the number of stamens (23–28 *vs.* 20–35 in *T. umbellata*). The gynoecium of *T. cornuta* is composed of long styles and tiny stigmas (Figs. 1H, 2F, 4C) that will give rise to a fruit with persistent dilated styles that are similar to horns (Figs. 1J, 2H, 4F), while the *T. umbellata* gynoecium is composed of sessile and wide stigmas (ca. 2 mm width) that will give rise to a fruit without apparent styles, with only the conspicuous stigmas at the apex.

Due to the dilated distal portion of the pedicel and the shiny leaves *in vivo*, *Tovomita cornuta* can also be compared

Table 1. Morphological comparison of *Tovomita cornuta* and related Amazonian species.

Character	<i>T. acutiflora</i> M.S. Barros & G. Mariz	<i>T. amazonica</i> (Poepp.) Walp.	<i>T. caudata</i> L. Marinho	<i>T. cornuta</i> Demarchi & L. Marinho	<i>T. spruceana</i> Planch. & Triana	<i>T. umbellata</i> Benth.
Shape of leaf blade apex	Slightly acuminate	Acute	Long-acuminate	Acuminate to acute	Acute	Acute to obtuse
Number of secondary veins (pairs)	20–30	13–18	18–26	25–28	15–18	10–15
Floral bud shape	Oblong	Ovoid	Ovoid	Ovoid to oblong	Oblong	Ovoid
Floral bud apex	Acute ♂ / rounded ♀	Rounded, rarely apiculate	Rounded	Rounded to slightly apiculate	Rounded	Apiculate
Floral bud length (mm)	5.5–9 (13)	5–7	2–4	3–4.3	6–8	4–6.5
Stamen number	50–70	24–28	ca. 23	23–28	30–40	20–35
Stamen length (mm)	4.7–6.5	2.8–4.7	2.3–2.8	1.5–3.5	7–9	3.5–5
Pedicel length on flower (mm)	9–24	5–8	6–11	3–5.5	5–9	5–9
Pedicel on the fruit	Non dilated	Slightly dilated	Fruit not seen	Dilated	Dilated	Dilated
Fruit epicarp	Smooth	Rugose		Smooth	Smooth	Smooth
Fruit shape when closed	Napiform to spheroid	Napiform		Narrowly obovoid	Pyriform	Pyriform / elliptic
Styles conation on the fruit	Free	Fused forming a rostrum		Free	Free	Fused forming a rostrum
Styles dilatation on the fruit	Non dilated	Non dilated		Dilated	Non dilated	Non dilated
Mesocarp color	Red	White	Purplish-red	Red	Red	
Aril color	Orange to red	Yellow	Orange	Orange	Orange to red	



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to the sympatric species *T. spruceana*. *Tovomita cornuta* can be differentiated from *T. spruceana* by the ovoid floral buds (*vs.* oblong in *T. spruceana*), heterodynamous stamens (*vs.* isodynamous in *T. spruceana*), 23–28 stamens (*vs.* 30–40 stamens in *T. spruceana*) and finally, the narrowly obovoid fruit with dilated styles (*vs.* pyriform with non-dilated styles).

The specimens Demarchi *et al.* 192, 193, 194, which belongs to *T. cornuta*, were mistakenly included by Marinho *et al.* (2016a) as paratypes of *T. trachycarpa*, now synonymized under *T. amazonica* (*sensu* Marinho 2020). The characters differentiating these three and other related species of *Tovomita* are presented in Table 1.

Considering the large estimated number of plants not yet described, especially in the Amazon Biome, the only way to bring this neglected biodiversity to light is through intensive collections followed by detailed taxonomic studies (Hopkins 2019). From this point of view, long-term ecological research is an appropriate investment option since it requires a multidisciplinary approach with frequent field expeditions (Lindenmayer *et al.* 2012). The discovery of *T. cornuta* is an example of the relevance of field work, and highlights how ecological and taxonomic studies can interact in order to reveal Amazonian biodiversity.

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