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Diversity and endemism of pholcid spiders in Brazil's Atlantic Forest, with descriptions of four new species of the Atlantic Forest endemic genus *Tupigea* (Araneae: Pholcidae)

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This study is based on an effort to collect all pholcid spider species at six localities in the Serra do Mar region of the Brazilian Atlantic Forest. All but one locality produced 11–15 species. This is compared with published and unpublished species counts worldwide, showing that only six other localities are known to contain more than 10 species. From the 39 species collected at the Atlantic Forest sites, 22 are new, and 24 were found at only one site each. The two extreme (northern and southern) localities did not share any species, suggesting a high level of endemism and immense unknown species diversity. The dominant genera are *Metagonia*, *Mesabolivar* and *Tupigea*, with the last genus being endemic to the Atlantic Forest. The second part provides new general information on *Tupigea*, describes four new species (*Tupigea angelim*, *T. penedo*, *T. ale*, *T. guapia*), provides descriptions of the previously unknown females of *T. teresopolis* and *T. maza*, and presents the first scanning electron micrographs of *T. cantareira*.

Keywords: Pholcidae; *Tupigea*; taxonomy; natural history; Atlantic Forest; Brazil; biodiversity; endemism

Introduction

The Atlantic forest biome can be defined as tropical rainforests that follow the Brazilian coastline from the states of Rio Grande do Norte to Rio Grande do Sul (Coutinho 2009). Like many other tropical forests, it combines high levels of endemism, fragmentation and continuing deforestation. However, at least with regard to the first two aspects it seems to be extreme, earning it a rank among the five "hottest hotspots" on earth (Myers et al. 2000). High levels of endemism are favoured by heterogeneous environmental conditions because of a wide latitudinal range, differences in rainfall depending on the distance from the coast, a large altitudinal range, and differences in soil type and forest composition (Tabarelli et al. 2005; Ribeiro et al. 2009). The 12% that are estimated to remain from the original Atlantic Forest are divided into about 245,000 fragments of which more than 80% are smaller than 50 ha, with probably significant negative effects on biodiversity (Tabarelli et al. 2008; Ribeiro et al. 2009). Finally, despite tremendous protection efforts over the last decades, only 9% of the remaining forest is protected, and 11,650 km^2 have been lost over the last 15 years (Tabarelli et al. 2005; Ribeiro et al. 2009).

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Most key factors for hotspot assessment rely on detailed knowledge of the taxonomy, systematics and geographic distribution of taxa and as a result plants and vertebrates are almost exclusively used for this purpose (e.g. Myers et al. 2000; Mittermeier et al. 2004). Tropical invertebrates continue to be largely undocumented, with the consequence that studies with a more general focus are necessarily limited to a few exceptional groups (such as bees, butterflies, beetles and ants in studies about the effects of tropical forest disturbance; references in Bragagnolo et al. 2007). Among arachnids, spiders are one of the two megadiverse groups (together with mites), with an estimated 80,000 species of which some 42,000 are scientifically described (Platnick 1999, 2010). This makes high-level comparisons in tropical forests difficult, except in a very regional context (e.g. Russell-Smith 2002; Hsieh et al. 2003; Floren and Deeleman-Reinhold 2005; Pinkus-Rendón et al. 2006). The present paper uses a different approach with methodological limitations but a worldwide scope, limiting comparisons to a manageable taxon but deliberately not to studies using statistically strictly comparable collecting protocols (cf. Fannes et al. 2008 on arboreal oonopid spiders in Africa).

The Pholcidae are a family of mainly tropical spiders, with currently slightly over 1100 described species (http://www.uni-bonn.de/~bhuber1/catalogue.htm). They occupy a wide range of microhabitats (including leaf-litter, between buttresses, among vegetation, underside of green leaves) and this is correlated with conspicuous differences in habitus, colouration and other morphological details (Huber 2005, 2009). Usually, intense specialist collecting in well-preserved tropical forests results in about six to 10 pholcid species per locality (B.A. Huber, unpublished data). Worldwide there are only 11 (mostly unpublished) cases reporting more than 10 species. The first aim of this paper is to document the remarkable fact that from these 11 localities known to contain more than 10 species, five are located in the Brazilian Atlantic Forest. The second part is dedicated to the Atlantic Forest endemic genus *Tupigea*, providing descriptions of some new species collected in the course of this project and descriptions of females from species previously known only from males.

Materials and methods

Study sites and collecting protocols

The comparison of pholcid diversity among sites worldwide is based on various studies by different research groups using different collecting protocols (Table 1). With the exception of the species from Porto Urucu and two species from Pakitza, the first author has seen all species from these studies. For this reason, undescribed species could be included in comparisons without the potential problem of duplication.

In all the Atlantic Forest sites and in Yacambú N.P. (Venezuela), the primary aim was to collect a maximum of species present at each locality. For this reason, common and easy species (e.g. those with webs among vegetation) were deliberately ignored after an initial period and the effort was increasingly focused on more cryptic and difficult species (e.g. leaf-dwellers and leaf-litter species). This method impedes an analysis of relative species abundance within a locality and makes comparisons of species abundances among localities meaningless but it is likely to collect most or all species with considerably less effort than a strict quantitative approach.

Table 1. Localities worldwide with more than 10 species of Pholcidae, sorted by numbers of species.

Locality	Details, coordinates	Species no. (singletons)	Adult specimens	Collecting protocol and estimate of intensity	Publication	Depository (collector/s)
Res. Ecol. Guapiaçú	Brazil, Rio de Janeiro, 22,41°S, 42,74°W	15 (1)	249	not quantitative (2 persons, 2 days)	herein	MNRJ, ZFMK (Giupponi, Huber)
Res. Rio das Pedras	Brazil, Rio de Janeiro, 22,99°S, 44,11°W	13 (1)	210	not quantitative (3 persons, 1 day)	herein	MNRJ, ZFMK (Giupponi, Huber, Kury)
Ubatuba	Brazil, São Paulo, 23,34°S, 45,07°W	13 (2)	258	not quantitative (4 persons, 2 days)	herein	IBSP, ZFMK (Huber, Indicatti, Rheims, Schulz)
Luki Forest Reserve	Congo DR, Kongo Centrale, 5,62°S, 13,10°E	13 (0)	1263	semi-quantitative* (2–3 persons, 34 days)	unpublished	MRAC (de Bakker, Hubau, Michiels)
Yacambú N.P.	Venezuela, Lara, 9,71°N, 69,58°W	12 (1)	202	not quantitative (5 persons, 2 days)	unpublished	MFLS, ZFMK (Giupponi, Huber, Perez, Striffler, Villarreal)
Zona Res. Pakitza	Peru, Madre de Dios, 11,93°S, 71,28°W	12 (3)	84/113†	semi-quantitative‡ (1 person, ~ 40 days)	Silva and Coddington 1996	MUSM, USNM (Silva)
Mazumbai Forest Res.	Tanzania, Usambara Mts., 4,82°S, 38,50°E	12 (1)	582	not quantitative (3 persons, 11 days) and quantitative (1 person, 12 days)	unpublished	CAS, ZMUC (Griswold, McKamey, Scharff, Ubick)
San Lorenzo Protected Area	Panama, 9,28°N, 79,98°W	11 (0)	254	quantitative	unpublished	ZMUC (IBISCA)
Porto Urucu	Brazil, Amazonas, 4,88°S, 65,33°W	11 (4)	241	semi-quantitative§ (1–4 persons, ~60 days)	Carvalho et al. 2010	MPEG (Bonaldo, Dias, Miglio, Hung, Bastos, Candiani, Carvalho)

(*Continued*)

Table 1. (Continued).

Locality	Details, coordinates	Species no. (singletons)	Adult specimens	Collecting protocol and estimate of intensity	Publication	Depository (collector/s)
Penedo	Brazil, Rio de Janeiro, 22,41°S, 44,55°W	11 (0)	239	not quantitative (1 person, 2 days)	herein	MNRJ, ZFMK (Huber)
Paraty	Brazil, Rio de Janeiro, 23,20°S, 44,77°W	11 (0)	150	not quantitative (1 person, 2 days)	herein	MNRJ, ZFMK (Huber)

Notes: *Some species were only collected outside the rigorous quantitative (fogging) protocol.
†There is an unresolved discrepancy between the 84 specimens reported in Silva and Coddington (1996) and the 113 specimens examined and described in Huber (2000).
‡"Sampling focused almost entirely on the shrub, tree-trunk, and aerial web-spinning fauna" (Silva and Coddington, 1996).
§"To complete the species list, a few individuals gathered on occasional collections were also computed" (Carvalho et al. 2010).

Material

Spiders studied (or cited) are deposited at various institutions as detailed in Table 1 and in the descriptive section: CAS, California Academy of Sciences, San Francisco; IBSP, Instituto Butantan, São Paulo; MFLS, Museo de Historia Natural de La Fundación La Salle, Caracas; MNRJ, Museu Nacional do Rio de Janeiro; MPEG, Museu Paraense Emílio Goeldi, Pará, Brazil; MRAC, Musée royale de l'Afrique Centrale, Tervuren; MUSM, Museo de Historia Natural, Lima; USNM, National Museum of Natural History, Washington DC; ZFMK, Zoologisches Forschungsmuseum Alexander Koenig, Bonn; ZMUC, Zoological Museum, University of Copenhagen.

Descriptions

Morphological descriptions follow the style of recent publications (e.g. Huber 2000, 2005, 2009). Measurements are in mm (± 0.02 mm if two decimals are given) unless otherwise noted. Eye measurements are ± 5 μm. Drawings were made with a camera lucida on a Leitz Dialux 20 compound microscope. Cleared epigyna were stained with chlorazol black. Photographs were taken with a Nikon Coolpix 995 digital camera (2048 × 1536 pixels) mounted on a Nikon SMZ 1500 dissecting microscope. For scanning electron micrographs (SEM), specimens were dried in hexamethyldisilazane (Brown 1993), and photographed on a Hitachi S-2460 electron microscope.

