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A specialist's audit of aggregated occurrence records

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Abstract

Occurrence records for named, native Australian millipedes from the Global Biodiversity Information Facility (GBIF) and the Atlas of Living Australia (ALA) were compared with the same records from the *Millipedes of Australia* (MoA) website, compiled independently by the author. The comparison revealed some previously unnoticed errors in MoA, and a much larger number of errors and other problems in the aggregated datasets. Errors have been corrected in MoA and in some data providers' databases, but will remain in GBIF and ALA until data providers have supplied updates to these aggregators. An audit by a specialist volunteer, as reported here, is not a common occurrence. It is suggested that aggregators should do more, or more effective, data checking and should query data providers when possible errors are detected, rather than simply disclaim responsibility for aggregated content.

Keywords

Millipede, Diplopoda, Australia, occurrence records, data quality, data cleaning, ALA, GBIF

Introduction

There are currently three online collections of occurrence records for native Australian millipedes. Two are in the aggregated datasets compiled by the Global Biodiversity Information Facility (GBIF; http://www.gbif.org/) and the Atlas of Living Australia (ALA; http://www.ala.org.au/). The third source is *Millipedes of Australia* (MoA; http://www.polydesmida.info/millipedesofaustralia/), a website built and maintained by the present author, who is a millipede specialist. (For more on MoA, see the Methods section below.)

All three online datasets contain errors. I try to minimise the number of errors in MoA by keeping the taxonomy of the recorded millipedes up to date, by checking latitude and longitude, by using simple digital tools to identify duplicate records and

inconsistencies, and by excluding the small number of doubtful records (such as those for museum specimens in taxonomically difficult groups with no recorded identifier).

The error-correcting process for MoA has been a cooperative undertaking with the museums from which MoA gets most of its data. In return for a 'snapshot' table of Australian millipede records on a particular date, including all relevant database fields, I audit data items, suggest corrections and query any conflicting or uncertain entries. With the help of museum staff, problems are usually resolved, and both the museum database and MoA benefit from improved data quality.

The process just outlined has been a two-way conversation in which museum collection databases are informally audited by a taxon specialist acting as an *amicus musei*. The conversation between museums, GBIF and ALA is more formal and one-way. Most Australian fauna records have been delivered to these aggregators through an intermediary, the Online Zoological Collections of Australian Museums (OZCAM; http://www.ozcam.org.au/), which is now managed and supported by ALA. Delivery is in the form of records translated from the original museum format into a standard schema developed by the Faunal Collections Informatics Group of the Council of Heads of Australian Faunal Collections (http://www.chafc.org.au/fcig/).

The translated records have been accepted 'as is' by the aggregators. Data quality has been the responsibility of the data providers, and the aggregators have warned their users accordingly in general disclaimers:

GBIF: 'The quality and completeness of data cannot be guaranteed. Users employ these data at their own risk.' (http://data.gbif.org/terms.htm)

ALA: 'The Atlas makes the Atlas website and Content available on the understanding that you use them at your own risk – they are provided 'as is' and 'as available' and you exercise your own skill, judgement and care with respect to their use or your reliance on them.

'The Atlas and data providers give no warranty regarding the quality, accuracy, completeness, currency, relevance or suitability for any particular purpose of the Content or the Atlas website.' (http://www.ala.org.au/about-the-atlas/terms-of-use/)

I recently went directly to GBIF and ALA in search of new records for MoA. The search developed into an audit which revealed some previously unnoticed errors in MoA, and a much larger number of errors and other problems in the aggregated datasets. In this paper I report on that audit, discuss some of the data quality problems associated with aggregated occurrence records, and suggest ways in which the conversation between data providers and aggregators can be improved.

Methods

GBIF and ALA

I queried GBIF for 'Diplopoda' from 'Australia' and ALA for 'Diplopoda' on 23 December 2012 and downloaded the two text files of records. Sorting and tallying of records were done using a spreadsheet program with assistance from Linux command

line tools (awk, comm, sort, sqlite3, uniq). Interested readers can contact me for details of the particular procedures I used, but the audit was straightforward (see Results) and could easily be done using other software. The Appendix to this paper contains the original downloaded GBIF and ALA files and two working files from the audit.

In the 23 December 2012 downloads, GBIF and ALA each held occurrence records from 10 data providers, although not the same 10. To avoid unnecessarily drawing attention to particular providers, I refer to them in this paper as 'provider A,' 'provider B', etc. Provider names are also partly obscured in the two working files in the Appendix, where records are identified by their unique GBIF or ALA identification numbers rather than their source.

MoA

MoA started in 2007 as a catalogue of species, with annotated synonymies of genus and species names and details of all known types. I added an occurrence records page for named natives (http://www.polydesmida.info/millipedesofaustralia/localities.html) in early 2012. Users can download records for individual genera either as CSV files or (in abbreviated form) as KML files, both made available with a Creative Commons license (attribution + non-commercial, by-nc). Each CSV and KML file is date-stamped in the file name; files are updated and renamed as I become aware of new records or make minor revisions to old ones. The CSV files can also be downloaded as a group from the records directory (http://www.polydesmida.info/millipedesofaustralia/records/).

I compiled the species occurrence records from the taxonomic literature, museum collection databases, and my own records of specimens that have been deposited in museums but not yet registered. Many of the data items from museum databases were corrected or annotated and most were re-formatted, making the MoA dataset a substantial re-working of information from those sources. Significant amendments were reported to staff at cooperating museums, who generously assisted in clarifying or correcting details of the records (see Introduction). The 23 fields in each CSV are genus; subgenus; species; subspecies; number of specimens (sometimes given separately for males, females and juveniles); identifier; repository; registration (catalogue) number; type status; specimen notes; locality in words; state or territory (within Australia); latitude and longitude (separate fields, in decimal degrees based on WGS84); spatial uncertainty; source of the spatial data; elevation; day, month and year of collection (separate fields); collector; collection notes; and source of the record. For more details see the MoA localities metadata page (http://www.polydesmida.info/millipedesofaustralia/metadata.html).

Audit limitations

The aim of the audit reported here was not to check every data item in the GBIF and ALA record sets. For many users (including the present author), the most important

occurrence records are those for specimens identified to species, and the most important data items are *species names*, *latitude and longitude* and *date of collection* – in other words, where and when a particular species occurred, as evidenced by a specimen lot. The MoA dataset only includes records for named, native Australian species, and currently lacks records for millipedes in the small subclass Penicillata (pincushion millipedes). For purposes of comparison with MoA, the GBIF and ALA datasets were therefore progressively trimmed (see Results) to records for named Australian natives in the other millipede subclass, Chilognatha.

Latitude and longitude comparisons

To compare latitude and longitude data for the corresponding records in MoA and GBIF or ALA, I calculated the Euclidean distance between the two reported locations. I assumed 111 km per degree of latitude, and 111 km times the cosine of the latitude per degree of longitude. I used Euclidean distance because the purpose of this comparison was to detect substantial differences, not to accurately determine the great-circle distance between corresponding MoA and aggregator localities. From this distance I then subtracted the uncertainty estimate included with every georeferenced MoA record. This difference is here called the 'offset' between MoA and aggregator latitude and longitude data (Fig. 1). The MoA uncertainty is the radius of a circle likely to contain the collection site (for more details see the MoA metadata page, http://www.polydesmida.info/millipedesofaustralia/metadata.html). I estimated this figure conservatively when compiling MoA; it ranges from 25 m (for most GPS data) to 200 km (e.g., for 'Kimberley district, Western Australia'). Distance and uncertainty were both rounded in this study to the nearest 1 km, so that the minimum difference between the two would be larger than any Australian datum difference (e.g., between AGD66 and GDA94).

A negative or zero offset meant that the aggregator location, although different from the MoA location, was within my uncertainty estimate (Fig. 1). Whatever the reason for the difference, I could be satisfied that a GBIF or ALA user was seeing an acceptably approximate latitude and longitude for the millipede collecting locality. A positive difference meant that the aggregator location was substantially set off from the location I had compiled in MoA, and the difference needed to be examined more closely (see Results). To reduce the number of records to be individually checked, I examined only those cases where the offset was 2 km or greater.

Results

Preparation: overview and minor exclusions

The GBIF dataset for Australian Diplopoda contained 5558 records and the ALA Diplopoda dataset 8690 records, with 4860 records shared and 9554 records in total.

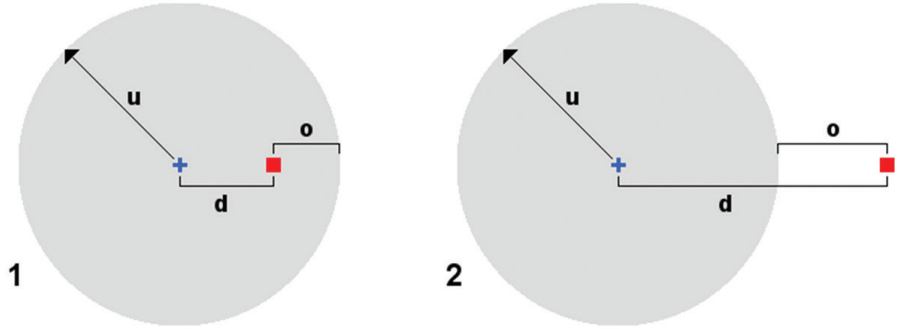

Figure 1. Illustration of 'uncertainty', 'distance' and 'offset'. In MoA, spatial uncertainty is defined using the point-radius method, where a site is assumed to be at the centre of a circle whose radius is the uncertainty **u**. In both diagrams, **d** is the Euclidean distance between the MoA estimate of the site's location (blue cross) and the aggregator estimate (red square). The offset **o** is the distance **d** minus the uncertainty **u**. In diagram **1** the aggregator site is within the circle of uncertainty surrounding the MoA site, and the offset is negative. In diagram **2** the aggregator site is outside the circle of uncertainty and the offset is positive

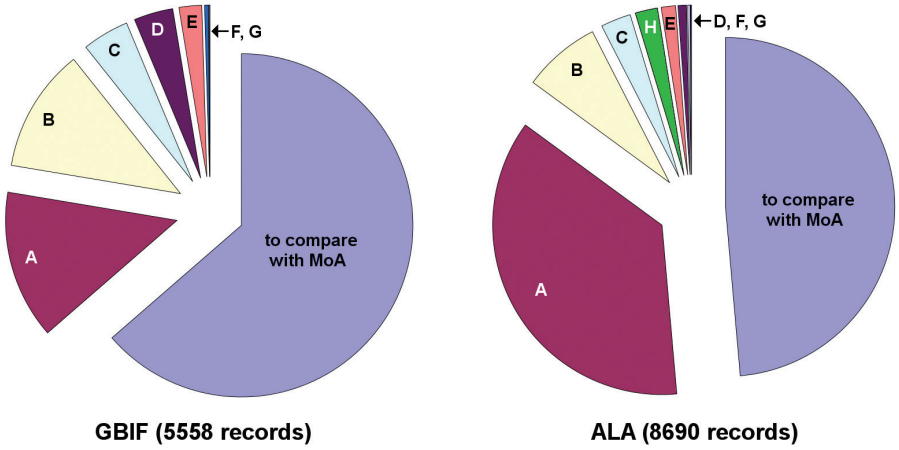

Figure 2. Exclusions from the GBIF and ALA datasets (see text for details). **A** not identified to species or only tentatively identified to species **B** undescribed species **C** non-native species **D** no latitude and longitude **E** manuscript names **F** miscellaneous duplicates **G** Penicillata **H** ALA preliminary exclusions (not in Australia, images, provider K observations). **D** and **F** categories do not include records already excluded for taxonomic reasons

ALA Diplopoda included 111 records from outside continental Australia and its territories. Fifteen ALA records were of millipede images; only three of these were for a named Australian native species, and I could not confirm that species' identity from the images. These 126 records were excluded from the audit (Fig. 2).

Another 60 ALA records were 'observations' of Tasmanian millipedes from provider K. Forty-one of these records were excluded because the sighted millipedes were identified only to genus. Eighteen of the remaining records were unconfirmed species

identifications by non-specialists, including two identifications of a species which was not named and described until eight years after the observations. The nineteenth species-sighting record and one of the genus-sightings were attributed to me, but I have never knowingly contributed records to provider K. Several of the 60 'observations' appeared to be duplicates of specimen records in a Tasmanian museum, but I could not be sure because the locations, dates and collector names differed in detail from the museum records. The 60 ALA records from provider K were excluded from the audit (Fig. 2).

Two data providers created minor bookkeeping issues. Provider J supplied GBIF with 75 records for specimen lots from three museums, but rather than the GBIF *Catalogue number* field being filled with the museums' catalogue numbers, the entries were instead provider J's own internal system numbers for the records. Provider B neglected to enter the catalogue number for a particular specimen lot; the *Catalog Number* field remains blank in the ALA dataset, but confusingly has been filled in the GBIF *Catalogue number* field with the ALA *Record ID* code. (The correct catalogue number was supplied to me for MoA use by provider B.)

Preparation: taxonomic exclusions

I excluded from the remaining GBIF and ALA records any which were not for named, native species in the suborder Chilognatha (Fig. 2). These taxonomic exclusions were for millipedes that were:

(a) identified only to class (640 records);
(b) identified only to order (2708 records);
(c) identified only to family (427 records);
(d) identified only to genus (88 records);
(e) identified as a non-native species (251 records);
(f) identified as a species of Penicillata (9 records);
(g) identified with unpublished names (manuscript or museum-label names), e.g. *Subarricrusta biconulata* (119 records);
(h) identified as an undescribed species in a named genus, e.g. *Myallosoma* 'wagga' (289 records);
(i) identified as an undescribed species in an undescribed genus, e.g. Genus QYY sp. QYY3 (361 records); and
(j) identified only tentatively to species, e.g. '*Antichiropus variabilis*?' (8 records).

Preparation: latitude and longitude exclusions

I excluded 212 records without latitude and longitude (Fig. 2). (Some records excluded earlier in the trimming process also lacked latitude and longitude.)

Preparation: excluding duplicates

The purpose of the GBIF and ALA audit was to check occurrence records which placed a particular species at a particular place at a particular time. This information might be repeated in a record set in a number of ways:

(a) 'Simple' duplicates repeat the record for a particular specimen lot in a particular repository. In the ALA dataset, provider H had two different names as data provider, and the same specimen lot appears under each provider name. In the GBIF dataset, provider J (a provider of records from a range of specimen repositories and the taxonomic literature) supplied a record identical to one from provider E. (4 simple duplicates, already excluded for other reasons)
(b) 'Satellite' duplicates are created when material is removed from a specimen for SEM work, DNA extraction, etc. Provider A gave the new collection object the same catalogue number as the source object, but with a suffix appended, e.g. 'X43302' and 'X43302.001'. (31 records, 27 already excluded)
(c) 'Bookkeeping' duplicates appear when a museum specimen lot is renumbered or donated to another museum, but the original catalogue number is not cleared of data. Another kind of bookkeeping duplicate appeared in the dataset supplied to GBIF by provider J: the only difference between paired duplicates was that the GBIF *Basis of record* field contained either 'Specimen' or 'Unknown'. Two records from provider B contained incorrect data, according to advice I had from provider B in 2012; their continued presence in the GBIF and ALA datasets is a bookkeeping issue. These two records have the same catalogue number as other specimen lots, but different suffixes. (60 records, 52 already excluded)
(d) 'Serial' duplicates appear when multiple catalogue numbers are assigned to a series of specimens of a single species arising from the same collection event, i.e. same species, same site, same collector, same date. The multiple catalogue numbers may refer to a single specimen lot; provider F, for example, puts multiple labels into individual glass vials, one for each millipede specimen in the vial. Alternatively, a specimen lot may be physically divided, e.g. into holotype and paratype lots, or male and female lots, with each lot being assigned its own catalogue number. Provider B assigns a single catalogue number to each specimen lot, but adds a suffix to distinguish male and female components of the sample.

I excluded all simple, satellite and bookkeeping duplicates from the audit, but included all serial duplicates except nine 'suffixed' provider B records (Fig. 2). Including serial duplicates simplified the comparison with MoA records, nearly all of which are uniquely identified by a museum catalogue number.

Preparation: summary

The final tallies of records for the audit were 3536 in the GBIF dataset (64% of the starting number), 4223 in the ALA dataset following the 186 preliminary exclusions (50%), 3524 records shared and 4235 records in total (Fig. 2). (The corresponding total for MoA was 10615 records.)

Comparison: introduction

One GBIF-ALA record was in the MoA dataset, but with a different provider G catalogue number; the specimen lot had been renumbered but the provider G database had not yet been updated. Thirty-five GBIF-ALA records were missing from the MoA dataset, for a variety of reasons:

(a) 3 provider A records I overlooked when compiling MoA;
(b) 7 provider I records and 1 provider A record were not in the provider databases at the time the MoA dataset was first compiled, in 2011-2012;
(c) 7 provider D records were not publicly available before they were published by GBIF;
(d) 5 provider G records are for specimen lots donated to other museums (whose records are not in GBIF or ALA), but not yet cleared from the provider G database;
(e) 4 provider G records for specimen lots identified only to genus are incorrectly listed as identified to species;
(f) 1 provider G record is for a blank catalogue number, incorrectly filled with data;
(g) 4 provider A records I excluded from MoA because the species concerned are in taxonomically difficult groups and no identifier was listed in the provider A database for those records;
(h) 2 provider A records I excluded because the identifications were clearly incorrect, one being a 'Paradoxosomatidae' specimen (Polydesmida) from Western Australia identified as a species of Spirobolida endemic to Lord Howe Island; and
(i) 1 provider A record I excluded because I judged the locality ('Tasmania') to be too vague to be georeferenced; provider A has georeferenced as 'Tasmania' a point near the north coast of the island.

For comparison with MoA, I added to the matching MoA dataset the (d), (e) and (g) records, and the above-mentioned, renumbered record from provider G, which was incorrectly listed as identified to species.

Comparison: species names

In addition to auditing species names, I checked the advice relating to names which is included with each ALA record. ALA assists users by comparing submitted names

to those on a relevant National Species List (NSL). ALA's list of millipede names is derived from the Australian Faunal Directory (AFD; http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/index.html), whose millipede section I updated in 2010.

ALA flags possible name problems in two ways. First, it attempts to match the provided name with one in the NSL, and if there is no match it offers – in the *Matched Scientific Name* field – a name in the lowest ranking taxonomic category above species which might apply to the provided name, e.g. a genus name. Second, it enters 'true' or 'false' in the field *Name not in national checklists*, where 'true' means that the name is not in the NSLs, but is listed in Catalogue of Life (CoL; http://www.catalogueoflife.org/). However, as shown below, name-matching was inconsistently effective as a check on data quality in the millipede dataset.

(a) Provider G supplied 67 records with the wrong species names, i.e. incorrect specimen identifications. I supplied correct identifications for these records in 2005, but provider G's database has not yet been updated. ALA accepted three of the names 'as is', since they were correctly spelled and in the NSL. ALA correctly matched the new genus combination applicable to the other 64 incorrect species names.

