RESEARCH ARTICLE



Neotypification of Drawida hattamimizu Hatai, 1930 (Annelida, Oligochaeta, Megadrili, Moniligastridae) as a model linking mtDNA (COI) sequences to an earthworm type, with a response to the 'Can of Worms' theory of cryptic species

R.J. Blakemore¹, E.K. Kupriyanova², M.J. Grygier³

I C/- 2 Faculty of Education and Human Sciences, Yokohama National University (YNU), Tokiwadai, Hodogaya, Yokohama 240-8501 3 Lake Biwa Museum (LBM), Oroshimo 1091, Kusatsu-shi, Shiga-ken 525-0001, Japan

Corresponding author: R.J. Blakemore (rob.blakemore@gmail.com)

Academic editor: Lyubomir Penev | Received 19 December 2009 | Accepted 3 March 2010 | Published 26 March 2010

Citation: Blakemore RJ, Kupriyanova EK, Grygier MJ (2010) Neotypification of *Drawida hattamimizu* Hatai, 1930 (Annelida, Oligochaeta, Megadrili, Moniligastridae) as a model linking mtDNA (COI) sequences to an earthworm type, with a response to the 'Can of Worms' theory of cryptic species. ZooKeys 41: 1–29. doi: 10.3897/zookeys.41.374

Abstract

A neotype is designated for the large and ecologically interesting species of Japanese earthworm, Drawida hattamimizu Hatai, 1930. Its morphological redescription is unambiguously combined with the neotype's sequence of the Cytochrome Oxidase I (COI) locus of the mitochondrial DNA, the first time an earthworm species' type has been thus profiled. Probably it is an introduced exotic rather than a translocated native, with a patchy distribution that appears only partly defined in Japan where it is both a restricted and an endangered listed species. Brief comparison of sympatric Drawida japonica (Michaelsen, 1892) to the type-species Drawida barwelli (Beddard, 1886) - and this latter from Shiga appears as a new record for Japan - allows the diagnosis of Drawida Michaelsen, 1900 to be amended slightly. The contentious issue of molecular 'cryptic species' is queried in relation to the lack of molecular data from type-specimens, the unique name-bearing references employed in zoological nomenclature. Without such reference, neither eco-taxonomic nor genomic studies of earthworm taxa can progress. In this regard, questions are raised concerning the molecular identities and provisional divergences of cosmopolitan generotypes Alloloophora chlorotica chlorotica (Savigny, 1826), the Aporrectodea caliginosa (Savigny, 1826) species-complex sensu Blakemore (2002), and of ecotoxicological standard test-species icon Eisenia fetida fetida (Savigny, 1826). Resurrection of their respective synonyms is mooted. Resolution of relationships within and between earthworm genera and families without DNA testing of the representative type-species and type-genera is flagged as another crucial concern.

Copyright RJ. Blakemore et al.. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Keywords

Lumbricidae, neotype, biodiversity, parthenogenesis, provisional species, COI barcode, OTUs, genomic phylogeny, genetic synonymy, ICZN

Introduction

Drawida hattamimizu Hatai, 1930 is the largest earthworm known in Japan, reaching ca. 1,000 mm in length. It is recognized as both a geographically restricted and as an endangered species in the Red Data Book of Japan (Anon. 2007) and that of Ishikawa Prefecture (Anon. 2009), being reported only from Kanazawa (type locality) to Lake Biwa in central Honshu. Its transportation away from inhabited paddies was voluntarily regulated by rice farmers since its burrows in paddy embankments supposedly drained the paddies to the detriment of the crop (Hatai 1930). Possibly it is an introduced species as yet unreported from its overseas homeland, rather than a translocated native or neoendemic, with a patchy distribution that is only partly documented in Japan. In the first comprehensive review of Japanese earthworms, Easton (1981: 37) raised doubts and questioned its identity when he said for Japanese Drawida: "None of the eight species considered here is particularly well known and the specific status of each requires closer investigation"; in his Table 1 of Marker Characters he included two "?"s for D. hattamimizu and some other features were poorly defined [see http://www.archive.org/stream/bulletinofbritis 40zoollond#page/38/mode/2up]; he also (erroneously) included Hokkaido in its distribution. Its type material cannot be traced, thus a topotypic specimen kept in 85% Ethanol (EtOH) at room temperature for around 7 years is designated as the neotype, and tissue from it has been used in the present study for DNA analysis (COI gene barcoding). This procedure provides a model for DNA barcoding of other earthworm types, without which eco-taxonomic studies in Japan, as elsewhere, especially where there is a prevalence of similar or parthenogenetic morphs, cannot progress far owing to the likely proliferation of mutually uncoordinated parataxonomies.

Problems in conventional systematics and taxonomy of megadrile earthworms are: lack of specialists, poor species descriptions, missing historical types, closely similar morphs and rampant parthenogenesis. Earthworm DNA barcoding offers a solution (Folmer et al. 1994; Siddal et al. 2001; 2009; Huang et al. 2007; Chang et al. 2009; Rougerie et al. 2009) but no previous work has yet sampled from either a species' type specimen or from a type-species of a genus. Although (ICZN, 1999: Art. 72.3) mandates fixation of a type for a new name, an ongoing obstacle is lack of types for older described species thereby precluding effective and efficient barcoding. This study attempts to remedy this for at least one enigmatic *Drawida* species in Japan belonging to the large Indo-oriental Family Moniligastridae Claus, 1880.

Especially Japanese earthworm taxonomy is in a desperately chaotic state with between 70 or 160+ nominal taxa including many homonyms and synonyms, plus parthenogenetic polymorphs of both natives and exotics in which just those anatomical characters needed to differentiate between species are degraded (Easton 1981; Blakemore 2003, 2007a, 2008a, in press). DNA sequence analysis is the only feasible means of resolving parthenogenetic clones or immature forms of earthworms, but only when initially referenced to a species' type. Few of the Japanese taxa are adequately described, many classical taxa lack types, and there is an urgent and exceptional need to perform molecular analyses to meet the aims of ICZN nomenclature for "stability and universality" thereby enabling ecological studies. Without this, the ambiguity and uncertainty of earthworm biodiversity will be compounded in Japan, and taint adjacent countries such as Korea, China or Russia. Despite the close proximity of some of these neighbours, and obvious similarity between their shared faunas, little attempt has been made to apply the Principle of Priority (ICZN 1999: Art. 23) and many new nationalistic taxonomic names have been precipitously published, further deferring resolution by adding complexity to existing systematic difficulty (see Blakemore 2003, 2008a, 2009, in press).

One of the earliest molecular studies of Annelida, which included a few earthworms, was by Siddall et al. (2001), and Siddall et al. (2009) summarize some intervening issues that specifically relate to success of DNA barcoding. Molecular studies of earthworms in general have been relatively rare and mostly restricted to a few groups such as holarctic Lumbricidae, yet even these have not considered type specimens. Gregory and Hebert (2002) recognized the ecological and economic importance of earthworms but stated: "Unfortunately, this importance appears not to have translated into interest among genome biologists. In fact, the genomic properties of oligochaetes have been almost totally ignored." Addressing this lapse, Blakemore (2009) and Stürzenbaum et al. (2009) provide some historical and predictive information on earthworm studies, particularly those made famous by Darwin (1881), commenting generally on genomic research.

In a recent study, the "first thought" of King et al. (2008) was to claim to "open a can of worms" by reporting "unprecedented sympatric cryptic diversity within British lumbricid earthworms" in the form of molecular cryptic species that "has profound consequences for all areas of earthworm research." But these authors did not anchor their work with comparison to the types of any of the species they claimed to study. Their conclusions, as with all previous molecular or DNA analyses of earthworms, were thus ungrounded. These and other issues of genetic analysis and GenBank accession are discussed further in the context of the current study based on the type of a known species.

Protocols for the Consortium for the Barcode of Life (CBOL 2010) recommend fresh or frozen sample material from voucher specimens. An ancillary aim of the current study was to demonstrate that molecular analysis of preserved earthworms via DNA extraction and amplification using current technology is possible from 'older' type material.

Methods

From among several specimens of *Drawida hattamimizu* collected from the type locality (Hatta-cho, Kanazawa, Ishikawa Prefecture) a suitably mature and complete exemplar was selected, anaesthetized in dilute ethanol until immobile, then fixed and preserved in 85% ethanol (EtOH) in a sufficiently large and robust jar. This specimen was not frozen, but was maintained at ambient room temperature for several years (~7 yr) before DNA extraction, amplification and sequencing (COI barcoding) was finally successfully achieved from small (ca. <5 mm²) integument tissue samples taken from non-essential, iterative, posterior segments that yet lie slightly in front of the terminus wherein parasitic debris and coelomocytes tend to accumulate in earthworms. Other *Drawida* specimens were sampled for comparison as detailed below. All specimens are deposited in the Lake Biwa Museum, Shiga Prefecture, Japan (LBM).

DNA extration, amplification and sequencing

Before genomic DNA extractions, ethanol (EtOH) was removed from samples by washing tissues three times in 0.5 ml of seawater. Qiagen DNeasy Kit for total DNA extraction (proteinase K digestion in lysis buffer and spin filter method) was used according to manufacturer's instructions. Stock DNA was diluted 1:10 with deionized water to produce template strength DNA for Polymerase Chain Reactions (PCR).

A fragment of the COI gene (approximately 600 bp) was amplified using standard Folmer primers (Folmer et al. 1994) and, for the neotype only on its second and final attempt, with a modified Folmer reverse primer (Bely and Wray 2004; see also the Appendix). PCR reactions were conducted with the GenAmp PCR System 9700 (Applied Biosystems) using Ex Taq Kit (TaKaRa) under the following conditions: 35 cycles, denaturation at 96 °C for 5 min, annealing at 46 °C for 45 sec and extension at 72 °C for 1 min. The reaction mix (total reaction volume was 50 µl) included: 36.75 µl of H₂O, 5 µl of 10x Buffer, 4 µl of 10 mM dNTP, 1 µl of each 5 µM primer, 0.25 µl of ExTaq 5U/µl, 2 µl of DNA template. The PCR products were separated by TBE gel electrophoresis in 1.5% agarose gel and visualized under UV after staining with ethidium bromide before being purified with 'Gel and PCR Clean-up DNA purification kit' (Promega) following the manufacturer's protocol. Amplification products were sequenced in both directions, using the same primers as in PCR. Sequencing reactions were done using BigDye Terminator v3 Cycle Sequencing Kit (Applied Biosystems). Each reaction contained 0.5 µl of primer, 1 µl of BigDye, 16 µl of H₂O, 1.5 µl of 5X BigDye buffer, and 1 µl of DNA (total reaction volume was 20 µl). Reactions (25 cycles, denaturation at 96 °C for 10 sec, annealing at 50 °C for 5 sec, and extension at 60 °C for 4 min) were run on the GenAmp PCR System 9700 (Applied Biosystems). Amplified products were purified using the Performa® DTR Gel Filtration Cartridge kit (EdgeBio). Products of the sequencing reactions were read using ABI 3130 Genetic Analyzer (Applied Biosystems). Sequences were assembled and edited using SeqEd ver. 1.0.3 (Applied Biosystems Inc.), and these raw data are presented in an Appendix.

Morphological description

The neotype was sketched using a Nikon SMZ-U binocular microscope with drawing tube, dissected, and described employing taxonomic conventions explained in Gates (1972) and Blakemore (1994, 2002, 2008a). Higher classification follows Michaelsen (1900) as modified by Blakemore (1994, 2000a, 2008a) rather than by Gates (1959, 1972) or Sims (1980).

Taxonomic Results

Phylum **Annelida** Lamarck, 1802 Class **Oligochaeta** Grube, 1850/**Clitellata** Michaelsen, 1919 Order **Megadrili** Benham, 1890/**Haplotaxida** Michaelsen, 1900 [Suborder MONILIGASTRIDA]

Family Moniligastridae Claus, 1880

Type-genus: Moniligaster Perrier, 1872.

Type-species: Moniligaster deshayesi Perrier, 1872 from Sri Lanka.

Family diagnosis: (from Michaelsen 1900: 109; Stephenson 1923: 116; Gates 1962: 299, 1972: 238; Blakemore 2008a): Setae lumbricine. Prostomium prolobous. Male pores one or two pairs (on 10 or in 10/11 or 11/12 and 12/13) behind spermathecal pores (in 7/8 and/or 8/9) and in front of female pores (in 11/12 or near 12/13 or 13/14). Testis and male funnels intraseptal in sacs. Gizzards multiple (e.g. 2–12 in region of segments 11–34) behind ovarian segment. Nephridia holoic. Clitellum unilayered (one cell thick). Ova macrolecithal (i.e., with large yolk-particles). Spermathecae with long tubular ducts. Last hearts in segment 9.

Distribution: Southeastern and eastern Asia, from Sri Lanka to eastern Siberia, also Korea, Japan, the Philippines, Borneo and Sumatra. Several species of *Drawida* have been reported outside the generic range, some of these later synonymized, but most moniligastrids are probably confined to their areas of origin in the Indo-Asian region (Gates 1972).

Genus Drawida Michaelsen, 1900

Type-species: Moniligaster barwelli Beddard, 1886 from Manila, by original designation.

Genus diagnosis (amended slightly from Michaelsen, 1900: 114; Stephenson, 1923, 1930; Gates, 1962, 1972; Blakemore, 2002, 2008a): Small to giant [~1,000 mm e.g. *Drawida hattamimizu*, *D. grandis* (Bourne, 1887)] terrestrial earthworms. Setae lumbricine [said to have a "*smooth body without setae*" in *D. zhangetalia* Blakemore, 2006 nom. nov. pro *D. cheni* Zhang et al., 2006 (non *D. cheni* Gates, 1935)]. Dorsal pores absent or intermittently present (e.g. in some *D. barwelli*, and cf. *D. japonica* RJB pers. obs.). Spermathecal pores

at 7/8 (spermathecae without Y-shaped "*dichotomously branched glands*" of *Moniligaster* Perrier, 1872). Clitellum includes segments 10–13 but its exact extent often obscure. Male pores usually in or near 10/11 and female pores in or near 11/12. A pair of testes and male funnels typically in intraseptal sacs of 9/10. Short or sessile pseudo-prostates associated with male atria. Ovaries and oviducts typically in 11 with a pair of ovisacs extending posteriorly from septum 11/12. Last hearts in 9. Several, i.e., two to eight (or exceptionally nine in *D. hattamimizu*) moniliform intestinal gizzards within segments 11–27 [or 27–34 in *D. nilamburensis* (Bourne, 1894)]. Holoic (and sometimes vesiculate) with blood capillaries on the nephridia. Oesophageal gizzards, calciferous glands, and intestinal caeca absent.

Taxonomic Note: Gender of the name *Drawida* – after the 'Dravidians' of Southern India/Sri Lanka – was not initially stated, but Easton (1984: 111), citing ICZN articles (now ICZN, 1999: Art. 30.1.4), proposed to continue its treatment as a Latinized feminine noun.

Distribution: Indo-Oriental region, very widespread: "Drawida has a self-acquired range which may only be exceeded by that of the Lumbricidae, and is larger than that of the Pheretima s. lat. domain, consequently it is expected to yield proportionately more species... Possibly, Drawida alone may prove to have the greater number of species" (Gates 1972: 238-239). However, currently only about 200 nominal taxa are known (cf. 670 holarctic Lumbricidae versus 940 or so valid species of oriental pheretimoids in the family Megascolecidae - Blakemore 2007a, 2008a). Described by Stephenson (1923: 118, 124, Chart 1) as "one of the large Indian genera", its centres of diversity appears to lie in Sri Lanka, southern India, the eastern Himalayas, and Myanmar. At least one supposed native, Drawida ghilarovi Gates, 1969 from Russia in south-east Siberia, is listed in the Red Data Book for that region (Anon. 1997). The type, Drawida barwelli, was first recorded as an exotic from Australia by Blakemore (1994, 1999), from China (Hainan) by Blakemore (2007a, 2008a), and is a new Japanese record as "D. cf. barwelli" in the present study (from Kurotsu and Inazu, Shiga-ken - Biwako samples 4 and 5, collected from rice paddies, 17.VI.2009 by RJB & MJG). Relatively few species, apart from the cosmopolitan D. barwelli, are peregrine: D. japonica (Michaelsen, 1892) has been reported from the western Indian Himalayas, Yunnan and Szechuan in China, Japan, and Korea, and is also found on Taiwan (also cf. D. ramnadana Michaelsen, 1907 from south India), but Gates (1972) was of the opinion that some records of D. japonica outside Japan/ Korea were misidentifications. This latter possibility is briefly investigated herein as part of further studies (Blakemore in prep.) on its relationship with *D. barwelli* proper.

Species *Drawida hattamimizu* Hatai, 1930 Figs 1–3

Synonymy:

Drawida hattamimizu Hatai, 1930: 485, figs 1–7; 1931: 85–98, fig. 6; Ohfuchi, 1938b: 395; Yuki, 1940a: 20?, b: 12; Kobayashi, 1941: 263; Ogawa, 1944: 81, fig. 30; Easton, 1981: 35, 37, 38, tab. 1; Uchida, 1988: 546; Blakemore, 2003; 2004;

2006; 2007a,b; Watanabe, 2005 (figs 1–5); Kamihira, 2005 (map fig. 1); Nishino, 2006: 542; Anon. 2009 (photos).

Drawida hattaminizu; (laps.) Reynolds & Cook, 1976: 111.

Etymology: Japanese – "Hatta earthworm".

Material inspected: LBM1380000078: **Neotype.** From mud and embankments of rice paddies at Hatta-cho (ca. 36°38'N 136°41'E), Kanazawa-shi, Ishikawa-ken; 21.VIII.2002; collected by R.J. Blakemore (YNU E.S.S.); preserved in 85% EtOH (as figured and dissected here) with small samples of body wall around segment 300 taken for testing in 2004 (unsuccessful), another tissue sample from around segment 350 taken in 2009 (also unsuccessful) together with a final sample from near segment 250 (successful DNA analysis as reported herein). **Neotype newly designated.**

Other material inspected: a cocoon (LBM1380000079) collected at same time as the neotype (by RJB, see Fig. 1). Also seven sub-adult/mature specimens from Kaideima-cho, Hikone-shi (ca. 35°14'N 135°16'E) Shiga-ken in rice paddy fields near the University of Shiga Prefecture's campus (Dr Misako Urabe's and Yuko Goto's sites); collected 18.VI.2009 by RJB, MJG, M. Urabe & Y. Goto; four preserved in 85% ethanol (LBM1380000083 one posterior regenerate semi-mature specimen also dissected); three other specimens in 99.5% EtOH for DNA comparison (LBM1380000084). Further LBM specimens collected by Kei Tanikawa on 10.IX.2008 from Hatta-cho, Kanazawashi, Ishikawa-ken used alive for a public exhibition display (LBM138000081-2); and on 4.IX.2008 from Asazumachikuma, Maibara-shi, Shiga-ken (LBM138000080). Plus a single, paler immature *D. hattamimizu* collected at Mano-ono 2-chome, Otsushi, Shiga-ken on 15.V.2009 by Y. Kusuoka (LBM1380000088).

Description (of neotype compared to descriptions by Hatai, Easton, etc.):

External characters: Length of preserved neotype ca. 400 mm, other specimens stretching up to ca. 1,000 mm in life but averaging 246 mm, Hatai 1930) by 9-10 mm wide. Segments ca. 400 (cf. average of 317, Hatai 1930); anterior segments stout and triannulate around genital region (Fig. 2). Colour dark blue-black, although ventrum appears paler, almost pinkish in alcohol; clitellum darker or obscure in life but becomes ash-grey on preservation in alcohol. Less mature worms may be brick-red in colour or paler. Prostomium prolobous. Setae minute and very closely paired (setal ratio as shown in Fig. 1); viewed perpendicularly appearing dark from the worm's viscera but are actually translucent when viewed from the side; genital setae not found. Dorsal pores absent. Nephropores not found (possibly minute and lateral in d lines as per Hatai?). Clitellum in 9,10–15,16 (ca. 1/29-1/215 in neotype), perhaps slightly more saddle-shaped than annular as setae cd seem occluded and the dorsum rugose. Genital markings as smallish tumescences paired just posterio-median to setae a on 6-9, sometimes in 10 but usually not, and on 11-12,13 (those in 13 missing from neotype but present in Hikone specimen); secondary, smaller pair seen in neotype on 7 in position of setae d (figured); one or more, or all, markings may be absent (maturity?). Spermathecal pores lateral to raised mounds in 7/8 at or slightly median to setae c (cf. Hatai who claims the pores are on the "on the tip of the prominent papillae", and Easton who



(C) RJB 2009

Figure 1. *Drawida hattamimizu*, Neotype showing dorsal view of anterior (prolobous prostomium and no dorsal pores); a rotated dorsolateral view showing spermathecal pores in 7/8; a cocoon (shaded); ventral view of posterior; spermathecae in 8, male organs in 9–10; female organs in 11–12; a nephridium in 15; and details of anterior ventrum with segments numbered and pores labeled. The clitellum is shaded to its fullest extent (in life the whole body is dark coloured with the clitellum only slightly darker).

Internal anatomy: Cerebral ganglia in segment 2 originating from ventral nerve cord. Pharyngeal mass with numerous tendons up to segment 5 (i.e., to septum 5/6). Septa 5/6–9/10 thinning slightly, 10/11–11/12 also thin but enclosing ovarian segment; thereafter becoming membranous; septa in segment 12 distended by paired ovisacs. Blood vessels: dorsal large, single; ventral vessel narrower; long concertinaed hearts paired on either side of oesophagus in 6-9. Oesophagus long and narrow to 12 the latter half of which sometimes modified. True gizzards in 13-18 (i.e., six in neotype and in typical specimens described by Hatai), less often with up to nine or nine-and-a-half in 1/2 12, 13-20, 21 (Hatai); becoming increasingly muscular posteriorly. Intestine origin in 19 (neotype) or in segment after the last gizzard, with initial two segments "narrow tubular" (Hatai). Calciferous glands, typhlosole and intestinal caeca absent. Spermathecal ampulla as simple sacs distended by white flocculent (seminal) material and attached anteriorly to septum 7/8 in 8, with convoluted duct to a simple, small spermathecal chamber in 7/8. Testes paired with each male funnel enclosed in intraseptal testis sacs of 9/10 (acting as seminal vesicles) bulging into both 9 and 10. Vasa deferentia emerging from septum 9/10, long and convoluted and entering body wall near position in 10/11 of male pores, these latter overlain by sessile prostate glands (male atrium small). Ovaries as paired glandular attachments anteriorly in segment 11 on septum 10/11, with oviducts posteriorly transgressing septum 11/12 to female pores in 12. Large paired ovisacs, gravid with masses of relatively large orange-coloured eggs, filling segments 12, displacing septum 12/13, and sometimes extending further back to 13/14 (Hatai). Sessile glands correspond in position to external manifestations of genital markings (thus probably they exude some secretions from these markings). Nephridia large, holoic from 3 (Hatai) or 4 (neotype, but those in 3 perhaps small and overlooked in pharyngeal mass), absent from 10 (or vestigial and lost in vasa deferentia in neotype and Hikone specimen); vesiculate with elongate, sausage-shaped bladders and fatty deposits to the tubules (in some segments of neotype)



Figure 2. D. hattamimizu unscaled habitus (from Watanabe, 2005, fig. 1 after Hatai's 1931 original).



