RECORDS OF THE WESTERN AUSTRALIAN MUSEUM 36 013–032 (2021) DOI: 10.18195/issn.0312-3162.36.2021.013-032

Are these the world's most colourful silverfish? Possible mutillid mimics from Western Australia (Zygentoma: Lepismatidae)

Graeme B. Smith[1*] and Andrew Mitchell[1]

[1] Australian Museum, 1 William St, Sydney, New South Wales 2010, Australia.

[*] Corresponding author: le_gbsmith@optusnet.com.au

ABSTRACT – Citizen scientists in Western Australia photographed silverfish with very striking colour patterns, resembling velvet ants. When collected and placed into alcohol these colour patterns disappear, possibly accounting for the previous lack of observations of such colours in Zygentoma. The specimens were found to belong to the genus *Hemitelsella* Smith. Two new species are described, *H. hortorum* sp. nov. and *H. mutilloides* sp. nov., and molecular data (28S and COI) presented for these as well as *H. transpectinata* (Smith) from Barrow Island and *H. clarksonorum* Smith from Tasmania.

KEYWORDS: Thysanura, taxonomy, new species, Batesian mimicry, Mutillidae

urn:lsid:zoobank.org:pub:7D7C568C-5382-430B-BB84-071F487012B4

INTRODUCTION

Even though more species of silverfish have been described from Australia than from any other country, the fauna is still very poorly known and many species lie undescribed in museum collections (Smith 2017). Faunal surprises were to be expected given the inadequate level of study but the species described here would have to be the most colourful silverfish so far reported worldwide and the first documented example of Batesian mimicry in the Zygentoma. Most commonly encountered silverfish species are very similar in appearance, being overall grey in colour and hence arousing little interest among non-specialists. Silverfish, like moths and butterflies, are covered in scales and it is perhaps surprising that differences in their scale patterns generally do not approach the patterns and colours seen in the Lepidoptera. Perhaps this is due to their cryptic behaviour where they generally hide in the dark, so colour patterns may be of little use.

Unfortunately, silverfish lose many of their scales between moults through normal activity but also during collection and handling. Any coloured scale pattern remaining becomes very difficult to distinguish once the species is placed into alcohol and virtually impossible to interpret when mounted onto slides. More often than not, species are described, never having been seen live by the describer. Scale pattern is rarely mentioned in most descriptions. Two species of the genus *Hemitelsella* Smith were recently described from alcohol preserved material collected on Barrow Island and near Launceston in Tasmania (Smith 2015, 2016). Even in alcohol, these species showed strong differences in the pattern of lighter and darker scales which the first author attempted to capture in his illustrations, although it now seems with only minimal success.

In October, 2018 Jean and Fred Hort photographed a large silverfish in south-western Western Australia which displayed a very remarkable pattern of reddish-brown, black and white scales. The image was posted on-line and found by the first author who contacted the Horts. They kindly collected three more specimens from the Wallaby Hills Nature Reserve, Malebelling, and another from Flynn. It was quickly confirmed that these silverfish also belong to the genus *Hemitelsella* and molecular data suggested there were two separate species.

On seeing these images, the second author commented that the scale pattern reminded him of the pattern on some velvet ants (Hymenoptera: Mutillidae) and suggested the silverfish may be mimicking these wasps as a means of discouraging predators. Velvet ants are known for their painful stings and Batesian mimicry of velvet ants has been recorded in several groups such as beetles (e.g. Acorn, 1988, Mawdsley, 1994, Lanteri, 2005), lacewing larvae (Brach, 1978) and spiders (e.g. Nentwig, 1985). We circulated an image of

one species to entomologists familiar with Mutillidae (Graham Brown at the Northern Territory Museum and Art Gallery, Kevin Williams at the California Department of Food and Agriculture, Juanita Rodriguez and Madalene Giannotta both at the Australian National Insect Collection) for their valued opinion as to whether these silverfish were likely to be mimicking velvet ants and all agreed they did.

We also present here molecular data for two genes (28S and COI) for both new species of *Hemitelsella* as well as for *Hemitelsella transpectinata* (Smith, 2015) and *H. clarksonorum* Smith, 2016, finding much smaller molecular distances between morphologically distinct species than that reported in Smith et al. (2019) for silverfish of the subfamily Heterolepismatinae. It is a pity that no photos exist of live specimens of the Barrow Island or Tasmanian *Hemitelsella* species as it is possible that all species of this genus could display striking scale patterns.

SPECIMEN COLLECTION AND PREPARATION METHODS

The holotype of both species and the allotype of one are deposited in the entomological collection of the Western Australian Museum in Perth. One paratype is retained in the Australian Museum collection as indicated in the material examined for each species.

Specimens are stored in 75–80% ethanol unless noted as slide mounted. Shortly after collection, a leg was removed from some specimens and placed in 100% ethanol and stored at 4°C for DNA sequencing.

Measurement data of whole specimens in alcohol and dissection methods used are as described in Smith (2013). Specimens were dissected and each mounted on two slides using Tendeiro medium (Molero-Baltanás et al., 2000), with the head and thorax mounted on one slide and the abdomen on a second slide. Roman numerals are used to indicate abdominal segment number. The following abbreviations are also used: AMS: Australian Museum, Sydney; HW: head width (in millimetres); H+B: head and body length (in millimetres); L/W: length to width (ratio); PI, PII, PIII: legs of pro-, meso- and metathorax respectively; WA: Western Australia. The term *macrochaetae* refers to the larger stronger pectinate bristles, *setae* refers to smaller thinner bristles (usually simple), *setulae* to the very small, usually straight setae and *cilia* to the curly thin hairs, often associated with the combs, setal collar or notal margins. In most cases, these cilia are sensilla trichodea (sensu Adel, 1984).

SAMPLING, DNA EXTRACTION, PCR EXTRACTION, PCR AND DNA SEQUENCING

DNA extractions were performed using the Bioline Isolate II Genomic DNA Kit (Bioline, Eveleigh, NSW) following the manufacturer's protocol with elution volume adjusted to 70 µL. Tissue samples (a single leg from each specimen) were soaked in DNA extraction buffer containing proteinase-K at 50°C for one hour.

Polymerase Chain Reaction (PCR) amplification of the DNA barcode region of the mitochondrial COI gene used the primers and followed the method of Mitchell (2015). For the 28S rDNA D9–D10 region, we used primers 28S_8fm and 28S_11rm, which are 5'-M13-tailed versions of Machida and Knowlton's (2012) primers [28S] #8 and [28S] #11_RC, respectively. PCR conditions for both genes followed those reported in Mitchell (2015) for COI. PCR products were purified using ExoSAP and sequenced in both directions using ABI Big Dye Terminator v.3.1 chemistry by Macrogen Inc. (Seoul, South Korea).

DNA SEQUENCE ASSEMBLY AND PHYLOGENETIC ANALYSIS

Forward and reverse direction sequence trace files were assembled using Geneious v.10.2.6 (Kearse et al., 2012). DNA consensus sequences, sequence trace files, and specimen collection data were uploaded to BOLD (Ratnasingham & Hebert, 2007) where they are accessible as public dataset DS-HEMIMUT (dx.doi.org/10.5883/DS-HEMIMUT). Sequences newly derived for this study were also deposited in GenBank (accession numbers MZ364329–364342). Table 1 lists the museum, BOLD and GenBank accession numbers. The outgroup, *Ctenolepisma longicaudatum*, was selected from the authors' previously published studies (Smith et al., 2019).

Consensus sequences were aligned by eye. Three data sets were constructed: 28S (10 sequences), COI (11 sequences), and combined data (11 concatenated sequences).

MEGA X v. 10.0.5 (Kumar et al., 2018) was used to calculate uncorrected distances (p-distances) between sequences and to select the most appropriate models for phylogenetic analysis, based on the Akaike Information Criterion, Corrected (AICc).

Phylogenetic analyses were performed by Bayesian Inference (BI) using MrBayes 3.2.6 (Ronquist et al., 2003) and under Maximum Likelihood (ML) using RAxML v8.2.10 (Stamatakis, 2014), both packages being run within Geneious. The BI analyses were set to run for 2 million generations, with a sample frequency of 1,000, using 2 runs, setting the number of chains to 4, and the burnin to 500 samples (i.e., the recommended 25% of samples). The average standard deviation of split frequencies was observed to drop below 0.01 after each analysis, indicating convergence of the chains. ML analysis used the hill climbing algorithm with 1,000 rapid bootstrap replicates. All trees were rooted with *Ctenolepisma longicaudatum*.

TABLE 1 Museum, BOLD and GenBank accession numbers for all new sequences obtained.

Species	Voucher Type	Sample ID	Museum Accession	COI GenBank Accession	28S GenBank Accession	Collection Date	Locality
Ctenolepisma longicaudatum		gbs001836	K377675	MT674899	MK185707	18 August 2011	TAS, Hobart
Qantelsella louisae	Holotype	gbs003917	T228755	MK185705	MK185709	17 February 2016	QLD, Bladensburg NP
Acrotelsella parvelar	Holotype	gbs004624	K261103	MT674895	MK185706	23 April 2015	TAS, Travellers Rest
Acrotelsella ernei	Paratype	gbs001438	K377609	MK185701		10 July 2009	NT, West MacDonnell NP
Hemitelsella clarksonorum	Holotype	gbs004625	K261105	MZ364329	MZ364336	14 April 2015	TAS, Travellers Rest
Hemitelsella transpectinata	Topotypic	gbs006167	K261328	MZ364330	MZ364337	2016	WA, Barrow Island
Hemitelsella transpectinata	Topotypic	gbs006166	K541612	MZ364332	MZ364339	2016	WA, Barrow Island
Hemitelsella hortorum sp. nov.	Holotype	gbs006161	E109767	MZ364331	MZ364338	17 October 2020	WA, Flynn
Hemitelsella mutilloides sp. nov.	Holotype	gbs006162	E109768	MZ364334	MZ364341	14 October 2020	WA, Malebelling
Hemitelsella mutilloides sp. nov.	Paratype	gbs006163	E109769	MZ364335	MZ364342	14 October 2020	WA, Malebelling
Hemitelsella mutilloides sp. nov.	Paratype	gbs006164	K377941	MZ364333	MZ364340	14 October 2020	WA, Malebelling

RESULTS

MOLECULAR DATA

Figure 1 shows the Bayesian tree for the combined data set. There is strong support (Bayesian posterior probability ≥ 0.9 and ML bootstrap percentage ≥ 70) for the monophyly of *Hemitelsella*, for the sister-group relationship between *H. clarksonorum* and *H. transpectinata*, a sister-group relationship between the two new species, and for the monophyly of the two species which were represented by multiple samples. The same tree structure was observed for COI data alone (Figure 2), except that support for the monophyly of *Hemitelsella* was weak. The 28S tree (Figure 3) showed strong support for the monophyly of *Hemitelsella* but less support for relationships among species, with *H. clarksonorum* and *H. transpectinata* having identical 28S sequences. The maximum difference found was 1.35% between *H. mutilloides* and *H. clarksonorum*.

Within *Hemitelsella*, COI distances among species ranged from a minimum of 5.18% between *H. clarksonorum* and *H. transpectinata* to a mean of 8.47% between the two new species, to a maximum of 13.99% between *H. mutilloides* and *H. clarksonorum*.