Results and Discussion

Diversity maxima worldwide

Eleven localities are currently known to contain more than 10 species of Pholcidae each (Figure 1). Five of them are located in the Serra do Mar biogeographic subregion of the Atlantic Forest, including the current worldwide maximum of 15 species in the Reserva Ecológica de Guapiaçú (Cachoeiras de Macacu, Rio de Janeiro). Most of the samples contain singletons, which is an indication that further species might exist at most or all localities, but there is no obvious reason to assume a significant bias in this respect favouring the Atlantic Forest sites. In fact, a mean percentage of singletons of 9.8% is far below the average for tropical arthropod surveys (29%; Coddington et al. 2009) and there is no significant difference between Atlantic Forest sites and other sites (Independent Samples t-test, $p = 0.32$). The high number of Atlantic Forest sites in Table 1 is also not simply the result of fewer or less intensive collecting efforts in other places. During numerous expeditions to various tropical countries including Central and South America (Panama, Costa Rica, Nicaragua, Honduras, Guatemala, Venezuela, Brazil), the Caribbean (Cuba, Haiti, Dominican Republic) and tropical Africa (Guinea, Cameroon, Kenya), the first author has made the same effort with the same aim of collecting a maximum of species at dozens of localities but only six of them produced more than 10 species (Yacambú and five of the six Atlantic Forest sites).

Diversity and endemism in the Atlantic Forest

All six Atlantic Forest sites combined produced a total of 39 pholcid species of which 22 are apparently new [Table 2; a few old species like *Metagonia*

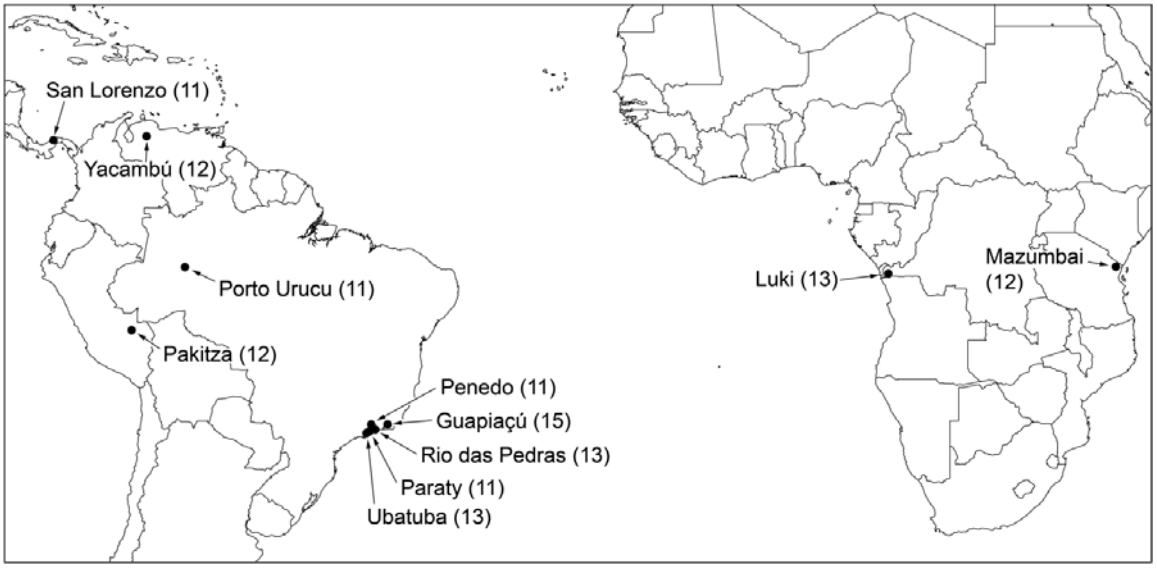

Figure 1. Localities worldwide at which more than 10 species of pholcid spiders have been collected (species numbers in parentheses).

heraldica Mello-Laitão, 1922, *Met. quadrifasciata* Mello-Leitão, 1926, *Met. unicolor* (Keyserling, 1891), and *Mesabolivar fluminensis* (Mello-Leitão, 1918) are so poorly known that they are not identifiable, cf. Huber 2000]. This alone is remarkable because these are not remote localities but they are all close to and easily accessed from São Paulo and Rio de Janeiro, cities with a rich and long tradition in arachnological research. Even more significant is the large number of species (24, i.e. 62%) that were found at only one locality (Table 2). Not surprisingly, most of them occur at the northernmost and southernmost localities (Guapiaçú, Paranapiacaba), which is in part probably simply a result of both localities having fewer neighbouring localities than the intermediate ones. However, the fact that these two localities, lying no more than 400 km apart within the same biogeographic sub-region, do not share a single one of their combined 22 species emphasizes the immense unknown diversity likely to be present along the over 3000 km of Atlantic Forest between Rio Grande do Norte and Rio Grande do Sul. Even the two localities that share the highest percentage of species (Paraty and Rio das Pedras, lying only 70 km apart, both near the coast) share only eight of their 16 species.

Taxonomy

Tupigea Huber, 2000

Tupigea Huber 2000: 314; type species: *T. lisei* Huber, 2000.

Diagnosis

See Huber (2000). A character not previously mentioned that seems to be diagnostic for *Tupigea* is the paired receptaculum-like structures in the female internal genitalia. They have previously been illustrated for *T. nadleri*, *T. paula* and *T. cantareira*

Table 2. Pholcid species and specimen numbers collected at the six Atlantic Forest localities.

Species	Guapiaçú	Rio das Pedras	Paraty	Ubatuba	Penedo	Paranapiacaba
Carapoia *genitalis*						5
Carapoia ubatuba				34		
Carapoia sp. nov. (near *ubatuba,* Br09-5)	25	8	10			
Mesabolivar *azureus*	23		2		7	
Mesabolivar brasiliensis	9	32	17	6		
Mesabolivar cavicelatus (?, Br07-17)				73	14	
Mesabolivar cyaneomaculatus		1	5	3	6	7
Mesabolivar cyaneotaeniatus	6	12	23		6	
Mesabolivar difficilis		16		1		
Mesabolivar luteus	16	32	27	4	15	
Mesabolivar togatus	50	10	13			
Mesabolivar sp. nov. (near *camussi,* Br09-6)	12					
Mesabolivar sp. nov. (near *cyaneomaculatus,* Br09-8)	14					
Mesabolivar sp. nov. (near *cyaneotaeniatus,* Br09-45)		46				
Mesabolivar sp. nov. (near *cyaneotaeniatus,* Br03-21)				31		
Mesabolivar sp. nov. (near *huberi, embapua*, Br07-19)					13	
Mesabolivar sp. nov. (Br03-14)				1		
Mesabolivar sp. nov. (Br03-38)						27
Mesabolivar sp. nov. (Br07-43)			4			
Mesabolivar sp. nov. (Br03-41)						6

(*Continued*)

Table 2. (Continued).

Species	Guapiaçú	Rio das Pedras	Paraty	Ubatuba	Penedo	Paranapiacaba
Metagonia *beni* (?, Br09-4)	31		19		42	
Metagonia bifida (?, Br09-56)		2			16	
Metagonia paranapiacaba						38
Metagonia sp. nov. (near *nadleri,* Br09-3)	2					
Metagonia sp. nov. (near *nadleri*, Br09-52)		19		45		
Metagonia sp. nov. (near *furcata*, Br09-55)		13	20	36		
Metagonia sp. nov. (near *petropolis,* Br09-2)	24					
Metagonia sp. nov. (near *petropolis,* Br07-1/2)					88	
Metagonia sp. nov. (near *petropolis,* Br03-14)				3		
Psilochorus *ybytyriguara*						1
Tupigea *ale* sp. nov.		11	10	9		
Tupigea angelim sp. nov.		8		12		
Tupigea guapia sp. nov.	21					
Tupigea maza	11					
Tupigea penedo sp. nov.					7	
Tupigea teresopolis					25	
Tupigea sp. (*iguassuensis*?, Br09-32)	1					
gen. indet., sp. nov. (*Tupigea*?, Br09-9)	4					
gen. indet., sp. nov. (*Mesabolivar*?, Br03-37)						14
Total specimens	249	210	150	258	239	98

Note: Grey-shaded entries are those species that were found at only one locality. Collection codes are provided for unnamed species to facilitate retrieval.

(figs. 1298 and 1307 in Huber 2000 and fig. 39 in Machado et al. 2007), and also occur in *T. angelim*, *T. penedo*, *T. ale*, *T. guapia*, *T. maza* and *T. teresopolis* (Figures 5E, 7E, 8D,E, 10B,E). They were not shown in the figure of the type species *T. lisei* (fig. 1271 in Huber 2000), but this may be because they are very poorly visible unless the cleared genitalia are stained, and this was not done in Huber 2000.

Description

See Huber (2000). Short vertical hairs on male legs may not only occur on tibiae but also on femora (*T. penedo*, *T. ale*, *T. guapia*, *T. teresopolis*; Figure 9A). Prolateral trichobothrium absent on tibia 1, present on other tibiae. Sexual dimorphism usually inconspicuous (except for longer male legs and larger female abdomen; Figure 4D–F), but distinct in *T. teresopolis* (Figures 3D,E, 4L–N). Females sometimes with conspicuous genital plugs (Figures 4C,H, 6H). Pore plate morphology extremely variable among species (Figures 6N, 9M, 11M). Males and females with comb-hairs distally on tarsus 4 (Figure 11C).

Composition and distribution

The genus now includes 13 species, but two of them continue to be known only from females and to be tentatively assigned (*T. altiventer*, *T. iguassuensis*; Huber 2000). The genus appears to be largely restricted to the Serra do Mar biogeographical sub-region of the Atlantic Forest (Figure 2), but at least in the north and in the south it extends into the neighbouring sub-regions.

Natural history

Tupigea includes both leaf-litter species and species that live in close association with the underside of green (alive) leaves (Figure 3A–G). Leaf-litter species are rather dark, short-legged, have a globose abdomen and eye triads close together (Figure 4A,D,I) while leaf-dwelling species are pale greenish (the green colour gets lost in ethanol), have longer legs, and triads are farther apart (Figures 3A–E, 4L–P). The leaf-dwelling *T. ale* and *T. teresopolis* were observed to build very fine single-layered webs with a diameter of about 20–40 cm, extending from the underside of a leaf towards the nearby vegetation (Figure 3F). During the day, these spiders are always found hanging from that part of the web that is attached to the underside of the leaf. Males and females of these two and of other species often share one web. When disturbed, they slowly move to another part of the sheet; they could never be induced to vibrate. In contrast, the litter-dwelling *T. penedo* runs quickly when disturbed; no web could be seen in this (or any other litter-dwelling) species.