Figure 3. *D. hattamimizu* detailed internal anatomy showing the disputed paired nephridial funnels ("*n.m.*") sketched for only three of the nephridia (after Hatai, 1930: fig. 4).

in other segments they have more noticeable convoluted mesentery. Nephridia supplied with blood capillaries (Hatai and RJB pers. obs. in neotype) as is definitive of Megadrili.

Ingesta: Organic paddy mud with plant fibres, including root hairs, and few grits.

Cocoon: With same collection details as neotype and commensurate with the clitellum (Fig. 1), a large, turgid sphere with tapering or tubular processes at its poles; the body wall is thin and transparent suggesting nutrients are supplied internally (from unfertilized eggs?); cf. Ohfuchi (1938b).

Behaviour: Semi-aquatic; casting activity takes place at least partly on surface; constructs burrows approximating to worm's body width; moves rapidly though these burrows but becomes docile when handled and can easily be extended by hand (to ca. 600 or 1,000 mm without damage). Posterior regenerates found (RJB pers. obs.)

and Hatai wrote that damaged worm survival was "*astonishing*". No details yet known of breeding habits of this species, but location of the genital markings (GMs) would align perfectly in amphimictic concopulants, those in 6 and 7 opposing those in 12 and 11, and 9 to 9 mutually co-incident, thereby locating the male pores precisely over the spermathecal pores. Outer markings in 7 and those in 8 may be unilateral 'sperm blockers'/suckers. Associated GM glands possibly provide adhesives, and/or other exudates to help sterilize and exclude parasites (such as microbes, protozoa, or nematodes) during sperm transfer. Despite their protrusion in the preserved neotype (Fig. 1), it is unlikely that the spermathecal mounds intrude into male openings pouches during sperm exchange, rather than vice versa as would be expected.

Distribution: Japan, Honshu, ISHIKAWA-KEN (Hatai 1930; Kobayashi 1941; Easton 1981; Watanabe 2005; and RJB pers. obs.) Hatta-mura (village), now Hattacho, Kanazawa-shi (ca. 36°38'N 136°41'E) in the embankments of rice paddies and in adjacent parts of Kanazawa city alongside Kahoku Lake (ca. 36°34'N 136°39'E); Chubu-Chiho (Kanazawa) (Kobayashi 1941); SHIGA-KEN (Hatai 1931: 90?; Yuki 1940a?, b; Kobayashi 1941; Easton 1981; Watanabe 2005; and RJB pers. obs.) Lake Biwa (ca. 35°20'N 136°10'E) on the western and eastern shores in restricted locations; Kinki-Chiho (Shiga) (Kobayashi, 1941); FUKUI-KEN found by Makoto Uenishi (in litt., 9.XII.2009) at Mikata-ko, one of Five Lakes of Mikata near the Sea of Japan northwest of Lake Biwa. Watanabe (2005) argued that Easton's inclusion of HOKKAIDO, Ishikai (near Sapporo) from the report by Ohfuchi (1938a: 23, 24) was a mistake as Ohfuchi only listed it as an aquatic species occurring in Japan, i.e., not from Hokkaido. Hatai (1930) could not find it in other districts for ca. 80 km around Kahoku Lake in Ishikawa Prefecture and thought it an exotic species to Japan, from "some Eastern tropical lands", possibly introduced following Asiatic voyages of local merchant explorer Gohei Zeniya who died in 1852. Its distribution around Lake Biwa also appears somewhat patchy and restricted (Blakemore 2007b and vide supra) without noticeable barriers, as is characteristic for a species relatively recently introduced.

Conservation status: The Red Data Book of Japan lists *D. hattamimizu* as endangered and "*quasi-extinct*" (Anon. 2007), that of Ishikawa Prefecture lists it as Endangered – Level I (Anon. 2009), and that of Shiga Prefecture lists it as an insufficiently documented species (Nishino 2006).

Habitat: Almost always associated with rice paddies and banks and ditches of ponds/lakes.

Species associations: Other earthworms at the Hatta type locality were not investigated, although Hatai (1930: 506) noted *D. hattamimizu* abundance to the exclusion of other worms, despite his later description of *Metaphire yamadai* (Hatai, 1930) from the same location. Specimens (pers. obs. RJB) found at Hikone paddy rice fields leased to Shiga Prefectural University were of these species: *Drawida japonica* (Michaelsen, 1892) that also compares with *D. barwelli, Helodrilus hachiojii* Blakemore, 2007, *Amynthas hupeiensis* (Michaelsen, 1895), *Amynthas robustus* (Perrier, 1872) and some miscellaneous *Amynthas*/*Metaphire* spp. immatures. A large (~10 cm) black leech (unidentified Hirudinea) was also present at the site. [Note that *Eukerria saltensis* (Beddard, 1895) was not found during this brief survey; however fine grandular casts looking similar to those it produces in other local paddies were seen around some fields]. All specimens are labeled and deposited in the LBM collection as part of Accession No. 'Misc. Invert.' FY2009–13.

Endosymbionts/Parasites/Predators: None neither observed nor yet recorded except possibly the black leech found on site at Lake Biwa.

Pharmacology: *Drawida hattamimizu* is one of the species listed as providing a powdered extract therapeutic medicament for the treatment of thrombosis and in antihyperlipemic, antidiabetic, antihypertensive and antihypotensive preparations under US Patent Nos. 5186944 and 5024844 by Ishii et al. (1991 - http://www.freepatentsonline.com/5186944.html/ http://www.freepatentsonline.com/5024844.pdf).

Ecological and economic importance: Hatai (1930) wrote that this species was being used by the local fisherman as live bait for eel fishing in Ishikawa. He also thought its many anatomical virtues made it an ideal subject for physiological investigation. Yuki (1940a, b) mentioned that fishermen in Shiga-ken, where Lake Biwa is situated, also using a worm that he identified as D. hattamimizu to catch 'gigi', Pelteobagrus nudiceps (Sauvage, 1883) – a type of freshwater catfish. This earthworm's current distribution has been restricted by voluntary transportation controls imposed by farmers who consider it a threat to paddy embankments and bunds (Hatai 1930; Watanabe 2005). Hatai was told by farmers that burrows of D. hattamimizu were "finger-sized" and drained the raised paddy fields; however, the burrow widths observed during the current work were all less than 1 cm. Larger crayfish burrows were seen in paddy embankments at Lake Biwa, which may easily be mistaken for large worm holes, as happened with Megascol*ides australis* McCoy, 1878 that was also at one time thought, erroneously, to construct chimneyed freshwater crayfish ('yabbies' = Engaeus sp.) hollows (vanPraagh 1992). Watanabe (2005) described and photographed small granular casts of D. hattamimizu in a harvested rice paddy, but larger ribbon casts – like toothpaste squeezed from a tube - were seen to be deposited in the burrows as the worms attempted to escape capture (RJB, pers. obs.). Watanabe (2005) further reports this species is still used extensively in Ishikawa by the local eel fishermen as bait, and he advocates its local conservation.

Remarks: The current report augments the original. Differences in the neotype from the original description by Hatai (1930) are that his specimens sometimes had an extra pair of markings in 13 (as observed in some specimens described herein) and that a smaller pair of markings was newly found in segment 7. Further, Hatai (1930) said that internal glands were present even if the external markings were absent, but in the neotype no such (non-functional?) internal glands were seen in segment 13 where markings would be expected. This character may thus be variable. Moreover, his detailed description of the nephridia is not wholly supported in the neotype and other specimens inspected inasmuch as the two membranous preseptal umbrella-like funnels he claimed to observe from each nephridium are not found (cf. Fig. 3). Perhaps Hatai interpreted the extensive mesentery on the nephridial tubules as being funnel-shaped and this misconception was enhanced in his artist's figures. Hatai (1930) reported the nephridia in 9 and 11 as being vestigial or absent whereas they are present in the neotype (and

in other specimens), and he reported nephridia in 10 as being present, whereas they are aborted (or vestigial and implicated within the convoluted vasa deferentia) in the current specimens. The forms and exact locations of the male and spermathecal pores are now brought into their proper relationships. In all other regards, the descriptions (including behaviours and locations) unequivocally confirm the neotype as belonging to the same species, from the same type locality, as that originally described nearly 80 years ago by Hatai (1930). Marker character queries from Easton (1981: tab. 1) and his other morphological and distributional mistakes from 30 years ago are now resolved.

DNA Results (raw data in Appendix)

Current COI sequences are reported online with CBOL's Internet GenBank facility with Accession Nos. GQ500899-GQ500902 - this the first ever for a described earthworm type specimen. The sequences of the neotype and a topotype agree 100%, whereas nucleotide bases of a *D. hattamimizu* specimen from Hikone near Lake Biwa differ from these by ca. 1.14%. Since this difference is only slight, the specimens are confirmed as conspecific despite the limited sample. This is the first known sequence for *D. hattamimizu* so, as expected, no correspondence was found from other Internet DNA/RNA sequence searches.

The COI nucleotide sequence of a specimen of *Drawida* cf. *japonica* also from the Hikone site concurs with corresponding sequences of *Drawida japonica japonica* vouchers in GenBank by ca. 82.87%. But, as this represents a concomitant difference of 17.13%, their mutual conspecificity may be questioned (data in Appendix).

Discussion

The overriding Principle of Typification (ICZN 1999: Art. 61) provides for "*the objective standard of reference*" of a nominal species, further stating that: "*No matter how the boundaries of a taxonomic taxon may vary in the opinion of zoologists the valid name of such a taxon is determined from the name-bearing type(s)*..". Hence there is a need for DNA sequence analyses aimed at helping resolve taxonomic ambiguities in earthworm systematics to be solidly based on types. This has been recognized for many years in the routine preservation of both types and voucher specimens, e.g. those in the Earthworm Collection of the Australian National Insect Collection (ANIC), in 85% EtOH ethanol rather than DNA-disruptive formalin (Blakemore 1994; 1995; 2000a).

In the current work, the historical literature and morphological data have been combined with modern molecular information for the first time for an earthworm having an indisputably correct scientific species name. Moreover, *Drawida hattamimizu* Hatai, 1930 usually occurs at the head of national species lists of Japanese earthworms that are systematically ordered by taxa (*Drawida* being one of the more primitive megadriles) and alphabetically (e.g. Easton 1981: 35; Blakemore 2004, 2005, 2007a).

As such, it sets a precedent for progressively DNA barcoding all the valid species of Japanese earthworms from their types, and, where expedient, from the types of their purported junior synonyms. It is here recommended that any future 'new' earthworm taxa named under ICZN from this country, or elsewhere, be simultaneously treated for such unambiguous CBOL barcodes to meet current genetic/informatic standards.

Neotypification

Although neotypification in the absence of a name-bearing type is non-routine under the current Code (ICZN 1999: Art. 75), this mechanism allows a name and its hypothetical species concept to be defined objectively and tied permanently to a tangible specimen from which DNA can be extracted. At the same time, the aim of DNA barcoding without some ultimate reference is ungrounded. It is thus necessary at some stage for molecular data to objectively refer to the name-bearing type of a taxon. The unambiguous ideal, as herein, is to sequence directly from a type. Qualifying conditions of ICZN (1999: Art. 75.3) are that: "*A neotype is validly designated when there is an exceptional need and only when that need is stated expressly and when the designation is published with the following particulars...*". The required particulars, in this case, are:

Exceptional need: The principal justification for neotypification of Drawida hattamimizu is the unique opportunity, nearly 80 years after its description, to meet ICZN qualifying conditions by collecting specimens from the type locality and to simultaneously provide morphological and molecular definitions that will leave no question about its identity or taxonomic status. It is designated with the express purpose of clarifying the taxonomic status. Thirty years ago, Easton (1981: 37) raised doubt on all Japanese Drawida when he wrote: "None of the eight species considered here is particularly well known and the specific status of each requires closer investigation." Also in his Table 1 of Marker Characters he has "?"s for D. hattamimizu and notes some of its other features that were poorly defined until now (e.g. forms and locations of the male and spermathecal pores). These doubts about its specific status, plus other omissions or errors in Hatai's original description are now reconciled through dissection and inspection of the neotype. Easton's (1981) mistaken listing of *D. hattamimizu* from Hokkaido has already been mentioned. Hatai (1930) had thought it an introduced species due partly to its restricted distribution in Ishikawa Prefecture. The subsequent finds do not fully refute this, and specimens from the Lake Biwa population conform to its specific identity, despite initial uncertainty (Yuki 1940a). Conspecificity was confirmed partly on barcode comparison with the neotype despite their being evidence of slight genetic drift (vide supra). Although Drawida hattamimizu appears well recognizable and its identity in Japan is now no longer in any doubt, the designation of a neotype is a practical necessity for the sake of anchoring its DNA (e.g. COI barcode) that will henceforth play a major rôle in identifying specimens of this species, genus and family. The neotype and its associated COI barcode will likely come into play in recognizing whether this species has been unearthed in its land(s) of origin, while also distinguishing it from any congeners there. This study is a first step towards the eventual taxonomic clarification, via DNA-based differentiation, of the Moniligastridae which is a notoriously difficult group to work on. In particular, the genus *Drawida* with its many small, similar looking and often misdescribed taxa – not least its type-species *D. barwelli* and its numerous synonyms as detailed by Blakemore (1994, 2008a) – requires discrimination. Thus *D. hattamimizu* Hatai, 1930 is offered as a start unto itself with the doubt about its identity in Japan raised by Easton now resolved and, moreover, by its being the first example of a single earthworm taxon removed from a real and pressing "*complex zoological problem*": that of objectively reconciling nomenclature, specimen identity, species boundaries and barcode genomics (*vide infra*). This complex zoological problem is especially acute and chronic for earthworm taxonomy in Japan, for reasons already mentioned in the Introduction above.

Differentiating characters and consistency with the original description: The data and description (morphology, ecology, behaviour) of the neotype herein complies tolerably with the original detailed description by Hatai (1930) except, most notably, some details of the nephridia, genital pores, and genital markings. Moreover, its morphological features confirm this taxon in *Drawida*, although Hatai (1930) initially thought it had some resemblance to *Eupolygaster* Michaelsen, 1900 (nom. nov. pro *Polygaster* Horst, 1896) as then defined. Characters that differentiate *Drawida hattamimizu* from its known congeners in *Drawida* are its unusual large size and dark colouration, the extent of its clitellum, its distinctively pronounced genital markings along with its polygiceriate arrangement - all now combined with its genomic COI profile.

Specimen recognition: The LBM and GenBank registration data, collection data, and morphological description provided herein ensure recognition of the unique specimen designated as the neotype of *D. hattamimizu*.

Confirmation of loss of original type specimens: Hatai failed to routinely typify his new species. No types were explicitly designated in Hatai's (1930) original description of D. hattamimizu despite the description being based on "many specimens". These specimens were thus all syntypes, but none is known to still exist. The same situation pertains to all other historical Japanese earthworm types that were not deposited in European institutions, e.g., those species poorly described by Goto and Hatai (1898, 1899). Type material of *D. hattamimizu* has not been reported by any prior authority who has mentioned this taxon (as listed in the synonymy above), including the catalogue by Reynolds and Cook (1976), and it is omitted from the limited JTYPES (2009) facility. Hatai was the first Professor of Biology at Tohoku University in Sendai, but our inquiries to the Department of Biology there (Dr. Jotaru Urabe) and to the Tohoku University Museum (Dr. Jun Nemoto) regarding his earthworms were fruitless: none are preserved there. The suggestion was made, however, to check the Saito Ho-on Kai Museum of Natural History in Sendai, inasmuch as Hatai's collecting trip to Hatta and other work was supported by funding from the Saito Ho-on Kai several years before the museum opened, and Hatai later published on other earthworms in that museum's journal. In 2006 all the collections of the Saito Ho-on Kai Museum were transferred to the National Museum of Nature and Science in Tokyo, where the cataloguing of the over 1,200 earthworm specmens has nearly been completed by Dr. Toshiaki Kuramochi who found no specimens labeled as *Drawida hattamimizu*. This was confirmed from personal enquiries and inspections by RJB and MJG in 2009/2010. Also, the only specimen clearly from Hatta is labeled as "*Pheretima acincta* (Goto and Hatai)" (= *Metaphire acincta*). Thus we firmly conclude that syntype material of *D. hattamimizu* no longer exists.

Proximity to type locality, and suitability of depository: The neotype is from the stated type locality and is deposited in a research institution with proper facilities and accessibility, *viz.* the Lake Biwa Museum in Kusatsu, Shiga Prefecture, Japan. Also, the DNA sequence data is freely available via BCOL website (GenBank).

Reiterating the main consideration, this study is the first known instance of DNA analysis and barcoding of an earthworm type specimen, as all other published molecular works (at species, genus and family levels) appear based on voucher specimens that are unfixed to the types of the specific names claimed and as such do not strictly comply with ICZN nomenclature. It is anticipated for future mandatory DNA barcoding, using prevailing technologies that are nevertheless expected to develop rapidly, of all new types and of all previously known taxa so that exhaustive and accurate biodiversity inventories and species identification libraries (e.g. that of the Barcode of Life Data Systems – BOLD 2010) may be compiled, despite the numerous obstacles such fledgling work entails.

DNA Barcoding

Criticism of the current GenBank as a repository for DNA barcodes has been made by Pleijel et al. (2008), who were concerned about routine voucher source materials, and by Chang et al. (2009) who were more worried about names – but both missed the bigger issue of species types. These latter authors re-evaluated barcode use in earthworm identifications by, amongst others, Huang et al. (2007) and concluded: "*The accuracy of species names is the basis of taxonomic and systematic studies. Certainly, the correct use of names is crucial for testing the ability of DNA barcoding as a tool to discriminate species. This fact might sound obvious, but several studies aiming to test DNA barcoding efficiency have neglected this basic requirement.*" Huang et al. (2007) had several misnamed or misplaced taxa in their list of Chinese species (cf. species checklists and inventories in Blakemore 2003, 2006, 2007a).

In one specific case, Huang et al.'s study showed a remarkably consistent intraspecific sequence agreement of 100.00% for four specimen samples claimed as *Drawida japonica japonica* (GenBank Accession Nos. EF077597-EF077600 from Huang et al. vouchers). In the current limited study, a sequence from a Hikone specimen of *Drawida* cf. *japonica*, included only for general comparison, differs somewhat from those Genbank *Drawida japonica japonica* vouchers by ~17.13%, thus conspecificity with these non-type Chinese specimens is not wholly supported. For resolution, further studies are required to check Japanese specimens against barcodes derived from *D. japonica* (syn-)types in Zoologisches Museum Hamburg (No. 403) and/ or the Museum für Naturkunde, Berlin (No. 2122), and the Chinese specimens, at least, require comparison with the types of synonymic *Drawida grahami* Gates, 1935 (Smithsonian Institution, USNM 20093), also with types of erstwhile sub-species *Moniligaster bahamensis* Beddard, 1893 and *Drawida japonica siemsseni* (Michaelsen, 1910) (Hamburg No. 6233) plus its likely new synonyms (Blakemore, in prep.) of *D. propatula* Gates, 1935: 449 from China and *Drawida calebi* Gates, 1945: 211 from India.

Moreover, if the supposedly distinctive but uneven genital markings of *D. japonica* eventually prove to be parasitic artefacts (e.g. in the Japanese material they appear similar to *Monocystis sp.* gregarine cysts - RJB, pers. obs.), then its synonymy with parts of a prior *D. barwelli* species-complex seems feasible. Further testing of *Drawida* relationships without molecular consideration of the types of the type-species *D. barwelli* (Beddard, 1896) (Natural History Museum, London BMNH:1904:10:5:522–3, 582, cf. Easton 1984: 112), plus those of its ten or more synonyms, is quite pointless.

Interminable debate (e.g. Chang et al. 2008) on "*non-monophyly*" and boundaries of megascolecid pheretimoid species in genera such as *Amynthas* Kinberg, 1867 and *Metaphire* Sims & Easton, 1972 can be quelled by objective molecular analysis and comparison of the types of their respective type-species (Blakemore 2002, 2008c). Furthermore, the status of the families Ocnerodilidae, Acanthodrilidae, Exxidae, Octochaetidae, and Megascolecidae etc. can be unequivocally determined only with reference to the characteristics, including the DNA, of the definitive types of the type-species of their type-genera (Blakemore 2005, 2008b) rather than piecemeal from random putative constituents.

ICZN Nomenclature vs. molecular diversity and "Cryptic" or "Provisional" species

Following the basic biological convention of binomial Linnaean scientific naming that has evolved over the past 250 years, the formulation and application of a taxon's name from sub-species to super-family level must strictly comply with the current edition of an International Code (ICZN 1999). Strains, morphs, varieties, ecotypes, haplotypes, avatars and other infrasubspecific entities are unrecognized by ICZN, as are higher theoretical classifications. In contrast, each valid taxon name is grounded under the Principle of Typification to a representative specimen – the Type – under a further Principle of Priority. Such nomenclatural considerations are only slightly more complex when parthenogenesis occurs, and this is common to many of the cosmopolitan earthworm species, whereby all the variously degraded morphs belong under the first valid and available name, regardless if originally applied to the amphimitic (i.e. sexual) form, where this is found to exist, or to some parthenogenetic form. Under ICZN (1999: Art. 72.5.1) an animal, whether mature or not, or any part of an animal, even as little as a fragmentary trace fossil, or just the nucleus of an embryo from a cocoon are eligible to provide the type. Thus all varieties of dogs are but a single taxon:

Canis lupus familiaris Linnaeus, 1758 (*typus amissus*), but not all terrestrial worms are the same as *Lumbricus terrestris* Linnaeus, 1758 (neotype BMNH 1973:1:1).

In the UK, King et al. (2008) recently claimed to "open a can of worms" by reporting "unprecedented sympatric cryptic diversity within British lumbricid earthworms" in the form of molecular cryptic species and stated that this "has profound consequences for all areas of earthworm research." But they did not anchor their work with comparison to the types of any of the six or so species they claimed to study. Their conclusions, as with all previous (and current) molecular or DNA analyses of earthworms, are thus ungrounded. For example, they claimed that "Phylogenetic analyses of mitochondrial COI and 16S genes showed the presence of five highly divergent lineages, suggesting the presence of multiple cryptic species within Allo. [i.e., Allolobophora] chlorotica", and "furthermore, detailed analysis of one common species - Allolobophora chlorotica - shows that it is made up of at least three species in Britain and one additional species in central Europe" (Anon. 2008). Intraspecific divergence was apparently set at between 12-14% (cf. >10% by Rougerie et al. 2009: fig. 2) which may be too low for COI genes as compared, say, to 16S or 18S genes (e.g. Cech et al. 2005; Siddal et al. 2001). However, even if their multi-species conclusions are valid, it would nevertheless be no more than an interim parataxonomy which, according to Krell (2004), "does not fulfill the criteria of a scientific method". One could not identify or arbitrarily name any one of King et al.'s specimens or strains as "A. chlorotica" proper without checking against the types. This is because Allolobophora chlorotica chlorotica (Savigny, 1826), a name that is objectively tied under ICZN to its extant Paris type, has 17 known synonyms plus three or more sub-species (including one new synonym as fully listed by Blakemore 2007a, 2008a). Each of these synonyms, if valid and available for use, competes for priority requiring their types to be tested progressively under the constraints of ICZN Principle of Priority. Only if DNA sequences of the types of none of these 20 prior taxa complied with King et al.'s "cryptic species" may it be strictly appropriate, or even possible, to suggest which are already scientifically named and which are potentially truly new to science.