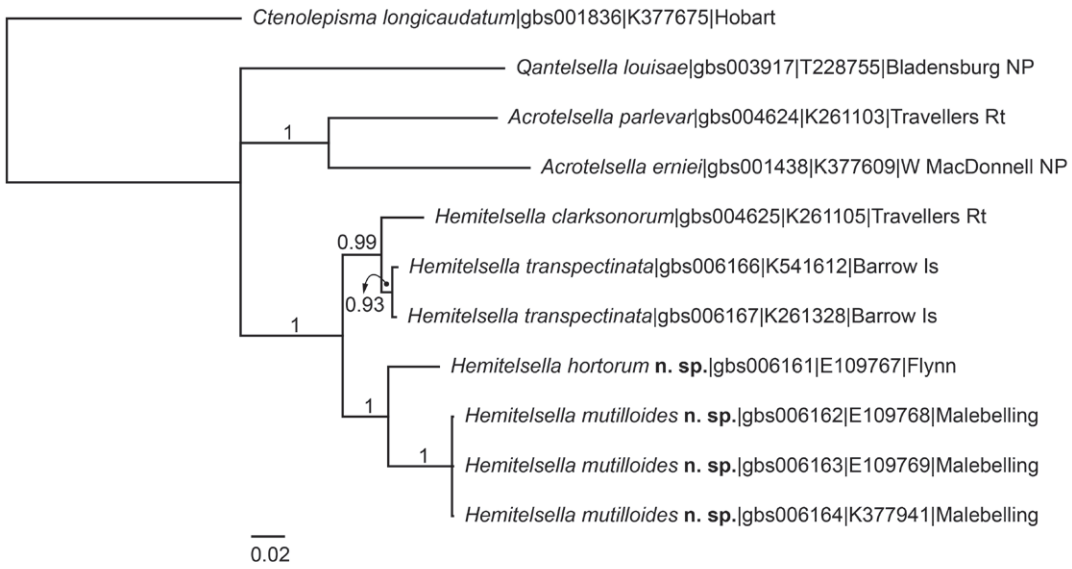


FIGURE 1 BI tree for concatenated COI and 28S genes with BI posterior probabilities shown above the branches.

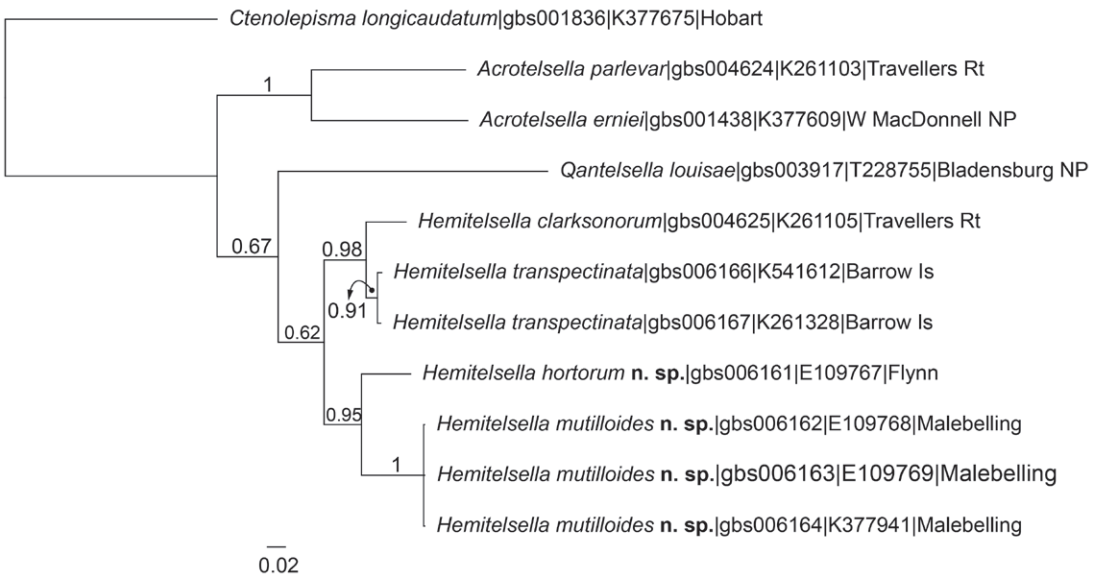


FIGURE 2 BI tree for COI gene with BI posterior probabilities shown above the branches.

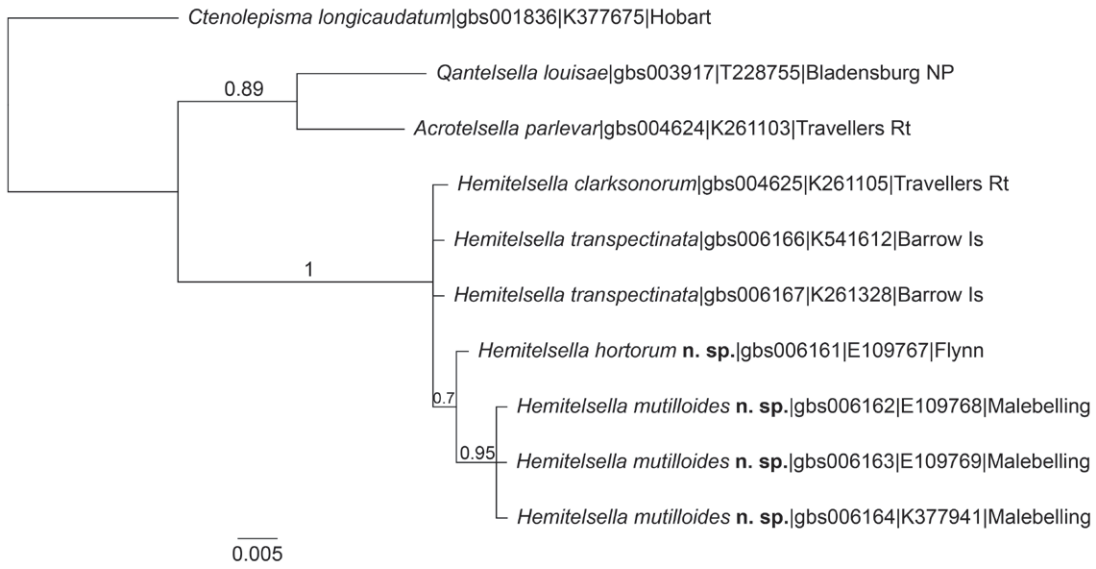


FIGURE 3 BI tree for 28S gene with BI posterior probabilities shown above the branches.

SYSTEMATICS

Family Lepismatidae Latreille, 1802

Subfamily Ctenolepismatinae Mendes, 1991

Ctenolepismatinae Mendes, 1991: 11.

Hemitelsella Smith, 2016

Hemitelsella Smith, 2016: 72.

TYPE SPECIES

Acrotelsella transpectinata Smith, 2015, by original designation.

Hemitelsella mutilloides sp. nov.

Figures 4, 8–36

urn:lsid:zoobank.org:act:8FD44026-93A4-464F-95F3-38B4F078C825

MATERIAL EXAMINED

Holotype

Australia: ***Western Australia:*** ♀ (HW 1.13), Malebelling, Wallaby Hills Nature Reserve (31.8459°S 116.9859°E), 14 October 2020, Jean and Fred Hort, hand collected on yellow sandy clay soil (WAM E109768) on two slides.

Paratypes

Australia: ***Western Australia:*** ♂ (HW 0.88), same data as holotype (WAM E109769) on two slides; ♀ (HW 1.08), same data as holotype (AMS K.377941) in alcohol.

DIAGNOSIS

This species can be distinguished from *Hemitelsella transpectinata* (Smith) by its striking colour pattern when live (as well as other characters (see Table 4), but this pattern may be similar to that of *H. clarksonorum* and *H. hortorum*. It can be distinguished from *H. clarksonorum* by the shorter length of the more posterior of the 3+3 combs of the prothoracic sternum versus 3+3 of subequal length as well as the reduced number of labial palp papillae (six versus 8–9) and from *H. hortorum* by the rounded inner corner of coxites VIII (versus almost square) and the larger number of modified spines on the apex of the apical division of the ovipositor (6–9 versus 3–4).

DESCRIPTION

Appearance: medium sized silverfish, with narrow body, thorax not much wider than abdomen which only tapers slightly posteriorly from about the fifth abdominal segment. Appearance when live quite dramatic (Figure 4) resembling a velvet ant (Mutillidae) (Figures 6–7) with anterior third even reddish brown and posterior two thirds black with white patches on the lateral sides of the anterior six abdominal segments as well as medially on the anterior three or four urotergites, urotergite X also with white medial patch, styli IX white, terminal filaments black; legs reddish brown. In alcohol, head uniformly covered with reddish-brown scales, without wide areas of hyaline scales along the sides and front of the head; pro and meso nota also fairly evenly covered in reddish-brown scales, metanotum and urotergite I with darker scales submedially but lighter scales medially and at outer margin, urotergites I–III also with darker scales along margins, these darker scales surround distinct circular light patches on IV–VI but these patches absent on urotergites VII–IX; eyes dark grey. Terminal

filaments very dark due to brown pigment and black scales.

Body length: 7.85 mm (♀); head width 1.13 mm; thorax: length 2.35 mm or 0.33 times H+B; width up to 1.48 mm with no great difference between the pro, meso and metanota although the metanotum is the widest and the pronotum the narrowest, pronotum slightly shorter than meso or metanota; antenna complete (?) 6.0 mm or 0.85 times H+B; terminal filaments all incomplete, maximum length of cercus remaining 5.0 mm or 0.7 H+B; maximum length of median dorsal appendage remaining 3.0 mm or 0.42 H+B.

FIGURES 4–5 *Hemitelsella* species: 4) *Hemitelsella mutilloides* sp. nov.; 5) *Hemitelsella hortorum* sp. nov. (photos courtesy Fred and Jean Hort).

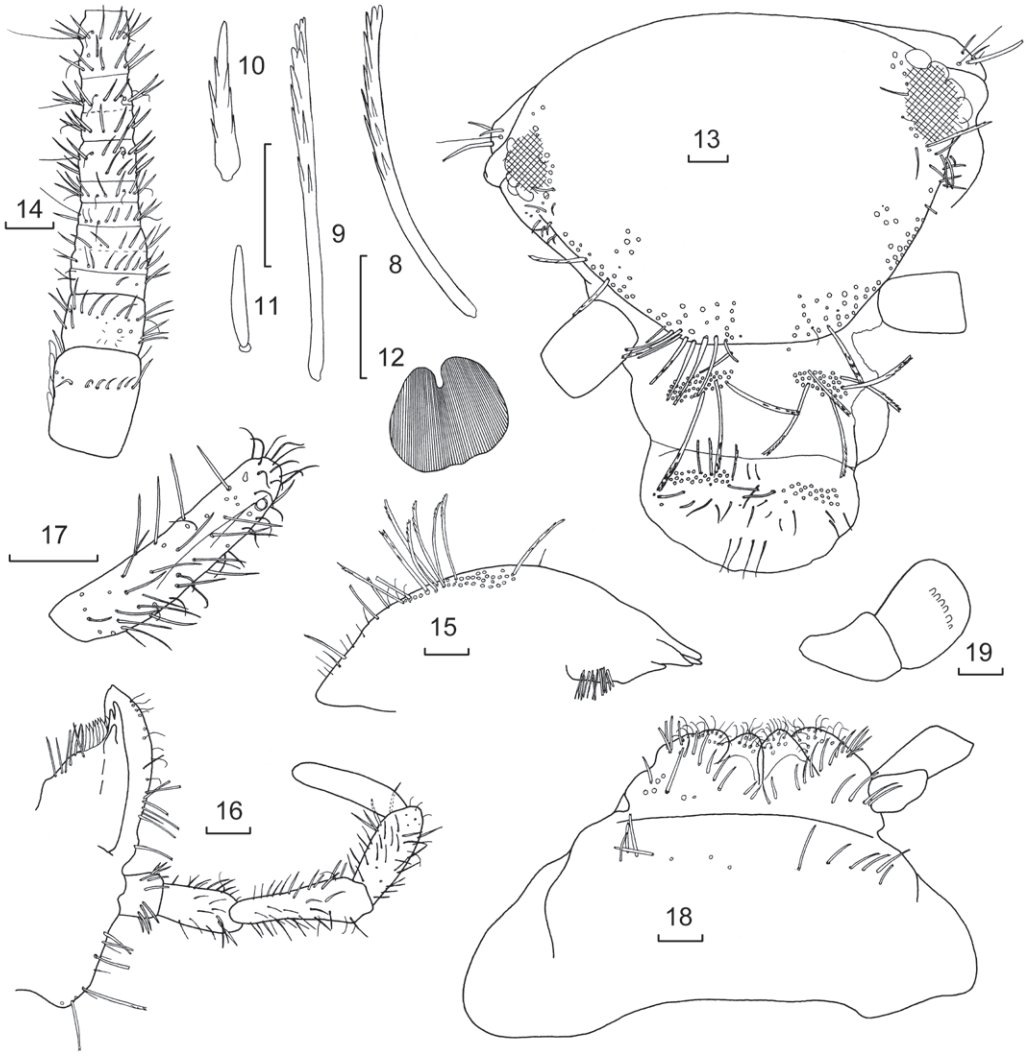
FIGURES 6–7 Possible velvet ant models for mimicry: 6) *Ephutomorpha* cf. *pacificatrix*; 7) *Ephutomorpha* sp. (photos courtesy K. Williams).