(b) Eight records had misspelled species names. ALA did not recognise *Hoplatessara pugonia* (= *H. pugiona*), *Myallosoma furculigerium* (= *M. furculigerum*) and *Reginaterreuma tarkensis* (= *R. tarkinensis*; two records), and matched these four names with the (correct) genus. The misspelled *Australiosoma ehteridgei* is now *Dicladosoma etheridgei*; ALA matched the record with the genus *Australiosoma*. Three records for *Siphonophora mjohergi* (= *Rhinosiphora mjoebergi*) were matched with the family Siphonophoridae.

(c) Two records had the misspelled genus name *Aethelosoma* for *Aethalosoma*. In this case ALA matched the two *A. solum* records with the correctly spelled genus (but not the species name), suggesting that fuzzy matching (or manual editing) had been applied.

(d) One record had *Tasmaniosoma hardyi* for *Tasmanodesmus hardyi*. ALA incorrectly matched this species with the genus *Tasmaniosoma*.

(e) Data providers submitted 157 records with outdated genus combinations, several of which are noted above. For 141 of these records ALA matched the outdated combination with its correct NSL combination. Five matchings were thwarted by incorrectly spelled species names (see above). *Cyliosoma excavatum* (now *Epicyliosoma excavatum*), *C. penrithensis* (*E. penrithense*, five records), *C. penicilligerum* (*E. penicilligerum*) and *Spirobolus lugubris* (*Spirobolellus lugubris*) were matched with the older combinations in CoL, although all names are in the AFD. The AFD also lists *Dicladosoma andersoni* (*Phyllocladosoma andersoni*), which was matched with *Dicladosoma*, and *Phyllocladosoma andersoni dorrigense* (*P. dorrigense*, two records), which was matched with *Phyllocladosoma*.

(f) Data providers submitted 14 records with two outdated synonyms of *Cladethosoma trilineatum*, one of *Akamptogonus novarae* and one of *Parwalesoma*

walesium. ALA matched synonyms correctly in eight of the cases. In the other six records *C. clarum* was accepted, although that synonym is referred to *C. trilineatum* in the AFD.

(g) The species *Prosopodesmus panporus* (two records) was matched with the genus *Prosopodesmus*, while both *P. crater* and *P. monteithi* were matched with their correct species names. All three names are listed in the AFD and all *Prosopodesmus* records were contributed by provider B.

(h) Finally, ALA accepted *Antichiropus variabilis ingens* (two records), apparently because the name is in CoL; the *Name not in national checklists* field has the entry 'true'. The subspecies name was suppressed in 1920 and does not appear in the AFD.

In all, 174 records had species names different from the correct species names in MoA, and another 10 records not in MoA also had incorrect or outdated names.

Comparison: latitude and longitude - overview and results

A trial comparison revealed that there were bookkeeping discrepancies in four MoA records from provider F. In two cases, two consecutive catalogue numbers and their collecting data in MoA had been exchanged, as compared to the entries in provider F's collection database. I hope to investigate the discrepancy on my next visit to provider F, later in 2013, but for the purposes of this comparison the four MoA records were renumbered to agree with those of provider F.

Following that renumbering, 1144 of the 4209 records compared (27%) were found to have an offset of 2 km or more and 651 records (15%) had an offset of at least 5 km; 19 records had an offset of 100 km or more. MoA was clearly to blame for 22 discrepancies, because I had:

(a) given provider F the wrong longitude (146°23'13"E instead of 146°28'13"E) for one of my collecting sites (15 records),

(b) incorrectly copied the latitude or longitude from providers' databases to MoA (1 record),

(c) assigned to a record in MoA the spatial data from the wrong collecting event (3 records),

(d) incorrectly georeferenced a record from label locality text (1 record), and

(e) used georeferences from provider B which provider B did not accept (2 records).

The last two discrepancies arose because I used latitude and longitude data downloaded for the samples concerned from a provider B website. Provider B has recently advised me that if the latitude and longitude are printed on a specimen label, then those figures are accepted for the provider B database. If there are no geographical coordinates on the label, a gazetteer-based georeferencing program is used to calculate a

location from the label locality text. In these two cases, provider B (correctly) ignored its own Web-published latitude and longitude data for the sites and calculated new ones for its database, whose records were then reformatted for export to OZCAM. This practice can lead to errors (see below, *Comparison: latitude and longitude - comments*).

The largest single explanation for the discrepancies, resulting in (at least) 968 incorrect latitude and longitude figures, was a decision made by provider G in the 1990s. When collectors supplied UTM grid references for collecting sites, these grid references were duly entered in UTM fields in the provider G database. However, to populate the latitude and longitude fields for those records, provider G chose not to convert directly from UTM. Instead, the data enterer at provider G would search in a lookup table for a 'nearest named place' (NNP) close to the place named in the locality text, then enter the latitude and longitude for that NNP. This practice resulted in three kinds of spatial errors:

(a) The data enterer chose the wrong NNP. For example, searching for 'Christmas Hill' in the lookup table, the data enterer selected 'Christmas Hills', 100+ km distant.
(b) The NNP was a substantial distance from the actual collecting site and was differently named. For example, the site was at River O'Plain Creek near English Town, and the NNP chosen was English Town.
(c) The NNP text and the locality text agreed, but the actual collecting site was a substantial distance from the location listed in the lookup table. For example, the site was identified as 'Mersey River', but the NNP for 'Mersey River' was at a different point on the same stream.

The great majority of the UTM grid references for these records had spatial uncertainties of 100 m. By replacing these grid references with latitude and longitude to the nearest minute, provider G not only misplaced the collecting sites, but increased their spatial uncertainties more than 10-fold. Provider G no longer replaces grid-referenced locations with NNP locations, but has not yet corrected the records created when the NNP policy was in place.

The remaining latitude and longitude discrepancies of 2 km or more had other explanations:

(a) The aggregator latitude and longitude had been rounded off, e.g. -36.9667 147.15 in the provider database became -37 147.2 (40 records). Provider I accounted for 38 of these discrepancies, in all cases because the species concerned was on a protected species list, and localities were partly disguised by rounding off (see below, *Comparison: latitude and longitude - comments*). On enquiry, provider F could not suggest why two of its latitude and longitude figures had been rounded off after uploading to OZCAM.
(b) The latitude and longitude were determined from locality text naming a large place (e.g. 'Fraser Island'), and the discrepancy arose because the provider and

the MoA spatial data source chose different georeference points in the place (16 records).

(c) As for (b) but the place was only vaguely named, e.g. 'Upper Richmond River', the name of a district in New South Wales in the 1890s (17 records).

(d) The locality text on the label (used in MoA) was more exact than the text used for georeferencing in the provider database, e.g. 'Blue Mountains - Katoomba - Echo Point' on the label vs. 'Blue Mountains' in provider A's database (25 records).

(e) The provider incorrectly georeferenced the collection site from locality text (47 records). In 11 of these cases, the provider subsequently corrected both the provider's database and MoA with an improved latitude and longitude.

(f) The provider entered spatial data into its database incorrectly (3 records). One of the discrepancies resulted from a simple transcription error, while in the other two cases a specimen lot was assigned to the wrong collecting event.

(g) The provider and I subsequently found that we had both incorrectly georeferenced the collecting site, and we agreed on an improved latitude and longitude for use by the provider and MoA (2 records).

Finally, four of the 1144 discrepancies remain unresolved at the time of writing, and will be further investigated by myself and the data providers concerned. In two cases it is possible that there has been a bookkeeping error like the one described at the beginning of this section. In the other two cases there is a puzzling disagreement between the locality text and the latitude and longitude provided by the collector.

Comparison: latitude and longitude - comments

A surprising feature of the aggregated occurrence records is that locality text is not always included. Only 1908 of the 4235 records used for comparison (45%) have locality text in the *locality* (ALA) or *Locality* (GBIF) fields, although 'locality' is a recommended field in the OZCAM schema. Nearly all of the 2000+ records without locality text in the GBIF and ALA datasets include that text in the relevant data provider's databases. (All MoA records include locality text.)

I was unable to see any fields in the ALA download which would alert users to possible georeferencing problems, other than a *Coordinates don't match supplied state* field. The download has a *Location Quality* field with the entries 'Spatially suspect' and 'Spatially valid'. These values are not explained on the website to which ALA users are directed for more information (https://docs.google.com/spreadsheet/ccc?key=0AjNtzhUIIHeNdHhtcFVSM09qZ3c3N3ItUnBBc09TbHc#gid=0), and I was unable to see how the values related to the records. A series of ALA records with exactly the same spatial data (serial duplicates), might have both 'suspect' and 'valid' in the *Location Quality* field.

Equally puzzling are the ALA flagging fields *missing Coordinate Precision* and *Coordinate uncertainty not specified*. In the full 8690-record ALA download, there are no

records at all with entries in the *Coordinate Precision* field, yet 121 of those records have 'false' instead of 'true' for *missing Coordinate Precision*. The *Coordinate Uncertainty in Metres - parsed* field is populated with numbers in 1728 records, yet for five of those records *Coordinate uncertainty not specified* reads 'true', and for 121 records without a parsed uncertainty entry, *Coordinate uncertainty not specified* reads 'false'.

It was curious to find that ALA and GBIF (and presumably OZCAM) had accepted georeferences to large numbers of decimal places, e.g. -17.6000003814697 145.699996948242 for a locality the collectors described in 1971 as 'ca 12 km SE of Millaa Millaa' (Queensland). The 13th decimal place locates the site with sub-micron accuracy, and the latitude and longitude could be simplified to -17.6 145.7 with no significant loss of precision. All MoA latitude and longitude data are compiled to four decimal places, which in Australia corresponds to ca 8-11 m on the ground. The implied spatial uncertainty of ca ±4-5 m is equal to or smaller than the error in most handheld GPS readings (Mesibov 2012).

Although there is an excellent, freely available guide (Chapman and Wieczorek 2006) to georeferencing from locality text, there is scope for disagreement between practitioners, as in the 'vague locality' cases above, about both location and spatial uncertainty. MoA and the aggregators will continue to disagree in these instances, and also with regard to latitude and longitude for protected Western Australian millipedes (see above). Disguising protected species localities in aggregated sources by rounding off latitude and longitude is appealing as a conservation measure. However, more accurate latitude and longitude figures for the same sites are often readily available online in digitised taxonomic literature and consultants' reports, so the disguise affects only those users who only consult aggregators.

As noted above, provider B uses a gazetteer-based georeferencing program when specimen labels lack latitude and longitude. I found a number of records for which this policy had resulted in an incorrect location. Two examples are worth examining in detail to demonstrate how the policy has been implemented:

(a) In 1990 and 1991, a number of Australian entomologists collected specimens near Pelion Hut, in Tasmania's Cradle Mountain National Park. Specimen labels were printed for most samples with the correct latitude and longitude, namely 41°50'S, 146°03'E. A 1991 Malaise trapping by one of the collectors also included samples from 'Pelion Hut', but no latitude and longitude was printed on the specimen labels. Provider B queried its georeferencing program, which located Pelion Hut at 41°50'S, 146°05'E, 3 km to the east. After alerting provider B to the problem, I contacted the collector for more information. He confirmed that his 1991 trap sites were all close to the Overland Track, which runs past Pelion Hut, and that he did not sample 3 km east of Pelion Hut. I passed this information on to provider B. (1 record in the trimmed GBIF and ALA datasets)

(b) In November 1982, a field worker collected a series of samples in the Mt Royal Range in New South Wales. The collecting sites were located as road distance

from the village of Moonan Flat, which lies west of the Range, e.g. 'Gologolie Creek, 17 km E of Moonan Flat', 'Horse Swamp, 24 km E of Moonan Flat' and 'Cobark Camp, 49 km E of Moonan Flat'. Another site was recorded as 'Mt Royal Range, Devils Hole, 36 km W of Moonan Flat'. The road distance to the Devils Hole camping ground is now approximately 32 km, and it is clear that 'W' is an error for 'E'. Because there were no latitude and longitude figures on the specimen labels for the Mt Royal Range collections, provider B queried its georeferencing program. In this case, provider B georeferenced '36 km W of Moonan Flat', ca 60 km west of Devils Hole, and ignored the locality text 'Mt Royal Range, Devils Hole'. According to a colleague, the specimen labels for this site also mention *Nothofagus* forest (temperate rainforest), which occurs in the Mt Royal Range but not in the dry country west of Moonan Flat. Provider B has now edited the latitude and longitude for this site in its own database to 31°55'S, 151°36'E for '36 km E of Moonan Flat' in the revised locality text. This is ca 10 km east of Devils Hole, whose correct latitude and longitude is 31°55'S, 151°29' E. (3 records in the full GBIF and ALA datasets)

Comparison: collecting dates

The combined GBIF and ALA datasets included collecting dates for all but 160 records; MoA had dates for 94 of these, taken from provider databases or specimen labels.

There were 384 date discrepancies in the comparison, but 274 of these were due to a difference in the way collecting periods were recorded. MoA had the finish date of a period in the day, month and year fields, and the whole of the period (e.g. '15 Mar - 6 Apr 1988') in the collecting notes field. The OZCAM schema requests a single date, and providers generally supplied the start date for a period (in 10 cases, a date in the middle of the period). The remaining discrepancies arose because:

(a) I entered the MoA date incorrectly, or assigned the wrong collecting event to the specimen lot (29 records);
(b) I used for MoA the date on the specimen label, which disagreed with the provider database date, e.g. '9 November 1970' (label) vs 'November 1970' (database) (3 records);
(c) The provider entered the wrong date in the database (46 records);
(d) ALA or provider I changed a month-year date to the last preceding day-month-year date; e.g. July 2003 became 30 June 2003 (20 records); or
(e) The date was uncertain and still needs to be checked (10 records).

The last two date discrepancies are between MoA and ALA, on the one hand, and GBIF, on the other. For unknown reasons GBIF has 27 April 1976 instead of 27 October 2005 for one record, and 10 September 2001 instead of 10 September 2004 for the other. The localities and collectors for these two records in GBIF are correct.

Discussion

Outcomes

I contacted six of the MoA data providers with suggestions for database corrections arising from the audit, and with requests for additional information. One of those requests led to museum staff discovering errors in two records recently uploaded to OZCAM but not yet added to MoA, and a number of the requests encouraged providers to revisit locality data and improve latitude and longitude figures for both their own databases and MoA. The latter was considerably improved as a result of the audit and the follow-up contacts: I added 11 occurrence records, deleted seven and corrected 95.

MoA has been updated, but it is uncertain when recent corrections to museum databases (following both the MoA compilation audit in 2012 and the audit described above) will be reflected in GBIF and ALA. The error-correction flow is

specialist → data providers → OZCAM → GBIF, ALA

and if I had contacted the aggregators directly, presumably

specialist → GBIF, ALA → data providers → OZCAM → GBIF, ALA

Aggregated datasets are only periodically updated, with data providers supplying edits and new records asynchronously. It will be some time before the many errors noted above in provider G's database will be corrected, although I have been advised that the database software currently used by provider G allows for easier record editing than was previously possible, and the millipede records, at least, should be up to date before the end of 2013.

Feedback

It is sometimes argued that a potential benefit of aggregating biodiversity datasets and putting them online is that errors are exposed to a larger audience than would be the case if records only appeared on individual museum websites, or were not otherwise publicly available. I write 'potential' because it is unclear whether non-specialist users would have the time or interest to audit aggregated, abbreviated records in the way I did for the unabbreviated records that are the basis for the MoA dataset. As noted above in the latitude and longitude comparison, a majority of the aggregated records lacked the locality text included in the data provider's own databases. Exposing records to a wide audience online may be a good way to crowd-source data quality checks, but only if the crowd gets to see the information it needs.

In any case, there do not seem to be established, well-used pathways for information about errors or possible errors to get back directly to data providers from the aggregators. Queries arising from the checking of species names done by ALA (see

Results) may not be routinely passed on to the institutions concerned, although they should be. Certainly questions about species names not on the NSLs could be asked, although data providers may need to consult specialists to get answers. As shown above, automated name-checking did not always work, but could be improved with a fuzzy-matching algorithm.

Checking procedures for other data problems may be even less effective. None of the duplicate records I found was flagged as 'true' in the ALA field 'Inferred Duplicate Record', or flagged in any way by GBIF despite recent advances in duplicate detection by that organisation (GBIF 2012). Georeferencing checks were minimal (see Results). The aggregators could explore the approach used in MoA, which is to define collecting events based on the union of data for locality, collector(s) and date. In addition to checks of the separate data items, checks of grouped events can reveal otherwise obscure errors; for an example, see the 'Moonan Flat' case in *Comparison: latitude and longitude - comments*, above.

The MoA occurrence records are freely available for use by aggregators. However, the MoA dataset is in large part derived from records provided by the same institutions that supply GBIF and ALA. It is unclear how aggregators would deal with two versions of the same record – one as received from a data provider, and one as amended in MoA – or with the attendant licensing issues. A possible solution would be for an aggregator to use the MoA dataset in data quality checks, as ALA uses National Species Lists, and to query data providers and the present author with regard to discrepancies. Since aggregators seem to prefer flagging possible errors to communicating with their data sources, it is unlikely that MoA will be used this way.

Value of aggregated data

Whether or not new checks are implemented by the aggregators and communicated to their data providers, the body of aggregated millipede data is likely to remain a curate's egg (http://en.wikipedia.org/wiki/Curate%27s_egg). Providers F and I only upload records of named millipede species to OZCAM, while provider A uploads everything in its database classified under 'Diplopoda'. Provider G has been through two changes of collection database software in the last 10 years, and most of its records have not been checked or updated in that time. The unused sighting records from ALA's provider K (see Results, *Preparation: overview and minor exclusions*) are not unique in their problems. In recent correspondence with that provider, I was told that a dataset for another taxon had been corrupted by unskilled data entry in 2007 and a problem with dates in Microsoft Excel (http://support.microsoft.com/kb/180162), which shifted observation dates by four years and one day. My contact told me that provider K had not yet had the time or resources to check its records carefully.

The aggregated occurrence records for Australian millipedes are not only variable in quality but a long way from complete, because not all major sources are aggregated.

Three of the Australian museum sources of the 10600+ MoA records are either minimally represented in the GBIF and ALA datasets, or not represented at all.

There is no reason to doubt that staff at both GBIF and ALA are genuinely interested in improving the quality of aggregated data, and both organisations regularly issue advice and discussion documents on improvements to the flagging of problems in records (e.g. ALA undated, GBIF 2011). Nevertheless, like Yesson et al. (2007), I found a fairly high error rate in the aggregated data I audited. Using a conservative spatial error criterion and excluding 'acceptable' spatial differences (protected species approximations, large or vague places to be georeferenced), and also excluding differences in the treatment of collecting periods (start date vs finish date of period), roughly one in four records in the combined GBIF-ALA dataset of 4235 records tested against MoA contained at least one error. The GBIF and ALA disclaimers quoted in the Introduction are pertinent warnings to users of aggregated data, and are likely to remain so for some time to come.

Acknowledgements

I am very grateful to the curators and data managers who have cooperated with me in improving Australian millipede occurrence records. Arthur Chapman, Mark Costello and Rod Page made helpful and constructive comments on a draft of this paper. The audit was voluntarily undertaken by the author.

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Appendix

ALA and GBIF occurrence records. (doi: 10.3897/zookeys.293.5111.app) File format: Comma Separated Value files (csv).