Moreover, to suggest, as these authors do, it necessary to consider which particular molecular lineage of *A. chlorotica* is being investigated in future studies, is not justified by evidence of any appreciable morphological, physiological nor ethological differences between any "*strains*" King et al. (2008) claim to have discovered. If resurrection of synonyms is not merited, then possibly these "*cryptic species*", at this particular level of genetic divergence, are analogous to ecotypes or to the botanical microspecies aggregate concept (Anon. 2010). Some components may represent a parthenogenetic species-complex, at least from continental Europe, where larger genetic distances are possible due to polyploidy and lack of back-crossing (Cs. Csuzdi pers. comm. to RJB). Alternatively, these findings may relate to mere ghosts of nuclear mitochondrial pseudogenes (numts) as discussed by Siddall et al. (2009).

Sims and Gerard (1985, 1999) said *A. chorotica* (only in UK?) is obligatory biparental; and they believed the colour dimorphs to be ecotypes with the nominal green-coloured phase in pastures and waterways while the unpigmented phase is from well-drained gardens and woodlands (e.g. Blakemore 2000b; Lowe and Butt 2007). Some reproductive separation of nominal *A. chlorotica "green morphs*" from one of its current synonyms, *Enterion virescens* Savigny, 1826 referred to as "*pink morphs*", was indicated by Lowe and Butt (2008), but this too needs to be confirmed against molecular evidence from its Paris type and the name-bearing types of all 20 synonyms and sub-species alluded to above. All the more so since Savigny's varietal name "*virescens*" in Latin suggests "*tending to a green colour*". Thus the taxonomic "*can of worms*" was already wide open well before King et al. (2008) added to the debate. Although a solution may depend on DNA profiling (with current or future methods), this technology needs to be combined with rigorous traditional and systematic eco-taxonomic study.

Taxonomic resolution also remains elusive, despite claims by Pérez-Losada et al. (2009), for boundaries of the *Aporrectodea caliginosa* (Savigny, 1826) species-complex *sensu* Blakemore (2002, 2007a; 2008a) with types of supposed component species as yet untested. Another detailed study by Briones et al. (2009) completely avoided types, thereby leaving most of the results invalid and serving to demonstrate the inherent weakness of failure to follow first principals. Surprisingly, Rougerie et al. (2009: 798, fig. 1) intentionally advocate such disassociation of specimen barcodes from *the* essential barcode of the "*Holotype*" of a named species.

Similar reports variously claiming to differentiate iconic Eisenia fetida fetida (Savigny, 1826) from E. fetida andrei Bouché, 1972 - this latter being cited as either a synonym, morph, variety, sub-species, or as a separate species - have never been satisfactorily proven because their relevant types have not been sequenced. Supposedly recorded from low pH composts and laboratory cultures of E. fetida, E. andrei differs imperceptibly as specimens vary in their colouration (e.g. Sims and Gerard 1999). [Moreover, the Eisenia nordenskioldi (Eisen, 1879) species-complex is implicated, at least in part - see Blakemore (2008a)]. The two entities are alleged to represent molecular taxa that can surely be differentiated only by enzymic gel electrophoresis (Jaenike 1982), but this too requires confirmation from types of both nominal taxa. Unfortunately, the starting point for Jaenike's definitive study was a greenhouse population maintained by Dr Roy Hartenstein at the SUNY Syracuse campus from founding stocks initially procured from a number of bait dealers obtained from "all over", and supposed to consist of striped ("foetida") and unstriped ("andrei") vouchers that were deposited in the American Museum of Natural History. Øien and Stenersen (1984) later obtained similar electrophoretic results, but their taxonomy was somewhat confused and was equally ungrounded.

Dominguez et al. (2005) claimed to have demonstrated "*reproductive isolation between* E. andrei *and* E. fetida; *they can therefore be considered distinct biological species.*" However, these authors failed to consider polyploidy, and the starting point for this study was Spanish and Brazilian populations, far removed from the type localities, that were differentiated neither by molecular/electrophoretic nor morphological analysis – presumably only striped or non-striped superficial colouration was used as the determinant. It should be stressed that colouration in earthworms,

although manifestly obvious in live specimens, is a notoriously unreliable character for morpho-taxonomic determination due partly to influence of age, habitat and diet. At some stage, dissection or sectioning and microscopy is required (Gates 1972; Sims and Gerard 1985, 1999; Blakemore 2002, 2008a).

In actuality, *Eisenia andrei* may yield taxonomic priority to one or more of about a dozen other junior synonyms of *E. fetida*. Moreover, it is possible that multiple additional *E. fetida* "varieties" are involved (as indicated by Pérez-Losada et al. 2005). However, since no morphological or molecular analysis of type material of any one of the *E. fetida* species-group prioritized synonyms has been attempted, claims of correct taxonomic assignment are inconclusive (see Blakemore 2007a, 2008a for synonymy and discussion).

In another example, Cech et al. (2005: 95) deduced that recent molecular analysis of "Eisenia andrei ... is most likely a misidentification error and actually Erseus & Kallersjo (2004) used in their analysis a specimen of Dd. subrubicundus" – but this identity too must be regarded as speculative without genetic comparison with the latter's types deposited in Turin.

Definitive results would not be quite as important for European regional taxa alone, were it not for the fact that those species mentioned above–and several of them are generic types–occur as cosmopolitans in places as distantly spread as Japan, Taiwan, New Zealand, Tasmania and Chile (Blakemore 2007a, 2008a, 2009), for example, and thus any nomenclatural implications have profound ripples worldwide.

Summary conclusions

As a relatively new science, molecular or genomic taxonomy has considerable scope for rapid development, there being both a technology lag and a taxonomic impediment. It is likely that some claims of species divergence are premature, especially where no attempt has been made to link the genetic information to any morphological or behavioural characteristics of the putative "*cryptic*" or "*provisional*" species vouchers except via their interim names.

Realistically, genetic studies and their future derivatives are the only hope to resolve some of the inherited nomenclatural impasses, notwithstanding taxonomic rigour as a prerequisite. Interestingly, Rougerie et al. (2009: 798), who preferentially advocate "Molecular Operational Taxonomic Units (MOTUs)" and surrogate vouchers, seem to further misconstrue the current ICZN concepts of synonyms, types and neotypification when they write: "In any case, the use of DNA to re-evaluate diagnostic morphological characters may allow a robust assignment of recently collected specimens to an ancient type using morphology, or alternatively, in these groups where overlooked cryptic species may be very frequent, the recourse to designation of neotypes for which DNA data are available might be the safest and most efficient way to proceed."

Museum shelves the world over are already stacked with vouchers and unsorted survey collections awaiting nomenclatural evaluation by overtaxed and often underresourced curatorial specialists. The definitive solution requires a coupling, once and for always, of each named species' types directly and expeditiously to their DNA profiles so that specimen identification in the field, or at the laboratory workbench, is autonomous – irrespective of morphological diagnoses – and the remaining specialist taxonomist's workload is unburdened. Indeed it would be obviously most sensible and efficient to at least seek competent taxonomic consultation before attempting any definitive phylogenetic study for a scientifically named earthworm taxon or, for that matter, any biodiversity survey or molecular systematics project, rather than to defer or to retrospectively delegate this responsibility. The first choice must be careful selection of proper reference specimens, ideally the types to which names are permanently attached, not merely to temporary OTU voucher surrogates which, as in the case of King et al.'s (2008) proposed cryptic lineage vouchers, seem ineligible to qualify as any sort of "*neotypes*".

It is hoped the present work will serve as a model for the kind of linkage of morphological species delimitation to DNA sequences and to ICZN name-bearing types that will, ultimately, be required to revive earthworm taxonomy and phylogeny and to realize all the benefits promised by the addition of molecular information to help define an earthworm species and its ecological interactions for both specialists and non-specialists.

A comprehensive world-wide, type-based resolution of these complex zoological issues in terrestrial earthworm nomenclature and genomic systematics – for all 6,000 nominal taxa – is essential and urgent, especially in this UN 'International Year of Biodiversity'. Sadly, no more than a simple start for just a single, relatively uncomplicated, species from a rice field in Japan is within the present scope and resources.

Acknowledgements

All taxonomic descriptions and conclusions presented here are by the first author (RJB). Laboratory, library and curatorial facilities were provided for a week at the Lake Biwa Museum by MJG; travel on that occasion was funded by LBM Comprehensive Research Project S06-02. All DNA sequences were run by EKK and her part of this study was partly supported by Japan Society for the Promotion of Science Invitation Fellowship (JSPS No. S42300038) and a KAKENHI (20008766) grant. Dr. Misako Urabe and Yuko Goto (University of Shiga Prefecture) provided assistance in the field in Hikone. We also thank M. Kawato, E. Fujiwara, and F. Pradillon for their help in the JAMSTEC molecular laboratory. Dr. Csaba Csuzdi from Hungarian National University, Budapest kindly commented on an earlier draft, and Yuko Hiramoto assisted with translation of some Japanese papers. Dr. Jotaro Urabe of the Department of Biology, Tohoku University and Dr. Jun Nemoto at the Tohoku University Natural History Museum, and Dr. Masaaki Tomokuni, head of Zoology at the National Museum of Nature and Science, Tokyo and Dr. Toshiaki Kuramochi, the Annelida curator there, are all thanked for confirmation of the absence of Dr. Shinkishi Hatai's Drawida hattamimizu materials at their respective institutions.

References

[For brevity, not all taxonomic citations are included. Anon. = Anonymous author(s)].

- Anon. (1997) Red Data Book of Russian Federation. http://enrin.grida.no/biodiv/biodiv/ national/russia/state/00440.htm
- Anon. (2007) Red Data Book of Japan. http://www.biodic.go.jp/english/J-IBIS.html
- Anon. (2008) Biotechnology and Biological Sciences Research Council (2008, October 19). Opening A Can Of Worms: Serendipitous Discovery Reveals Earthworms More Diverse Than First Thought. ScienceDaily. http://www.sciencedaily.com/releases/2008/10/081010081652.htm [accessed August 4, 2009]
- Anon. (2009) Red Data book for Ishikawa-ken. http://www.pref.ishikawa.jp/sizen/reddata/ RDB_2009/4_ato/kennsaku2/9-1hattajyuzuimimizu.pdf
- Anon. (2010) Wikipedia article on botanical 'microspecies'. http://en.wikipedia.org/wiki/ Apomixis [accessed 13.I.2010]
- Bely AE, Wray GA (2004) Molecular phylogeny of naidid worms (Annelida : Clitellata) based on cytochrome oxidase I. Molecular Phylogenetics and Evolution 30: 50–63.
- BenhamWB (1890) An Attempt to Classify Earthworms. Quarterly Journal of Microscopy Science XXXI 1890 175–200. http://jcs.biologists.org/cgi/reprint/s2-31/122/201.pdf
- Blakemore RJ (1994) Earthworms of south-east Queensland and their agronomic potential in brigalow soils. PhD thesis, Brisbane, Queensland: University of Queensland.
- Blakemore RJ (1995) A curatorial inventory of earthworms in the ANIC earthworm collection. CSIRO, Division of Entomology, Canberra. http://bio-eco.eis.ynu.ac.jp/eng/database/ earthworm/Australasian%20Earthworms%5CRegister.xls
- Blakemore RJ (1999) The diversity of exotic earthworms in Australia a status report. In: Ponder W, Lunney D (Eds) Proceedings of "The Other 99%". Transactions of the Royal Zoological Society of NSW, 1999: 182–187. http://bio-eco.eis.ynu.ac.jp/eng/ database/earthworm/Australasian%20Earthworms%5CAustralian%20Exotics.pdf or http://biocollections.org/pub/worms/docs/Blakemore-eworms-Diversity-of-exotics. html
- Blakemore RJ (2000a) Tasmanian Earthworms. CD-ROM Monograph with Review of World Families. 'VermEcology', Canberra, 800pp.
- Blakemore RJ (2000b) Ecology of earthworms under the "Haughley Experiment" of organic and conventional management regimes. Biological Agriculture & Horticulture 18(2): 141– 159. http://bio-eco.eis.ynu.ac.jp/eng/database/earthworm/Haughley%5CHaughley.pdf
- Blakemore RJ (2002) Cosmopolitan Earthworms an Eco-Taxonomic Guide to the Peregrine Species of the World. VermEcology, Kippax, Australia, 426 pp.
- Blakemore RJ (2003) Japanese Earthworms (Annelida: Oligochaeta): a Review and Checklist of Species. Organisms, Diversity and Evolution 3(3): 241–244.
- Blakemore RJ (2005) Whither Octochaetidae? A review of its family status (Annelida: Oligochaeta). In: Pop AA, Pop VV (Eds) Advances in Earthworm Taxonomy II. Proceedings IOTM2, Cluj University Press. Romania: 63–84.

- Blakemore RJ (2007a) Chapters in: A Series of Searchable Texts on Earthworm Biodiversity, Ecology and Systematics from Various Regions of the World. In: Ito MT, Kaneko N (eds) CD-ROM publication by Soil Ecology Research Group, Graduate School of Environment & Information Sciences, Yokohama National University, 79–7 Tokiwadai, Yokohama 240–8501, Japan. http://bio-eco.eis.ynu.ac.jp/eng/database/earthworm/ [accessed March, 2007].
- Blakemore RJ (2007b) Review of Criodrilidae (Annelida : Oligochaeta) including *Biwadrilus* from Japan. Opuscula Zoologica 37: 11–22. http://opuscula.elte.hu/PDF/Tomus37/2_Review%20of%20Criodrilidae.pdf
- Blakemore RJ (2007c) *Helodrilus hachiojii* sp. nov. (Oligochaeta: Lumbricidae) from Japan. Edaphologia 82: 17–25. http://www.soc.nii.ac.jp/jssz/htmls/Edaphologia/Edaphol50E. html
- Blakemore RJ (2008a) Cosmopolitan earthworms an Eco-Taxonomic Guide to the Species (3rd Edition). VermEcology, Yokohama, Japan, 757pp.
- Blakemore RJ (2008b) Phylogeny of Megascolecidae revisited with recourse to non-molecular means. In: Pavlíček T, Cardet P (Eds) Advances in earthworm taxonomy III (Annelida: Oligochaeta). The Environment of Service of the Ministry of Agriculture, Natural Resources and Environment of Cyprus, Nicosia: 11–22.
- Blakemore RJ (2008c) Review of Oriental pheretimoids (*Pheretima* auct. Megascolecidae) with description of a new genus. In: Pavlíček T, Cardet P (Eds) Advances in earthworm taxonomy III (Annelida: Oligochaeta). The Environment of Service of the Ministry of Agriculture, Natural Resources and Environment of Cyprus, Nicosia: 23–36.
- Blakemore RJ (2009) Cosmopolitan earthworms a global and historical perspective. Chapter 14. In: Shain DH (Ed) Annelids as Model Systems in the Biological Sciences. John Wiley & Sons, NewYork, 257–283.
- Blakemore RJ (in press) Saga of Herr Hilgendorf's worms. In: Pavlicek T, Csuzdi Cs (Eds) IOTM Book of Abstracts. Dicle University, Diyarbakır, Turkey.
- BOLD (2010) Barcode of Life Systems online informatics workbench facility. http://www. boldsystems.org/views/login.php [accessed 23.II.2010]
- Briones MJI, Morán P, Posada D (2009) Are the sexual, somatic and genetic characters enough to solve nomenclatural problems in lumbricid taxonomy? Soil Biology & Biochemistry 41(11): 2257–2271.
- CBOL (2010) 'Protocols'. Consortium for the Barcode of Life. Barcode of Life Secretariat C/- National Museum of Natural History, Washington, DC. http://www.barcoding.si.edu/protocols.html [accessed 23.II.2010]
- Cech G, Csuzdi Cs, Marialigeti K (2005) Remarks on the molecular phylogeny of the genus Dendrobaena (sensu Pop 1941) based on the investigation of 18S rDNA sequences. In: Pop AA, Pop VV (Eds) Advances in Earthworm Taxonomy II. Proceedings IOTM2, Cluj University Press, Romania: 85–98.
- Chang C-H, Lin S-M, Chen J-H (2008) Molecular systematics and phylogeography of the gigantic earthworms of the *Metaphire formosae* species group (Clitellata, Megascolecidae), Molecular Phylogenetics and Evolution 49: 958–968.

- Chang C-H, Rougerie R, Chen J-H (2009) Identifying earthworms through DNA barcodes: Pitfalls and promise. Pedobiologia 52: 171–180. doi: 10.1016/j.pedobi.2008.08.002.
- Darwin CR (1881) The Formation of Vegetable Mould through the Action of Worms with Observations on their Habits. Murray, London, 326pp.
- Dominguez J, Velando A, Ferreiro A (2005) Are *Eisenia fetida* (Savigny, 1926) and *Eisenia andrei* Bouché (1972) (Oligochaeta, Lumbricidae) different biological species? Pedobiologia 49: 81–87.
- Easton EG (1981) Japanese earthworms: a synopsis of the Megadrile species (Oligochaeta). Bulletin of the British Museum (Natural History) Zoology 40(2): 33–65.
- Easton EG (1984) Earthworms (Oligochaeta) from islands of the south-western Pacific, and a note on two species from Papua New Guinea. New Zealand Journal of Zoology 11: 111–128.
- Folmer O, Black M, Hoeh W, Lutz R, Vrijenhoek R (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3: 294–297.
- Gates GE (1959) On a taxonomic puzzle and the classification of the earthworms. Bulletin of the Museum of Comparative Zoology, Harvard 121(6): 229–261.
- Gates GE (1962) On some Burmese earthworms of the moniligastrid genus *Drawida*. Bulletin of the Museum of Comparative Zoology, Harvard 127: 297–373.
- Gates GE (1972) Burmese Earthworms, an introduction to the systematics and biology of Megadrile oligochaetes with special reference to South-East Asia. Transactions of the American Philosophical Society 62(7): 1–326.
- Goto S, Hatai S (1898) New or imperfectly known species of earthworms. No. 1. Annotationes Zoologicae Japonensis 2: 65–78.
- Goto S, Hatai S (1899) New or imperfectly known species of earthworms. No. 2. Annotationes Zoologicae Japonensis 3(1): 13–24.
- Gregory TR, Hebert PDN (2002) Genome size estimates for some oligochaete annelids. Canadian Journal of Zoology 80: 1485–1489.
- Hatai S (1930) On *Drawida hattamimizu*, sp. nov. Science Reports of the Tohoku Imperial University. 4th Series. Biology 5(3): 485–508.
- Hatai S (1931) Mimizu (Earthworms). Kaizou Sha, Tokyo, 218 pp. [In Japanese].
- Huang J, Xu Q, Sun ZJ, Tang GL, Su ZY (2007) Identifying earthworms through DNA barcodes. Pedobiologia 51: 301–309. doi: 10.1016/j.pedobi.2007.05.003
- ICZN (1999) International Code of Zoological Nomenclature (4th edition). International Trust for Zoological Nomenclature, London, 306 pp.
- Jaenike J (1982) 'Eisenia foetida' is two biological species. Megadrilogica 4(1-2): 6-8.
- JTYPES (2009) Database of Japanese type specimens. Union of Japanese Societies for Systematic Biology online facility: http://foj.c.u-tokyo.ac.jp/jtypes/index-j.html [accessed 11.XI.2009].
- Kamihira, Y (2005) Fauna and Distribution of Moniligastrida (Terrestrial Oligochaeta) in and around Japan : Zoogeographical consideration of the primitive earthworm. Bulletin of Hakodate Junior College 31: 1–9. [in Japanese]

- King RA, Tibble AL, Symondson WOC (2008) Opening a can of worms: unprecedented sympatric speciation within British lumbricid earthworms. Molecular Ecology 17: 4684–4698. doi:10.1111/j.1365–294X.2008.03931.x.
- Kobayashi S (1941) Earthworms. Japanese Zoological Magazine 53: 258–266. [In Japanese].
- Krell F-T (2004) Parataxonomy vs. taxonomy in biodiversity studies pitfalls and applicatbility of 'morphospecies' sorting. Biodiversity and Conservation 13: 795–812.
- Lowe CN, Butt KR (2007) Life cycle traits of the dimorphic earthworm species Allolobophora chlorotica (Savigny, 1826) under controlled laboratory conditions. Biology & Fertility of Soils 43: 495–499.
- Lowe CN, Butt KR (2008) *Allolobophora chlorotica* (Savigny, 1826): Evidence for classificaton as two separate species. Pedobiologia 52: 81–84.
- Michaelsen W (1900) Das Tierreich Vol. 10: Vermes, Oligochaeta. Friedländer & Sohn, Berlin, XXIX+575pp.
- Nishino, M (2006) *Drawida hattamimizu*. Red Data Book of Shiga Prefecture, 2005, Wildlife Survey Group in Shiga Prefecture, Sunrise Press, Shiga, 563pp.
- Ogawa F (1944) Mimizu no Kansatsu (Examining Earthworms), Sogensha, Tokyo [in Japanese].
- Ohfuchi S (1938a) Zoological observations of the earthworms of the genus *Pheretima* from the ricefield in Ishikai, Hokkaido. Botany Zoology, Tokyo 6(12): 1991–1998 (issue pagination 21–28). [In Japanese].
- Ohfuchi S (1938b) On the Cocoon of *Drawida hattamimizu* Hatai. Japanese Zoological Magazine, Tokyo, 50(8): 395–397. [In Japanese].
- Øien N, Stenersen J (1984) Esterases of earthworms III. Electrophoresis reveals that *Eisenia fetida* (Savigny) is two species. Comparative Biochemistry and Physiology – Part C 78: 277–282.
- Pleijel F, Jondelius U, Norlinder E, Nygren A, Oxelman B, Schander C, Sundberg P, Thollesson M (2008) Phylogenies without roots? A plea for the use of vouchers in molecular phylogenetic studies. Molecular Phylogenetics and Evolution 48: 369–371.
- Pérez-Losada M, Eiroa J, Mato S, Domínguez J (2005) Phylogenetic species delimitation of the earthworms *Eisenia fetida* (Savigny, 1826) and *Eisenia andrei* Bouché, 1972 (Oligochaeta, Lumbricidae) based on mitochondrial and nuclear DNA genes. Pedobiologia 49: 317–324.
- Pérez-Losada M, Ricoy M, Marshall J, Domínguez J (2009) Phylogenetic assessment of the earthworm *Aporrectodea caliginosa* species complex (Oligochaeta: Lumbricidae) based on mitochondrial and nuclear DNA sequences. Molecular Phylogenetics and Evolution 52(2): 293–302.
- Reynolds JW, Cook DG (1976) Nomenclatura Oligochaetologica: a catalogue of names, descriptions and type specimens of the Oligochaeta. University of New Brunswick, Fredericton, 217 pp.
- Rougerie R, Decaëns T, Deharveng L, Porco D, James S, Chang C-H, Richard B, Potapov M, Suhardjono Y, Hebert PDN (2009) DNA barcodes for soil animal taxonomy. Pesquisa Agropecuária Brasileira 44(8): 789–801.

