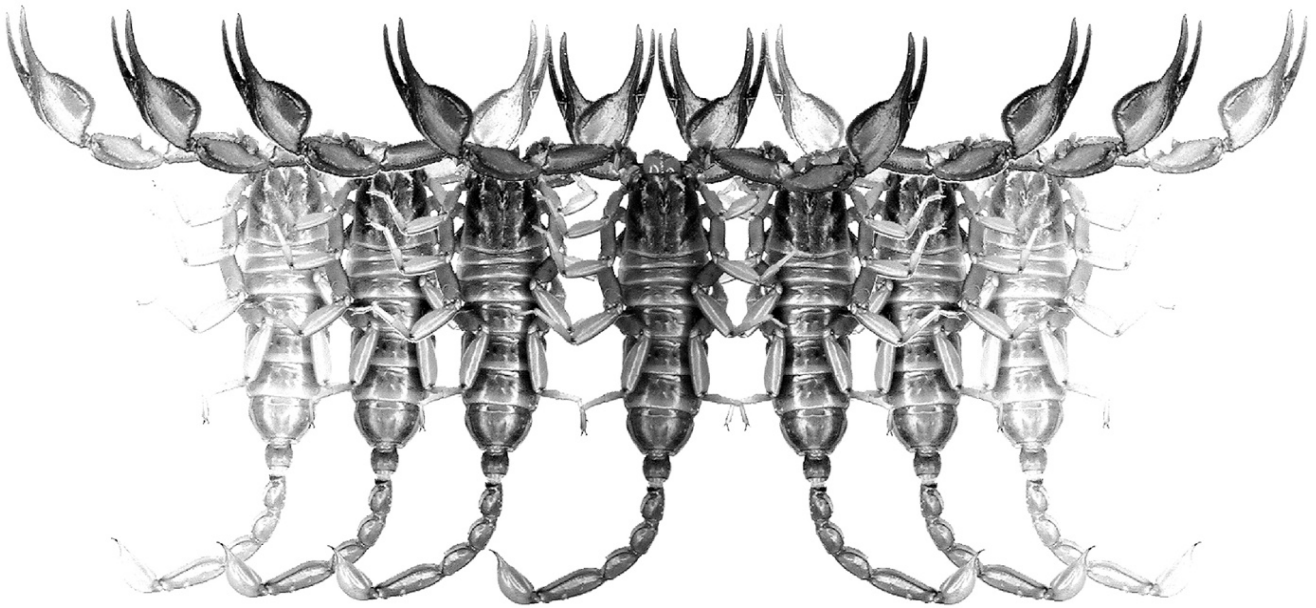


# *Euscorpius*

Occasional Publications in Scorpiology



**Two new species of *Chiromachetes*  
(Scorpiones: Hormuridae)  
from the northern Western Ghats, India**

Shauri Sulakhe, Shubhankar Deshpande, Nikhil Dandekar, Makarand Ketkar,  
Gaurang Gowande, Anand Padhye & Deshabhushan Bastawade

October 2020 — No. 320

# *Euscorpius*

## *Occasional Publications in Scorpiology*

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**Two new species of *Chiromachetes*  
(Scorpiones: Hormuridae)  
from the northern Western Ghats, India**

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<http://zoobank.org/urn:lsid:zoobank.org:pub:A3C18398-5DB2-449B-B87C-B2E614AE2936>

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## Summary

Two new species of *Chiromachetes* Pocock, 1899 (Hormuridae) are described from the northern Western Ghats of India using an integrated taxonomic approach. *Chiromachetes parakrami* sp. n. and *C. ramdasswamii* sp. n. are closely related and differ from each other and *C. sahyadriensis* by morphological features and raw genetic divergence of 7.9–9.4 %.

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## Introduction

Scorpion fauna of India has recently taken a new leap with new species descriptions supported by molecular phylogeny and in some cases an integrated taxonomic approach. As a result, the scorpion fauna of the northern Western Ghats (Maharashtra) is revealing high cryptic diversity (Sulakhe et al., 2020a, 2020b, 2020c; Mirza et al., 2019; Mirza, 2020).

The family Hormuridae Laurie, 1896, has had a complex taxonomic history and currently comprises 11 genera and 90 species. Several hormurid taxa are found in southeastern Asia and Australia (Rein, 2020). Previously included as a subfamily in Hemiscorpidae Pocock, 1893 (Soleglad et al., 2005), Hormuridae is today considered a valid family (Monod & Prendini, 2015). The genus *Chiromachetes* Pocock, 1899, includes three species, all restricted to the Indian Peninsula: the type species *Chiromachetes fergusonii* (Pocock, 1899) from Trivandrum (Kerala), *C. tirupati* Lourenço, 1997 from Tirupati (Andhra Pradesh), and the recently described *C. sahyadriensis* Mirza et al., 2015 from Tamhini Ghat, Pune (Maharashtra) situated in the northern Western Ghats. *C. sahyadriensis* was assigned to the genus *Chiromachetes* based on the presence of ventral tarsal spines and spinules, as well as the shape of hemispermatophore.

During the arachnological surveys of northern Western Ghats, we encountered two populations of *Chiromachetes*, which were morphologically and genetically different from their congeners. In this study we describe these two new species using an integrated taxonomic approach. We also provide a preliminary molecular phylogeny of the species of genus *Chiromachetes* from the northern Western Ghats. First description of male of *C. fergusonii* with color photographs is provided.

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## Methods, Materials & Abbreviations

Sampling was carried out in northern Western Ghats in Amba Ghat, Vishalgad Road, Kolhapur District (16°55'37"N 73°47'49"E, 842 m a. s. l.) and Varandha Ghat, Pune District (18°07'23"N 73°36'07"E, 473 m a. s. l.). Specimens were located with the help of ultraviolet light (AmiciVision 18w 100 LED UV Torch) and collected. All photographs of holotypes and paratypes presented in this study were taken using Nikon D500, 105 mm F2.8 micro lens and R1C1 flash kit. Specimens were euthanized and preserved in absolute ethanol, and later transferred to 70% ethyl alcohol in collection jars for long term preservation. Examination and morphological measurements were done using LEICA EZ4HD microscope with LEICA application suite. Morphological terminology follows Hjelle (1990). Morphometry was performed following Stahnke (1971). Measurements were taken (in mm) for 44 morphological characters (Tables 1–3). The trichobothrial terminology follows Vachon (1974). Hemispermatophore was dissected using scalpel, pointed needles and was treated with 5% KOH and cleaned with clove oil. Hemispermatophore terminologies follow Lamoral (1979) and Monod et al. (2017).

Specimens collected and studied are deposited in the museum collection of the BMNH (The Natural History Museum, London, United Kingdom), BNHS (Bombay Natural History Society), INHER (Mumbai and Institute of Natural History Education and Research), ZSI (Research Laboratory, Pune, Maharashtra, India and Zoological Survey of India), WGRC (Western Ghats Regional Centre Kozhikode, India).

*Additional material examined.*

*Chiromachetes sahyadriensis* Mirza et al., 2015

**India**, Maharashtra State, Pune District, Tamhini Ghat, 18°24'09"N 73°23'10"E, 428 m a. s. l., 1♂ (INHER 74), 1♀ (INHER-69), 30 September 2018, leg. S. Sulakhe, 2♂ (INHER 172, 273), 1♀ (INHER 272), 30 August 2019, leg. S. Sulakhe, M. Ketkar, C. Risbud.

The coordinates of the type locality of *C. sahyadriensis* by Mirza et al. (2015) were incorrectly published as (18°45'53"N 73°22'02"E, 558 m a. s. l.). The correct coordinates are as mentioned above in the comparative material examined.

Additional morphological data used for comparison, diagnosis and analysis of *C. sahyadriensis*, *C. fergusonii* and *C. tirupati* have been sourced from Lourenço (1997) and Mirza et al. (2015).

*STATISTICAL ANALYSIS.*

A discriminant function analysis (DFA) was performed using 12 morphometric variables that were size-corrected to nullify the influence of body size. Size correction was obtained by expressing the measurements of pedipalp femur length (PFL), pedipalp femur width (PFW), pedipalp manus width (PMW), total chela length (TCL), total pedipalp length (TPPL), movable finger length (MFL), mesosoma total length (MTL), metasoma total length (MSL), telson vesicle width (TVW), telson vesicle depth (TVD), telson total length (TTL) as percent of carapace median length (CML). Multivariate normality of the size corrected variable was checked following Doornik & Hansen (2008) omnibus. MANOVA was performed to understand whether related species of *Chiromachetes* form significantly different clusters (Huberty & Olejnik 2006). Pillai's trace statistic was performed to find the significant difference between the clusters (Harris 2001). Statistical analysis was performed in PAST 3.25 (Hammer et al. 2001). Due to availability of single specimen, *C. tirupati* was excluded from this analysis.

*MOLECULAR ANALYSIS.*

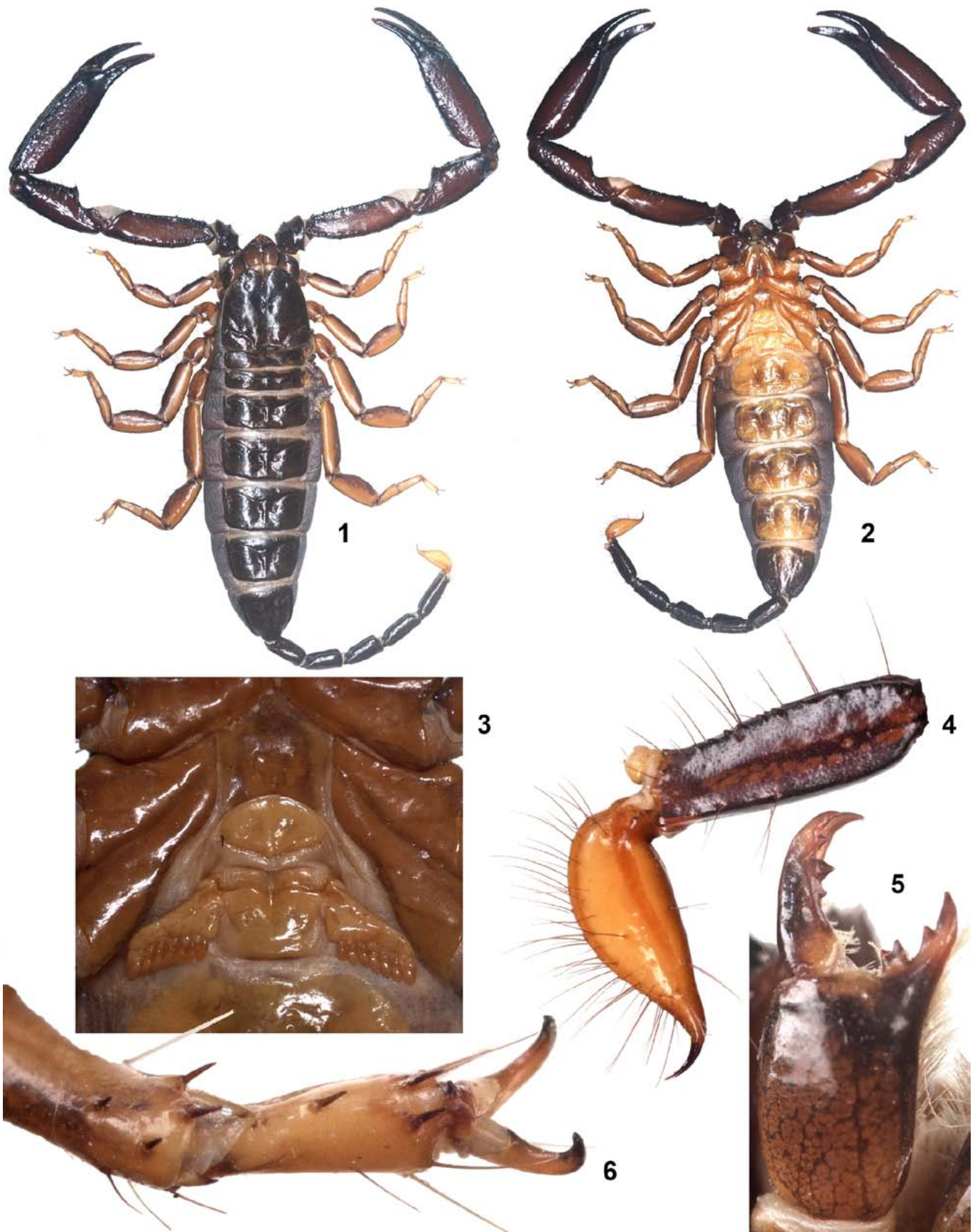
*DNA extraction, amplification and sequencing.* Protocol as per Sulakhe et al. (2020b) was followed. Whole genomic DNA was extracted from preserved (ethanol 99.9%) muscle tissue (leg fragment) of freshly collected material, (Voucher numbers of specimens used for DNA analysis are mentioned in Table 7 and Figs. 65, 66) with MACHEREY-NAGEL NucleoSpin® DNA Insect kit as per manufacturer's protocols. A 550–600 base pair (bp) fragment of the cytochrome c oxidase subunit I (*COI*) mitochondrial gene was amplified by polymerase chain reaction (PCR) using the primers listed in Table 6. A 25 µl PCR reaction (TaKaRa Taq™ DNA Polymerase) was set containing 1 unit of Taq DNA polymerase (0.2µL), 2.5µL of 10x buffer, 2 µl of dNTPs (2.5mM each), 2 µl (5mM) of each primer, 2µl template DNA, and 14.3 µl of water, carried out with a Miniamp Thermal Cycler. The thermal cycler program used for amplification is as follows: 95° C for 3 min (denaturation temperature 95° C for 30 seconds, annealing temperature 50° C for 30 seconds, elongation temperature 72° C for 1 minute) x 35 cycles, 72° C for 7 minutes, hold at 4° C. PCR products were cleaned through

column purification method with Qiagen PCR Cleanup Kit and sequenced with a 3730 DNA Analyzer. The sequencing primers were the same as those used in the PCRs. All sequences were deposited in the GenBank® nucleotide sequence database (<http://www.ncbi.nlm.nih.gov>) under accession numbers as per Table 7.

The sequences were also checked in BLAST (Altschul et al., 1990) tool to find the closest available sequences in the GenBank® and the related ones were downloaded for analysis.

*Sequence alignment.* Generated sequences were cleaned manually in MEGA 7 (Kumar et al., 2016) using chromatograms visualised in Chromas v.2.6.5 (Technelysium PTY. Ltd.). Cleaned and downloaded sequences were aligned using MUSCLE (Edgar, 2004) implemented in MEGA 7 (Kumar et al., 2016) using default parameters. The final alignment contained nine sequences each of 604 bp length including two sequences of *Paravaejovis gravicaudus* published for the first time in (González-Santillán & Prendini, 2015) which are used as outgroup to root the phylogenetic tree (Table 7). The single sequence of *Iomachus laeviceps* (Pocock, 1890) is included as it belongs to the family Hormuridae. This alignment was used in molecular phylogenetic analyses.