Explanation note: The Appendix file contains three sets of data. ALA_Diplopoda_23-Dec-2012 and GBIF_Diplopoda_Australia_23-Dec-2012 are CSV files of occurrence records as downloaded on 23 December 2012. Working_files contains two CSV files: (1) Full GBIF and ALA records for Australian millipedes, with annotations for those excluded from the audit (Exclusions_within_full_datasets.csv), and (2) Comparison of GBIF and ALA records with corresponding MoA records, as described in paper (Comparison_table.csv).

Citation: Mesibov R (2013) A specialist's audit of aggregated occurrence records. ZooKeys 293: 1–18. doi: 10.3897/zookeys.293.5111.app

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RESEARCH ARTICLE

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On the cicada genus *Nipponosemia* Kato, with description of one new species from China (Hemiptera, Cicadidae)

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Abstract

The cicada genus *Nipponosemia* Kato is reviewed. Four species are illustrated, photographed and described, including three known species and one new species. A key to all species of this genus is presented, and information on the biology of *Nipponosemia* are provided. The systematic status of the tribe Cicadatrini and biogeography of *Nipponosemia* are discussed.

Keywords

Cicadatrini, Cicadinae, Cicadettinae, morphology, taxonomy, biogeography

Introduction

The cicada genus *Nipponosemia* was established by Kato (1925a) based on external morphology, e.g., head (including eyes) about as wide as base of mesonotum, a little shorter than pronotum, mesonotum distinctly longer than pronotum, abdomen moderately robust and shorter than distance from head to cruciform elevation, timbal cover large, covering timbal almost entirely, opercula reaching middle of abdomen, fore wing

with eight apical cells, hind wing with six apical cells, *etc*. This genus was formerly treated as a member of Cicadini (Metcalf 1963; Duffels and van der Laan 1985; Chou et al. 1997). However, Hayashi (1974) defined *Nipponosemia* as a member of Moganniini Distant (*sensu* Lee and Hayashi 2004, Pham and Yang 2009) after examining the male genitalia of *Nipponosemia* and its relatives. Chou et al. (1993) described two species from Guangxi Province of China for *Nipponosemia*, increasing the known species from two to four of this genus. Recently, Lee and Hill (2010) recognized Moganniini as a junior synonym of Cicadatrini Distant, and redefined the latter by including *Nipponosemia* Kato, *Cicadatra* Kolenati, *Psalmocharias* Kirkaldy, *Mogannia* Amyot and Serville and *Emathia* Stål. Wei et al. (2010) established another genus and species, *Shaoshia zhangi* Wei, Ahmed and Rizvi for the Cicadatrini. More recently, the genus *Klapperichicen* Jacobi was also included in the Cicadatrini by Lee (2012).

In the present paper we review the *Nipponosemia* including the description of one new species. A key to all the five species of *Nipponosemia* is provided. In addition, the biogeography of *Nipponosemia* and the systematic status of the tribe Cicadatrini are discussed.

Material and methods

This study is based on specimens deposited in the Entomological Museum, Northwest A&F University, Yangling, China (abbreviated as NWAF in the text). The type specimens of the new species are also deposited in NWAF.

External morphology was observed and illustrated using a Motic SMZ 168-BL microscope. Photos were taken using a Scientific Digital micrography system equipped with an Auto-montage imaging system and a QIMAGING Retiga 4000R digital camera (CCD). The male genitalia were studied and illustrated using a compound light microscope (Nikon Eclipse 50i).

Terminology for morphological features follows that of Moulds (2005).

Taxonomy

Family Cicadidae Latreille
Subfamily Cicadinae Latreille
Tribe Cicadatrini Distant

Genus *Nipponosemia* Kato, 1925
http://species-id.net/wiki/Nipponosemia

Nipponosemia Kato, 1925a: 55. Type species: *Abroma terminalis* Matsumura, 1913.

Diagnosis. Body medium-sized. Head short, slightly produced anteriorly, not longer than pronotum; about as wide as base of mesonotum; postclypeus moderately swollen,

longitudinally sulcate medially. Pronotum nearly trapezoid in dorsal view, wider than head; anterolateral margin not dentate, lateral angle of pronotal collar ampliated. Abdomen moderately obconical, usually shorter than distance from head to cruciform elevation; timbal cover somewhat semicircular, slightly wider than long, covering timbal almost entirely. Fore wing and hind wing with eight and six apical cells, respectively. Male pygofer with basal lobe absent; upper lobe present; uncus short, not dominant, median lobe of uncus weakly developed; claspers separated from each other in ventral view, with median clasper process long and lateral clasper lobe rounded; aedeagus cylindrical, long and somewhat stout, with six to eight spine-like processes apically and subapically.

Key to the males of the species of *Nipponosemia* Kato

1 Fore wing with infuscations on most apical cells **2**
– Fore wing without infuscations on apical cells, or merely with a infuscation on apical cell 1 ..... **3**
2 Body small (approximately 20mm in length); mesonotum with two pair of obconical marks originated from anterior margin; primary spine of fore femur slanted..... ***N. metulata***
– Body large (approximately 28mm in length); mesonotum with only one pair of obconical marks originated from anterior margin; primary spine of fore femur prostrate ..... ***N. guangxiensis***
3 Fore wing with an infuscation on apical cell 1 ..... ***N. terminalis***
– Fore wing without infuscations on apical cells **4**
4 Pronotum with a pair of large reddish brown to dark brown patches with border black; male opercula with subapical portion enlarged toward body center, posterior margin broadly rounded ..... ***N. longidactyla* sp. n.**
– Pronotum without distinct markings; male opercula with apical two-thirds somewhat oblong, posterior margin strongly convex..... ***N. virescens***

***Nipponosemia terminalis* (Matsumura, 1913)**
http://species-id.net/wiki/Nipponosemia_terminalis
Figures 1–3

Abroma terminalis Matsumura, 1913: 82.
Cicada fuscoplaga Schumacher, 1915: 109; Kato 1925b: 9.
Lemuriana terminalis, Matsumura 1917: 208.
Cicada terminalis, Kato 1925b: 9.
Nipponosemia terminalis, Kato 1925a: 56; Duffels and van der Laan 1985: 164; Chou et al. 1997: 123; Lee and Hayashi 2004: 61; Hayashi and Saisho 2011: 175.

Material examined. 1♂ (NWAF), China: Sichuan Prov., Chengdu, ?-VI-1951, coll. Huang Keren; 1♂ (NWAF), China: Sichuan Prov., Mt. Emeishan, 17-VII-1957, coll. Zheng Leyi

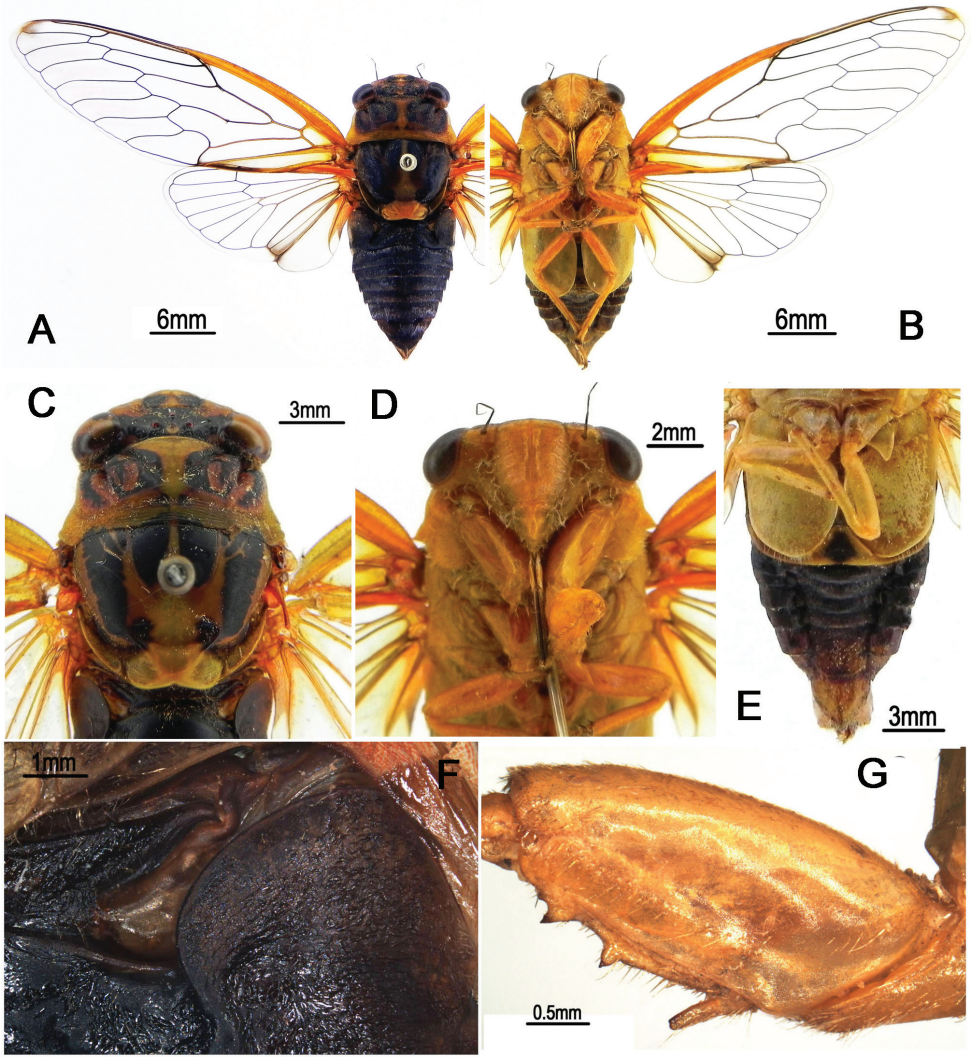

Figure 1. *Nipponosemia terminalis* (Matsumura, 1913), male. **A** habitus, dorsal view **B** habitus, ventral view **C** head and thorax, dorsal view **D** face **E** abdomen and posterior part of thorax, ventral view **F** timbal and timbal cover, dorsal view **G** left fore leg, showing the spines on fore femur.

and Cheng Hanhua; 1♀ (NWAF), China: Fujian Prov., Mt. Baiyunshan, 25-V-1987, coll. unknown; 1♂ (NWAF), China: Chongqing, Xiema, 25-VII-2007, coll. Wu Yiling; 1♂ (NWAF), China: Sichuan Prov., Mt. Emeishan, 7-VII-2010, coll. Wang Junchao.

Additional material. 1♀ (NWAF), China: Fujian Prov., Mt. Baiyunshan, 25-V-1987, coll. unknown.

Description. Head (Fig. 1A–D) mostly yellowish brown, with black markings on vertex and postclypeus in dorsal view; clypeus brownish yellow and depressed; ocellus reddish, eye dark castaneous, distance between lateral ocellus and corresponding eye a lit-

tle longer than distance between lateral ocelli; gena and lorum brownish yellow, with tuft of golden hairs; rostrum yellowish with apical half black, extending to apex of mid coxae.

Pronotum (Fig. 1C) with central longitudinal greenish yellow fascia well broadened at anterior part; symmetrically with two brown and black areas lateral to the central fasciae; pronotal collar greenish yellow. Mesonotum (Fig. 1C) mostly reddish yellow, with central longitudinal yellowish fascia extending to cruciform elevation; pair of somewhat obconical black fasciae lateral to the central longitudinal fascia short and curved outwardly, reaching to about 2/5 of mesonotum; pair of somewhat obconical black fasciae lateral to the short fasciae long and curved outwardly, with apices connecting with the black roundish spots enclosing scutal depressions; cruciform elevation greenish yellow. Ventral surface of thorax brownish yellow.

Legs (Fig. 1G) brownish yellow except for black pretarsal claws; fore femur with primary spine long, digitate and slanted; secondary spine short, sharp and erect; subapical spine short, sharp and slanted.

Wings (Fig. 1A–B) hyaline, veins in basal half yellowish brown and dark brown apically; fore wing with a light brown infuscation on apical part of apical cell 1.

Male abdomen (Fig. 1A–B) mostly black dorsally and yellowish green ventrally, with yellowish brown band on each posterior margin of terga 3–8; timbal cover (Fig. 1F) dark reddish brown; operculum (Fig. 1E) pale greenish yellow, extending slightly beyond posterior margin of abdominal sternite II, widest at half-length, medial margin somewhat convex, posterior margin rounded, lateral margin very weakly sinuate and gradually curved inwardly, medial margins nearly touching each other. Female abdomen mostly black dorsally and yellowish brown ventrally; operculum small, somewhat semicircular, with posterior margin extending not beyond posterior margin of abdominal sternite II, both opercula well separated from each other.

Male genitalia (Fig. 2A–D). Pygofer oval in ventral view; dorsal beak long, slightly protruding upwards in lateral view; distal shoulder very broad and sinuate, with somewhat triangular process near upper lobe of pygofer; upper lobe of pygofer short and obtuse in lateral view. Uncus with median lobe with rounded process adjacent anal tube in lateral view. Clasper in ventral view with median clasper process fairly broadened basally and narrowed apically, with apex acute and curved inwardly; lateral clasper lobe roundly developed, without distinct concave between median clasper process and corresponding lateral clasper lobe. Aedeagus with broadened and curved membranous sheet apically; eight short to long processes present on the sheet marginally, of which two long ones curved dorsad and the others curved downward in ventral view, with the basal-most ventral one the longest in lateral view. Posterior margin of sternite VII short and angularly produced.

Female pygofer (Fig. 3A–B) with dorsal beak short and acute, much shorter than protruding part of ovipositor; posterior margin of sternite VII with median incision very deep and broad, deep to about 4/5 the length of sternite VII.

Measurements (4♂♂, 1♀) (in mm). Body length: ♂ 25.0–26.0, ♀ 24.5; fore wing length: ♂ 27.0–30.0, ♀ 29.5; fore wing width: ♂ 9.5–10.5, ♀ 10.5; width of head including eyes: ♂ 7.5–9.5, ♀ 7.5; pronotum width (including pronotal collar): ♂ 9.0–10.0, ♀ 9.5; mesonotum width: ♂ 7.5–8.5, ♀ 8.0.

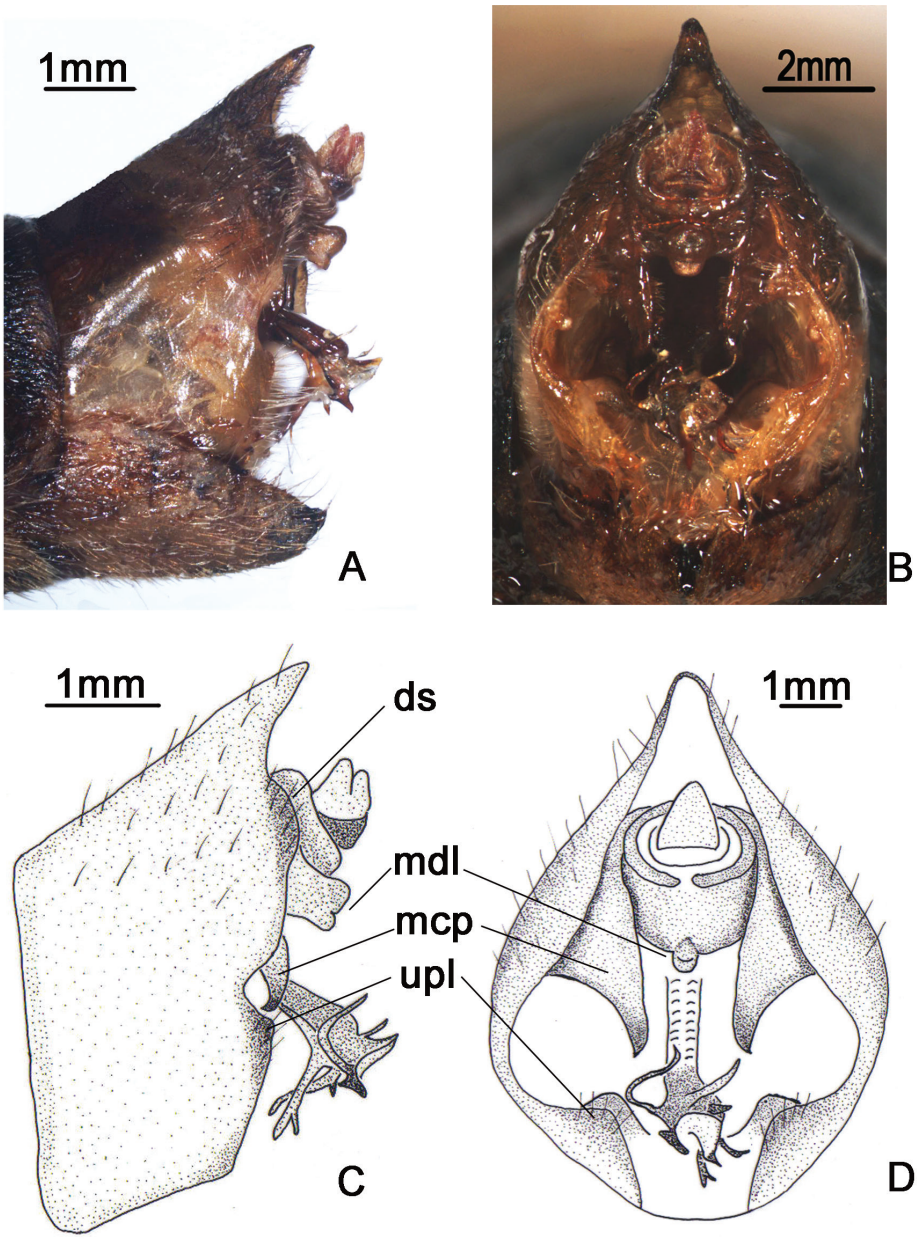

Figure 2. *Nipponosemia terminalis* (Matsumura, 1913), male. **A, C** male genitalia, left lateral view **B, D** male genitalia, ventral view. ds, distal shoulder; mcp, median clasper process; mdl, median lobe of uncus; upl, upper lobe of pygofer.

Biology. This species is distributed from lowlands to low mountainous areas. Adults appear from May to August. They usually perch on low branches or trunks of various trees and sing in the sunshine (Lee and Hayashi 2004).

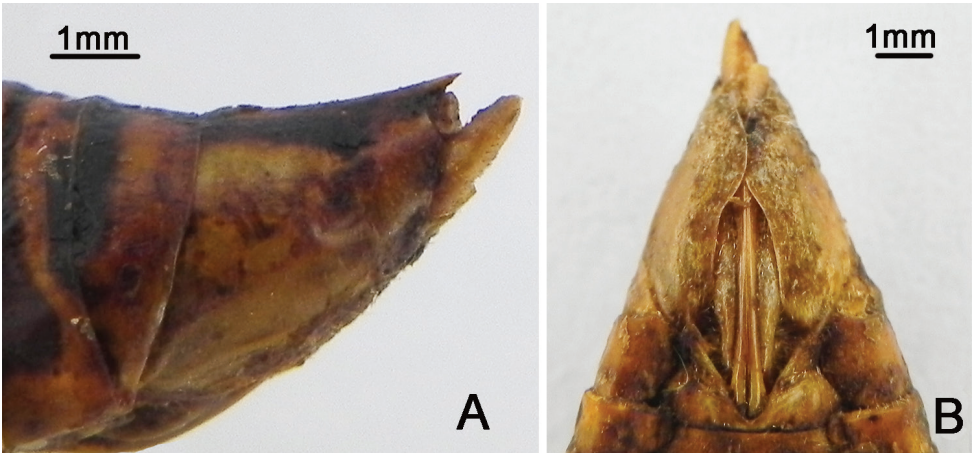

Figure 3. *Nipponosemia terminalis* (Matsumura, 1913), female. **A** female genitalia, left lateral view **B** female genitalia, ventral view.