- Siddall ME, Apakupakul K, Burreson EM, Coates KA, Erséus C, Gelder SR, Källersjö M, Trapido-Rosenthal H (2001) Validating Livanow's hypothesis: molecular data agree that Leeches, Branchiobdellidans and Acanthobdella peledina form a Monophyletic Group of Oligochaetes. Molecular Phylogenetics and Evolution 21: 346–351.
- Siddall ME, Fontanella FM, Watson SC, Kvist S, Erséus C (2009) Barcoding bamboozled by bacteria: convergence to Metazoan Mitochondrial primer targets by marine microbes. Systematics Biology 58: 445–451.
- Sims RW (1980) A Classification and the distribution of earthworms, suborder Lumbricina (Haplotaxida: Oligochaeta). Bulletin of the British Museum (Natural History) Zoology 39: 103–124.
- Sims RW, Gerard BM (1985) Earthworms. Keys and notes to the identification and study of the Species. Synopsis of the British Fauna (New series). No. 31. E.J. Brill, Leiden, 171pp.
- Sims RW, Gerard BM (1999) Earthworms: Notes for the identification of British species. 4th Edition. Published for The Linnean Society of London and The Estuarine and Coastal Sciences Association by Field Studies Council, Montford Bridge, Shrewsbury, UK, 169pp.
- Stephenson J (1923) The fauna of British India, including Ceylon and Burma. Oligochaeta. Taylor & Francis, London, 518 pp.
- Stephenson J (1930) The Oligochaeta. Oxford University, Clarendon Press, 978 pp.
- Stürzenbaum SR, Andre J, Kille P, Morgan AJ (2009) Earthworm genomes, genes and proteins: the (re)discovery of Darwin's worms. Proceedings of the Royal Society, B 276(1658): 789–797.
- Uchida T (1988) *Drawida japonica* cf. *D. hattamimizu*. In: Okada Y, Uchida S, Uchida T (Eds) New Illustrated Encyclopedia of the Fauna of Japan (Shinpen Nihon Doubutsu Zukan), Part I, Hokuryukan, Tokyo, 803 pp. [In Japanese].
- Uenishi M (in press) Note on "*Hattamimizu*" in the paddy fields from near Mikata Lake, in Mikata Five Lakes, Wakasa-cho, Fukui Prefecture. Fukui Rikusui Seibutsu Kaiho 16. [in Japanese].
- van Praagh BD (1992) The biology and conservation of the giant Gippsland earthworm *Megas-colides australis* McCoy, 1878. Soil Biology and Biochemistry 24: 1363–1367.
- Watanabe H (2005) On hatta mimizu (*Drawida hattamimizu*), a unique semi-aquatic earthworm, distributed around the Lake Biwa and it's conservation. KONC, Bulletin of Kansai Organization for Nature Conservation 27 (2): 5–19. [In Japanese].
- Yuki H (1940a) Hakubutsu danpen (sono 1). Omi Hakubutsu Dokokaishi 8: 16–25. [in Japanese].
- Yuki H (1940b) Hakubutsu danpen (sono 2). Omi Hakubutsu Dokokaishi 9: 11–15. [in Japanese].

Appendix

The primer sets used, LCO1490 and HCO2198, amplify a 658 bp fragment of the COI gene in a wide range of invertebrate taxa (Folmer et al 1994):

LCO1490: 5'-GGTCAACAAATCATAAAGATATTGG-3'

HCO2198: 5'-TAAACTTCAGGGTGACCAAAAAATCA-3'

For Oli 5 only (*D. hattamimizu* Neotype) modified Folmer primer was used (Bely & Wray, 2004) for the reverse modified primer (the forward was the standard LCO Folmer primer), viz.:

5'-TATACTTCTGGGTGTCCGAAGAATCA-3':

Sequence data differences between *D. hattamimizu* specimens below are indicated by **bolding** and, whereas the 616 common sequential nucleotides agree 100% for the Neotype and topotype, the Hikone specimen (with 613 bases) differs in only 7 (bold) = ~1.14% real difference in sequences identity (standard errors not applied); this small variation supports its acceptance as the same taxon.

Hikone *Drawida* cf. *japonica* sequence is included for general comparison; it differs considerably from Genbank EF077597 ["*Drawida japonica* COI-5P"]: of the 607 consecutive bases, approximately 104 differ (=17.13%), thus conspecificity of these non-type Chinese specimens is not wholly supported.

Seq 1 GenBank Accession No. (submitted 20.VIII.2009) GQ500899.

Oli5 *Drawida hattamimizu...* Spec No. 1 (LBM1380000078) **Neotype** 21.vi.2002 ex Hatta 85% EtOH.

AGGTGTATGAGCTGGAATAATCGGGGGCTGGTATAAGACTTCTTAT-TCGAATTGAACTAAGACAGCCTGGAACATTTTTAGGGAGTGATCAAT-TATATAATACTATTGTTACAGCACATGCGTTTATTATAATTTTCTTCT-TAGTTATACCAGTATTTATTGGGGGGGGTTTGGTAACTGGCTTCTTCCTT-TAATACTGGGGGCACCAGATATAGCATTTCCACGACTTAATAATTTAA-GATTTTGATTACTCCCACCATCTTTAATTTTATTAGTTTCCTCAGCT-GCTGTTGAAAAGGGGGCAGGAACAGGTTGAACTGTATACCCCCCCATT-AGCCAGAAATATTGCACATGCTGGTCCGTCAGTAGACTTAGCTATTTTT-TCTCTTCATTTGGCACGGTGCCTCATCTATCTTAGGAGCTATTAATTT-TATTACAACAGTGATTAATATACGATGAGCTGGACTCCAGTTAGAGCG-TATTCCACTTTTGTGTGTGGGGGAGTATTTATCACTGTAATTCTTC TCTTTTATCTCCCCAGTATTAGCCGGAGCCATTACAATACTACTACA-GATCGTAATTTAAATACATCATTTTTGACCCGGAGCCATTACAATACTACTACA-GATCGTAATTTAAATACATCATTTTTTGACCCTGCTGGTGGGGGGTGAT

BLAST *Hormogaster elisae* haplotype LOZ4 cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial Length=648

Seq 2 GenBank Accession No. (submitted 20.VIII.2009) GQ500900.

Oli3 *Drawia hattamimizu*... Ex Hatta (**topotype**) 10.ix.2008 Spec No. 2 (LBM1380000082) in 85% EtOH.

TTTtATTTAGGTGTATGAGCTGGAATAATCGGGGCTGGTATAAGACT-TCTTATTCGAATTGAACTAAGACAGCCTGGAACATTTTTAGGGAGTGAT-CAATTATATAATACTATTGTTACAGCACATGCGTTTATTATAATTTTCT-TCTTAGTTATACCAGTATTTATTGGGGGGGTTTGGTAACTGGCTTCTTC-CTTTAATACTGGGGGGCACCAGATATAGCATTTCCACGACTTAATAATT-TAAGATTTTGATTACTCCCACCATCTTTAATTTTATTAGTTTCCTCAGCT-GCTGTTGAAAAGGGGGCAGGAACAGGTTGAACTGTATACCCCCCCATT-AGCCAGAAATATTGCACATGCTGGTCCGTCAGTAGACTGTATACCCCCCCATT-TCTCTTCATTTGGCAGGTGCCTCATCTATCTTAGGAGCTATTATTT-TATTACAACAGTGATTAATATACGATGAGCTGGACTCCAGTTAGAGCG-TATTCCACTTTTGTGTGTGGGGGAGTATTTATCACTGTAATTCTTC TCTTTTATCTCTCCCAGTATTAGCCGGAGCCATTACAATACTACTAACA-GATCGTAATTTAAATACAATCATTTTTTGACCCTGCTGGTGGGGGGTGAT**C**-**CTATTT**

BLAST *Hormogaster elisae* haplotype LOZ4 cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial Length=648

Seq 3 GenBank Accession No. (submitted 20.VIII.2009) GQ500901.

Oli2 – *D. hattamimizu...* Hikone Spec. 18.vi.2009 No. 3 (LBM1380000084) 99.5% EtOH.

xxxTGTATGAGCTGGAATAATCGGGGCTGGTATAAGACTTCTTATTC-GAATTGAACTAAGACAGCCTGGAACATTTTTAGGGAGTGATCAGT-TATATAATACTATTGTTACAGCACATGCATTTATTATAATTTTCTTCT-TAGTTATACCAGTATTTATTGGGGGGGTTTGGTAACTGACTTCTTCCTT-TAATACTGGGGGCACCAGATATAGCATTTCCACGACTTAATAATTTAA-GATTTTGATTACTTCCACCATCTTTAATTTTATTAGTTTCCTCAGCT-GCTGTTGAAAAGGGGGCAGGAACAGGTTGAACTGTATACCCCCCCATT-AGCCAGAAATATTGCACATGCTGGTCCGTCGGTAGACCTAGCTATTTTT-TCTCTTCATTTGGCAGGTGCCTCATCTATCTTAGGAGCTATTAATTT-TATTACAACAGTGATTAATATACGATGAGCTGGACTCCAGTTAGAGCG-TATTCCACTTTTGTGTGGGGGGGAGTATTTATCACTGTAATTCTCT TCTTTTATCTCCCCAGTATTAGCGGGGGGCCATTACAATACTACTACA-GATCGTAATTTAAATACATCATTTTTGACCCTGCTGGTGGGGGGCCGATC-CTATTT

BLAST *Hormogaster elisae* haplotype LOZ4 cytochrome oxidase subunit I (COI) gene, partial cds; mitochondrial Length=648 82% identity.

Seq 4 GenBank Accession No. (submitted 20.VIII.2009) GQ500902.

BLAST *Drawida japonica japonica* voucher 06–273 cytochrome c oxidase subunit I (COI) gene, partial cds; mitochondrial Length=640 83%

Cf. Genbank Accession No. EF077597 ["*Drawida japonica* COI-5P"] from Huang et al. vouchers.

RESEARCH ARTICLE



The millipede genus *Tasmaniosoma* Verhoeff, 1936 (Diplopoda, Polydesmida, Dalodesmidae) from Tasmania, Australia, with descriptions of 18 new species

Robert Mesibov

Queen Victoria Museum and Art Gallery, Launceston, Tasmania 7250, Australia

urn:lsid:zoobank.org:author:24BA85AE-1266-494F-9DE5-EEF3C9815269

Corresponding author: Robert Mesibov (mesibov@southcom.com.au)

Academic editor: Sergei Golovatch | Received 28 February 2010 | Accepted 17 March 2010 | Published 26 March 2010

urn:lsid:zoobank.org:pub:FC5CFE57-05F9-4685-BC02-BB82AB9E4894

Citation: Mesibov R (2010) The millipede genus *Tasmaniosoma* Verhoeff, 1936 (Diplopoda, Polydesmida, Dalodesmidae) from Tasmania, Australia, with descriptions of 18 new species. ZooKeys 41: 31–80. doi: 10.3897/zookeys.41.420

Abstract

Tasmaniosoma armatum Verhoeff, 1936 is redescribed from topotypical specimens and the following congeners are described from Tasmania: T. alces **sp. n.**, T. aureorivum **sp. n.**, T. australe **sp. n.**, T. barbatulum **sp. n.**, T. bruniense **sp. n.**, T. cacofonix **sp. n.**, T. clarksonorum **sp. n.**, T. compitale **sp. n.**, T. decussatum **sp. n.**, T. fasciculum **sp. n.**, T. fragile **sp. n.**, T. gerdiorivum **sp. n.**, T. hesperium **sp. n.**, T. hickmanorum **sp. n.**, T. laccobium **sp. n.**, T. maria **sp. n.**, T. orientale **sp. n.** and T. warra **sp. n.**

Keywords

Diplopoda, Polydesmida, Dalodesmidae, millipede, Australia, Tasmania, parapatry

Introduction

The rich dalodesmid fauna of Tasmania includes many species with a "head + 19 rings" (H+19; head + 17 podous rings + 1 apodous ring + telson) and high, prominent paranota with rounded posterior corners.

I placed six species from this assemblage in the new genus *Atrophotergum* Mesibov, 2004 because they share several apomorphies: solenomere arising from a large,

Copyright Robert Mesibov. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. mediolaterally flattened posterior process on the gonopod telopodite; unusually large size difference between tergites 3 and 4 and more posterior metatergites; and paired, sometimes finger-like processes on the sternites of the last few rings (Mesibov 2004). Another three species in the assemblage have a remarkable pseudo-articulated gonopod telopodite (Mesibov 2005) and were grouped in *Ginglymodesmus* Mesibov, 2005.

Most of the remaining species in the H+19 assemblage are not so easily sorted into genera. Many have short, rod-like gonopod telopodites tipped with a closely packed cluster of processes of varying sizes and shapes. In this paper I assign 18 of the larger undescribed species of this kind to the formerly monotypic *Tasmaniosoma* Verhoeff, 1936. Relationships within this expanded *Tasmaniosoma* are considered in the Discussion section, below.

Tasmaniosoma armatum Verhoeff, 1936 and its congeners are long-legged, often quick-running and sometimes brightly coloured millipedes (Fig. 1) with an apparent preference for eucalypt forest. Adults of most species are usually found in moist (not wet) leaf and bark litter, or under bark on standing trees. They are only rarely found in the soil or inside rotting logs, and they are more abundant in patches of open forest, woodland and scrub than in closed, shady forest in the same area. Adults can be collected throughout the year but can be difficult to find in the austral summer, when forest litter dries out.

The genus *Tasmaniosoma* as circumscribed here is very widely distributed in Tasmania and may have been nearly ubiquitous before European settlement. Several of the new species have small known ranges (<2000 km²) and more small-range species may remain to be discovered. As with *Atrophotergum* spp. (Mesibov 2004), some *Tasmaniosoma* spp. are distributed in mosaic parapatry (see below and Mesibov, in preparation).

Methods

"Male" and "female" in the text refer to stadium VII adults. Many females and juveniles possibly referrable to *Tasmaniosoma*, but not collected together with males, remain unidentified. All identified specimen lots are listed in the Appendix; only holotype and paratype lots are detailed in the main text.

The most complete description below is given for *T. armatum*. New species descriptions refer mainly to character states which clearly differ from those in the type species. All reported *T. armatum* characters were checked in the new species except gonocoxa shape and setation, and microscopic details of the sphaerotrichomes, spinnerets and limbus.

Shorthand descriptions are given below for characters of the the ring 6 sternite in males (Fig. 5). In some species the lateral edge of the sternite is extended ventrally as a flat tab pressed against the leg 6 coxa; this tab may or may not bear setae. Most species also have a similar tab by the leg 7 coxa with considerable variation between species in size, shape and setation. The anterior margin of the ring 6 sternite may or may not bear setae, which may or may not be elevated on sternal protuberances. These ring 6 structures are likely to assist males in protecting or orienting their gonopod telopodites.

Locality details in the text are given in all cases with latitude and longitude based on the WGS84 datum. Most localities also have a UTM grid reference (grid zone 55G, datum AGD66), because these are the coordinates most often written on 20th century specimen labels in Tasmania.

Specimens are preserved in 80% ethanol. Gonopods were cleared when necessary in 80% lactic acid and temporarily mounted in 60% lactic acid for microscopic examination. Other body parts were temporarily mounted in a 1:1 glycerine:water mixture. Preliminary drawings on graph paper were made using an eyepiece grid at 64× or 160× on a binocular microscope. Photomicrographs were taken with a Canon EOS 1000D digital SLR camera mounted on a Nikon SMZ800 binocular dissecting microscope equipped with a beam splitter. Measurements were made with the same microscope using an eyepiece scale. An FEI Quanta 600 ESEM operated in high-vacuum mode was used to examine preserved material which had been air-dried before sputter-coating with gold. Material from species represented by only a few specimens was air-dried for a few minutes, examined in low-vacuum mode on the ESEM and returned immediately afterwards to alcohol. All images and drawings were prepared for publication using GIMP 2.6 software.

Abbreviations: QVM = Queen Victoria Museum and Art Gallery, Launceston; Tas = Tasmania; ZSM = Zoologische Staatssammlung München.

Results

Order **Polydesmida** Pocock, 1887 Suborder **Dalodesmidea** Hoffman, 1980 Family **Dalodesmidae** Cook, 1896

Tasmaniosoma Verhoeff, 1936

Tasmaniosoma Verhoeff, 1936:11. Attems, 1940:442. Jeekel, 1971:355; 1982:12; 1983:146; 1984:85; 1985:52. Hoffman, 1980:150,185.

Type species. Tasmaniosoma armatum Verhoeff, 1936, by monotypy.

Tasmaniosoma armatum Verhoeff, 1936

Figs 1A, 2, 3C, 4B, 5A, 6A, 6B, 7A; map Fig. 23

Tasmaniosoma armatum Verhoeff, 1936:12, Figs 3–8. Attems, 1940:443, Figs 630, 631. Jeekel, 1971:355; 1984:85.

Syntypes. Two males, Australia, Tasmania, Lake Leake, G.E. Nicholls, date not known, ZSM A20033578, A20033579, A20052437 (see Remarks).



Figure 1. A Living male *Tasmaniosoma armatum* Verhoeff, 1936. Image by Hans Henderickx, used with permission. **B–I** Dorsal views of midbody rings and left lateral views of midbody ring of freshly killed *T. clarksonorum* sp. n. male, QVM 23:51683 (**B**, **F**); *T. compitale* sp. n. female, QVM 23:51680 (**C**, **G**); *T. fasciculum* sp. n. male, QVM 23:51665 (**D**, **H**); and *T. hickmanorum* sp. n. male, QVM 23:51681 (**E**, **I**). **A–I** not to same scale. Pigmentation of the four species in **B–I** fades progressively in alcohol and long-preserved specimens may be colourless. The whitish patch (**p**) below the paranotal margin in *T. compitale* sp. n. **G** and the whitish patches dorsally **C** change to light yellow in freshly preserved specimens (ca 1–10 weeks in alcohol).

Other material examined. 153 males, 128 females and 4 stadium VI males from 128 unique localities (see Appendix).

Diagnosis. Metatergites without tubercles; ring 6 sternite with discrete setal brushes on anterior margin; gonopod telopodite with stout, rod-like setae in longitudinal



Figure 2. *Tasmaniosoma armatum* Verhoeff, 1936 male (ex QVM 23:46567). **A** Leg 2 bases, posterior view, showing position of gonopore (**go**) and cowl (**c**) **B** enlargement of cowl on left leg 2 coxa **C** sphaero-trichomes on leg 6 postfemur **D** brush setae on leg 6 prefemur **E** spiracles on midbody ring, left lateral view, anterior to left **F** spinnerets, ventral view. Scale bars **A**, **E** = 0.1 mm **F** = 0.05 mm **B** = 0.025 mm **D** = 0.02 mm **C** = 0.01 mm.

tract on posteromedial surface and two upright (distally directed), Y-shaped processes arising anterolaterally near apex.

Description. The following description is based on nine males and 10 females from the type locality (in QVM 23:46547, 23:46548 and 23:46567).

Male/female approximate measurements: length 14/14 mm, ring 12 paranota width 1.7/1.7 mm. Body, head and antennae uniformly dark reddish-brown in life



Figure 3. A, B Dorsal views of ring 12 metatergite of **A** *Tasmaniosoma warra* sp. n., paratype male QVM 23:46038, showing smooth surface, and **B** *T. barbatulum* sp. n., paratype male ex QVM 23:51512, showing three transverse rows of large, low, contiguous tubercles. **C, D** Ventral views of legpair 2 of **C** *T. armatum* Verhoeff, 1936, topotypical female ex QVM 23:46567, and **D** *T. australe* sp. n., paratype female ex QVM 23:46575, showing prefemoral swelling (**s**) and peg-like projection (**p**). Scale bars = 0.5 mm.

(Fig. 1A), legs pinkish-red basally and darker distally; head and leg colour fades in alcohol, but body colour persists for many years.

Male with head moderately setose anteriorly, vertex sparsely setose; sockets slightly impressed, separated by ca 2 × socket diameter; antennal groove deep laterally. Antenna slender, slightly clavate, when manipulated reaching back to ring 3; antennomere 6 widest, relative antennomere lengths (2,3)>6>(4,5). Collum from above reniform, convex anteriorly; corners rounded. Tergites 2-4 distinctly narrower than more posterior metatergites; overall widths tergite 6>5>4>(3,head)>2>collum; rings 6-15 about the same width. In lateral view, margin of ring 2 tergite slightly lower than margins of collum and ring 3 tergite. Ring 2 ventrally on either side with fairly shallow pit (Fig. 4B), rim well defined anterolaterally but not medially or posteriorly. Ring suture and waist distinct on diplosegments, no longitudinal striations on waist; prozonites smooth; transverse furrow indistinct, metatergite smooth, not sculptured, with three transverse rows of ca 12 small setae: two rows anterior to transverse furrow, one close to posterior margin of metatergite; posterior metatergal margin slightly emarginate medially. Limbus composed of flat tabs, irregularly notched distally. Midbody paranota ca 1.5 × as wide as prozonite, slightly inflated, marginal groove distinct, anterior corner smoothly convex, posterior corner smoothly convex without projecting posteriorly on any rings, but with 2-3 very small tooth-like irregularities,


Figure 4. Male ring 2, ventral view of right side (anterior to right) showing variation in structure. A *Tasmaniosoma compitale* sp. n., paratype male QVM 23:45970, pit not apparent B *T. armatum* Verhoeff, 1936, topotypical male ex QVM 23:46567, pit fairly shallow, not well defined medially and posteriorly C *T. cacofonix* sp. n., voucher male ex QVM 23:46724, pit deep, small D *T. decussatum* sp. n., male paratype ex QVM 23:46699, pit deep, large. Scale bars = 0.2 mm.

each bearing small seta; lateral margin very slightly convex, in lateral view slightly oblique (anterior lower) at ca 2/3 ring height. Midbody metatergites ca $2.2 \times$ as wide as long. Pore formula 5, 7, 9, 10, 12, 13, 15–18; ozopore small, round, opening dorsolaterally close to margin near posterior corner of paranotum. Spiracle small, round, opening on short, crater-like elevation; on diplosegments anterior spiracle just above and anterior to first leg, posterior spiracle about midway between leg bases (Fig. 2E). Sternites moderately setose, as wide as long, transverse impression deep, longitudinal impression indistinct. Anterior legs with prefemur greatly swollen dorsally, femur less so (Figs 6A, 6B); swellings begin leg 3, gradually decrease to leg 15; tarsus long, slightly curved, ca $1.6 \times$ as long as femur on anterior legs, but proportionally shorter posteriorly; relative podomere lengths tarsus>(prefemur, femur)>(postfemur, tibia). Sphaerotrichomes on 3-4 most distal podomeres, shafts tapered (Fig. 2C). Brush setae on distal end of coxa/trochanter, prefemur, base of femur; brush setae unbranched, tapering (Fig. 2D). Gonopore on distomedial bulge of leg 2 coxa, pro-



Figure 5. Male ring 6, ventral view (anterior to top) showing variation in structure. **A** *Tasmaniosoma armatum* Verhoeff, 1936; no leg 6 tab; short, thin leg 7 tab with brush of fine setae; paired and raised brushes of fine setae medially on anterior margin of sternite **B** *T. barbatulum* sp. n.; short leg 6 tab with a few fine setae; long, thickened leg 7 tab with brush of stout setae; a few scattered setae on anterior margin **C** *T. fasciculum* sp. n.; short leg 6 tab with a few fine setae; no setae on anterior margin **D** *T. hickmanorum* sp. n.; no leg 6 tab; long, thickened leg 7 tab with brush of stout setae; a few scattered setae on anterior margin **D** *T. hickmanorum* sp. n.; no leg 6 tab; long, thickened leg 7 tab with brush of stout setae; anterior margin with wide median notch. Scale bars = 0.2 mm.

tected by thin cowl (Figs 2A, 2B). Short brushes of fine setae on sternite between legpairs 3, 4 and 5. Leg 6 and 7 bases (Fig. 5A) well- and equally separated; no leg 6 sternal tab; leg 7 tab short, thin, with brush of fine setae; anterior edge of sternite medially with paired, conjoined brushes of fine setae on low protuberance. Pre-anal ring moderately setose; hypoproct subtrapezoidal; epiproct from above tapering smoothly to rounded tip, extending slightly past anal valves. Spinnerets (Fig. 2F) in square array; setae with tightly-fitting basal sheaths; dorsal setae unprotected, ventral setae in shallow depression.