Tupigea angelim Huber sp. nov.

(Figures 4A–C, 5A–E, 6A–H)

Tupigea sp. 1: Astrin et al. 2006: 445, 2007: 20.

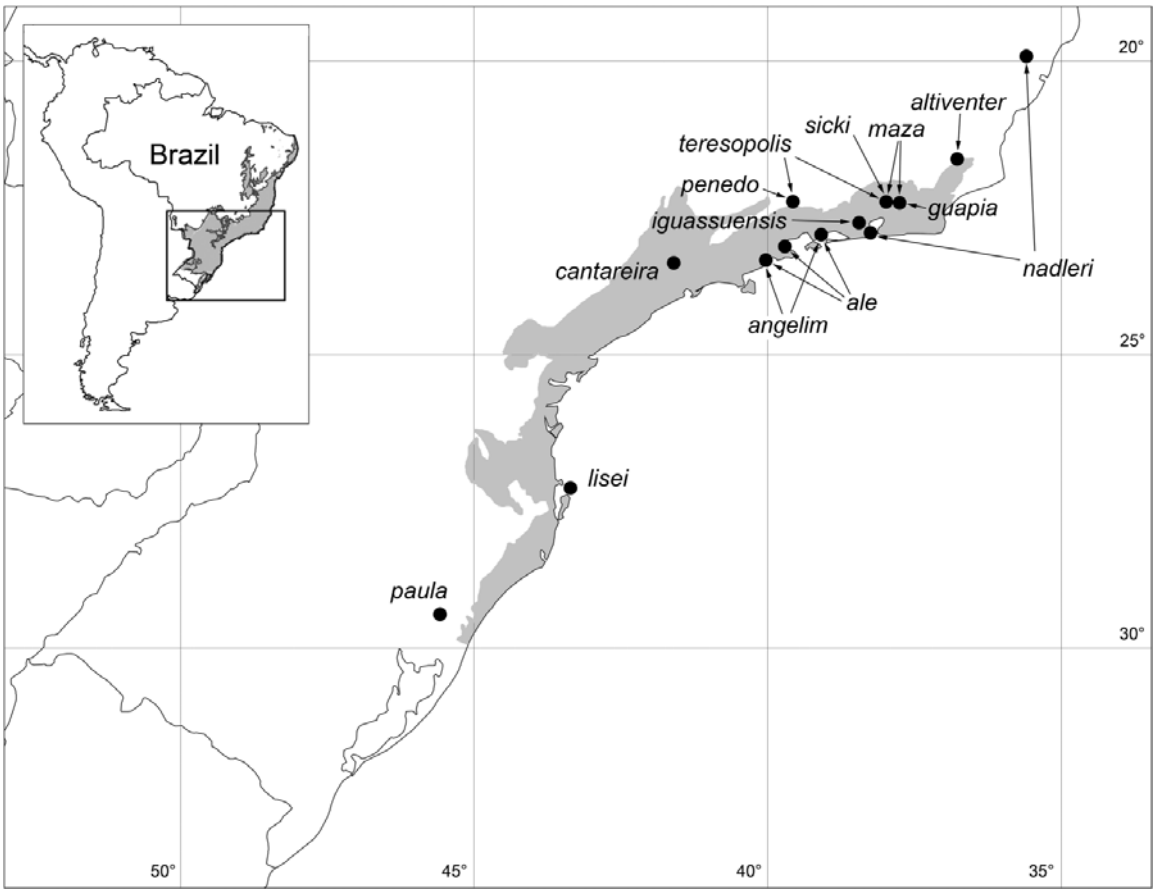

Figure 2. Known distribution of *Tupigea*. Grey shade in inset: extension of Atlantic Forest in Brazil (inset modified from Ribeiro et al. 2009). Grey shade in main map: extension of Serra do Mar biogeographic sub-region, from Silva and Casteleti (2003) in Ribeiro et al. (2009).

Types

Male holotype and 2♂, 4♀ paratypes from Brazil, São Paulo, Ubatuba, Fazenda Angelim (23°23.6′ S, 45°03.8′ W), ~ 50 m above sea level (a.s.l.), 16–18 December 2003 (B.A. Huber), holotype and 1♀ in IBSP, 2♂, 3♀ paratypes in ZFMK.

Etymology

The specific name is a noun in apposition, taken from the type locality.

Diagnosis

Easily distinguished from known congeners by armature on male chelicerae (pair of frontal apophyses, Figure 5C) and by dorsal worm-shaped projection of bulb (Figures 5A, 6C); also by male palp (modifications of femur, procursus shape, embolic division of bulb, Figures 5A,B, 6C,D), and female genitalia (Figures 5D,E, 6G).

Male (holotype)

Total body length 1.6, carapace width 0.67. Leg 1: 14.9 (3.7 + 0.2 + 3.8 + 5.9 + 1.3), tibia 2: 2.0, tibia 3: 1.4, tibia 4: 1.9, tibia 1 L/d: 72. Habitus as in Figure 4A;

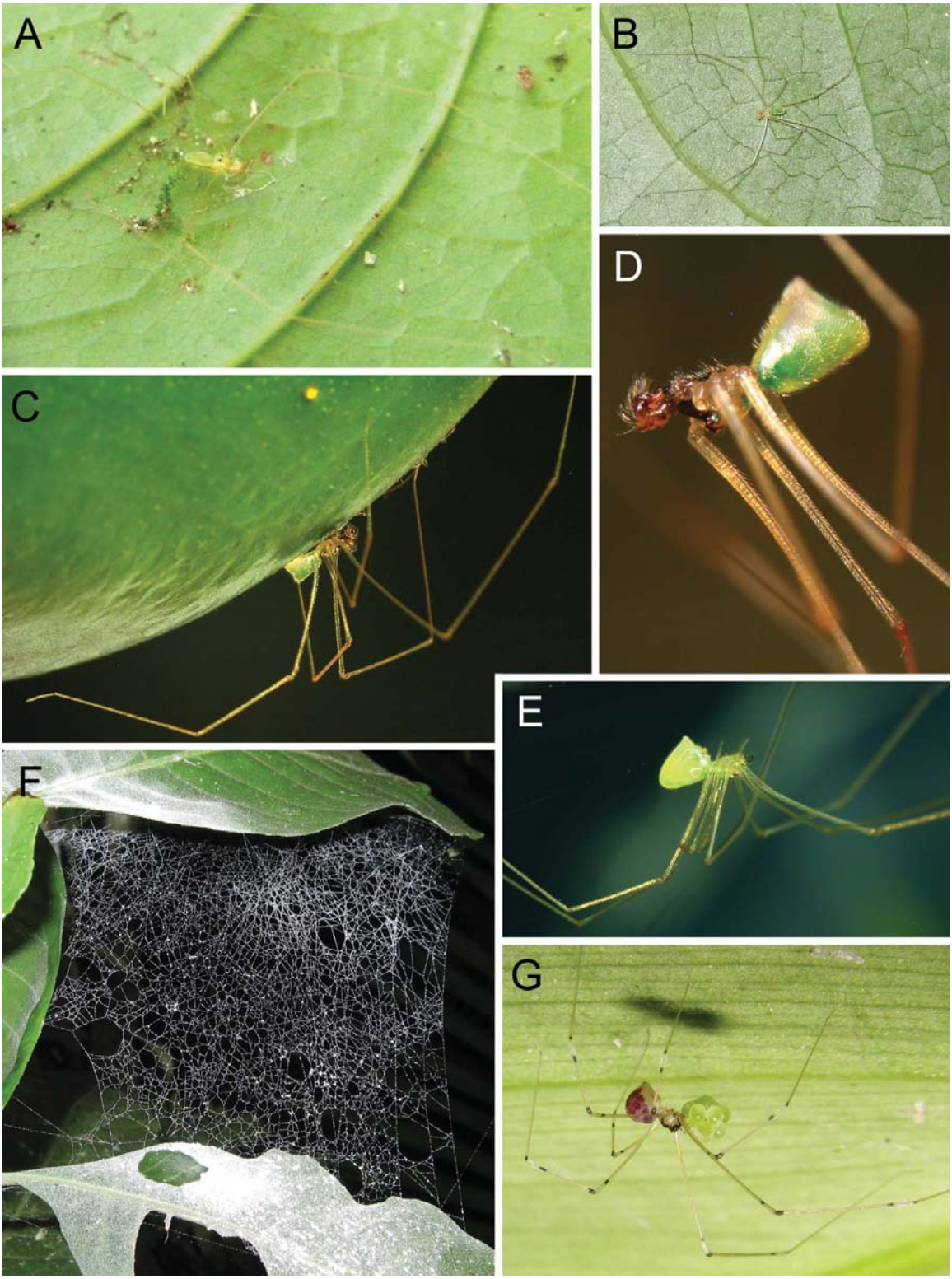

Figure 3. Leaf-dwelling *Tupigea* species and their web in the natural habitat. (A, B) *T. ale* from Rio das Pedras (A) and Paraty (B). (C–F) *T. teresopolis* from Penedo, males (C, D), female (E), and web dusted with starch to improve visibility (F). (G). Unidentified species from Guapiaçú ("Br09-32" in Table 2), female with egg sac.