Distribution. China (Sichuan, Fujian, Chongqing, Taiwan), Japan.

Remarks. Hayashi and Saisho (2011) recorded the variation in body coloration of this species among geographic populations from the Ryukyus. The materials of this species from China mainland examined in the present paper are most externally similar to those distributed in Miyuan, Ishigaki Island. In addition, we include one female specimen as additional material for this species based on its external morphology and collecting data. This specimen has some differences with the one female specimen of *N. terminalis* we examined in body coloration and the length of ovipositor. The identity of this female specimen needs to be investigated further when more specimens become available.

***Nipponosemia metulata* Chou & Lei, 1993**
http://species-id.net/wiki/Nipponosemia_metulata
Figures 4–6

Nipponosemia metulata Chou & Lei, 1993: 83; Chou et al. 1997: 125.

Material examined. 1♀ (NWAF), China: Guangxi Prov., Longzhou, 17-VI-1980, coll. Xi Fusheng; 1♂ (NWAF), China: Guangxi Prov., Longzhou, light strap, 21-V-1982, coll. unkuown; 1♂ (NWAF), China: Guangxi Prov., Ningming, light strap, 16-V-1984, coll. Zhi Tian.

Description. Head (Fig. 4A–D) mostly brownish yellow, with black markings on vertex and postclypeus in dorsal view; clypeus brownish yellow and depressed; ocellus reddish, eye dark castaneous, distance between lateral ocellus and corresponding eye as long as distance between lateral ocelli; gena and lorum brownish yellow, with tuft of golden hairs; rostrum yellowish with apical half brown, extending to apex of mid coxae.

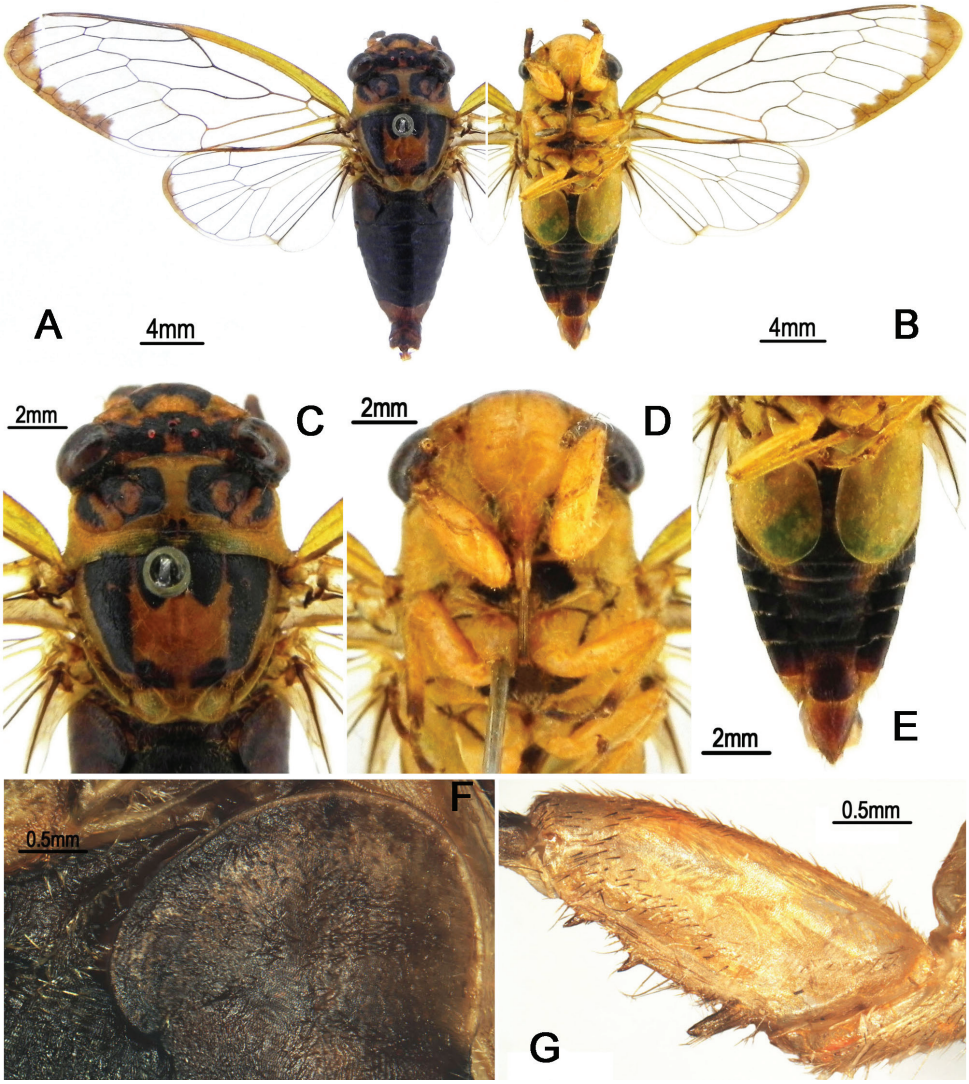

Figure 4. *Nipponosemia metulata* Chou & Lei, 1993, male. **A** habitus, dorsal view **B** habitus, ventral view **C** head and thorax, dorsal view **D** face **E** abdomen and posterior part of thorax, ventral view **F** timbal and timbal cover, dorsal view **G** left fore leg, showing the spines on fore femur.

Pronotum (Fig. 4C) with central longitudinal brownish yellow fascia well broadened at anterior part; symmetrically with two brown and black areas lateral to the central fasciae; pronotal collar mostly greenish yellow. Mesonotum (Fig. 4C) mostly reddish yellow, centrally with pair of obconical black fasciae short and slightly curved outwardly, reaching to about 1/4 of mesonotum; pair of obconical black fasciae lateral to the short outwardly curved fasciae long and curved inwardly, with apices connecting with the black roundish spots enclosing scutal depressions; cruciform elevation mostly greenish yellow. Ventral surface of thorax mostly brownish yellow.

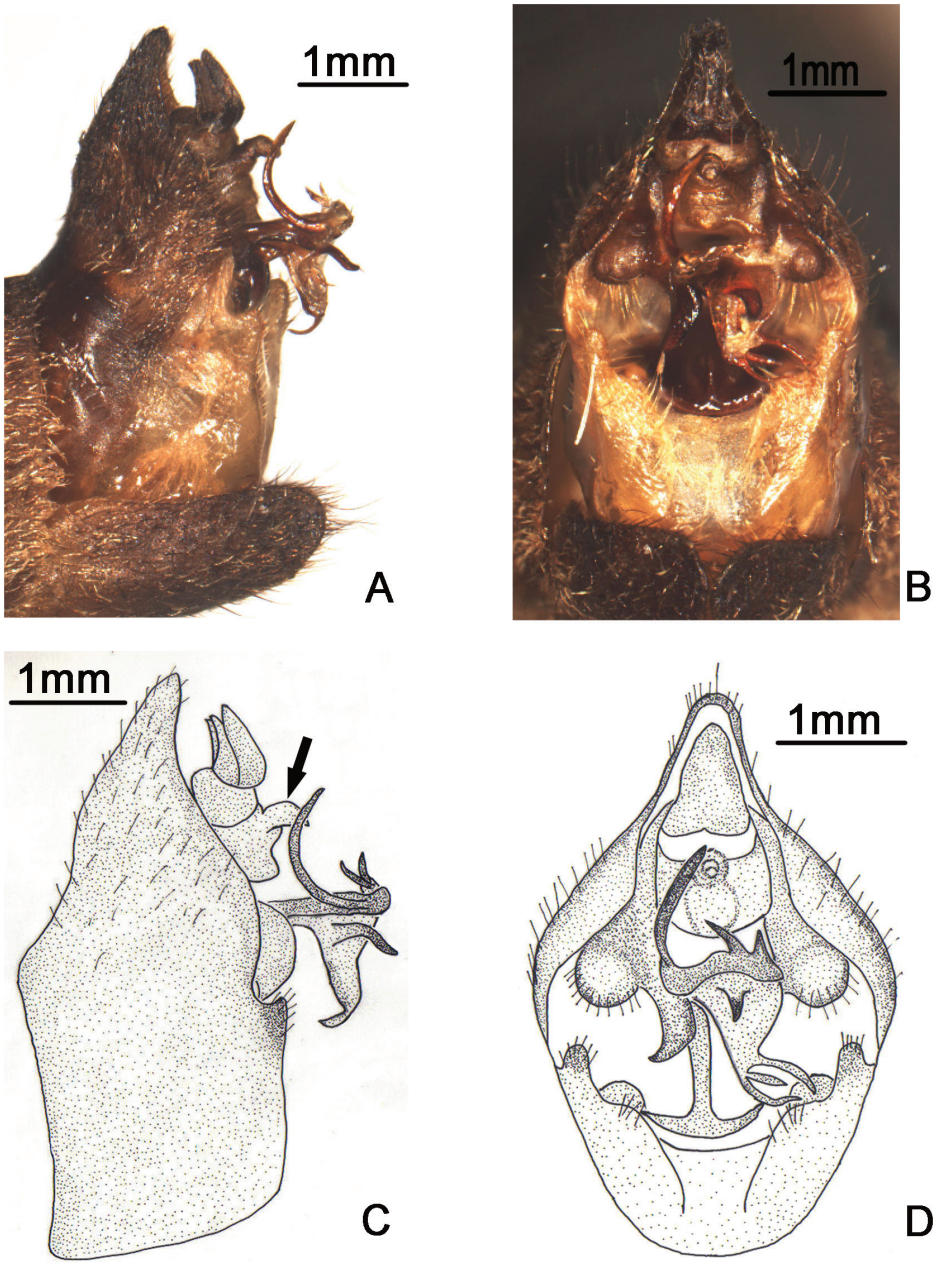

Figure 5. *Nipponosemia metulata* Chou & Lei, 1993, male. **A, C** male genitalia, left lateral view **B, D** male genitalia, ventral view.

Legs (Fig. 4G) mostly yellow; tarsi and tibiae brown to dark brown and apices of pretarsal claws reddish brown; fore femur with primary spine long, digitate and slanted; secondary and subapical spines short, sharp and somewhat erect.

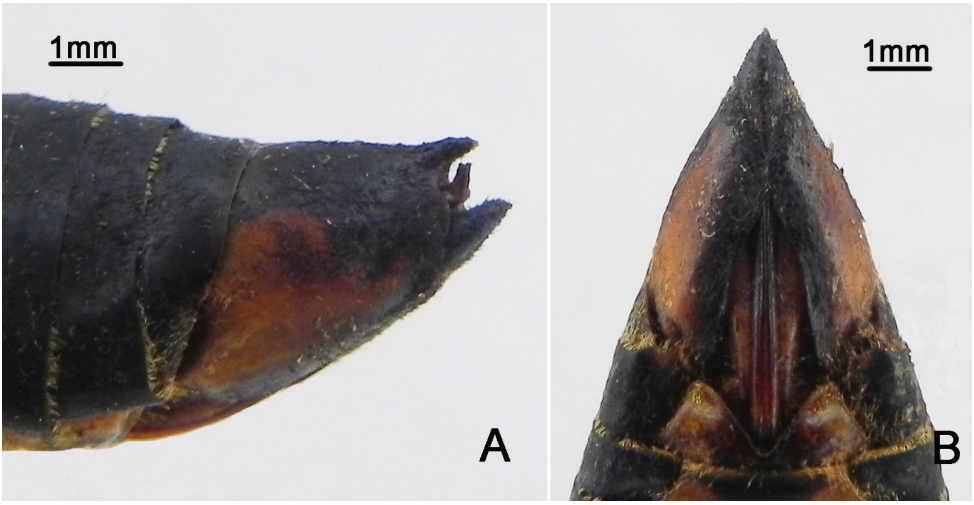

Figure 6. *Nipponosemia metulata* Chou & Lei, 1993, female. **A** female genitalia, left lateral view **B** female genitalia, ventral view.

Wings (Fig. 4A–B) hyaline, veins generally in basal half yellowish green and dark brown apically; fore wing with continuous brown fascia along apical parts of apical cells 1–7 and associated outer margin of fore wing; hind wing with continuous brown fascia along apical parts of apical 1–4 and associated outer margin of hind wing.

Male abdomen (Fig. 4A–B) mostly black except for reddish brown tergite 8; timbal cover (Fig. 4F) dark brown; operculum (Fig. 4E) mostly brownish yellow with apical 1/3 mostly greenish, extending slightly beyond posterior margin of abdominal sternite II, obliquely ellipsoidal, subapical portion enlarged toward body center, posterior margin rounded, medial margins not touching each other. Female abdomen mostly black dorsally and reddish brown ventrally, with golden hairs on each posterior margin of terga 2–8; operculum small, somewhat semicircular, with posterior margin truncated, extending not beyond posterior margin of abdominal sternite II, both opercula well separated from each other.

Male genitalia (Fig. 5A–D). Pygofer oval in ventral view; dorsal beak well developed, protruding upwards in lateral view; distal shoulder very broadly rounded; upper lobe of pygofer produced posteriorly, triangular-shaped in lateral view. Uncus with beak-like process adjacent to anal tube in lateral view (as arrow indicated in Fig. 5C). Clasper in ventral view with median clasper process long, with apex acute and curved laterally, falcate in shape; lateral clasper lobe roundly developed. Aedeagus in ventral view with broadened membranous sheet apically, which is remarkably developed ventrally and bears seven short to long processes: one long and two short processes at the upper margin curved upward, three at the lower margin curved downward, and one short process arising medially in ventral view. Posterior margin of sternite VII short and rounded.

Female pygofer (Fig. 6A–B) with dorsal beak short and acute, slightly shorter than protruding part of ovipositor; posterior margin of sternite VII with median incision broad and deep, deep to about 4/5 the length of sternite VII.

Measurements (2♂♂, 1♀**)** (in mm). Body length: ♂ 20.0–20.5, ♀ 22.0; fore wing length: ♂ 22.0–23.0, ♀ 24.5; fore wing width: ♂ 8.0–8.5, ♀ 9.0; width of head including eyes: ♂ 7.0–7.5, ♀ 8.5; pronotum width (including pronotal collar): ♂ 7.0–7.5, ♀ 8.5; mesonotum width: ♂ 6.0–6.5, ♀ 7.5.

Biology. Unknown.

Distribution. China (Guangxi).

Remarks. This species is similar to *N. terminalis,* but it can be distinguished from the latter by a smaller body size, the big markings on wings, the shape of clasper and aedeagus, and the shorter protruding part of ovipositor (Chou et al. 1993, 1997).

Nipponosemia guangxiensis Chou & Wang, 1993

http://species-id.net/wiki/Nipponosemia_guangxiensis
Figures 7–9

Nipponosemia guangxiensis Chou & Wang, 1993: 84; Chou et al. 1997: 127; Pham and Yang 2009: 5.

Material examined. 1♂ (NWAF), China: Guangxi Prov., Ningming, 19-V-1984, coll. Wang Jijian; 1♀ (NWAF), China: Guangxi Prov., Longzhou, 17-V-1983, coll. Liu Sikong.

Description. Head (Fig. 7A–D) mostly reddish brown, symmetrically with small black stripes on vertex; clypeus reddish brown and depressed; ocellous reddish, eye castaneous, distance between lateral ocellus and corresponding eye as long as distance between lateral ocelli; gena and lorum mostly reddish brown, with tuft of golden hairs and lorum symmetrically with pair of black stipes; rostrum reddish with apical half dark brown, extending to apex of mid coxae.

Pronotum (Fig. 7C) reddish brown, with paramedian and lateral fissures ochreous. Mesonotum (Fig. 7C) mostly reddish brown, centrally with pair of short and slightly outwardly curved obconical black fasciae, reaching to about the 1/4 of mesonotum; pair of slender short black stripes and irregular markings lateral to the outwardly curved fasciae; cruciform elevation reddish brown. Ventral surface of thorax mostly reddish brown.

Legs (Fig. 7G) mostly reddish brown; tarsi and pretarsal claws dark reddish brown; fore femur with primary spine long, digitate and prostrate; secondary spine short, sharp and erect; subapical spine short, sharp and almost prostrate.

Wings (Fig. 7A–B) hyaline, veins generally in basal half reddish brown and brown apically; fore wing with continuous brown fascia along apical parts of apical cells 1–7 and associated outer margin; hind wing with two continuous brown fascia: one along apical parts of apical cells 1–5 and associated outer margin, the other along outer margin of vannal region.

Male abdomen (Fig. 7A–B) mostly black dorsally and reddish brown ventrally, with central trapezoid reddish brown mark on tergite II; timbal cover (Fig. 7F) reddish brown; operculum (Fig. 7E) reddish brown, extending slightly beyond posterior margin of abdominal sternite II, widest at half-length, medial margin of operculum

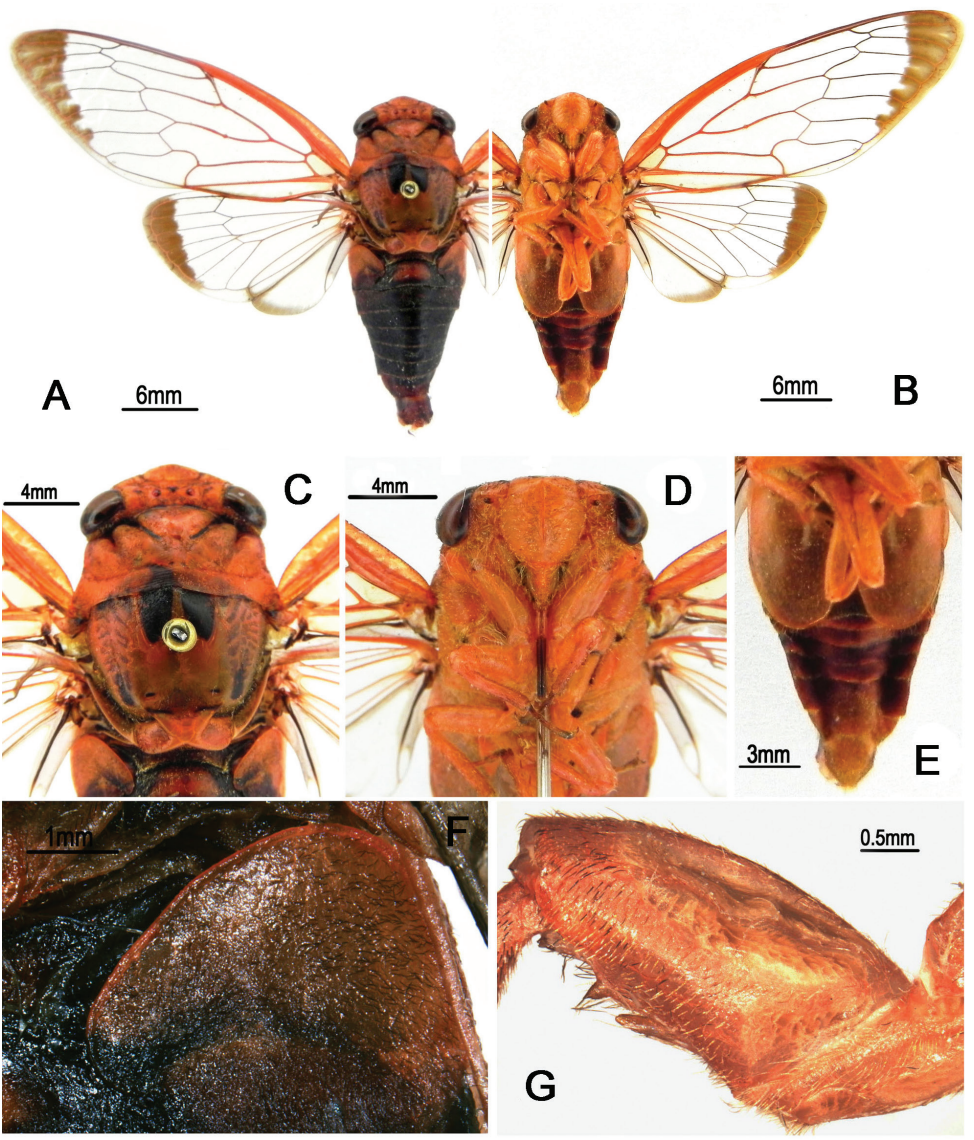

Figure 7. *Nipponosemia guangxiensis* Chou & Wang, 1993, male. **A** habitus, dorsal view **B** habitus, ventral view **C** head and thorax, dorsal view **D** face **E** abdomen and posterior part of thorax, ventral view **F** timbal and timbal cover, dorsal view **G** left fore leg, showing the spines on fore femur.

slightly convex, posterior margin rounded, lateral margin weakly sinuate and gradually curved inwardly, medial margins nearly touching each other. Female abdomen mostly black dorsally and yellowish brown ventrally, with golden hairs on each posterior margin of terga 2–8; operculum small, triangular, with posterior margin truncated, extending not beyond posterior margin of abdominal sternite II, both opercula well separated from each other.

