

Research article

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Phylogenetic placement of *Carrhotus* Thorell, 1891 with three new species from Sri Lanka (Araneae: Salticidae)

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Abstract. The Sri Lankan species of the genus *Carrhotus* Thorell, 1891 have remained taxonomically unrevised. The present study reviews all species of the genus in the island. Here we describe and diagnose three new species: *Carrhotus albosetosus* sp. nov. (♀), *C. atratus* sp. nov. (♂♀) and *C. lobatus* sp. nov. (♂). Further, *C. silanthi* Caleb, 2020 is reported in Sri Lanka for the first time. *Carrhotus taprobanicus* Simon, 1902 and *C. viduus* (C.L. Koch, 1846) are redescribed based on material from Sri Lanka. A key to the *Carrhotus* species in Sri Lanka is given.

Keywords. Islands, biogeography, South Asia, India, invertebrates.

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Introduction

Jumping spiders (Salticidae Blackwall, 1841) is the most diverse spider family and includes species commonly encountered in many habitats (World Spider Catalog 2022). This is also the case in Sri Lanka, where they are remarkably diverse. Currently, 86 species placed in 50 genera, with a large endemic component, are known from the island (Benjamin 2004, 2010, 2015; Benjamin & Bambaradeniya 2006; Edwards & Benjamin 2009; Benjamin & Kanesharatnam 2016; Kanesharatnam & Benjamin 2016). However, recent fieldwork conducted around the country suggests that this might only be a small fraction of the island's jumping spider diversity.

The genus *Carrhotus* was erected by Thorell in 1891 with *Plexippus viduus* C.L. Koch, 1846 as its type species. It currently contains 33 species, mostly from the Oriental region (World Spider Catalog 2022). The first species of the genus from Sri Lanka, the endemic *Carrhotus taprobanicus* Simon, 1902, was nominally described, sans illustrations a few years thereafter (Simon 1902). Recently, *Carrhotus viduus* (C.L. Koch, 1846) was recorded from the island by Prószyński (2009), with descriptions based on a pair of specimens collected by Fruhstorfer in 1889. Further, a very recent revision of the Indian *Carrhotus*

provides descriptions of three new species and updates the taxonomy of the genus. One species newly described therein, *C. silanthi* Caleb, 2020, is recorded from Sri Lanka for the first time (Caleb *et al.* 2020).

Maddison (2015) based on an explicit phylogenetic framework placed *Carrhotus* in the tribe Salticini Blackwall, 1841 of the subfamily Salticinae Blackwall, 1841. Previously, *Carrhotus* was classified in the Hylleae by Simon (1903) and later considered a Chrysillinae based on the conformation of its copulatory organs (Prószyński 1976, 2017). However, these placements were not tested within a phylogenetic framework, until recently. In this paper we review the taxonomy of *Carrhotus* spp. of Sri Lanka and describe three new species. Further, we infer the phylogenetic placement of the *Carrhotus* spp. of Sri Lanka using two target genes.

Material and methods

Taxon sampling

Fieldwork was conducted in all climatic regions of Sri Lanka (Koelmeyer 1958). Spiders were collected by beating vegetation and general hand collection up to a height of approximately 1.5 m. The collected specimens were preserved in either 70% or 100% ethanol. Our phylogenetic analysis contains 38 terminal taxa, including 20 in-groups (6 of 38 taxa were newly sequenced for this study). Additional sequences of *Carrhotus* spp. were obtained from GenBank to represent a geographically widely distributed sample. The outgroup taxa included closely related genera. This selection of ingroup and outgroup was based on Maddison (2015). The outgroup taxa are from the genera *Thiania* C.L. Koch, 1846, *Euryattus* Thorell, 1881, *Siler* Simon, 1889, *Chrysilla* Thorell, 1887, *Phintella* Strand, 1906, *Chinattus* Logunov, 1999, *Hasarius* Simon, 1871, *Habrocestum* Simon, 1876, *Idastrandia* Strand, 1929, *Yllenus* Simon, 1868, *Aelurillus* Simon, 1885, *Phlegma* Simon, 1876, *Frigga* C.L. Koch, 1850, *Freya* C.L. Koch, 1850, *Salticus* Latreille, 1804, *Evarcha* Simon, 1902, *Pancorius* Simon, 1902 and *Marengo* G.W. Peckham & E.G. Peckham, 1892. *Marengo* was used to root the tree. For this analysis *Carrhotus* sp. (WPM-10), *Carrhotus* sp. (WPM-2008), *Carrhotus xanthrogramma* (Latreille, 1819), *Philaeus chrysops* (Poda, 1761), *Pignus* sp., *Tusitala lyrata* (Simon, 1903), *Phaulostylus grammicus* Simon, 1902 and *Mogrus* sp. were included within the ingroup. The *Carrhotus* species *C. silanthi* Caleb, 2020, *C. viduus*, *C. taprobanicus*, *C. atratus* sp. nov., *C. lobatus* sp. nov. and *C. albosetosus* sp. nov. are from Sri Lanka. Further, *Carrhotus* sp. (WM10 isolate) is from Malaysia, *Carrhotus* sp. (WPM-2008) is from Malaysia and *C. viduus* is from India. Accession numbers for all sequences and locality information are given in Table 1.

Morphology

Methodology and taxonomic descriptions are based on the format of Benjamin & Kanesharatnam (2016), and Benjamin (2004, 2010). Specimens for the morphological study were preserved in 70% ethanol and identified using an Olympus SZX7 stereo microscope. Female genitalia were excised using insect pins and digested with the Sigma Pancreatin Ip 1750 enzyme complex in a solution of sodium borate (Dingerkus & Uhler 1977). Male palps and epigynes were cleared with methyl salicylate and mounted for study. Drawings of male palps, epigynes and vulvae were made with the aid of a drawing tube attached to a Leica DM3000 LED compound microscope. Either a Nikon D80 or a D7000 camera with a macro lens was used to take photographs of live spiders. Photographs of palps, epigynes and intact spiders were taken with a Leica MC170 HD camera mounted on a Leica M205C stereo microscope using Leica Application Suite software (Leica Microsystems Limited, Germany). Images were merged with Helicon Focus image stacking software (ver. 6, Helicon soft Ltd). Images were then edited with Adobe Photoshop CC and assembled using Adobe Illustrator CS6. All measurements are in millimeters. Body length was measured as carapace length plus abdomen length (excluding spinnerets). Types and other specimens of the new species described herein are currently deposited in the National Institute of Fundamental Studies, Kandy, Sri Lanka (NIFS). For a complete list of taxonomic references for the previously described species see World Spider Catalog (2022).

Table 1 (continued on the next page). Details of exemplars used in this study including NIFS voucher numbers, geographic origin and GenBank accession numbers. Accession numbers in bold denote sequences generated for this study. All species belong to the family Salticidae Blackwall, 1841. Abbreviations: CP = Central Province; NCP = North Central Province; NP = Northern Province; SL = Sri Lanka; SP = Southern Province; UP = Uva Province; WP = Western Province.

Species	Voucher number	Geographic origin	COI	28S
Ingroup taxa				
<i>Carrhotus silanthi</i>	NIFS_Sal_824	SL, NCP, Mihintale	MW655747	–
<i>Carrhotus silanthi</i>	NIFS_Sal_825	SL, NCP, Mihintale	MW655746	MW678611
<i>Carrhotus albosetosus</i> sp. nov.	NIFS_Sal_911	SL, WP, Pillikutuwa	–	MW678609
<i>Carrhotus atratus</i> sp. nov.	NIFS_Sal_1289	SL, NP, Mandaitivu	–	MW678612
<i>Carrhotus atratus</i> sp. nov.	NIFS_Sal_932	SL, NP, Mandaitivu	MW655745	MW678608
<i>Carrhotus taprobanicus</i>	NIFS_Sal_279	SL, UP, Ohiya	MW655748	MW678606
<i>Carrhotus taprobanicus</i>	NIFS_Sal_1155	SL, CP, Knuckles	MW698742	MW678607
<i>Carrhotus lobatus</i> sp. nov.	NIFS_Sal_1285	SL, SP, Hiyare	MW655749	MW678613
<i>Carrhotus lobatus</i> sp. nov.	NIFS_Sal_282	SL, CP, Gammaduwa	–	MW678605
<i>Carrhotus lobatus</i> sp. nov.	NIFS_Sal_403	SL, CP, Pitawala Pathana	MW655744	MW678604
<i>Carrhotus viduus</i>	NIFS_Sal_888	SL, CP, Gannoruwa	MW698741	MW678610
<i>Carrhotus viduus</i>		India	KT383765	–
<i>Carrhotus xanthrogramma</i>		South Korea	JN817255	JN817037
<i>Carrhotus</i> WM10		Malaysia	KY017891	KY017322
<i>Carrhotus</i> WM2008		Malaysia	EU815606	EU815494
<i>Philaeus chrysops</i>		Italy	EU815590	EU815475
<i>Pignus</i> sp.		South Africa	EU815596	EU815481
<i>Tusitala lyrata</i>		Gabon	JX145689	JX145771
<i>Phaulostylus grammicus</i>		Madagascar	–	KM033186
<i>Mogrus</i> sp.		–	MF135532	EU815508
Outgroup taxa				
<i>Chrysilla volupe</i>	NIFS_Sal_443	SL, WP, Ballagola	MG910461	MG883389
<i>Siler semiglaucus</i>	NIFS_Sal_731	SL, SP, Galle	KY888770	KY888731
<i>Phintella vittata</i>	NIFS_Sal_816	SL, NCP, Mihintale	KY888751	KY888728
<i>Habrocestum hantanensis</i>	NIFS_Sal_827	SL, CP, Loolecondera	KY888765	KY888739
<i>Hasarius adansoni</i>	NIFS_Sal_268	SL, CP, Kandy	KY888756	KY888749
<i>Marengo crassipes</i>	NIFS_Sal_038	SL, CP, Riverstone	MT828396	MW699920
<i>Evarcha proshynskii</i>		Canada	–	DQ665765
<i>Phlegra fasciata</i>		USA	AY297415	AY297288
<i>Aelurillus</i> cf. <i>ater</i>		Kazakhstan	EU815615	EU815504
<i>Idastrandia orientalis</i>		Malaysia: Sabah	EU815608	EU815496

Table 1 (continued). Details of exemplars used in this study including NIFS voucher numbers, geographic origin and GenBank accession numbers. Accession numbers in bold denote sequences generated for this study. All species belong to the family Salticidae Blackwall, 1841.

Species	Voucher number	Geographic origin	<i>COI</i>	<i>28S</i>
<i>Chinattus parvulus</i>		Canada	KP655069	EU815464
<i>Yllenus arenarius</i>		Poland	EU815583	–
<i>Salticus scenicus</i>		Canada	KY017900	EU815467
<i>Euryattus</i> sp.		Australia	KC615750	KY017335
<i>Thiania latibola</i>		Malaysia	–	KC615569
<i>Frigga crocuta</i>		–	AY297402	AY297275
<i>Freya decorata</i>		Ecuador	KY017892	KY017324
<i>Pancorius</i> sp. B		Canada	JX145697	JX145781

Abbreviations

Morphology

AG	=	accessory glands
AL	=	abdominal length
ALE	=	anterior lateral eyes
AME	=	anterior median eyes
AW	=	abdominal width
CO	=	copulatory opening
E	=	embolus
FD	=	fertilization ducts
Fm	=	femur
ML	=	mid line
Mt	=	metatarsus
PEB	=	posterior epigynal border
PL	=	prosoma length
PLE	=	posterior lateral eyes
PLP	=	posterior lateral protrusion
PME	=	posterior median eyes
Pt	=	patella
PW	=	prosoma width
RTA	=	retrolateral tibial apophysis
S	=	spermathecae
SD	=	sperm duct
Ta	=	tarsus
Tb	=	tibia
TE	=	tegulum
TL	=	total length
Tr	=	trochanter

Additional abbreviation

FR	=	Forest Reserve
ML	=	Maximum likelihood

Table 2. Gene targets, PCR conditions and primer data used in this study. References: a = Simon *et al.* 1994; b = Dallas *et al.* 2005; c = Whiting *et al.* 1997.

Gene	Primers	Amplicon length (bp)	Annealing temperature/time	5'-Primer Sequence-3'	Reference
<i>COI</i>	COI-1628 (F)	500–600	46°C / 50 s	ATAATGTAATTGTTACTGCTCA	a
	CI-N-2191 (R)			CCCGGTAAAATTTAAAATATAAA	b
<i>28S</i>	28S O (F)	700–800	50°C / 1.5 min	GAAACTGCTCAAAGGTAAACGG	c
	28S C (R)			GGTTCGATTAGTCTTTTCGCC	c

Repositories

MNHN	=	Muséum national d'histoire naturelle, Paris, France
NIFS	=	National Institute of Fundamental Studies, Kandy, Sri Lanka
NZC-ZSI	=	National Zoological Collections, Zoological Survey of India, Kolkata
ZMB	=	Museum für Naturkunde, Leibniz Institute for Research on Evolution and Biodiversity at the Humboldt University, Berlin, Germany

Gene targets and primers

A multilocus molecular approach was used for this study and the target loci were selected based on prior molecular phylogenetic studies of salticids (e.g., Hedin & Maddison 2001; Bodner & Maddison 2012). A partial fragment of the mitochondrial protein-encoding gene Cytochrome *c* oxidase subunit I (*COI* – 534 bp) and partial fragments of the nuclear gene, 28S ribosomal RNA (*28S* – 796 bp) were amplified. Details of each primer pair used, primer sequences, annealing temperatures and related references are given in Table 2.