*Molecular phylogenetic analysis.* Maximum Likelihood (ML) and Bayesian Inference (BI) methods of phylogenetic analysis were implemented. The *COI* region was partitioned per codon position and the best substitution model for phylogenetic analysis was determined using PartitionFinder v.1.1.1 (Lanfear et al., 2012). Model search was performed using the Bayesian Information Criterion (BIC) with a greedy search algorithm (Schwarz, 1978), for ML as well as BI. Maximum Likelihood analysis was performed using RAxML GUI v. 1.3 (Silvestro & Michalak, 2011). Two different sets of models of sequence evolution had to be used since RAxML allows the use of only GTR models, whereas many more models are available in MrBayes. Accordingly, GTR+G was the model of sequence evolution used for each partition in the ML analysis, as recommended by PartitionFinder results. Branch support was tested using 1000 non-parametric rapid bootstrap pseudo-replicates. Bayesian trees were generated using MrBayes v. 3.2.6 (Ronquist et al., 2012). The models of sequence evolution were as follows: HKY+G for codon position 1, HKY+I for codon position 2 and F81 for codon position 3, as per the results of PartitionFinder analysis. Two simultaneous, independent analyses were run starting from different random trees. Three heated and one cold chain was used in each runs. Markov chains were sampled every 100 generations for 1 million generations. At the end of the run the standard deviation of split frequencies was less than 0.005, indicating convergence, and the analyses were not continued further. The convergence was further checked using Tracer v. 1.7 (Rambaut et al., 2003), the absence of bimodal distribution indicating clear convergence. Additionally, all the ESS values were above 200. A total of 25% trees were discarded as burn-in. The tree representing the best evolutionary hypothesis was selected using a 50% majority consensus rule. Uncorrected pairwise genetic divergence “*p*-distance” was calculated in MEGA 7 (Kumar et al., 2016).



**Figures 1–6.** *Chiromachetes parakrami* sp. n., male, holotype, dorsal (1) and ventral (2) views, sternopectinal area (3), metasomal segment V and telson in lateral view (4), chelicera in dorsal view (5) and tarsi IV (6).

Dimensions (mm)		<i>Chiromachetes parakrami</i> sp. n.				
		♂ holotype BNHS SC179	♂ paratype BNHS SC180	♂ paratype INHER199	♂ paratype INHER200	♀ paratype BNHS SC181
Carapace	L / W	7.3 / 8.1	7.6 / 8.0	7.3 / 7.8	7.0 / 7.5	8.2 / 9.2
Mesosoma	L	22.9	23.3	24.5	20.2	30.1
Tergite VII	L / W	5.1 / 4.8	4.9 / 5.1	5.3 / 5.6	4.1 / 4.9	6.1 / 6.6
Metasoma and telson	L	22.5	23.9	22.4	22.9	24.7
Segment I	L / W / D	3.2 / 2.0 / 1.7	3.3 / 2.0 / 1.8	3.0 / 1.9 / 1.8	3.2 / 2.0 / 1.6	3.4 / 2.2 / 2.1
Segment II	L / W / D	3.3 / 1.7 / 1.8	3.6 / 1.6 / 1.9	3.4 / 1.6 / 1.9	3.5 / 1.5 / 1.7	3.9 / 1.8 / 2.2
Segment III	L / W / D	3.4 / 1.4 / 2.0	3.9 / 1.5 / 2.0	3.5 / 1.5 / 1.9	3.6 / 1.4 / 1.8	4.0 / 1.7 / 2.2
Segment IV	L / W / D	3.5 / 1.4 / 1.7	4.0 / 1.4 / 1.9	3.8 / 1.2 / 1.8	3.9 / 1.3 / 1.8	4.1 / 1.5 / 2.1
Segment V	L / W / D	4.4 / 1.3 / 1.5	4.3 / 1.4 / 1.7	4.1 / 1.2 / 1.6	4.4 / 1.3 / 1.7	4.4 / 1.4 / 1.7
Telson	L / W / D	4.7 / 1.2 / 1.6	4.8 / 1.2 / 1.6	4.6 / 1.2 / 1.6	4.3 / 1.1 / 1.8	4.9 / 1.2 / 1.8
Pedipalp	L	37.0	36.6	36.4	35.8	38.4
Femur	L / W	10.2 / 3.0 / 1.4	10.0 / 3.1 / 1.3	10.1 / 3.0 / 1.3	10.0 / 2.9 / 1.2	10.3 / 3.4 / 1.7
Patella	L / W	9.4 / 3.5 / 1.9	9.2 / 3.6 / 2.1	9.3 / 3.5 / 1.9	8.9 / 3.6 / 1.7	9.2 / 4.0 / 2.3
Chela	L	17.4	17.4	17.1	16.9	18.9
Manus	L / W / D	4.0 / 2.4	4.0 / 2.3	3.9 / 2.3	3.9 / 2.1	5.5 / 2.5
Movable finger	L	6.8	6.8	7.0	6.8	8.1
Pectine	L / W	2.9 / 1.7	3.6 / 1.6	3.3 / 1.6	3.0 / 1.8	3.1 / 1.9
Genital Operculum	L / W	1.6 / 2.6	1.7 / 2.8	1.5 / 2.8	1.5 / 2.4	2.1 / 3.1
<b>Total</b>	<b>L</b>	<b>52.7</b>	<b>54.8</b>	<b>54.2</b>	<b>50.1</b>	<b>63.0</b>
Pectinal teeth count		7 / 7	8 / 8	8 / 8	8 / 9	6 / 8

**Table 1.** Morphometric data for *Chiromachetes parakrami* sp. n. Abbreviations: length (L), width (W, in carapace it corresponds to median width), depth (D), holotype (HT), paratype (PT).

*Species delimitation analysis.* Species delimitation analysis was performed on the BI tree using Bayesian Poisson Tree Process using 500000 Markov chain Monte Carlo (MCMC) generations with thinning parameter of 100 and burn-in of 0.1 (Zhang et al., 2013).

## Systematics

### Family Hormuridae Laurie, 1896

#### Genus *Chiromachetes* Pocock, 1899

(Figures 1–83, Tables 1–7)

<http://zoobank.org/urn:lsid:zoobank.org:act:D1B455F7-E75B-4DF5-BAC7-31B0341D1784>

TYPE SPECIES. *Chiromachetes fergusonii* Pocock, 1899.

#### *Chiromachetes parakrami* sp. n.

(Figures 1–30, 61, 81–83, Tables 1, 4–7)

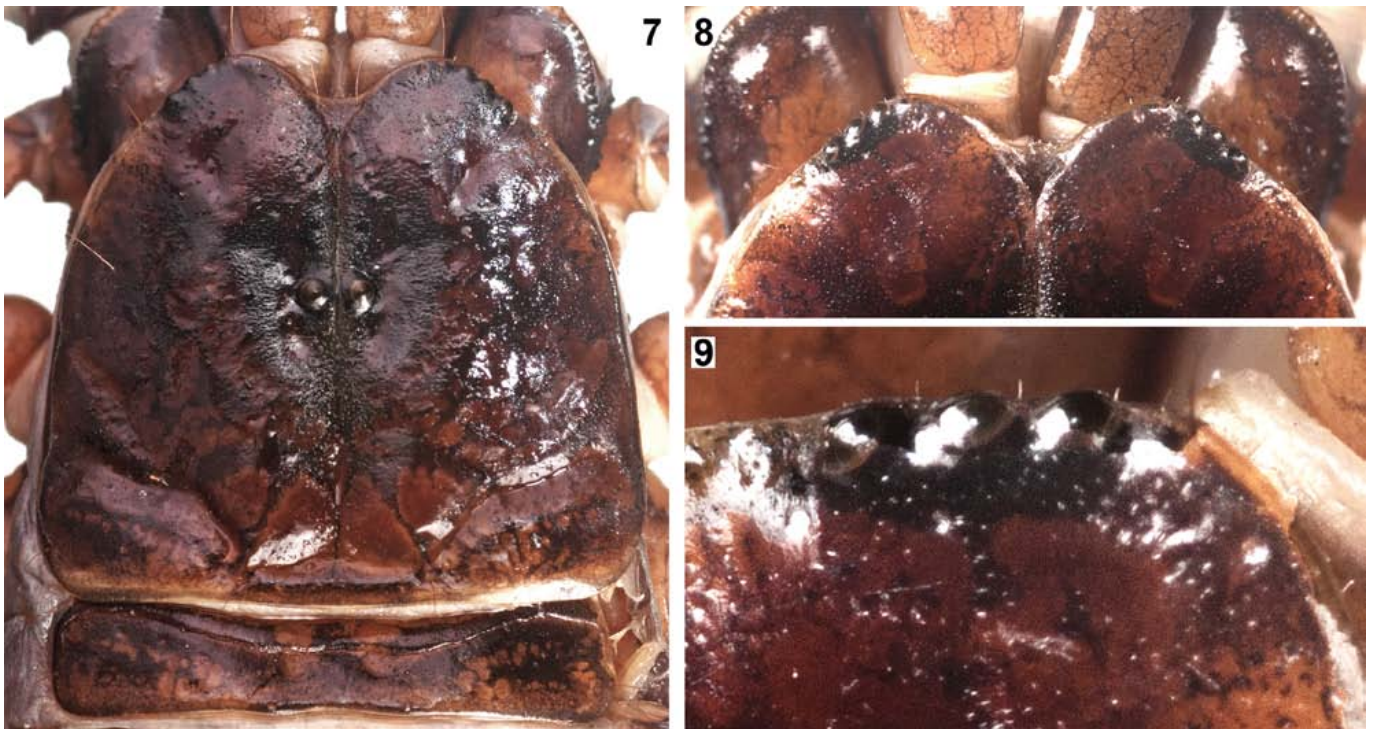
<http://zoobank.org/urn:lsid:zoobank.org:act:7566607F-3C16-4002-8299-7E911CC95084>

TYPE LOCALITY AND TYPE REPOSITORY. **India**, *Maharashtra State*, Kolhapur District, Vishalgad Road, Amba Ghat, Amba Village, 16°55'37"N 73°47'49"E; BNHS.

TYPE MATERIAL. **India**, *Maharashtra State*, Kolhapur District, Vishalgad Road, Amba Ghat, Amba Village, 16°55'37"N 73°47'49"E, 842 m a. s. l., 1♂ (holotype, BNHS SC 179), 3♂ (paratypes, INHER 199, 200, BNHS SC 180), 1♀ (paratype, BNHS SC 181), 22 October 2019, leg. M. Ketkar & A. Marathe.

ETYMOLOGY. The specific epithet is derived from a Sanskrit word *parakram*, meaning act of valour, shown by the great Maratha warrior Baji Prabhu Deshpande and his army on 3 July 1660 to defend his king against the Sultanate of Bijapur, at the location named Pawan Khind (Pass), very close to the type locality. The battle of Pawan Khind is recorded in history as one of the best known “last man stands”.

DESCRIPTION (♂ holotype, measurements in Table 1) **Coloration** (in preserved condition) (Figs. 1, 2, 14, 15). Overall body color dark brownish to blackish with glossy surface. Legs yellowish brown. Telson yellow on vesicle and black on aculeus. Ventral portion of body yellowish brown. Carapace and fingers of manus blackish. Pedipalps dark brown and almost black on the carinae. Chelicera basal segment yellowish brown with black reticulation. Fingers of chelicera dark brown.



**Figures 7–9.** *Chiromachetes parakrami* sp. n., male, holotype, carapace (7), anterior margin of carapace (8) and left lateral eyes in dorsal view (9).

**Carapace** (Figs. 7–10, 12). Carapace wider than long. Entire surface of carapace almost smooth with fine and sparse granulation present along the central median furrow. Median furrow distinct only on anterior portion. Posterior lateral furrow almost smooth. Posterior median furrow triangular with a shallow triangular depression. Anterior margin of carapace with deep U-shaped emargination in the middle. Lateral ocular tubercle with three pairs of lateral eyes. Carapace without carinae. Pair of median eyes situated on carapace in the proportions 1:1.5 (distance of median eyes to anterior margin : distance of median eyes to posterior margin). Margins entirely smooth.

**Chelicerae** (Fig. 5). Fixed finger of chelicera with three large triangular denticles on inner margin. Ventral tooth of movable finger lacks denticulation. Dorsal tooth of movable finger with 3 denticles on inner margin.

**Pedipalp** (Figs. 19–25). Pedipalps dorsoventrally flat. Femur with three (dorsal retrolateral, ventral retrolateral, median prolateral) and patella with four carinae (dorsal prolateral, ventral prolateral, dorsal retrolateral, ventral retrolateral). Intercarinal space with weak granulation. Prolateral surface of patella with large spur bearing two equal sized tubercles. Chela with five carinae (dorsal prolateral, ventral prolateral, dorsal retrolateral, median retrolateral, ventral retrolateral). Intercarinal space smooth on dorsal and ventral surface and sparsely granular on prolateral and retrolateral surface. Dentate margins of both chela fingers composed of two rows of granules. Movable finger densely granular on retrolateral and sparsely granular on prolateral surface. Trichobothrial pattern of ‘type C’ typical of the genus. Number of trichobothria: chela dorsal (4), chela ventral (4), chela prolateral (2), chela

retrolateral (15), patella dorsal (2), patella ventral (3), patella prolateral (1), patella retrolateral (13), femur dorsal (1), femur prolateral (1) and femur retrolateral (1).

**Legs** (Figs. 1, 2, 6, 10, 11, 14, 15). Legs I–IV; femur carinated on anterior portion; intercarinal space with granulation; tarsomere I with four spines distally and tarsomere II with three spines distally and a few spinules at the proximal end (fig.6).

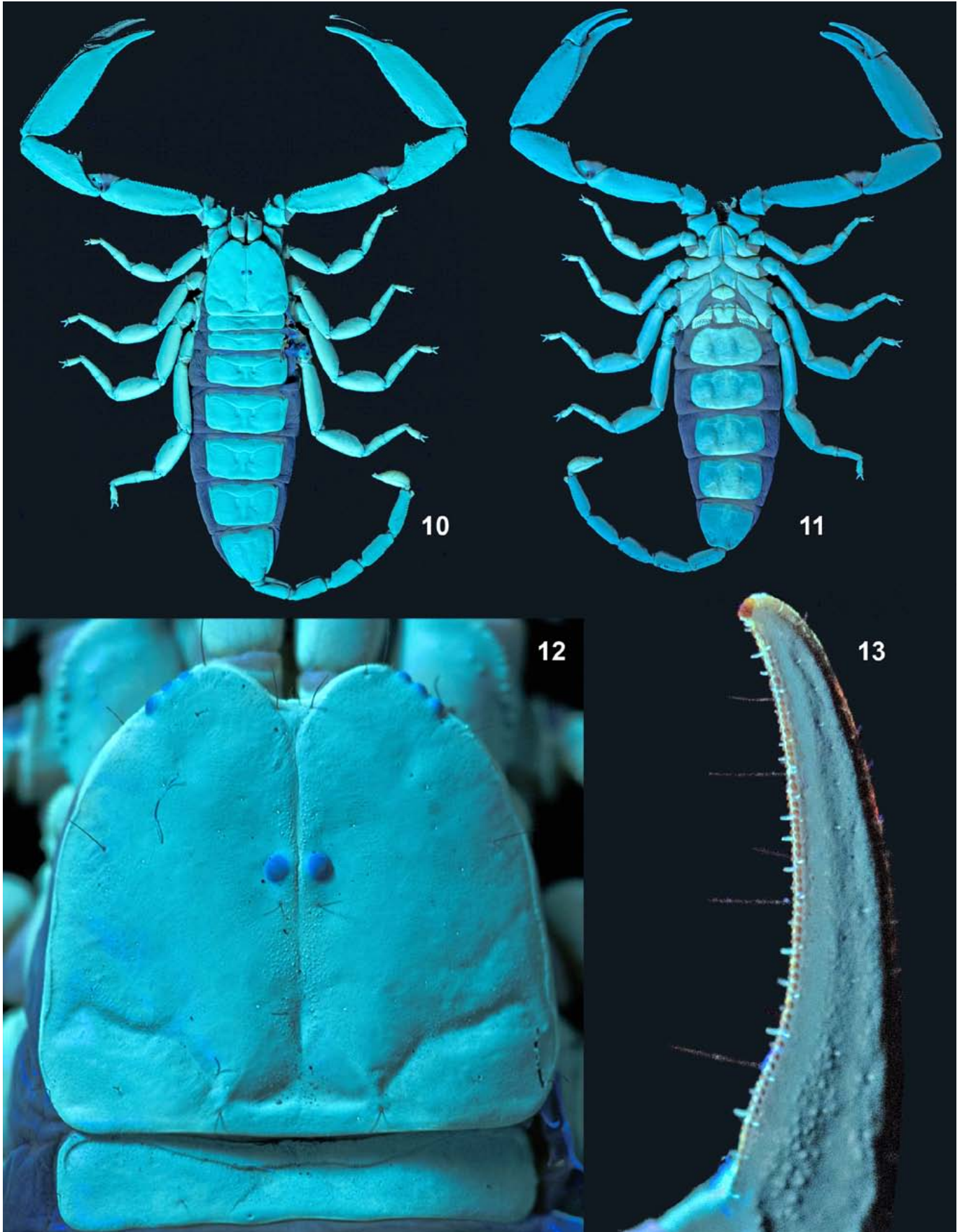
**Sternum, genital operculum and pectines** (Figs. 3, 16). Sternum broad, pentagonal and entirely smooth. Genital operculum with a pair of genital papillae. Posterior sclerite with slight depression on middle portion. Pectines with 7/7 pectinal teeth and 6/6 fulcra.