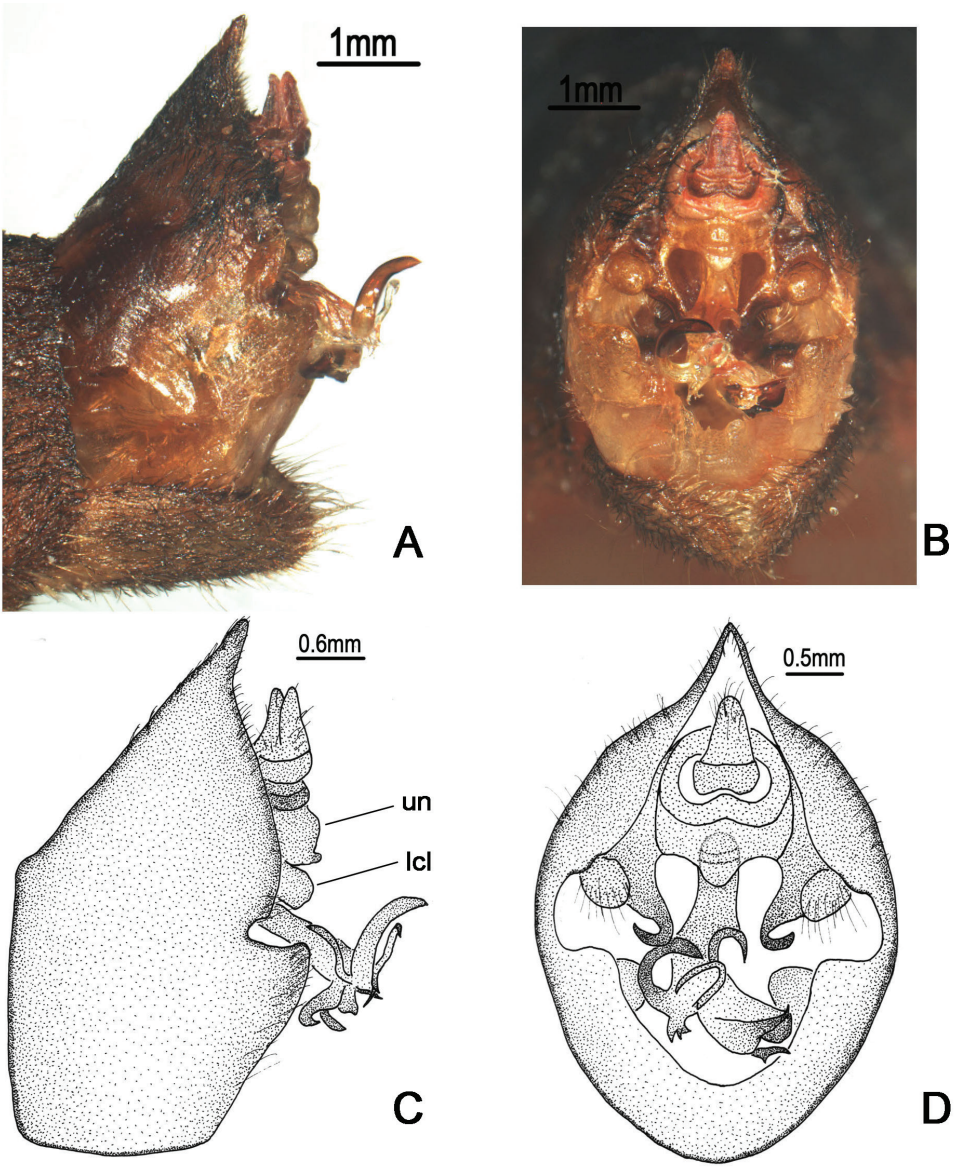

Figure 8. *Nipponosemia guangxiensis* Chou & Wang, 1993, male. **A, C** male genitalia, left lateral view **B, D** male genitalia, ventral view. un, uncus; lcl, lateral clasper lobe.

Male genitalia (Fig. 8A–D). Pygofer oval in ventral view; dorsal beak protruding upwards in lateral view; distal shoulder broadly rounded; upper lobe remarkably developed, forming a very large triangular-shaped protrusion in lateral view. Uncus with apex of median lobe slightly developed ventrally, forming a small process in both lateral and ventral views. Clasper in ventral view with median clasper process very long, broaden basally, apex strongly curved laterally, hook-like in shape; lateral

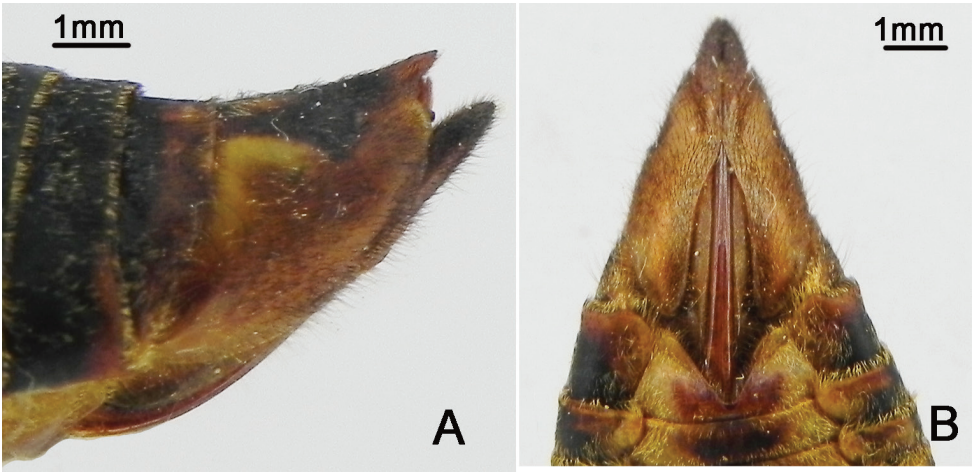

Figure 9. *Nipponosemia guangxiensis* Chou & Wang, 1993, female. **A** female genitalia, left lateral view **B** female genitalia, ventral view.

clasper lobe roundly developed. Aedeagus in ventral view with three long apical processes curved dorsad and other three small to large lobe-like processes curved ventrad; the shortest lobe-like process with three short spines apically in ventral view; the medial lobe-like process bifurcate subapically, with apices acute; the third lobe-like process large, with apex somewhat rounded. Posterior margin of sternite VII short and rounded.

Female pygofer (Fig. 9A–B) with dorsal beak short and acute, shorter than protruding part of ovipositor; posterior margin of sternite VII with median incision large and broad, deep to about 4/5 the length of sternite VII.

Measurements (1♂, 1♀) (in mm). Body length: ♂ 28.0, ♀ 26.0; fore wing length: ♂ 31.0, ♀ 31.0; fore wing width: ♂ 11.5, ♀ 11.0; width of head including eyes: ♂ 9.5, ♀ 9.0; pronotum width (including pronotal collar): ♂ 10.0, ♀ 11.0; mesonotum width: ♂ 9.0, ♀ 10.0.

Biology. Unknown.

Distribution. China (Guangxi), Vietnam.

Remarks. This species is similar to *N. terminalis* but can be distinguished from the latter by a larger body size, the wings with large brown markings, the pronotum without markings, and the mesonotum with only one pair of obconical marks, in addition to the differences in male genitalia (Chou et al. 1993, 1997).

Nipponosemia virescens Kato, 1926

http://species-id.net/wiki/Nipponosemia_virescens

Nipponosemia virescens Kato, 1926: 172; Hayashi 1979: 262; Duffels and van der Laan 1985: 164; Chou et al. 1997: 125; Lee and Hayashi 2004: 62.

Material examined. No specimen available.

Biology. This species is found in lowlands. Adults appear from April to July and both sexes are attracted to electric light at night (Lee and Hayashi 2004).

Distribution. China (Taiwan).

Remarks. Chou et al. (1997) incorrectly recorded this species from Japan. Considering the morphological similarity between this species and *N. terminalis*, Lee and Hayashi (2004) suggested that they may represent one species and *N. virescens* should be a kind of geographical variation within *N. terminalis*, and the identity of this species needs to be confirmed when material becomes available. We included this species in the key in this paper according to the photograph provided by Lee and Hayashi (2004).

***Nipponosemia longidactyla* sp. n.**

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http://species-id.net/wiki/Nipponosemia_longidactyla

Figures 10–12

Material examined. Type material. Holotype: ♂ (NWAF), **China**: Hainan Prov., Jianfengling Nature Reserve, 1-VI-1982, coll. Liu Yuanfu. **Paratypes:** 1♂ (NWAF), **China**: Hainan Prov., Limushan Nature Reserve, light trap, 26-V-1984, coll. Gu Maobin; 1♀ (NWAF), **China**: Hainan Prov., Jianfengling Nature Reserve, 980 m, light trap, 5-V-2008, coll. Fu Qiang. **Additional material.** 1♂ (NWAF), **China**: Hainan Prov., Jianfengling Nature Reserve, 960 m, light trap, 29-V-2011, coll. Yang Mingsheng.

Diagnosis. This new species can be easily distinguished from other species of *Nipponosemia* by the following features: upper lobe of pygofer very long and arched, protruding inward; median lobe of uncus weak, with apex slightly produced, forming a small process curved upwards in ventral view; median clasper process well developed and twisted subbasally, forming a large process curved laterally; lateral clasper lobe roundly developed inwards and partially overlapped by the large subapical process of the median clasper process. In addition, we include one male specimen from Jianfengling Nature Reserve as additional material for this species based on its external morphology and the morphology of genitalia except for the aedeagus, as the aedeagus was broken, and its identity needs to be investigated further when more specimens become available.

Description. Head (Fig. 10A–B) mostly pale yellow, with reddish markings on vertex; clypeus yellow and depressed; ocellus orange, eye castaneous, distance between lateral ocellus and corresponding eye about as long as distance between lateral ocelli; face and gena yellow; rostrum yellowish with apical half light brown, extending to apex of mid coxae.

Pronotum (Fig. 10C) with central longitudinal yellowish fascia well broadened at both anterior and posterior parts; symmetrically with two large reddish brown to dark brown patches with border black; pronotal collar mostly reddish with lateral part pale yellow. Mesonotum (Fig. 10C) mostly yellowish, symmetrically tinged with red to reddish brown laterally in male but with blackish fasciae in female; cruciform elevation yellowish. Ventral surface of thorax mostly yellow, without distinct markings.

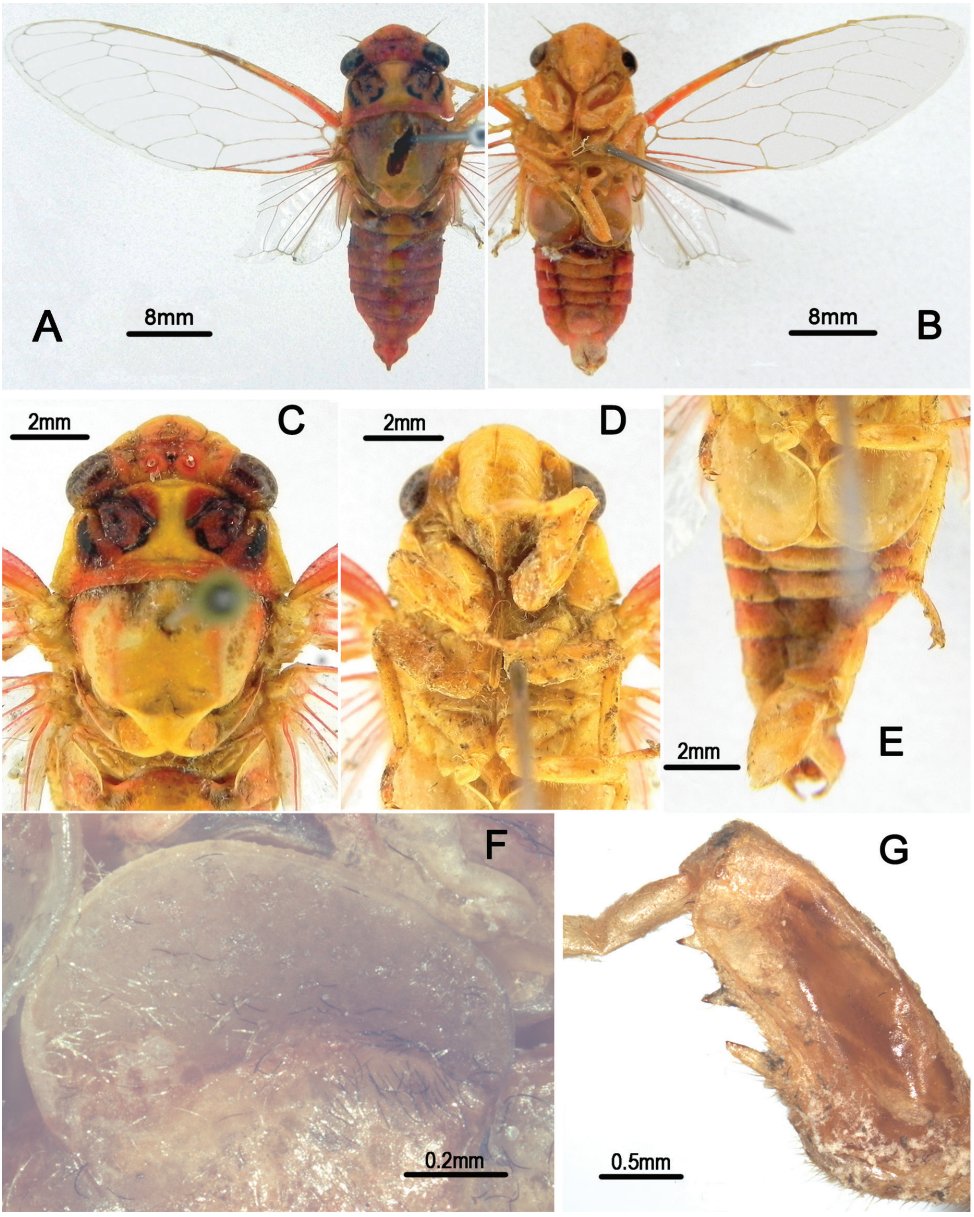

Figure 10. *Nipponosemia longidactyla* sp. n., male. **A** habitus (holotype), dorsal view **B** habitus (holotype), ventral view **C** head and thorax (paratype), dorsal view **D** face (paratype) **E** abdomen and posterior part of thorax (paratype), ventral view **F** timbal and timbal cover (paratype), dorsal view **G** left fore leg (paratype), showing the spines on fore femur.

Legs (Fig. 10G) yellow except for reddish brown pretarsal claws; fore femur with primary spine long, digitate and slanted; secondary spine short, sharp and erect; subapical spine short, sharp and slanted.

Wings (Fig. 10A–B) hyaline, without any markings; veins in basal half reddish and yellowish apically.

Male abdomen (Fig. 10A–B) obconical, mostly dark red, with discontinuous central longitudinal yellowish fascia in dorsal view; timbal cover (Fig. 10F) ochreous; operculum (Fig. 10E) pale yellowish, obliquely ellipsoidal, subapical portion enlarged toward body center, extending slightly beyond posterior margin of abdominal sternite II, medial margins almost touching (holotype) or even touching (male paratype) each other. Female abdomen mostly black dorsally and yellowish brown ventrally, with discontinuous central longitudinal yellowish fascia in dorsal view, with reddish brown band on each posterior margin of terga 2–7; operculum small, semicircular, extending slightly beyond posterior margin of abdominal sternite II, both opercula well separated from each other.

Male genitalia (Fig. 11A–D). Pygofer oval in ventral view; dorsal beak long with obtuse tip; distal shoulder broadly convex in lateral view; upper lobe of pygofer remarkably long, digitate, curved inwardly. Uncus undeveloped in lateral view; apex of median lobe slightly produced, forming a small process curved upwards in ventral view. Clasper in ventral view with median clasper process well developed and twisted subbasally, forming a large process curved laterally; apex of median clasper process curved laterally and acute apically; lateral clasper lobe roundly developed inwards, partially overlapped by the large subapical process of median clasper process. Aedeagus with seven short to long processes apically and subapically, which are all pointed upward in ventral view but arranged into two groups in lateral view (three located ventrally and four dorsally). Posterior margin of sternite VII rounded.

Female pygofer (Fig. 12A–B) with dorsal beak short and acute; ovipositor short, not extending beyond the end of abdomen; posterior margin of sternite VII with median incision very broad and relatively shallow, deep to about 1/2 the length of sternite VII.

Measurement (2♂♂, 1♀) (in mm). Length of body: ♂ 20.0–21.0, ♀ 21.0; length of fore wing: ♂ 21.0, ♀ 25.5; width of fore wing: ♂ 7.0, ♀ 8.0; width of head including eyes: ♂ 6.0, ♀ 6.5; width of pronotum (including pronotal collar): ♂ 7.0, ♀ 7.5; width of mesonotum: ♂ 6.5, ♀ 7.0.

Biology. All the examined materials including the additional material were collected from the same tropical rainforest.

Distribution. China (Hainan).

Etymology. The specific name is derived from Latin prefix "*longi-*"and "*dactyla*" which refer to the long upper lobe of pygofer.