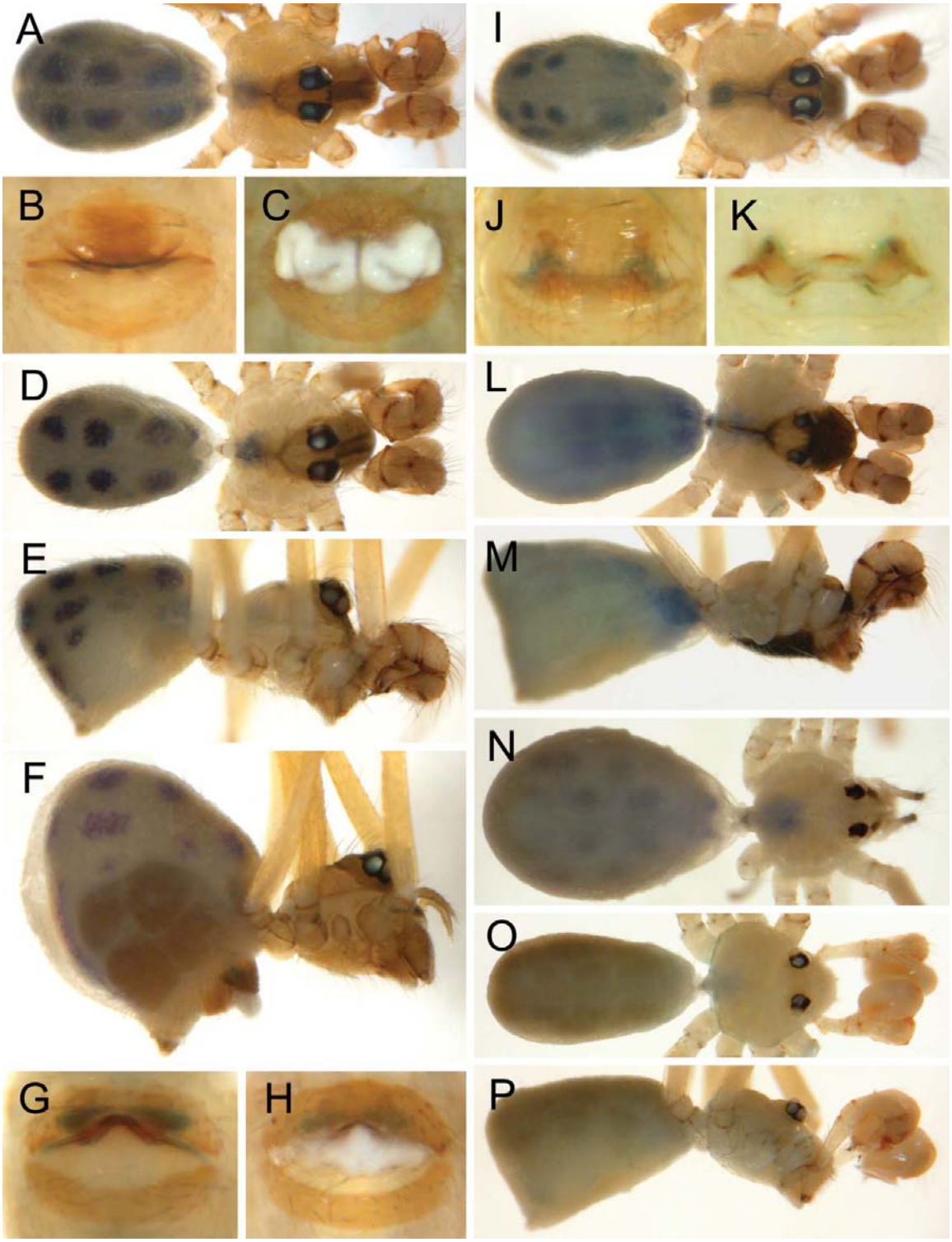

Figure 4. Preserved specimens of *Tupigea* species showing habitus, epigynum and genital plugs. (A–C) *T. angelim*, male (A), epigyna without (B) and with (C) genital plug. (D–H) *T. penedo* sp. nov., male (D, E), female (F), epigyna without (G) and with (H) genital plug. (I, J) *T. maza*, male (I) and epigynum (J). (K–N) *T. teresopolis*, epigynum (K), male (L, M), and female (N). (O, P) *T. ale* sp. nov., male.

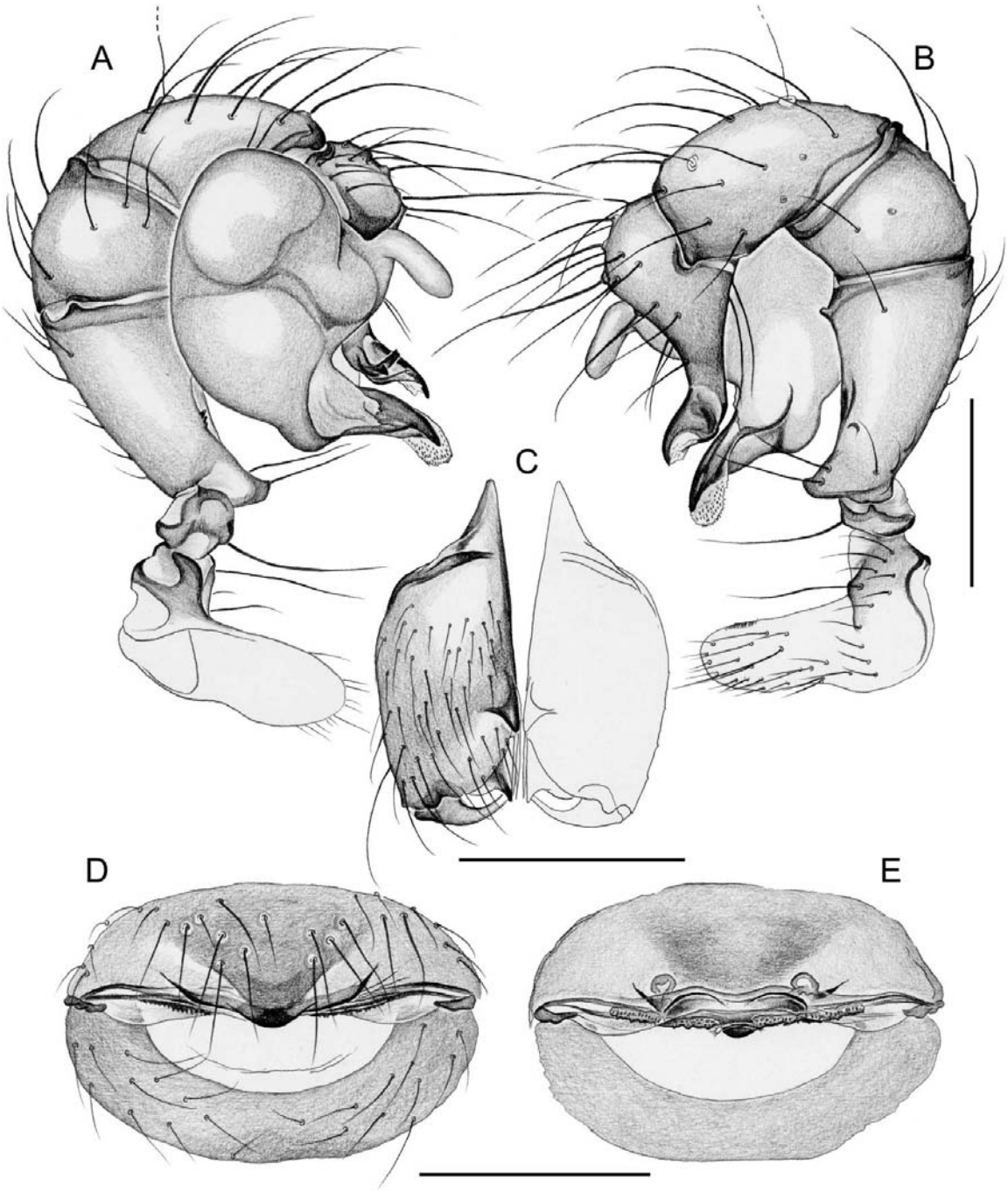

Figure 5. *Tupigea angelim* sp. nov. Male left palp in prolateral (A) and retrolateral (B) views, male chelicerae, frontal view (C), and cleared female genitalia in ventral (D) and dorsal (E) views. Scale bars: 0.2 mm.

carapace ochre-yellow, darker around thoracic furrow, ocular area and clypeus light brown, clypeus medially with dark brown band that is lined by two cuticular ridges (Figures 6A,B), sternum and legs ochre-yellow, legs with darker rings subdistally on femora and tibiae, abdomen greenish-grey with large darker marks on dorsal half. Distance PME–PME 70 μm, diameter PME 70 μm, distance PME–ALE 35 μm; AME absent, only irregular pigment spots. Ocular area slightly elevated, thoracic furrow shallow but distinct, clypeus unmodified (Figure 6A). Chelicerae as