Pigmentation: frons, clypeus, labrum and scape without obvious pigment, pedicel slightly darker, the intervals of the flagellum becoming increasingly darker distally. Mandibles, maxillae, labium and its palp unpigmented, maxillary palp with light reddish-brown pigment on distal two articles. Legs with light to medium reddish-brown pigment overall, becoming stronger in more distal articles. Nota without obvious pigment but cuticle closer to lateral margins of more granular appearance, urotergites and urosternites I–VIII appear to be unpigmented, urotergite X with even light brown pigment. Coxites IX of female with brown blotchy pigment. Penis with light pigment overall, styli without pigment, cerci and median filament reddish-brown, darker distally with the basal two annuli of each division lighter than the others in the allotype but not so in the holotype. Ovipositor with distinctly orange pigmented anterior gonapophyses with sutures even darker than the surface, posterior gonapophyses lightly brown pigment.

Macrochaetae: pectinate and of variable form (Figures 8–10), mostly light to quite dark brown, but hyaline or straw coloured in some cases. The macrochaetae along the edges of the nota do not have bifurcated apices and only very subtle pectinations along the shaft and quite different to the submarginal macrochaetae which are obviously pectinate especially apically. The larger setae of the tarsi are strongly sclerotised and have rounded tips (Figure 11).

Scales: with numerous subparallel ribs that do not surpass the margin of the scale; ribs mostly close together or even very close together in the darker scales but a rare few scales observed where the ribs are a little further apart (Figure 12), these ribs are often diverging from each other distally giving an open fan appearance rather than being almost parallel; shape of scales generally round, although the posterior margin can be quite straight for those scales overhanging the posterior margins of the tergites and others are shaped to fit around setae or combs. Scales found on top of head, on clypeus, scape, all nota, all thoracic sterna, legs but absent from trochanter and tarsi (except probably the basal article of the tarsus of PIII). present on all urotergites and urosternites, styli and on the terminal filaments, even the more distal divisions. Scales of the terminal filaments very diverse in shape including some very broad as well as lanceolate scales.

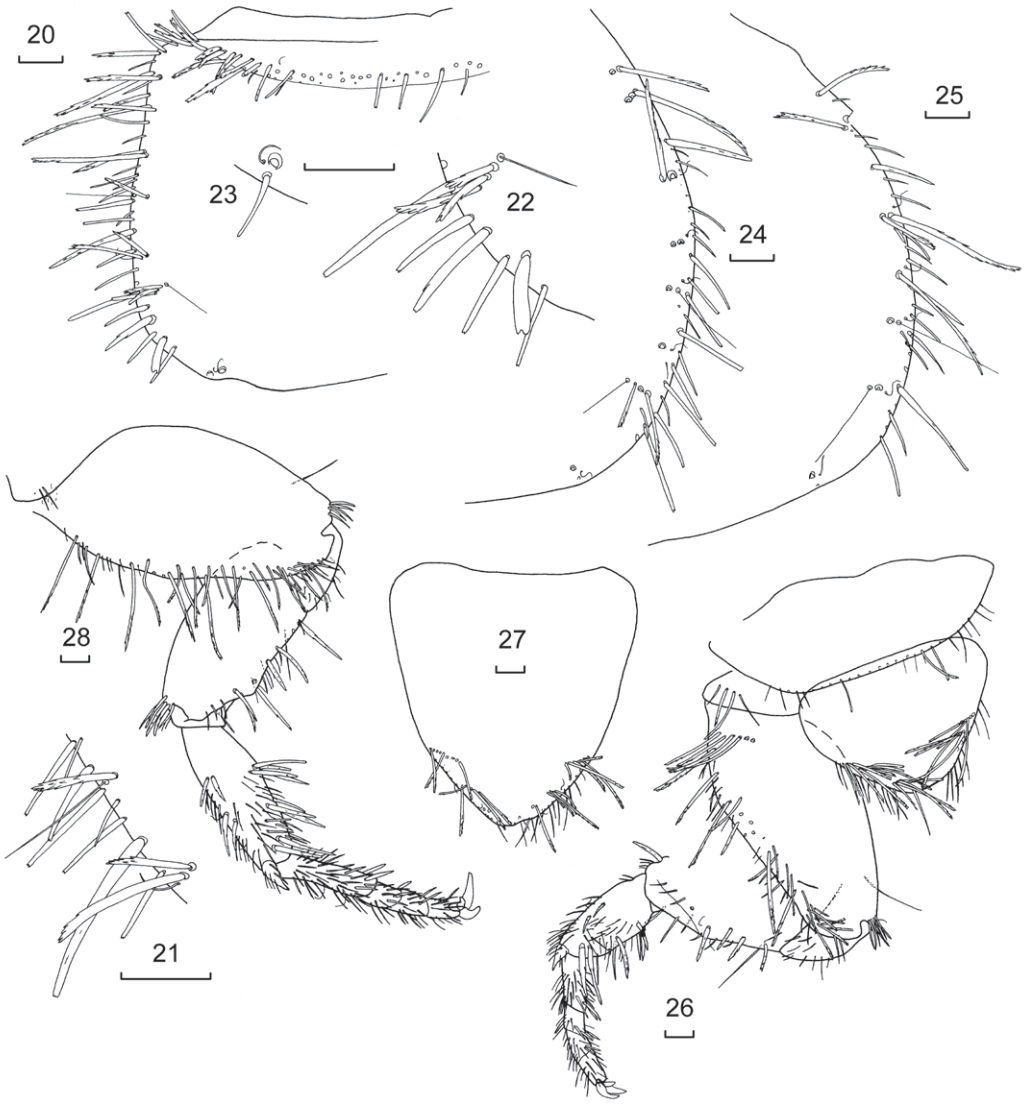
Head: wider than long (Figure 13), with 1+1 weak bushes of pectinate macrochaetae on the antero-lateral corners, not very dense and only weakly aligned in distinct rows. A small gap in the chaetotaxy of only 1–2 macrochaetae wide along the margin above the antennae and the macrochaetae continue along the margin only one or perhaps two macrochaetae wide to the level of the eyes and then running above the eyes and beyond the eyes. The 1+1 peri-antennal groups a little isolated from marginal rows consist of only 4–5 macrochaetae perhaps also with a cilium or long thin setae (lost in all specimens); 1+1 isolated single



FIGURES 8–19 *Hemitelsella mutilloides* sp. nov. holotype ♀ (E109768): 8) pectinate macrochaeta of clypeus; 9) pectinate macrochaetae of coxa of PI; 10) carrot-shaped pectinate macrochaeta from femur of PI; 11) strong apically rounded seta of tarsus or PI; 12) darker scale of pronotum; 13) head (cross-hatched area obscured by eye pigment, graphically reconstructed to re-join left eye region to remainder of head; 14) antenna, scape, pedicel and basal articles of flagellum; 15) mandible; 16) maxilla, smaller setae of last article omitted; 17) idem, ultimate article of palp; 18) labium, prementum and mentum, palps not connected; 19) ultimate and penultimate articles of labial palp, setae not shown. Scale bars 0.1 mm.

cilia are found anterior to and mediad to these groups. Eyes not well visible on slide material but with each ommatidium somewhat isolated from the adjacent. Clypeus with 1+1 bushes of about 30–40 macrochaetae slightly separated from smaller (2–3 macrochaetae) more lateral groups (very difficult to observe on slides), 1+1 setae between the larger bushes close to the dorsal margin. Labrum also with 1+1 bushes of about 20–30 smaller pectinate macrochaetae as well as a few setae between these groups and two transverse lines of smaller setae, one about midway along the labrum which may be of only four simple setae (in the allotype) or a longer irregular line extending across the labrum, the other located three quarters behind the anterior end of the labrum. — Scape of antenna (Figure 14) not very long, with scales over surface and short robust simple subapical setae, pedicel with a subapical ring of stout setae and another incomplete ring about midway along the pedicel, first annulus (interval) of flagellum with a partial ring of setae, intervals two to five of flagellum each of a single annulus with a single ring of setae, cilia and at least two trichobothria, interval six with second incomplete ring of stout setae only, interval eight with two complete rings of setae and cilia, the trichobothrium only present in the most distal ring, seventh interval with two complete rings, the eight interval with a third ring developing between the other two, ninth interval with four complete rings with the cilia in the most distal and second rings, the trichobothria restricted to the most distal ring; intervals beyond 13th are lost; there may be a circular sensillum on the basal ring but no other specialised sensilla seen on the short preserved section.

— Mandibles (Figure 15) typical for Ctenolepismatinae; a group of about 12 strong and short or thin and longer, apically bifurcated setae distally adjacent to the molar area and a bush of about 40 macrochaetae externally. — Maxilla (Figure 16) with 2–6 thick apically bifurcate macrochaetae and some small simple setae externally proximal to the palp, the lacinia with three strong teeth, one set further back than the other two, followed by about 6–7 lamellate processes and a row of 6–7 thin simple setae, galea with several strong, smooth, pointed setae externally in its basal half and a few cilia distally; apical article of maxillary palp (Figure 17) 3.7–3.9 times longer than wide and only slightly longer than the penultimate article, the ultimate article with a poculiform sensilla near the apex, rod-like basiconic sensilla were not seen, last three articles of palp with simple setae only although some thicker than others, two basal articles with subapical rings of slightly thicker setae. — Labium (Figure 18) wider than long, prementum with an interrupted transverse row of smooth strong setae, glossae and paraglossae with lateral and oblique groups of strong apically bifurcated setae and with short curved setulae distally; labial palp with oval/subrectangular apical article, not greatly widened medially (Figure 19), 1.03–1.07 times longer than wide with row of probably six papillae arranged in a single curved row (very difficult to see in mounted material and only one ultimate article present on K.377941, still in alcohol), other sensilla not observed but possibly present, covered with numerous fine short, sometimes pigmented, setae as well as longer fine setae on along the distal end; penultimate article as long as the ultimate article.