**Mesosoma** (Figs. 1–3, 10, 11, 14–16). All tergites smooth with median elevated portion. All sternites entirely smooth except sternite VII granular on lateral portion and with symmetrical depressions on both halves posteriorly.

**Metasoma** (Figs. 1, 2, 4, 10, 11, 14, 15, 17). Metasomal segments I–IV smooth, finely punctate and with very weak carinae. Intercarinal space smooth. Ventrolateral carina on segment V strongly and densely serrated only on the posterior portion and weak on the anterior portion. Intercarinal space granular. Anal rim weakly tuberculated.

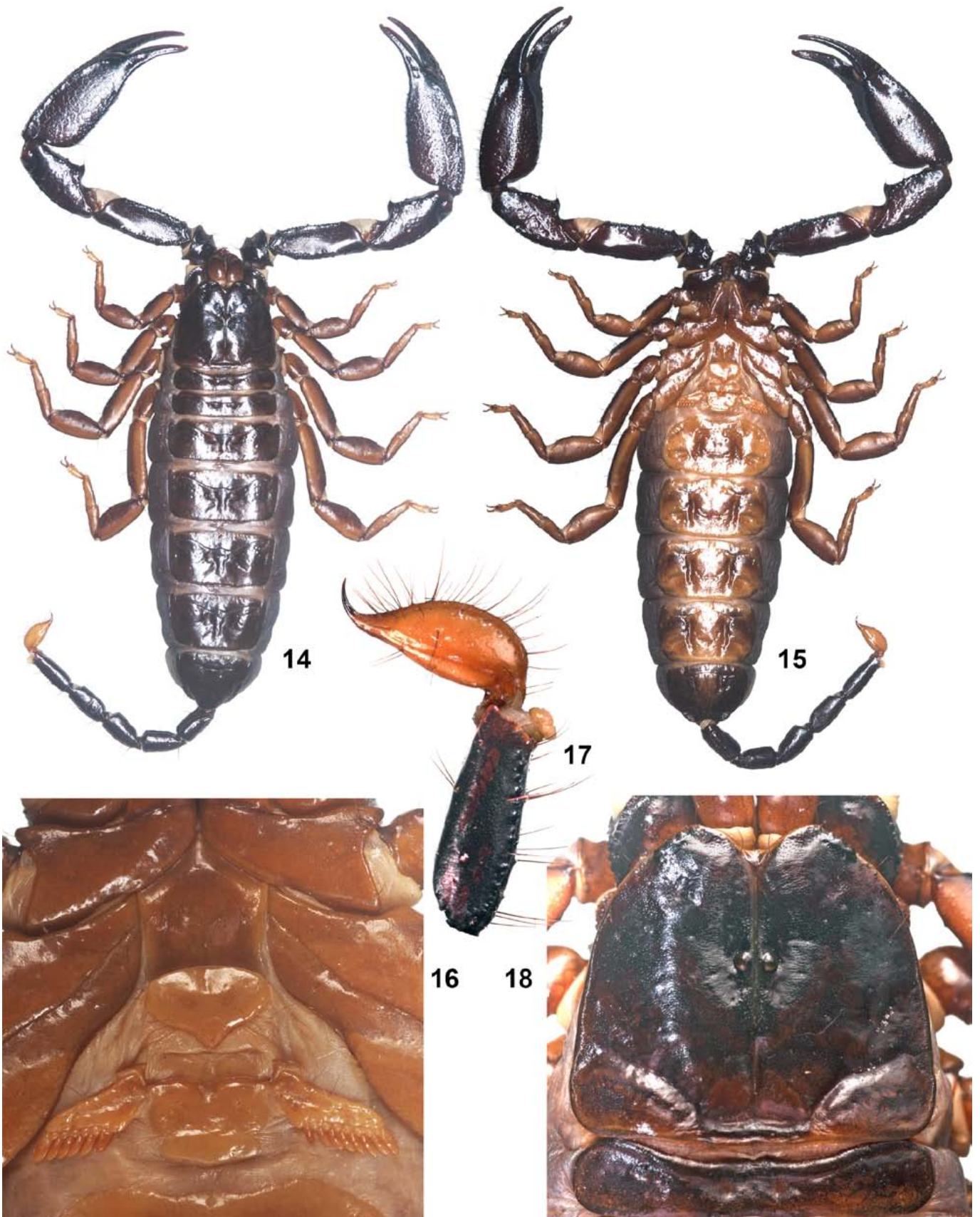
**Telson** (Figs. 4, 17). Pyriform, almost entirely smooth and hirsute on the ventral side. Aculeus short and strongly curved.

**Hemispermatothore** (♂ paratype, BNHS SC 180, Figs. 26, 27). Lamelliform; capsular region appears to be complex and bulbous. Lamella slender and long. Single lamellar hook, curved and pointed upwards, situated distally at the base of the lamella. Lamella longer than the trunk and capsular region together. Pedicel 1.15 mm long; trunk 2.45 mm long; capsule 1.44 mm long and 1.90 mm wide; lamella 7.64 mm long.

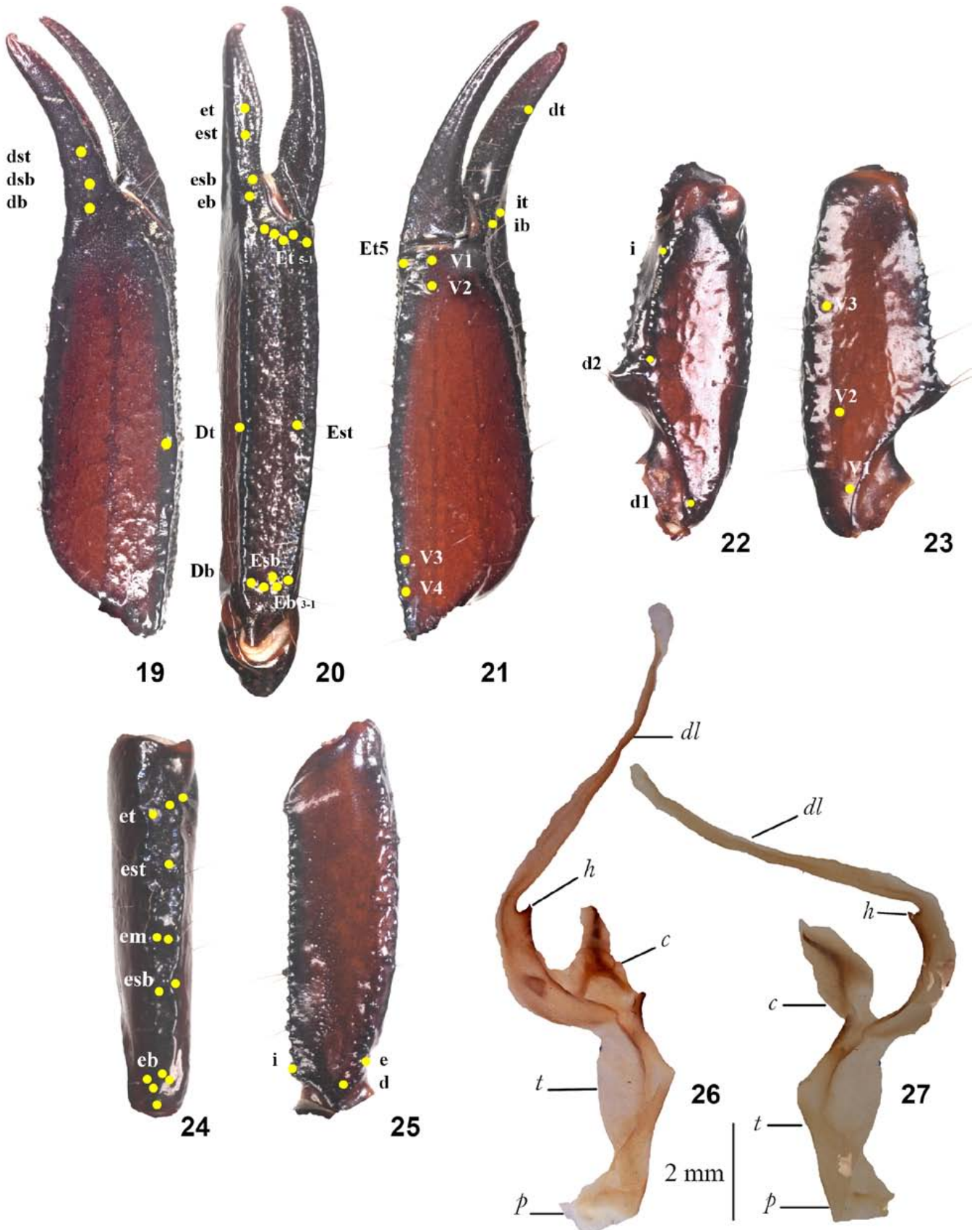


Figures 10–13. *Chiromachetes parakrami* sp. n., male, holotype in dorsal (10) and ventral (11) views, carapace (12) and dentition on movable finger of chela (13) under UV fluorescence.

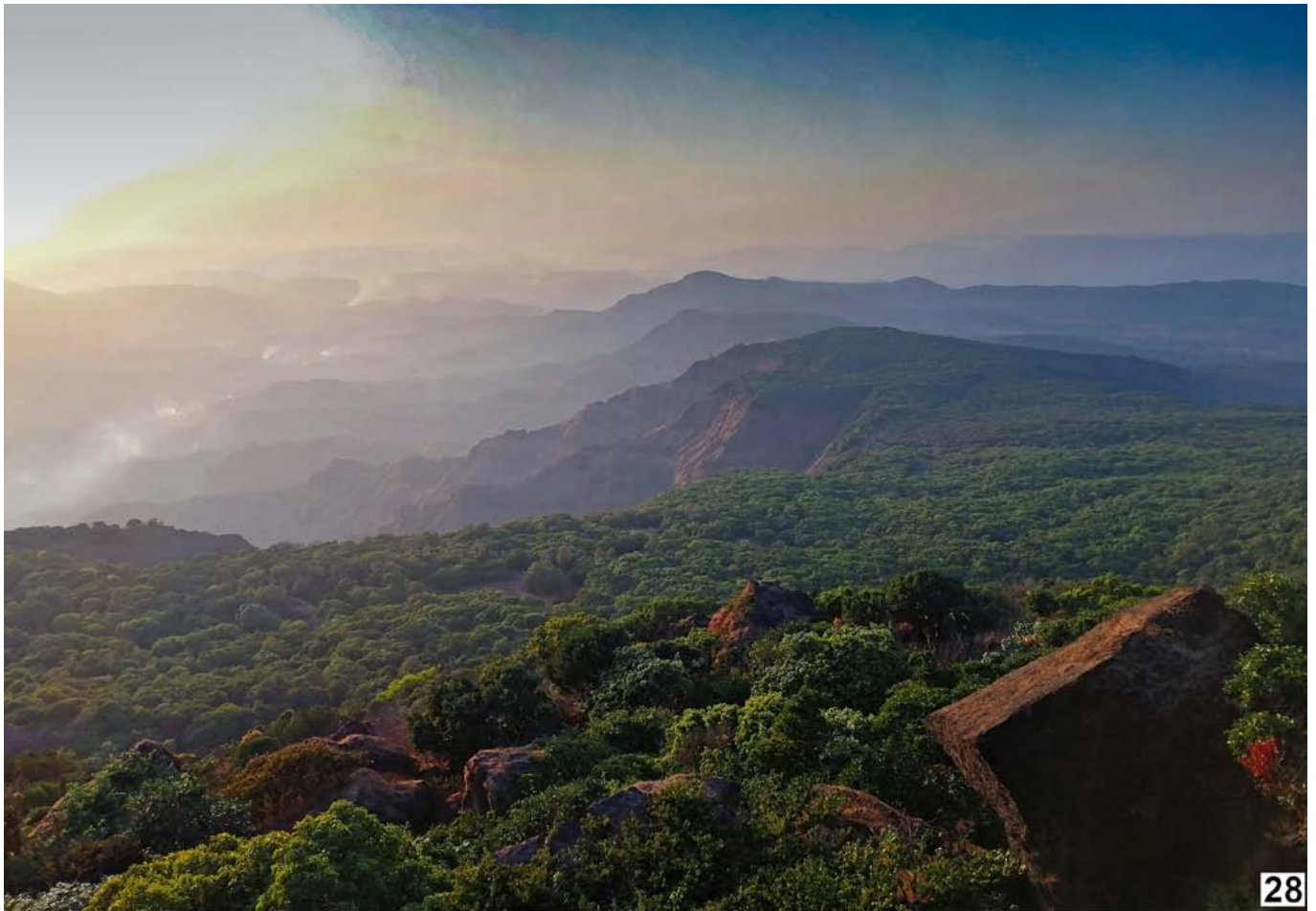




Figures 14–18. *Chiromachetes parakrami* sp. n., female, paratype, BNHS SC 181, in dorsal (14) ventral (15) views, sternopectinal area (16), metasomal segment V and telson in lateral view (17) and carapace (18).



**Figures 19–27:** *Chiromachetes parakrami* sp. n. **Figures 19–25:** Male, holotype, pedipalp chela dorsal (19), external (20) and ventral (21) views, patella dorsal (22), ventral (23) and external (24) views and femur dorsal (25) view. Trichothrial pattern indicated by yellow circles. **Figures 26–27:** Male, paratype, BNHS SC 180, right hemispermatophore in internal (26) and external (27) views. Abbreviations: *p*, pedicel; *t*, trunk; *c*, capsule; *h*, hook; *dl*, distal lamina.



**Figures 28–30.** Type locality of *Chiromachetes parakrami* sp. n., view of the dense semi-evergreen forest and mountains of Amba Ghat (28), view of the Amba Ghat road with adjacent boulders (29) and columnar basaltic boulder at the type locality from where the type series is collected (30).

SEXUAL DIMORPHISM. Male genital operculum with pair of genital papillae. In females, the genital operculum medially sutured. Pedipalp manus slender in males and stouter in females (Figs. 1–3, 14–16).