Gonopod aperture ovoid, ca 1/2 as wide as ring 7 prozonite, posterolateral margins raised. Telopodites straight, parallel but slightly divergent apically; extending nearly to leg 5 bases when retracted. Gonocoxa short (ca 1/3 length of telopodite), more or less truncated-conical with anterior side longer than posterior; lateral surface projected distally as rounded lobe pressed to telopodite base, medial surface slightly projected

distally; with sparse long setae distally on posterolateral surface. Gonocoxae weakly joined distomedially. Cannula prominent, inserting basomedially in depression on telopodite. Telopodite (Fig. 7A) a distally tapering cylinder with setose base protruding posteriorly as rounded lobe; with small, discrete, setose bump on anteromedial side of base; and with buttress-like ridge on anterolateral surface from articulation with gonocoxa to ca 1/3 telopodite height. Numerous minute setae near cannula insertion; fine, tapering setae on telopodite base, on posterolateral surface and in longitudinal row of three long setae on lateral surface at about half telopodite height. Telopodite also with narrow, discrete zone of 30–40 stout, rod-like setae on posteromedial surface from ca 1/3 to 2/3 telopodite height; these setae often broken or broken away, but sockets always visible. Apex of telopodite with cluster of six major processes, labelled here and in Fig. 7A from lateral to medial:

- broad Y-shaped process flattened anteroposteriorly, divided at 1/3 to 1/2 the process height, the two tips acute ['ta1' of Verhoeff (1936)];
- (2) similar, slightly smaller, less deeply divided process ['ta2'];
- (L) laminate process resembling bird's head in profile, flattened mediolaterally, broadly curved distally with posterior, hook-like extension ['ti'];
- (S) short, thorn-like solenomere curving posteromedially ['sl'];
- (3) short process possibly continuous with solenomere, divided into posterolaterally directed tab with rounded tip, and posteromedially directed rod with several apical teeth ['n'];
- (4) thin, rod-like process arising posteromedially below the telopodite apex and bending very slightly posteriorly, with a flattened tip ['psl'].

In addition, very short finger-like process arising just lateral to process 3 and directed posterolaterally. Prostatic groove curving first anteriorly, then posteriorly from base and running more or less directly to solenomere, passing posterior to base of process 4.

Female as large as male or slightly smaller, legs more slender and prefemora and femora not swollen, sternites ca $1.2 \times as$ wide as long. Epigynum ca 1/3 width of ring 2, posterior margin produced medially as small, rounded triangle (Fig. 3C). Cyphopods not examined.

Distribution. Common and sometimes locally abundant in eucalypt forest over ca 25 000 km² in central and eastern Tasmania from sea level to at least 960 m elevation, including Schouten and Maria Islands and Forestier and Tasman Peninsulas, but absent from much of the inland northeast (Fig. 23).

T. armatum is parapatric with *T. hickmanorum* sp. n. in the west of its range, notably along the Tasmanian biogeographical divide known as the Mersey Break (Mesibov 1999), and is sympatric or parapatric with *T. clarksonorum* sp. n. and *T. gerdiorivum* sp. n. along the East Tamar Break (Mesibov 1994, 1997). It may be parapatric with *T. orientale* sp. n. in the Eastern Tiers.

T. armatum may have been introduced to Tasmanian localities outside its natural range. Adults are often found under loose eucalypt bark, and might be carried from place to place in shipments of logs and firewood. For example, the specimen in Fig. 1A

was collected in 2007 at Tahune Forest Reserve in southern Tasmania, well within the range of *T. warra* sp. n. and well outside the main range of *T. armatum*. Another specimen was found near Tahune Bridge in the Reserve in 1994. Tahune Forest Reserve is a much-visited tourist attraction and the road through the Reserve has been used by log-carting vehicles for many years.

Remarks. Verhoeff (1936, p. 14) thanks "Prof. Nicholls an der University of Western Australia, Perth-Crawlay [Crawley]" for material from Lake Leake. George Edward Nicholls was Professor of Biology at the University of Western Australia from 1921 to 1947. He is known to have visited Tasmania in 1928, 1929 and 1939 (Nicholls 1943, p. 142) and it is likely that *T. armatum* was collected during one of the first two visits.

The type material was located by Dr Jörg Spelda and imaged by him at my request. It consists of three registered museum lots. A20033578 is a slide mount with disarticulated legs, antennae, metatergites and right and left gonopods. From images of this mount it is clear that Verhoeff used this slide to draw his Figs 3 and 4 (leg 3) and Figs 7 and 8 (medial views of left gonopod). A20033579 is a slide mount with a leg, a ring 7 metatergite and a joined pair of gonopods. The latter were used by Verhoeff for his Figs 5 and 6 (posterior view of left gonopod). Verhoeff's description is thus based on two males. A20052437 consists of two male trunk pieces in alcohol (dried out at some time in the past). The original label has been lost but the pieces are likely to be from the two males dissected by Verhoeff for the slide mounts. Only one of the slide mount labels, for A20033578, specifies Lake Leake, Tasmania, but since Verhoeff used both slides for his description and does not mention another locality, it is also likely that both males illustrated were from Lake Leake.

The gonopod drawings (Figs 5–8) in Verhoeff (1936) are clear and accurate, but Verhoeff offers no evidence for the homologies he proposes for the apical processes on the telopodite, and I am reluctant to use his names for these processes.

T. armatum varies very little over its large range in colour and morphological details. Specimens from lower elevations tend to be slightly larger, to ca 15 mm in length.

Tasmaniosoma alces sp. n.

urn:lsid:zoobank.org:act:10C7B840-CBC0-45C1-89FF-67A67B1A7296 Figs 6F, 6G, 7B; map Fig. 24

Holotype. Male, Australia, Tasmania, NW of Triabunna, 42°27'50"S 147°54'56"E ±25 m, 100 m, 25 August 2009, R. Mesibov, QVM 23:51552.

Paratypes. 3 males, Salmons Creek, Tas, 42°28'57"S 147°50'54"E (EN696961) ±100 m, 150 m, 17 April 1991, R. Mesibov, QVM 23:46762.

Other material. None known.

Diagnosis. Metatergites without tubercles; ring 6 sternite with discrete setal brushes on anterior margin; gonopod telopodite with stout, rod-like setae in longitudinal tract on posteromedial surface and large, fishtail-shaped process arising at about 3/4 telopodite height and directed laterally.



Figure 6. *Tasmaniosoma armatum* Verhoeff, 1936, topotypical male ex QVM 23:46567, legs 6 **A** and 7 **B**. *T. australe* sp. n., voucher male QVM 23:46573, left leg 6 lateral **C** and dorsal view **D**. *T. bruniense* sp. n., paratype male ex QVM 23:51633, left leg 6 **E**. *T. alces* sp. n., paratype male ex QVM 23:46762, legs 6 **F** and 7 **G**. Setation not shown; scale bar = 0.5 mm.

Description. Male ca 16 mm long; ring 12 paranota width ca 1.5 mm. Live colour as for *T. armatum*; in alcohol, decoloured with traces of reddish pigmentation distally on legs, antennae and paranota.

Most non-gonopodal details as for *T. armatum*, but relative widths tergite $6>5>head>(3,2)>collum; ring 12 paranota <math>1.3 \times as$ wide as prozonite; leg 6 with prefemur unusually swollen, i.e. more so than leg 5 or 7 (Figs 6F, 6G); relative podomere lengths tarsus>prefemur>femur>(postfemur, tibia); leg 6 tarsus $1.7 \times as$ long as femur. Ring 6 sternite with legs 6 a little closer together than legs 7; leg 6 tab short, without setae; leg 7 tab long, thin, with rounded knob anterodistally bearing numerous fine setae pointed in all directions; anterior margin of sternite medially with brush of fine setae on low protuberance, i.e. as in *T. armatum* but without evident separation into paired conjoined brushes.

Gonopod telopodite similar to that of *T. armatum*, but process 2 topologically replaced by flat, broadly round-tipped tab curving anteromedially and closely applied to anterior surface of laminate process; the latter broadly round-edged, without hook-like posterior extension. Solenomere flattened mediolaterally and bifid; distal branch bearing the end of the prostatic groove, acute, curving medially; basal branch acute. Process 4 bent posteriorly at ca 45° angle. In addition, large, fishtail-shaped process arising posterolaterally at ca 3/4 telopodite height and directed laterally, the concave outer edge variably toothed. Posteromedial row of short, stout setae from ca 1/3 to 2/3 telopodite height, frequently broken off. Longitudinal lateral setal row with 4–8 setae.

Female not yet recognised.



Figure 7. A *Tasmaniosoma armatum* Verhoeff, 1936, topotypical male ex QVM 23:46567 **B** *Tasmaniosoma alces* sp. n., paratype male ex QVM 23:46762. Left posteroventral views of gonopods in situ, showing solenomere **S**, laminate process **L** and processes numbered in text. Medial bend in laminate process on *T. alces* telopodite is a preparation artifact. Scale bars = 0.2 mm.

Distribution. Known from two sites ca 6 km apart in dry eucalypt forest northwest of Triabunna on the east coast of Tasmania (Fig. 24). Possibly sympatric with *T. armatum*, which has been found ca 2 km from one of the *T. alces* sites.

Etymology. Latin *alces*, "elk", noun in apposition. The gonopods in situ remind me of the head of a male elk with antlers.

Tasmaniosoma aureorivum sp. n.

urn:lsid:zoobank.org:act:CFA149D3-3B8C-4425-A626-E3FC5BACC621 Fig. 8; map Fig. 24

Holotype. Male, Australia, Tasmania, Gold Creek, 42°47'41"S 146°35'04"E (DN659617) ±100 m, 570 m, 24 February 1994, R. Mesibov, QVM 23:46599.

Paratypes. 3 males, 3 females, Growling Swallet, Junee-Florentine karst, Tas, 42°41'S 146°30'E (DN590735) ±1 km, 26 March 1989, S. Eberhard, Glowworm Chamber, field no. JF36-10, QVM 23:12120; 1 male, Ray Benders Cave, Risbys Basin, Junee-Florentine karst, Tas, 42°46'11"S 146°36'15"E (DN675645) ±1 km, 10 June 1992, S. Eberhard, QVM 23:12972.



Figure 8. *Tasmaniosoma aureorivum* sp. n., paratype male ex QVM 23:12120. Posterior **A**, lateral **B** and anterior **C** views of left gonopod telopodite. Scale bar = 0.2 mm; dashed line marks course of prostatic groove.

Other material. None known.

Diagnosis. Metatergites without tubercles, gonopod telopodite with large, laterally directed, rod-like, pointed process.

Description. Male/female approximate measurements: length 13/12 mm, ring 12 paranota width 1.3/1.3 mm. Live colour not known; in alcohol, completely decoloured.

Most non-gonopod details as for *T. armatum*, but antennomere 3 longest, ring 12 paranota $1.3 \times as$ wide as prozonite, leg 6 tarsus $1.5 \times as$ long as femur. Ring 6 sternite with legs 6 closer together than legs 7; legs 6 and 7 tabs long with sparse fine setae (not in discrete brushes); no setae on anterior margin of sternite.

Gonopod telopodites straight, tapering distally; base extended posterolaterally as distally concave shelf; posterior surface with thickened longitudinal ridge to ca 1/2 telopodite height. Telopodite apex with four processes: (a) pointed, rod-like process arising on anterior surface and directed distally; (b) large, rod-like, pointed process arising on posterior surface, bent at base and directed laterally; (c) laminate process arising apically and curving posteriorly, the tip sometimes notched; (d) small solenomere arising posteromedially and directed posterodistally. Apex produced as small, rounded knob between solenomere and laminate process. Basal shelf concavity with long, fine setae; row of short, stout setae on posteromedial surface to ca 3/4 telopodite height, increasing in length and thickness distally. Prostatic groove on medial surface of telopodite, curving gradually to solenomere base. Female with sternites as wide as long; posterior margin of epigynum produced as short trapezoid.

Distribution. Known from three sites in eucalypt forest (holotype) and caves (paratypes) near Maydena in south central Tasmania, with a maximum distance between sites of ca 15 km (Fig. 24).

Etymology. Latin *aureus*, "golden", + *rivus*, "stream", noun used as adjective, after the type locality, Gold Creek.

Remarks. Telopodite details vary a little among the five known males. In the holotype the process arising on the anterior surface is longer than in the paratype illustrated and reaches almost as far distally as the top of the laminate process, which has a small tooth on the concave, posterior edge.

The paratypes are not troglomorphic and are likely to be from accidentally cavedwelling populations. The holotype is from a non-karst site in the Styx River catchment. I have unsuccessfully searched for this species in forest in the adjoining Tyenna River catchment, where it may be rare.

Tasmaniosoma australe sp. n.

urn:lsid:zoobank.org:act:2F05F087-0398-4F19-AFCD-9744B838E2B2 Figs 3D, 6C, 6D, 9; map Fig. 24

Holotype. Male, Australia, Tasmania, Lake Osborne Track, 43°13'04"S 146°46'03"E (DN810148) ±100 m, 880 m, 7 February 2004, K. Bonham, QVM 23:46574.

Paratypes. 3 males, 2 females, details as for holotype but 43°13'07"S 146°45'58"E (DN809147) ±100 m, 900 m, 13 February 2004, QVM 23:46575.

Other material examined. 4 males and 2 females from 4 other localities (see Appendix).

Diagnosis. Metatergites without tubercles, small rounded teeth posterolaterally on paranota, male leg 6 with triangular extension basally on prefemur, solenomere the longest telopodite process, with broad and flattened tip produced as three tooth-like or tab-like extensions.

Description. Male/female approximate measurements: length 18/18 mm, ring 12 paranota width 2.2/2.2 mm. Live colour not known; in alcohol, body fairly uniform light to medium brown.

Most non-gonopod details as for *T. armatum*, but antennomere 3 longest, relative widths tergite 6>5>4>2>head>3>collum, ring 12 paranota $1.3 \times$ as wide as prozonite, posterior corners of most paranota produced as very small, rounded tooth, leg 6 tarsus $1.4 \times$ as long as femur and femur longer than prefemur. From ca ring 8 posteriorly, sternites with small, blunt projection at each corner, i.e. just posterior to each of four leg bases. Ring 2 pit deep with well-defined semicircular rim, convex laterally. Ring 6 sternite with sparse fine setae near anterior margin; leg 6 tab barely detectable, with a few fine setae; leg 6 prefemur with rounded triangular extension posteriorly (Figs 6C, 6D); leg 7 tab very long (ca 1/2-2/3 length of leg 7 coxa), extending laterad of leg 6



Figure 9. *Tasmaniosoma australe* sp. n., paratype males ex QVM 23:46575. **A** Posterior view of gonopod telopodites in situ **B** anterior and **C** medial views of right gonopod telopodite. Setation not shown in **B** and **C**; dashed lines mark course of prostatic groove. Scale bar = 0.2 mm.

prefemoral swelling, with sparse brush of fine setae basally on anteromedial surface; leg 7 coxa swollen distomedially, the swelling lying posterior to the leg 7 tab.

Gonopod telopodite (Fig. 9) straight, tapering distally, divided into four processes at between 2/3 and 3/4 telopodite height. Undivided portion with posterior surface roundly ridged longitudinally, base laterally extended as rounded protuberance. Processes comprise: (a) short, rod-like, round-tipped anterolateral process bent slightly outwards; (b) short, somewhat flattened posterior process with a rounded-truncate tip bent slightly posteromedially; (c) large solenomere, cylindrical basally, flattening at ca 1/2 process height, curving medially and terminating in rounded tooth apically, with posterior tab carrying opening of prostatic groove and finger-like posterobasal extension; (d) large, rod-like, apically acute process arising just anteromedial to solenomere base and reaching nearly as far distally, slightly bent posterolaterally. Tracts of fine setae posteriorly on either side of the longitudinal telopodite ridge, and on anterolateral surface to ca 1/2 telopodite height. Prostatic groove running distally on medial surface of telopodite to level of division into processes, then running posterolaterally to enter solenomere base.

Female with leg 2 prefemur long and with large swelling distally on posterior surface; rings 2 and 3 ventrally with small, peg-like projection just lateral to epigynum (Fig. 3D). Sternite projections as in male but generally smaller, not as consistently expressed.

Distribution. Known from wet eucalypt forest and subalpine scrub to 1240 m elevation in south central Tasmania, extending in a ca 80 km-long line from northwest of Maydena to northwest of Southport (Fig. 24). Possibly parapatric with *T. aureorivum* sp. n. in the north of its range and with *T. warra* sp. n. in the south; not yet known to co-occur with either species.

Etymology. Latin *australis*, "southern", adjective, for the southern distribution of this species.

Remarks. Females of *T. australe* are readily distinguished from females of *T. aureorivum* sp. n. and *T. warra* sp. n. by their leg 2 prefemoral swellings. A female from Hastings Caves (in QVM 23:46570) has the posterior margin of the epigynum produced not as a low triangle with rounded apex, but as an oblong with rounded corners.

Tasmaniosoma barbatulum sp. n.

urn:lsid:zoobank.org:act:8B93AB56-F248-4A5C-99C9-EBAC6901ED28 Figs 3B, 5B, 10A; map Fig. 25

Holotype. Male, Australia, Tasmania, Scamander, 41°26'45"S 148°14'51"E (FQ041108) ±100 m, 80 m, pitfall emptied January 2001, R. Bashford, QVM 23:51554.

Paratypes. 1 male, Thompsons Marshes, Tas, 41°41'54"S 148°13'21"E (FP016828) ±250 m, 490 m, 9 June 1988, R. Mesibov, QVM 23:51521; 1 male, S of Dogwood Hill, Tas, 41°41'07"S 148°10'48"E (EP981843) ±250 m, 580 m, 14 July 1988, R. Mesibov, QVM 23:51522; 2 males, details as for holotype, QVM 23:51512.

Other material. None known.

Diagnosis. Metatergites with three transverse rows of large, low, contiguous tubercles; leg 7 sternal tab with dense brush of stout, rod-like setae; gonopod telopodite with two combs of long, stout, rod-like setae, the posterior comb directed basally, the anterior comb distally.

Description. Male ca 10 mm long, ring 12 paranota width ca 1.0 mm. Live colour not known; in alcohol completely decoloured.

Most non-gonopod details as for *T. armatum*, but antennal sockets separated by ca $2.5 \times$ socket diameter, relative widths tergite 6>(5,head)>4>(3,2)>collum, ring 12 paranota ca $1.2 \times$ as wide as prozonite, brush setae lacking on femur, gonopod aperture rim not produced. Metatergite (Fig. 3B) almost completely covered with three transverse rows of ca 12 large, low tubercles, each with small seta near posterior edge. Ring 2 pit not apparent except as slight concavity near anterior margin of ring. Ring 6 sternite



Figure 10. Posterior views of gonopod telopodites in situ of topotypical male paratypes, with solenomere (s) indicated. **A** *Tasmaniosoma barbatulum* sp. n., ex QVM 23:51512 **B** *Tasmaniosoma clarksonorum* sp. n., ex QVM 23:46583. Scale bars: (A) = 0.1 mm, (B) = 0.2 mm. Slight bending of flattened apical process in (A) is a preparation artifact; tip of central branch of central process on right telopodite in (B) is broken off. Portions of the background in (A) have been digitally edited for clarity.

(Fig. 5B) with short leg 6 tab bearing a few fine setae; leg 7 tab long, thickened, with brush of stout setae; a few fine setae on anterior margin of sternite.

Gonopod telopodite (Fig. 10A) subcylindrical with small posterior extension at base, concave distally. Apex slightly produced posteriorly as rounded, thickened ridge, oriented obliquely to telopodite longitudinal axis (medial end of ridge lowest); basal surface of ridge with comb of 15–20 stout, pointed, rod-like setae, up to ca 1/4 telopodite height in length, directed basally. Solenomere short. cylindrical, acute, arising from medial end of ridge on distal side, directed distally. Telopodite apex with laminate process arising anteromedially; outer edge of process extended distally as long, rounded-truncate tab and medially as short, round-tipped tab, and bearing a small, flattened process arising mid-laterally near laminate process base and directed posterodistally. Anterior surface of telopodite with comb of 5–10 stout, pointed, rod-like setae, directed distally and arising in near-longitudinal row, increasing in length distally. A few fine setae posterolaterally near telopodite base and on concave surface of basal extension; ca 6 fine setae in midlength lateral row. Prostatic groove running distally on medial surface of telopodite directly to solenomere base.

Female not yet recognised.

Distribution. Known from dry and wet eucalypt forest at three sites on the northern part of the east coast of Tasmania, from Scamander to ca 10 km south of St Marys, a distance of ca 30 km (Fig. 25). Sympatric with *T. orientale* sp. n.

Etymology. Latin *barbatulus*, "with a small beard", adjective, for the basally directed comb of rod-like processes on the gonopod telopodite.

Tasmaniosoma bruniense sp. n.

urn:lsid:zoobank.org:act:2925D795-06EF-47EF-86CF-EB6BA3949921 Figs 6E, 11; map Fig. 24

Holotype. Male, Australia, Tasmania, Cuthberts Road, South Bruny Island, 43°23'57"S 147°17'53"E (EM240946) ±25 m, 340m, 27 October 2009, R. Mesibov, QVM 23:51631.

Paratypes. 1 stadium VI male, Mt Tobin, South Bruny Island, Tas, 43°23'55"S 147°19'12"E (EM258947) ±100 m, 6 February 2001, K. Bonham, QVM 23:51634; 3 males, 6 females, 3 stadium VI males, 1 stadium VI female, Staffords Road, South Bruny Island, Tas, 43°26'11"S 147°17'20"E (EM233905) ±25 m, 1 July 2009, S. Tassell, QVM 23:51633.

Other material. 1 male, details as for holotype but 43°23'55"S 147°17'59"E (EM242947) ±25 m, 360m, 26 October 2009, in 95% ethanol.

Diagnosis. Metatergites without tubercles, small rounded teeth posterolaterally on paranota, male leg 6 with triangular extension basally on prefemur, solenomere the longest telopodite process, with broad and flattened tip notched into two extensions.

Description. Male/female approximate measurements: length 14/13 mm, ring 12 paranota width 1.7/1.7 mm. Live and recently preserved specimens mainly dark brown, paler ventrally and in patches on paranota and sometimes medially at rear of metatergites; legs pale, light brown distally.

Most non-gonopod details as for *T. armatum*, but relative widths tergite 6>5>4>(2,head)>3>collum, ring 12 paranota 1.4 × as wide as prozonite, male sternites ca 1.2 × longer than wide. Most paranota with small rounded tooth at posterior corner, some paranota with second, smaller, rounded tooth just medial to corner; paranota decreasing in width from ring 11, ring 16 paranota merely a thickening without marginal groove, ring 17 without trace of paranota. Leg 6 with tarsus ca 1.5 × as long as femur; prefemur with unusually long brush setae and thin, triangular projection on posterior surface, directed basally (Fig. 6E). Ring 2 pit deep, wide, rim not well-defined postero-medially. Ring 6 sternite with legs 6 closer together than legs 7; short, thin leg 6 tab with brush of fine setae; leg 7 tab long, thickened, with brush of fine setae; anterior margin of sternite with a few long, fine setae.