FIGURES 20–28 *Hemitelsella mutilloides* sp. nov. holotype ♀ (E109768) unless otherwise indicated by specimen number: 20) pronotum, left half; 21) idem, left anterior trichobothrial area; 22) idem, left posterior trichobothrial area; 23) idem, left posterior comb of E109769; 24) mesonotum, right side; 25) metanotum, right side; 26) presternum, prothoracic sternum and PI; 27) mesothoracic sternum; 28) PII. All scale bars 0.1 mm.

Thorax: pronotum (Figure 20) with narrow setal collar about two macrochaetae wide and some setae with rare cilia; lateral margins with many strong smooth or subtly pectinate carrot-shaped macrochaetae along the margins as well as some submarginal setae and a few cilia, with 6–7 submarginal combs of 1–2 strongly pectinate macrochaetae, the anterior trichobothrial area about 0.45 along the margin associated with comb N-2 (terminology of Molero-Baltanás, 2010) the trichobothrium located between the mediad strongly pectinate macrochaeta and a strong smooth marginal macrochaeta (Figure 21), the posterior trichobothrium located at the mediad end of a comb of 2–3 pectinate macrochaetae located about 0.70 distance along the margin (Figure 22). Posterior margin with 1+1 single macrochaetae each associated with a marginal seta and a cilium (Figure 23), the posterior combs being positioned quite laterally and almost contiguous with the chaetotaxy of the lateral margin. — Mesonotum (Figure 24) with lateral chaetotaxy similar to pronotum with 5–7 combs of one to three pectinate macrochaetae, the anterior trichobothrial area located about 0.6 along the lateral margin, associated with comb N-2 of just one macrochaeta with the trichobothria located between the macrochaeta and the margin and with a cilium between the trichobothrium and the seta on the margin. Posterior trichobothrial area 0.75 along margin, the trichobothrium located mediad to a group of 2–3 macrochaetae (=N) arranged in a line not in a triangle, (which was an unusual arrangement reported in the description of for the single known specimen of *H. clarksonorum*). Posterior margin with quite laterad 1+1 combs each of a single macrochaeta with a cilium at the outer end and a marginal seta. — Metanotum (Figure 25) similar to mesonotum but with only six combs of 1–2 macrochaetae, the anterior trichobothrial area associated with the comb (N-1) with the trichobothrium located between the single macrochaeta and the margin about 0.74 along the margin, the posterior trichobothrial area associated with the most posterior comb (N) of a single macrochaeta about 0.84 along the margin and the posterior 1+1 combs again quite laterad with a single macrochaeta and a laterad cilium.

Presternum fairly wide, with transverse row of pectinate macrochaetae and smooth setae (Figure 26). All thoracic sterna with hyaline scales. — Prothoracic sternum (Figures 26) short, wider at base than long, (L/W 0.70–0.75) subtriangular but broadly rounded posteriorly, antero-lateral corners without fringe of setae, posterior two thirds of lateral margins with long simple setae as well as 2–3+2–4 irregular combs of 4–6, 3–9, 0–5 and 0–1 pectinate macrochaetae (anterior to posterior) running at an angle of about 20–40° to the margin. — Mesosternum (Figure 27) about as wide as long (L/W 0.98–1.01) and 1.6–1.8 times as long as the prosternum, with long, thin simple marginal setae and a few cilia around the distal third of the margin, 3+3 combs in its distal third, with 4–9, 3–5 and 1–2 pectinate macrochaetae per comb (anterior to posterior). — Metasternum (Figure 29) apically slightly pointed, about 1.2 times wider than long (L/W 0.88) with long marginal setae and cilia along distal one third of lateral margins and (2–3)+(2–3) combs of longer and shorter pectinate macrochaetae, the more proximal with seven macrochaetae the more distal with 0–2.

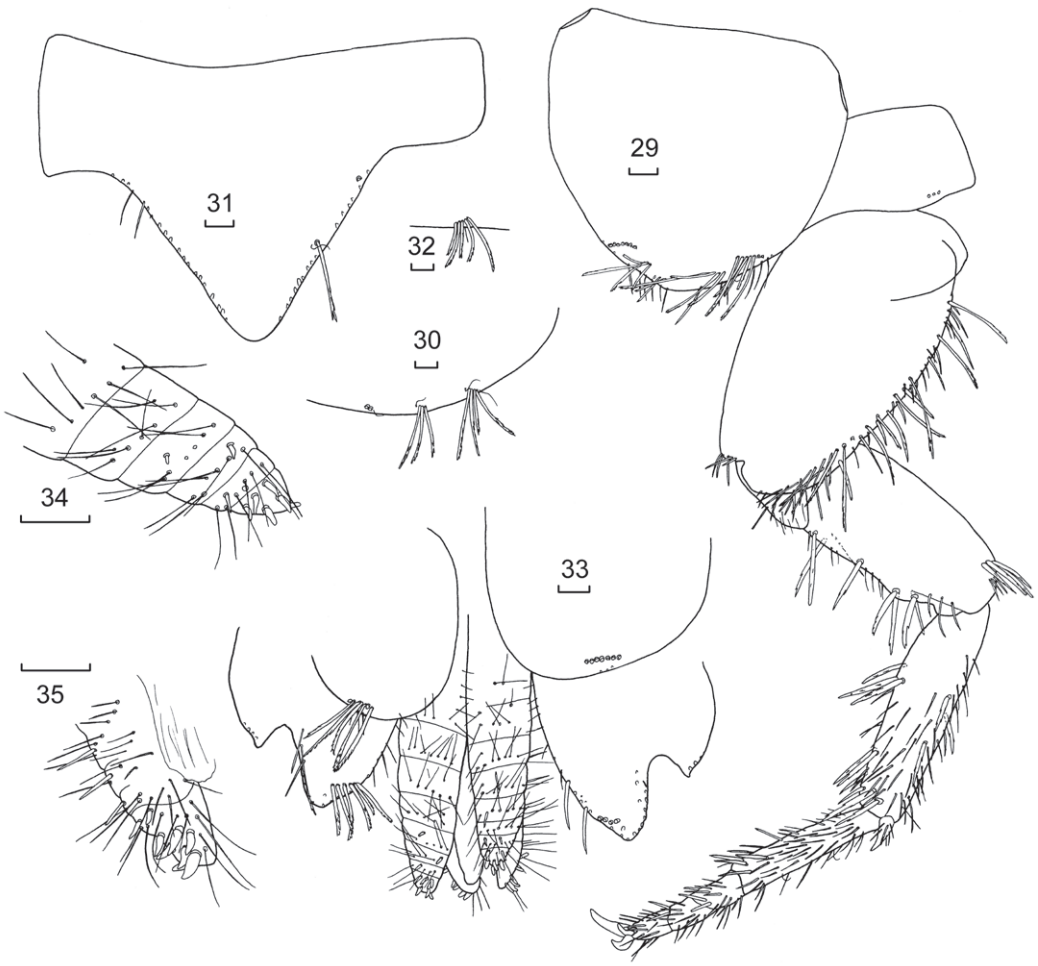
Legs (Figures 26, 28, 29) becoming progressively longer and more slender, tibia L/W ratio of legs PI 2.2–2.6, PII 3.1–3.5, PIII 4.0; tarsi L/W ratio PI 5.3–6.7, PII 7.2–8.1, PIII 9.9–10.3. PI (Figure 26) with comb of four macrochaetae laterally on precoxa. Coxa with scales and a comb of about six macrochaetae on the anterolateral corners followed by scattered strong pectinate macrochaetae along the external margin, never grouped into combs of two macrochaetae, the more marginal macrochaetae being much less pectinate, curved and tapering; inner margin without a macrochaeta on the margin and two long thin setae on the dorsal face and about six setae of varying thickness distally over the articulation. Trochanter with several stout curved setae and one small pectinate seta. Femur ventrally with four strong, thick pectinate tapering macrochaetae between the trochanter and the posterior bulge and two thinner tapered smooth setae between the bulge and the tibia plus a row of three short setae and a macrochaeta anterior to this margin; dorsally with one pectinate macrochaeta plus some smaller setae over the articulation, in addition to setae scattered over the mediad half of the dorsal surface, ventral surface with scales rather than setae. Tibia of PI with several very long carrot-shaped, slightly pectinate macrochaetae along most of the ventral margin as well as a few smaller setae on the margin and ventral face of distal half, external margin with stout setae denser in the distal half and two carrot-shaped macrochaetae on the ventral face remote from the margin about half way along its length; apex of tibia with two very long strong pectinate macrochaetae and the usual apical spur which has several setae but no small denticulations on the posterior margin. Tarsi of four articles, the basal tarsal article of PI about 40% of the total length of the tarsus, its join with the next article not particularly oblique, the ventral face of all tarsal articles with stout setae that are slightly rounded apically, especially near the distal end of each article where they are longer and stronger, dorsally with smaller setae. Pretarsus with two long curved lateral claws and a much shorter curved medial claw. PII and PIII (Figures 28–29) similar to PI with comb of only 2–3 smooth macrochaetae on the precoxa, lacking the antero-lateral comb on the coxae; legs progressively longer anterior to posterior with the tibia of PII being 1.4–1.5 times longer than that of PI and the tibia of PIII being 1.9–2.2 times longer than that of PI, the relative length of the basal tarsal article is progressively longer, being about 55% of the total length on PIII.

Abdomen: urotergite I with 1+1 lateral combs of 2–3 macrochaetae each comb associated with one or two marginal setae, urotergites II–VII (Figure 30) with 3+3 combs of macrochaetae as in table 2, the lateral combs also associated with 1–2 small marginal setae and a cilium at each end, the sublateral combs usually stand alone, rarely associated with a cilium, the submedial combs associated with a cilium at the laterad end of the comb; urotergite VIII with 2+2 combs, lacking the sublateral comb; urotergite IX glabrous. Urotergite X (Figure 31) almost equilateral triangular (67°) with rounded apex, wider than long (L/W at base about 0.56–0.63) with strong weakly pectinate setae close to the margins; with 0+1 combs of a single pectinate submarginal macrochaeta.

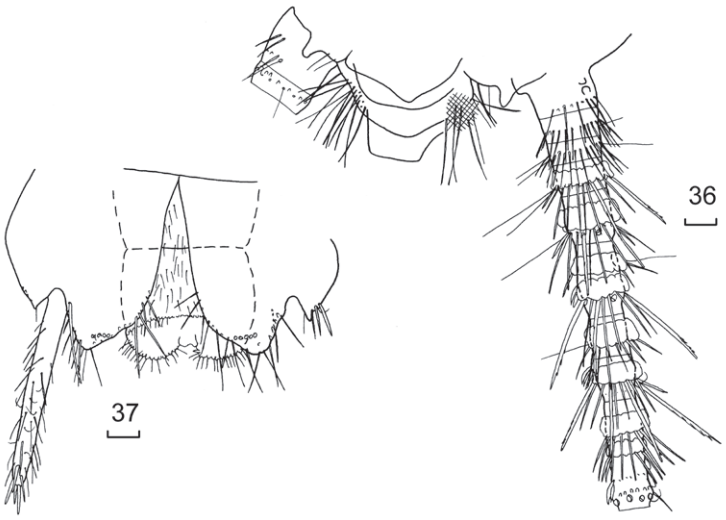
Urosternite I and II glabrous, urosternites III–VII with 1+1 lateral combs of 3–7 pectinate macrochaetae (Figure 32) each sometimes associated with 1–2 marginal setae but without a cilium.

TABLE 2 Number of macrochaetae per bristle comb *H. mutilloides* sp. nov.