Discussion

We review the cicada genus *Nipponosemia* and describe a new species, *N. longidactyla* sp. n., for this genus in this paper. However, compared to other species of *Nipponosemia*, this new species has several peculiar characters, viz, the well developed upper

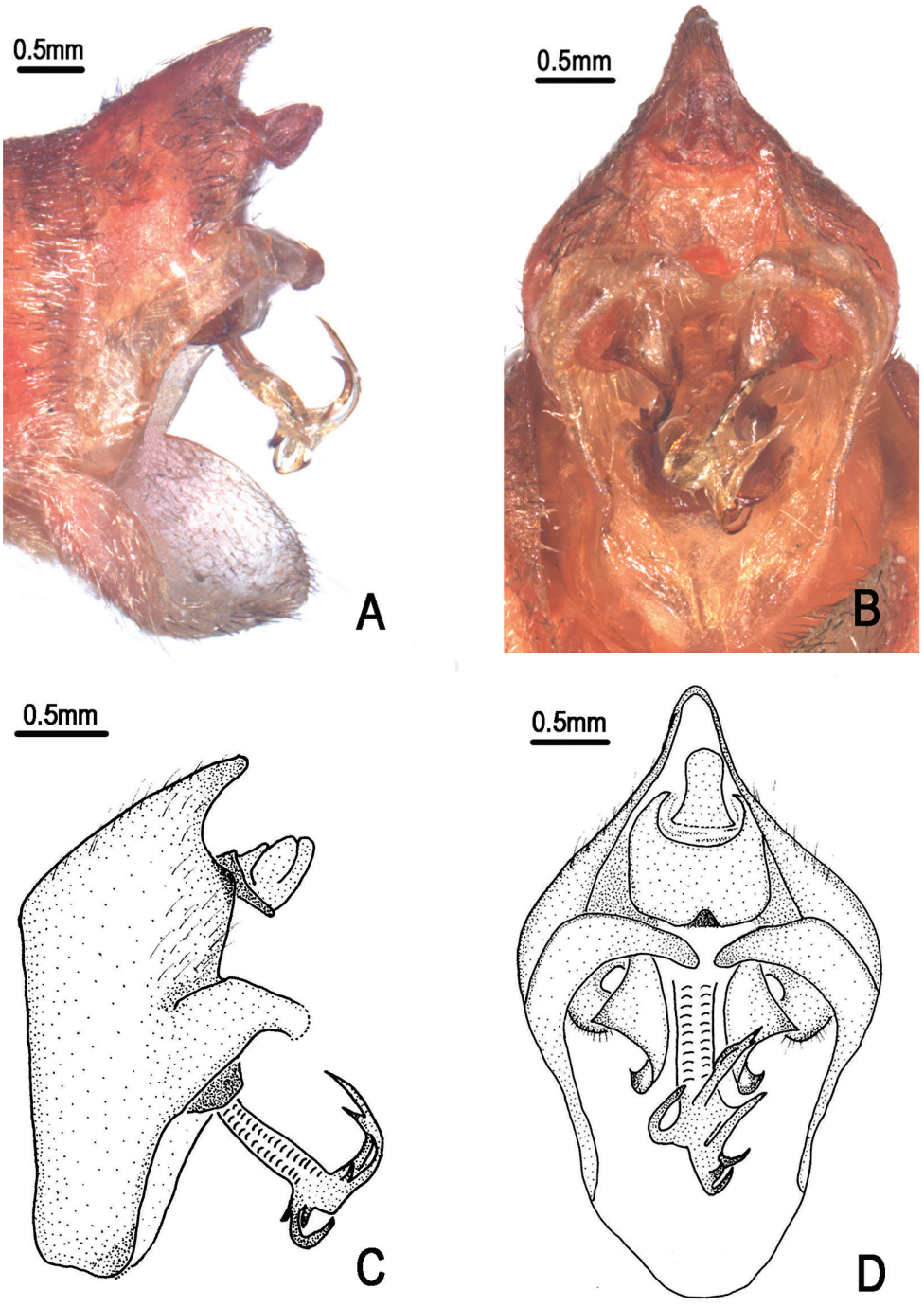

Figure 11. *Nipponosemia longidactyla* sp. n., male (holotype). **A, C** male genitalia, left lateral view **B, D** male genitalia, ventral view

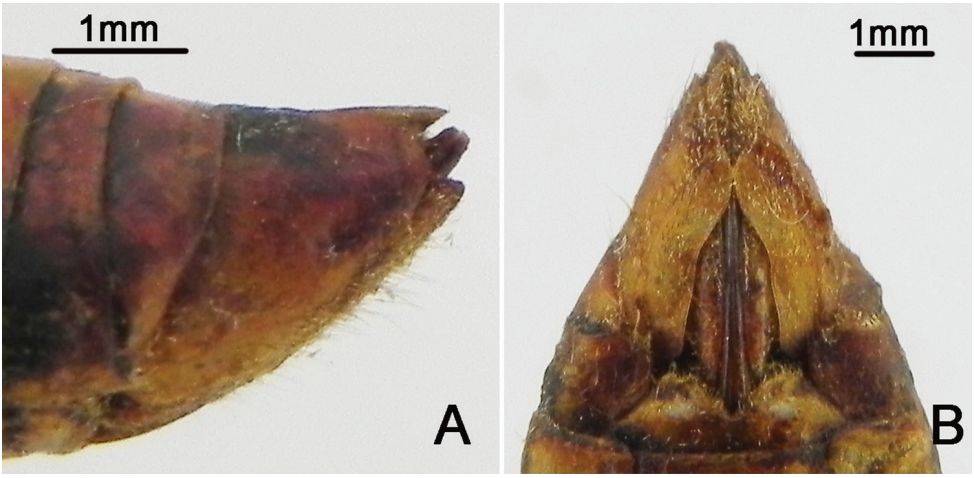

Figure 12. *Nipponosemia longidactyla* sp. n., female (paratype). **A** female genitalia, left lateral view **B** female genitalia, ventral view.

lobe of pygofer and the complicated and twisted median clasper process, as indicate that this species might not be congeneric to other species of *Nipponosemia*. We tentatively place this new species in *Nipponosemia* until its status being addressed definitely via phylogenetic analysis.

Chen et al. (2012) reviewed the *Mogannia* from China and noted that the Cicadatrini (represented by *Mogannia*) could be a member of the subfamily Cicadettinae, but they tentatively retained it in the subfamily Cicadinae since other genera of Cicadatrini such as *Nipponosemia*, *Cicadatra*, *etc*. were not addressed. Herein, we scored the morphological attributes for *Nipponosemia* that are identified in Moulds (2005, Fig. 59 and associated text) as defining subfamilies. Similar to *Mogannia*, *Nipponosemia* also appears to be more allied to the Cicadettinae in having the following morphological characters: 1) width of first cubital cell of hind wing at distal end much broader than second cubital cell (twice or more); 2) upper lobe of pygofer present; 3) large claspers dominating the whole 10th abdominal segment; 4) uncus short, not dominant; 5) aedeagus restrained by claspers; and 6) fore wing vein CuA_1 divided by crossvein (m-cu) so that proximal portion is shorter. However, we tentatively retained *Nipponosemia* in Cicadinae, as the phylogenetic relationship of genera in the Cicadatrini (*sensu* Lee and Hill 2010) with other related taxa needs to be adequately analyzed by more morphological features and molecular data from extensive sampling taxa.

Regarding the biogeography of *Nipponosemia*, *N. terminalis* has the widest distribution range among the five *Nipponosemia* species (Fig. 13), i.e., from southwestern China (Sichuan and Chongqing) to Taiwan Island and the southern Ryukyus. This disjunctive distribution indicates that *N. terminalis* had dispersed over oceanic barriers

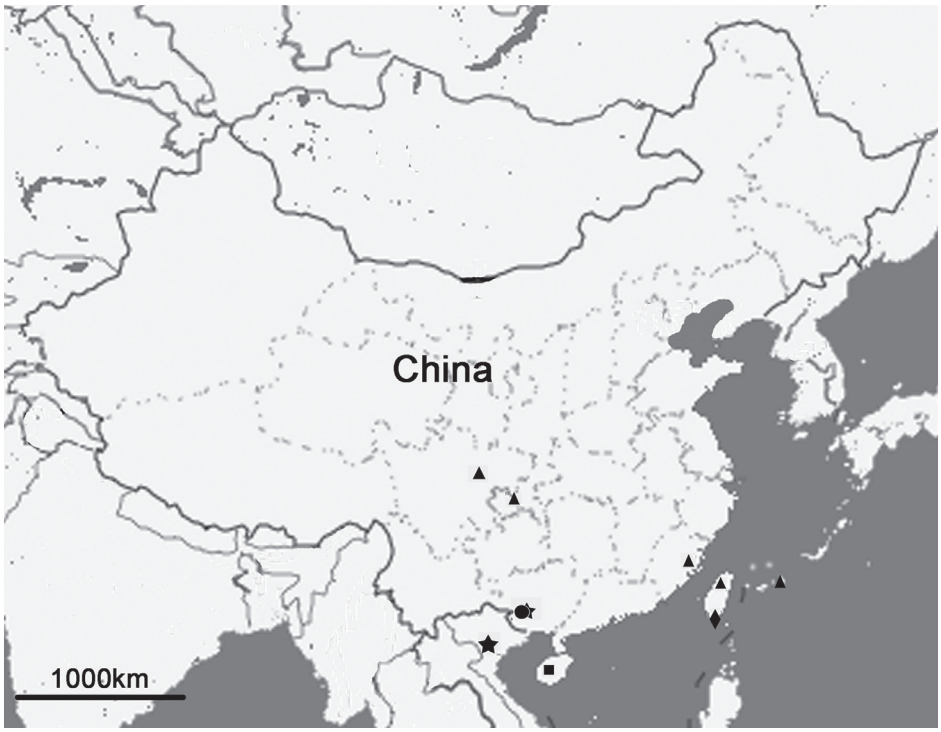

Figure 13. Distribution of *Nipponosemia* species. *N. terminalis* (triangle); *N. metulata* (round); *N. guangxiensis* (five-pointed star); *N. virescens* (diamond); *N. longidactyla* sp. n. (square).

during the Ice Ages. The remaining species of *Nipponosemia* are all restricted to narrow regions: *N. guangxiensis* occurs in Guangxi Prov. of southern China and Vinh Phuc of northern Vietnam (Pham and Yang 2009); *N. metulata* is only known from Guangxi Prov. of China (Chou et al. 1993, 1997); *N. virescens* is restricted to southernmost Taiwan of China (Lee and Hayashi 2004); and *N. longidactyla* sp. n. is currently only known from Hainan Island of China. The above distribution pattern indicates that this genus is distributed in the Oriental Region, particularly southern China and Pacific islands adjacent to the China Mainland. Higher biodiversity of this genus in the Oriental Region probably can be revealed when more biodiversity inventory projects covering biodiversity hotspots there are completed.

Acknowledgements

We are grateful to Ms. Xiao Chen (Northwest A&F University, Yangling, China) for illustrating and photographing the known species of the genus *Nipponosemia*. This work is supported by the National Natural Science Foundation of China (Grant No. 31093430) and Program for New Century Excellent Talents in Universities of China (NCET-10-0691).

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RESEARCH ARTICLE

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Revision of Australian Matini diving beetles based on morphological and molecular data (Coleoptera, Dytiscidae, Matinae), with description of a new species

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Abstract

Morphological characters and mitochondrial DNA sequence data were used to revise the Australian diving beetles in the genera *Allomatus* Mouchamps, 1964 and *Batrachomatus* Clark, 1863. As a result of these studies *Allomatus* **syn. n.** is synonymised with *Batrachomatus,* and *Allomatus nannup* Watts, 1978 from SW Australia and *A. wilsoni* Mouchamps, 1964 from SE Victoria are transferred to *Batrachomatus*. The four Australian Matini species known so far are re-described, and *B. larsoni* **sp. n.** from the Windsor Tableland in NE Queensland is described. After more than 40 years *B. wilsoni* has been re-discovered in two rivers in Victoria. We delineate the species using traditionally employed morphological structures such as in the male genitalia and body size, shape and colour pattern, as well as mitochondrial *cox1* sequence data for 20 individuals. Important species characters (median lobes, parameres and colour patterns) were illustrated. We provide an identification key and outline distribution and habitat preferences of each species. All Australian Matini are lotic, inhabiting permanent and intermittent streams, creeks and rivers.

Keywords

Allomatus, *Batrachomatus*, new species, synonymy, morphological characters, molecular taxonomy

Introduction

The Matini, the single tribe of the subfamily Matinae, is thus far known to contain eight species in three genera. Their current distribution is highly disjunct. *Matus* Aubé, 1836 is distributed in the Nearctic region with four species and one subspecies. In Australia there are two species so far assigned to *Allomatus* Mouchamps, 1964 and two assigned to *Batrachomatus* Clark, 1863. The American species were revised by Larson et al. (2000), and the Australian ones by Mouchamps (1964) and Watts (1978). The larvae of *A. nannup*, *B. daemeli*, *M. bicarinatus* (Say, 1823) and *M. leechi* Young, 1953 have been described and phylogenetic relationships within the Matini based on larval characters have been discussed by Wolfe and Roughley (1985), Alarie et al. (2001) and Alarie and Butera (2003).

Despite their disjunct distribution, members of the Matinae are postulated to share a monophyletic origin and to be relicts of a once more extensively distributed taxon (Alarie et al. 2001, Alarie and Butera 2003).

The aim of this paper is to revise the Australian Matini taxonomically, combining morphology and mitochondrial DNA sequence data. *Allomatus* syn. n. is synonymized with *Batrachomatus,* we describe one new species from the Atherton Tableland in Queensland and provide a key to the five Australian species known so far. All DNA sequence data and digital images of morphological structures were also made available online in Wiki format for faster dissemination of taxonomic knowledge and the option of future edits and additions to the species pages in a fully versioned framework.

The two species of the genus *Batrachomatus* are widespread in tropical northern Australia (*B. wingii*) and in south-eastern Australia (*B. daemeli*), whereas all species of the former genus *Allomatus* are restricted to one or two river systems in the southwest (*A. nannup*), or the southeast (*A. wilsoni*). Except for *A. nannup* and *B. daemeli*, all other species are very rarely collected and are mainly known from only a few specimens from their type localities. One undescribed species from northern Queensland was found among the Dytiscidae donated by D.J. Larson (Maple Creek, Canada) to the Australian National Insect Collection (ANIC) in Canberra.

Material and methods

Material: We examined 401 specimens, including the type material of all species.

Descriptions: Beetles were studied with a Leica MZ 12.5 microscope at 10–100x. Photos of the male genitalia, used for the drawings, were made using a digital photo imaging system, composed of a Leica DM 2500 M microscope and a Tucsen 5.0 MP camera. This microscope was fitted with Leica HCX PL "Fluotar" 5x and 10x metallurgical grade lenses (Buffington and Gates 2008). Image stacks were aligned and assembled with the computer software Helicon Focus 4.77™. The drawings were scanned and edited, using the software Adobe Illustrator CS5.1. Label data of type material were cited in quotation marks. All type specimens of the herein described species were provided with red labels.

The terminology to denote the orientation of the genitalia follows Miller and Nilsson (2003). The following abbreviations were used: TL (total length), TL-H (total length without head), and MW (maximum width).

Coordinates are given in decimal notation unless cited verbatim from labels. Beside various Australian road maps, we also used Google Earth (http://earth.google.com) to locate localities.

DNA sequencing and data analysis: The sequence data originate from Hendrich et al. (2010). We preserved a part of our collections in 96% ethanol and later extracted DNA for sequencing. The laboratory methods employed are detailed on our DNA laboratory wiki: http://zsm-entomology.de/wiki/The_Beetle_D_N_A_Lab. PCR conditions with Mango Taq (Bioline) were 1' 94°C – 40x (30s 94°C – 30s 47°C – 1' 72°C) – 10' 72°C – (hold at 14°C) with primers Jerry and Pat to amplify and sequence the 3' of the gene encoding for cytochrome *c* oxidase 1 (Simon et al. 1994). Individual beetles from which we extracted and sequenced DNA all bear a green cardboard label that indicates the DNA extraction number of M. Balke (e.g. "DNA M. Balke 2775"). This number links the DNA sample, the dried mounted voucher specimen, deposited in ZSM and GenBank entries (FR733184, FR733183, AY138729, FR733508, FR733182, FR733180, FR732763, FR733507, FR733506, HF912239, HF912240, FR733181, FR732655, AY138730, FR733515, FR733517, FR733516, FR732697, FR733514, FR733513, FR732698, HF912238). We use GARLI V.0.951 (Zwickl 2006) with default settings (using the GTR model of evolution with parameter estimation) to obtain a maximum likelihood tree based on our cox1 data, node confidence was evaluated using the same program and 100 bootstrap replications.

Codens

AMS Australian Museum Sydney, New South Wales, Australia
ANIC Australian National Insect Collection, Canberra, Australia
BMNH The Natural History Museum, London, UK
CGC Collection Gilbert L. Challet, Florida, United States
CLH Collection Lars Hendrich, Munich, Germany; property of the NMW
MVMA Museum of Victoria, Melbourne, Victoria, Australia
NMW Naturhistorisches Museum Wien, Austria
SAMA South Australian Museum, Adelaide, South Australia, Australia
HNHM Hungarian Natural History Museum,Budapest, Hungary
ZSM Zoologische Staatssammlung München, Munich, Germany.

Collecting procedures

All of the specimens collected by the senior author were obtained by using a strong aquatic Kick Sampling Net with a long pole. Mesh diameters varied from 0.5 to 1.0 mm.

Submerged roots and vegetation, stones and rotten logs were swept heavily; the material obtained was then placed on a white nylon sheet (1 m²) or in a white plastic box. Specimens were collected with forceps or by hand.

Taxonomy

***Batrachomatus* Clark, 1863**
http://species-id.net/wiki/Batrachomatus

Batrachomatus Clark, 1863: 15 (type species *Batrachomatus wingii* Clark, 1863, by monotypy); Zimmermann 1919: 215 (cat.); Mouchamps 1964: 137 (descr.); Watts 1978: 119 (descr.); Watts 1985: 23 (cat.); Lawrence et al. 1987: 351 (cat.); Nilsson 2001: 261 (cat.); Larson 1993: 50 (cat.); Watts 2002: 31, 46 (cat.).

Allomatus Mouchamps, 1964: 137 (type species *Allomatus wilsoni* Mouchamps, 1964, by original designation); Watts 1978: 117 (descr.); Watts 1985: 23 (cat.); Lawrence et al. 1987: 351 (cat.); Nilsson 2001: 261 (cat.); Watts 2002: 30, 46 (cat.); **syn. n.**

Remarks. Medium-sized (TL = 6.9–9.6 mm), elongate, shiny and flattened mainly black diving beetles, unicolorous or with testaceous or ferruginous markings on elytra. Epipleuron in apical half more than twice as wide as base of longer spur of metatibia. Both parameres abruptly narrowed near middle. Outer metatarsal claw curved, prosternum with median furrow. Body covered with dense fine punctures and/or very fine microreticulation, meshes irregular, polygonal.

Allomatus was justified as a genus based only on the presence of a reticulated pronotum and elytra without any punctuation in contrast to *Batrachomatus* which has a non-reticulate but densely and finely punctate pronotum and elytra (Mouchamps 1964, Watts 1978). *Brachomatus larsoni* sp. n. has characters from both genera: a polygonal double reticulation with punctures at the intersections of all meshes.