Gonopod telopodite (Fig. 11) tapering distally from laterally swollen lower portion; divided into four main processes at ca 2/3 telopodite height. Undivided portion with posterior surface roundly ridged longitudinally, base posteriorly extended as thin shelf, concave



Figure 11. *Tasmaniosoma bruniense* sp. n., paratype male ex QVM 23:51633. Lateral **A**, anterior **B**, medial **C** and posterior **D** views of left gonopod telopodite. Setation only shown in **A**, dashed lines mark course of prostatic groove. Scale bar = 0.2 mm.

distally. Four distal processes comprise: (a) long, mediolaterally flattened, apically acute, slightly sinuous process arising on posteromedial surface; (b) short, somewhat flattened posterolateral process with rounded-truncate tip; (c) large solenomere arising on anterolateral surface, slightly flattened mediolaterally, the apex bent posteriorly and curving laterally, the tip bifid with the prostatic groove terminating in the lower portion; (d) large, apically acute process, slightly flattened mediolaterally, arising just anteromedial to solenomere base, closely pressed to solenomere and reaching nearly as far distally. In addition, a short, acute process arising at ca 1/2 telopodite height on anterolateral surface and terminating just distal to level of solenomere base. Tracts of fine setae posteriorly on posterior longitudinal ridge, and running obliquely from posterobasal shelf to just basal to anterior process on anterolateral surface. Prostatic groove running distally on medial surface of telopodite to just basal to division into processes, then running posterolaterally to enter solenomere base.

Female leg 2 prefemur distally swollen, with small, rounded, tooth-like projection arising midlength on posteromedial surface; sternites as wide as long; posterior margin of epigynum produced as short, wide trapezoid.

Distribution. Known from three sites in wet eucalypt forest with cool temperate rainforest understorey on South Bruny Island, with a maximum distance between sites of ca 5 km (Fig. 24). Co-occurs with *T. warra* sp. n. at the type locality.

Etymology. Adjective; all known specimens are from Bruny Island.

Remarks. Females and subadults can be recognised by the prominent tooth on the posterior margin of the metatergites, and females can also be distinguished from co-oc-curring females of *T. warra* sp. n. by the projection on the leg 2 prefemur in *T. bruniense*.

Tasmaniosoma cacofonix sp. n.

urn:lsid:zoobank.org:act:2857F774-8881-4A40-A182-6C423BCAD7F1 Figs 4C, 12; map Fig. 26

Holotype. Male, Australia, Tasmania, Glennons Road area, 41°03'41"S 147°34'17"E (EQ479541) ±100 m, 130 m, 6 January 1994, R. Mesibov, QVM 23:51661.

Paratypes. 8 males, 2 females, Eddystone Point, Tas, $40^{\circ}59'44''S 148^{\circ}19'29''E$ (FQ113607) ±100 m, 10 m, pitfall emptied 22 April 1987, T. Churchill, QVM 23:46776; 1 male, 1 female, same details but 18 November 1987, QVM 23:46777; 7 males, Old Chum Dam, Tas, $41^{\circ}02'59''S 148^{\circ}02'46''E$ (EQ878550) ±100 m, 140 m, pitfall 7/2 emptied February 2000, R. Bashford, QVM 23:46748; 1 male, Sapphire Creek, Mt Cameron, Tas, $40^{\circ}59'02''S 147^{\circ}56'30''E$ (EQ791624) ±50 m, 360 m, 14 November 2009, K. Bonham & A. Throssell, QVM 23:51660.

Other material examined. 79 males and 1 female from 40 other sites (see Appendix).

Diagnosis. Metatergites without tubercles, gonopod telopodite with five processes, the largest and longest terminating in thorn-like extension.

Description. Male/female approximate measurements: length 14/13 mm, ring 12 paranota width 1.6/1.4 mm. Live colour pale greenish-yellow, with darker yellowish-brown patches on sides and (variably) along dorsal midline, and with fine red speck-ling on paranota posteriorly and on head. In alcohol, specimens often completely de-coloured or with reddish patches dorsally.

Most non-gonopod details as for *T. armatum*, but antennomere 3 longest, relative widths tergite 6>5>head>(4,2)>3>collum, ring 12 paranota 1.4 × as wide as prozonite, male midbody metatergites ca 1.8 × as wide as long. Ring 2 pit (Fig. 4C) deep, wide, rim well-defined except posteriorly. Ring 6 sternite with short leg 6 and 7 tabs each bearing short, linear brush of fine setae; legs 6 closer together than legs 7; sternite with anterior portion elevated on either side, creating triangular depression with apex at anterior margin.

Gonopod telopodite (Fig. 12) somewhat flattened anteroposteriorly, almost fusiform in lateral or medial view but with slight longitudinal concavity on posterior surface. Divided at ca 2/3 telopodite height into tight cluster of five processes, described here from longest to shortest: (a) large central process, appearing to be continuation of telopodite body, tapering distally, curving slightly medially and terminating in distally curving, thorn-like structure set off by slight constriction; (b) subcylindrical, acute process arising lateral and slightly posterior to central process, curving slightly anteriorly; (c) and (d) pair of closely pressed, mediolaterally flattened processes, medial to central process, the outer the solenomere; (e) lateral to solenomere and arising slightly basal to it, a rod-like, acute process directed posterodistally. Small patch of short, fine setae on posterior surface at ca mid-height; sparse, fine setae running anterodistally from base on posterior surface and terminating at ca 1/3 telopodite height; small linear group of fine setae midlaterally on slight longitudinal thickening. Prostatic groove curving posterodistally on medial surface, turning distally just posterior to process (e) base before entering solenomere base.



Figure 12. *Tasmaniosoma cacofonix* sp. n., paratype male ex QVM 23:46748. **A** Anterior view of gonopods in situ **B** medial and **C** posterolateral views of left gonopod telopodite. Setation only shown in **C**, dashed line marks course of prostatic groove. Scale bars = 0.2 mm.

Female somewhat smaller than male, not with long midbody metatergites; posterior margin of epigynum produced as short, wide trapezoid.

Distribution. Common and sometimes locally abundant in eucalypt forest and coastal heath and scrub over ca 3000 km² in northeast Tasmania, from sea level to at least 370 m elevation (Fig. 26). Known from the north coast south almost to Mathinna, and from the east coast west to the neighbourhood of Bridport. Sympatric with *T. decussatum* sp. n. in various parts of its range, and possibly parapatric with *T. clarksonorum* sp. n., *T. gerdiorivum* sp. n. and *T. orientale* sp. n.

Etymology. Noun in apposition, honouring the village bard Cacofonix in the English version of the much-loved series of graphic novels *The Adventures of Asterix*. In anterior or posterior view, the paired central processes on the gonopod telopodite (Fig. 12A) remind me of the frame of a lyre, as played so memorably by Cacofonix.

Remarks. *T. cacofonix* is abundant in eucalypt forest near Old Chum Dam, ca 10 km south-southeast from Gladstone in northeast Tasmania. Pitfall-trapping in this

area in 1989/90 yielded 40 males, but many of these are partly macerated. As Old Chum Dam paratypes I selected five males that were trapped in 2000 and are in much better condition. Old Chum Dam is also the type locality of *Atrophotergum sodalis* Mesibov, 2004 (see Introduction).

Tasmaniosoma clarksonorum sp. n.

urn:lsid:zoobank.org:act:F8AE3AE0-B587-4720-B41A-CFCD5EE353EA Figs 1B, 1F, 10B; map Fig. 25

Holotype. Male, Australia, Tasmania, Mt Barrow, 41°21'33"S 147°24'54"E (EQ346211) ±100 m, 740 m, 1 August 2005, W. & L. Clarkson, under bark on *Eucalyptus*, QVM 23:46584.

Paratypes. 10 males, 2 females, 1 stadium VI female, details as for holotype, QVM 23: 46583; 9 males, 5 females, details as for holotype but 41°21'30"S 147°24'24"E (EQ339212) ±100 m, 750 m, QVM 23:46582.

Other material examined. 80 males and 17 females from 28 other sites (see Appendix).

Diagnosis. Metatergites with three transverse rows of large, low, contiguous tubercles; leg 7 sternal tab with dense brush of stout, rod-like setae; gonopod telopodite with central, flattened process notched into three parts and two combs of long, stout, rodlike setae on posterior surface, the distal comb directed distally and the much smaller basal comb directed basally.

Description. Male/female approximate measurements: length 11/11 mm, ring 12 paranota width 1.4/1.5 mm. Live and freshly preserved males with head violet dorsally; antennae purplish-brown; legs pale, reddish distally; paranota with reticulate red pattern (Fig. 1B); prozonites dorsally brown, darker laterally and posteriorly, with small paramedian pale yellow patches, arcuate or semicircular, in posterior half; metazonites dorsally with paramedian pale yellow patches on waist contrasting with dark brown colouring medially and laterally, and metatergites light brown with darker patches bordering paranota, and paramedian pale yellow spots in posterior half; laterally (Fig. 1F) a mottled brown on metazonites below paranota and on prozonites, pale yellow on metazonites. Female live colouring similar, but with pale yellow patches more distinct, and with median longitudinal dark brown band dorsally on metazonites. In alcohol, long-preserved specimens light brown with reddish markings laterally on metatergites.

Most non-gonopod details as for *T. armatum*, but antennomeres 3 and 6 equal in length and longest, relative widths tergite 6>5>(4,head)>(3,2)>collum, ring 12 paranota $1.3 \times$ as wide as prozonite, leg 6 tarsus $2 \times$ as long as femur, prefemur not as swollen. Anterior margin of metatergite smoothly curving into lateral edge of paranota (shoulder less distinct than in *T. armatum*); metatergite almost completely covered with three transverse rows of 10-12 large, low tubercles, each with small seta near pos-

terior edge. Ring 2 pit with rim only defined anteriorly and laterally. Ring 6 sternite with no leg 6 tab; leg 7 tab long, thickened, with row of fine setae on anterior surface; sparse row of fine setae on anterior sternal margin.

Gonopod telopodite (Fig. 10B) straight, subcylindrical, divided at slightly more than 3/4 telopodite height into apical cluster of three major processes: (a) short, rod-like, slightly curved, acute solenomere medially; (b) long, rod-like, acute and slightly sinuous lateral process, directed laterally before abruptly turning distal; (c) broad, flattened central process between (a) and (b), deeply notched to produce blade-like, curved anterolateral branch, slender, acute central branch and rounded, tab-like posteromedial branch. In addition, very short, stout process arising just anterior to solenomere base and directed anteromedially, the tip notched. Closely packed row of 15–20 stout, rod-like, distally directed setae on distal side of oblique thickening on the posterior surface, the row running from a point basal to solenomere origin distolaterally to a point basal to lateral process origin; cluster of 5–10 stout, rod-like setae arising at ca 1/2 telopodite height on posterolateral surface and directed posterolaterally and slightly basally; and sparse fine setae on posterolateral surface to ca 1/3 telopodite height. Prostatic groove running more or less straight base of solenomere on medial surface.

Female more robust than male and with distinctly shorter midbody metatergites, width:length 3.0 in female vs 2.3 in male.

Distribution. Often locally abundant in cool temperate rainforest and wet eucalypt forest over ca 2000 km² in northeast Tasmania from ca 250 m to at least 1000 m elevation (Fig. 25). Occurs west almost to Lilydale, north and east to the Weldborough area, and south to Mt Stewart between Epping Forest and Avoca. The southern outlier on Mt Stewart may not be a disjunct population; the forests between this *T. clarksonorum* locality and the more northern ones have not yet been carefully surveyed for millipedes. Sympatric with *T. decussatum* sp. n. and *T. gerdiorivum* sp. n., parapatric with *T. armatum* on Mt Barrow and near Weavers Creek, and possibly parapatric with *T. cacofonix* sp. n. in the east of the *T. clarksonorum* range.

Etymology. In honour of Tasmanian field naturalists Wade and Lisa Clarkson, who enthusiastically searched for this and other *Tasmaniosoma* species in 2005 and 2006.

Tasmaniosoma compitale sp. n.

urn:lsid:zoobank.org:act:B431F3B4-C271-4396-8ADB-8D56E804C2E7 Figs 1C, 1G, 4A, 13; map Fig. 23

Holotype. Male, Australia, Tasmania, Deep Gully Creek, 41°25'02"S 145°35'43"E (CQ825138) ±100 m, 610 m, 13 October 1991, R. Mesibov, QVM 23:45968.

Paratypes. 1 female, details as for holotype, QVM 23:45969; 1 male, same details but 14 October 1991, QVM 23:45970; 1 female, same details but 18 October 1991, QVM 23:45971; 1 female, same details but 24 October 1991, QVM 23:45974; 1 male, Fingerpost, Tas, 41°24'37"S 145°37'44"E (CQ853146) ±100 m, 610 m, 17 September 1991, R. Mesibov, QVM 23:45955; 2 females, same details, QVM 23:45956;



Figure 13. *Tasmaniosoma compitale* sp. n. **A** Posterior view of gonopods in situ (paratype male ex QVM 23:45971) **B** medial view of right gonopod telopodite (ex QVM 23:45963, from close to type locality). Dashed line marks course of prostatic groove. Scale bar ca 0.2 mm.

1 male, same details but 18 September 1991, QVM 23:45957; 1 female, same details, QVM 23:45958; 1 female, 1 stadium VI male, same details but 23 September 1991, QVM 23:45959; 1 female, same details but 26 September 1991, QVM 23:45961.

Other material examined. 53 males, 33 females, 3 stadium VI females and 1 stadium V female from 46 other sites (see Appendix).

Diagnosis. Metatergites with three transverse rows of large, low, contiguous tubercles; leg 7 sternal tab with dense brush of stout, rod-like setae; gonopod telopodite with central, flattened process notched into three parts and two comparably sized combs of long, stout, rod-like setae on posterior surface, the basal comb directed basally, the distal comb distally.

Description. Male/female approximate measurements: length 12/13 mm, ring 12 paranota width 1.4/1.6 mm. Freshly preserved specimens yellowish-brown to unaided eye, under microscope with complex pattern (Figs 1C, 1G): paired paramedian light-yellow patches on prozonite and anteriorly on metatergite, contrasting with adjoining dark brown patches; metatergite otherwise light mottled yellowish brown; rings laterally with mottled yellowish-brown and large yellowish patch (Fig. 1G, **p**) just under paranotal margin; head reddish; antennae dark brown; legs pale, reddish distally. Live specimens similarly coloured but yellow not so intense; in alcohol, long-preserved specimens completely decoloured.

Most non-gonopod details as for *T. armatum*, but relative widths tergite $6>5>4>head>(3,2)>collum, ring 12 paranota <math>1.3 \times as$ wide as prozonite, leg 6 tarsus $1.5 \times as$ long as femur and femur longer than prefemur. Anterior margin of metatergite smoothly curving into lateral edge of paranota (shoulder less distinct than in *T. armatum*); metatergite almost completely covered with three transverse rows of 10-12 large, low tubercles, each with small seta near posterior edge. Ring 2 pit not apparent (Fig. 4A). Ring 6 sternite with no leg 6 tab; leg 7 tab long, thickened, with brush of stout setae; small rounded process medially on leg 7 coxa just posterior to sternal tab; anterior sternite margin with two long, fine, paramedian setae.

Gonopod telopodite (Fig. 13) straight, slender, slightly excavate basally on posterior surface, divided at ca 3/4 telopodite height into four processes: (a) short, slightly flattened, acute solenomere arising on medial surface and directed distally; (b) short, bladelike, acute process arising on anterolateral surface just basal to solenomere origin and directed distally and slightly anteriorly; (c) large central process, anteroposteriorly flattened, the wide distal margin divided into acute anterolateral branch and round-edged, tab-like posteromedial branch, the latter giving rise on distal edge to short, slender, tapered process directed posterodistally; (d) large, blade-like, acute process arising on lateral surface, abruptly bent and directed distally. Two dense clusters of stout, rod-like setae: 30–40 arising at ca 1/2 telopodite height on posterior surface, directed posteriorly or posterobasally; 20–30 in band running anterolaterally across posterior surface from ca 1/2 to ca 3/4 telopodite height, mainly directed distally. Sparse fine setae running from posterior surface near base anterodistally along lateral surface to ca 1/2 telopodite height. Prostatic groove running more or less directly on medial surface to base of solenomere.

Female with sternites as wide as long; legs 2 usually missing (Mesibov, in preparation).

Distribution. Sometimes locally abundant in wet eucalypt forest, cool temperate rainforest and riparian tea-tree forest over at least 3000 km² in northwest Tasmania, from Table Cape west to the Marrawah area, and from near sea level at Black River south to the Waratah area at 650 m elevation (Fig. 23). The *T. compitale* range is bounded on three sides by the range of *T. hickmanorum* sp. n. and the two species are tightly parapatric at some localities (Mesibov, in preparation).

T. compitale has also been collected in plantations of *Pinus radiata* (Bonham, Mesibov and Bashford 2002; specimens coded as *Tasmaniosoma* sp. 1).

Etymology. Latin *compitalis*, "of crossroads", adjective. The types were collected near the Fingerpost, a well-known crossroads in northwest Tasmania.

Remarks. Gonopod structure is nearly constant across the *T. compitale* range, but overall body size varies, with the largest specimens (to ca 15 mm long) occurring in coastal and near-coastal areas.

The bright and complex pigmentation of *T. compitale* is lost with long storage in alcohol, and long-preserved females of *T. compitale* and *T. hickmanorum* n sp. cannot be separated. Live and freshly preserved females can be distinguished by colour: *T. compitale* yellowish-brown with a large, prominent yellowish patch just under the paranotal margin (Fig. 1G), *T. hickmanorum* reddish-brown with only a small yellowish patch under paranotal margin (Fig. 1I).

Tasmaniosoma decussatum sp. n.

urn:lsid:zoobank.org:act:28ECADB3-5E75-4A06-B6D2-61D431FF7E53 Figs 4D, 14; map Fig. 25

Holotype. Male, Australia, Tasmania, Rattler Hill, 41°13'43"S 147°53'20"E (EQ744353) ±100 m, 650 m, 27 August 1990, R. Mesibov, plot NE2, QVM 23:51555.

Paratypes. 2 males, 3 females, Pearly Brook, Tas, 41°04'18"S 147°39'43"E (EQ555529) ± 100 m, 80 m, 1 March 1992, R. Mesibov, QVM 23:46692; 2 males, details as for holotype, QVM 23:46703; 2 males, same details but 3 September 1990, QVM 23:46704; 1 male, Rattler Hill, Tas, 41°13'49"S 147°53'21"E (EQ744351) ± 100 m, 680 m, 23 August 1990, R. Mesibov, plot NE1, QVM 23:46700; 2 males, same details but 25 August 1990, QVM 23:46701; 1 male, same details but 26 August 1990, QVM 23:46702; 4 males, E of Rattler Hill, Tas, 41°13'43"S 147°53'16"E (EQ743353) ± 100 m, 650 m, 18 January 2005, R. Mesibov, QVM 23:46699.

Other material examined. 86 males from 13 other localities (see Appendix)

Diagnosis. Metatergites with three weakly developed, transverse rows of low tubercles, gonopod telopodite apex divided into cluster of five processes including broad, flattened solenomere, the most lateral process curving medially.

Description. Male/female approximate measurements: length 11/11 mm, ring 12 paranota width 1.3/1.3 mm. Live colour not known; in alcohol, decoloured with small reddish patches dorsally.

Most non-gonopod details as for *T. armatum*, but antennomere 3 longest, relative widths tergite 6>5>(4,head)>2>3>collum, ring 12 paranota 1.3 × as wide as prozonite, leg 6 femur longer than prefemur, male midbody metatergites 1.8 × as wide as long. Three transverse rows of ca 10 large, low tubercules on tergites sometimes just detectable in lateral view with oblique lighting, not as clearly expressed as in co-occurring *T. clarksonorum* sp. n. Ring 2 pit (Fig. 4D) deep, very wide, with rim well-defined except posteriorly. Ring 6 sternite with legs 6 not as widely separated as legs 7; no leg 6 tab;



Figure 14. *Tasmaniosoma decussatum* sp. n., paratype male ex QVM 23:46699. **A** Posterior view of gonopods in situ **B** posterior and slightly lateral view of left gonopod telopodite. Setation not shown in **B**, dashed line marks course of prostatic groove. Scale bars = 0.2 mm. A small portion of the background in **A** has been digitally edited for clarity.

leg 7 tab short with brush of fine setae; anterior margin of sternite with groups of fine setae laterally, not in dense brushes.

Gonopod telopodite (Fig. 14) straight, stout, slightly tapered distally; base extended posteriorly as concave shelf (concave upwards); posteromedial surface roundly ridged longitudinally. Telopodite divided at ca 3/4 telopodite height into tight cluster of five processes: (a) solenomere anteroposteriorly flattened, produced as small rounded tab directed medially and larger distal tab with rounded edge and small medial tooth, prostatic groove opening centrally on distal edge; (b) short, slender, acute process arising anteromedial to solenomere origin and slightly bent medially; (c) laminate process closely applied to distal tab of solenomere on anterolateral side and slightly longer than solenomere; (d) and (e), two long, blade-like processes arising anterior to laminate process, the lateral process acute and curving slightly posteromedially, the medial process strongly tapered and curved posteromedially, the tip turning distally. Small group of short, fine setae at ca 1/2 telopodite height on lateral surface of posterior ridge; sparse, fine setae running anterodistally from basal shelf; and a few fine setae in row on lateral surface at ca 1/2 telopodite height. Prostatic groove running distally, then curving laterally to enter base of distal tab of solenomere, and curving within tab (concave medially).

Female with posterior margin of epigynum produced as short, wide trapezoid.

Distribution. Often locally abundant in wet eucalypt forest and cool temperate rainforest over ca 1500 km² in the eastern portion of northeast Tasmania, from 80 to at least 740 m elevation (Fig. 25). Co-occurs with *T. clarksonorum* sp. n. at Mt Michael and Mt Victoria and near Weldborough in the northeast highlands. Sympatric with *T. cacofonix* sp. n., but co-occurrences may be rare because the latter species prefers drier, more open forest. Possibly parapatric with *T. gerdiorivum* sp. n. in the western part of the *T. decussatum* range.

Etymology. Latin *decussatus*, "X-shaped", adjective, for the usually crossed tips of two of the gonopod processes in situ.

Tasmaniosoma fasciculum sp. n.

urn:lsid:zoobank.org:act:C6C55E40-6555-4146-9BB6-7401CFDD9858 Figs 1D, 1H, 5C, 15; map Fig. 26

Holotype. Male, Australia, Tasmania, Little Claytons Rivulet, 41°12'24"S 146°12'07"E (DQ330378) ±25 m, 100 m, 27 December 2009, R. Mesibov & T. Moule, QVM 23:51664.

Paratypes. 1 male, same locality as holotype but 41°12'28"S 146°12'12"E (DQ331377) ±100 m, 100 m, 30 November 1997, R. Mesibov & T. Moule, QVM 23:46644; 2 males, 1 stadium VI male, 2 stadium VI females, same details as holotype, QVM 23:51665.

Other material examined. 20 males and 3 females from 17 other sites (see Appendix).

Diagnosis. Metatergites with three transverse rows of large, low, contiguous tubercles; leg 7 sternal tab with dense brush of stout, rod-like setae; gonopod telopodite with central, anvil-shaped process and two comparably sized combs of long, stout, rod-like setae on posterior surface, both directed distally.