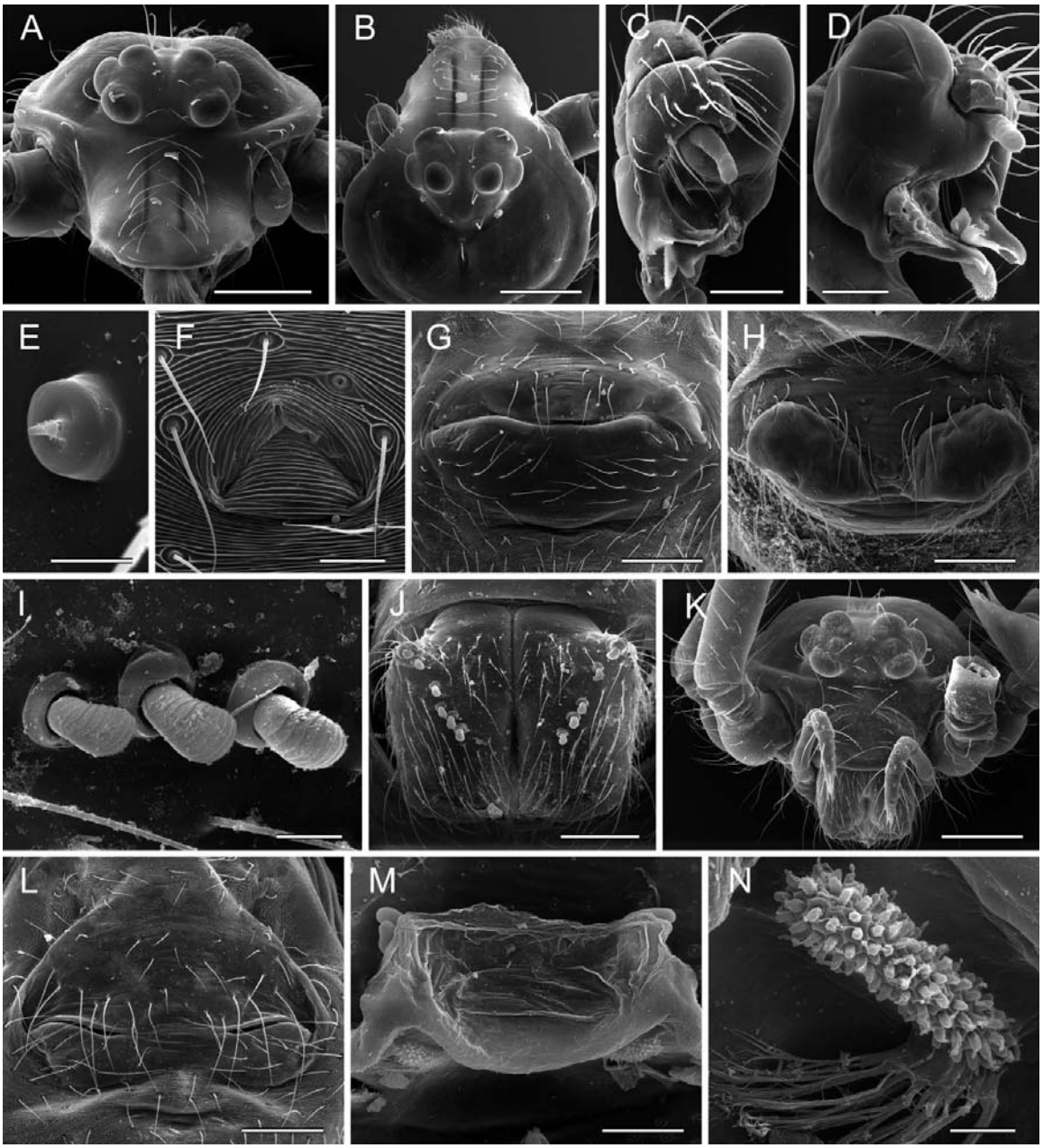

Figure 6. Scanning electron micrographs of *Tupigea angelim* sp. nov. (A–H) and *T. maza* (I–N). (A, B) Male prosoma, frontal and dorsal views, showing ridges on clypeus; (C) right palp in dorsal view; (D) left palp in prolatero-dorsal view; (E) male palpal tarsal organ; (F) male gonopore; (G, H) epigynum without (G) and with (H) genital plug. (I) Modified hairs on male chelicerae; (J) male chelicerae, frontal view; (K) female prosoma; (L) epigynum; (M) cleared epigynum, dorsal view; (N) pore plate. Scale bars: 5 μm (E), 10 μm (I, N), 20 μm (F), 50 μm (M), 80 μm (D, J), 100 μm (C, G, H, L), 200 μm (A, B, K).

in Figure 5C, with distinctive pair of frontal apophyses. Sternum wider than long (0.46/0.38), unmodified. Palps as in Figure 5A,B, coxa with indistinct retrolateral apophysis, trochanter barely modified, femur with proximal projection, tiny cones on prolatero-ventral side, tiny retrolateral apophysis, and small ventral apophysis distally, patella relatively long ventrally, procursus short, distally with distinctive sclerotized and membranous elements, bulb large, with distinctive dorsal worm-shaped

projection and partly membranous embolic division with terminal apophysis and transparent flap. Palpal tarsal organ exposed (Figure 6E). Legs without spines and curved hairs, with some vertical hairs on tibiae dorsally; retrolateral trichobothrium on tibia 1 at 22%; tarsus 1 with 16 pseudosegments, quite distinct. Anterior lateral spinnerets with two spigots each; gonopore without epiandrous spigots (Figure 6F).

Variation. Tibia 1 in four other males: 3.7, 3.9 (type locality), 3.0, 3.3 (Rio das Pedras); in males from Rio das Pedras the tiny cones ventrally on the femur are replaced by a single slightly larger apophysis; otherwise palps and chelicerae identical.

Female

In general similar to male but without darker median band and cuticular ridges on clypeus; carapace medially and ocular area darker brown; tibia 1 in eight females: 1.6–2.0 (mean 1.85). Epigynum (Figures 4B, 5D, 6G) frontal plate darkened medially, posterior margin sclerotized, posterior plate with pair of frontal indentations; internal genitalia as in Figure 5E. In females from Rio das Pedras the posterior margin of the frontal plate is barely sclerotized and less protruding, but the internal genitalia appear indistinguishable. Two females with genital plugs (Figure 4C, 6H).

Distribution

Known from two localities in São Paulo and Rio the Janeiro states (Figure 2).

Material examined

BRAZIL: São Paulo: Ubatuba, Fazenda Angelim: 3♂, 4♀ types above; same data, 5♀ in pure ethanol, in ZFMK. Rio de Janeiro: Reserva Ecológica Rio das Pedras (22°59.5′ S, 44°06.0′ W), 50 m a.s.l., night collecting, 25 September 2009 (B.A. Huber), 1♂, 3♀ in ZFMK; same locality but 22°59.5′ S, 44°06.0′ to 06.8′ W, 50–200 m a.s.l., day collecting, 26 September 2009 (B.A. Huber, A. Giupponi), 1♂, 3♀ in MNRJ (1♂, 2♀) and ZFMK (1♀).

Tupigea penedo Huber, sp. nov.

(Figures 4D–H, 7A–E, 11G)

Types

Male holotype and 1♂, 2♀ paratypes from Brazil, Rio de Janeiro, ~ 4 km northwest Penedo (22°24.5′ S, 44°33,0′ to 33,4′ W), forest along river, 700–770 m a.s.l., 14–16 August 2007 (B.A. Huber), holotype and 1♀ in MNRJ, 1♂, 1♀ paratypes in ZFMK.

Etymology

The specific name is a noun in apposition, taken from the type locality.

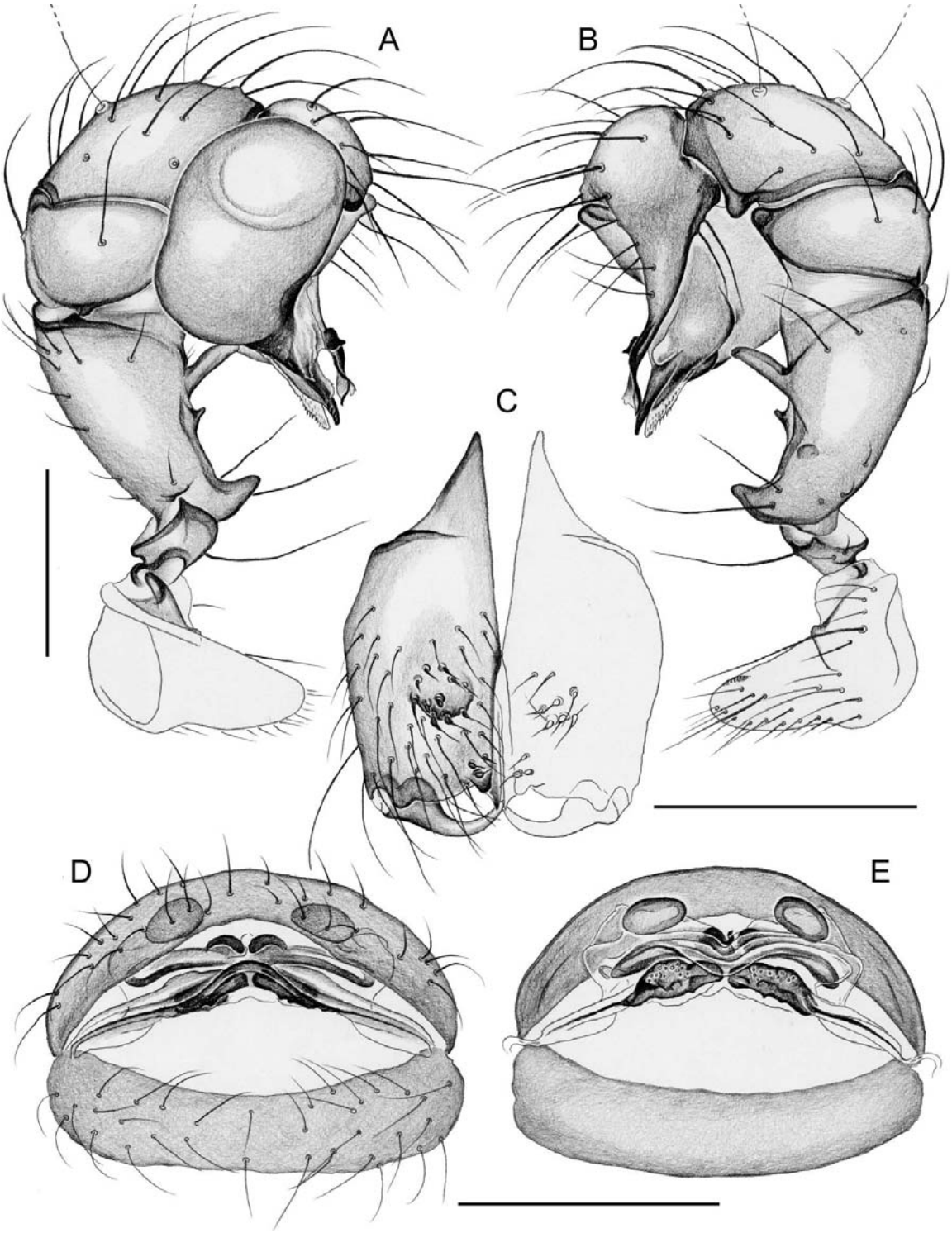

Figure 7. *Tupigea penedo* sp. nov. Male left palp in prolateral (A) and retrolateral (B) views, male chelicerae, frontal view (C), and cleared female genitalia in ventral (D) and dorsal (E) views. Scale bars: 0.2 mm.

Diagnosis

Easily distinguished from known congeners by armature on male chelicerae (several small modified hairs and distal apophyses, Figure 7C); also by male palp (femur

apophyses, procursus shape, embolic division of bulb, Figure 7A,B), and female genitalia (distinctive arch on frontal plate; Figures 4G, 7D).