DNA extraction, PCR and sequencing

Genomic DNA was extracted using the Qiagen DNeasy Tissue kit (Qiagen Inc., Valencia, CA, USA) following the manufacturer's protocols. Depending on size, either the first leg only, or the first and second legs from each specimen was removed. The remainder of the vouchered specimen is stored in 70% ethanol and deposited in the NIFS arachnid collection. Polymerase Chain Reaction (PCR) was carried out using either the Multiplex PCR kit (Qiagen) or the PuReTaq Ready-To-Go™ PCR beads (GE Healthcare, UK). For the former, the total reaction mixture consisted of 20 µL, including 2.5 µL undiluted DNA template, 1.6 µL forward and reverse primers, 10 pmol L⁻¹ of Q-Solution, 10 µL 'Multiplex PCR Master Mix' containing hot start Taq DNA Polymerase, buffers and 2.3 µL of water (all the components come with the Multiplex kit). In the case of PCR beads, the total reaction mix was 25 µL and included 13 µL of ultrapure RO (Reverse Osmosis) water, 1 µL of each of the forward and reverse primers (10 pmol L⁻¹) and 10 µL undiluted DNA template. A negative control (minus the template) was included to test for contamination during PCR runs. The primers used for amplification and their sources are given in Table 2. PCR products were verified on a 1% agarose gel and purified using the Gene Clean™ Turbo kit (MP Biomedicals, LLC, USA). All purified PCR products were Sanger sequenced (Sanger *et al.* 1977) in both directions by Macrogen (Seoul, South Korea).

Phylogenetic analysis

Sequences were assembled and edited using the Geneious ver. 11.0 software package. Sequence alignment was also done with the same software using default parameters and then edited manually using Mesquite ver. 3.51 (Maddison & Maddison 2018). The protein-coding *COI* was easily aligned.

The alignment of the non-coding 28S was further refined manually in Mesquite. The final alignments of the two gene fragments were then concatenated using the same program. Details of the fragments are provided in Table 2.

A model-based (maximum likelihood, ML) approach was used to infer the phylogenetic relationships of the targeted taxa. The best-fit model for likelihood analysis was searched by running the ‘find best DNA/

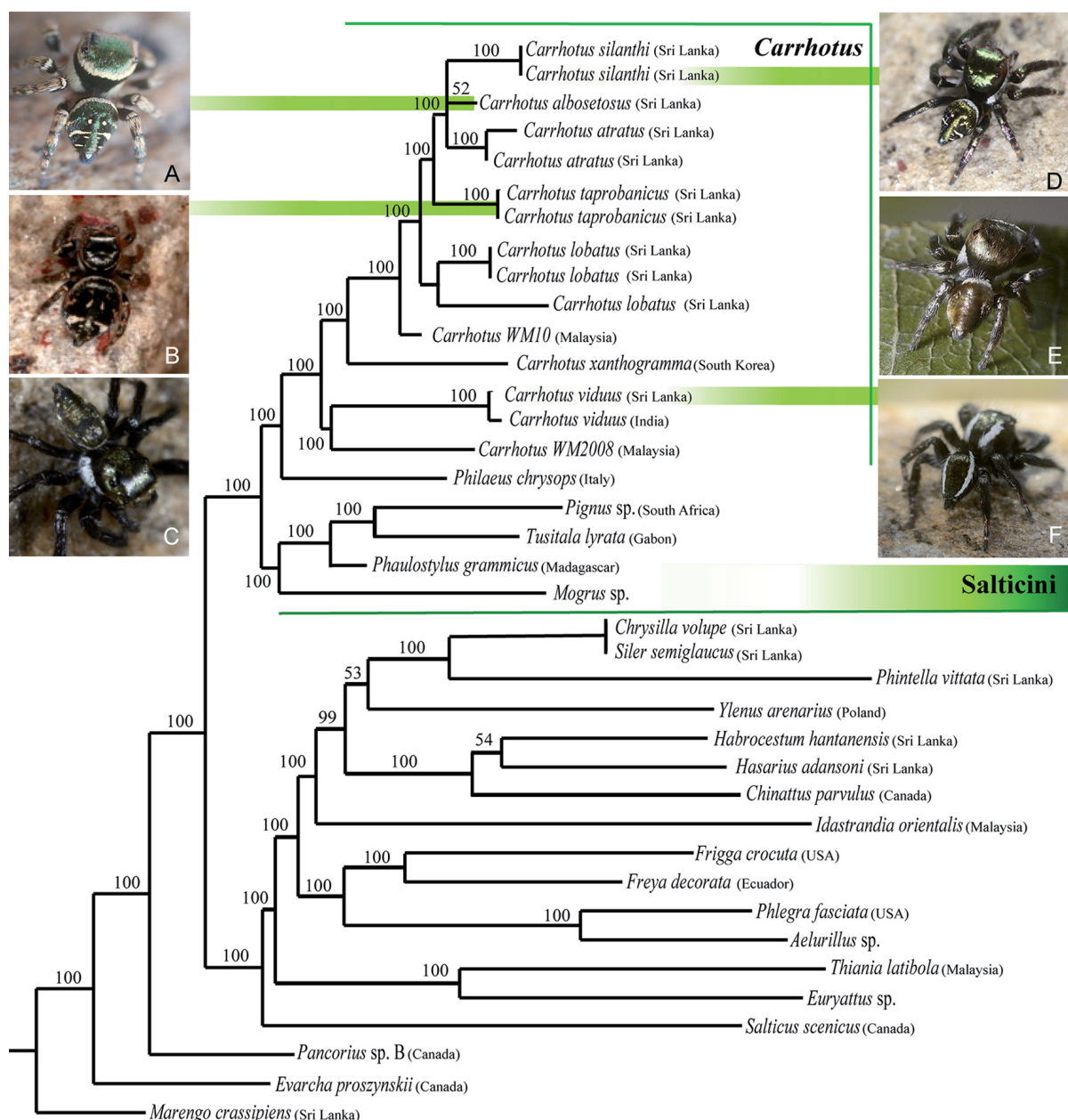


Fig 1. The single most likely tree obtained by ML analysis of the combined molecular data in RAxML–VI–HPC. The numbers above the nodes represent bootstrap values (only values 50 and above are given). Nodes that are unsupported have been collapsed. Collection country is given if available. In life images: A. *Carrhotus albosetosus* sp. nov. from Pillikutuwa. B. *C. taprobanicus* Simon, 1902 from Gomaraya. C. *C. silanthi* Caleb, 2020 from Ussangoda. D. *C. silanthi* from Giants Tank Sanctuary. E. *C. atratus* sp. nov. from Hiyare. F. *C. viduus* from Mandaitivu.

protein model (ML)’ option in MEGA X and models with the lowest Akaike Information Criteria were selected. After selecting the model (GTR+G+I), the phylogenetic tree was obtained through the online server for RAXML-VI-HPC (randomized accelerated maximum likelihood for high-performance computing ver. 2.0.1; Stamatakis 2006) as implemented in T-REX (Tree and reticulogram REConstruction; Boc *et al.* 2012), were performed for maximum likelihood analysis using the non-parametric bootstrap program. The parameters used were as follows: substitution model (GTRGAMMAI), algorithm executed (Hill climbing-default), and the bootstrap was estimated by 1000 alternative runs on distinct starting trees.

Results

Phylogenetic results

The assembled matrix of the concatenated fragments included 38 taxa (20 ingroups, 18 outgroups) and the total length was 1330 bp. The length of the two individual sequenced fragments, excluding the primers, was as follows: *28S*, 796 bp and *COI*, 534 bp. The best fit model for the combined data matrix generated using MEGA was GTR+G+I and, accordingly, GTRGAMMAI was selected as the compatible model in RAXML.

The phylogenetic tree resulting from ML analysis of the combined data matrix is presented in Fig. 1. The phylogenetic tree obtained from ML analysis of the combined data matrix recovers a well-supported *Carrhotus* clade. The Sri Lanka species *C. atratus* sp. nov., *C. albosetosus* sp. nov. and *C. silanthi* group together, whereas *C. taprobanicus* and *C. lobatus* sp. nov. are in a separate clade. *Carrhotus viduus* exemplars from both India and Sri Lanka group together and is sister species to *Carrhotus* sp. (WM.2008) from Malaysia. The placement of *Carrhotus* in Salticinae was expected as previously suggested by Maddison (2015).

Taxonomy

Class Arachnida Cuvier, 1812
Order Araneae Clerck, 1757
Family Salticidae Blackwall, 1841
Subfamily Salticinae Blackwall, 1841
Tribe Salticini Blackwall, 1841

Genus *Carrhotus* Thorell, 1891

Type species

Plexippus viduus C.L. Koch, 1846.

Diagnosis

Carrhotus can be readily distinguished from other salticid genera by the combination of the following characteristics: RTA stout, tegulum with at least a retrolateral and/or proximal lobe, embolus broad-based, tip mostly stout (Figs 6E–F, 7A–B, 8C–D, 9A–B, 11E–H, 12A–B, 13E–F, 14A–B, 15E–F, 16A–B) (C.L. Koch 1846; Simon 1902; Jastrzebski 1999; Caleb *et al.* 2020: 58, Figs 33–56). Females can be distinguished by the distinctive accessory glands on the external spermathecal walls and well sclerotized FD (Figs 4A–B, 7C–D, 12C–D, 12C–D, 14C–D, 16C–D). Spermatheca one chambered, oval to kidney-shaped (C.L. Koch 1846; Simon 1902; Jastrzebski 1999; Caleb *et al.* 2020: 58, Figs 33–56).

Description

Medium sized spiders. Cephalothorax longer than wide, eye field shorter than 50% of total cephalothorax length. PME mid-way between anterior and posterior laterals. Abdomen egg-shaped, beige to brown

with a lighter pattern. Chelicerae unident with 2 promarginal teeth and 1 retromarginal tooth. RTA not prominent; cymbium in some species with apical process; tegulum oval, expands beyond apical border of tibia (PLP); embolus stout, set laterally on top of tegulum, wider base. Female epigyne moderately sclerotized, strongly haired. CD well sclerotized, straight, curved or coiled. Spermatheca one-chambered, oval to kidney-shaped. FD is well sclerotized. Accessory glands on external spermathecal walls. Legs I and II robust with scopulae, III and IV more delicate. Hairs and bristles blackish. Leg formula: 1-2-4-3 (Jastrzebski 1999).

Distribution

Bhutan, Borneo, Brazil, China, Egypt, Ethiopia, Gabon, Libya, India, Indonesia, Iran, Madagascar, Malaysia, Myanmar, Nepal, Turkey, Vietnam, Seychelles, Sri Lanka, South Africa (World Spider Catalog 2022).

Composition in Sri Lanka

Currently, the genus consists of 33 species worldwide [for a full list see World Spider Catalog (2022)]. The following species are now recorded from Sri Lanka: *Carrhotus atratus* sp. nov., *C. albosetosus* sp. nov., *C. lobatus* sp. nov., *C. silanthi* Caleb, 2020, *C. taprobanicus* Simon, 1902 and *C. viduus* C.L. Koch, 1846. *Carrhotus silanthi* and *C. viduus* are also known from India.

Carrhotus albosetosus sp. nov.

urn:lsid:zoobank.org:act:8E87E441-3B3F-43D8-B5B3-9B647FC853B1

Figs 2A–B, 3A–C, 4A–B, 17

Diagnosis

Females of *C. albosetosus* sp. nov. can be separated from other congeners by the white hairs on the legs (Fig. 2A–B). The epigyne of this species is close to that of *C. silanthi*; however, it differs by the absence of prominent CD and FD as well as in the position of the opening of the accessory glands, which open at the 2'o clock position at the anterior region of the lateral walls of the spermathecae (Fig. 4A–B).

Etymology

The specific epithet is derived from a combination of Latin words; 'albi' meaning 'white' and 'comus' meaning 'legs', loosely referring to the white legs/white leg setae.

Material examined

Holotype

SRI LANKA • ♀; Western Province, Gampaha District, Pillikutuwa FR; 07°03'52.4" N, 80°03'04" E; 69 m a.s.l.; 28 Sep. 2016; N. Kanesharatnam. leg.; beating; NIFS_SAL_911.

Other material

SRI LANKA • 1 ♀; Central Province, Matale District, NIFS Arboretum; 07°51'65" N, 80°40'53" E; 184 m a.s.l.; 11–13 Oct. 2019; S.P. Benjamin *et al.* leg.; beating; NIFS_SAL_1262.

Description

Female

MEASUREMENTS. TL 4.9, PL 1.85, PW at PLEs 1.68, AL 2.1, AW 1.06. Eye field: diameter of AME 0.48; ALE 0.24; PME 0.22; PLE 0.08; PME–PME 1.4; PLE–PLE 1.44; ALE–PME 0.72; ALE–PLE 0.34. Leg I: Tr 1.1, Fm 0.9, Pt 0.8, Tb 0.5, Mt 0.4; Leg II: Tr 0.9, Fm 0.46, Pt 0.8, Tb 0.6, Mt 0.5; Leg III: Tr 1.5, Fm 0.42, Pt 0.82, Tb 0.34, Mt 0.42; Leg IV: Tr 1.6, Fm 0.5, Pt 1.02, Tb 0.6, Mt 0.34.

COLOR AND BODY. Live spider with clypeal region brown; covered with iridescent hairs providing a metallic sheen to green colour; lateral margins of carapace lined by thin line of white hairs; posterior region black (Fig. 2A–B). ALEs and PLEs surrounded by blackish orbital setae. Chelicerae dark brown with curved outer margins and excavated inner margins: two promarginal and one retromarginal teeth. Sternum oval, brownish; labium and maxillae reddish-brown, with paler outer margins. Abdomen ovoid, densely covered with rusty brown hairs; anterior margin covered with a thin line of white hairs; pattern present on black background with pair of two white spots anteriorly and pairs of transverse stripes and two pairs of white spots following posteriorly. Mid-dorsum covered with scales of metallic sheen; venter yellowish brown, with a thin dark brown scattered pattern on median region. Spinnerets blackish, covered with a patch of white hairs dorsally (Fig. 3A–B).

EPIGYNUM. Epigyne with a pair of simple copulatory openings and short copulatory ducts diverge to join semioval-shaped spermathecae. Accessory glands open at 2’o clock position on anterior region of lateral walls of spermathecae (Figs 3C, 4A–B).

Distribution and habitat

Known only from the two localities mentioned above. The spiders were collected by beating foliage up to a height of 2 m. This species occurs in the lowland secondary rainforest of the dry zone and submontane forest of the central highlands of Sri Lanka (Fig. 17).