Segment	Lateral Urotergite	Sublateral Urotergite	Submedial Urotergite	Urosternite
I	2–3	-	-	-
II	3	2	1–2	-
III	3	2	2	4
IV	4–5	2–3	1	5
V	4	2–3	2	5
VI	4	2	2	5–7
VII	4–5	3	1–2	7
VIII	5	-	1	4–7
IX	-		-	6–7



FIGURES 29–35 *Hemitelsella mutilloides* sp. nov. holotype ♀ (E109768): 29) PIII; 30) right side combs of urotergite IV; 31) urotergite X; 32) left sublateral comb of urosternite IV; 33) coxites VIII and IX and ovipositor, styli IX lost; 34) apical divisions of anterior gonapophyses; 35) apical divisions of posterior gonapophyses. All scale bars 0.1 mm.



FIGURES 36–37 *Hemitelsella mutilloides* sp. nov. holotype ♀ (E109768): 36) base of cerci, cross hatched area obscured; paratype ♂ (E109769): 37) coxites IX, penis and stylus. All scale bars 0.1 mm.

Genital region of female (Figure 33) with coxites VIII having quite rounded inner corners, each coxite bearing a comb of seven pectinate macrochaetae as well as two small marginal setae and a cilium at the lateral end; internal process of coxites IX short, 0.68–0.78 as long as wide at its base and only 2.0–2.5 times longer than the pointed external process, not reaching to the end of the ovipositor. Apex of internal process rounded with macrochaetae along much of the margins, a distinct transverse comb of 4–6 macrochaetae present but only occupying the mediad half of the process. — Ovipositor short (0.69–0.81 HW) of secondary type, slightly surpassing the apex of the short internal processes of coxites IX, both pairs of gonapophyses consisting of a long basal division (about half the length of the ovipositor), and six or seven smaller divisions; anterior gonapophyses (Figure 34) with six modified spines (conules) on the last division, plus one modified spine on each of the next three divisions which also have several long fine setae, posterior gonapophyses with seven conules or perhaps nine as the presumed suture between the group of seven and the following two conules could not be discerned, following divisions with long setae and each with a thicker more conical seta which becomes progressively thinner in the more anterior divisions (Figure 35).

Cerci (Figure 36) basal division about as long as wide with a partial ring of setae on outer side, following two divisions much wider than long, each with a single ring of setae as well as some trichobothria, divisions four and five with a broad ring of very dark rounded scales sub-basally which cover the insertion points of the ring of pectinate macrochaetae and smooth setae, divisions six and seven with a sub-basal ring of dark scales, then a ring of strong smooth macrochaetae and a trichobothrium then another ring of dark scales followed by the sub-apical ring of large pectinate macrochaetae, smooth setae and some cilia. Subsequent divisions lost. Median dorsal appendage lost.

Male: each coxite IX (Figure 37) with a transverse comb of about 4–5 macrochaetae across medial half of the inner process and a single macrochaeta on the face posterior to the transverse comb; the internal process not acute nor elongated, about twice as long as the external process but only 0.59–0.63 as long as broad at its base; external and internal margins of internal process and external margin of outer process with several long, often pectinate setae. Outer process small, acute triangular with a few robust setae along the outer margin. Only one pair of long slender styli (Figure 37) present (IX); each stylus with several short robust round-tipped macrochaetae apically. Styli IX in male holotype (excluding the apical macrochaetae) almost four times the length of the internal process. Penis typical (Figure 37) with numerous glandular setae apically, each set on a protuberance. Parameres absent.

HABITAT

Collected with trowel while free-roaming over yellow sandy clay soils in open woodland during daylight hours.

ETYMOLOGY

The species is named *mutilloides* because of its uncanny resemblance to velvet ants [Hymenoptera: Mutillidae].

Hemitelsella hortorum sp. nov.

Figures 5, 38–72

urn:lsid:zoobank.org:act:3D14BBE5-E922-4070-962C-084775D9699C

MATERIAL EXAMINED

Holotype

Australia: ***Western Australia:*** ♂ (HW 1.18) Flynn, Wandoo National Park (32.1045°S 116.5814°E), 17 October 2020, Jean and Fred Hort, hand collected on yellow sandy clay soil (WAM E109767) on two slides.

DIAGNOSIS

This species can be distinguished from *Hemitelsella transpectinata* (Smith) by its striking colour pattern when live (as well as other characters (see Table 4), but this pattern may be similar to that of *H. clarksonorum* and *H. mutilloides*. It can be distinguished from *H. clarksonorum* by the shorter length of the more posterior of the 3+3 combs of the prothoracic sternum versus 3+3 of subequal length, the reduced number of labial palp papillae (6–8 versus 8–9) and possibly by the arrangement of macrochaetae in the posterior trichobothrial areas of the mesonotum (three in line versus three in triangle) and from *H. mutilloides* by the almost square inner corner of coxites VIII (versus rounded) and the larger number of modified spines on the apex of the apical division of the ovipositor (3–4 versus 6–9).

DESCRIPTION

Appearance: medium sized silverfish, with narrow body, thorax not much wider than abdomen which only tapers slightly posteriorly from about the fifth abdominal segment. Appearance when live similar to *H. mutilloides* sp. nov. (Figure 5) resembling a velvet ant (Mutillidae) with anterior third even reddish brown and posterior two thirds black with white patches on the lateral sides of the anterior five abdominal segments as well as medially on the anterior three or four urotergites, urotergite X also with white medial patch, styli IX white, terminal filaments black; legs reddish brown. In alcohol, head uniformly covered with reddish-brown scales, without wide areas of hyaline scales along the sides and front of the head; pro and meso nota also fairly evenly covered in brown scales, metanotum and urotergite I with darker scales submedially but lighter scales medially and at outer margin, urotergites II–III also with darker scales along margins, these darker scales surround distinct circular light patches on IV–VI but these patches become more indistinct on urotergites VII–IX; eyes dark grey. Terminal filaments very dark due to brown pigment and black scales.

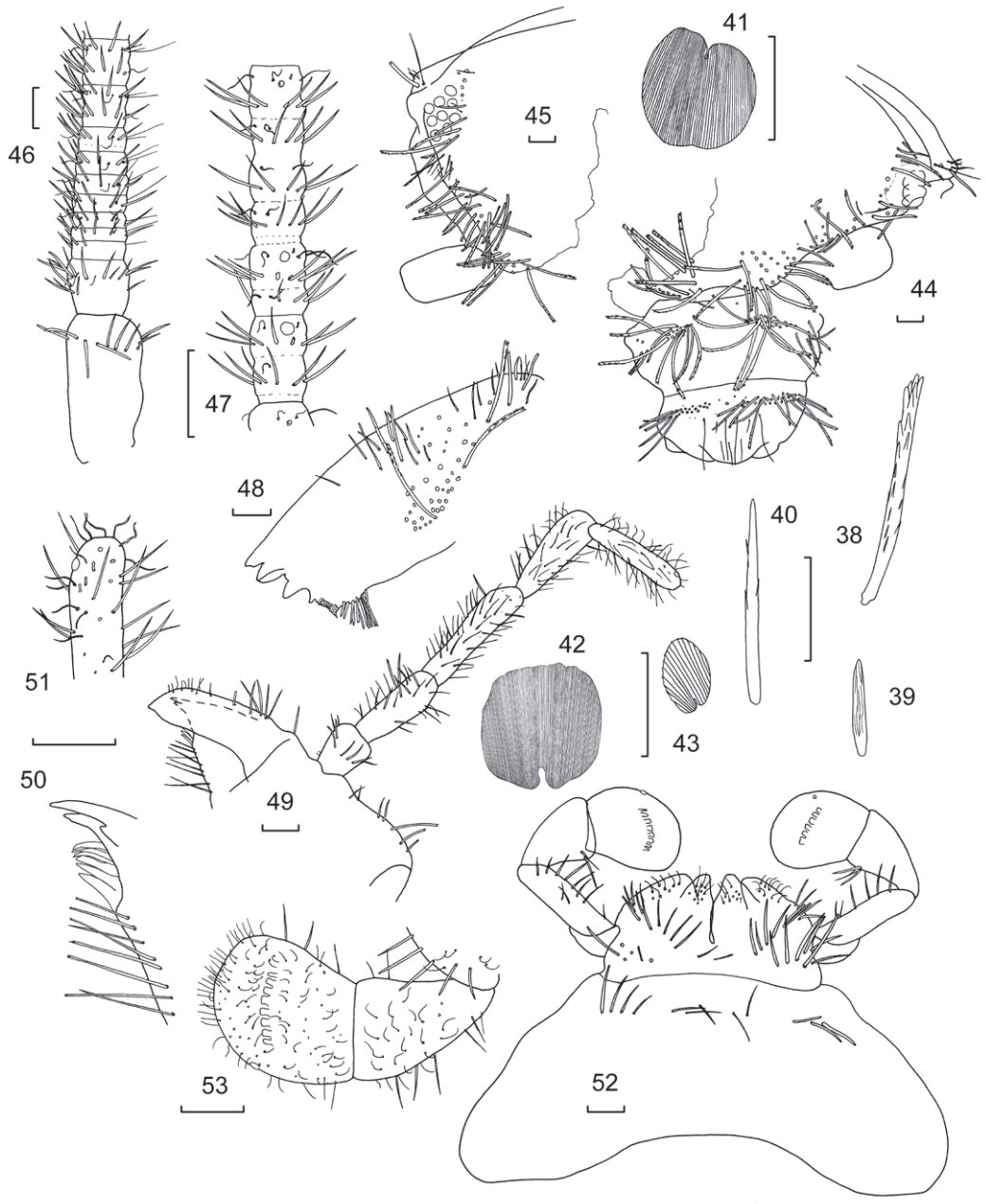
Body length: 8.05 mm (♀); head width 1.26 mm; thorax: length 2.4 mm or 0.30 H+B; width up to 1.54 mm with no great difference between the pro, meso and metanota although the mesonotum is the widest and the pronotum the narrowest; antenna incomplete (?) 4.6 mm or 0.57 times H+B; terminal filaments all incomplete; maximum length of median dorsal appendage remaining 2.8 mm or 0.34 H+B.

Pigmentation: frons, clypeus and labrum without obvious pigment, pedicel and scape slightly darker, the intervals of the flagellum becoming increasingly darker distally. mandibles, maxillae and labium evenly but lightly pigmented, maxillary palp with medium reddish-brown pigment on all articles, somewhat less in distal articles, labial palp with very little pigment, just a little laterally on the sides of the three distal-most articles, legs with reddish-brown pigment overall, becoming stronger in more distal articles, more reddish along all lateral margins before dissection which may be due to scales as the pigmentation looks quite even in the slide mounted material; prothorax with very slight pigmentation along notal collar and antero-lateral corners, otherwise nota, urotergites and sternites appear to be unpigmented, styli without pigment, cerci and median filament reddish-brown, darker distally. Inner process of coxites IX pigmented in alcohol but this not visible in slide mounted material. Ovipositor with distinct orange lines of pigment along suture but only before dissection.

Macrochaetae: pectinate and of variable form (Figures 38–40), mostly light to quite dark brown, but hyaline or straw coloured in some cases. The macrochaetae along the edges of the nota do not have bifurcated apices and only very subtle pectinations along the shaft and quite different to the submarginal macrochaetae which are obviously pectinate especially apically. The larger setae of the tarsi are strongly sclerotised and have rounded tips.