Male (holotype)

Total body length 1.6, carapace width 0.63. Leg 1: 11.0 (3.0 + 0.3 + 2.9 + 3.8 + 1.0), tibia 2: 1.6, tibia 3: 1.1, tibia 4: 1.5, tibia 1 L/d: 55. Habitus as in Figure 4D,E; carapace ochre-yellow, darker around thoracic furrow, ocular area and clypeus brown, clypeus medially with dark brown band (possibly with ridges like *T. angelim*, but no male prosoma was studied with SEM), sternum and legs pale ochre-yellow, very indistinct darker rings subdistally on femora and tibiae, abdomen pale greenish-grey with some darker bluish marks dorsally. Distance PME–PME 60 μm, diameter PME 70 μm, distance PME–ALE 70 μm; AME absent, only pair of pigment spots. Ocular area slightly elevated, thoracic furrow shallow but distinct, clypeus unmodified. Chelicerae as in Figure 7C, with small distal apophyses and distinctive modified hairs on frontal humps and near lamina. Sternum wider than long (0.46/0.36), unmodified. Palps as in Figure 7A,B, coxa with indistinct retrolateral apophysis, trochanter barely modified, femur with large proximal projection and two ventral apophyses more distally, with small retrolateral hump, patella relatively long ventrally, procursus short and slender (wider in dorsal than in retrolateral view, Figure 11G), distally with distinctive sclerotized and membranous elements, bulb large, with partly membranous embolic division with terminal apophysis and transparent flap. Legs without spines and curved hairs, with some vertical hairs on tibiae dorsally; retrolateral trichobothrium on tibia 1 at 21%; tarsus 1 with ~ 15 pseudosegments.

Variation. Tibia 1 in other male: 3.1; this male is paler but has the rings on the legs more distinct; no AME pigment spots.

Female

In general similar to male but without darker median band on clypeus; tibia 1 in two females: 1.7 (both). Epigynum frontal plate with distinctive sclerotized arch posteriorly (Figures 4G, 7D), internal structures visible through cuticle, posterior plate simple; internal genitalia as in Figure 7E. One female with genital plug (Figure 4H).

Natural history

Leaf-litter dwelling species (see above).

Distribution

Known from type locality only (Figure 2).

Material examined

BRAZIL: Rio de Janeiro: ~ 4 km northwest Penedo: 2♂, 2♀ types above; same data, 1♂, 2♀ in pure ethanol, in ZFMK.

Tupigea ale Huber, sp. nov.

(Figures 3A,B, 4O,P, 8A–D, 9A–E)

Types

Male holotype and 3♂, 2♀ paratypes from Brazil, Rio de Janeiro: Reserva Ecológica Rio das Pedras (22°59.5′ S, 44°06.0′ to 06.8′ W), 50–200 m a.s.l., day collecting, 26 September 2009 (B.A. Huber), in MNRJ (holotype and 1♂, 1♀ paratypes) and ZFMK (2♂, 1♀ paratypes).

Etymology

Named for Alejandra Rojas Vargas in recognition of her hospitality during the 2009 trip by the first author. The name is here used as a noun in apposition.

Diagnosis

Distinguished from the very similar *T. guapia* by armature on male chelicerae (modified hair-bases on proximal elevations, Figures 8C, 9B,D) and by extremely simple external female genitalia (no large triangular scape; Figure 8D); from other known congeners also by male palp (femur without ventral modification, procursus shape, bulb shape, Figure 8A,B).

Male (holotype)

Total body length 1.8, carapace width 0.6. Leg 1: 19.3 (4.8 + 0.3 + 4.7 + 8.0 + 1.5), tibia 2: 3.0, tibia 3: 2.1, tibia 4: 2.9, tibia 1 L/d: 89. Habitus as in Figure 4O,P; prosoma and legs pale ochre-yellow, abdomen pale greenish-grey. Distance PME–PME 140 μm, diameter PME 55 μm, distance PME–ALE 35 μm, no trace of AME. Ocular area barely elevated, each triad on low hump, thoracic furrow shallow but distinct, clypeus unmodified. Chelicerae as in Figures 8C and 9D, with distinctive rows of modified hair-bases (Figure 9B) on proximal elevations. Sternum wider than long (0.48/0.40), unmodified. Palps as in Figure 8A,B, coxa without retrolateral apophysis, trochanter barely modified, femur slender, only proximally with retrolateral projection, patella relatively long ventrally, procursus short and slender, distally with distinctive sclerotized and membranous elements, bulb large, with partly membranous embolic division with terminal apophysis. Legs without spines and curved hairs, with vertical hairs on femora (Figure 9A) and tibiae; retrolateral trichobothrium on tibia 1 at 9%; tarsus 1 with ∼ 22 pseudosegments. Gonopore without epiandrous spigots.

Variation. In males from Ubatuba the modified cheliceral hair-bases are less clearly in a row (Figure 9E). Some males from all localities with sternum medially slightly darkened. Tibia 1 in 11 other males: 4.2–5.3 (mean: 4.8).

Female

In general similar to male; tips of palps darkened, no vertical hairs on legs; sternum colouration variable as in males. Tibia 1 in six females: 3.1–3.5 (mean: 3.3). Epigynum very simple, barely anything visible in light microscope except for internal greenish transversal structure visible through cuticle, either with small protruding

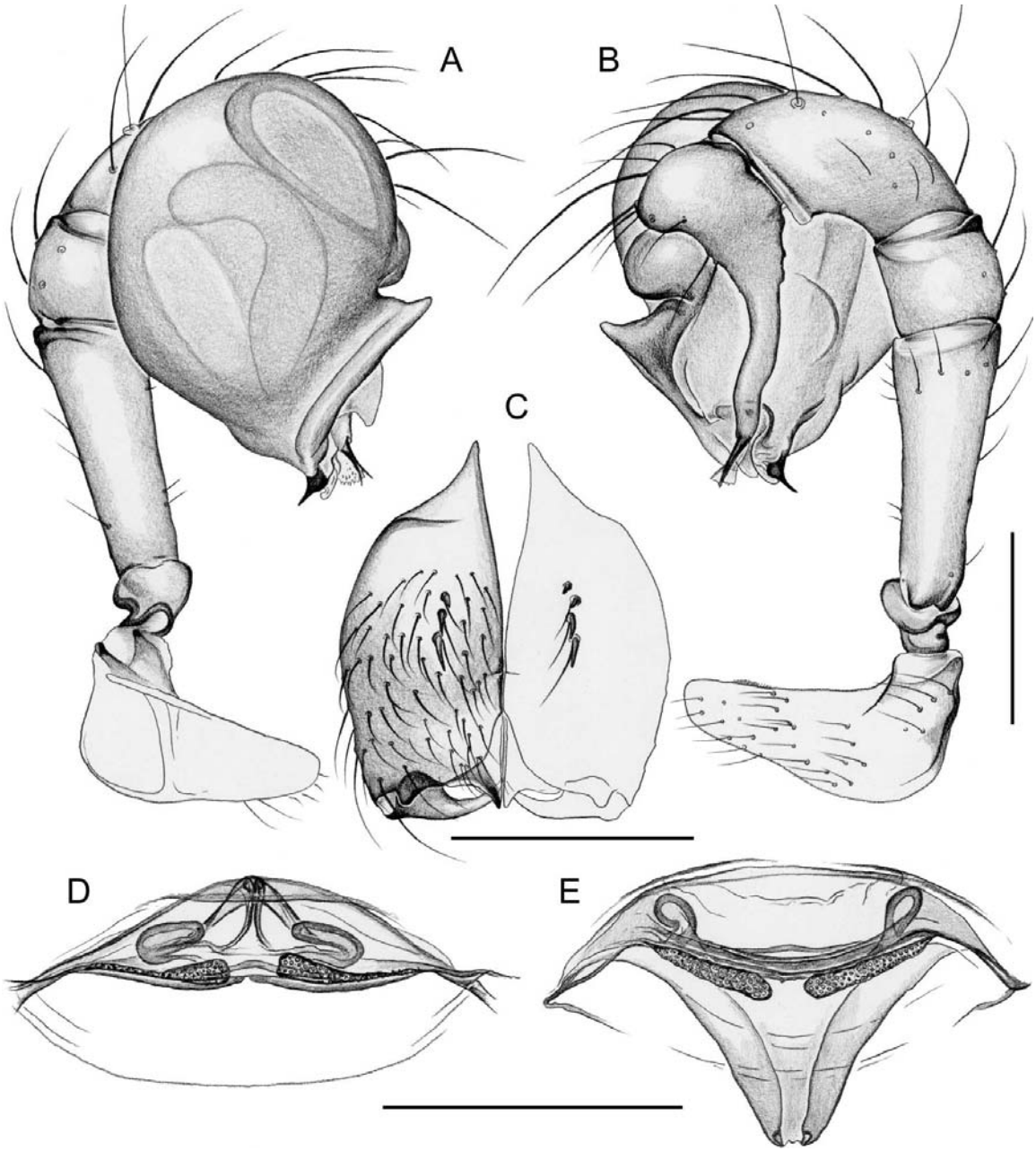

Figure 8. *Tupigea ale* sp. nov. (A–D) and *T. guapia* sp. nov (E). Male left palp in prolateral (A) and retrolateral (B) views, male chelicerae, frontal view (C), and cleared female genitalia in dorsal views (D, E). Scale bars: 0.2 mm.

scape (type locality), or without scape (Paraty, Ubatuba, Figure 9C). Internal genitalia as in Figure 8D.

Natural history

Leaf-dwelling species (see above).

Distribution

Known from three localities in Rio de Janeiro and São Paulo states (Figure 2).