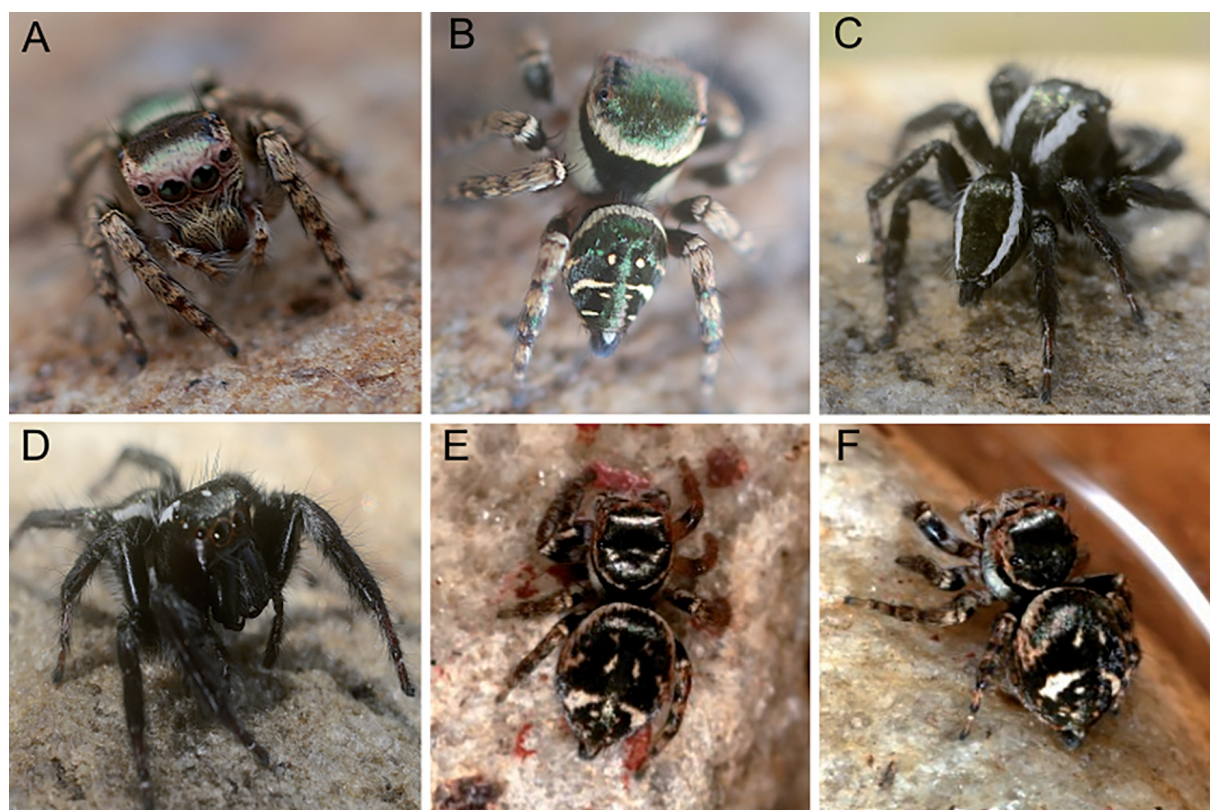


Fig 2. Photographs of live *Carrhotus* spp. **A–B.** *Carrhotus albosetosus* sp. nov., female from Pillikutuwa. **C–D.** *C. viduus*, male from Mandaitivu. **E–F.** *C. taprobanicus*, female from Gomaraya.

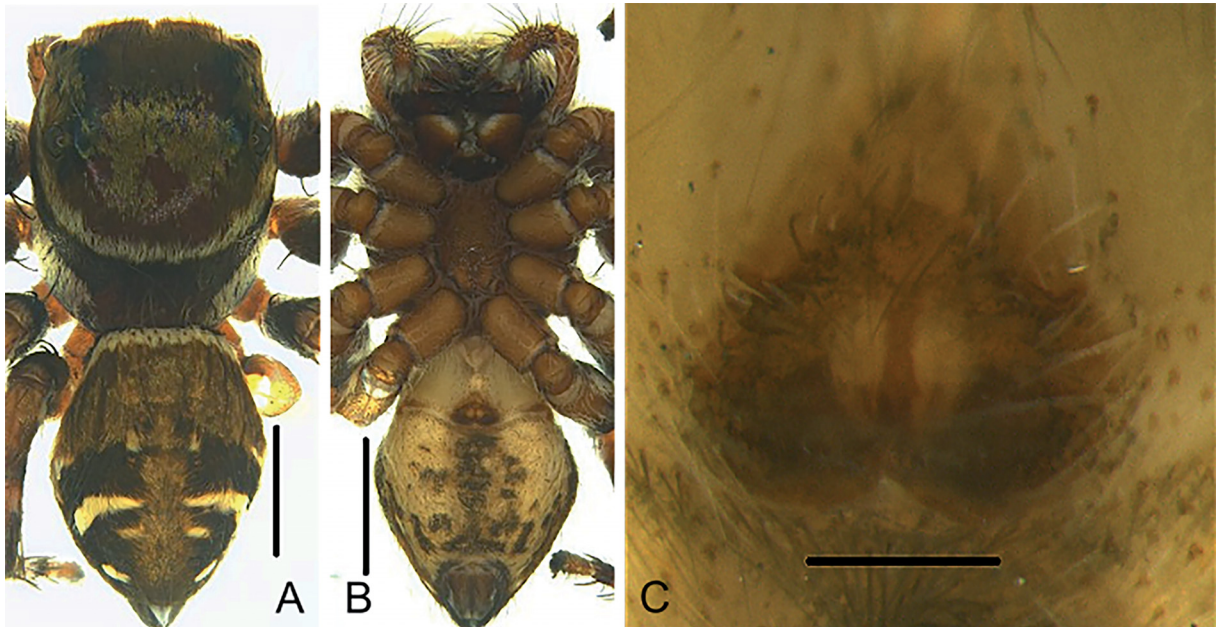


Fig 3. *Carrhotus albosetosus* sp. nov., female. **A.** Habitus, dorsal view. **B.** Habitus, ventral view. **C.** Epigynum. Scale bars: A–B = 2 mm; C = 0.1 mm.

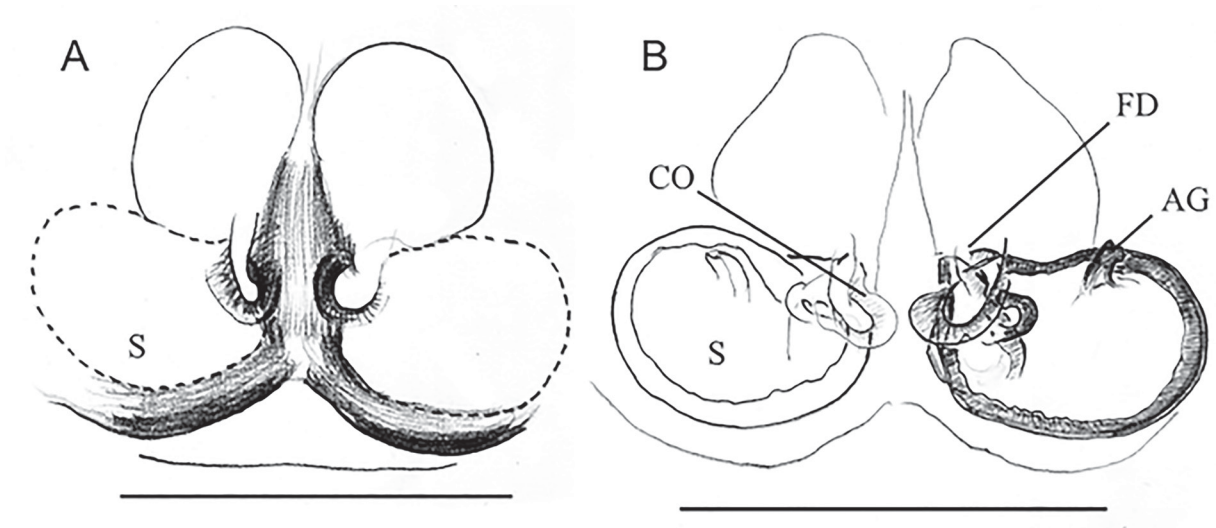


Fig 4. *Carrhotus albosetosus* sp. nov. **A.** Epigynum, ventral view. **B.** Vulva, dorsal view. Abbreviations: AG = accessory gland; CO = copulatory opening; FD = fertilization duct; S = spermatheca. Scale bars = 0.1 mm.

Carrhotus atratus sp. nov.

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Figs 5A–I, 6A–G, 7A–D, 17

Diagnosis

Males of *C. atratus* sp. nov. can be separated from those of other congeners by their triangular-shaped PLP and cone-shaped anticlockwise directed embolus tip (Figs 6E–F, 7A–B). The palp of *C. atratus* closely resembles that of *C. erus* Jastrzebski 1999; however, its PLP is relatively short, rounded and RTA is not pointed. RTA is smaller and tapered (Fig. 6F) than in other *Carrhotus* species from Sri Lanka. Females are distinguished by the prominent hood at the CO and hook-shaped CD (Fig. 7C–D).

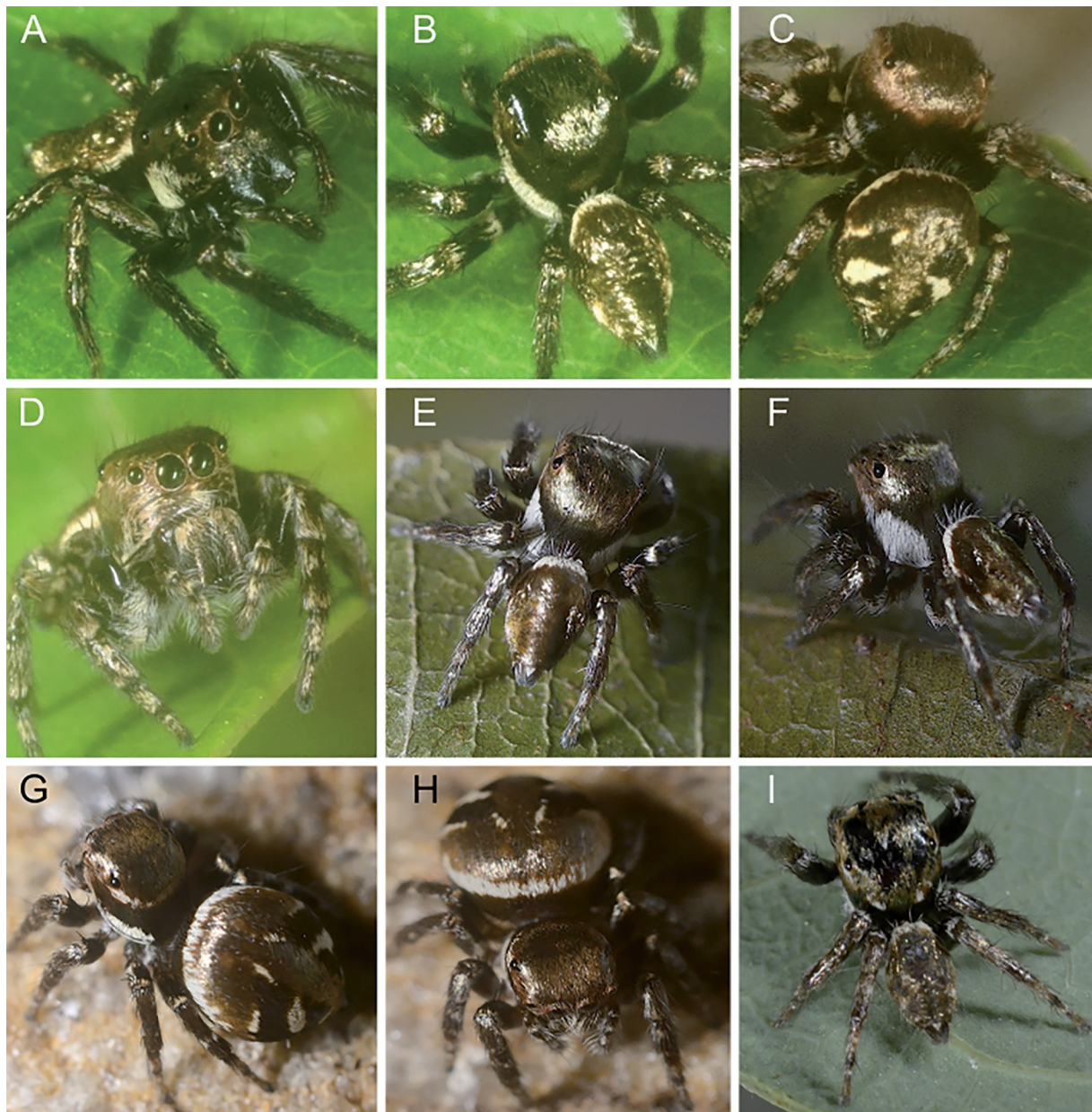


Fig 5. Photographs of live *Carrhotus atratus* sp. nov. A–B, E–F, I. Males. C–D, G–H. Females. A–H from Mandaitivu, I from Hiyare.

Etymology

The specific epithet is derived from the Latin word '*atratus*' meaning 'darkened', loosely referring to its blackish body colour.

Material examined

Holotype

SRI LANKA • ♂; Northern Province, Jaffna District, Mandaitivu; 09°61'67" N, 79°99'22" E; 12 m a.s.l.; 12 Jan. 2020; S.P. Benjamin *et al.* leg.; beating; NIFS_SAL_1280.

Paratype

SRI LANKA • 1 ♀; same collection data as for holotype; NIFS_SAL_1281.

Other material

SRI LANKA • 2 ♂♂, 5 ♀♀; same collection data as for holotype but 20–22 Oct. 2016; NIFS_SAL_932 to SAL_938 • 1 ♂, 2 ♀♀; same collection data as for holotype; NIFS_SAL_1282 to SAL_1284 • 1 ♀; Jaffna District, Vantharavathai; 09°37'14" N, 79°59'52" E; 9.5 m a.s.l.; 26 Jan. 2021; S.P. Benjamin leg.; beating; NIFS_SAL_1441.