Scales: with numerous subparallel ribs that do not surpass the margin of the scale, with ribs mostly close together or even very close together in the darker scales but a rare few scales observed (e.g. on frons) where the ribs are comparatively far apart (Figures 41–43); shape of scales generally round, although the posterior margin can be quite straight for those scales overhanging the posterior margins of the tergites and others are shaped to fit around setae or combs. Scales found on top of head, medially on clypeus, scape, all nota, all thoracic sterna, legs but absent from trochanter and tarsi, present on all urotergites and urosternites, styli and on parts of the terminal filaments. Scales of the terminal filaments very diverse in shape including some very broad as well as lanceolate scales.

Head: wider than long (Figures 44–45), with 1+1 weak bushes of pectinate macrochaetae on the antero-lateral corners, not very dense and only weakly aligned in distinct rows. Any gap along the margin above the antennae hard to distinguish and the macrochaetae continue along the margin about two macrochaetae wide to the level of the eyes and then running above the eyes and beyond the eyes. The 1+1 peri-antennal groups not obviously isolated from marginal rows consist of only three to five macrochaetae without any associated cilia or long thin setae. Eyes with each dark grey ommatidium isolated from the adjacent ommatidia by light grey areas.



FIGURES 38–53 *Hemitelsella hortorum* sp. nov., holotype ♀ (E109767): 38) pectinate macrochaeta of head; 39) carrot-shaped macrochaeta from margin of nota; 40) finely pectinate macrochaeta of cercus; 41) darker scale from face of pronotum; 42) darker scale from margin of urotergite; 43) scale with wider rib spacing on frons; 44) head, left side, including clypeus and labrum; 45) head, right side; 46) antenna, scape, pedicel and basal articles of flagellum; 47) idem, most distal surviving article; 48) mandible; 49) maxilla; 50) idem, apex of lacinia: 51) idem, ultimate article of palp; 52) labium, minor setae of palp omitted; 53) idem, apical articles of maxillary palp. Scale bars 0.1 mm.

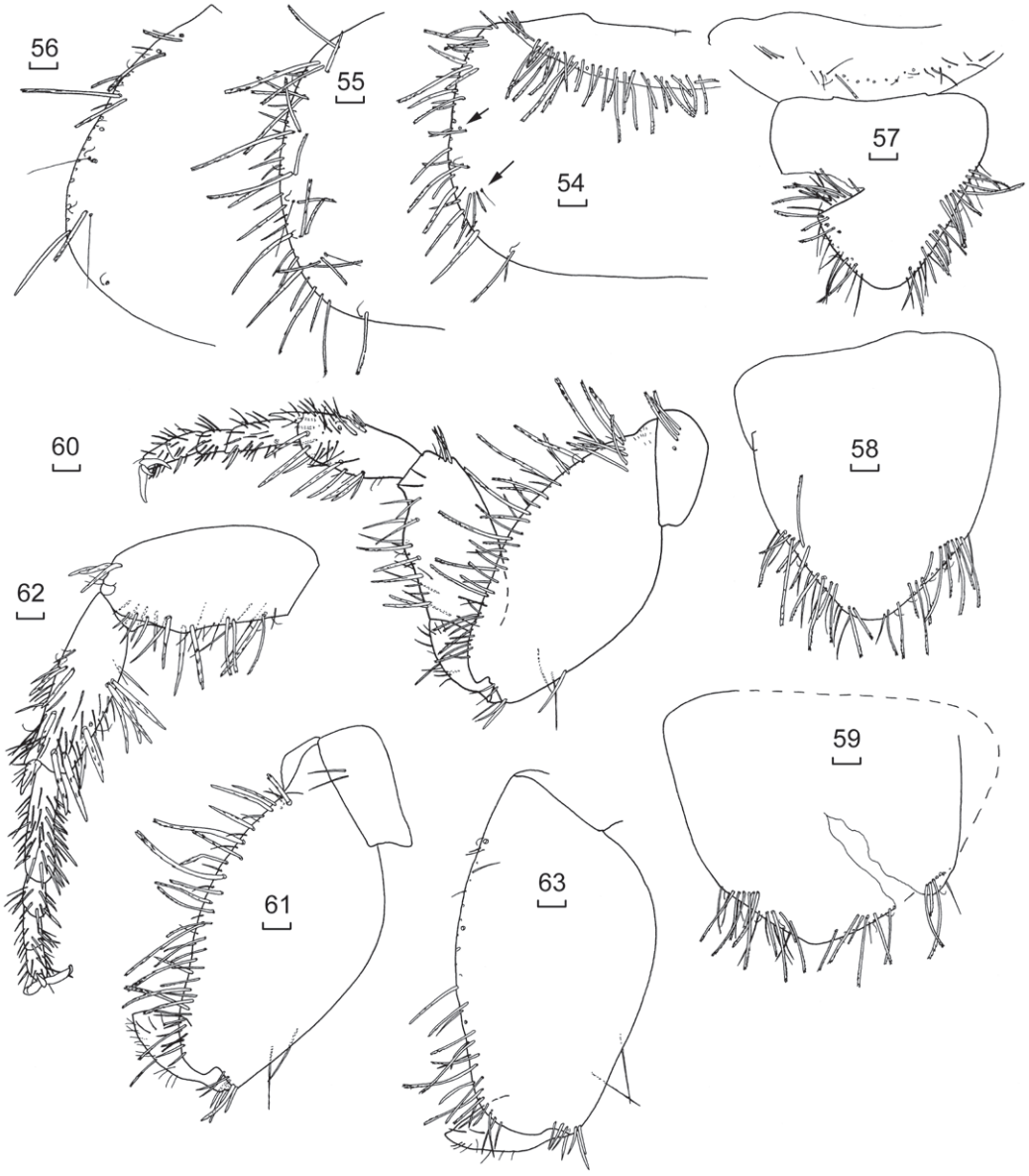
Clypeus with 1+1 bushes of about 20–25 macrochaetae slightly separated from smaller (2–5 macrochaetae) more antero-lateral groups, 1+1 setae between the larger bushes close to the posterior margin. Labrum also with 1+1 bushes of about 30 pectinate macrochaetae as well as a few simple setae and two lines of four thin setae, one about midway along the labrum the other three quarters behind the anterior end. — Scape of antenna (Figure 46) quite long with scales over surface and short robust simple subapical setae, pedicel with two or three rings of setae, first annulus (interval) of flagellum with a partial ring of setae, intervals two to seven of flagellum each of a single annulus with a single ring of setae, cilia and at least 2–3 trichobothria, intervals eight and nine subdivided into two annuli each with a ring of setae and cilia, two trichobothria only in the most distal ring, intervals 10 and 11 subdivided into three annuli and beyond the twelfth into four annuli

again with the trichobothrium in the most distal ring and eventually subdividing into eight annuli per interval (Figure 47), when the trichobothria no longer appear to be present but circular sensilla (poculiform of Mendes, 1986d)) become larger in size and more obvious on the second and fourth most basal annuli, the most distal annulus with a smaller raised circular sensillum (like 'Sensilla of Silvestri' in Mendes, 1986d) and a basiconic sensillum type B (of Adel, 1984). — Mandibles (Figure 48) typical for Ctenolepismatinae with well-developed molar and incisor areas; a group of about ten strong and short or thin and longer, apically bifurcated setae distally adjacent to the pectinate molar area and a bush of about 40 macrochaetae externally. — Maxilla (Figure 49) with one thick apically bifurcate macrochaeta and several simple setae externally proximal to the palp, the lacinia (Figure 50) with three strong teeth, one set further back than the other two, followed by about six lamellate processes and a row of eight thin simple setae, galea with several strong, smooth, pointed setae externally in its basal half and a few cilia distally; apical article of maxillary palp (Figure 51) 3.5 times longer than wide and only slightly longer than the penultimate article, the ultimate article with three rod-like basiconic sensilla and a poculiform sensilla near the apex, last three articles of palp with simple setae only although some thicker than others, two basal articles with subapical rings of slightly thicker setae. — Labium (Figure 52) wider than long, prementum with an interrupted transverse row of smooth strong setae, glossae and paraglossae with lateral and oblique groups of strong apically bifurcated setae and with short curved setulae distally; labial palp with oval/subrectangular apical article, not greatly widened medially (Figure 53), 1.1 times longer than wide with 6–8 papillae arranged in a single curved row, with at least one poculiform sensilla on the outer margin, covered with numerous fine short setae as well as longer fine setae on along the distal end; penultimate article as long as the ultimate article.

Thorax: pronotum (Figure 54) with narrow setal collar about two macrochaetae wide and some setae but no cilia; lateral margins with many strong smooth and subtly pectinate macrochaetae along the margins as well as some submarginal setae and a few cilia, with eight submarginal combs of 1–3 strongly pectinate macrochaetae, the anterior trichobothrial area about 0.44 along the margin associated with comb N-2 (terminology of Molero-Baltanás, 2010) the trichobothrium located between the mediad strongly pectinate macrochaeta and a strong smooth marginal macrochaeta, the posterior trichobothrium located at the mediad end of a comb of three pectinate macrochaetae located about 0.70 distance along the margin. Posterior margin with 1+1 single macrochaetae each associated with a marginal seta and a cilium, the posterior combs being positioned quite laterally and almost contiguous with the chaetotaxy of the lateral margin. — Mesonotum (Figure 55) with lateral chaetotaxy similar to pronotum with 7–8 combs of one to three pectinate macrochaetae, the anterior trichobothrial area located about 0.63 along the lateral margin, associated with comb N-2 of just one macrochaeta with the trichobothrium located between the macrochaeta and the margin and with a cilium between the trichobothrium and the seta on the margin. Posterior trichobothrial area 0.78 along margin, the trichobothrium located mediad of a group of three macrochaetae (=N) arranged in a line not in a triangle, (which was an unusual arrangement reported in the description of the single known specimen of *H. clarksonorum*). Posterior margin with quite laterad 1+1 combs each of a single macrochaeta with a cilium at the outer end and a marginal seta. — Metanotum (Figure 56) similar to mesonotum but with only six combs of one or two macrochaetae, the anterior trichobothrial area associated with the comb (N-1) of just one macrochaeta about 0.57 along the margin, the posterior trichobothrial area associated with the most posterior comb (N) of a single macrochaeta about 0.72 along the margin and the posterior 1+1 combs again quite laterad with a single macrochaeta and a laterad cilium.

Presternum narrow, with weak transverse row of short pectinate macrochaetae and smooth setae (Figure 56). All thoracic sterna with hyaline scales. — Prothoracic sternum (Figure 57) wider at base than long, (L/W 0.75) subtriangular, rounded posteriorly, antero-lateral corners without fringe of setae, posterior three quarters of lateral margins with long simple setae as well as 3+3 combs of 8–9, 5–5 and 1–2 pectinate macrochaetae (anterior to posterior) running at an angle of about 20° to the margin. — Mesosternum (Figure 58) about as wide as long (L/W 1.05) and 1.5 times as long as the prosternum, with long, thin simple marginal setae and a few cilia around the distal half of the margin, 3+3 combs in its distal third, with 6–7, 3–4 and 2 pectinate macrochaetae per comb (anterior to posterior). — Metasternum (Figure 59) apically slightly pointed, about 1.4 times wider than long (L/W 0.73) with long marginal setae and cilia along distal one third of lateral margins and 2+2 combs of longer and shorter pectinate macrochaetae, the more proximal with six macrochaetae the more distal with 4–5 although the most distal macrochaeta of each comb is somewhat more distantly spaced from the others suggesting it could be seen as a separate comb in some individuals.