AFFINITIES. *Chiromachetes parakrami* sp. n. differs from all species of *Chiromachetes* from the northern Western Ghats by a raw genetic divergence of 7.9–9.4 % (Table 5). It is also distinguished from all its congeners based on the following set of morphological characters:

1. Pectinal teeth number in males 7–9, females 6–8 as opposed to males 5–6, females 3–4 in *C. tirupati*, males 9–11, females 7–8 in *C. fergusonii* (Tables 1–3).
2. Chela length to manus width ratio in males 4.3–4.4, females 3.5 as opposed to males 3.6 in *C. tirupati*, males 3.4 and female 3.6 in *C. fergusonii*, males 4.9–5.0, females 3.3–3.4 in *C. ramdasswamii* sp. n. (Table 4).
3. Pedipalp femur length to width ratio in males 3.2–3.5, females 3.0 as opposed to males 2.5 in *C. tirupati*, males 2.3, females 2.6 in *C. fergusonii*, males 3.3–3.8, females 2.7–2.8 in *C. sahyadriensis*, males 3.7–4.1, females 2.6–2.9 in *C. ramdasswamii* sp. n. (Table 4).
4. Chela length to movable finger length ratio in males 2.4–2.6, as opposed to 2.1 in *C. fergusonii*, 2.7 in *C. ramdasswamii* sp. n. (Table 4).
5. Carapace posterior median furrow triangular with a shallow triangular posterior depression as opposed to triangular with a deep triangular posterior depression in *C. sahyadriensis*, triangular with a horizontal and elliptical posterior depression in *C. ramdasswamii* sp. n. (Figs. 12, 42, 62).
6. Ventrō-lateral carina of metasoma segment V strongly and densely serrated only on the posterior portion and weak on the anterior portion as opposed to strongly and sparsely serrated in *C. sahyadriensis*, strongly and densely serrated in *C. ramdasswamii* sp. n. (Figs. 4, 17, 34, 47, 63).
7. Hemispermatophore with position of lamellar hook distal and shape of distal lamella slender and long as opposed to position of lamellar hook basal and shape of distal lamella stout and short in *C. ramdasswamii* sp. n. (Figs. 26, 27, 56, 57).

DISTRIBUTION, HABITAT AND ECOLOGY. Presently *C. parakrami* sp. n. is only known from its type locality, Vishalgad Road, Amba Ghat, Amba Village, Kolhapur District, Maharashtra, India. The specimens were observed in the crevices of columnar joints of basaltic boulders in the semi-evergreen forest patches along the road. The type locality is surrounded by a mountain range with top cap laterite and withered boulders on the slopes on one side of the road and a valley facing the west on the other side. The species might be ubiquitous in similar micro habitats around, however this needs to be confirmed with further surveys. Individuals were found to be active at night sitting at the openings of very narrow rock crevices. The ecology and morphology of the new species is congruent with the lithophilic scorpions (Figs. 28–30).

***Chiromachetes ramdasswamii* sp. n.**

(Figures 31–60, 61, 81–83, Tables 1, 4–7)

<http://zoobank.org/urn:lsid:zoobank.org:act:F054DFD1-B3D9-4780-A0A2-90E72CA6E1FD>

TYPE LOCALITY AND TYPE REPOSITORY. **India**, *Maharashtra State*, Pune District, Varandha Ghat, 18°07'23" N 73°36'07"E, 473 m a. s. l.; BNHS.

TYPE MATERIAL. **India**, *Maharashtra State*, Pune District, Varandha Ghat, 18°07'23"N 73°36'07"E, 473 m a. s. l., 1♂ (holotype, BNHS SC 182), 9 July 2020, 2♂ (paratypes, INHER 254, BNHS SC 183), 11 July 2020, 4♀ (paratypes, INHER 246, 249, BNHS SC 184, 185), 9 July 2020, leg. M. Ketkar, A. Marathe, S. Deshpande & S. Sulakhe.

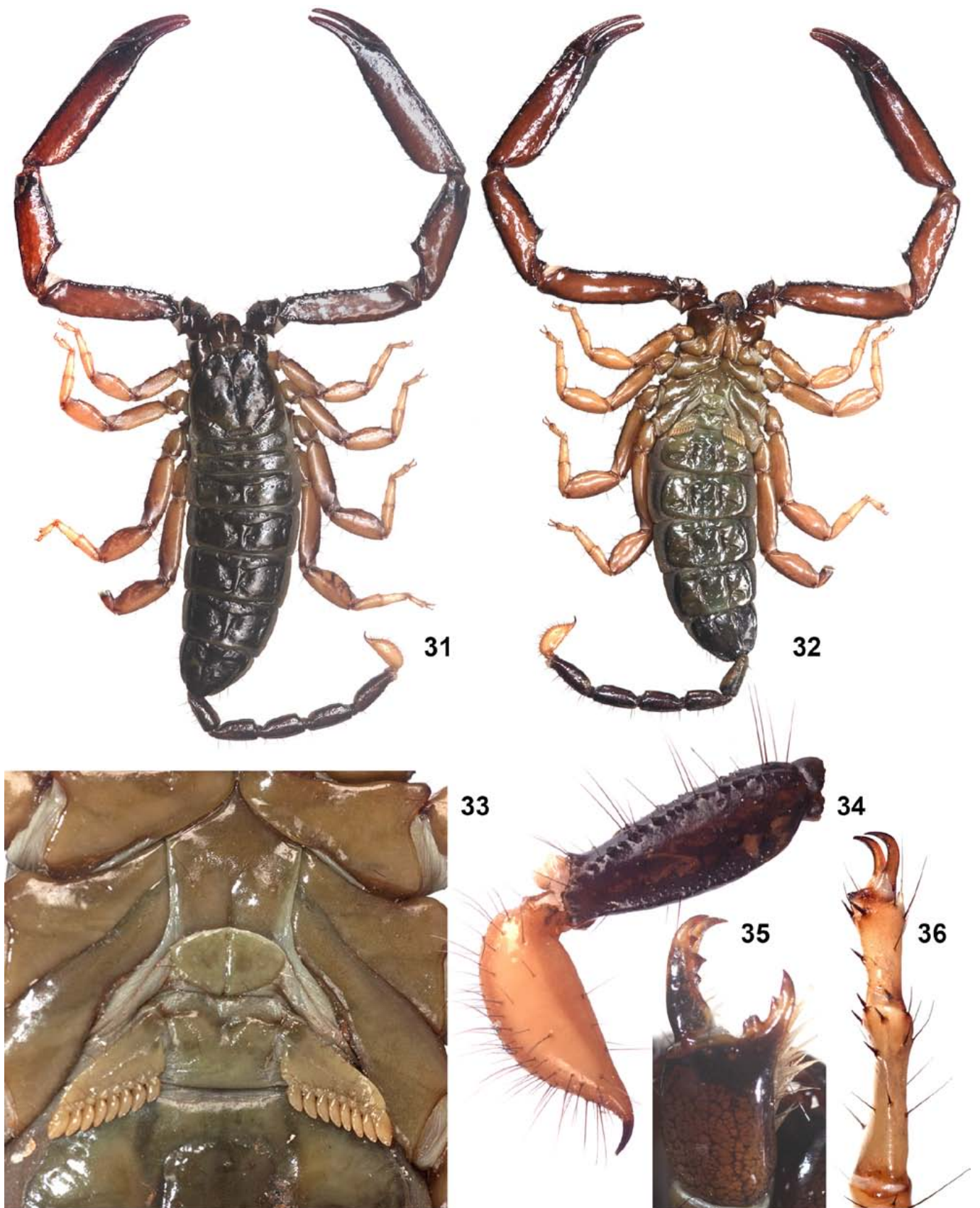
ETYMOLOGY. The species epithet is a patronym honouring Samartha Ramdas Swami, who was a renowned Hindu saint, philosopher, poet, writer, social reformer, and spiritual master of the 17<sup>th</sup> century. It is believed that he dictated his famous literary trait “Dasbodh” while residing in a natural cave behind a waterfall known as Shivtharghal, very close to the type locality.

DESCRIPTION. (♂ holotype, measurements in Table 2). **Coloration** (in preserved condition) (Figs. 31, 32, 44, 45). Overall body color blackish with glossy surface. Legs yellowish brown. Telson vesicle yellow and aculeus black. Ventral aspect yellowish brown. Carapace and fingers of manus blackish. Pedipalps dark brown, carinae almost black. Chelicera basal segment yellowish brown with black reticulation. Fingers of chelicera dark brown.

**Carapace** (Figs. 37–40, 42). Carapace wider than long. Entire surface of carapace almost smooth with fine and dense granulation present along the central median furrow. Median furrow distinct only on anterior and middle portion. Posterior lateral furrow deep with coarse and dense granulation along the margin. Posterior median furrow triangular with a prominent horizontal and elliptical posterior depression. Anterior margin of carapace with deep U shaped emargination in the middle. Lateral ocular tubercles with three pairs of lateral eyes. Carapace lacks carinae. Pair of median eyes situated on carapace in the proportions of 1:1.6 (distance of median eyes to anterior margin and distance of median eyes to posterior margin). Margins entirely smooth.

**Chelicerae** (Fig. 35). Fixed finger of chelicera with one large triangular and two blunt conjoined subtriangular denticles on inner margin. Ventral tooth of movable finger lacks denticulation. Dorsal tooth of movable finger with 3 denticles on inner margin.

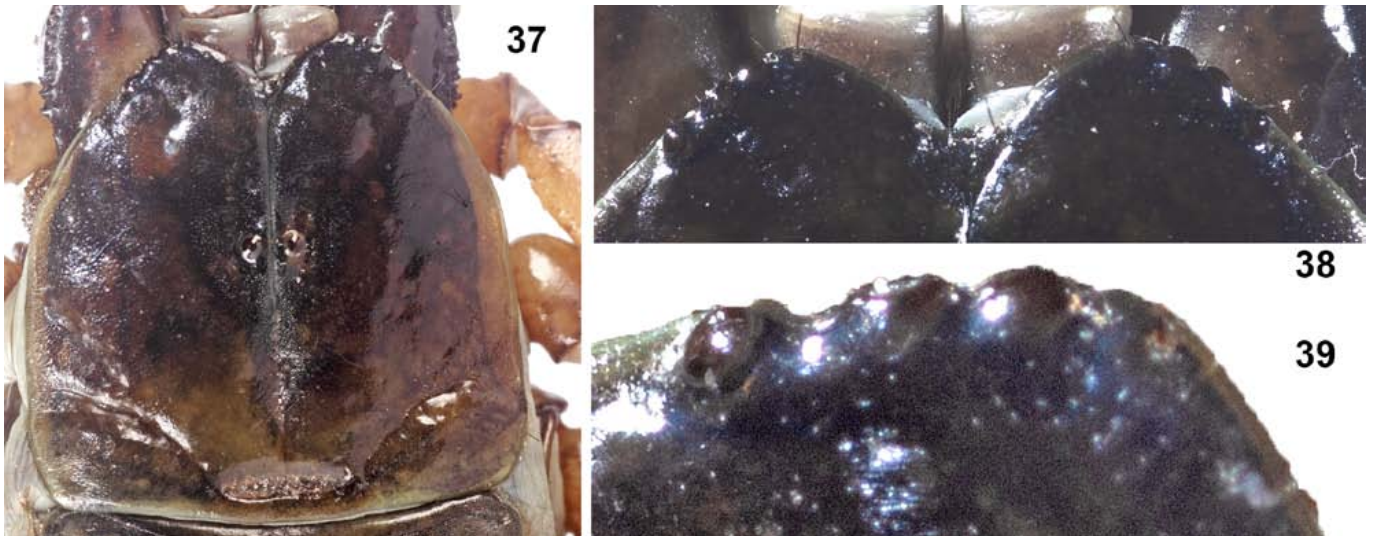
**Pedipalp** (Figs. 49–55). Pedipalps dorsoventrally flat. Femur with three (dorsal retrolateral, ventral retrolateral, median prolateral) and patella with four carinae (dorsal prolateral, ventral prolateral, dorsal retrolateral, ventral retrolateral). Intercarinal space with weak granulation. Prolateral surface of patella with large spur bearing two equal sized tubercles. Chela with five



**Figure 31–36.** *Chiromachetes ramdasswamii* sp. n., male, holotype, dorsal (31) and ventral (32) views, sternopectinal area (33), metasomal segment V and telson in lateral view (34), chelicera in dorsal view (35) and tarsi IV (36).

Dimensions (mm)		<i>C. ramdasswamii</i> sp. n.			
		♂ HT-BNHS SC182	♂ PT-INHER254	♂ PT-BNHS SC183	♀ PT-INHER246
Carapace	L / W	8.1 / 8.2	7.2 / 7.7	7.5 / 7.9	8.3 / 9.1
Mesosoma	L	27.8	22.3	25.3	27.9
Tergite VII	L / W	6.1 / 6.5	5.2 / 5.6	5.5 / 5.5	5.7 / 6.3
Metasoma and telson	L	26.4	21.5	24.4	23.8
Segment I	L / W / D	3.7 / 2.8 / 2.0	2.9 / 2.1 / 1.8	3.3 / 2.2 / 1.8	3.2 / 2.2 / 1.8
Segment II	L / W / D	4.0 / 1.8 / 2.1	3.2 / 1.8 / 1.8	3.8 / 1.8 / 2.0	3.6 / 1.8 / 2.1
Segment III	L / W / D	4.2 / 1.8 / 2.3	3.3 / 1.6 / 1.9	3.9 / 1.6 / 2.1	3.8 / 1.8 / 2.2
Segment IV	L / W / D	4.3 / 1.7 / 2.2	3.5 / 1.4 / 1.8	4.0 / 1.5 / 2.0	4.1 / 1.5 / 2.0
Segment V	L / W / D	5.1 / 1.4 / 2.0	4.1 / 1.2 / 1.7	4.4 / 1.4 / 1.8	4.5 / 1.0 / 1.8
Telson	L / W / D	5.1 / 1.1 / 2.1	4.5 / 1.4 / 1.8	5.0 / 1.4 / 2.1	4.6 / 1.4 / 2
Pedipalp	L	48.5	39.3	42.9	37.3
Femur	L / W	14.1 / 3.4 / 1.2	11.1 / 3.0 / 1.1	12.5 / 3.2 / 1.4	9.5 / 3.5 / 1.8
Patella	L / W	12.8 / 3.8 / 1.8	9.8 / 3.5 / 1.6	11.2 / 3.8 / 1.8	9.1 / 4.3 / 2.5
Chela	L	21.6	18.3	19.3	18.7
Manus	L / W / D	4.4 / 2.4	3.7 / 2.3	3.8 / 2.3	5.6 / 3.0
Movable finger	L	7,9	6,8	7,1	8.0
Pectine	L / W	3.9 / 2.4	3.7 / 2.1	3.7 / 2.2	3.6 / 2.3
Genital Operculum	L / W	1.5 / 2.7	1.4 / 2.5	1.6 / 2.8	1.5 / 2.9
<b>Total</b>	<b>L</b>	<b>62.3</b>	<b>51.0</b>	<b>57.2</b>	<b>60.0</b>
Pectinal teeth count		8 / 8	8 / 8	9 / 8	7 / 7
Dimensions (mm)		<i>C. ramdasswamii</i> sp. n.			<i>C. fergusonii</i>
		♀ PT-INHER249	♂ PT-BNHS SC184	♂ PT-BNHS SC185	♂ WGRC-9811
Carapace	L / W	8.4 / 9.8	8.5 / 9.6	9.1 / 9.4	6.7 / 7.8
Mesosoma	L	30.4	31.3	30.2	22.3
Tergite VII	L / W	6.3 / 8.1	7.0 / 7.8	6.32 / 7.3	4.5 / 5.6
Metasoma and telson	L	24.7	24.8	25.2	19.7
Segment I	L / W / D	3.5 / 2.5 / 2.1	3.5 / 2.4 / 2.3	3.6 / 2.4 / 2.1	2.5 / 1.9 / 1.8
Segment II	L / W / D	3.7 / 2.0 / 2.3	3.5 / 2.0 / 2.4	3.8 / 1.9 / 2.1	2.8 / 1.5 / 1.8
Segment III	L / W / D	3.7 / 1.8 / 2.4	4.0 / 2.0 / 2.2	3.8 / 1.9 / 2.2	2.9 / 1.5 / 1.9
Segment IV	L / W / D	4.1 / 1.7 / 2.1	4.1 / 1.7 / 2.2	4.2 / 1.6 / 2.1	3.2 / 1.3 / 1.6
Segment V	L / W / D	4.6 / 1.4 / 1.9	4.5 / 1.4 / 2.1	4.8 / 1.2 / 2.0	3.9 / 1.1 / 1.4
Telson	L / W / D	5.1 / 1.4 / 2	5.2 / 1.5 / 1.6	5.0 / 1.3 / 2.0	4.4 / 1.3 / 1.6
Pedipalp	L	39.2	39.4	39.8	31.6
Femur	L / W	10.2 / 3.7 / 1.8	10.7 / 3.8 / 1.8	10.1 / 3.9 / 1.6	8.4 / 3.6
Patella	L / W	10.1 / 4.3 / 2.6	9.7 / 4.2 / 2.3	9.9 / 4.4 / 2.6	7.5 / 3.7
Chela	L	18.9	19.0	19.8	15.7
Manus	L / W / D	5.8 / 3.2	5.8 / 2.9	5.9 / 3.1	8.7 / 4.6 / 2.5
Movable finger	L	8.0	8.3	8.6	7.6
Pectine	L / W	3.8 / 2.5	3.3 / 2.3	3.8 / 2.1	3.7 / 2.2
Genital Operculum	L / W	1.8 / 3.2	1.7 / 3.2	1.8 / 2.9	1.3 / 2.3
<b>Total</b>	<b>L</b>	<b>63.5</b>	<b>64.6</b>	<b>64.5</b>	<b>48.7</b>
Pectinal teeth count		7 / 7	6 / 7	7 / 7	11 / 10

**Table 2.** Morphometric data for *Chiromachetes ramdasswamii* sp. n. and *C. fergusonii* Abbreviations: length (L), width (W, in carapace it corresponds to median width), depth (D), holotype (HT), paratype (PT).