Description

Male

MEASUREMENTS. TL 4.5, PL 1.92, PW at PLEs 1.5, AL 1.83, AW 1.32. Eye field: diameter of AME 0.4; ALE 0.26; PME 0.06; PLE 0.12; PME–PME 1.34; PLE–PLE 1.3; ALE–PME 0.22; ALE–PLE 0.54. Leg I: Tr 1.02, Fm 0.46, Pt 1, Tb 0.64, Mt 0.5; Leg II: Tr 0.9, Fm 0.46, Pt 0.7, Tb 0.6, Mt 0.52; Leg III: Tr 1.08, Fm 0.46, Pt 0.88, Tb 0.82, Mt 0.44; Leg IV: Tr 0.9, Fm 0.84, Pt 0.4, Tb 0.72, Mt 0.42.

COLOR AND BODY (live spiders). Carapace black, sparsely covered with black hairs; lateral margins sparsely covered with white hairs; posterior region black (Fig. 5A–B, E–F, I). Clypeal region blackish; eyes surrounded by blackish orbital setae. Chelicerae black, curved outer margins, excavated inner margins; two promarginal and one retromarginal teeth. Sternum oval, blackish; labium and maxillae blackish brown, paler outer margins. Abdomen ovoid, sparsely covered with black hairs; anterior margin sparsely covered by white hairs; no prominent pattern present on posterior region, beige pairs of transverse lines covered with white hairs on mid dorsum. Venter blackish with a very broad dark black median region covered with two thin greyish longitudinal lines. Spinnerets blackish, covered with a patch of black hairs dorsally (Fig. 6A–B). Leg I robust; femora I–IV black dorsally; patellae and tibiae black; tarsi and metatarsi of all legs blackish.

PALP. Dark black colour and embolus long, bow-shaped and tip directed anticlockwise, its base visibly separated from tegulum (Figs 6E–F, 7A–B).

Female

MEASUREMENTS. TL 5.75, PL 2.04, PW at PLEs 1.74, AL 2.7, AW 2.22. Eye field: diameter of AME 0.6; ALE 0.2; PME 0.1; PLE 0.2; PME–PME 1.4; PLE–PLE 1.54; ALE–PME 0.32; ALE–PLE 0.72. Leg I: Tr 0.8, Fm 0.46, Pt 0.7, Tb 0.56, Mt 0.44; Leg II: Tr 1.06, Fm 0.34, Pt 0.46, Tb 0.62, Mt 0.52; Leg III: Tr 0.72, Fm 0.46, Pt 0.9, Tb 0.46, Mt 0.54; Leg IV: Tr 0.7, Fm 0.4, Pt 0.8, Tb 0.4, Mt 0.5.

COLOR AND BODY (live spiders). Same as in male except for the following. Clypeal region covered with iridescent hairs providing a metallic sheen; lateral margins of carapace lined by a thin line of white hairs; posterior region black (Fig. 5C–D, G–H). ALEs and PLEs surrounded by blackish orbital setae. Sternum oval, brownish; labium and maxillae reddish-brown, with paler outer margins. Abdomen ovoid, densely covered with rusty brown hairs; anterior margin covered with a thin line of white hairs; pattern present

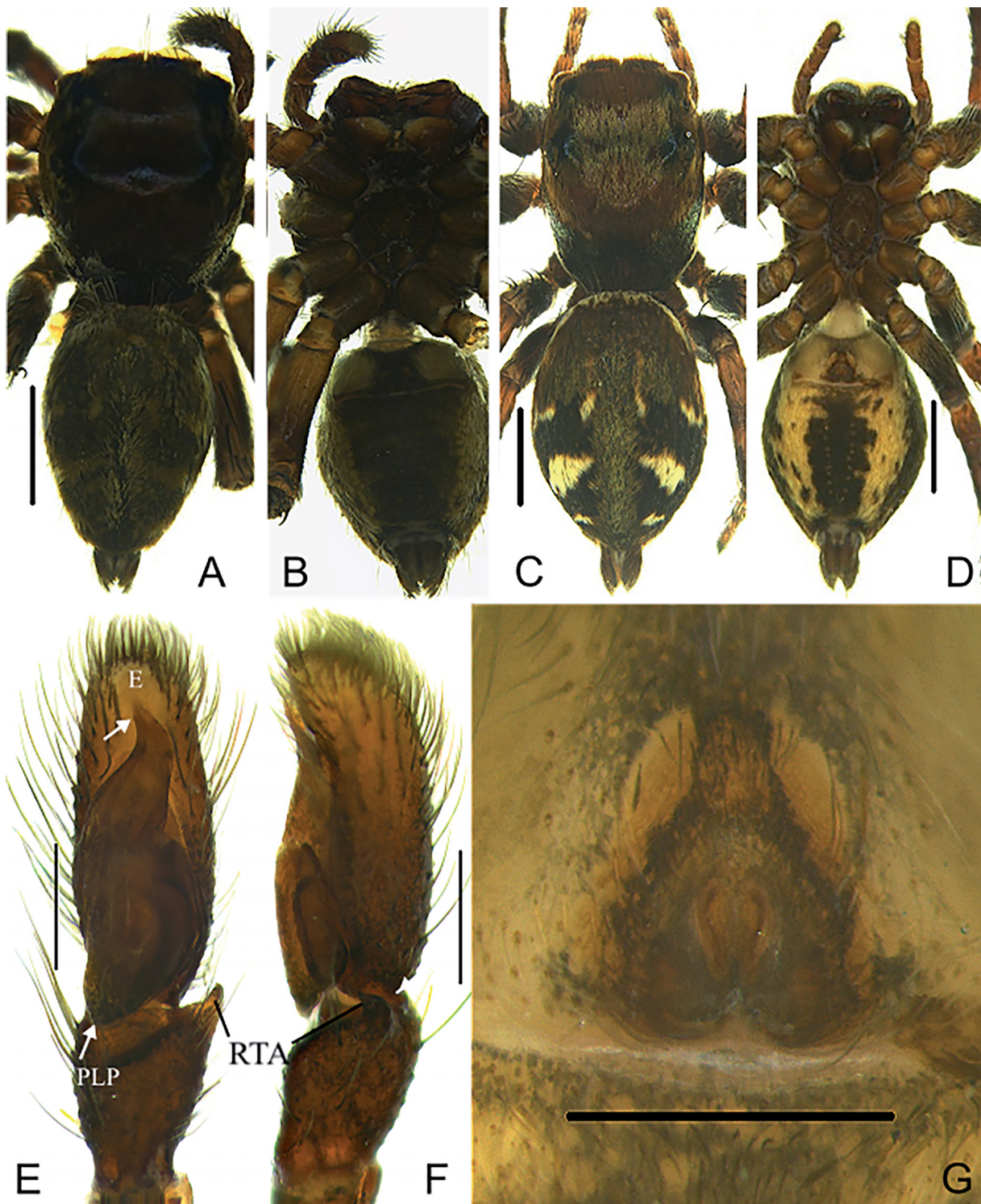


Fig 6. *Carrhotus atratus* sp. nov. **A–B.** Male habitus. **A.** Dorsal view. **B.** Ventral view. **C–D.** Female habitus. **C.** Dorsal view. **D.** Ventral view. **E–F.** Palp. **E.** Ventral view. **F.** Retrolateral view. **G.** Epigynum. Abbreviations: E = embolus; PLP = posterior lateral protrusion; RTA = retrolateral tibial apophysis. Scale bars: A–D = 2 mm; E–F = 0.2 mm; G = 0.1 mm.

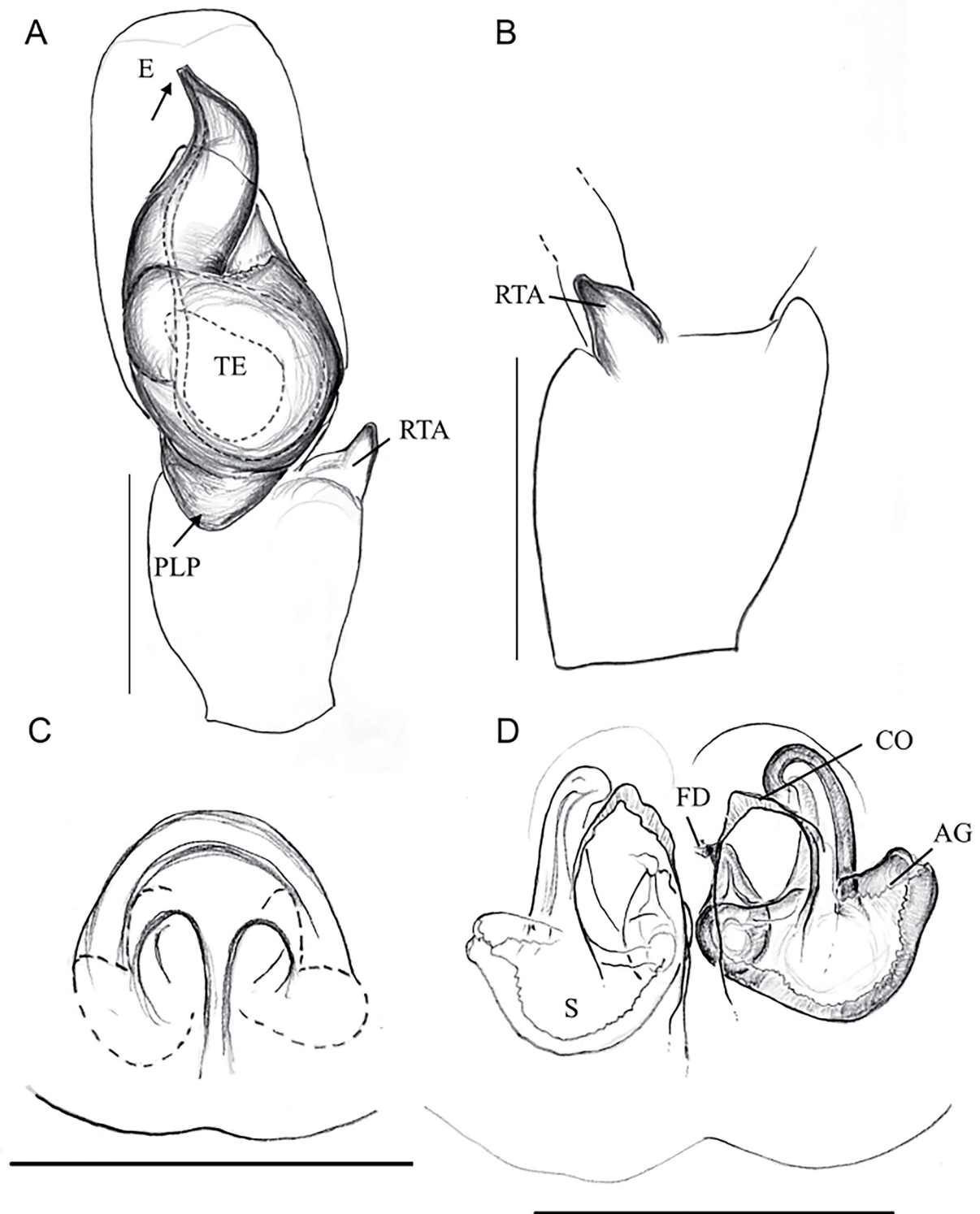


Fig 7. *Carrhotus atratus* sp. nov. **A–B.** Palp. **A.** Ventral view. **B.** Retrolateral view. **C.** Epigynum ventral view. **D.** Vulva dorsal view. Abbreviations: AG = accessory gland; CO = copulatory opening; E = embolus; FD = fertilization duct; PLP = posterior lateral protrusion; RTA = retrolateral tibial apophysis; S = spermatheca; TE = tegulum. Scale bars: A–B = 0.2 mm; C–D = 0.1 mm.

on black background with pair of two white spots anteriorly and pairs of transverse stripes following posteriorly. Mid-dorsum covered with scales of metallic sheen; venter yellowish, with a broad dark brown median region (Fig. 6C–D).

EPIGYNUM. Epigyne with a pair of copulatory ducts with a loop or flap-like structure arising from elongated pear-shaped spermathecae, whose latter part is narrowing. Accessory glands open at 3 o'clock position at narrowing anterior region of lateral walls of spermathecae (Figs 6G, 7C–D).

Distribution and habitat

This species occurs in the mangrove forest, in the arid zone and lowland secondary rainforest of Sri Lanka (Fig. 17). Specimens were collected by beating foliage up to a height of 2 m.

Carrhotus lobatus sp. nov.

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Figs 8A–D, 9A–B, 17

Diagnosis

This species is distinguishable by the distinctive double-lobed PLP and short and hook-shaped embolus tip directed in a clockwise path (Figs 8C–D, 9A–B).

Etymology

The specific epithet is derived from the Latin word '*lobatus*' meaning 'lobed', loosely referring to its distinctive proximal lobe of the tegulum.

Material examined

Holotype

SRI LANKA • ♂; Central Province, Matale District, Gammaduwa, Knuckles Range; 07°27'57" N, 80°46'24" E; 900 m a.s.l.; 18 Nov. 2009; S.P. Benjamin and S. Batuwita leg.; hand collection; NIFS_SAL_282.

Other material

SRI LANKA – **Central Province** • 1 ♂; Matale District, Knuckles range, Pitawala Pathana; 07°27'57" N, 80°46'24" E; 17 Mar. 2015; N.P. Athukorala leg.; hand collection; NIFS_SAL_403 • 1 ♂; Kandy District, Peradeniya; 07°14'58" N, 80°36'43" E; 674 m a.s.l.; 22 Dec. 2017; N.P. Athukorala *et al.* leg.; beating; NIFS_SAL_1114. – **Southern Province** • 1 ♂; Galle District, Hiyare, Kombala-Kottawa FR; 06°03'53" N, 80°18'56" E; 110 m a.s.l.; 24–26 May 2016; N.P. Athukorala *et al.* leg.; beating; NIFS_SAL_1285.