Legs (Figures 60–63) becoming progressively longer and more slender, tibia L/W ratio of legs PI 2.5, PII 3.5, PIII lost; tarsi L/W ratio PI 4.5, PII 6.4, PIII lost. PI (Figure 60) with comb of four macrochaetae laterally on precoxa. Coxa with scales and a comb of about six macrochaetae on the anterolateral corners followed by many strong pectinate macrochaetae along the external margin, never grouped into combs of two macrochaetae, the more marginal macrochaetae being much less pectinate, curved and tapering; inner margin with a macrochaeta on the margin and two long thin setae on the dorsal face and about five setae of varying thickness



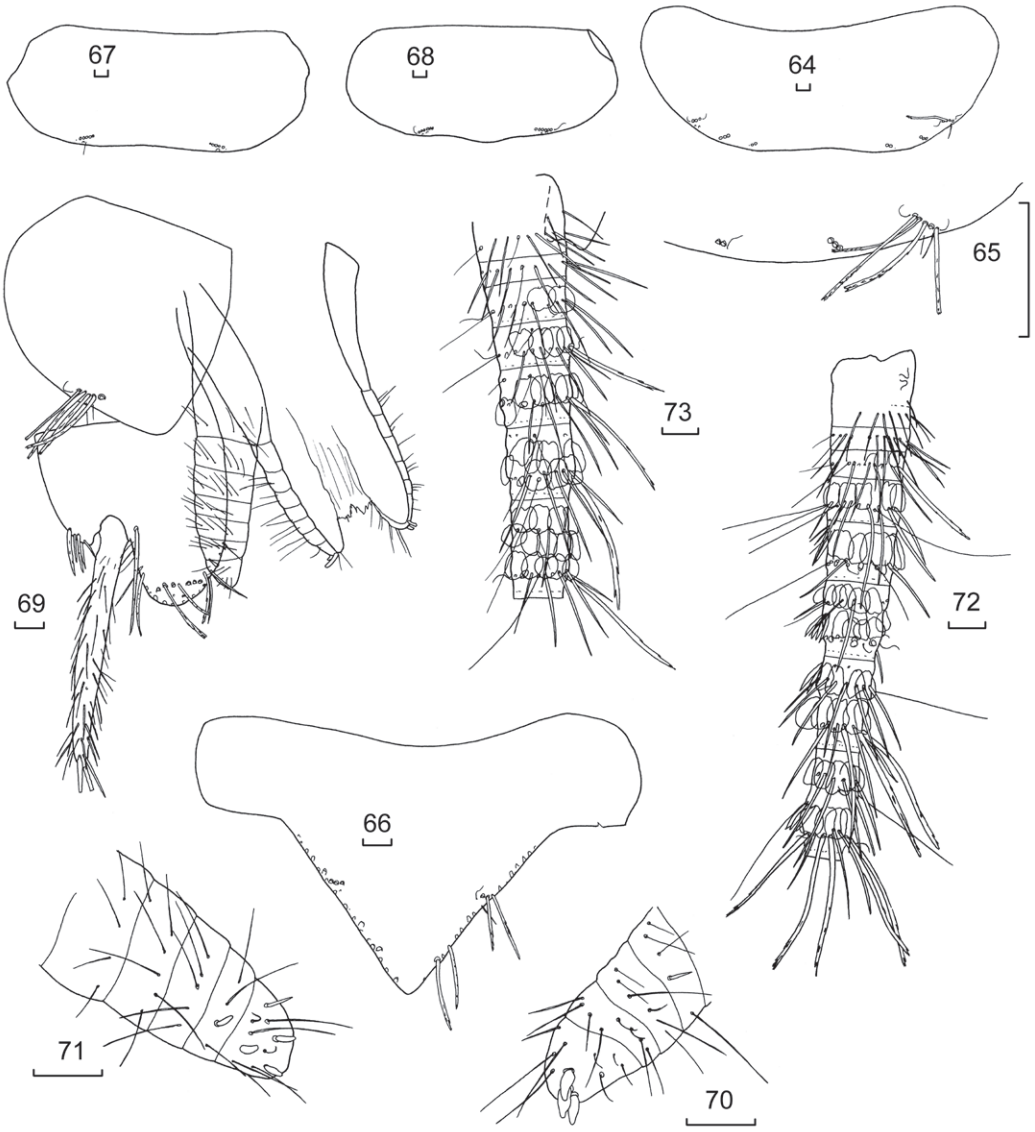
FIGURES 54–63 *Hemitelsella hortorum* sp. nov., holotype ♀ (E109767): 54) pronotum, left half; 55) mesonotum, left half; 56) metanotum, left half; 57) presternum and prothoracic sternum; 58) mesothoracic sternum; 59) metathoracic sternum; 60) PI; 61) PII, coxa and trochanter; 62) PII, femur, tibia and tarsus; 63) PIII, coxa and trochanter. All scale bars 0.1 mm.

distally over the articulation. Femur ventrally with several strong, thick pectinate tapering macrochaetae and dorsally with three pectinate macrochaetae over the articulation in addition to setae scattered over the mediad half of the dorsal surface, ventral surface with scales rather than setae. Tibia of PI with several very long carrot-shaped, slightly pectinate macrochaetae along most of the ventral margin as well as a few smaller setae on the margin and ventral face of distal half, external margin with group of stout setae about half the distance along the margin; apex of tibia with two stout pectinate macrochaetae and the usual apical spur which has several seta but no small denticulations on the posterior margin. Tarsi of four articles, the basal tarsal article of PI about 40% of the total length of the tarsus, its join with the next article not particularly oblique, the ventral face of all tarsal articles with stout setae that are not conspicuously rounded apically, stout setae which are longer near the apex of each article, dorsally with similar setae. Pretarsus with two long curved lateral claws and a much shorter curved medial claw. PII (Figures 61–62) similar to PI except PII with comb of only two smooth macrochaetae on the precoxa, lacking the antero-lateral comb on the coxae; legs progressively longer anterior to posterior with the tibia of PII being 1.5 times longer than that of PI; PIII lost beyond trochanter (Figure 63).

Abdomen: urotergite I with 1+1 lateral combs of three macrochaetae each comb associated with one or two marginal setae and a cilium at the laterad end of the comb, urotergites II–VII (Figures 64–65) with 3+3 combs of macrochaetae as in table 3, the lateral combs also associated with 1–2 small marginal setae or setulae and one or two cilia, always at the laterad end of the comb but usually at both ends, the sublateral combs usually stand alone, rarely associated with a small seta or setulae (all lost), the submedial combs associated with a cilium at the laterad end of the comb; urotergite VIII with 2+2 combs, lacking the sublateral comb; urotergite IX glabrous. Urotergite X (Figure 66) almost equilateral triangular (73°) with slightly rounded apex, wider than long (L/W at base about 0.60) with strong weakly pectinate setae close to the margins; with 2+2 combs of one or two pectinate macrochaetae per comb.

Urosternite I and II glabrous, urosternites III–VII with 1+1 lateral combs of 4–7 pectinate macrochaetae (Figures 67–68) (all lost from holotype) each usually associated with 1–2 thin marginal setae or setulae and always with a cilium at the laterad end of the comb.

Genital region of female (Figure 69) with coxites VIII having almost square inner corners, each coxite bearing a comb of 5–7 pectinate macrochaetae as well as two small marginal setae and a cilium at the lateral end; internal process of coxites IX short, 0.58–0.60 as long as wide at its base and only 2.4–3.8 times longer than the pointed



FIGURES 64–73 *Hemitelsella hortorum* sp. nov., holotype ♀ (E109767): 64) urotergite III; 65) urotergite VI, right side combs; 66) urotergite X; 67) urosternite VI; 68) urosternite VII; 69) right coxites VIII and IX, ovipositor and stylus IX; 70) apex of anterior gonapophysis; 71) apex of posterior gonapophysis; 72) base of cercus; 73) base of median dorsal appendage. All scale bars 0.1 mm.

TABLE 3 Number of macrochaetae per bristle comb *Hemitelsella hortorum* sp. nov.

Segment	Lateral Urotergite	Sublateral Urotergite	Submedial Urotergite	Urosternite
I	3	-	-	-
II	3	3	2	-
III	3–4	3	2	4
IV	4	3	2	5
V	4–5	3	2	5
VI	5–6	3	2	5
VII	5	3–4	2	6
VIII	5	-	2	5–7
IX	-	-	-	

external process, almost as long as the ovipositor. Apex of internal process rounded with macrochaetae along much of the margins, a distinct transverse comb of 8–10 macrochaetae present. — Ovipositor short (0.62 HW), only just reaching the apex of the short internal processes of coxites IX, both pairs of gonapophyses consisting of a long basal division (about half the length of the ovipositor) and six or seven smaller divisions (Figure 70); of secondary type, anterior gonapophyses with 2–3 modified spines on the last division, as well as several long fine setae plus one or two stout seta on the third and fourth last divisions, posterior gonapophyses with 2–3 on the last division and sometimes one on the penultimate division (Figure 71), with also with long fine setae.

Cerci (Figure 72) basal division about as long as wide with one or two partial rings of setae on outer side (but may actually be two divisions with an indistinct suture separating them), following division much wider than long with a single ring of setae as well as some trichobothria, subsequent three divisions increasing in length with a basal ring of wide round scales and a subapical ring of setae, macrochaetae, cilia and trichobothria; sixth, seventh and eighth divisions longer than wide with a sub-basal ring of scales, followed by a ring of setae and long trichobothria, then a ring of scales, the outer most of which are lanceolate and a subdistal ring of setae, pectinate macrochaetae and cilia but lacking trichobothria; ninth division with six rings, three of which are scales, pectinate macrochaetae confined to the most distal ring and trichobothria to the second ring; tenth division with four rings of setae and four of scales, although some scales appear on rings predominantly of setae and some setae can be found on rings predominantly of scales, trichobothria restricted to the second most basal ring of setae; trichobothria and round scales appear to be absent or only very small on most distal surviving divisions but some lanceolate scales can be found. — Median dorsal appendage (Figure 73) with longer first division bearing two rings of small setae and trichobothria, the setae above simple while those below are noticeably pectinate, following three divisions about 2–3 times as long with a subapical ring of setae, cilia and trichobothria, as well as having a sub-basal ring of broad scales and a short trichobothria; sixth division similar but with an additional ring of broad scales in the middle of the division; seventh division longer again with three distinct rings of broad setae and two of setae, macrochaetae restricted to the most distal ring. Most distal surviving divisions (probably about two thirds of undamaged length) with five rings of pectinate setae, the macrochaetae of the most distal ring not much larger than the setae of the other rings, scales no longer visible, trichobothria, present in some annuli but consistent pattern not defined.

Male: unknown.

HABITAT

Collected with trowel while free-roaming over yellow clay sandy soils in open woodland during daylight hours. The Hort's noted on their web-posting of the image that

> 'This pretty silverfish runs around in the daytime in relatively open sandy soil between shrubs and leaf litter. They look like ants hurrying across the ground as mostly all you see is the black section of the body.
>
> I watched this one move over the ground and was surprised to see it move tiny rocks and push its head against the rock and sit very still. At one stage it raised the rear of its abdomen and waved the cerci and filament around in circles.
>
> I think they are very pretty especially seeing the rainbow colours reflected in its scales.'

ETYMOLOGY

The species is named for the discoverers of the species, Jean and Fred Hort.

DISCUSSION

MOLECULAR DATA AND SPECIES BOUNDARIES

In contrast to the results obtained for the Heterolepismatinae (Smith et al., 2019) where we failed to identify morphological differences between clades with comparatively large DNA distances of 0.9–1.8% for 28S and 7.2% for COI, we find quite pronounced differences in morphology between two species that have identical 28S sequences and 5.2% difference in COI. Based on characters usually considered as stable within the Ctenolepismatinae (the arrangements of combs on the thoracic sternites, the number of labial palp papillae and the shape of the inner corners of coxites IX) as well as the greatly different scale pattern there seems little

doubt that all four species are distinct. *Hemitelsella clarksonorum* and *H. hortorum* have however, only been described from single specimens, so we have no knowledge of morphological variability in these species. It would appear that the molecular differences between morphologically distinct species, are considerably smaller than observed in the Heterolepismatinae and more in line with that observed in other more recent insect orders.