**Figures 37–39.** *Chiromachetes ramdasswamii* sp. n., male, holotype, carapace (37), anterior margin of carapace (38) and right lateral eyes in dorsal view (39).

carinae (dorsal prolateral, ventral prolateral, dorsal retrolateral, median retrolateral, ventral retrolateral). Intercarinal space smooth on dorsal and ventral surface and sparsely granular on prolateral and retrolateral surface. Dentate margins of both chela fingers composed of two rows of granules. Movable finger granular on retrolateral surface and smooth with weak granulation basally on prolateral surface. Trichobothrial pattern of 'type C' typical of the genus. Number of trichobothria: chela dorsal (4), chela ventral (4), chela prolateral (2), chela retrolateral (15), patella dorsal (2), patella ventral (3), patella prolateral (1), patella retrolateral (13), femur dorsal (1), femur prolateral (1) and femur retrolateral (1).

**Legs** (Figs. 31, 32, 36, 40, 41, 44, 45). Legs I–IV; femur carinated on anterior portion; Intercarinal space with granulation. Tarsomere I with four spines distally and tarsomere II with three spines distally and a few spinules proximally.

**Sternum, genital operculum and pectines** (Figs. 33, 46). Sternum broad, pentagonal and entirely smooth. Genital operculum with a pair of genital papillae. Posterior sclerite with slight depression on middle portion. Pectines with 8/8 pectinal teeth and 7/7 fulcra.

**Mesosoma** (Figs. 31–33, 40, 41, 44–46). All tergites smooth with median elevated portion. All sternites entirely smooth. Sternite VII granular on lateral portion and with symmetrical depressions on both halves posteriorly.

**Metasoma** (Figs. 31, 32, 34, 40, 41, 44, 45, 47). Metasomal segments I–IV smooth, finely punctate and with very weak obsolete carinae. Intercarinal space smooth. Ventrolateral carina on segment V strongly and densely serrated. Intercarinal space granular. Anal rim weakly tuberculated.

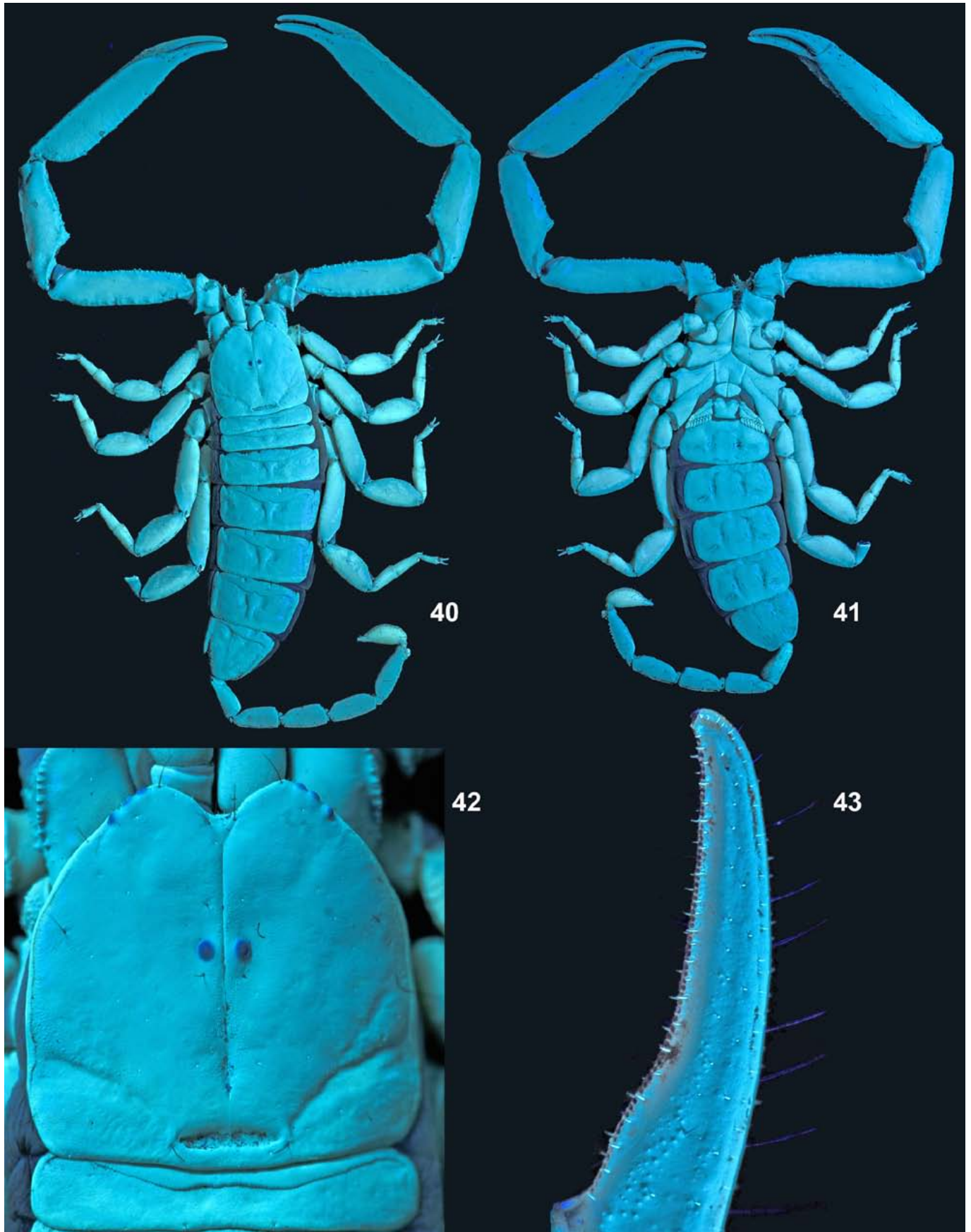
**Telson** (Figs. 34, 47). Bulbous, almost entirely smooth and hirsute on the ventral side. Aculeus short and strongly curved.

**Hemispermatothore** (♂ paratype, INHER 254, Figs. 56, 57). Lamelliform; Capsular region appears to be complex, bulbous, sclerotized and wider than long. Lamella stout and short. Single lamellar hook, blunt and pointed upwards, situated at the base of the lamella. Pedicel 0.74 mm long; trunk 1.84 mm long; capsule 1.29 mm long and 1.68 mm wide; lamella 4.22 mm long.

**SEXUAL DIMORPHISM.** Male genital operculum with pair of genital papillae. In females, genital operculum medially sutured. Pedipalp manus slender in males and stouter in females (Figs. 31–33, 44–46).

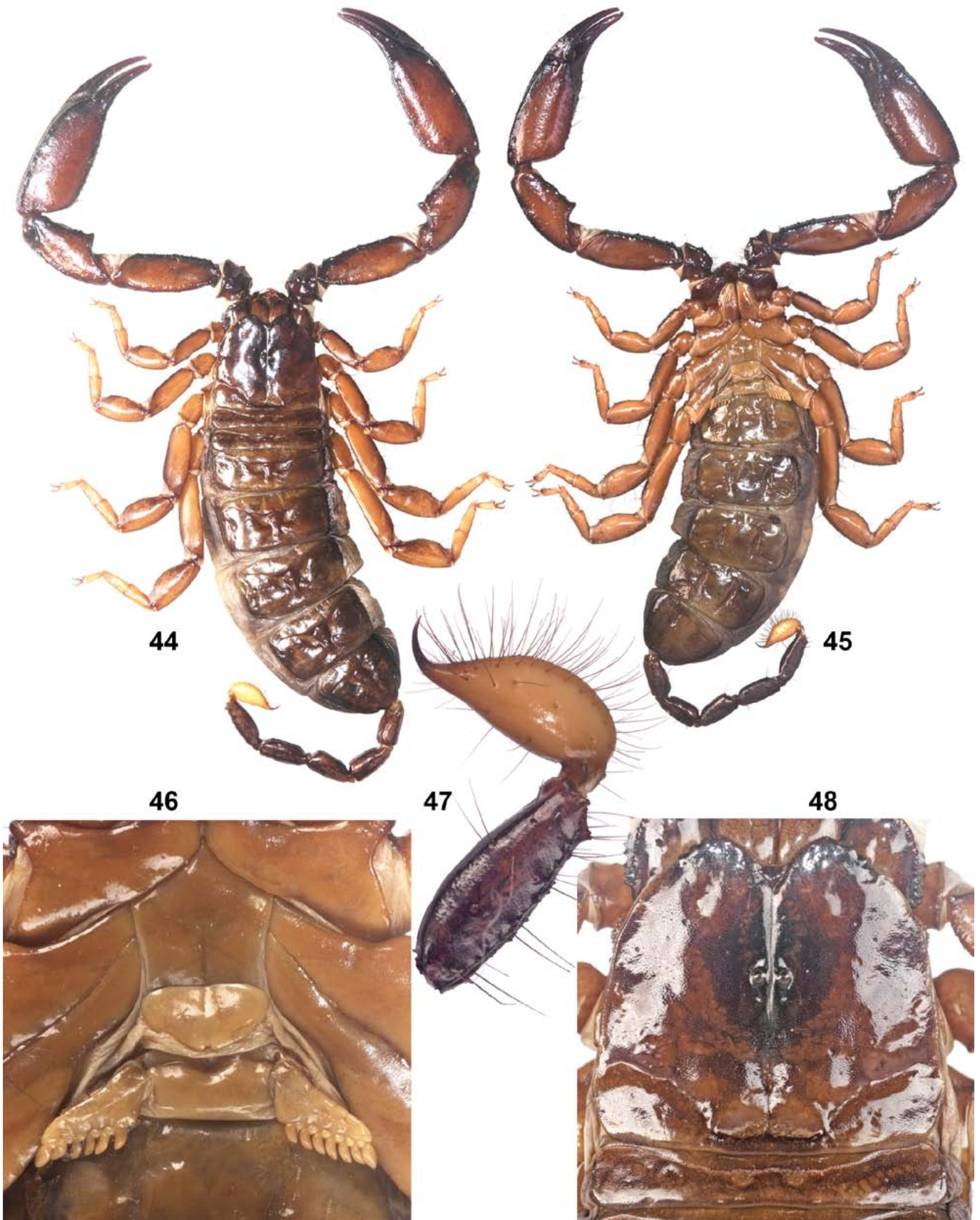
**AFFINITIES.** *Chiromachetes ramdasswamii* sp. n. differs from all species of *Chiromachetes* from northern Western Ghats by a raw genetic divergence of 7.9–9.4 % (Table 5). It is also distinguished from all its congeners based on the following set of morphological characters:

1. Pectinal teeth number in males 8–9, females 6–7 as opposed to males 5–6, females 3–4 in *C. tirupati*, males 9–11, females 7–8 in *C. fergusonii* (Tables 1–3).
2. Chela length to manus width ratio in males 4.9–5.0, females 3.3–3.4 as opposed to males 3.6 in *C. tirupati*, males 3.4 and females 3.6 in *C. fergusonii*, males 4.3–4.4, females 3.5 in *C. parakrami* sp. n. (Table 4).
3. Pedipalp femur length to width ratio in males 3.7–4.1, females 2.6–2.9 as opposed to males 2.5 in *C. tirupati*, males 2.3, females 2.6 in *C. fergusonii*, males 3.2–3.5, females 3.0 in *C. parakrami* sp. n. (Table 4).
4. Chela length to movable finger length in males 2.7, as opposed to 2.1 in *C. fergusonii*, 2.4–2.6 in *C. parakrami* sp. n. (Table 4).
5. Carapace posterior median furrow triangular with a horizontal and elliptical posterior depression at the base as opposed to triangular with a shallow triangular posterior depression in *C. parakrami* sp. n., triangular with a deep triangular depression in *C. sahyadriensis* (Figs. 12, 42, 62), triangular with a deep, narrow and horizontal posterior depression in *C. fergusonii* (Figs. 72–73).
6. Ventrolateral carina of metasoma segment V strongly and densely serrated as opposed to strongly and sparsely serrated in *C. sahyadriensis*, strongly and densely serrated only on the posterior portion and weak on the anterior portion in *C. parakrami* sp. n. (Figs. 4, 17, 34, 47, 63).
7. Hemispermatothore with position of lamellar hook basal and shape of distal lamella stout and short as opposed to position of lamellar hook distal and shape of distal lamella slender and long in *C. parakrami* sp. n. (Figs. 26, 27, 56, 57)..

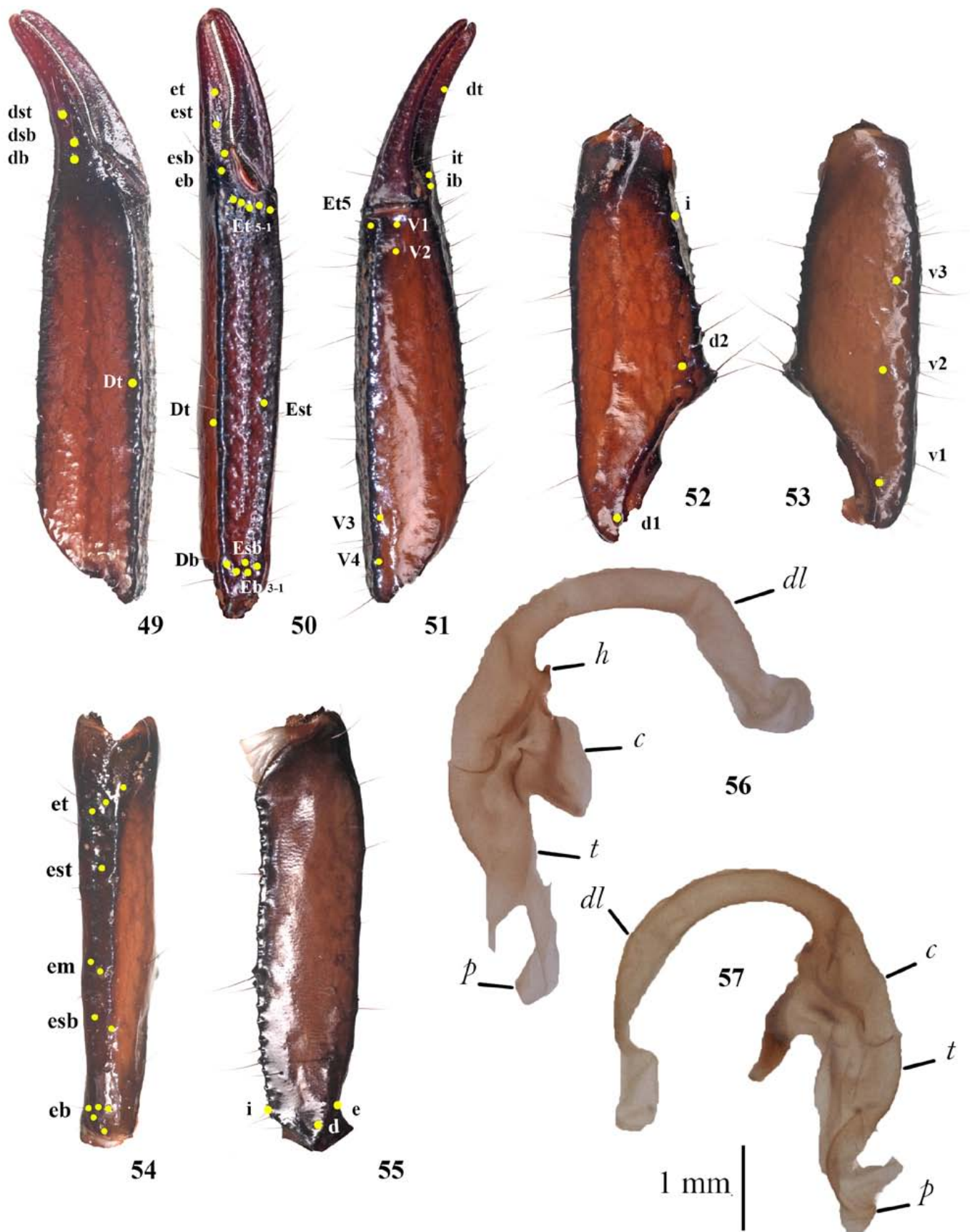


Figures 40–43. *Chiromachetes ramdasswamii* sp. n., male, holotype in dorsal (40) and ventral (41) views, carapace (42) and dentition on movable finger of chela (43) under UV fluorescence.