Description

Male

MEASUREMENTS. TL 5.15, PL 2.13, PW at PLEs 1.71, AL 2.19, AW 1.71. Eye field: diameter of AME 0.46; ALE 0.28; PME 0.08; PLE 0.26; PME–PME 1.46; PLE–PLE 1.34; ALE–PME 0.24; ALE–PLE 0.6. Leg I: Tr 0.82, Fm 1.08, Pt 1.36, Tb 0.86, Mt 0.5; Leg II: Tr 0.7, Fm 0.82, Pt 0.8, Tb 0.6, Mt 0.4; Leg III: Tr 1, Fm 0.9, Pt 0.74, Tb 0.8, Mt 0.44; Leg IV: Tr 0.92, Fm 0.5, Pt 1.08, Tb 0.74, Mt 0.46.

COLOR AND BODY. In ethanol, carapace brown, posterior region blackish-brown. Clypeal region brown; ALEs and PLEs surrounded by blackish orbital setae. Lateral margins of carapace slightly truncated and steep. Chelicerae brownish with curved outer margins and excavated inner margins: two promarginal and one retromarginal teeth. Sternum pentagonal, blackish brown; labium and maxillae brown. Leg I

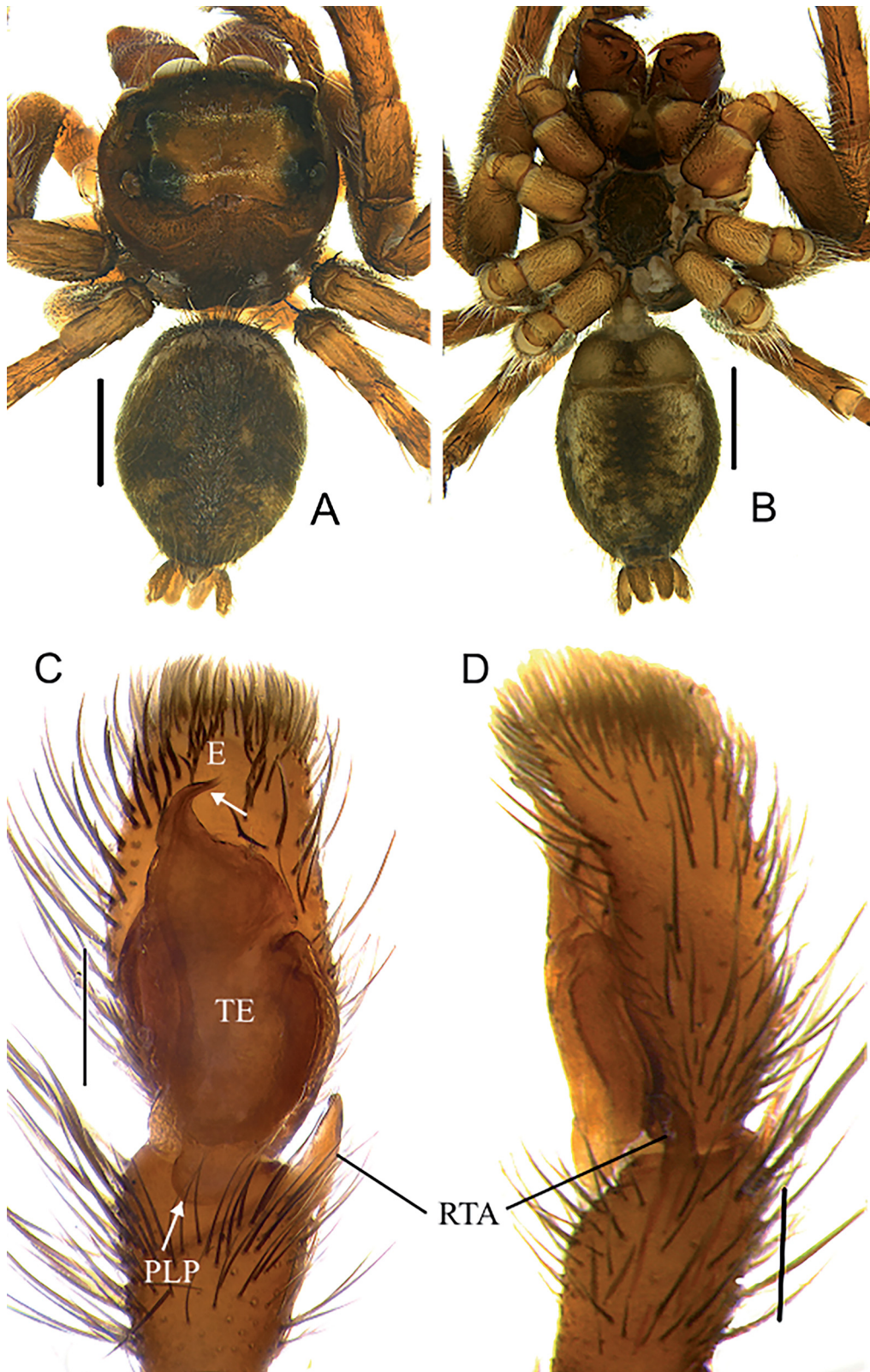


Fig 8. *Carrhotus lobatus* sp. nov. **A–B.** Male habitus. **A.** Dorsal view. **B.** Ventral view. **C–D.** Palp, **C.** Ventral view. **D.** Retrolateral view. Abbreviations: E = embolus; PLP = posterior lateral protrusion; RTA = retrolateral tibial apophysis; TE = tegulum. Scale bars: A–B = 2 mm; C–D = 0.2 mm.

robust; femora I–IV dark brown dorsally; patellae and tibiae dark brown; tarsi and metatarsi of all legs dark brown. Abdomen oblong, sparsely covered with black hairs; anterior margin covered with long black scales with sparse white hairs making an arc; no prominent pattern present on posterior region, beige pairs of transverse lines and pair of beige spots covered with white hairs on mid dorsum; venter blackish brown with a blackish brown median region. Spinnerets blackish brown, covered with a patch of white hairs dorsally (Fig. 8A–B).

PALP. Dark brown; embolus short and hook-shaped and embolus tip directed in the clockwise path; its base separated from the tegulum. The double-lobed PLP is very distinctive compared to that of the other species considered here. RTA long and angle between the RTA and tibia is about 45° (Fig. 9A–B).

Distribution and habitat

This species occurs in the montane and submontane forests of the central highlands of Sri Lanka with limited distribution (Fig. 17). Specimens were collected by beating vegetation up to a height of 1–2 m.

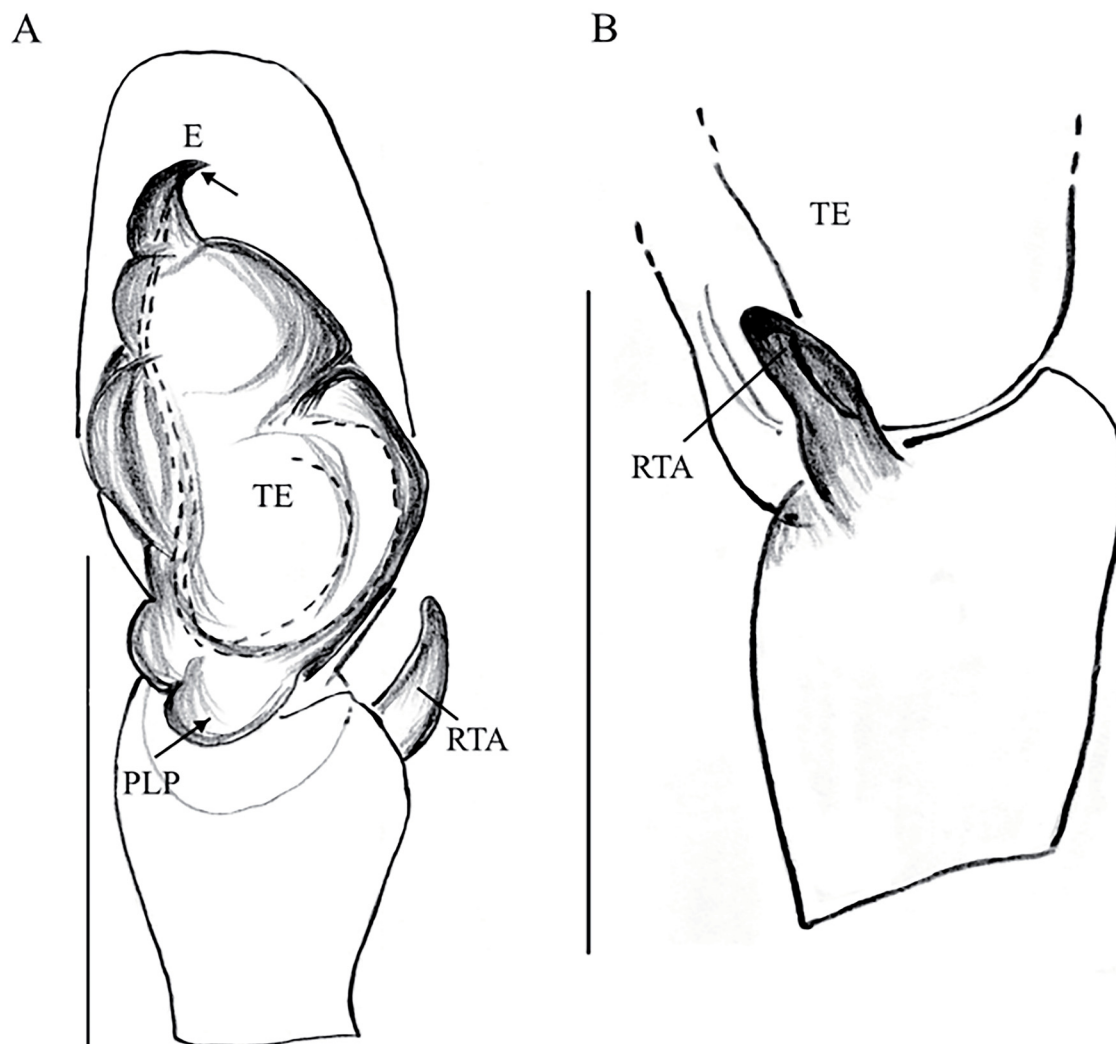


Fig 9. *Carrhotus lobatus* sp. nov., palp. **A.** Ventral view. **B.** Retrolateral view. Abbreviations: E = embolus; PLP = posterior lateral protrusion; RTA = retrolateral tibial apophysis; TE = tegulum. Scale bars = 0.2 mm.

Carrhotus silanthi Caleb, 2020
Figs 10A–F, 11A–H, 12A–D, 17

Carrhotus silanthi Caleb in Caleb *et al.*, 2020: 58, Figs 33–56.

Diagnosis

Males of *C. silanthi* can be separated from other congeners by having the RTA markedly hook-shaped, slanted ventrally, and the distally pointed acuminate embolus (Fig. 12A–B). Females can be readily separated from those of *C. albosetosus* sp. nov. by the prominent ML and the position of the opening of the accessory glands on the internal spermathecal walls, close to the base of the copulatory ducts (Figs 11G, 12C–D).

Type material

Carrhotus silanthi Caleb in Caleb *et al.*, 2020: 58, Figs 33–56 (male holotype and female paratype from Madras Christian College, Tambaram, Chennai, India, deposited in NZC-ZSI, Kolkata (NZC-ZSI 6939/18, NZC-ZSI 6940/18)). Not examined.

Material examined

SRI LANKA – **Uva Province** • 1 ♂, 1 ♀; Monaragala District, Nilgala FR; 07°11'08" N, 81°24'24" E; 122 m a.s.l; 12 Jul. 2017; N. Athukorala and I.S. Ieperuma Arachchi leg.; beating; NIFS_SAL_1042, SAL_1043. – **North Central Province** • 1 ♂, 1 ♀; Anuradhapura District, Mihintale Sanctuary;



Fig 10. Photographs of live *Carrhotus silanthi* Caleb, 2020, males. **A–C.** From Giants Tank Sanctuary. **D–F.** From Ussangoda.

08°20'59" N, 80°30'20" E; 119 m a.s.l; 14 Jun. 2016; N. Athukorala *et al.* leg.; beating; NIFS_SAL_824, SAL_825 • 1 ♂; Allepothana, Kok-ebe FR; 08°26'58" N, 80°46'39' E; 88 m a.s.l; 24 Apr. 2017; N. Kanesharatnam leg.; beating; NIFS_SAL_1032. – **Northern Province** • 2 ♂♂, 1 ♀; Mannar District, Giant's Tank Sanctuary (Site 1); 27 m a.s.l; 4 Apr. 2018; S.P. Benjamin *et al.* leg.; beating; NIFS_SAL_1137 to SAL_1139 • 1 ♀; same collection data as for preceding; NIFS_SAL_1162. – **Southern**



Fig. 11. *Carrhotus silanthi* Caleb, 2020. A–B. Male habitus. A. Dorsal view. B. Ventral view. C–D. Female habitus. C. Dorsal view. D. Ventral view. E–H. Palp. E–F. Ventral view; the arrows showing the embolus tip directed in clockwise (11E) or directed in apical (11F). G–H. Retrolateral view. Abbreviations: PLP = posterior lateral protrusion; RTA = retrolateral tibial apophysis; TE = tegulum. Scale bars: A–D = 2 mm; E–H = 0.2 mm.

Province • 1 ♂; Hambantota District, Ussangoda NP; 06°05'43" N, 80°59'15" E; 22 Nov. 2017; S.P. Benjamin *et al.* leg.; beating; NIFS_SAL_1116.

Description (based on material from Sri Lanka)

Male

MEASUREMENTS. TL 4.8, PL 2.16, PW at PLEs 1.786, AL 2.19, AW 1.44. Eye field: diameter of AME 0.44; ALE 0.26; PME 0.12; PLE 0.24; PME–PME 1.68; PLE–PLE 1.44; ALE–PME 0.36; ALE–PLE 0.6. Leg I: Tr 1.2, Fm 0.82, Pt 0.78, Tb 1.22, Mt 0.62; Leg II: Tr 1.48, Fm 0.42, Pt 0.62, Tb 1.02, Mt 0.56; Leg III: Tr 1, Fm 0.7, Pt 0.72, Tb 1.06, Mt 0.5; Leg IV: Tr 0.84, Fm 0.6, Pt 1, Tb 1.02, Mt 0.62.