Smith (2018) considered the Heterolepismatinae to have originated in the proto-Australian part of Gondwana after it broke away from Africa. The subfamily predominates now in the moister forested parts of the Australian continent and only a few species have been collected in desert habitat. It is present on many islands in the Pacific and seems to be able to survive ocean crossings better than to thrive in a desert. In contrast, the Ctenolepismatinae predominate in desert habitats of Africa, Australia and Central Asia. The Australian genera (*Acrotelsella*, *Qantelsella*, *Hemitelsella*) are totally distinct at the genus level from those found in Africa and Central Asia (*Ctenolepisma*, *Thermobia* and a number of highly adapted psammophilous genera). Several Ctenolepismatinae species have been shown to absorb moisture through their rectum at relative humidity levels as low as 45.7% (Edney, 1971) and can be abundant in the driest of deserts (e.g. the Kalahari sand desert). We suggest that the Ctenolepismatinae have been more successful at adapting to the drier climate resulting from Australia's drift northward and are morphologically evolving more rapidly, occupying new niches. The Heterolepismatinae, on the other hand appear to be highly conserved morphologically and perhaps already optimally adapted for the niche they occupy (generally the bark of trees or leaf litter protected from rain) but somehow also limited to this niche. They might not be as efficient at moisture control. Smith (2020) observed specimens of *Heterolepisma sclerophyllum* Smith, 2014 apparently taking up moisture from wet cotton wool with their mouth. Perhaps their physiology is less suited to drier conditions and their distribution has contracted along with the forests, rather changing morphologically to the increasingly drier environment. There is however at least one species (*Heterolepisma parvum* Smith) that has been collected in large numbers on arid Barrow Island, suggesting that some species have been able to adapt to aridity.

MORPHOLOGY

When *Hemitelsella transpectinata* (Smith) was originally described from material in alcohol, the presence of longitudinal lines of darker scales on the thorax and anterior abdomen was striking enough that the author attempted to illustrate this pattern. When a second species (*Hemitelsella clarksonorum*) was sent to the author (also in alcohol), the colour pattern appeared to be quite different with no darker bands on the thorax. Placing the original illustrations alongside the photos of the two new western Australian species it would appear that *H. clarksonorum* could be very similar in colour pattern and hence probably also a mutillid mimic.

TABLE 4 Table of characters of described *Hemitelsella* species.

	H. clarksonorum	*H. hortorum*	*H. mutilloides*	*H. transpectinata*
Thorax colour pattern	Even reddish-brown	Even reddish-brown	Even reddish-brown	White margins, two longitudinal lines
Prosternum L/W (approx.)	0.8	0.75	0.73	1.0
Prosternum combs	3+3 subequal in length	3+3 anterior combs longer	3+3 anterior combs longer	(4–6)+(4–6) subequal or slightly longer anteriorly
Labial palp papillae	8–9	6–8	6	11–12
Macrochaetae in posterior mesonotal trichobothrial area	3 in triangle	3 in line	3 in line	3 in line
Macrochaetae per comb coxites VIII	8–9	4–7	5–7	7–11
Shape inner corners coxites VIII ♀	unknown	subsquare	round	subsquare
Spines on apical division of ovipositor	unknown	3–4	6–9	3–4

Hemitelsella transpectinata appears to be quite different in scale pattern. Molecular data however show that, in spite of the pattern differences, *H. clarksonorum* and *H. transpectinata* are quite closely related, whereas much greater molecular differences are observed between the new species and *H. clarksonorum* in spite of their apparently similar colour patterns. Further species of *Hemitelsella* have been collected in Western Australia and South Australia, however we do not have photos of them when live, depriving us of what appears to be a remarkably interesting and useful character.

While the colour pattern makes it easy to distinguish *H. transpectinata* from the other three species, morphological differences between the latter are more subtle. Table 4 summarises the differences between all four species. However, with the exception of *H. transpectinata*, we have seen very few specimens of the other three species and the female of *H. clarksonorum* is unknown. It is possible, indeed likely, that the range of variability for some of these characters will render them less useful, especially with regards to juvenile specimens.

BATESIAN MIMICRY

These species appear to represent the first instances of Batesian mimicry in the Zygentoma. Their similarity to velvet ants probably discourages potential predators allowing them to be active in daylight hours and on open ground.

ACKNOWLEDGEMENTS

Thanks are due to Jean and Fred Hort for noticing these amazing animals in the field, posting their images online and collecting specimens for us. We would also like to thank Graham Brown (Northern Territory Museum and Art Gallery), Kevin Williams (California Department of Food and Agriculture), Juanita Rodriguez and Madalene Giannotta (Australian National Insect Collection) for their valued opinion as to whether these silverfish were likely to be mimicking velvet ants.

REFERENCES

Acorn, J. H. (1988). Mimetic tiger beetles and the puzzle of cicindelid coloration (Coleoptera: Cicindelidae). *Coleopterists Bulletin* **42**: 28–33.

Adel, T. (1984). Sensilleninventar und sensillenmuster auf den Antennen von *Thermobia domestica* und *Lepisma saccharina* (Insecta: Zygentoma). *Braunschweiger Naturkundliche Schriften* **2:** 191–217.

Brach, V. (1978). *Brachynemurus nebulosus* (Neuroptera: Myrmeleontidae): a possible Batesian mimic of Florida mutillid wasps (Hymenoptera: Mutillidae). *Entomological News* **89**: 153–156.

Edney, E.B. (1971). Some aspects of water balance in tenebrionid beetles and a thysanuran from the Namib Desert of Southern Africa. *Physiological Zoology* **44**(2): 61–76. doi: 10.1086/physzool.44.2.30155557

Edwards, G. (1984). Mimicry of velvet ants (Hymenoptera: Mutillidae) by jumping spiders (Araneae: Salticidae). *Peckhamia* **2**: 46–49. doi: 10.1080/01650528509360679

Kearse, M., Moir, R. and Wilson, A. (2012). Geneious Basic: An integrated and extendable desktop software platform for the organization and analysis of sequence data. *Bioinformatics* **28**(12): 1647–1649. doi: 10.1093/bio=informatics/bts199

Kumar, S., Stecher, G., Li, M., Knyaz, C. and Tamura, K. (2018). MEGA X: Molecular Evolutionary Genetics Analysis across computing platforms. *Molecular Biology and Evolution* **35**: 1547–1549. doi: 10.1093/molbev/msy096.

Lanteri, A. A. and Del Rio, M. G. (2005). Taxonomy of the monotypic genus *Trichaptus* Pascoe (Coleoptera: Curculionidae: Entiminae), a potential weevil mimic of Mutillidae. *Coleopterists Bulletin* **59**: 47–54. doi: 10.1649/683

Latreille, P.A. (1802). *Histoire Naturelle, générale et particulière des Crustacés et des Insectes. 3.* Dufart, Paris, 468 pp.

Machida, R.J. and Knowlton, N. (2012). PCR Primers for metazoan nuclear 18S and 28S ribosomal DNA sequences. *PLoS ONE* **7**(9): e46180. doi: 10.1371/journal.pone.0046180

Mawdsley, J. R. (1994). Mimicry in Cleridae (Coleoptera). *Coleopterists Bulletin* 48: 115–125.

Mendes, L.F. (1991) 1.1. On the phylogeny of the genera of Lepismatidae (Insecta: Zygentoma). pp. 3–13 *in* Veeresh, G.K., Rajagopal, D. and Viraktamath, C.A. (eds) *Advances in management and conservation of soil fauna*. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi Bombay Calcutta.

Mitchell, A. (2015). Collecting in collections: a PCR strategy and primer set for DNA barcoding of decades–old dried museum specimens. *Molecular Ecology Resources* **15**: 1102–1111. doi: 10.1111/1755-0998.12380

Molero–Baltanás, R., Gaju–Ricart, M. and Bach de Roca, C. (2000). On the taxonomic use of the distribution pattern of the antennal asteriform sensilla in *Neoasterolepisma* and *Tricholepisma* (Insecta, Zygentoma, Lepismatidae). *Pedobiologia* **44**: 248–256. doi: 10.1078/S0031-4056(04)70045-1

Molero-Baltanás, Gaju-Ricart, M., Bach de Roca, C. and Mendes, L.F. (2010). On *Ctenolepisma ciliata* and a new related species, *Ctenolepisma armeniaca* n. sp. (Zygentoma, Lepismatidae). *Deutsche Entomologische Zeitschrift* **57**(2): 243–252. doi: 10.1002/mmnd.201000021

Nentwig, W. (1985) A mimicry complex between mutillid wasps (Hymenoptera: Mutillidae) and spiders (Araneae). *Studies on Neotropical Fauna and Environment* 20: 113–116. doi: 10.1080/01650528509360679

Ratnasingham, S. and Hebert, P.D.N. (2007). BOLD: The Barcode of Life Data System (www.barcodinglife.org). *Molecular Ecology Notes* **7**: 355–364. doi: 10.1111/j.1471-8286.2007.01678.x

Ronquist, F. and J. P. Huelsenbeck. (2003). MrBayes 3: Bayesian phylogenetic inference under mixed models. *Bioinformatics* **19**: 1572–1574. doi: 10.1093/bioinformatics/btg180

Smith, G.B. (2013). A new species of *Heterolepisma* from Barrow Island (Zygentoma: Lepismatidae). *Records of the Western Australian Museum* Supplement **83**: 229–240. doi: 10.18195/issn.0313-122x.83.2013.229-240

Smith, G.B. (2015). New silverfish species (Zygentoma: Lepismatidae) from Barrow Island. *Records of the Western Australian Museum* **30**: 98–131. doi: 10.18195/issn.0312-3162.30(2).2015.098-131

Smith, G.B. (2016) On some silverfish taxa from Tasmania (Zygentoma: Lepismatidae and Nicoletiidae). *Records of the Australian Museum* **68**(2): 45–80. doi: 10.3853/j.2201-4349.68.2016.1652

Smith, G.B. (2017). The Australian silverfish fauna (Order Zygentoma) — abundant, diverse, ancient and largely ignored. *General & Applied Entomology* **45**: 9–58.

Smith, G.B. (2018). The contribution of silverfish (Insecta: Zygentoma) to Australian invertebrate biodiversity and endemism). PhD thesis School of Applied Sciences, Federation University, Ballarat, Australia. 432 pp.

Smith, G.B., Mitchell, A., Lee, T.R.C. and Espinasa, L. (2019). DNA barcoding and integrative taxonomy of the *Heterolepisma sclerophylla* species complex (Zygentoma: Lepismatidae: Heterolepismatinae) and the description of two new species. *Records of the Australian Museum* **71**(1): 1–32. doi: 10.3853/j.2201-4349.71.2019.1677

Smith, G.B. (2020). Some observations on rearing the silverfish *Heterolepisma sclerophyllum* Smith (Zygentoma: Lepismatidae: Heterolepismatinae). *General & Applied Entomology* **48**: 19–20.

Stamatakis A. (2006). RAxML-VI-HPC: Maximum Likelihood-based phylogenetic analyses with thousands of taxa and mixed models. *Bioinformatics* **22**: 2688–2690. doi: 10.1093/bioinformatics/btl446

MANUSCRIPT RECEIVED 22 JUNE 2021; ACCEPTED 2 AUGUST 2021.