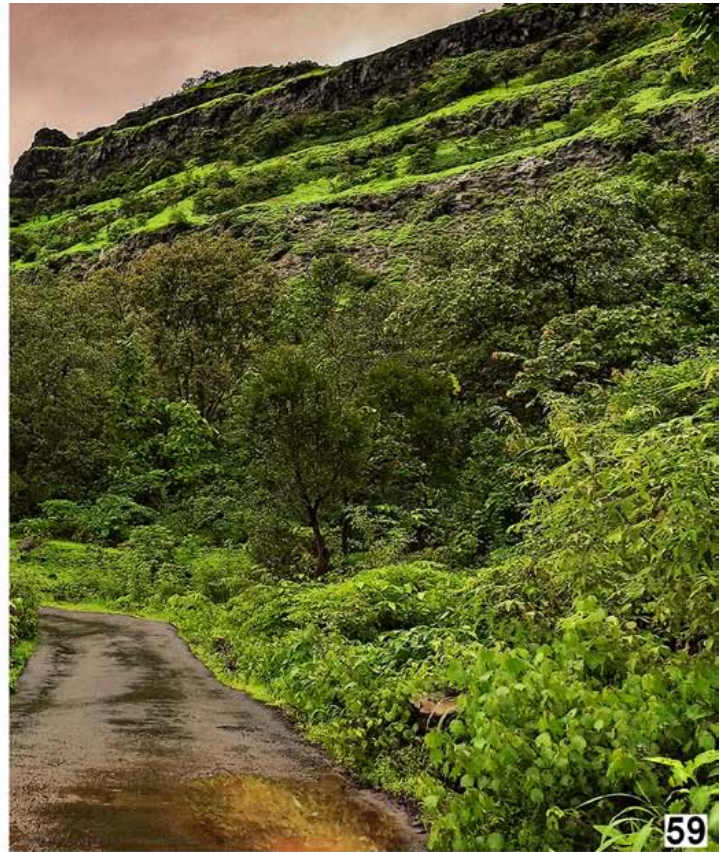




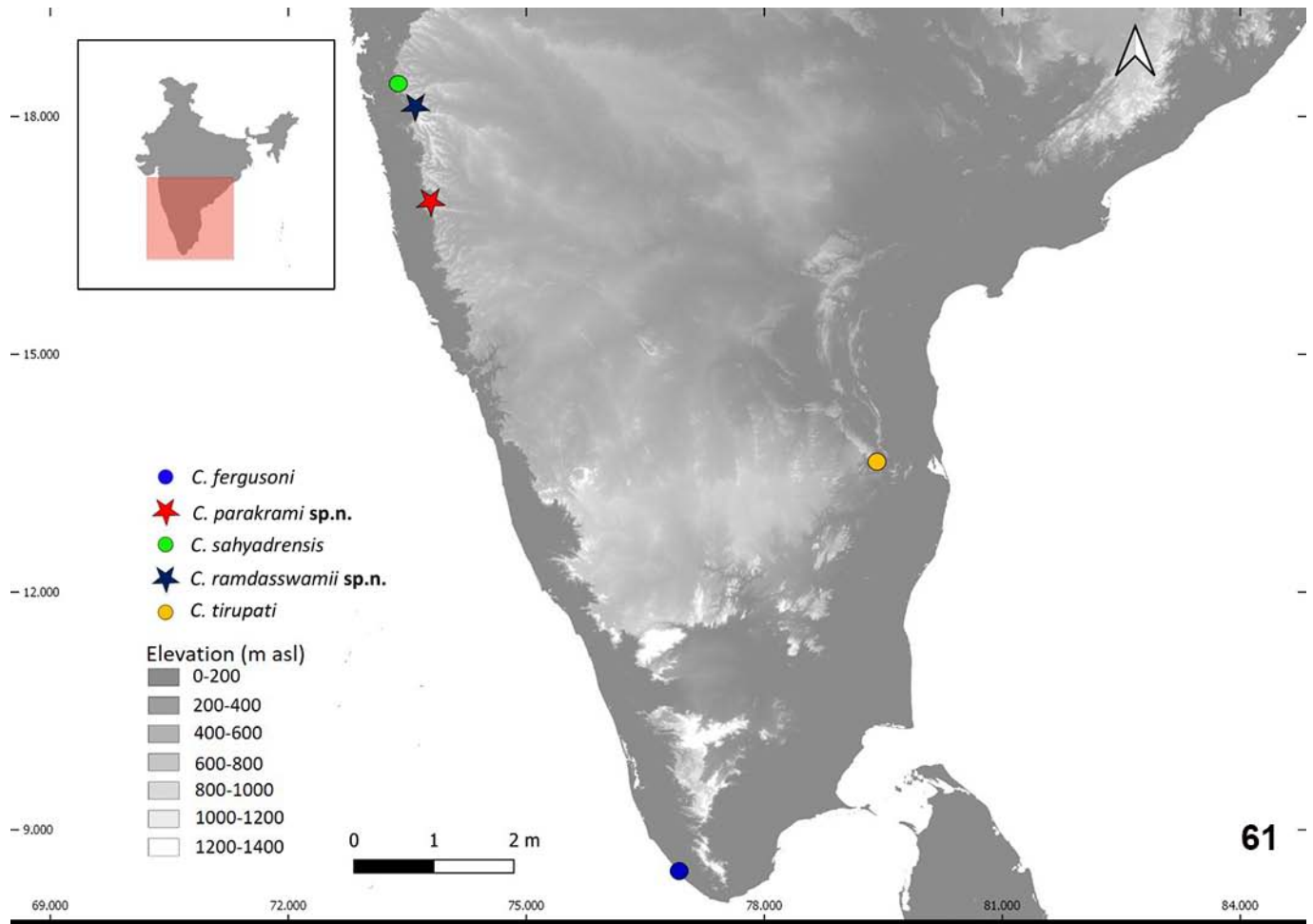
Figures 44–48. *Chiromachetes ramdasswamii* sp. n., female, paratype, BNHS SC 184, in dorsal (44) ventral (45) views, sternopectinal area (46), metasomal segment V and telson in lateral view (47) and carapace (48).



**Figures 49–57:** *Chiromachetes ramdasswamii* sp. n. **Figures 49–55.** Male, holotype, pedipalp chela dorsal (49), external (50) and ventral (51) views, patella dorsal (52), ventral (53) and external (54) views and femur dorsal (55) view. Trichpobothrial pattern indicated by yellow circles. **Figures 56–57.** Male, paratype, INHER 254, right hemispermatophore in internal (56) and external (57) views. Abbreviations: *p*, pedicel; *t*, trunk; *c*, capsule; *h*, hook; *dl*, distal lamina.



**Figures 58–60.** Type locality of *Chiromachetes ramdasswamii* sp. n., view of riparian forest with waterfall at the type locality (58), view of Kawla fort through which the Varandha Ghat road is carved (59) and basaltic boulder adjacent to the Varandha Ghat road from where the type series is collected (60).



**Figures: 61–63.** **Figure 61.** Distribution of *Chiromachetes* in India. **Figures 62–63.** *Chiromachetes sahyadrensis*, male, INHER 172, carapace under UV light (62) and metasomal segment V and telson in lateral view (63).

Dimensions (mm)		<i>Chiromachetes sahyadriensis</i>				
		♂ INHER 74	♂ INHER 172	♂ INHER 273	♀ INHER 69	♀ INHER 272
Carapace	L / W	8.5 / 8.9	8.8 / 9.2	7.1 / 7.6	8.4 / 8.9	8.5 / 8.6
Mesosoma	L	26.9	22.8	21.0	28.7	28.8
Tergite VII	L / W	5.4 / 6.1	5.6 / 6.7	4.6 / 5.3	5.6 / 6.7	5.9 / 6.9
Metasoma and telson	L	26.5	29.4	24.8	26.6	26.4
Segment I	L / W / D	3.7 / 2.1 / 2.1	4.0 / 2.5 / 2.3	3.0 / 2.0 / 1.8	3.5 / 2.4 / 2.1	3.3 / 2.3 / 2.0
Segment II	L / W / D	4.0 / 1.8 / 2.2	4.3 / 2.0 / 2.4	3.2 / 1.2 / 1.9	3.7 / 1.7 / 2.1	4.0 / 1.8 / 2.2
Segment III	L / W / D	4.1 / 1.7 / 2.3	4.5 / 1.9 / 2.6	4.2 / 1.2 / 1.9	4.4 / 1.7 / 2.4	4.3 / 1.4 / 2.4
Segment IV	L / W / D	4.4 / 1.5 / 2.1	5.1 / 1.7 / 2.4	4.6 / 1.5 / 1.9	4.8 / 1.4 / 2.1	4.6 / 1.1 / 2.0
Segment V	L / W / D	4.7 / 1.3 / 2.0	5.7 / 1.6 / 2.1	4.9 / 1.2 / 1.8	5.0 / 1.2 / 1.9	4.9 / 0.9 / 1.7
Telson	L / W / D	5.6 / 1.4 / 2.1	5.8 / 1.8 / 2.3	4.9 / 1.3 / 1.9	5.2 / 1.4 / 1.9	5.3 / 1.2 / 1.9
Pedipalp	L	49.1	51.5	37.7	37.8	37.2
Femur	L / W	14.7 / 3.7 / 1.3	14.8 / 3.9 / 1.9	10.8 / 3.2 / 1.5	10.6 / 3.8 / 1.6	10.2 / 3.6 / 1.5
Patella	L / W	12.7 / 4.4 / 2.1	13.2 / 4.7 / 1.8	9.7 / 3.7 / 2.0	9.2 / 4.2 / 2.5	8.9 / 4.2 / 2.6
Chela	L	22.1	23.5	17.2	18.6	18.1
Manus	L / W / D	4.5 / 2.6	4.8 / 2.9	4.0 / 2.2	5.4 / 2.9	5.3 / 2.9
Movable finger	L	7.7	8.3	6.6	8.0	7.5
Pectine	L / W	3.6 / 2.4	4.1 / 2.3	3.2 / 1.6	3.7 / 2.1	3.6 / 2.0
Genital Operculum	L / W	1.5 / 2.5	1.8 / 2.5	1.4 / 2.5	2.0 / 2.9	1.6 / 3.1
<b>Total</b>	<b>L</b>	<b>61.9</b>	<b>61.0</b>	<b>52.9</b>	<b>63.7</b>	<b>63.7</b>
Pectinal teeth count		8 / 8	8 / 8	8 / 8	7 / 7	7 / 7

**Table 3.** Morphometric data for *Chiromachetes sahyadriensis*. Abbreviations: length (L), width (W, in carapace it corresponds to median width), depth (D).

**DISTRIBUTION, HABITAT, AND ECOLOGY.** Presently, *C. ramdasswamii* sp. n. is only known from its type locality, Varandha Ghat, Pune District, Maharashtra, India. The specimens were observed in the rock crevices all along the western escarpment. The type locality is surrounded by a tall mountain range with withered boulders on the slopes on one side and deep valley on the other side of the road. Individuals were also seen in crevices of the rock cliffs of the Kawla Fort, through which the Varandha Ghat road is carved. This species is also very commonly seen residing in the gaps of constructed rock walls along the Varandha Ghat road. The species is particularly not seen on the eastern slope of the crest line. Individuals were found to be active at night sitting at the openings of very narrow rock crevices. Females were more commonly observed at the type locality in large numbers. Males were comparatively less in numbers and thus difficult to find. The ecology and morphology of the new species is congruent with the lithophilic scorpions (Figs. 58–60).

***Chiromachetes fergusonii* Pocock, 1899**

(Figures 64–81, Tables 2, 4)

<http://zoobank.org/urn:lsid:zoobank.org:act:09E131DF-9E83-4C7B-8B50-8B3688050A25>

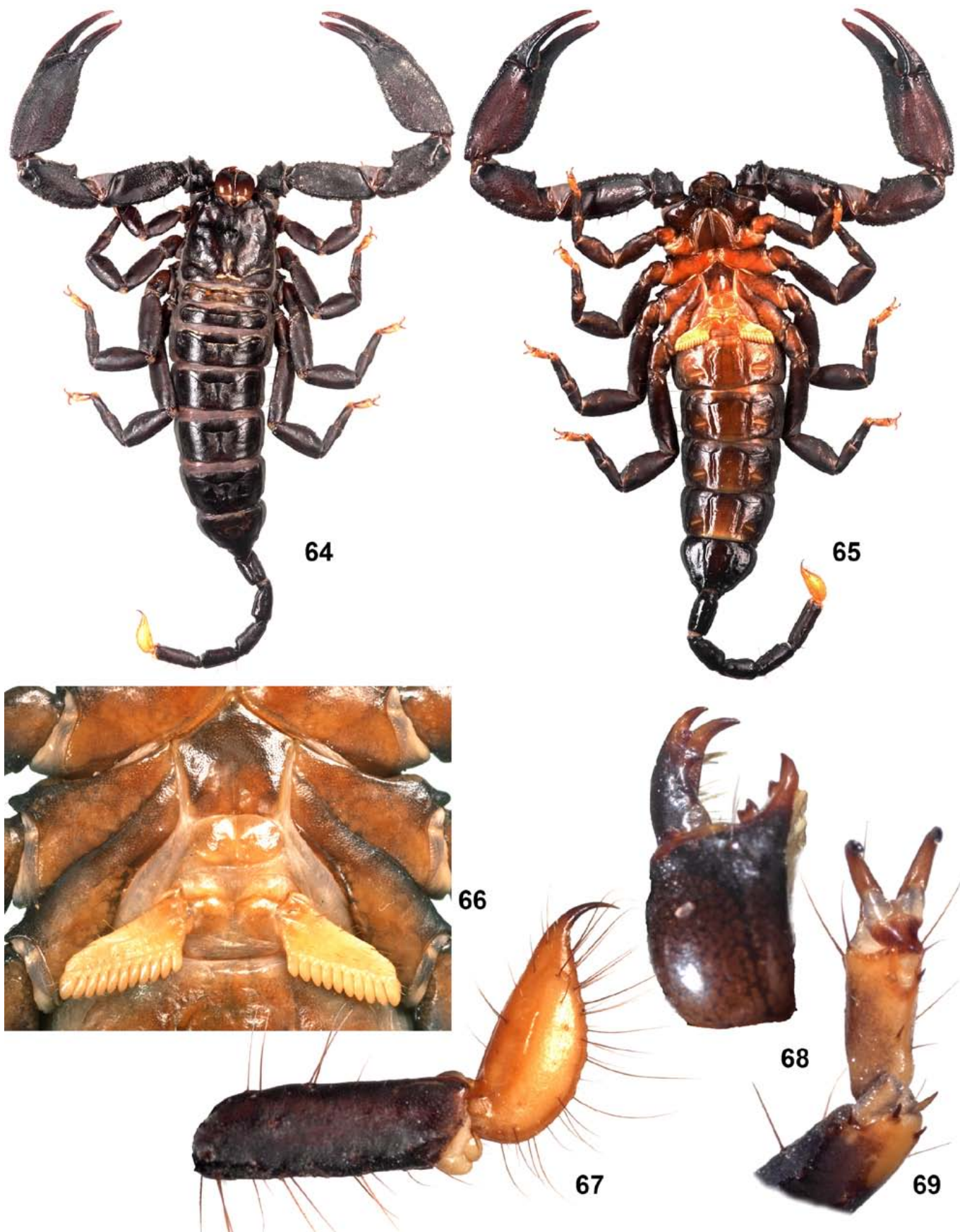
**TYPE LOCALITY AND TYPE REPOSITORY:** India, Kerala State, Trivandram (now Thiruvananthapuram); BMNH.