The *cox1* sequence data show (Fig. 15) that *Allomatus wilsoni* is sister to *Batrachomatus daemeli*, *B. wingi* sister to these two, and *A. nannup* sister to all of these. We use *Matus bicarinatus* (Say, 1823) from North America as well as *Hygrobia maculata* Britton, 1981 and *H. wattsi* Hendrich, 2001 as outgroups (*Hygrobia* were pruned for Fig. 15). Consequently *Allomatus* Mouchamps, 1964 is here synonymised with *Batrachomatus* Clark, 1863.

Species checklist

Abbreviations: NSW = New South Wales, QLD = Queensland, TAS = Tasmania, VIC = Victoria.

Batrachomatus daemeli (Sharp, 1882)	NSW, VIC, TAS
Batrachomatus larsoni **sp. n.**	N QLD

Batrachomatus nannup (Watts, 1978) **comb. n.**	SW Australia (Blackwood River)
Batrachomatus wilsoni (Mouchamps, 1964) **comb. n.**	S VIC, S NSW
Batrachomatus wingii Clark, 1863	N WA, NT, QLD

For detailed distribution, see also Figs 13, 14.

***Batrachomatus daemeli* (Sharp, 1882)**
http://species-id.net/wiki/Batrachomatus_daemeli

Matus daemeli Sharp, 1882: 600 (orig. descr.); Zimmermann 1920: 194 (cat.).
Batrachomatus daemeli (Sharp, 1882): Zimmermann 1919: 215 (comb. n.); Mouchamps 1964: 137 (descr.); Watts 1978: 119 (descr.); Watts 1985: 23 (cat.); Lawrence et al. 1987: 351 (cat.); Nilsson 2001: 261 (cat.); Watts 2002: 31, 46 (cat.).
Batrachomatus burnsi Mouchamps, 1964: 138; Watts 1978: 119 (comb. n.).
Batrachomatus burnsi var. *obscurior* Mouchamps, 1964: 140 (orig. descr.), **syn. n.**

Type locality. Sydney, New South Wales, Australia.

Type material studied. Lectotype ♂ **of *Matus daemeli*** : "Lectotype" [Watts des. 1978: 119], "Type", "Sydney Austr" [handwritten label], "S.Australia", "Sharp Coll. 1905-313", "Type 860 B. Daemeli" [handwritten label], "Batrachomatus daemeli Sydney" [handwritten label], "Matus daemeli Sharp Det. C. Watts 1979" (BMNH). **Holotype** ♂ **of *Batrachomatus burnsi***: "Macalister River, XI.1946, F.E.Wilson leg", "Holotype" [red printed label], "Batrachomatus burnsi sp.n. Mouchamps" [handwritten and printed label] (MVMA).

Additional material studied (142 specimens): **Queensland**: 3 exs., "N QLD, Atherton Tableland, Millaa Millaa Falls, 2500 feet, IV.1932, Australia Harvard Exp. Darlington" (ANIC, SAMA); 1 ex., "S QLD, Brisbane, 1.I.1952, C.Oke leg." (MVMA). **Australian Capital Territory**: 1 ex., "Canberra, I.1961, C.H.S. Watts leg." (SAMA). **New South Wales**: 4 exs., "N NSW, 20 km NE Tenterfield, Boonoo Boonoo River Cross., 949m, 12.X.2006, 28°52.486S, 152°06.246E, L. & E. Hendrich leg." (NSW 67) (CLH, ZSM); 21 exs., "N NSW, 35–40 km S Grafton, road [Orara Way] to Coffs Harbour, Flaggy Creek NR, 5m, 15.X.2006, 29.58.587S, 152.58.452E, L. & E. Hendrich leg. (NSW 77)", one specimen with green printed label "DNA M.Balke 1829" (CLH, ZSM); 6 exs., "C NSW, Glouchestershire, Barrington River at Barrington, 133m, 18.X.2006, 31°58.225S, 151°54.160E, L. & E. Hendrich leg. (NSW 82)", one specimen with green printed label "DNA M.Balke 1799" (CLH); 8 adults and 14 larvae (LA III), "C NSW, 3 km W Albion Park, North Macquarie Road at creek crossing, 19m, 30.X.2006, 34°34.337S, 150°43.456E, L. & E. Hendrich leg. (NSW 87)" (CLH); 8 exs., "C NSW, Endrick River at Braidwood Road, 554m, 1.XI.2006, 35°05.193S, 150°07.182E, L. & E. Hendrich leg. (NSW 94)" (CLH); 9 ex., "C NSW, 10 km W Braidwood, Shoalhaven River at Bombay Bridge, 628m, 2.XI.2006, 35°25.419S, 149°42.582E, L. & E. Hendrich

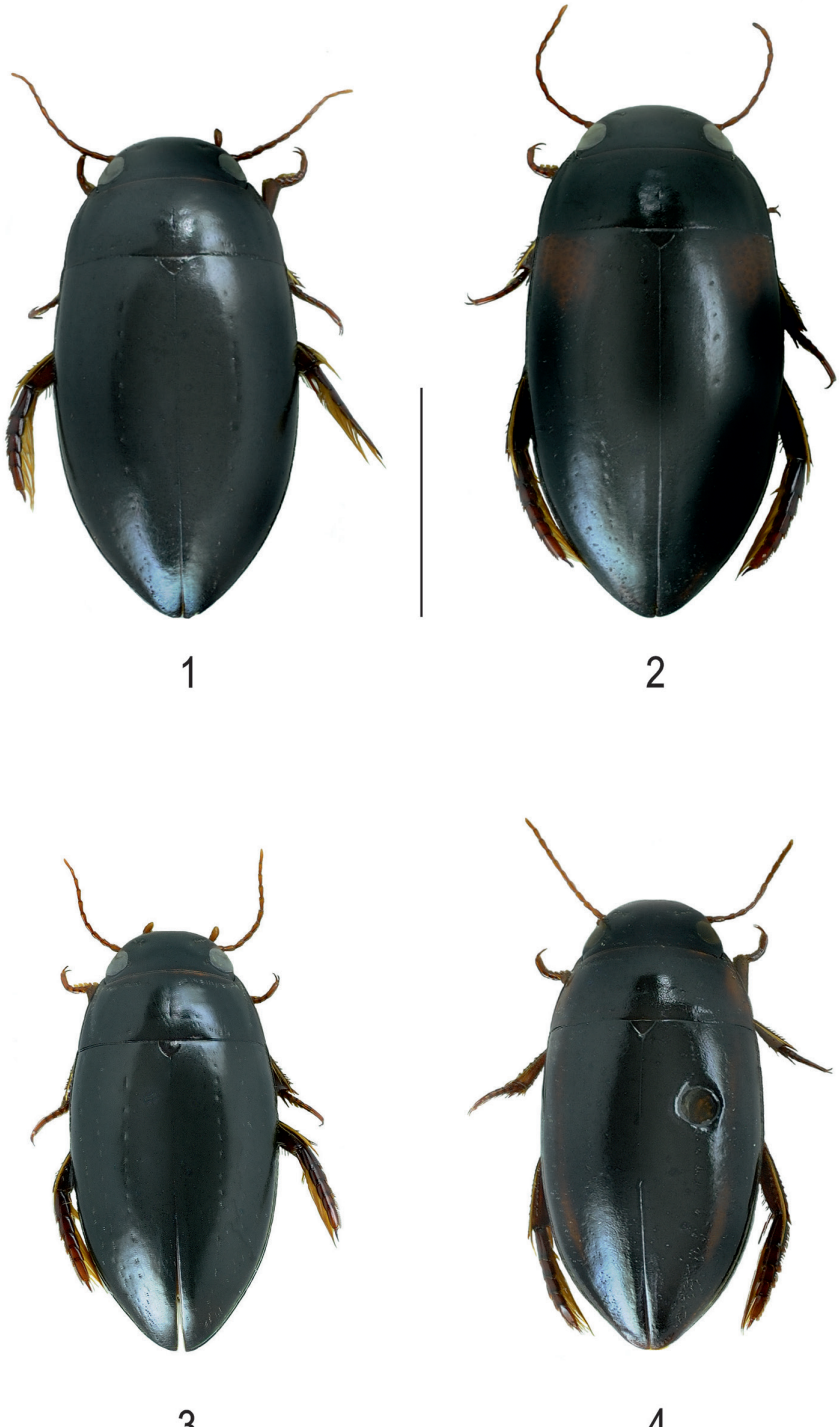
leg. (NSW 96)" (CLH, ZSM); 4 exs., "S NSW, Wallagaraugh River Picnic Area, 43 km SW Eden, 54m, 17.XI.2006, 37.22.079S 149.43.073E, L. & E. Hendrich leg. (NSW 112)", four specimens "DNA M.Balke 2371", "DNA M.Balke 2373", "DNA M.Balke 2374", "DNA M.Balke 2375" (CLH, ZSM); 1 ex., "Williams River near Dungog, 27.XI.1996, C.H.S. Watts leg." (SAMA); 5 exs., "5 km W Bombala, Saucey Creek, 18.I.1997, C.H.S. Watts leg." (SAMA); 24 exs., "Eccleston, J. Hopson" (ANIC, SAMA); 2 ex., "N NSW, Caparra (Lots 72, 73, 148) 35 km NW Taree, 3.I.1990" (ANIC); 2 exs., "Kindee N.S.W Sept. 1934 H.J. Carter", "Batrachomatus daemeli Shp. Det. C. Watts 1971", "K 215108" (AMS); 1 ex., "N NSW, Kindee [Kindee Creek] 50 km W Port Macquarie, IX.1934" (ANIC); 1 ex., "C NSW, Shoalhaven River, 3.I.2001, W.D. Shepard leg." (ANIC); 1 ex., "C NSW, Wollondilly R. Jooriland, 60 km W Wollongong, 16.XII.1931" (ANIC); 1 ex., "NSW EPA Survey MRHI SHOA (Shoalhaven River System) 01, Kangaroo River and Gerrigong Creek, 26.XI.1997, 34°41.17S 150°35.58E J. Potts leg. K 227447 Riffle" (AMS); 1 ex., "NSW EPA Survey MRHI CLYD (Clyde River System) 13 d/s, Bimberamala River, 25.X.1995, 35°25.59S, 150°11.36E, A. Leask leg. EPA 08191 Edge" (AMS); 1 ex., "NSW EPA Survey MRHI SHOA 08 (Shoalhaven River System), Upper Corang River, 22.XI.1995, 35°12.19S, 150°03.24E, J. King leg., K 227320, edge" (AMS); 1 ex., "NSW EPA Survey MRHI HAST (Hastings River) 10 Forbes River: Round Flat, 2.X.1994, 31°20.20S, 152°20.23E, E. Turak leg., EPA 10992, logs" (AMS); 8 exs., "S NSW, Albury, 16.VII.1989, P. Walker leg." (SAMA). **Victoria**: "6 exs., E VIC, Thurra River at Hwy 1, Water Point Rest Area, 138m, 5.XI.2001, 37°34.061S 149°16.338E, G.L.Challet leg." (CGC, ZSM); 5 exs., "C VIC, Hughes Creek at Avenel, 161m, 25.XI.2006, 36°54.221S, 145°14.191E, L. & E. Hendrich leg. (VIC 120)", one specimen with green, printed label "DNA M.Balke 2763", "DNA M.Balke 2764", "DNA M.Balke 2765" (CLH); 1 ex., "Western District Lakes Surv 78, 16.I.1980, W.D.Williams leg." (SAMA); 1 ex., "Tamao Crossing, 24.I.1960, A.Neboiss leg." (MVMA); 2 exs., "Maffra, I.1939, F.E.Wilson leg." (MVMA). **Tasmania**: 1 ex., "Deloraine, Deloraine River, I.1961, C.H.S.Watts leg." (SAMA).

Description. Measurements. TL = 7.9–9.1 mm, TL-H = 7.3–8.2 mm; MW = 4.0–4.6 mm.

Colour. Dorsal surface shiny, head, pronotum and elytra black, legs dark reddish, antennae and palpi reddish pale. Some specimens with reddish basal markings on elytra (Figs 1, 2, 3).

Structure and sculpture. Body outline oblong oval. Dorsal surface densely and evenly covered with small punctures, and with a very fine, almost subobsolete close reticulation with large meshes. Serial punctures on elytron distinct, large and shallow. Ventral surface finely and densely punctate. Prothoracic process broad, flat, apex pointed, broadly grooved in middle for whole length, sides strongly margined. Metacoxal lines raised, well separated, reaching almost to hind margin of metaventrite, diverging a little anteriorly.

Male. Pro- and mesotarsi dilated and stouter than in female, furnished beneath with dense, short, stout setae arranged in groups, many of the setae ending in minute



Figures 1–4. Habitus of **1** *Batrachomatus daemeli* (black form) **2** *B. daemeli* (reddish shoulders) **3** *B. daemeli* (small form) **4** *B. larsoni* sp. n. (paratype) (scale bar = 4 mm).

suction cups. Aedeagus: median lobe in lateral (Figs 8a) and in ventral view (Figs 8b); paramere (Fig. 8c).

Variability. A very variable species in size and colour. Specimens having reddish shoulders of various form and extension were named *B. burnsi* Mouchamps, 1964 (Fig. 2, large red patch on the shoulder) and *B. burnsi* var. *obscurior* (smaller and interrupted reddish patch on shoulder). Such specimens can be found all over the species distributional range.

According to our study of the complete material of *B. daemeli* two different forms can be recognized: larger specimens (see measurements above) with larger median lobes and smaller specimens [Measurements: TL = 7.3–8.0 mm, TL-H = 6.5–7.05 mm; MW = 3.6–3.9 mm] (Fig. 3) with smaller and less elongated median lobes. The latter have been collected at several places in New South Wales and Victoria, sometimes syntopic with the larger form. Despite the fact that intergrades between the typical *B. daemeli* and the "smaller form" have been found, for some time we even have been strongly tempted to describe those smaller specimens as another new species. On the other hand we have not been able to find any constant extern morphological character—except of the size—and also the shapes of the male genitalia are more or less the same. In addition, in our c*ox1* tree (Fig. 15) specimens of both forms are grouped in the same clade.

Affinities. *B. daemeli* differs from the northern Australian *B. larsoni* sp. n. and *B. wingii* in the broader, more oblong shape, the lack of colour pattern on upper surface in most specimens, the weakly diverging metacoxal lines and the shape of the median lobe.

Distribution. The most widespread and common species of the genus in Australia (Fig. 13). From the Atherton Tableland in Queensland along the east coast of New South Wales, Canberra area, to western Victoria and north-eastern Tasmania (Watts 1978).

Habitat. *Batrachomatus daemeli* inhabits permanent streams, creeks and slow flowing larger rivers at an altitude from about sea level to almost 1000 m, from more or less open country in cultivated areas to closed-canopy forest sites (Figs 20–23). Most specimens were found in low-gradient stream or river sections where the substrate was enriched with rotten leaves, wood and larger stones. In this habitat the beetles were found in areas of medium, laminar flow, generally in deeper water (50 cm depth and more) under larger logs and stones. When disturbed the adults can be observed swimming around and coming to the surface. In dryer periods the species can be found in the deepest parts of the remaining rest pools of a creek or river. All the mentioned smaller specimens from Coffs Harbour, Flaggy Creek were collected in a peaty and intermittent creek, with muddy bottom, shaded by wet eucalypt forest. The adults were mainly being located in a mixture of water and mud under a larger rotten tree trunk (Fig. 20). At this site *B. daemeli* was associated with the rarely collected *Sternopriscus wallumphilia* Hendrich & Watts, 2004, a dytiscid known before only from its type locality, a single creek in the Wallum heath near Glasshouse Mountains in southern Queensland (Hendrich and Watts 2004). In New South Wales the larvae of *B. daemeli* were collected together with the adults in October and November. Adults can be found all over the year.

***Batrachomatus larsoni* sp. n.**
urn:lsid:zoobank.org:act:D753FBD7-A28A-4AA5-A6A8-5FF35E0B3495
http://species-id.net/wiki/Batrachomatus_larsoni

Allomatus new species: Larson 1993: 49 (cat.).

Type locality. Creek, Windsor Tableland access road [16°13'55S, 145°1'27E], Queensland, Australia.

Type material. Holotype ♂: "AUSTRALIA, QLD Windsor Tableland access rd km 40 Nov. 12/90 Larson" [white printed label], "Holotype Batrachomatus larsoni sp.n. Hendrich & Balke des. 2010" [red printed label] (ANIC). **Paratype** ♀ with same data as holotype (ANIC). The single paratype is provided with a red printed paratype label.

Description. Measurements. Holotype: TL = 7.9 mm, TL-H = 7.1 mm; MW = 3.85 mm. Paratype: TL = 7.7 mm, TL-H = 7.0 mm; MW = 3.8 mm.

Colour. Dorsal surface shiny, black, appendages reddish. Head black with epistome and labrum lighter. Pronotum with reddish broad lateral margin. Elytron with narrow reddish band along 2/3 of length of elytron (Fig. 4).

Structure and sculpture. Body outline oblong oval, only slightly convex. Head, pronotal and elytral surface covered by polygonal double reticulation, smaller superficial meshes inside larger and more visible meshes, with punctures at intersections of all the larger meshes. Sides of pronotum moderately curved and convergent anteriorly. Sculpture on elytra as in pronotum but punctures at the intersections of all larger meshes smaller. Serial punctures on elytron distinct, large and shallow. On ventral side, metacoxal plate with very fine microreticulation, meshes very elongate, inside minutely and sparsely punctate. Lateral wings of metaventrite very narrow. Prosternal process flat, broad, broadly carinate in midline, parallel-sided, weakly pointed apically, weakly margined. Metacoxal lines well separated, strongly diverging anteriorly. Area between metacoxal lines with many small punctures.

Male. Pro- and mesotarsus a little dilated, basal 3 tarsomeres with dense short setae beneath suction cups. Aedeagus: median lobe (Fig. 9a, b); paramere (Fig. 9c).

Etymology. This species is dedicated to our Canadian colleague David Larson (Maple Creek, Canada) who collected the only known specimens and recognized the species as new. The specific epithet is a substantive in the genitive case.

Affinities. *Batrachomatus larsoni* sp. n. differs from *B. wilsoni* by its smaller size (*B. larsoni* TL = 7.9 mm and *B. wilsoni* TL = 8.4–8.5 mm), in the lack of any reddish humeral angles on elytra, the more flattened and narrowly formed body, and in having the reticulation on the elytra weak without punctuation, instead of moderately strong and punctate. Both species can be separated by the shape of their median lobes.

Distribution. Only known from the type locality in NE Queensland (Fig. 14).

Habitat. The Windsor Tableland is a granite plateau at about 1100 m, near to but further inland from Mt. Spurgeon and Mt. Lewis, in north-east Queensland. Because

of its altitude, it receives enough rainfall to sustain mountain rainforest over much of the plateau surface, although it is surrounded by tropical eucalypt savannah at lower altitudes. Access to the Windsor Tableland is now for scientific study only, the public are permanently barred. A very detailed habitat description is given by Larson (1993): "Two specimens were collected from a low gradient section of a small, permanent, closed forest stream. The stream was largely shaded by a tall, more or less closed tree canopy. The stream bed was coarse sand and consisted of shallow, gentle riffles which separated pools formed where sand had been scoured from around and behind logs and from under tree roots to produce pools under overhanging roots-mats. The specimens were found swimming in a pool after the trailing roots on an overhanging bank on one side of the pool had been vigorously swept with a net. It is assumed the beetles came from under the bank but similar habitat, which was common along the stream, was searched without yielding additional specimens".