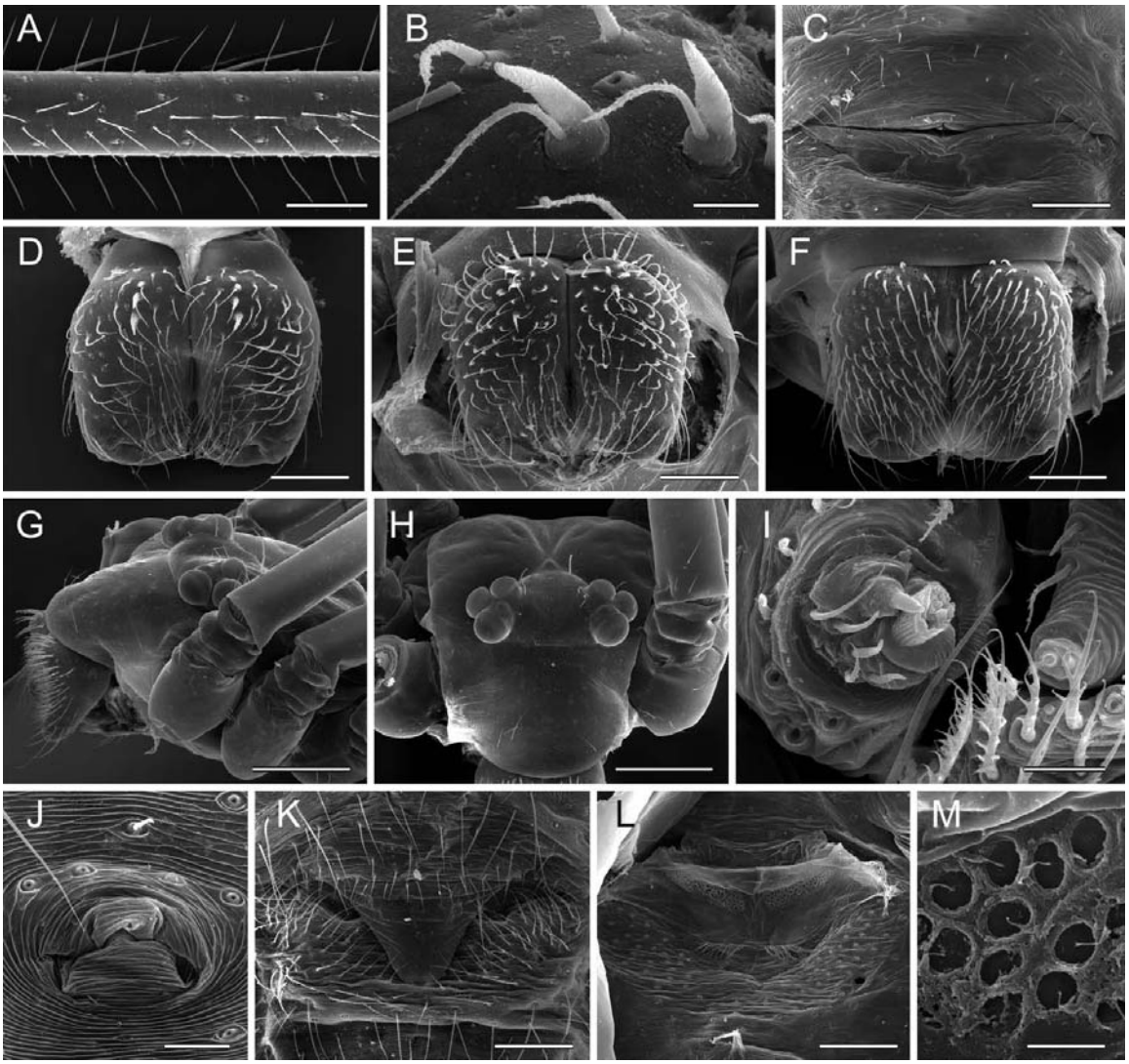

Figure 9. Scanning electron micrographs of *Tupigea ale* sp. nov. (A–E) and *T. guapia* sp. nov. (F–M). (A) Male femur 4, mid-section; (B) modified hair-bases on male chelicerae; (C) epigynum, female from Ubatuba; (D–F) male chelicerae, males from Rio das Pedras (D), Ubatuba (E) and Guapiaçú (F); (G, H) male prosoma in lateral and frontal views; (I) male spinnerets; (J) male gonopore; (K) epigynum; (L) cleared female genitalia, dorsal view; (M) detail of pore-plate. Scale bars: 6 μm (M), 10 μm (B, I), 20 μm (J), 50 μm (A), 80 μm (C–F, K, L), 200 μm (G, H).

Material examined

BRAZIL: Rio de Janeiro: Reserva Ecológica Rio das Pedras: 4♂, 2♀ types above; same data but 50 m a.s.l., night collecting, 25 September 2009 (B.A. Huber), 1♂, 1♀ in ZFMK. ~ 3.5 km northwest Paraty (23°11.5′ S, 44°43.9′ W), degraded forest, ~ 50 m a.s.l., 21 August 2007 (B.A. Huber), 2♂, 1♀ in ZFMK; same data, 3♂ in pure ethanol in ZFMK. Cachoeira da Pedra Branca near Paraty (23°11.8′ S, 44°46.0′ W), forest near river, ~ 230 m a.s.l., 22 August 2007 (B.A. Huber), 2♂, 1♀ in ZFMK; same data, 1♂, 1♀ in pure ethanol in ZFMK. São Paulo: Ubatuba, Fazenda Angelim (23°23.6′ S, 45°03.8′ W), 16–18 December 2003 (B.A. Huber), 5♂, 4♀ in ZFMK (4♂, 3♀) and IBSP (1♂, 1♀); same data, 1♂ in pure ethanol, in ZFMK.

Tupigea guapia Huber, sp. nov.

(Figures 8E, 9F–M)

Types

Male holotype and 2♂, 3♀ paratypes from Brazil, Rio de Janeiro: Cachoeiras de Macacú, Reserva Ecológica Guapiaçú (22°24.4′ to 25.3′ S, 42°44.2′ to 44.3′ W), 140–280 m a.s.l., 25 September 2009 (B.A. Huber), in MNRJ (holotype, 1♀ paratype), and ZFMK (2♂, 2♀ paratypes).

Etymology

The specific name is a noun in apposition, taken from the type locality.

Diagnosis

Very similar to *T. ale*, distinguished by male chelicerae (slightly stronger hairs on proximal elevation, no modified hair-bases; Figure 9F) and epigynum (large triangular scape, Figures 8E, 9K). From other known congeners also by male palp (femur without ventral modification, procursus shape, bulb shape).

Male (holotype)

Total body length 1.8, carapace width 0.6. Leg 1: 20.3 (5.1 + 0.3 + 4.9 + 8.5 + 1.5), tibia 2: 3.1, tibia 3: 2.2, tibia 4: 2.9, tibia 1 L/d: 79. Habitus as in *T. ale* (cf. Figure 4O,P); prosoma and legs pale ochre-yellow, abdomen pale greenish-gray. Distance PME–PME 170 μm, diameter PME 60 μm, distance PME–ALE 35 μm, no trace of AME. Ocular area barely elevated, each triad on low hump, thoracic furrow shallow but distinct, clypeus unmodified. Chelicerae as in Figure 9F, with slightly stronger hairs on proximal elevation but without modified hair-bases. Sternum wider than long (0.46/0.40), unmodified. Palps mostly as in *T. ale* (cf. Figure 8A,B), only bulbal apophysis slightly stronger and straighter; tarsal organ exposed. Legs without spines and curved hairs, with vertical hairs on femora and tibiae; retrolateral trichobothrium on tibia 1 at 9%; tarsus 1 with > 20 pseudosegments, poorly visible. Anterior lateral spinnerets with two spigots each (Figure 9I).

Variation. Tibia 1 in seven other males: 4.4–5.4 (mean: 4.9).

Female

In general similar to male; tips of palps darkened, no vertical hairs on legs. Tibia 1 in nine females: 3.3–3.9 (mean: 3.5). Epigynum with large triangular scape directed backwards (Figures 8E, 9K); internal genitalia as in Figures 8E and 9L.

Distribution

Known from type locality only (Figure 2).

Material examined

BRAZIL: Rio de Janeiro: Cachoeiras de Macacú, Reserva Ecológica Guapiaçú: 3♂, 3♀ types above; same data but 23 September 2009 (B.A. Huber, A. Giupponi), 1♂, 1♀ in ZFMK; same data but 23–24 September 2009 (B.A. Huber), 1♀, 1 juvenile in pure ethanol, in ZFMK; forest fragment near Res. Ecol. Guapiaçú (~22°27.9′ S, 42°45.8′ W), ~ 150 m a.s.l., 24 September 2009 (A. Giupponi), 5♂, 7♀ in MNRJ (3♂, 5♀) and ZFMK (2♂, 2♀).

Tupigea maza Huber, 2000

(Figures 4I,J, 6I–N, 10A,B)

Tupigea maza Huber 2000: 321, figs. 1299–1302.

Note

This species was previously known from two male specimens from Teresópolis, without further locality information. The new material below was collected about 20 km east of Teresópolis and appears indistinguishable from the type specimens.

Updated diagnosis

Males are easily distinguished from congeners (Huber 2000); females are fairly distinctive by large trapezoidal frontal epigynal plate (Figure 6L) and pair of receptacle-like structures clearly visible through cuticle (Figures 4J, 10A).

Male

See Huber (2000). The habitus of this species is very similar to that of *T. angelim* and *T. penedo*, but the clypeus lacks a distinct median band. Modified hairs on chelicerae as in Figure 6I,J. Tibia 1 in four males: 3.5–4.1.

Female

In general similar to male; tibia 1 in four females: 2.1–2.2. Epigynum simple externally, with large trapezoidal frontal plate (Figure 6L), internal receptacle-like structures visible through cuticle (Figures 4J, 10A), posterior plate simple and narrow; internal genitalia as in Figures 6M and 10B, with pore plates restricted to cuticular folds (Figure 6N).

Distribution

Known from two localities in Rio de Janeiro state (Figure 2).

New record

BRAZIL: Rio de Janeiro: Cachoeiras de Macacú, Reserva Ecológica Guapiaçú (22°24.3′ S, 42°44.1′ W), ~300–400 m a.s.l., 24 September 2009 (B.A. Huber, A. Giupponi), 4♂, 4♀ in MNRJ (1♂, 1♀) and ZFMK (3♂, 3♀); same data, 3♀ in pure ethanol, in ZFMK.

Tupigea teresopolis Huber, 2000

(Figures 3C–F, 4K–N, 10C–E, 11A–F)

Tupigea teresopolis Huber 2000: 317, figs. 1272–1277.

Notes

This species was previously known from a single male specimen from Teresópolis, without further locality information. The new material below was collected about 160 km west of Teresópolis but the distinctive morphology of the male palps appears indistinguishable. However, the male chelicerae consistently have an additional pair of small apophyses (Figure 10C), which is here tentatively regarded as intraspecific variation.

Updated diagnosis

Even considering intraspecific variation (see Note above) the male chelicerae are highly diagnostic; further distinguishing characters are the male palpal femur (ventral apophysis; Figure 11D), the bulb with transparent dorsal projection (Figure 11E), and the procursus with subdistal spine (fig. 1274 in Huber 2000); females have extremely simple external genitalia but internal structures are visible through the cuticle that make them distinguishable morphologically from close relatives (Figures 4K, 10D).