**MATERIAL EXAMINED.** India, Kerala State, Thiruvananthapuram District, Peppara Wildlife Sanctuary, 8°37'24"N 77°08'08"E, 120 m a. s. l., 1♂, WGRC-9811 (formerly in ZSI, Table 2), 12 November 2016, leg. Bindu.

**DESCRIPTION** (based on ♂ topotype; measurements in Table 2).

**Coloration** (in preserved condition) (Figs. 64, 65). Overall body color dark brownish to blackish with glossy surface. Legs blackish brown, yellow on tarsomere II. Telson yellow on vesicle and black on aculeus. Ventral portion of body brownish black, except sternopectinal area yellowish brown. Carapace and fingers of manus blackish. Pedipalps black on dorsal surface and dark brownish on ventral surface. Chelicera basal segment blackish brown with black reticulation. Fingers of chelicera blackish brown.

**Carapace** (Figs. 72–73). Carapace wider than long. Entire surface of carapace almost smooth, finely punctate throughout with fine and sparse granulation present all along the longitudinal median furrow. Posterior lateral furrow distinct with very fine granulation. Posterior median furrow triangular with a deep, narrow and horizontal posterior depression. Anterior margin of carapace with deep U-shaped emargination in the middle. Lateral ocular tubercle with three pairs of lateral eyes. Carapace without carinae. Pair of median eyes situated on carapace in the proportions 1:2.1 (distance of median eyes to anterior margin: distance of median eyes to posterior margin). Margins entirely smooth.



**Figures 64–69.** *Chiromachetes fergusoni*, male topotype, dorsal (64) and ventral (65) views, sternoplectinal area (66), metasoma V and telson lateral view (67), chelicera dorsal (68) and tarsi IV (69).

Ratios of males	<i>C. parakrami</i> sp. n. 4♂	<i>C. tirupati</i> 1♂	<i>C. fergusonii</i> 1♂	<i>C. sahyadriensis</i> 3♂	<i>C. ramdasswamii</i> sp. n. 3♂
Pedipalp chela (L/W)	4.3–4.4	3.6	3.4	3.9–4.9	4.9–5.0
Pedipalp femur (L/W)	3.2–3.5	2.5	2.3	3.3–3.8	3.7–4.1
Chela / Movable finger (L)	2.4–2.6	–	2.1	2.6–2.9	2.7
Ratios of females	<i>C. parakrami</i> sp. n. 1♀	<i>C. tirupati</i> ♀	<i>C. fergusonii</i> 1♀	<i>C. sahyadriensis</i> 2♀	<i>C. ramdasswamii</i> sp. n. 4♀
Pedipalp chela (L/W)	3.5	–	3.6	3.4–3.5	3.3–3.4
Pedipalp femur (L/W)	3.0	–	2.6	2.7–2.8	2.6–2.9
Telson (L/D)	2.8	–	–	2.7	2.3–2.5

**Table 4.** Comparison among *Chiromachetes* species based upon selected morphometric ratios of adults. Abbreviations: length (L), width (W) depth (D).

Species	PG	CSW	CP	CSH	IL
<i>Paravaejovis gravicaudus</i> (PG)	(0–2.6)				
<i>Chiromachetes ramdasswamii</i> sp. n. (CSW)	12.6–13.7	(0)			
<i>Chiromachetes parakrami</i> sp. n. (CP)	14.9	7.9	(0)		
<i>Chiromachetes sahyadriensis</i> (CSH)	14.6–14.9	9.4	8.3–8.4	(0)	
<i>Iomachus laeviceps</i> (IL)	18.5–19.0	14.9	14.9	16.9	(0)

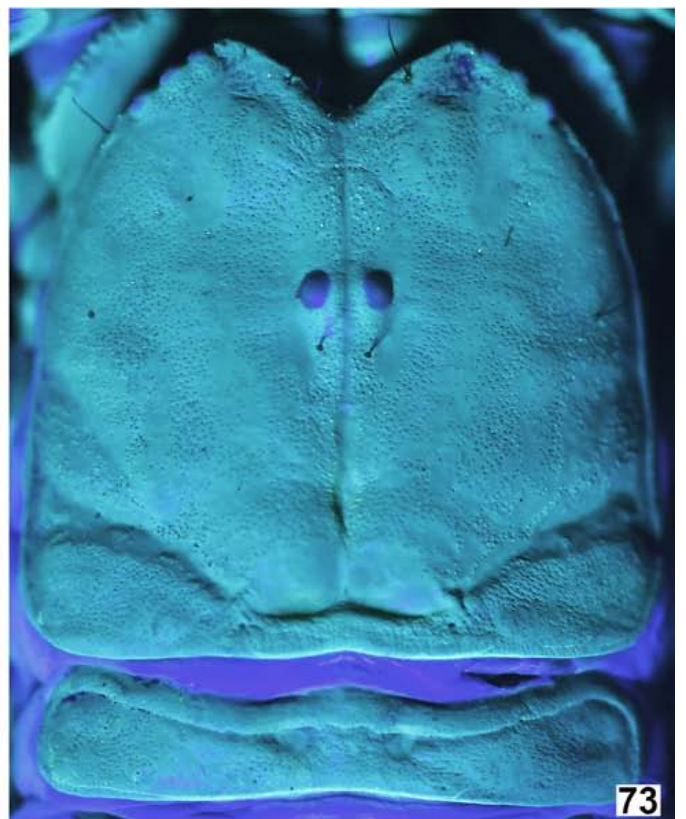
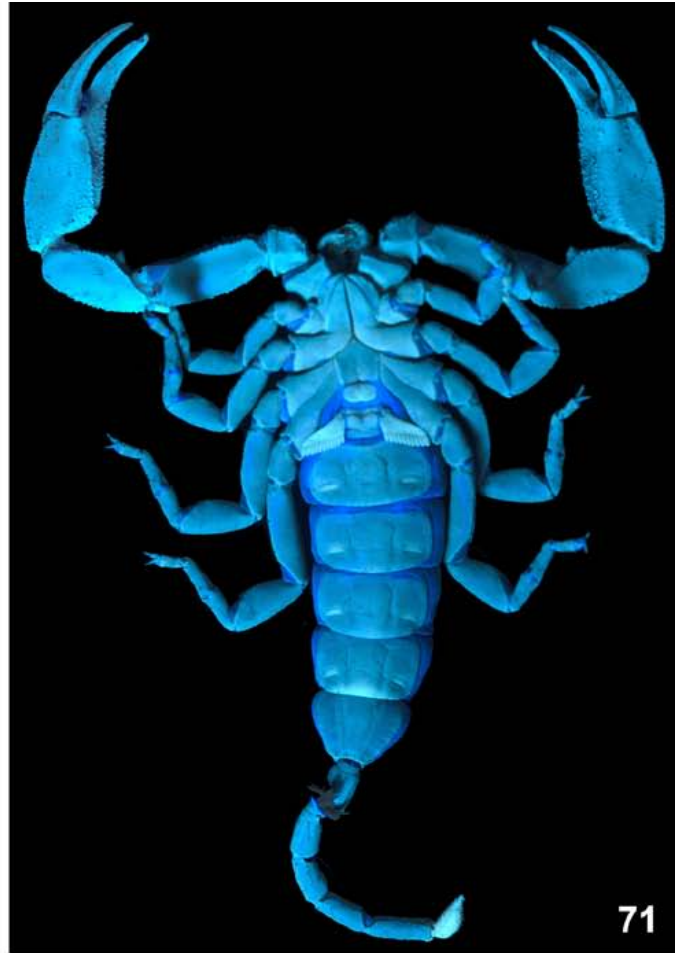
**Table 5.** Pairwise uncorrected raw distances (%) expressed as minimum–maximum based on COI gene sequence for *Chiromachetes* species from northern Western Ghats, India. Values in brackets are intra-clade distances.

Primers- Cytochrome c Oxydase I	5' –3' Primer Sequence	Source
HCO2198	TAAACTTCAGGGTGACCAAAAAATCA	Folmer et al. (1994)
HCOoutout	GTAAATATATGRTGDGCTC	Folmer et al. (1994)
LCO1490	GGTCAACAAATCATAAAGATATTGG	Folmer et al. (1994)
Nancy	CCCGGTAAAATTTAAAATATAAACTTC	Simon et al. (1994)
Chelicera F1	TACTCTACTAATCATAAAGACATTGG	Barrett & Hebert (2005)
Chelicera R1	CCTCCTCCTGAAGGGTCAAAAAATGA	Barrett & Hebert (2005)
Chelicera R2	GGATGGCCAAAAAATCAAATAAATG	Barrett & Hebert (2005)

**Table 6:** Primers used for PCR amplification and sequencing of (COI) mitochondrial gene.

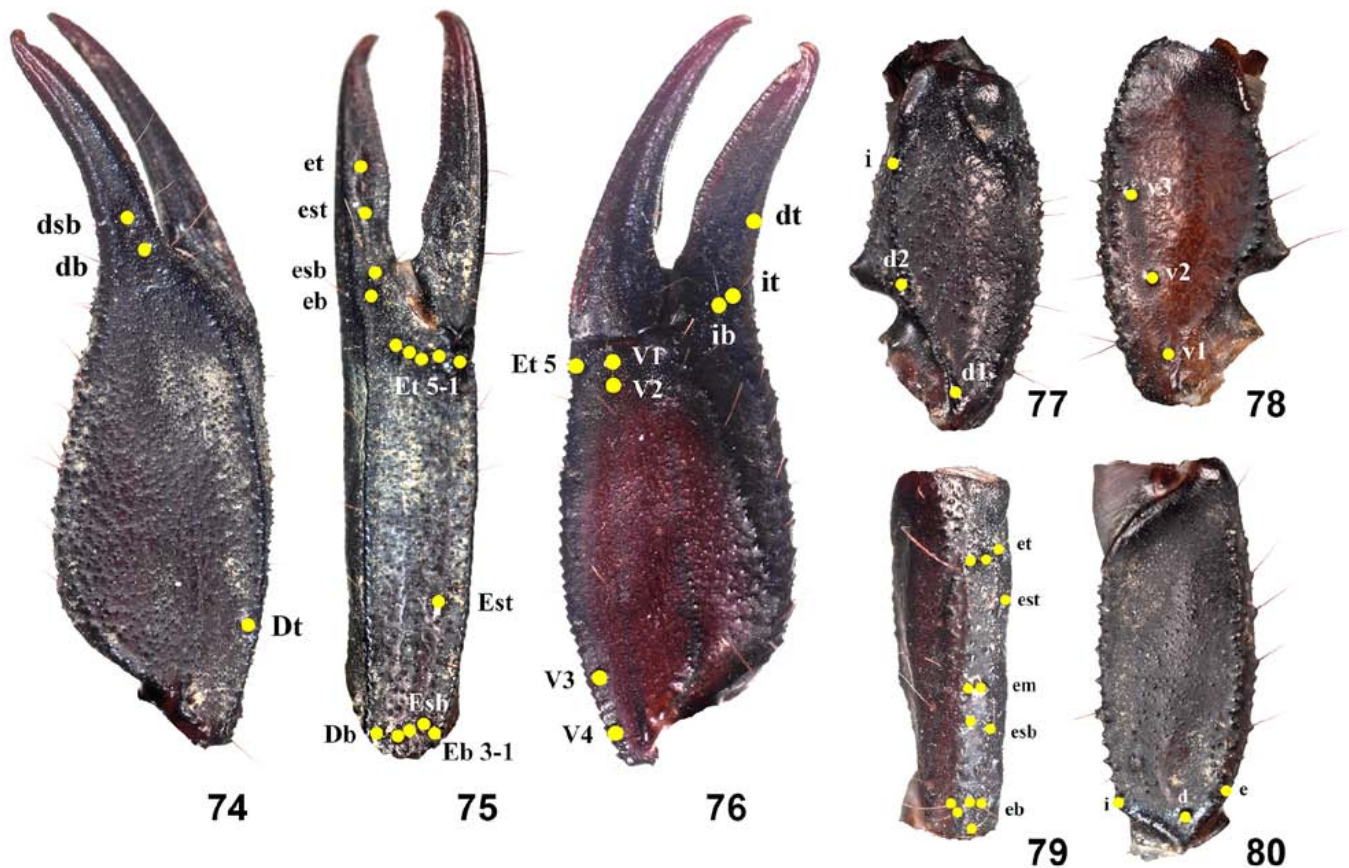
Species	Voucher	GeneBank Accession Number
<i>Chiromachetes parakrami</i> sp. n.	INHER198	MT876671
<i>Chiromachetes parakrami</i> sp. n.	*INHER199	MT876672
<i>Chiromachetes ramdasswamii</i> sp. n.	BNHS SC 184	MT876669
<i>Chiromachetes ramdasswamii</i> sp. n.	*INHER250	MT876670
<i>Chiromachetes sahyadriensis</i>	WILD-17-ARA-4005	MF422297
<i>Chiromachetes sahyadriensis</i>	BNHS SC 152	MF422298
<i>Iomachus laeviceps</i>	INHER169	MT876673
<i>Paravaejovis gravicaudus</i>	LP8783	KM274825
<i>Paravaejovis gravicaudus</i>	LP3163	KM274824

**Table 7:** Voucher numbers and GenBank accession numbers for the sequence data used for the phylogenetic analysis (\* Indicate non-type specimens).



**Figures 70–73.** *Chiromachetes fergusonii*, male topotype, dorsal (70) and ventral (71) views under UV lights, carapace under white (72) and UV (73) light.





**Figures 74–80.** *Chiromachetes fergusonii*, male topotype, pedipalp chela dorsal (74), external (75) and ventral (76) views, patella dorsal (77), ventral (78) and external (79) views and femur dorsal (80) view. Trichobothrial pattern indicated by yellow circles.

**Chelicerae** (Fig. 68). Fixed finger of chelicera with three large triangular denticles on inner margin. Ventral tooth of movable finger lacks denticulation. Dorsal tooth of movable finger with 3 denticles on inner margin.