COLOR AND BODY. In live spiders, both sexes look similar in general body colour pattern and are clothed with iridescent hairs. Colour varies from metallic sheen to bronze-green as shown in Fig. 10A–F. Carapace: prosoma reddish-brown covered with iridescent hairs providing a metallic sheen; lateral margins of carapace lined by broad patches of white hairs; posterior region black. Hairs sparse. Sternum oval, brownish; labium and maxillae dark brown, with paler outer margins. Clypeal region brownish; eyes surrounded by yellowish orbital setae. Chelicerae dark brown with curved outer margins and excavated inner margins: two promarginal and one retromarginal teeth. Abdomen ovoid, densely covered with rusty brown hairs; anterior margin covered by white scales; pattern present on black background with pair of white spots anteriorly and pairs of transverse stripes following posteriorly (Fig. 11A–B). Mid-dorsum covered with scales of metallic sheen; venter yellowish, with a broad dark brown median region. Spinnerets brownish, covered with a patch of white hairs dorsally. Leg I robust; femora I–IV dark brown dorsally; patellae and tibiae dark brown; tarsi and metatarsi of all legs dark brown.

PALP. Dark brown; embolus short and thick with a blunt tip and embolus tip directed in clockwise path, its base separated from tegulum; bulbus with PLP; RTA markedly hook-shaped bent ventrally and angle between RTA and tibia about 45° (Figs 11E–F, 12A–B).

Female

MEASUREMENTS. TL 5.5, PL 2.04, PW at PLEs 1.95, AL 2.64, AW 2.16. Eye field: diameter of AME 0.48; ALE 0.26; PME 0.12; PLE 0.24; PME–PME 1.5; PLE–PLE 1.46; ALE–PME 0.44; ALE–PLE 0.78. Leg I: Tr 1, Fm 0.92, Pt 0.94, Tb 0.56, Mt 0.38; Leg II: Tr 1.2, Fm 0.78, Pt 1.1, Tb 0.7, Mt 0.46; Leg III: Tr 1.3, Fm 0.8, Pt 1.02, Tb 0.6, Mt 0.42; Leg IV: Tr 1, Fm 0.74, Pt 1.1, Tb 0.4, Mt 0.32.

COLOR AND BODY. Colouration pattern as in male, but differs as follows: AMEs surrounded by yellow orbital setae; clypeus covered with white hairs; carapace with white hairs making an arc behind PLEs. Abdomen ovoid, densely covered with rusty brown hairs; anterior margin covered by white scales; pattern present on black background with pair of white spots anteriorly and pairs of transverse stripes following posteriorly (Fig. 11C–D). Mid-dorsum covered with scales of metallic sheen; venter yellowish, with a broad dark brown median region. Spinnerets brownish, covered with a patch of white hairs dorsally. Legs with white border on distal margin of femur I–IV; other segments covered with sparse white hairs and black annulations alternatively.

EPIGYNUM. Epigyne with a pair of simple copulatory openings placed in small oval, yellowish depressions; copulatory ducts short, diverge to join stomach-shaped spermathecae. Accessory glands open on internal spermathecal walls close to base of copulatory ducts (Fig. 12C–D).

Intraspecific variation

The palpal conformation of NIFS_SAL_1116 closely resembles that of *C. silanthi*. However, it differs by having the PLP shorter and less rounded (Fig. 11F) vs oval-shaped PLP in *C. silanthi* (Fig. 11E), and a short, cone-shaped embolus (Fig. 11F) in NIFS_SAL_1116 vs a thinner embolus in *C. silanthi* (Fig. 11E).

Distribution and habitat

This species occurs in the lowland secondary rainforests of the dry and wet zones of Sri Lanka including the Ussangoda dry zone National Park in Hambantota District in the Southern Province (Fig. 17). Specimens were collected by beating vegetation up to a height of 1–2 m.

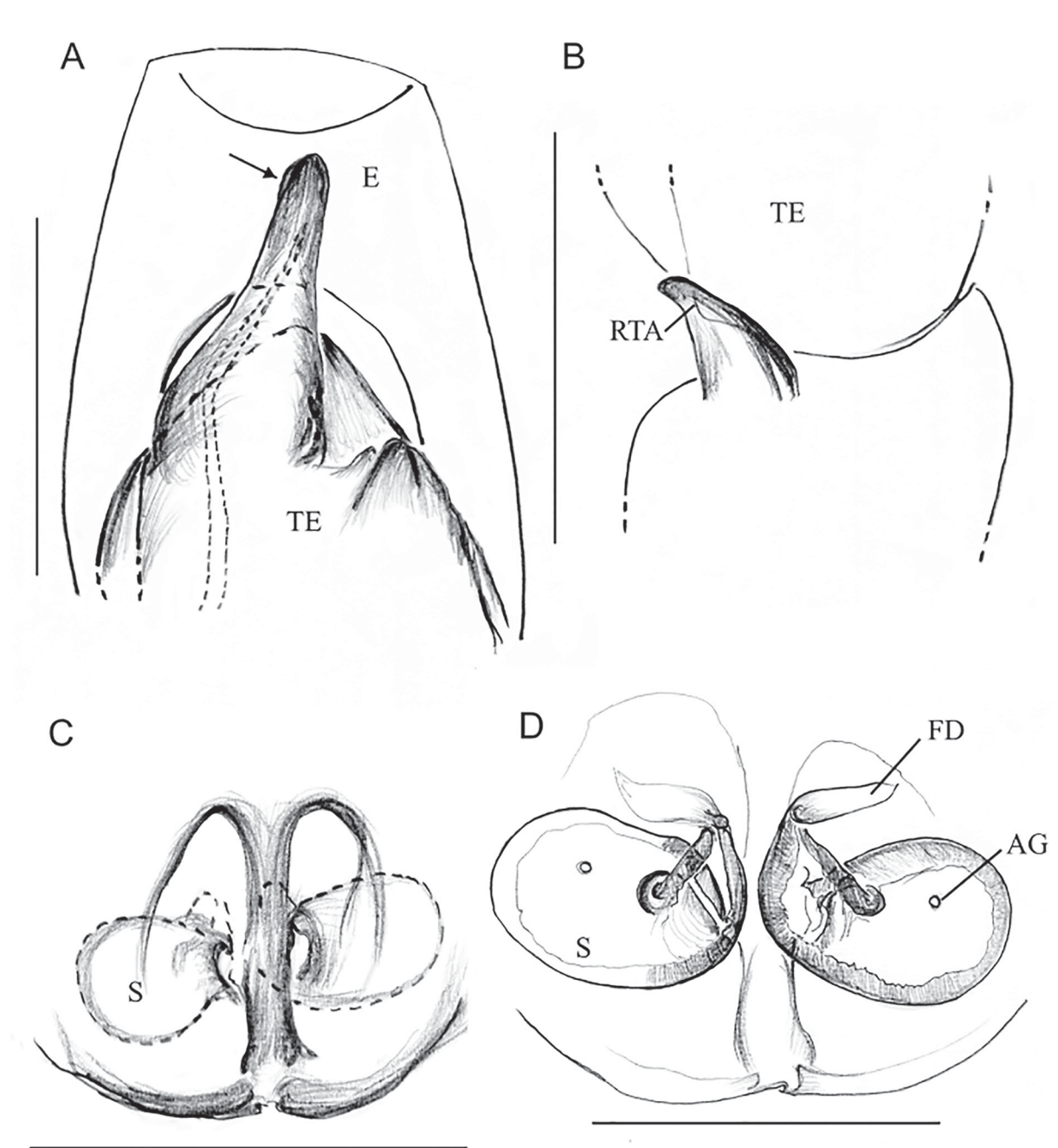


Fig 12. *Carrhotus silanthi* Caleb, 2020. **A–B.** Palp. **A.** Ventral view. **B.** Retrolateral view. **C–D.** Epigynum. **C.** Ventral view. **D.** Dorsal view. Abbreviations: AG = accessory gland; E = embolus; FD = fertilization duct; RTA = retrolateral tibial apophysis; S = spermatheca; TE = tegulum. Scale bars: A–B = 0.2 mm; C–D = 0.1 mm.

Carrhotus taprobanicus Simon, 1902

Figs 2E–F, 13A–G, 14A–D, 17

Carrhotus taprobanicus Simon, 1902: 394.

Diagnosis

Males of *C. taprobanicus* can be separated from those of *C. viduus* by their body colour pattern with no longitudinal stripes on the carapace and abdomen (present in *C. viduus*) (Fig. 15A, C). Further, the cheliceral front part is more wrinkled in *C. viduus* (Fig. 13B). The palpal conformation of *C. taprobanicus* closely resembles that of *C. viduus*; however, it can be distinguished by the shorter embolus and its rounded base (Fig. 13E). Further, the RTA is more slanted ventrally in *C. taprobanicus* (Fig. 14A–B). Females can be separated from those of *C. viduus* by the narrower ML and stouter CD and FD (Fig. 14C–D).

Type material

Carrhotus taprobanicus Simon, 1902; ♂♀ syntypes from Colombo and Kandy, Sri Lanka; should be in MNHN, not examined.

Material examined

SRI LANKA – **Central Province** • 1 ♂; Kandy District, Knuckles Range, along Dothalugala Nature Trail; 07°20'19" N, 80°51'3" E; 1202 m a.s.l.; 3 Mar. 2018; S.P. Benjamin *et al.* leg.; beating; NIFS_SAL_1143 • 1 ♂; same collection data as for preceding; 3 May 2018; NIFS_SAL_1155 • 1 ♀; same collection data as for preceding; SAL_1156 • 6 ♀♀; same collection data as for preceding; 17–18 Oct. 2019; NIFS_SAL_1241 to SAL_1246 • 1 ♂; same collection data as for preceding; NIFS_SAL_1248 • 1 ♀; same collection data as for preceding; NIFS_SAL_1275 • 1 ♂; same collection data as for preceding but 17–18 Nov. 2019; NIFS_SAL_1252 • 2 ♀♀; same collection data as for preceding but 18 Jun. 2020; NIFS_SAL_1308, SAL_1309 • 1 ♀; Gomaraya; 07°23'10" N, 80°44'30" E; 600 m a.s.l.; 2 Feb. 2010; S. Batuwita and P.M.H. Sandamali *et al.* leg.; hand collection; NIFS_SAL_660 • 1 ♀; Nuwara Eliya District, Victoria, Randenigala, Rantembe Sanctuary; 07°08'42" N, 80°51'28" E; 436 m a.s.l.; 22 Sep. 2018; N.P. Athukorala *et al.* leg.; beating; NIFS_SAL_1273. – **Uva Province** • 1 ♂; Badulla District, Ohiya; 06°50'32" N, 80°53'05" E; 26 May 2012; S.P. Benjamin *et al.* leg.; beating; NIFS_SAL_279. – **Western Province** • 1 ♂; Panadura, Mahabellana, along Bolgoda South Lake; 06°42'48" N, 79°54'09" E; Jul. 2008; S.P. Benjamin *et al.* leg.; NIFS_SAL_694.

Description

Male

MEASUREMENTS. TL 4.7, PL 2.1, PW at PLEs 1.8, AL 1.95, AW 1.32. Eye field: diameter of AME 0.4; ALE 0.24; PME 0.2; PLE 0.08; PME–PME 1.06; PLE–PLE 1.1; ALE–PME 0.5; ALE–PLE 0.3. Leg I: Tr 1.3, Fm 0.9, Pt 1.4, Tb 0.7, Mt 0.44; Leg II: Tr 1, Fm 0.8, Pt 0.84, Tb 0.4, Mt 0.36; Leg III: Tr 1.04, Fm 0.86, Pt 0.8, Tb 0.7, Mt 0.6; Leg IV: Tr 0.7, Fm 0.8, Pt 0.7, Tb 0.72, Mt 0.6.

COLOR AND BODY. Live spider with carapace blackish-brown, covered with iridescent hairs providing a metallic sheen; lateral margins of carapace lined by broad patches of white hairs; posterior region black (Fig. 2E–F). Clypeal region blackish; eyes surrounded by yellowish orbital setae. Chelicerae brown with curved outer margins and excavated inner margins: two promarginal and one retromarginal teeth. Sternum pentagonal, blackish brown; labium and maxillae yellowish brown, with paler outer margins. Abdomen ovoid, densely covered with black hairs; lateral sides of anterior margin with two white longitudinal lines; pattern present on black background with three pairs of white transverse stripes lateral margins of mid-dorsum. Mid-dorsum covered with scales of metallic sheen; venter yellowish, with a broad black

median region covered with two broad whitish longitudinal bands. Spinnerets brownish, covered with a patch of white hairs dorsally (Fig. 13A–B). Leg I robust; femora I–IV dark brown dorsally; other segments covered with sparse black hairs and black annulations.

PALP. Dark brown; embolus thinner and cone-shaped, its base separated from tegulum. PLP shorter and similar to that of *C. viduus*, angle between RTA and tibia about 45° vs about early 20° in *C. viduus* (Figs 13E–F, 14A–B).