Description. Male/female approximate measurements: length 12 /11 mm, ring 12 paranota width 1.2/1.2 mm. Live and freshly preserved specimens with reddishbrown head and antennae and complex pattern of strongly contrasting yellow and brown patches on most rings (Figs 1D, 1H): prozonites have paired paramedian yellow patches with brown patches medially and laterally, metazonites have paired paramedian yellow patches marginally on paranota and more diffuse paramedian brown bands along posterior margin and just anterior to transverse furrow. Live specimens similarly coloured but yellow not so intense; in alcohol, long-preserved specimens completely decoloured.



Figure 15. *Tasmaniosoma fasciculum* sp. n., paratype males. **A** Right posterolateral view of gonopods in situ (ex QVM 23:46638) **B** lateral and slightly anterior and **C** medial views of left gonopod telopodite (ex QVM 23:46635). Scale bars = 0.2 mm.

As for *T. armatum* in most non-gonopod details, but relative widths tergite $6>5>(4,head)>(3,2)>collum, leg 6 tarsus <math>1.5 \times as$ long as femur. Metatergite almost completely covered with three transverse rows of 10-12 large, low tubercles, each with a small seta near posterior edge. Ring 2 pit not apparent except as slight concavity near anterior margin of ring. No setae on anterior margin of ring 6 (Fig. 5C); leg 6 tab short, with a few fine setae; leg 7 tab long, thickened, with brush of stout setae.

Gonopod telopodite (Fig. 15) arching anteriorly, strongly narrowed at ca 1/4 telopodite height, tip divided into four processes: (a) small, subcylindrical, distally tapered solenomere arising on medial surface and directed distally, curving medially near tip; (b) thick, tab-like bulge arising posterolaterally and bearing a tight cluster of 6–8 long, stout, rod-like setae directed anterodistally and slightly laterally; (c) anvil-shaped process arising on anteromedial surface, flattened anteroposteriorly, rounded medial end and pointed lateral end of "anvil" both curving posteriorly; (d) long, blade-like, acute process arising on anterolateral surface and directed distally. Second tight cluster of ca 15 stout, rod-like setae arising on posterior surface just basal to division of telopodite into processes, setae reaching almost as far distally as solenomere; sparse fine setae on posterior surface near base and along lateral surface directly to solenomere base.

Female with sternites as wide as long.

Distribution. Known from eucalypt forest over ca 2000 km² in north central Tasmania to 550 m elevation (Fig. 26). Not yet found west of the Dial Range, south of Maggs Mountain or east of the Birralee Road. Co-occurs with *T. hickmanorum* sp. n.

Etymology. Latin *fasciculus*, diminutive of *fascis*, "sheaf", adjective, for the tight sheaf of stout, rod-like setae on the tip of the gonopod.

Remarks. I have not been able to recognise species-diagnostic features in long-preserved, decoloured females of *T. fasciculum*. As a result, I cannot confidently assign to *T. fasciculum* a number of possible female specimens from localities within the known range (in the QVM collection) because no there are no associated males. The description of the female (above) is based on three specimens found close to sites in the Gog Range and Dial Range where I have also collected males.

I may also have overlooked *T. fasciculum* outside its known range in north central Tasmania. In the field, an adult of this uncommon species can easily be mistaken for a stadium V or VI juvenile of the co-occurring *T. hickmanorum* sp. n.

Tasmaniosoma fragile sp. n.

urn:lsid:zoobank.org:act:066F3EC2-2202-410C-B7A5-AA99E4C448A6 Fig. 16; map Fig. 25

Holotype. Male, Australia, Tasmania, Apsley River, 41°51'16"S 148°12'05"E (EP996655) ±100 m, 130 m, 20 July 1988, R. Mesibov, QVM 23:51666.

Paratypes. 1 male, details as for holotype, QVM 23:46766; 1 male, same details but 41°51'16"S 148°11'47"E (EP992655) ±100 m, 19 July 1988, QVM 23:46765.

Other material examined. 5 males and 3 females from four other localities (see Appendix).

Diagnosis. Metatergites with three transverse rows of large, low, contiguous tubercles; leg 7 sternal tab with dense brush of stout, rod-like setae; gonopod telopodite with central, flattened process notched into three parts and three comparably sized combs of long, stout, rod-like, setae: distally directed on lateral and anterior surfaces, basally directed on posterior surface.

Description. Male/female approximate measurements: length 12/14 mm, ring 12 paranota width 1.5/1.8 mm. Live colour not known; in alcohol, uniformly pale yellowish brown.

Most non-gonopod details as for *T. armatum*, but antennomere 3 longest, relative overall widths tergite 6>5>4>(3,2,head)>collum, ring 12 paranota $1.4 \times as$ wide as prozonite, metatergite ca $2.8 \times as$ wide as long, prefemora not as swollen dorsally, leg 6 tarsus $1.3 \times as$ long as femur and femur longer than prefemur. Metatergite almost completely covered with three transverse rows of ca 10 large, low tubercles, each with small seta near posterior edge. Ring 6 sternite with a few fine setae along anterior edge; leg 6 tab short, without setae; leg 7 tab long, thickened, with brush of stout setae. Ring 7 sternite with paired paramedian brushes of fine setae just posterior to gonopod aperture.



Figure 16. *Tasmaniosoma fragile* sp. n., paratype males. **A** Posterior view of gonopods in situ (ex QVM 23:46766) **B** medial view of left gonopod telopodite, setation omitted for clarity (ex QVM 23:46767). Scale bars = 0.2 mm. The 'hole' at the top of each telopodite is the broken-off tip of the distal extension of the central process.

Gonopod telopodite (Fig. 16) straight, slender, slightly narrowed just above base, divided at ca 2/3 telopodite height into four major processes: (a) short, subcylindrical solenomere arising on medial surface and directed distally; (b) blade-like, acute process arising on anteromedial surface just basal to solenomere origin and directed anterodistally; (c) large central process with posterodistally sloping flat surface, extending medially as round-edged, tab-like structure just posterior to solenomere and extending distally as acute, subcylindrical, posteriorly curving structure; (d) long, blade-like, acute, posterolaterally curving process arising on lateral surface just basal to solenomere origin and directed distolaterally, 15–20 arising on posterior surface a little basal to lateral cluster and directed posterobasally, and 5–10 arising on anterolateral surface near apex and directed distally. Sparse fine setae running from posterior surface near base anterodistally along lateral surface to ca 1/2 telopodite height. Prostatic groove running on medial surface directly to solenomere base.

Female with legs 2 missing in the three known specimens.

Distribution. Known from six localities over ca 1000 km² in eastern Tasmania up to 630 m elevation, from Mt Allen close to the east coast at Douglas River to ca 10 km east of Campbell Town in the Midlands, and south in the Eastern Tiers to the Swansea area (Fig. 25). Sympatric with *T. armatum*, co-occurs with *T. orientale* sp. n.

Etymology. Latin *fragilis*, "breakable", adjective. The stout, rod-like setae on the gonopod are usually broken. Females are readily distinguished from those of sympatric, similarly sized *T. armatum* and *T. orientale* sp. n. by the presence of prominent tubercles on *T. fragile* tergites.

Tasmaniosoma gerdiorivum sp. n.

urn:lsid:zoobank.org:act:6333E909-8104-403A-B6C3-50FB376FB357 Fig. 17; map Fig. 26

Holotype. Male, Australia, Tasmania, Weavers Creek area, 41°25'37"S 147°22'16"E (EQ309136) ±100 m, 540 m, 23 March 1995, R. Mesibov, QVM 23:51667.

Paratypes. 6 males, 1 female, details as for holotype, QVM 23:46675; 1 male, 1 female, same details but $41^{\circ}26'00$ "S $147^{\circ}21'55$ "E (EQ304129) ±100 m, 700 m, 4 August 1994, QVM 23:46667; 3 males, 4 females, same locality but $41^{\circ}24'09$ "S $147^{\circ}22'59$ "E (EQ319163) ±100 m, 970 m, 8 January 1995, R. Mesibov & T. Moule, QVM 23:46669; 2 males, same details but $41^{\circ}26'58$ "S $147^{\circ}22'47$ "E (EQ316111) ±100 m, 470 m, 22 March 1995, R. Mesibov, QVM 23:46671; 1 male, same details but $41^{\circ}27'01$ "S $147^{\circ}23'04$ "E (EQ320110) ±100 m, 530 m, QVM 23:46672; 2 males, same details but $41^{\circ}27'27$ "S $147^{\circ}23'13$ "E (EQ322102) ±100 m, 440 m, QVM 23:46673; 1 male, same details but $41^{\circ}26'19$ "S $147^{\circ}22'04$ "E (EQ306123) ±100 m, 710 m, 23 March 1995, QVM 23:46674.

Other material examined. 66 males and 15 females from 39 other sites (see Appendix).

Diagnosis. Metatergites with three weakly developed, transverse rows of low tubercles, gonopod telopodite apex divided into cluster of four processes including broad, flattened solenomere, the most lateral process directed bent laterally.

Description. Male/female approximate measurements: length 10/11 mm, ring 12 paranota width 0.9/1.0 mm. Live colour very pale yellow with sparse, reddish mottling and reticulation on metatergites, mainly along posterior margin, antennae light brown and head pinkish-red dorsally; in alcohol, pale yellowish-brown or completely decoloured.

Male as for *T. armatum* in most non-gonopod details, but overall widths tergite $6>head>5>4>(3,2)>collum, antennomere 3 longest, leg 6 tarsus <math>1.5 \times as$ long as femur, femur longer than prefemur, prefemoral swellings not apparent posterior to ring 11. Ring 12 paranota $1.3 \times as$ wide as prozonite; paranotum with distinct shoulder anteriorly, almost quadrate, lateral margin almost straight; metatergite almost completely covered with three transverse rows of 10-12 large, very low tubercles, each with small seta near posterior edge, but tubercles hard to detect with light microscopy. Ring 6 ster-



Figure 17. *Tasmaniosoma gerdiorivum* sp. n., paratype males ex QVM 23:46675. **A** Posterior view of gonopods in situ **B** medial view of left gonopod telopodite. Setation not shown in **B** dashed line marks course of prostatic groove. Scale bars = 0.1 mm. In **A**, the bends in the three flattened terminal processes are a preparation artifact; in wet specimens the bent portions seen in (A) are nearly planar.

nite as for *T. armatum* but with marginal band of fine setae along anterior edge of sternite; at high magnification, band is seen to consist of four evenly spaced, loose clusters.

Gonopod telopodite (Fig. 17) straight, stout, slightly flattened anteroposteriorly; base extended posteriorly and laterally as shelf, concave upwards, with thickened margin; anterior surface with gently convex medial extension at ca 1/2 telopodite height. Telopodite divided at ca 3/4 height into four processes: (a) mediolaterally flattened, tab-like solenomere arising medially, the distal edge subtriangular; (b) anteroposteriorly flattened process arising just lateral to solenomere with acute apex and short, shelf-like posterior extension at base; (c) long, blade-like, bluntly acute, mediolaterally flattened anterolateral process; (d) rod-like, acute process arising just anterolateral to anterolateral process. Sparse tract of fine setae running from basal shelf anterodistally to ca 1/2 telopodite height on lateral surface; a few fine setae on posterolateral surface at ca 1/2 telopodite height. Prostatic groove running on medial surface more or less directly to solenomere base and terminating at apex of triangle on distal solenomere edge.

Female with posterior margin of epigynum produced as rectangular process almost as long as posterior margin.

Distribution. Sometimes locally abundant in wet eucalypt and subalpine forest over ca 1500 km² in northeast Tasmania from 80 m to at least 1050 m elevation (Fig. 26). The western limit of this distribution coincides approximately with the biogeographical boundary known as the East Tamar Break (Mesibov 1994, 1997). *T. gerdiorivum* occurs ca 5 km from the sea in the north of its range; it has not yet been found east of Mt Saddleback or south of the North Esk River. It co-occurs with *T. armatum* and *T. clarksonorum* sp. n. in the west of its range, and may be parapatric with *T. cacofonix* sp. n. and *T. decussatum* sp. n. in the east.

A male of *T. gerdiorivum* has been found at Gardners Ridge in north central Tasmania, at least 60 km west of all other known localities. This specimen may be from a translocated population, or it may indicate a natural disjunction in the *T. gerdiorivum* range. A similar northeast-north central disjunction has been found in the distribution of *Lissodesmus devexus* Mesibov 2006 (Mesibov 2006).

Etymology. Latin *gerdius*, "weaver", + *rivus*, "stream", noun used as adjective, after the type locality, Weavers Creek.

Tasmaniosoma hesperium sp. n.

urn:lsid:zoobank.org:act:8802E448-74E6-4BB9-8936-E31CDA3132FE Fig. 18A; map Fig. 24

Holotype. Male, Australia, Tasmania, Mt Hesperus, Alpha Moraine, 43°06'43"S 146°14'22"E (DN380263) ±100 m, 580 m, 28 February 1999, K. Bonham & R. Crookshanks, QVM 23:46600, dissected, in genitalia vials.

Paratype. 1 male, Junction Creek, Western Arthur Plains, Tas, 43°06'21"S 146°16'35"E (DN410270) ±5 km, 7 February 1966, A. Neboiss, QVM 23:46602.

Other material. None known.

Diagnosis. Gonopod telopodite apex divided into four processes, the central flattened process projecting posteriorly between solenomere and lateral process.

Description. Male with ring 12 paranota width ca 1.5 mm. Live colour unknown; in alcohol completely decoloured.

As for *T. armatum* in most non-gonopod details, but overall widths tergite $6>5>(4,2,head)>3>collum, antennomere 3 longest, ring 12 paranota <math>1.3 \times as$ wide as prozonite, leg 6 tarsus $1.3 \times as$ long as femur and femur longer than prefemur. Ring 2 pit circular with well-defined rim. Three barely detectable transverse rows of large, low tubercles on metatergites; just visible on holotype in lateral view with reflected light, not as well developed as in other *Tasmaniosoma* spp., e.g. *T. hickmanorum* sp. n. Leg 6 sternal tab short with brush of fine setae; no leg 7 tab; no setae on anterior margin of ring 6 sternite.

Gonopod telopodite (Fig. 18A) straight, slightly tapering distally, somewhat flattened mediolaterally, posteriorly with small shelf-like projection at base (concave



Figure 18. *Tasmaniosoma hesperium* sp. n., paratype male, QVM 23:46602 (**A**, **B**) and *T. maria* sp. n., paratype male ex QVM 23:46759 (**C**, **D**). **A** Medial and slightly ventral **B** posterior and slightly lateral **C** medial and **D** anterolateral views of the respective left gonopod telopodites. Setation not shown; dashed lines mark course of prostatic groove. Scale bar = 0.2 mm. Dotted lines in **C** and **D** indicate reconstructed process based on holotype.

upwards), divided at ca 3/4 telopodite height into cluster of three processes: (a) long posteromedial solenomere, curving slightly laterally; (b) central, broad, mediolaterally flattened process extending posteriorly below solenomere tip; (c) bladelike, acuminate process arising on posterolateral surface close to solenomere origin and directed distally on lateral side of central process. In addition, slender process with forked tip with origin on medial surface at ca 2/3 telopodite height, basal and slightly anterior to solenomere origin, directed anterodistally. Two tracts of sparse, fine setae: one running from basal shelf anterodistally to end laterally at ca 1/3 telopodite height, other running distally from base on posteromedial surface to ca 1/2 telopodite height. Prostatic groove running on medial surface more or less directly to solenomere base.

Female not yet recognised.

Distribution. Known only from two sites less than 5 km apart in the southwest Tasmanian wilderness, ca 40 km south-southeast of Strathgordon (Fig. 24).

Etymology. Latin *hesperius*, "western", adjective, referring to the names of the two known localities.

Remarks. Very similar to *T. laccobium* sp. n., differing mainly in gonopod details.

Tasmaniosoma hickmanorum sp. n.

urn:lsid:zoobank.org:act:271BC147-2CDE-4392-91E0-F9A5930643F0 Figs 1E, 1I, 5D, 19; map Fig. 23

Holotype. Male, Australia, Tasmania, Mossy Marsh Creek, 42°18'34"S 146°22'44"E (DP487155) ±100 m, 630 m, 18 February 1994, R. Mesibov, QVM 23:51669.

Paratypes. 6 males, details as for holotype, QVM 23:46089; 3 males, Tarraleah, Tas, 42°18'19"S 146°25'52"E (DP530160) ±10 km, May 1952, V.V. Hickman, from dead fern leaves, QVM 23:46042; 1 male, same details but under logs, QVM 23:46043; 8 males, 6 females, same details but 26 December 1952 to 2 January 1953, QVM 23:46044; 5 males, Tarraleah, Tas, 42°18'44"S 146°21'48"E (DP474161) ±100 m, 690 m, 16 April 1992, R. Mesibov, plot 1, QVM 23:46057; 2 males, same details but 42°18'11"S 146°21'48"E (DP474162) ±100 m, 700 m, plot 3, QVM 23:46058; 1 male, 1 female, same details but 42°17'58"S 146°21'48"E (DP474166) ±100 m, 710 m, 18 April 1992, plot 11, QVM 23:46060; 1 male, 1 female, same details but 42°16'27"S 146°21'35"E (DP471194) ±100 m, 750 m, 2 May 1992, plot 47, QVM 23:46065; 1 male, same details but 42°16'21"S 146°21'36"E (DP471196) ±100 m, 760 m, plot 45, QVM 23:46066; 2 males, same details but 3 May 1992, plot 52, QVM 23:51668; 1 male, same details but 42°16'08"S 146°21'40"E (DP472200) ±100 m, 790 m, plot 50, QVM 23:46068; 2 males, same details but 4 May 1992, plot 55, QVM 23:46069; 1 male, same details but 42°16'24"S 146°21'57"E (DP476195) ±100 m, 720 m, 8 May 1992, plot 73, QVM 23:46071.

Other material examined. 154 males, 67 females, 3 stadium VI males and 1 stadium VI female from 120 other sites (see Appendix).

Diagnosis. Metatergites with three transverse rows of large, low, contiguous tubercles; leg 7 sternal tab with dense brush of stout, rod-like setae; gonopod telopodite with central, flattened process notched into three parts, a single comb of long, stout, rod-like, setae on posterior surface, and anteromedial process lying obliquely against central process.

Description. Male/female approximate measurements: length 16/16 mm, ring 12 paranota width 1.7/1.7 mm. Freshly preserved specimens finely mottled or reticulated reddish-brown (Fig. 1E); head reddish above, antennae dark brown, legs pale, reddish distally; prozonite with paired paramedian yellowish patches contrasting with adjoining dark brown patches; metatergites sometimes with paired paramedian, yellowish patches near anterior edge; rings laterally (Fig. 1I) finely mottled reddish-brown with small, pale patch under paranotal margin. In alcohol, pale reddish or decoloured.

Male as for *T. armatum* in most non-gonopod details, but overall widths 6>5>(4,head)>(3,2,collum), antennomere 3 longest, ring 12 paranota $1.4 \times as$ wide as prozonite, leg 6 tarsus $1.4 \times as$ long as femur. Anterior margin of metatergite smoothly curving into lateral edge of paranota (shoulder less distinct than in *T. armatum*); metatergite almost completely covered with three transverse rows of 10-12 large, low tubercles, each with small seta near posterior edge. Ring 6 sternite (Fig. 5D) with no



Figure 19. *Tasmaniosoma hickmanorum* sp. n. **A** Posterolateral view of gonopods in situ, voucher male ex QVM 23:46055 **B** anterior view of tip of left gonopod telopodite, paratype male ex QVM 23:46057. **C** anterior view of left gonopod telopodite, paratype male ex QVM 23:46057. Setation not shown in **C** dashed line marks course of prostatic groove. Scale bars: **A**, **C** = 0.2 mm, **B** = 0.1 mm.

leg 6 tab; leg 7 tab long, thickened, with brush of stout setae; anterior margin without setae but with medial notch, about 1/3 width of margin.

Gonopod telopodite (Fig. 19) straight, in cross-section with posterior, anterolateral and anteromedial longitudinal ridges, divided at ca 3/4 telopodite height into tight cluster of four processes: (a) small, slender, acute, medial solenomere, directed distally but curving laterally; (b) large, anteroposteriorly flattened laminate process divided by notches into three acute portions, their lengths decreasing from anteromedial to posterolateral; (c) large, blade-like, acute lateral process curving laterally; (d) blade-like, acute process arising near medial edge of anterior surface, directed distolaterally and closely pressed to anterior surface of laminate process. Sparse group of fine setae near base posterolaterally; ca 20 fine setae laterally from ca 2/3 to ca 3/4 telopodite height; two dense, adjoining clusters of stout, rod-like setae on posterior surface ridge at ca 2/3 telopodite height, the basal cluster of 10–15 setae directed mainly posterobasally, the distal cluster of ca 30 setae directed distally with a few outlying setae in line extending towards base of lateral process. Prostatic groove running along medial surface more or less directly to solenomere base.

Female with sternites as wide as long, legs 2 usually missing (Mesibov, in preparation).

Distribution. Often locally abundant in wet eucalypt forest (with or without a cool temperate rainforest understorey), riparian tea-tree forest and coastal dune scrub over the whole of western Tasmania (ca 28 000 km²), from the northern part of King Island (northwest of the main island of Tasmania) to Melaleuca in the far south, with

an elevation range from sea level to at least 940 m (Fig. 23). Part of the eastern range boundary is congruent with the Mersey Break, a major biogeographical divide in north central Tasmania (Mesibov 1999; species coded as *Tasmaniosoma* sp. 2). *T. hickmanorum* is sympatric with *T. fasciculum* sp. n., broadly parapatric with *T. armatum* along the Mersey Break, and at some localities tightly parapatric with *T. compitale* sp. n. (Mesibov, in preparation), with an overlap zone less than 500 m wide.

T. hickmanorum is remarkably abundant in *Eucalyptus globulus* and *E. nitens* plantations established on sites converted from native forest. I have not yet found it in plantations established on former pasture.

Etymology. In honour of V. V. Hickman (1894–1984) and his son J. L. Hickman (1926–2007), Tasmanian invertebrate zoologists and collectors of this millipede species and many others.

Remarks. This species varies a little in size and colouration over its large range, and in some populations females are smaller than males. Gonopod structure, however, is nearly constant.

Long-preserved, decoloured females of *T. hickmanorum* sp. n. and *T. compitale* cannot be separated. Live and freshly preserved females can be distinguished by colour: *T. hickmanorum* reddish-brown with only a small yellowish patch under paranotal margin (Fig. 1I), *T. compitale* yellowish-brown with a large, prominent yellowish patch just under the paranotal margin (Fig. 1G).

Tasmaniosoma laccobium sp. n.

urn:lsid:zoobank.org:act:12CBDFC1-DC15-400E-9CD6-D03C6A75D359 Fig. 20; map Fig. 24

Holotype. Male, Australia, Tasmania, Lake Sydney, 43°17'15"S 146°36'52"E (DN686070) ±100 m, 690 m, 2 February 1994, R. Mesibov, QVM 23:46601, dissected, in genitalia vials.

Paratypes. 1 stadium VI male, 1 stadium VI female, details as for holotype, QVM 23:51542.

Other material. None known.

Diagnosis. Gonopod telopodite apex divided into four processes, the central flattened process projecting posterobasally below (basal to) solenomere and lateral process.

Description. Male with ring 12 paranota width ca 1.4 mm. Live colour not known; in alcohol decoloured.

As for *T. armatum* in most non-gonopod details, but overall widths tergite 6>5>4>(3,2,head)>collum, antennomere 3 longest, ring 12 paranota 1.25 × as wide as prozonite, leg 6 tarsus 1.4 × as long as femur and femur longer than prefemur. Ring 2 pit circular with well-defined rim. Three barely detectable transverse rows of large, low tubercles on metatergites; just visible on holotype in lateral view with reflected light, not as well developed as in other *Tasmaniosoma* spp., e.g. *T. hickmanorum* sp. n. Leg 6 sternal tab short with brush of fine setae; no leg 7 tab; no setae on anterior margin of ring 6 sternite.