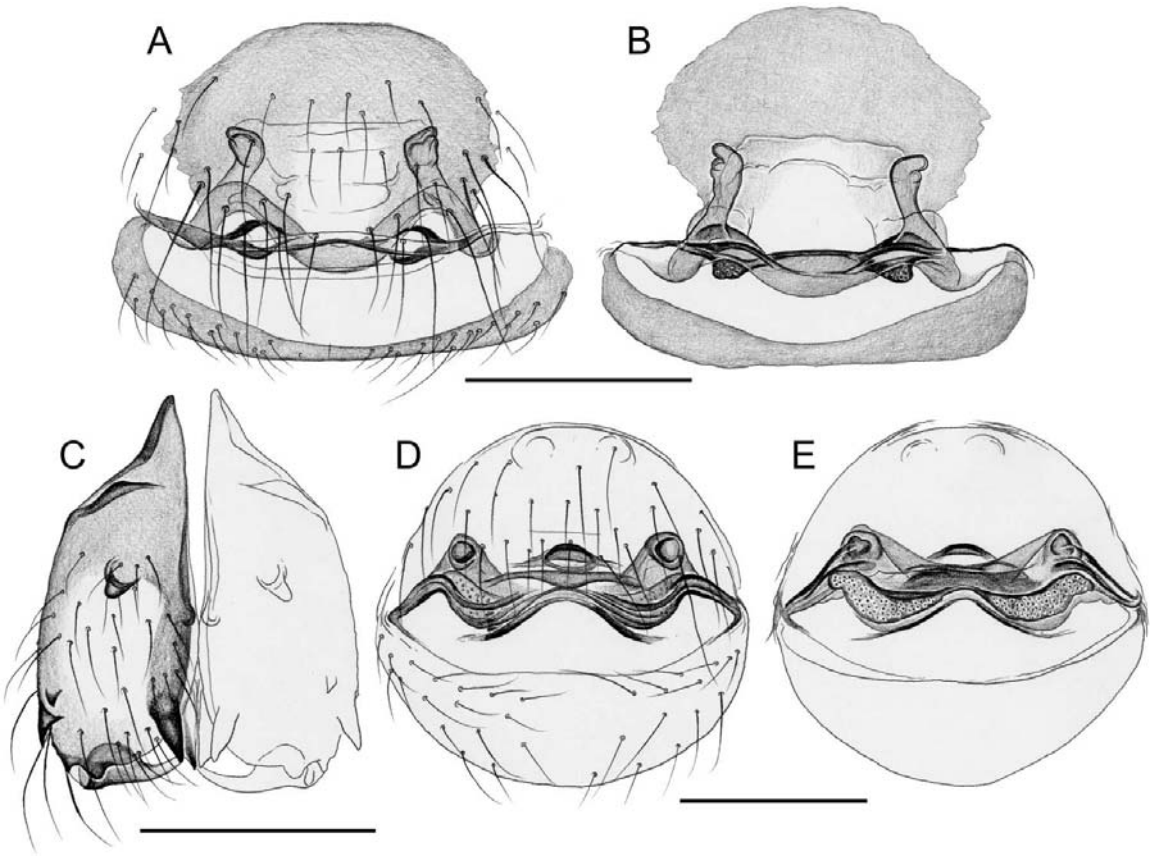

Figure 10. *Tupigea maza* (A, B) and *T. teresopolis* (C–E). Cleared female genitalia in ventral (A, D) and dorsal (B, E) views, and male chelicerae of male from Penedo (C). Scale bars: 0.2 mm.

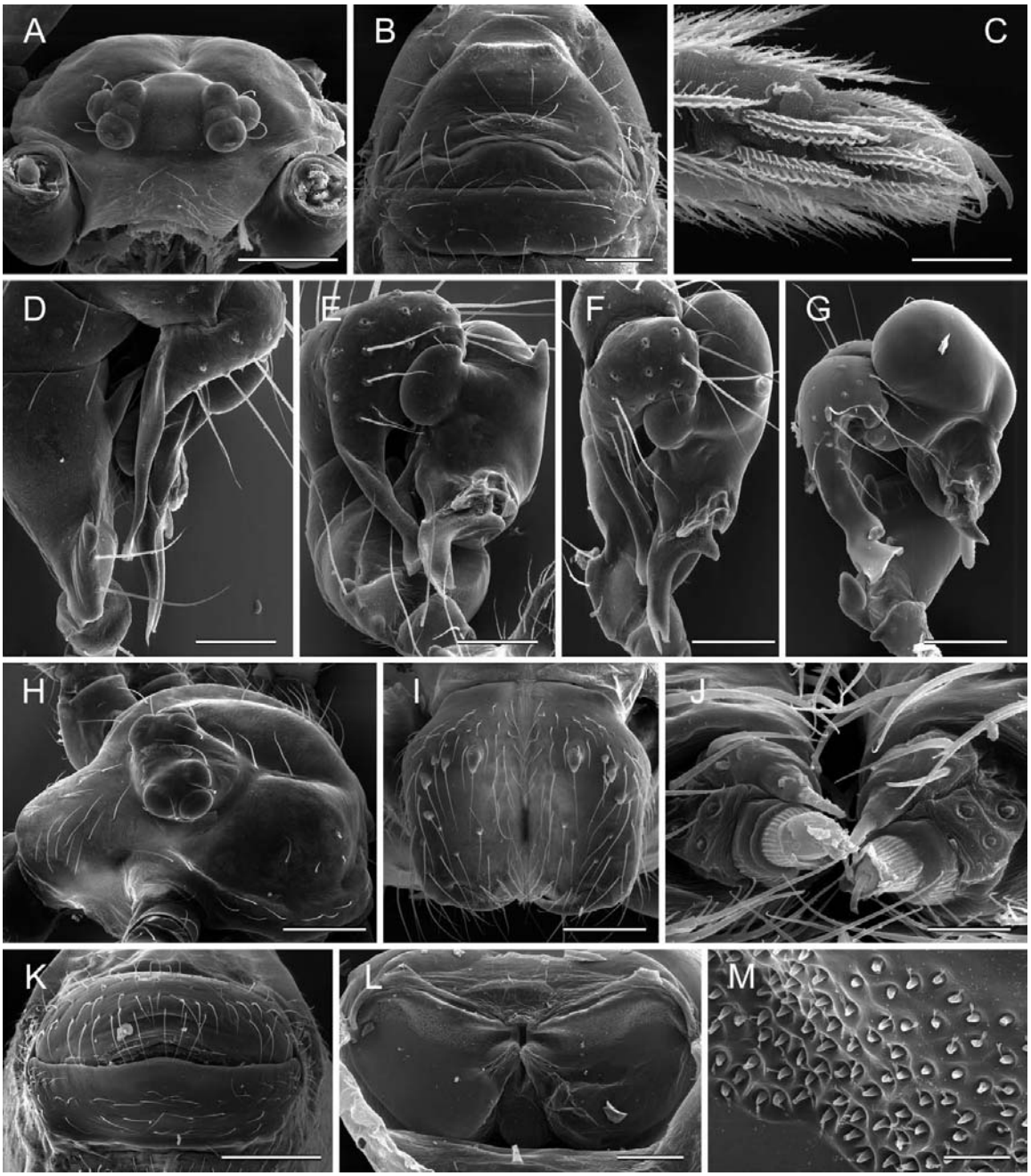

Figure 11. Scanning electron micrographs of *Tupigea teresopolis* (A–F), *T. penedo* sp. nov. (G), and *T. cantareira* (H–M). (A) Male prosoma, frontal view; (B) epigynum; (C) female tarsus 4 tip with comb-hairs; (D–G) male right palps in retrolateral (D), retrolatero-dorsal (E) and dorsal (F, G) views; (H) male prosoma, dorsolateral view; (I) male chelicerae; (J) female anterior lateral spinnerets; (K) epigynum; (L) cleared female genitalia, dorsal view; (M) detail of pore plate. Scale bars: 10 μm (J, M), 20 μm (C), 80 μm (D, E), 100 μm (B, F, G, I, L), 200 μm (A, H, K).

Male (see Huber 2000)

Newly collected male specimens with dark brown sternum, chelicerae with additional pair of small lateral apophyses (Figure 10C), total length 1.8 rather than 1.4 as in holotype. Tibia 1 in 11 males: 4.7–5.6 (mean 5.2); tibia 1 L/d: 86; retrolateral trichobothrium on tibia 1 at 11%, tarsus 1 with > 20 pseudosegments; vertical hairs on femora and tibiae. Tarsus 4 comb-hairs as in Figure 11C.

Female

Body shape similar to male but sternum whitish and carapace without brown Y-mark, clypeus mostly with pair of small light brown spots below triads, in two females entire clypeus light brown; tips of palps darkened, no vertical hairs on legs. Tibia 1 in six females: 3.2–3.7 (mean: 3.5). Epigynum very simple externally (Figure 11B), internal greenish-brown structures visible through cuticle (Figure 4K, 10D); internal genitalia as in Figure 10E. Some females with genital plugs.

Natural history

Leaf-dwelling species (see above).

Distribution

Known from two localities in Rio de Janeiro state (Figure 2).

New record

BRAZIL: Rio de Janeiro: ~ 4 km northwest Penedo (22°24.5′ S, 44°33.0′ to 33.4′ W), forest along river, 700–770 m a.s.l., 14–16 August 2007 (B.A. Huber), 12♂, 8♀ in MNRJ (1♂, 1♀) and ZFMK (11♂, 7♀); same data, 4♀ in pure ethanol, in ZFMK.

Tupigea cantareira Machado et al., 2007

(Figure 11H–M)

Tupigea sp. 2: Astrin et al. 2006: 445; 2007: 20.
Tupigea cantareira Machado et al. 2007: 32, figs. 29–40.

Note

Figure 11H–M supplement the original description that did not include SEM images: deep thoracic groove (Figure 11H), cheliceral apophyses in regular arches (Figure 11I), anterior lateral spinnerets with only two spigots each (Figure 11J), epigynum consisting of two large plates of approximately equal size (Figure 11K), pore plates relatively small and in frontal position (Figure 11L,M).

Acknowledgements

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