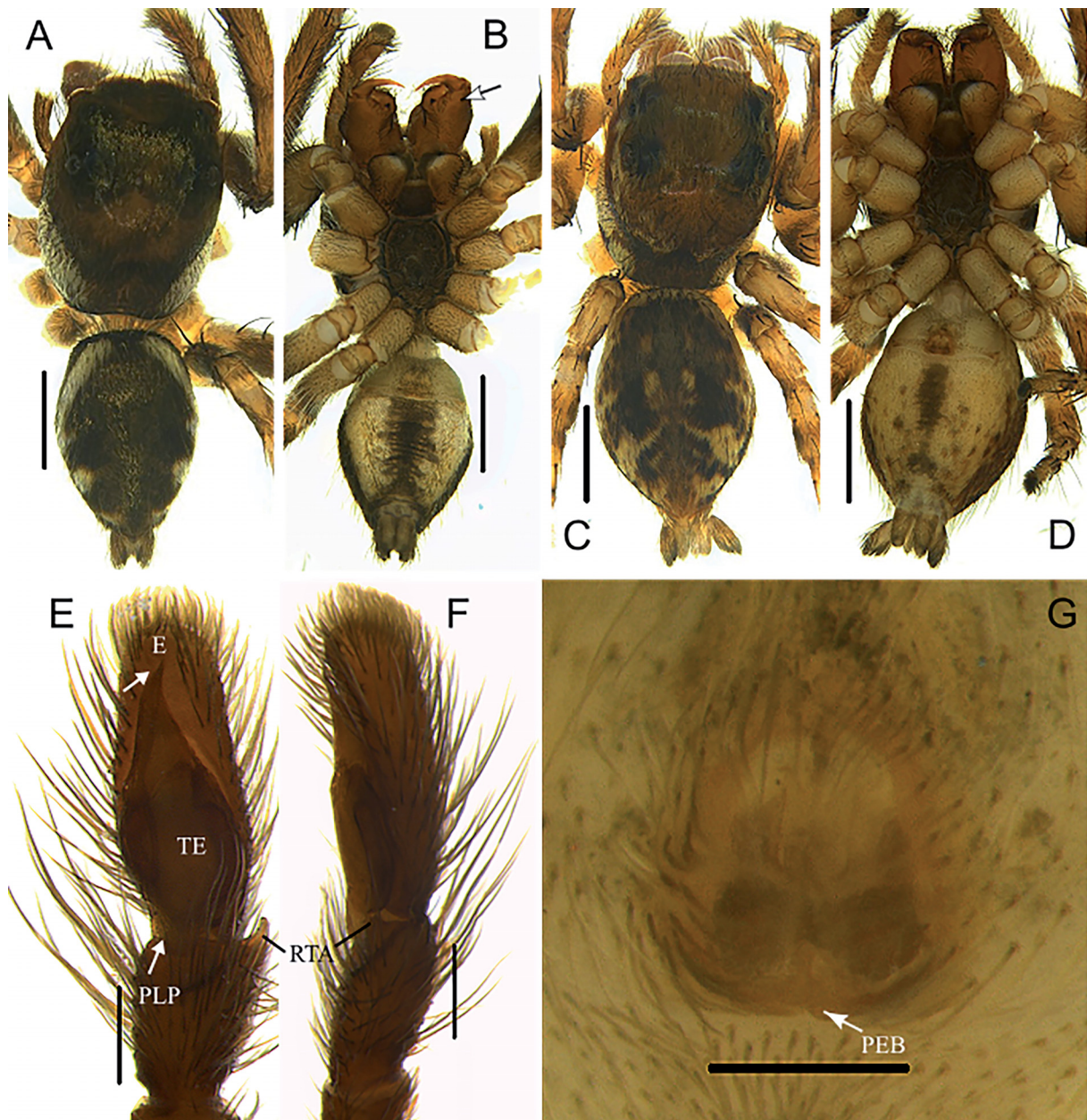


Fig 13. *Carrhotus taprobanicus* Simon, 1902. **A–B.** Male habitus. **A.** Dorsal view. **B.** Ventral view. **C–D.** Female habitus. **C.** Dorsal view. **D.** Ventral view. **E–F.** Palp. **E.** Ventral view. **F.** Retrolateral view. **G.** Epigynum, ventral view. Abbreviations: E = embolus; PEB = posterior epigynal border; PLP = posterior lateral protrusion; RTA = retrolateral tibial apophysis; TE = tegulum. Scale bars: A–D = 2 mm; E–F = 0.2 mm; G = 0.1 mm.

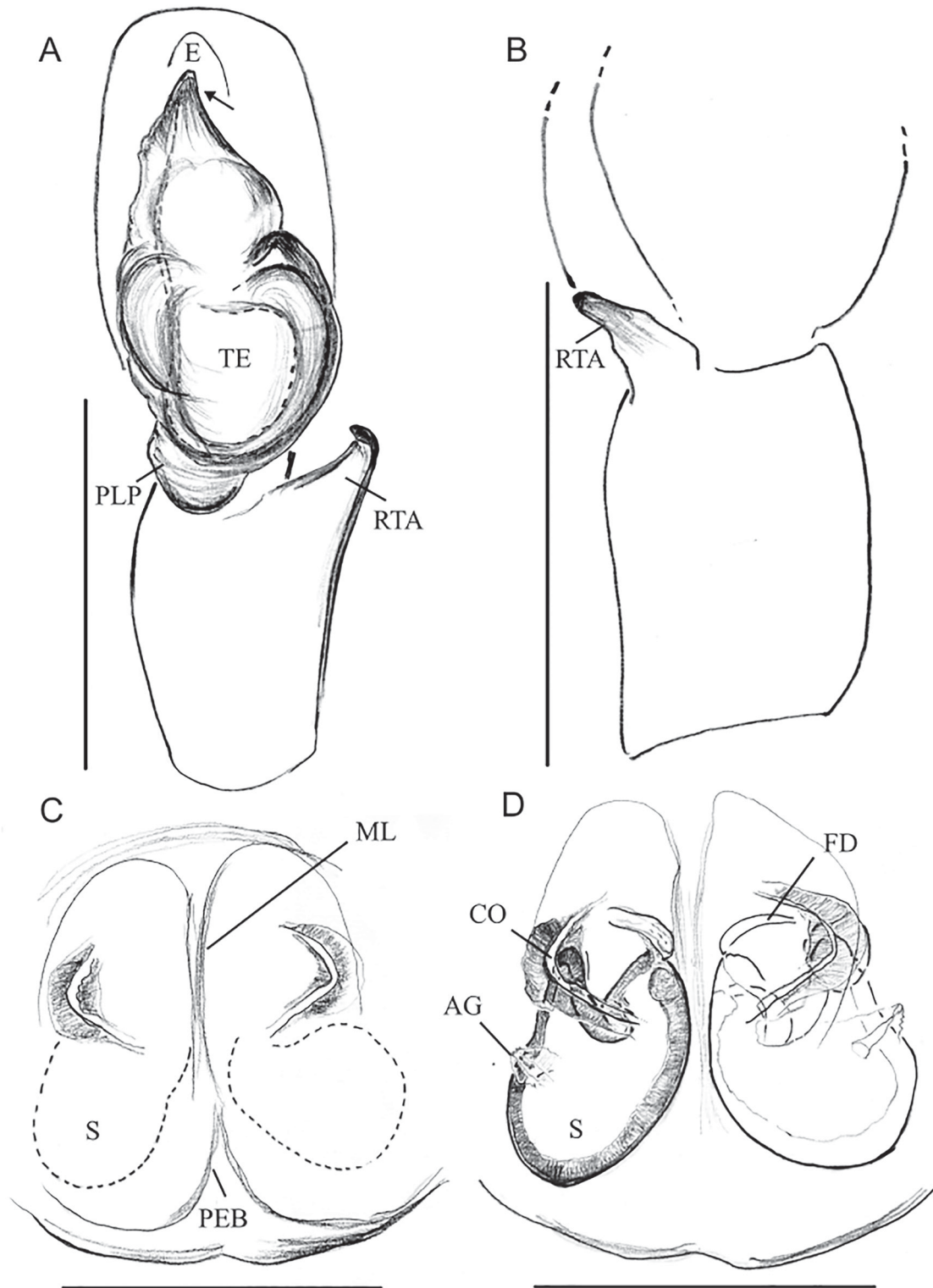


Fig 14. *Carrhotus taprobanicus* Simon, 1902. **A–B.** Palp. **A.** Ventral view. **B.** Retrolateral view. **C–D.** Epigynum. **C.** Ventral view. **D.** Dorsal view. Abbreviations: AG = accessory gland; CO = copulatory opening; E = embolus; FD = fertilization duct; PEB = posterior epigynal border; PLP = posterior lateral protrusion; RTA = retrolateral tibial apophysis; S = spermatheca; TE = tegulum. Scale bars: A–B = 0.2 mm; C–D = 0.1 mm.

Female

MEASUREMENTS. TL 4.9, PL 2.07, PW at PLEs 1.68, AL 2.1, AW 1.06. Eye field: diameter of AME 0.48; ALE 0.24; PME 0.22; PLE 0.08; PME–PME 1.4; PLE–PLE 1.44; ALE–PME 0.72; ALE–PLE 0.34. Leg I: Tr 1.1, Fm 0.9, Pt 0.8, Tb 0.5, Mt 0.4; Leg II: Tr 0.9, Fm 0.46, Pt 0.8, Tb 0.6, Mt 0.5; Leg III: Tr 1.5, Fm 0.42, Pt 0.82, Tb 0.34, Mt 0.42; Leg IV: Tr 1.6, Fm 0.5, Pt 1.02, Tb 0.6, Mt 0.34.

COLOR AND BODY. Abdomen ovoid, sparsely covered with black hairs; lateral sides of anterior margin with four pairs of white herringbone-shaped pattern present on brown background with two pairs of white spots in mid-dorsum. ALEs surrounded by blackish orbital setae; clypeus covered with white hairs (Fig. 13C–D).

EPIGYNUM. Epigyne with a pair of copulatory openings, long copulatory ducts move anteriorly and almost sub-parallel to elongated, pear-shaped spermathecae. Accessory glands open at 2 o'clock position of mid-region of lateral walls of spermathecae (Figs 13G, 14C–D). Resembles the epigynes of *C. viduus* but differs in relative proportions of spermathecae, rather kidney-shaped in *C. taprobanicus* (Fig. 14C–D), PEB less curved inwards and margins of CO less sclerotized than in *C. viduus* (Fig. 13G).

Remarks

Our identification is based on Simon's (1902) description of the male and female syntypes. Though we were unable to examine the types of *C. taprobanicus*, the description by Simon (1902) was clear enough for an unambiguous identification of the species, which we translate here to English:

“♂. Length 6.5 mm. Cephalothorax darkened upper part, bronze-colour-haired, white hair belts at the thoracic margins, short clypeus and yellowish-red hairs around the eyes. Chelicerae long, planar and hairless with bronze and leathery transverse folds; curved outer margins and excavated inner margins: promarginal and one retromarginal teeth. Sternum; black, white-haired. Abdomen shorter and oval-shaped. Venter greyish and covered on both sides with white margins. Legs I, II darkened, tarsi lightened, metatarsi, lower tibia very slightly black-haired, patella inwardly white-haired. Legs: coxa, trochanter, metatarsi darker, metatarsi dark annulated.

♀. Length 7.8 mm. Cephalothorax black, bronze-colour-haired, reddish-white hair belts at the thoracic margins and around the eyes. The males can be distinguished from those of *C. viduus* (C.L. Koch, 1846) by their body colour pattern with no longitudinal stripes on the carapace and abdomen and the cheliceral front part is more wrinkled in *C. viduus*”.

Distribution and habitat

This species occurs in the montane and submontane forests of the central highlands of Sri Lanka (Fig. 17). Specimens were collected by beating vegetation up to a height of 1–2 m.

***Carrhotus viduus* (C.L. Koch, 1846)**
Figs 2C–D, 15A–G, 16A–D, 17

Plexippus viduus C.L. Koch, 1846: 104, fig. 1166.

Carrhotus viduus – Thorell 1891: 142. — Andreeva *et al.* 1981: 103, figs 39–42. — Prószyński 1984a: 16; 1992b: 169, fig. 7. — Caleb *et al.* 2020: 61, figs 57–73, 76–78, 80–82.

Diagnosis

Males of this species are distinguishable by the presence of white longitudinal stripes on the carapace and abdomen, as well as the relatively larger retromarginal cheliceral tooth. The palpal conformation

of *C. viduus* closely resembles that of *C. taprobanicus*; however, it can be distinguished by the longer, ventrally projecting embolus and its oval base (Fig. 16A). Further, the RTA is less slanted ventrally in *C. viduus* (Fig. 16A–B). Females can be separated from those of *C. taprobanicus* by the broader ML and longer CD and FD (Fig. 16C–D). Females can be readily distinguished from those of *C. silanthi* by the kidney-shaped spermathecae (Figs 12C–D, 16C–D).

Type material

Plexippus viduus C.L. Koch, 1846: 2 ♂♂; depository unknown. Our identification is based solely on the description and illustrations of Prószyński (2009). He mentioned two possible specimens currently deposited in ZMB. However, their geographic origin is ambiguous (see Prószyński 2009).

Remarks

According to Sudhin *et al.* (2021), *C. tholpettyensis* Sudhin, Nafin, Caleb & Sudhikumar, 2021 differs by the absence of a pair of white longitudinal stripes found on the abdomen of male *C. viduus*. The mentioned minor genitalic differences could easily be attributed to intraspecific variation. Thus, we consider *C. tholpettyensis* as a possible junior synonymy of *C. viduus*.

Material examined

SRI LANKA – **Northern Province** • 1 ♂; Jaffna District, Mandaitivu; 09°36'26" N, 79°59'5" E; 20–22 Sep. 2016; S.P. Benjamin leg.; beating; NIFS_SAL_958 • 1 ♀; same collection data as for preceding but 26 Jan. 2021; NIFS_SAL_1442. – **Central Province** • 1 ♂; Kandy District, Gannoruwa FR; 07°17'16" N, 80°35'47" E; 575 m a.s.l.; 30 Jul. 2016; N.P. Athukorala *et al.* leg.; beating; NIFS_SAL_888 • 1 ♂; Kandy District, NIFS premises; 600 m a.s.l.; 12 Mar. 2017; S.P. Benjamin leg.; hand collection; NIFS_SAL_1025. – **North Western Province** • 1 ♂; Kurunegala District, Nikaravatiya; 1–3 Nov. 2007; Ziyad Jaleel leg.; hand collection; NIFS_SAL_506.

Description

Male

MEASUREMENTS. TL 6.85, PL 2.58, PW at PLEs 2.31, AL 1.35, AW 0.87. Eye field: diameter of AME 0.28; ALE 0.18; PME 0.1; PLE 0.14; PME–PME 0.82; PLE–PLE 0.84; ALE–PME 0.32; ALE–PLE 0.42. Leg I: Tr 1, Fm 1.3, Pt 1.6, Tb 0.8, Mt 0.6; Leg II: Tr 1.12, Fm 1.1, Pt 1.06, Tb 0.7, Mt 0.42; Leg III: Tr 1.1, Fm 1.12, Pt 1.4, Tb 0.52, Mt 0.3; Leg IV: Tr 0.76, Fm 0.52, Pt 0.82, Tb 0.84, Mt 0.52.