Figure 20. *Tasmaniosoma laccobium* sp. n., male holotype, QVM 23:46601. **A** medial, **B** posterior and **C** lateral and slightly posterior views of left gonopod telopodite. Setation not shown in **A** and **C** dashed line marks course of prostatic groove. Scale bar = 0.2 mm.

Gonopod telopodite (Fig. 20) slender, tapering slightly distally, curved posteriorly, slightly constricted near base, with short, shelf-like basal extension posteriorly. Divided at ca 3/4 telopodite height into tight cluster of four processes: (a) slender, rod-like, slightly sinuous, medial solenomere directed posterodistally; (b) blade-like, mediolaterally flattened, apically acute process arising just anterior and basal to solenomere and curving posteriorly; (c) mediolaterally flattened central process directed posteriorly, the basal portion of the broad apex extending posterobasally as finger-like extension; (d) broad, anteroposteriorly flattened lateral process, the medial corner of wide, truncate apex extending just posterior to solenomere. Two groups of sparse, fine setae: posterobasal group reaching to ca 1/4 telopodite height, and longitudinal medial tract extending from ca 1/4 to ca 2/3 telopodite height. Prostatic groove running on medial surface more or less directly to solenomere base.

Female not yet recognised.

Distribution. So far known only from cool temperate rainforest at the type locality in the mountains of far southern Tasmania (Fig. 24).

Etymology. Greek *lakkos*, "pond", + *bios*, "life", noun used as adjective, after the type locality, Lake Sydney.

Remarks. Very similar to *T. hesperium* sp. n., differing mainly in gonopod details.

Tasmaniosoma maria sp. n.

urn:lsid:zoobank.org:act:F33C87DA-B288-4E93-8CA5-C8A744522097 Fig. 18B; map Fig. 24

Holotype. Male, Australia, Tasmania, Maria Island, Four Mile Creek, 42°37'20"S 148°04'11"E (EN876804) ±250 m, 60 m, 14 August 1991, R. Mesibov, QVM 23:46760, dissected, in genitalia vials.

Paratypes. 1 male, 4 females, Pine Hut Creek, Maria Island, Tas, 42°39'25"S 148°05'49"E (EN898765) ±250 m, 20 m, 13 August 1991, R. Mesibov, QVM 23:46759; 1 male, 2 females, Blind Creek, Maria Island, Tas, 42°42'24"S 148°04'42"E (EN882710) ±250 m, 120 m, 15 August 1991, R. Mesibov, QVM 23:46761.

Other material. None known.

Diagnosis. Metatergites without tubercles; ring 6 sternite with discrete setal brushes on anterior margin; gonopod telopodite with stout, rod-like setae in longitudinal tract on posteromedial surface and flattened lateral and medial processes with irregular apical margins on either side of a large, central laminate process.

Description. Male/female approximate measurements: length 16/16 mm, ring 12 paranota width 2.1/1.9 mm. Live colour not known; in alcohol, uniformly pale yellowish brown or decoloured.

Male as for *T. armatum* in most non-gonopod details, but overall widths tergite 6>5>4>3>(2,head)>collum, antennomere 3 longest, ring 12 paranota $1.4 \times as$ wide as prozonite. Ring 6 sternite as for *T. armatum*, but with very short, thin sternal tab by leg 6, not bearing setae.

Gonopod telopodite (Fig. 18B) straight, tapering distally, somewhat constricted just above base, posteriorly thickened as ridge running distally, divided above ca 2/3 telopodite height into cluster of six processes: (a) medial, rod-like, acuminate process directed distally and slightly anteriorly; (b) medial, flattened process with expanded tip and fimbriate distal margin, directed posterodistally; (c) medial, slender solenomere bent posteriorly near tip; (d) large, mediolaterally flattened laminate process with curved margin, broken posteriorly by U-shaped notch, the distal border of notch slightly extended and acute; (e) anterior lateral process rod-like, directed anterolaterally, tip slightly flattened and minutely toothed; (f) posterior lateral process rod-like, acuminate, directed posterodistally. Sparse, fine setae running from base distally on lateral side of posterior ridge to ca 1/3 telopodite height; mid-lateral, longitudinal line of 3-4 fine setae; 30-40 stout, rod-like setae from ca 1/3 to 2/3 telopodite height on posteromedial surface. Prostatic groove running on medial surface more or less directly to solenomere base, curving slightly around base of medial process with fimbriate tip. (Note: Fig. 18B is a reconstruction drawn from a paratype and modified using the holotype. None of the three available males has undamaged gonopods, and the stout, rod-like setae are almost all broken off, detectable only as large setal sockets.)

Female with posterior margin of epigynum raised medially as large, rounded triangle with irregular edge. **Distribution.** So far known from eucalypt forest at three localities on North and South Maria Island, with a maximum separation of ca 10 km (Fig. 24). Co-occurs with *T. armatum* at Four Mile Creek, and *T. armatum* has also been collected at Ned Ryans Creek, between the two *T. maria* localities on North Maria Island.

Etymology. Noun in apposition; all known specimens are from Maria Island.

Remarks. The assignment of the Pine Hut Creek and Blind Creek females to *T. maria* is tentative. They are larger than females of sympatric *T. armatum* but are otherwise very similar.

Tasmaniosoma orientale sp. n.

urn:lsid:zoobank.org:act:783D6984-EE76-4BC7-86A8-8C9B883E5C30 Fig. 21; map Fig. 26

Holotype. Male, Australia, Tasmania, Elephant Pass, 41°38'26"S 148°14'32"E (FP034892) ±25 m, 340 m, 20 August 2009, R. Mesibov, QVM 23:51551.

Paratypes. 1 male, Tinmine Creek, Tas, 41°41'55"S 148°11'41"E (EP993828) ±250 m, 530 m, 11 June 1988, R. Mesibov, QVM 23:45991; 1 male, same details but 41°42'08"S 148°12'38"E (FP006824) ±250 m, 450 m, 22 June 1988, QVM 23:46000; 1 female, same details, QVM 23:46001; 1 female, same details but 41°41'33"S 148°10'36"E (EP978835) ±250 m, 550 m, 29 June 1988, QVM 23:46008; 1 male, same details but 41°41'59"S 148°11'15"E (EP987827) ±250 m, 500 m, 30 June 1988, QVM 23:51550.

Other material examined. 37 males and 38 females from 43 other sites (see Appendix).

Diagnosis. Metatergites without tubercles; ring 6 sternite with discrete setal brushes on anterior margin; gonopod telopodite with stout, rod-like setae in longitudinal tract on posteromedial surface and solenomere divided into apically bifid distal branch and distally curved, acuminate basal branch.

Description. Male/female approximate measurements: length 16/16 mm, ring 12 paranota width 1.8/1.8 mm. Male as for *T. armatum* in live colour and most non-gono-pod details, but long-preserved specimens completely decoloured, overall widths tergite 6>5>4>3>(2,head)>collum, ring 12 paranota 1.4 × as wide as prozonite. Ring 6 sternite as for *T. armatum*, but with very short, thin sternal tab by leg 6, not bearing setae.

Gonopod telopodite (Fig. 21) similar to that of *T. armatum* (see Fig. 7A), but process 1 simply acute (but see Remarks) rather than Y-shaped; process 2 undivided, curving medially, apically expanded and flattened with dentate margin; distal margin of laminate process not extended posteriorly, instead curving smoothly to posterior extension, the latter shorter and straighter than in *T. armatum*; solenomere divided into distal branch with bifid tip carrying prostatic groove, and basal branch directed posteriorly but curving distally, with pointed tip; process 3 an anteroposteriorly flattened, quadrate tab, the margin free distally apart from central attachment; process 4 as in *T. armatum*; laterally with group of 5–6 setae, rather than three.

Female with posterior margin of epigynum raised in centre as irregularly edged triangle.



Figure 21. *Tasmaniosoma orientale* sp. n. **A** Posterolateral view of gonopods in situ, voucher male ex QVM 23:46018 **B** medial and **C** posterolateral views of left gonopod telopodite of paratype male ex QVM 23:51550. Setation not shown in **A** and **C**; dashed line marks course of prostatic groove. Processes labelled as in Fig. 7A. Scale bars = 0.2 mm.

Distribution. Common and sometimes locally abundant in dry and wet eucalypt forest over ca 1500 km² in the northern part of the east coast and Eastern Tiers of Tasmania, from near sea level to at least 1000 m elevation (Fig. 26). Not yet found north of Beaumaris or south of Bicheno on the coast, or west of St Pauls Dome in the Fingal Valley. Sympatric with *T. barbatulum* sp. n. and *T. fragile* sp. n.; co-occurs with the latter. *T. orientale* may be parapatric with *T. armatum* in the west and south of its range, and with *T. cacofonix* sp. n. in the north; further sampling is needed to better define the range boundaries of these three species.

Etymology. Latin *orientalis*, "eastern", for the eastern Tasmanian distribution of this species.

Remarks. The lateral process on the gonopod telopodite (process 1) is simply acute in the holotype and the specimen illustrated in Figs 21B and 21C. In some East Coast males the process is apically forked, as in the right telopodite in Fig. 21A. In the west of the *T. orientale* range, the lateral process is wider and Y-shaped, as in *T. armatum*.

Female *T. orientale* are readily distinguished from those of sympatric, similarly sized *T. fragile* sp. n. by the presence of large tubercles on *T. fragile* tergites.
Tasmaniosoma warra sp. n.

urn:lsid:zoobank.org:act:C2EDE9C4-E146-4F5B-A848-74068E27C92B Figs 3A, 22; map Fig. 24

Holotype. Male, Australia, Tasmania, Huon River (Manuka Road), 43°05'36"S 146°43'03"E (DN769286) ±100 m, 100 m, 29 April 1997, R. Mesibov, plot 1R4, QVM 23:46037.

Paratypes. 1 male, details as for holotype, QVM 23:46038; 1 female, details as for holotype but 43°05'42"S 146°42'41"E (DN764284) ±100m, 110 m, plot 1R1, 28 April 1997, QVM 23:46587; 1 female, same details but 43°05'49"S 146°42'28"E (DN761282) ±100m, 80 m, 14 May 1997, plot 1M6, QVM 23:46588; 1 male, same details but 43°05'36"S 146°42'45"E (DN765286) ±100m, 130 m, 15 May 1997, plot 1R5, QVM 23:46039; 1 female, same details but 43°05'33"S 146°42'41"E (DN764287) ±100m, 140 m, plot 1R6, QVM 23:46589; 1 female, Huon River (Arve Road), Tas, 43°5'56"S 146°44'45"E (DN792280) ±100m, 170 m, plot 3M4, 20 May 1997, R. Mesibov, QVM 23:46590.

Other material examined. 12 males and 10 females from 16 other sites (see Appendix).

Diagnosis. Metatergites without tubercles; ring 6 sternite with discrete setal brushes on anterior margin; gonopod telopodite with stout, rod-like setae in longitudinal tract on posteromedial surface and two large, upright (distally directed) processes arising anterolaterally near apex, the taller, more lateral one Y-shaped, the more anterior one with broad, minutely dentate apical margin.

Description. Male/female approximate measurements: length 16/16 mm, ring 12 paranota width 1.8/2.2 mm. Male as for *T. armatum* in live colour, colour in alcohol and most non-gonopod details, but overall widths tergite 6>5>4>(3,2,head)>collum, ring 12 paranota 1.3 × as wide as prozonite, 6-7 small setae in transverse rows on midbody metatergites (Fig. 3A), ozopore opening very close to paranotal margin. Ring 6 sternite as for *T. armatum*, but with paired paramedian brushes of fine setae on anterior margin separated by shallow notch.

Gonopod telopodite (Fig. 22) straight, slightly constricted just above base, with narrow buttress near base on anterolateral surface. Divided between 2/3 and 3/4 telopodite height into five processes (noted here lateral to medial): (a) large, anteroposteriorly flattened process, widely expanded distally, distal margin lower medially and minutely dentate, lateral end of margin broadly acuminate; (b) large, Y-shaped process, flattened anteroposteriorly, divided at ca 2/3 process height, tips roundly acuminate; (c) mediolaterally flattened laminate process, hook-shaped posteriorly; (d) solenomere with slender, distally directed, posteriorly curving distal branch and short, broad, posteriorly directed basal branch; (e) small, slender medial process arising basal to solenomere origin, directed posterodistally, with expanded, truncate tip. Posterodistally directed tract of 20–30 stout, rod-like setae on posteromedial surface from ca 1/3 to 2/3 telopodite height; small group of fine setae on posterolateral surface just above base; longitudinal row of 5–6 fine setae laterally at mid-height on telopodite. Prostatic groove running distally and slightly posteriorly on posteromedial surface to base of solenomere.



Figure 22. *Tasmaniosoma warra* sp. n., paratype male, QVM 23:46038 **A** and voucher male QVM 23:46040 **B–D**. **A** Right posterolateral view of gonopods in situ **B** medial, **C** anterior and **D** lateral views of right gonopod telopodite. Setation not shown in **B–D**; dashed line marks course of prostatic groove. Scale bars = 0.2 mm.

Female more robust than male; posterior margin of epigynum slightly elevated at both ends and produced medially as small, rounded triangle.

Distribution. Common in wet eucalypt forest (with and without a cool temperate rainforest understorey) over ca 2500 km² on the southeast Tasmanian mainland and on South Bruny Island, from near sea level to at least 370 m (Fig. 24). On the Tasmanian mainland, not yet found more than a few kilometres north of Grove, south of Dover or west of Mt Weld. Co-occurs with *T. bruniense* sp. n. on Bruny Island; possibly parapatric with *T. australe* sp. n., as the two species occur within ca 7 km of each other and have not yet been found together.

Etymology. Noun in apposition, for the type locality in the Warra Long Term Ecological Research (LTER) site in the Southern Forests.

Discussion

Five species groups are recognisable within Tasmaniosoma as circumscribed above:

(1) *alces, armatum, maria, orientale* and *warra*, with nearly uniform red-brown dorsal colouration (likely in the case of *maria*), a gonopod telopodite with a single, lon-



Figure 23. A Localities as of 31 January 2010 for *Tasmaniosoma hickmanorum* sp. n. (squares), *T. compitale* sp. n. (stars) and *T. armatum* Verhoeff, 1936 (crosses). Scale bar = 100 km. **B** Preliminary mapping of eastern parapatric boundary between *T. compitale* sp. n. (stars) and *T. hickmanorum* sp. n. (squares). Bounding rectangle as in map (**A**); scale bar = 20 km.



Figure 24. A Localities as of 31 January 2010 for *Tasmaniosoma alces* sp. n. (filled triangles), *T. aureoriv-um* sp. n. (crosses), *T. australe* sp. n. (filled squares), *T. bruniense* sp. n. (stars), *T. hesperium* sp. n. (open circles), *T. laccobium* sp. n. (open triangle), *T. maria* sp. n. (filled circles) and *T. warra* sp. n. (open squares). See also Fig. 23. Scale bar = 50 km. (**B**) Map of Tasmania showing location of main map (rectangle).



Figure 25. A Localities as of 31 January 2010 for *Tasmaniosoma barbatulum* sp. n. (squares), *T. clarksonorum* sp. n. (crosses), *T. decussatum* sp. n. (open circles) and *T. fragile* sp. n. (triangles). See also Figs 23 and 26. Scale bar = 50 km. **B** Map of Tasmania showing location of main map (rectangle).



Figure 26. A Localities as of 31 January 2010 for *Tasmaniosoma cacofonix* sp. n. (crosses), *T. fasciculum* sp. n. (squares), *T. gerdiorivum* sp. n. (triangles) and *T. orientale* sp. n. (open circles). See also Fig. 23. Scale bar = 50 km. **B** Map of Tasmania showing location of main map (rectangle).

gitudinal, posteromedial tract of stout, rod-like setae and a particularly arranged cluster of five or six apical processes, and a ring 6 sternite with dense, discrete setal brushes on the anterior margin;

- (2) *clarksonorum*, *compitale*, *fasciculum* and *hickmanorum*, with complex, fugitive, dorsal colouration including paramedian light patches on pro- and metazonites, three transverse rows of well-developed metatergal tubercles, a gonopod telopodite with at least two separate non-longitudinal tracts of stout, rod-like setae, and leg 7 sternal tabs bearing stout, rod-like setae (this group is likely to include *barbatulum* and *fragile*, whose live colour is unknown);
- (3) *australe* and *bruniense*, with a broad, flattened solenomere arising on the lateral side of the apex, small rounded teeth posterolaterally on the paranota, a posterior triangular extension on the male leg 6 prefemur and a distal swelling on the female leg 2 prefemur;
- (4) *hesperium* and *laccobium*, with a particularly arranged cluster of four apical processes on the gonopod telopodite; and
- (5) *decussatum* and *gerdiorivum*, with three transverse rows of weakly developed metatergal tubercles and a gonopod telopodite with a well-defined trough-like 'shelf' basally and a broad, flattened solenomere arising on the medial side of the apex.

Grouping species in this way leaves *T. aureorivum* and *T. cacophonix* as seemingly unrelated isolates. Rather than place 19 species in seven genera, six of them new, I leave *Tasmaniosoma* here as a fairly heterogeneous miscellany.

Another unresolved question is how the type species *T. armatum* Verhoeff, 1936 or any of the other *Tasmaniosoma* species are related to other Australasian H+19 dalodesmid genera. A possible sister taxon to the *clarksonorum* species group is *Icosidesmus* Humbert and de Saussure, 1869. As described by Johns (1964), New Zealand *Icosidesmus* species have long, slightly curved tarsi, low tubercles on metatergites, males with a pit ventrally on either side of ring 2, and a more or less cylindrical telopodite with an apical cluster of small processes and dense clusters of stout, rod-like setae.

Acknowledgements

I began collecting and sorting *Tasmaniosoma* spp. more than 20 years ago and was initially supported in this work by a grant from the Plomley Foundation. I am grateful to Karsten Goemann (University of Tasmania) for assistance in acquiring the SEM images, and to Robert Raven and Owen Seeman (Queensland Museum) and Dennis Black (La Trobe University) for the loan of specimens. I am especially grateful to Jörg Spelda (Staatliche Naturwissenschaftliche Sammlungen Bayerns, München, Germany) for locating and imaging the *T. armatum* syntypes, to Hans Henderickx for Fig. 1 and for images of that specimen's gonopods, and to Kevin Bonham (Hobart, Tasmania), Wade and Lisa Clarkson (Riverside, Tasmania) and

Sarah Tassell (Hobart, Tasmania) for their careful collection and documentation of specimens.

References

- Attems C (1940) Das Tierreich. 70. Polydesmoidea. III. Fam. Polydesmidae, Vanhoeffeniidae, Cryptodesmidae, Oniscodesmidae, Sphaerotrichopidae, Peridontodesmidae, Rhachidesmidae, Macellolophidae, Pandirodesmidae. Walter de Gruyter and Co, Berlin, 577 pp.
- Bonham KJ, Mesibov R, Bashford R (2002) Diversity and abundance of grounddwelling invertebrates in plantation vs. native forests in Tasmania, Australia. Forest Ecology and Management 158: 237–247.
- Cook OF (1896) Cryptodesmus and its allies. Brandtia 5: 19-28.
- Hoffman RL (1980) ['1979'] Classification of the Diplopoda. Muséum d'Histoire Naturelle, Genève, 237 pp.
- Humbert A, de Saussure H (1869) Description de divers Myriapodes du Musee de Vienne. Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wien 19: 669–692.
- Jeekel CAW (1971) Nomenclator generum et familiarum Diplopodorum: a list of the genus and family-group names in the Class Diplopoda from the 10th edition of Linnaeus, 1758, to the end of 1957. Monografieën van de Nederlandse Entomolo-gische Vereniging 5: i-xii + 1–412.
- Jeekel CAW (1982) Millipedes from Australia, 4: A new genus and species of the family Dalodesmidae from Australia (Diplopoda, Polydesmida). Bulletin Zoölogisch Museum, Universiteit van Amsterdam 9(2): 9–15.
- Jeekel CAW (1983) Millipedes from Australia, 8: A new genus and species of the family Dalodesmidae from Victoria (Diplopoda, Polydesmida). Bulletin Zoölogisch Museum, Universiteit van Amsterdam 9(16): 145–151.
- Jeekel CAW (1984) Millipedes from Australia, 7: The identity of the genus *Lissodesmus* Chamberlin, with the description of four new species from Tasmania (Diplopoda, Polydesmida, Dalodesmidae). Papers and Proceedings of the Royal Society of Tasmania 118: 85–101.
- Jeekel CAW (1985) Millipedes from Australia, 9: A new polydesmoid millipede from Queensland (Diplopoda, Polydesmida: Dalodesmidae). Entomologische Berichten (Amsterdam) 45: 50–55.
- Johns PM (1964) The Sphaerotrichopidae (Diplopoda) of New Zealand. 1. Introduction, revision of some known species and description of new species. Records of the Canterbury Museum 8(1): 1–49.
- Mesibov R (1994) Faunal breaks in Tasmania and their significance for invertebrate conservation. Memoirs of the Queensland Museum 36(1): 133–136.
- Mesibov R (1997) A zoogeographical singularity at Weavers Creek, Tasmania. Memoirs of the Museum of Victoria 56: 563–573.

- Mesibov R (1999) The Mersey Break: an unexplained faunal boundary on the north coast of Tasmania. In: Ponder W, Lunney D (Eds) The Other 99%. The Conservation and Biodiversity of Invertebrates. Transactions of the Royal Zoological Society of New South Wales. Royal Zoological Society of New South Wales, Mosman (NSW), 246–252.
- Mesibov R (2004) A new genus of millipedes (Diplopoda: Polydesmida: Dalodesmidae) from Tasmania, Australia with a mosaic distribution. Zootaxa 480: 1–23.
- Mesibov R (2005) A new genus of millipede (Diplopoda: Polydesmida: Dalodesmidae) from Tasmania with a pseudo-articulated gonopod telopodite. Zootaxa 1064: 39–49.
- Mesibov R (2006) The millipede genus *Lissodesmus* Chamberlin, 1920 (Diplopoda: Polydesmida: Dalodesmidae) from Tasmania and Victoria, with descriptions of a new genus and 24 new species. Memoirs of Museum Victoria 62(2): 103–146.
- Nicholls GE (1943) The Phreatoicoidea. Papers and Proceedings of the Royal Society of Tasmania 1942: 1–145.
- Pocock RI (1887) On the classification of the Diplopoda. Annals and Magazine of Natural History (5) 20: 283–295.
- Verhoeff KW (1936) Die Sphaerotrichopidae der südlichen Halbkugel und ihre Beziehungen. Zoologischer Anzeiger 114(1/2): 1–14.

Appendix

Specimen records for the *Tasmaniosoma* species described in this paper. doi:10.3897/ zookeys.41.420.app.1.ds.

Note: Specimen records for the *Tasmaniosoma* species described in this paper are available on the ZooKeys website as a Microsoft Excel file (Appendix.xls) and a CSV file (Appendix.csv).

Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Citation: Mesibov R (2010) Specimen records for the *Tasmaniosoma* species described in this paper. doi:10.3897/ zookeys.41.420.app.1.ds. Dataset published in: Zookeys 41: 31–80. doi:10.3897/zookeys.41.420.