**Pedipalp** (Figs. 74–80). Pedipalps dorsoventrally flat. Femur and patella with four carinae (dorsal prolateral, ventral prolateral, dorsal retrolateral, ventral retrolateral). Intercarinal space with coarse granulation. Prolateral surface of patella with large spur bearing two equal sized tubercles. Chela with five carinae (dorsal prolateral, ventral prolateral, dorsal retrolateral, median retrolateral, ventral retrolateral). Intercarinal space coarsely granular. Dentate margins of both chela fingers composed of two rows of granules. Movable finger granular on both surfaces. Trichobothrial pattern of 'type C' typical of the genus. Number of trichobothria: chela dorsal (3), chela ventral (4), chela prolateral (2), chela retrolateral (15), patella dorsal (2), patella ventral (3), patella prolateral (1), patella retrolateral (13), femur dorsal (1), femur prolateral (1) and femur retrolateral (1).

**Legs** (Figs. 64, 65, 69, 71, 72). Legs I–IV; femur carinated on anterior portion; intercarinal space with fine granulation; tarsomere I with four spines distally and tarsomere II with three spines distally and one or two spinules at the proximal end.

**Sternum, genital operculum and pectines** (Fig. 66). Sternum broad, pentagonal and entirely smooth. Genital operculum

with a pair of genital papillae. Posterior sclerite with slight depression on middle portion. Pectines with 10/11 pectinal teeth and 9/10 fulcra.

**Mesosoma** (Figs. 64, 65, 71, 72). All tergites smooth with median elevated portion. All sternites entirely smooth except sternite VII entirely punctate, granular only on lateral portion and with symmetrical depressions on both halves posteriorly.

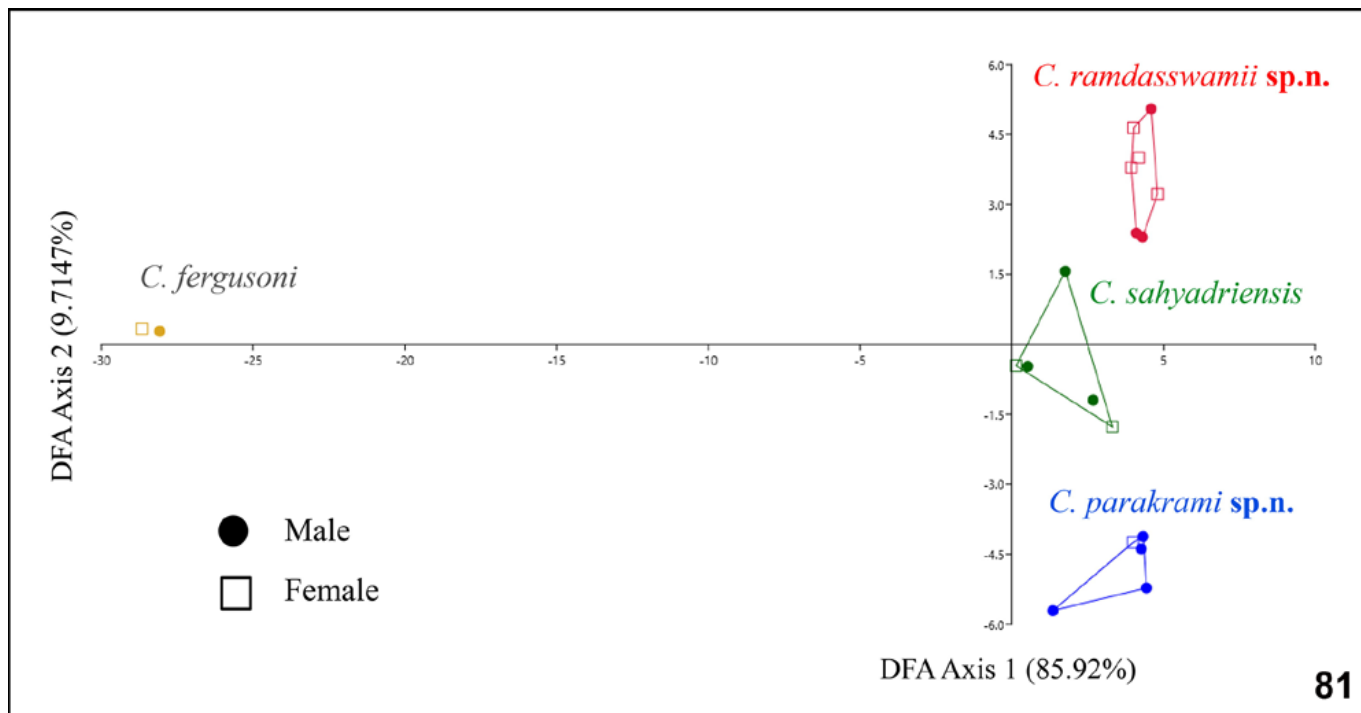
**Metasoma** (Figs. 64, 65, 70–71). Metasomal segments I–IV smooth, finely punctate and with very weak carinae. Intercarinal space smooth and finely punctate. Ventrolateral carina on segment V very weakly serrated mostly on the middle portion. Intercarinal space very weakly granular. Anal rim weakly tuberculated.

**Telson** (Fig. 67). Pyriform, almost entirely smooth and hirsute on the ventral side. Aculeus short and curved.

**DISTRIBUTION.** *C. fergusonii* is known only from the type locality, Kerala State, Trivandram (now Thiruvananthapuram), India.

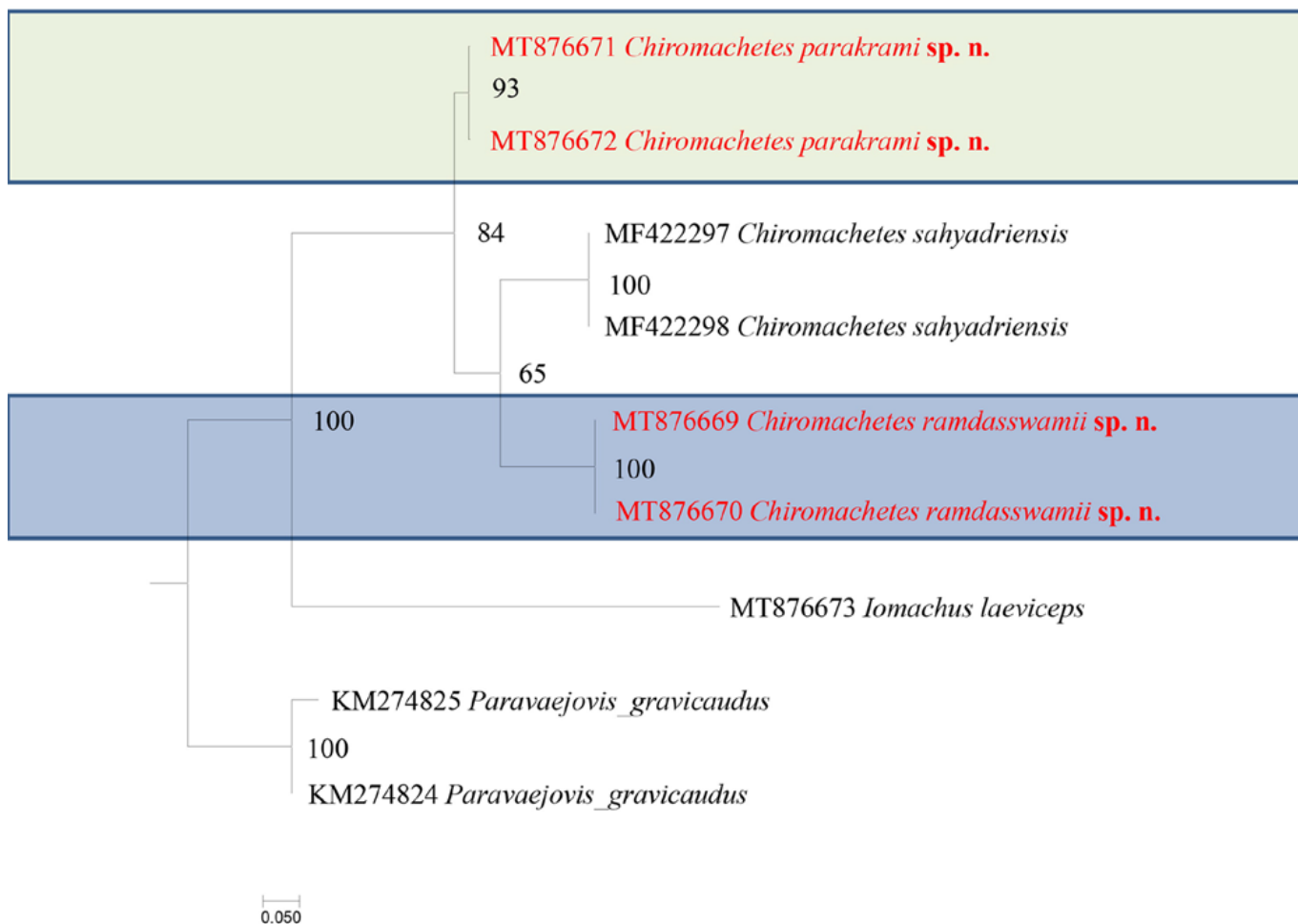
### Statistical analysis

Size corrected morphometric data was not significantly different from multivariate normal (Doornik & Hansen omnibus,  $E_p = 23.43$ ,  $p = 0.4943$ ). MANOVA suggested that all species formed significantly distinct clusters (Pillai's trace = 2.784,  $F_{18, 36} =$


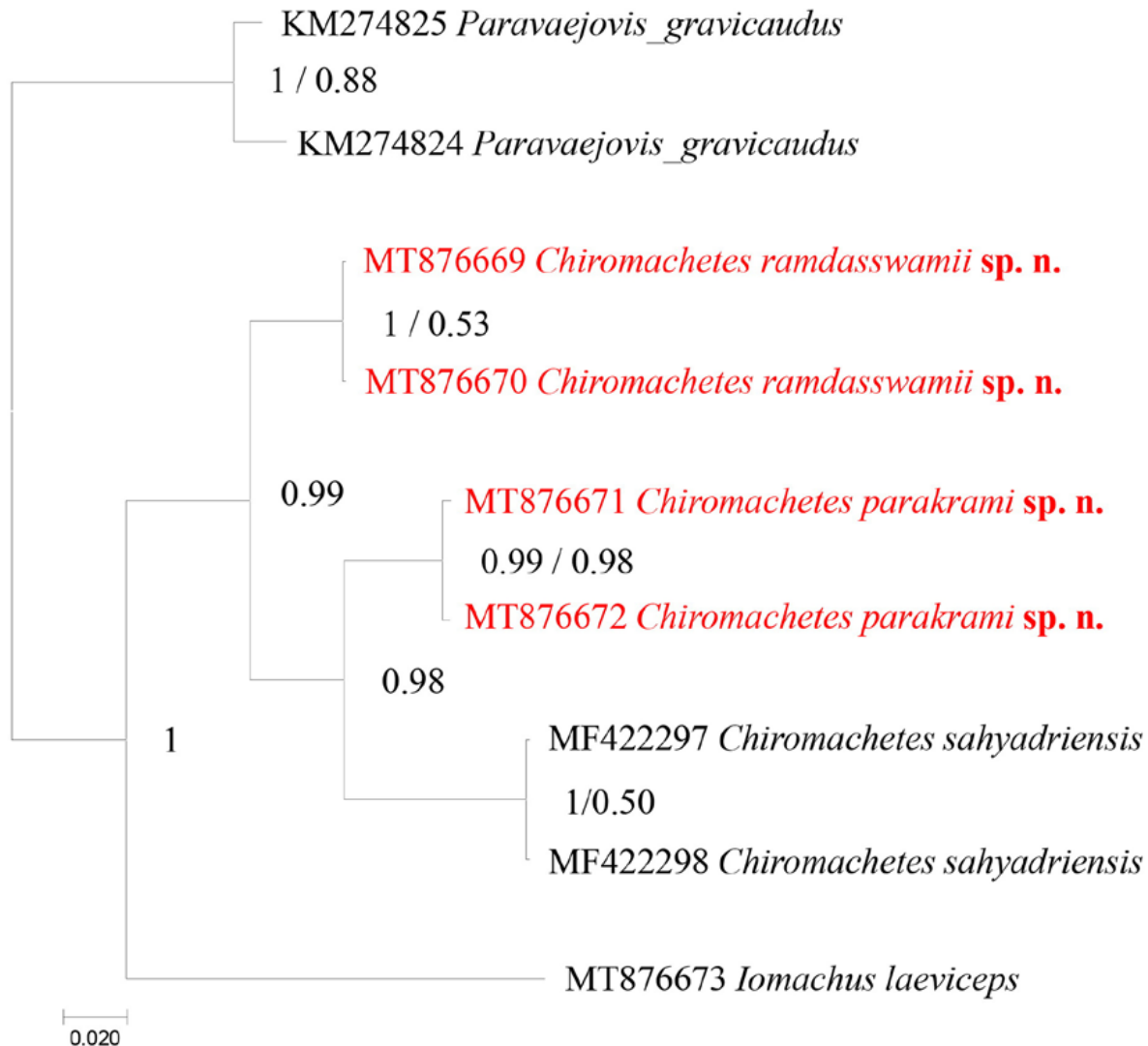


81

82



**Figures 81–82.** **Figure 81.** Discriminant function analyses projection on first two factor planes explaining 96.85% of variation among the five species. Abbreviations: Circle cells (males), Square cells (females). **Figure 82.** Maximum Likelihood phylogenetic tree (ML) for *Chiromachetes* from northern Western Ghats of India. Values along the nodes are bootstraps for 1000 iterations.

Species Delimitation -  bPTP (*cox1*)

**Figure 83.** Bayesian phylogenetic tree for *Chiromachetes* from northern Western Ghats of India. Values along the nodes are Bayesian posterior probabilities for Bayesian Inference and Bayesian Poisson Tree Process (bPTP), respectively.

6.451,  $p < 0.0001$ ). The DFA resulted in 100% individuals being classified into their respective species. The four discriminant functions with eigenvalues greater than 1.0 explained 100% of variation among these species and all species formed distinct clusters on the factor plane using the first two DFA axes (Fig 81). DFA data available with the authors.

### Molecular analysis

Maximum Likelihood (ML) and Bayesian analysis (BI) generated trees with different topologies. In the BI analysis, the species *C. parakrami* sp. n. was recovered as a sister clade to *C. sahyadriensis* (posterior probability 1) while *C. ramdasswamii* sp. n. was a sister clade to *C. parakrami* sp.

n. and *C. sahyadriensis* (posterior probability 0.99). On the other hand, in the ML analysis, *C. ramdasswamii* sp. n. was recovered as a sister clade to *C. sahyadriensis* (bootstrap values 65) and *C. parakrami* sp. n. formed a sister clade to *C. ramdasswamii* sp. n. and *C. sahyadriensis* (bootstrap values 84) (Figs. 82, 83).

*C. parakrami* sp. n. differs from *C. sahyadriensis* by a raw genetic distance of 8.4–9.4%, and from *C. ramdasswamii* sp. n. by 7.9%. *C. ramdasswamii* sp. n. differs from *C. sahyadriensis* by a raw genetic distance of 9.4% (Table 5). Bayesian Poisson Tree Process (bPTP) result supported the distinctness of the two species *C. parakrami* sp. n. and *C. ramdasswamii* sp. n. (Posterior probabilities 0.98 and 0.53 respectively) (Table 5, Fig. 83).

## Discussion

The species in the genus *Chiromachetes* have been poorly studied in India. The descriptions of previously known *Chiromachetes fergusoni* and *C. tirupati* are both based on single specimens, the former based on a female holotype and the latter, on a male holotype. This study is the first effort to use integrated taxonomy for the description of new species in this genus highlighting the endemic and cryptic diversity within the northern Western Ghats. It further establishes the need for dedicated surveys, which may lead to the discovery of more undescribed species of Hormuridae in India.

The species from northern Western Ghats are known only from their respective type localities, which are the Ghats sections on the roadside boulders, and any attempt of road widening poses a direct threat to the survival of these species.

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