COLOR AND BODY. Live spider with carapace robust and relatively broad, blackish-brown covered with long black hairs sparsely and two longitudinal stripes of white hairs (Fig. 2C–D). Sternum oval, brown; labium and maxillae yellowish brown, with paler outer margins. Clypeal region brownish; eyes surrounded by blackish orbital setae. Chelicerae brown with curved outer margins and excavated inner margins: two promarginal and one retromarginal teeth (Fig. 15B). Abdomen blackish brown, ovoid with two longitudinal belts of white hairs and entire surface covered with a few whitish hairs. Mid-dorsum with four median beige spots in different shapes, covered with black scales; venter greyish with a blackish-brown median region covered with two broad whitish longitudinal bands. Spinnerets brown, covered with a patch of black hairs dorsally. Leg I robust; femora I–IV dark brown dorsally; patellae and tibiae dark brown; tarsi and metatarsi of all legs dark brown.

PALP. Dark brown; embolus short and thick with blunt tip; bulbus with PLP; RTA only slightly bent ventroapically, curved and claw-like (Figs 15E–F, 16A–B).

Female

MEASUREMENTS. TL 5.5, PL 2.04, PW at PLEs 1.95, AL 2.64, AW 2.16. Eye field: diameter of AME 0.48; ALE 0.26; PME 0.12; PLE 0.24; PME–PME 1.5; PLE–PLE 1.46; ALE–PME 0.44; ALE–PLE 0.78. Leg I: Tr 1, Fm 0.92, Pt 0.94, Tb 0.56, Mt 0.38; Leg II: Tr 1.2, Fm 0.78, Pt 1.1, Tb 0.7, Mt 0.46; Leg III: Tr 1.3, Fm 0.8, Pt 1.02, Tb 0.6, Mt 0.42; Leg IV: Tr 1, Fm 0.74, Pt 1.1, Tb 0.4, Mt 0.32.



Fig 15. *Carrhotus viduus* (C.L. Koch, 1846). **A–B.** Male habitus. **A.** Dorsal view. **B.** Ventral view. **C–D.** Female habitus. **C.** Dorsal view. **D.** Ventral view. **E–F.** Palp. **E.** Ventral view. **F.** Retrolateral view. **G.** Epigynum, ventral view. Abbreviations: E = embolus; PEB = posterior epigynal border; PLP = posterior lateral protrusion; RTA = retrolateral tibial apophysis; TE = tegulum. Scale bars: A–D = 2 mm; E–F = 0.2 mm; G = 0.1 mm.

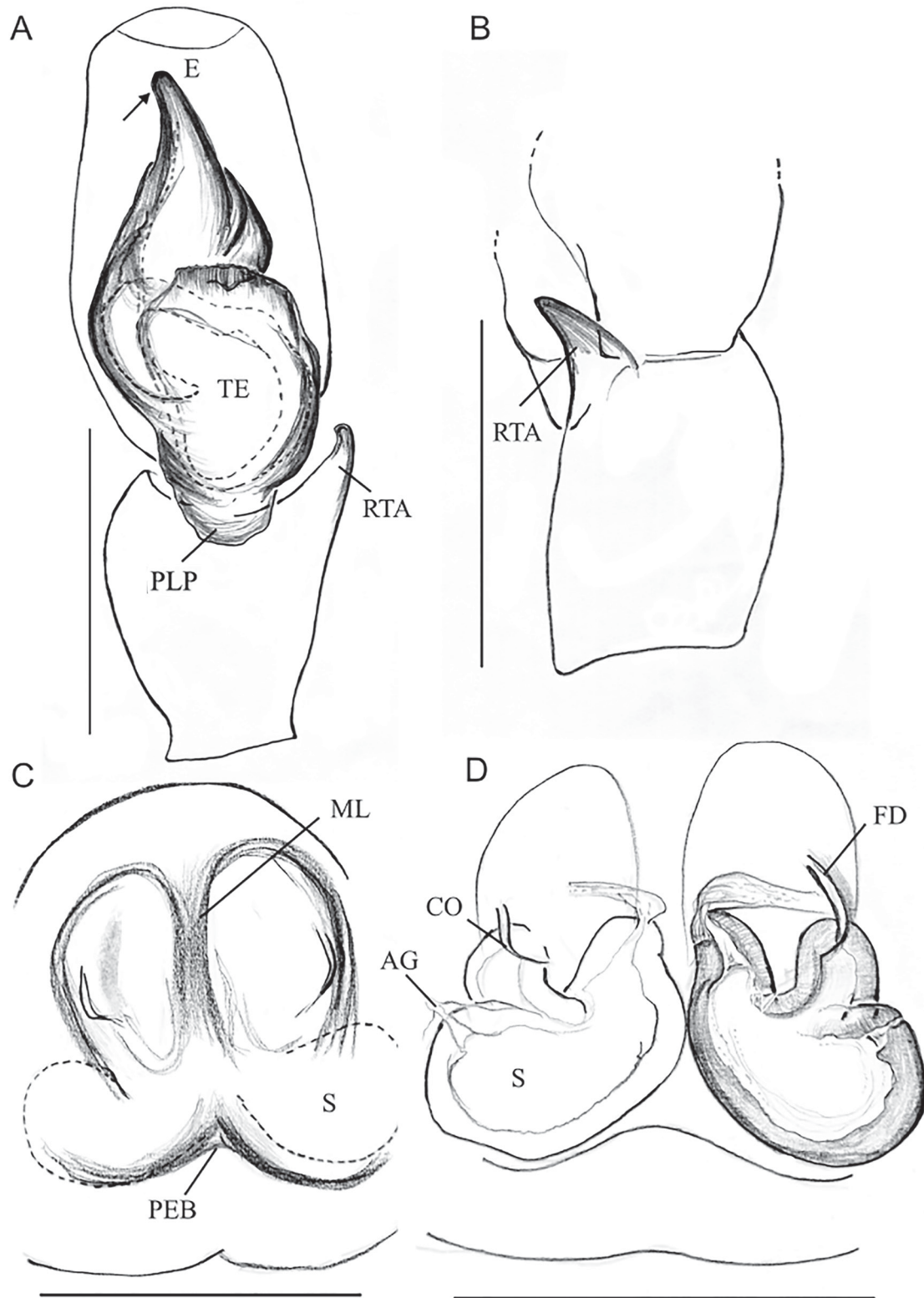


Fig 16. *Carrhotus viduus* (C.L. Koch, 1846). **A–B.** Palp. **A.** Ventral view. **B.** Retrolateral view. **C–D.** Epigynum. **C.** Ventral view. **D.** Dorsal view. Abbreviations: AG = accessory gland; CO = copulatory opening; E = embolus; FD = fertilization duct; ML = mid line; PEB = posterior epigynal border; RTA = retrolateral tibial apophysis; S = spermatheca; TE = tegulum. Scale bars: A–B = 0.2 mm; C–D = 0.1 mm.

COLOR AND BODY. Colouration pattern as in the male, but differs as follows: AMEs surrounded by yellow orbital setae; clypeus covered with white hairs; carapace with white longitudinal stripes (Fig. 15C).

EPIGYNUM. Structure of epigyne of *C. viduus* (Figs 15G, 16C–D) resembles that of *C. taprobanicus* but differs in relative proportions of spermathecae, rather elongated and globular in *C. viduus* (Fig. 16C–D), PEB more curved inwards by forming a prominent central curve, presence of a well-sclerotized midline, margins of CO well sclerotized and shape of CO more prominently C shaped than in *C. taprobanicus* (Fig. 15G).

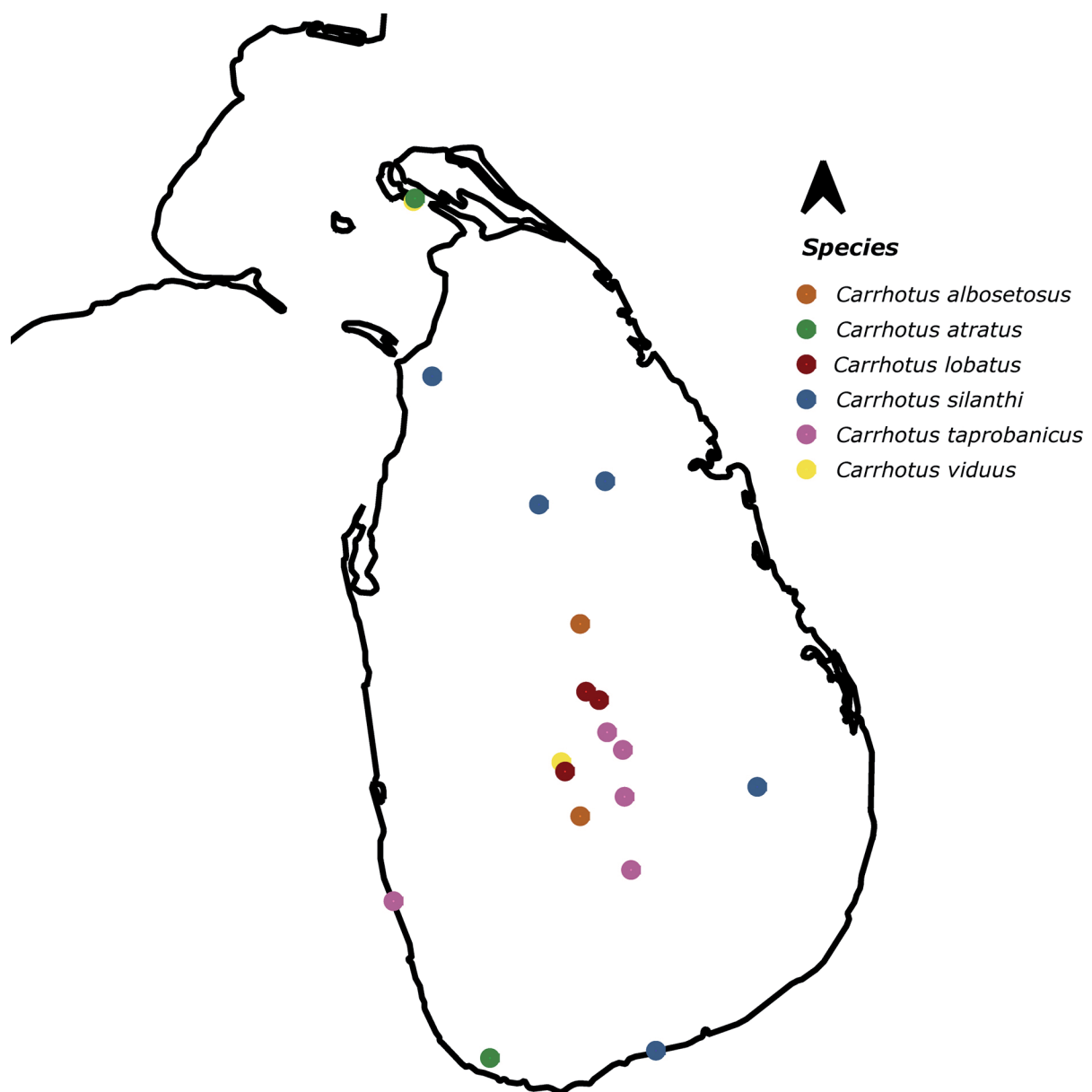


Fig 17. Distribution of *Carrhotus* spp. of Sri Lanka.

Distribution and habitat

This species occurs in the mangrove forests in the arid zone and lowland secondary rainforests of the dry and wet zones of Sri Lanka (Fig. 17). Specimens were collected by beating vegetation up to a height of 1–2 m.

Key to the species of *Carrhotus* in Sri Lanka

1. Males (males of *C. albosetosus* sp. nov. unknown) 2
 – Females (females of *C. lobatus* sp. nov. unknown) 6
2. PLP with two lobes (Figs 8C, 9A) *Carrhotus lobatus* sp. nov.
 – PLP with single lobe 3
3. Embolus straight 4
 – Embolus curved 5
4. Embolus long, acuminate, RTA as in Figs 11G–H, 12B *Carrhotus silanthi* (Caleb, 2020)
 – Embolus short, acute, RTA as in Figs 13F, 14B *Carrhotus taprobanicus* (Simon, 1902)
5. Embolus tapered, RTA tapered (Fig. 7D) *Carrhotus viduus* (C.L. Koch, 1846)
 – Embolus bow-shaped, RTA stout (Figs 6E, 7D) *Carrhotus atratus* sp. nov.
6. CD and FD prominent 7
 – CD and FD not prominent 9
7. Spermathecae boat-shaped, CD hook-shaped (Fig. 7D) *Carrhotus atratus* sp. nov.
 – Spermathecae kidney-shaped, CD otherwise 8
8. ML prominent (Figs 15G, 16C–D) *Carrhotus viduus* (C.L. Koch, 1846)
 – ML less prominent (Figs 13G, 14C–D) *Carrhotus taprobanicus* (Simon, 1902)
9. ML and CO as in Fig. 4A, D *Carrhotus albosetosus* sp. nov.
 – ML and CO as in Fig. 12C–D *Carrhotus silanthi* (Caleb, 2020)

Discussion

Carrhotus silanthi occurs in the lowland secondary rainforests of the dry and wet zones of Sri Lanka; *C. taprobanicus* and *C. lobatus* sp. nov. are distributed in the montane and submontane forests of the central highlands of Sri Lanka. *Carrhotus viduus* and *C. atratus* sp. nov. occur in the mangrove forests of the Jaffna district. *Carrhotus sannio* (Thorell, 1877) and *C. assam* Caleb, 2020 have a long filiform embolus. In *Carrhotus catagraphus* Jastrzebski, 1999 the CD stretches distally from the CO and curls up prior to entry in the spermathecae (Jastrzebski 1999). These species might be misplaced in *Carrhotus*.

This study further highlights that a large amount of Sri Lanka's invertebrate biodiversity remains unknown and that intensive sampling and taxonomic study is need to better understand their biodiversity.

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