***Batrachomatus nannup* (Watts, 1978) comb. n.**
http://species-id.net/wiki/Batrachomatus_nannup

Allomatus nannup Watts, 1978: 117 (orig. descr.); Watts 1985: 23 (cat.); Lawrence et al. 1987: 351 (cat.); Nilsson 2001: 261 (cat.); Watts 2002: 30, 46 (cat.).

Type locality. Bridgetown [Blackwood River, 33°58′02 S 116°07′58 E], Western Australia, Australia.

Type material. Holotype ♂: "Bridgetown Nov 8 31 W.A." [handwritten label], "Australia Harvard Exp. Darlington" [printed label], "Holotype Allomatus nannup Det. C. Watts 1976" [handwritten and printed label] (ANIC). **Paratype** ♂: "Bridgetown Nov 8 31 W.A." [handwritten label], "Australia Harvard Exp. Darlington" [printed label], "Paratype Allomatus nannup Det. C. Watts 1976" [handwritten and printed label], "SAMA Database No. 25-006714" [printed label] (SAMA).

Additional material (178 specimens): **Western Australia**: 2 exs., "Nannup-Balingup Road, Blackwood River, 28.IX.1965, E.B. Britton leg." (ANIC); 57 exs., "Blackwood River near Nannup, 20.X.1996, C.H.S. Watts" (SAMA); 8 exs., "Blackwood River near Nannup, 20.IX.2000, C.H.S. Watts" (SAMA); 1 ex., "Blackwood River near Bridgetown, 21.IX.2000, C.H.S. Watts" (SAMA); 20 exs., "Nannup, Balingup-Nannup Road, Blackwood River at Revelly Bridge, 79m, 33.55.226S, 115.48.549E, 25.XI.1996, L. Hendrich leg. (Lok. 33)" (CLH, ZSM); 65 exs., "Blackwood River, 8.3 Km NE Nannup, Revelly Bridge, 79m, 6.I.2007, 33.55.226S, 115.48.549E, L. & E. Hendrich leg. (WA 166)", four specimens provided with green printed labels "DNA M.Balke 1712", "DNA M.Balke 1713", "DNA M.Balke 2771", "DNA M.Balke 2772" (BMNH, NMW, ZSM); 25 exs., "Nannup, Balingup-Nannup Road, Revelly Bridge, 79m, 31.XII.1999, 33.55.226S, 115.48.549E, Hendrich leg. (Loc. WA 6/153)" (CLH, ZSM).

Description. Measurements. TL = 9.1–9.6 mm, TL-H = 8.2–8.6 mm; MW = 4.0–4.3 mm.

Colour. Dorsal surface shiny, black; appendages reddish. Head black with epistome and labrum lighter (Fig. 5).

Structure and sculpture. Body outline narrowly oval, flattened and only slightly convex, pointed apically. Head with strongly impressed reticulation, meshes moderately large and irregular, some scattered small punctures; reticulation and punctures in pronotum rather weak. Elytron with fine reticulation, with transversely elongate small meshes, virtually impunctate apart from serial punctures, being comparatively large and well marked.

Ventral side with metacoxal plate covered by very fine microreticulation, meshes very elongate, inside minutely and sparsely provided with small punctures. Prosternal process flat, broad, broadly carinate in midline, parallel-sided, weakly pointed apically, weakly margined. Metacoxal lines well separated, subparallel in anterior 2/3, moderately diverging posteriad, area between lines with many small punctures.

Male. Pro- and mesotarsi a little dilated, basal 3 tarsomeres with dense short setae beneath suction cups. Aedeagus: median lobe (Fig. 10 a, b); paramere (Fig. 10 c).

Affinities. *Batrachomatus nannup* differs from most specimens of *B. wilsoni* and *B. larsoni* sp. n. in the lack of any reddish humeral angles to elytra, the more flattened and narrowly formed body, and in having the reticulation on the elytra weak without punctuation, instead of moderately strong and punctuate. All three species can be easily separated by the shape of their median lobes and their distribution.

Distribution. An endemic species of the Blackwood River in south-western Australia. All records between Bridgetown and Nannup but probably more widespread in the Blackwood River and its larger tributaries (Fig. 13).

Habitat. The Blackwood River is the largest river in south-western Australia. The river begins near Quelarup and runs in a south-western direction through the town of Bridgetown then through Nannup until it discharges into the Southern Ocean at Hardy Inlet near the town of Augusta. The river has 41 tributaries and the upper or larger catchment area of the river is in agricultural areas, while the middle catchment area passes through forested areas, and the lower portion of the river passes into mixed forest, agricultural and residential lands (Wikipedia).

At the sampling localities the Blackwood is partly shaded by old River gum trees. In late spring the adults of *B. nannup* can be either found in larger (6–10 m^2) and deeper (40–80 cm depth) sandy pools in the floodzone of the river or among floating roots, rotten twigs and logs in shallow water of protected embayments of the slow flowing river (Fig. 16). In summer and in dryer periods the adults were collected only in the deepest parts of the almost standing river, under larger logs, stones and rotten debris (Fig. 17). When disturbed the beetles can be observed swimming around and coming to the surface.

***Batrachomatus wilsoni* (Mouchamps, 1964) comb. n.**
http://species-id.net/wiki/Batrachomatus_wilsoni

Allomatus wilsoni Mouchamps, 1964: 140 (orig. descr.); Watts 1978: 116 (descr.); Watts 1985: 23 (cat.); Lawrence et al. 1987: 351 (cat.); Nilsson 2001: 261 (cat.); Watts 2002: 30, 46 (cat.).

Type locality. Kerrisdale [King Parrot Creek, 165 m, 37°8'8S, 145°15'36 E], Victoria, Australia.

Type material. Holotype ♂: Not seen. **Paratype** ♂: "Macalister Riv 11/46 Vic F.E.Wilson", "Wilson Coll" [handwritten label by Mouchamps], "Paratype" [red, printed label], "Paratype 3804" [blue printed label], "R.Mouchamps det., Allomatus wilsoni nsp." [handwritten, white label by Mouchamps] (MVMA).

Additional material (2 specimens): **New South Wales**: 1 ex., "S NSW, Wallagaraugh River Picnic Area, 43 km SW Eden, 54m, 17.XI.2006, 37.22.079S 149.43.073E, L. & E. Hendrich leg. (NSW 112)", "DNA M.Balke 2372" [green printed label] (ZSM). **Victoria**: 1 ex., "E VIC, Thurra River at Hwy 1, Water Point Rest Area, 138m, 17.XI.2006, 37.34.061S, 149.16.338E, L. & E. Hendrich leg. (VIC 114)" (CLH).

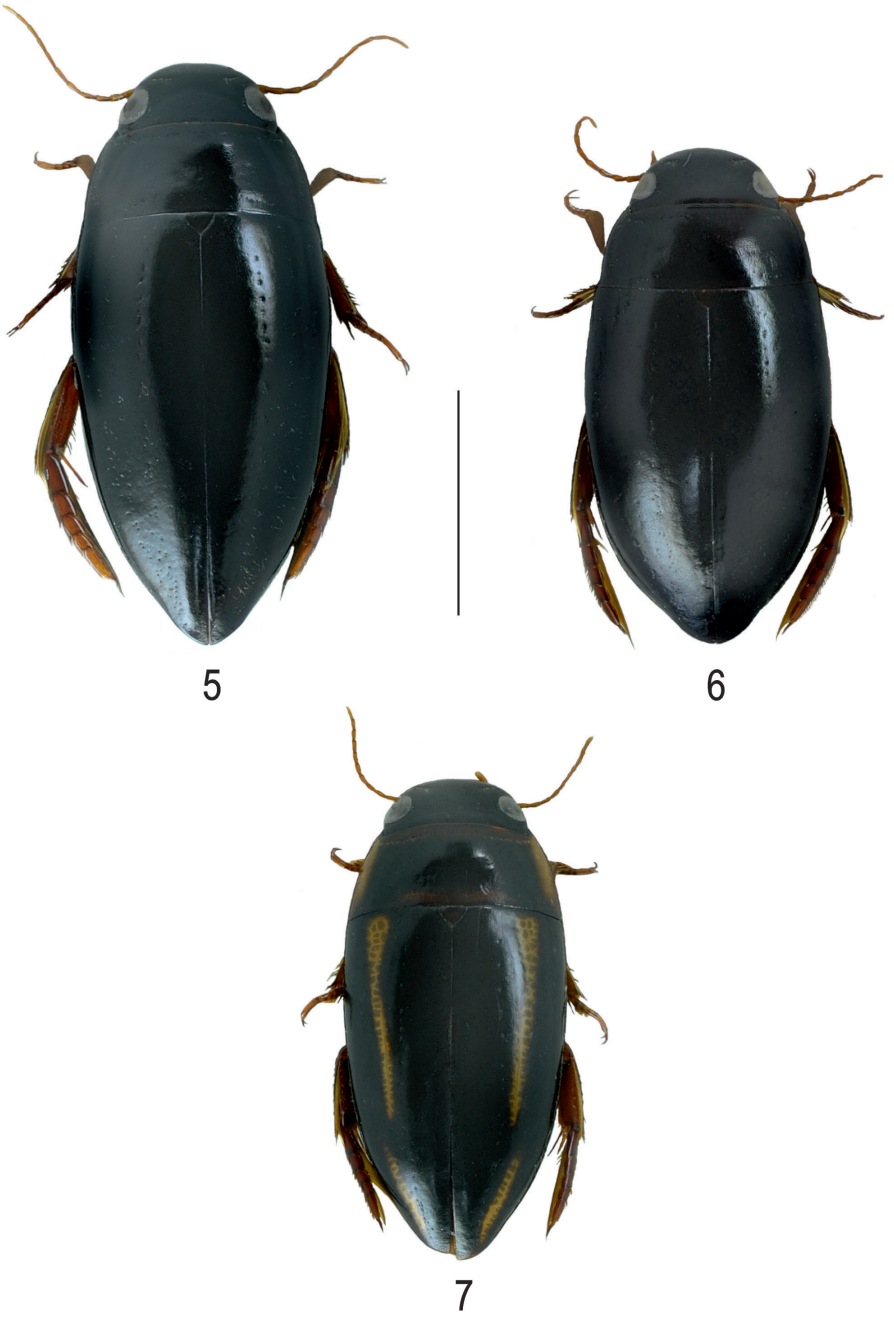
Description. Measurements. TL = 8.4–8.5 mm, TL-H = 7.5–7.7 mm; MW = 4.0–4.15 mm.

Colour. Head black with epistome and labrum lighter. Palpi and antennae brownish. Pronotum entirely black, slightly lighter at margins. Elytra completely black or with more or less developed brownish humeral patch. Ventral side black, appendages lighter with tarsi reddish brown (Fig. 6).

Structure and sculpture. Body outline oval, large, slightly convex. Head with anterior border of epistome a little excavated, not bordered. Head and pronotum surface covered by polygonal double reticulation, smaller superficial meshes inside bigger meshes, with punctures at intersections of all bigger meshes. Sides of pronotum moderately curved and convergent anteriorly. Sculpture on elytra consisting of a weak double reticulation, meshes polygonal, large, smaller and very fine punctures at intersections of very few meshes. Serial punctures on elytra distinct, large and shallow. Ventral surface covered with weakly defined reticulation, meshes, very elongate and more or less oblique or transverse. Prosternal process flat and excavated in anterior midline by median groove. Lateral borders of prosternal process clearly raised. Lateral wings of metaventrite narrow. Metacoxal lines separating metacoxal plate into three unequal parts; the median sparsely punctured, the lateral and the intralinear space almost smooth with an extremely sparse and scarcely visible microreticulation.

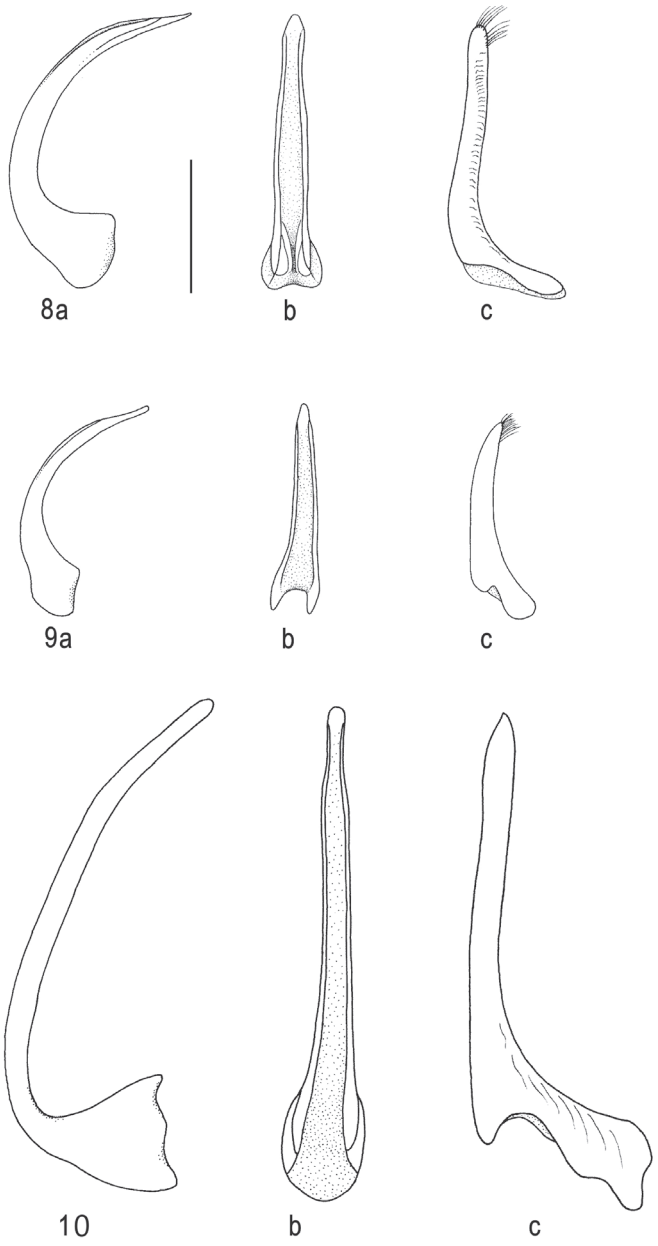
Male. Pro- and mesotarsi dilated and stouter than in female, furnished beneath with dense, short, stout setae arranged in groups, many of the setae ending in minute suction cups. Aedeagus: median lobe (Fig. 11 a, b); paramere (Fig. 11 c).

Affinities. *Batrachomatus wilsoni* is in body outline and coloration very near to *B. daemeli* but can be easily separated by the presence of a superficial polygonal double reticulation on pronotum and elytra. *Batrachomatus wilsoni* differs from *B. larsoni* sp. n.



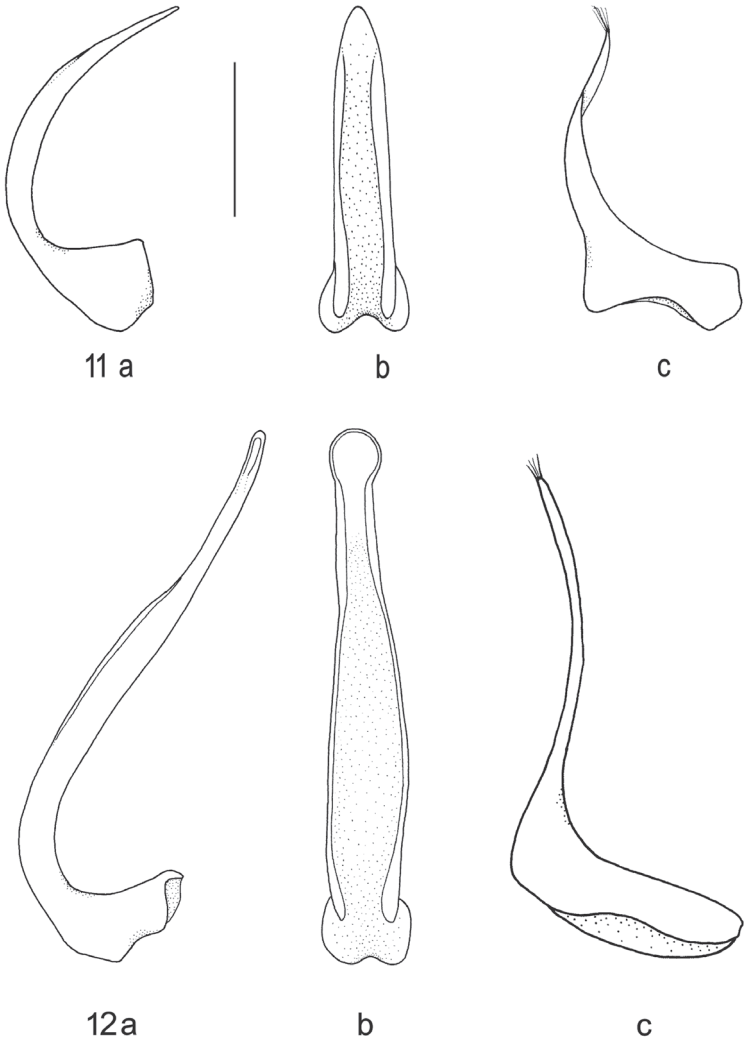
Figures 5–7. Habitus of **5** *B. nannup* **6** *B. wilsoni* **7** *B. wingii* (scale bar = 4 mm).

by its larger size (*B. wilsoni* TL = 8.4–8.5 mm and *B. larsoni* TL = 7.9 mm), the different elytral coloration, and the more oblong and less narrowly formed body. Furthermore, all three species can be separated by the shape of their median lobes.



Figures 8–10. Median lobe of aedeagus in ventral (**a**) and lateral view (**b**), and right paramere in lateral view (**c**): **8** *B. daemeli* **9** *B. larsoni* sp. n. **10** *B. nannup* (scale bar = 0.5 mm).

Distribution. South-eastern Australia (Fig. 13). A rarely collected species with a very limited distribution. Only known from four sites from southern New South Wales (Wallagaraugh River) to southern and south-eastern Victoria (Macalister River, King Parrot Creek, Thurra River).



Figures 11–12. Median lobe of aedeagus in ventral (**a**) and lateral view (**b**), and right paramere in lateral view (**c**): **11** *B. wilsoni* **12** *B. wingii* (scale bar = 0.5 mm).

Habitat. *Batrachomatus wilsoni* inhabits permanent slow flowing larger rivers, at an altitude from about sea level to almost 170 m, in closed-canopy old growth forest sites. The type locality King Parrot Creek, near Kerrisdale, is in many parts a low gradient river, similar to the south-western Australian Blackwood River. The two recently collected specimens from Victoria and New South Wales were found in low-gradient river sections where the substrate was enriched with rotten leaves, wood and larger stones (Figs 18, 19). In this habitat the beetles were found in areas of medium, laminar flow, generally in deeper water (50 cm and more) under larger logs and stones, always together with numerous *B. daemeli*.

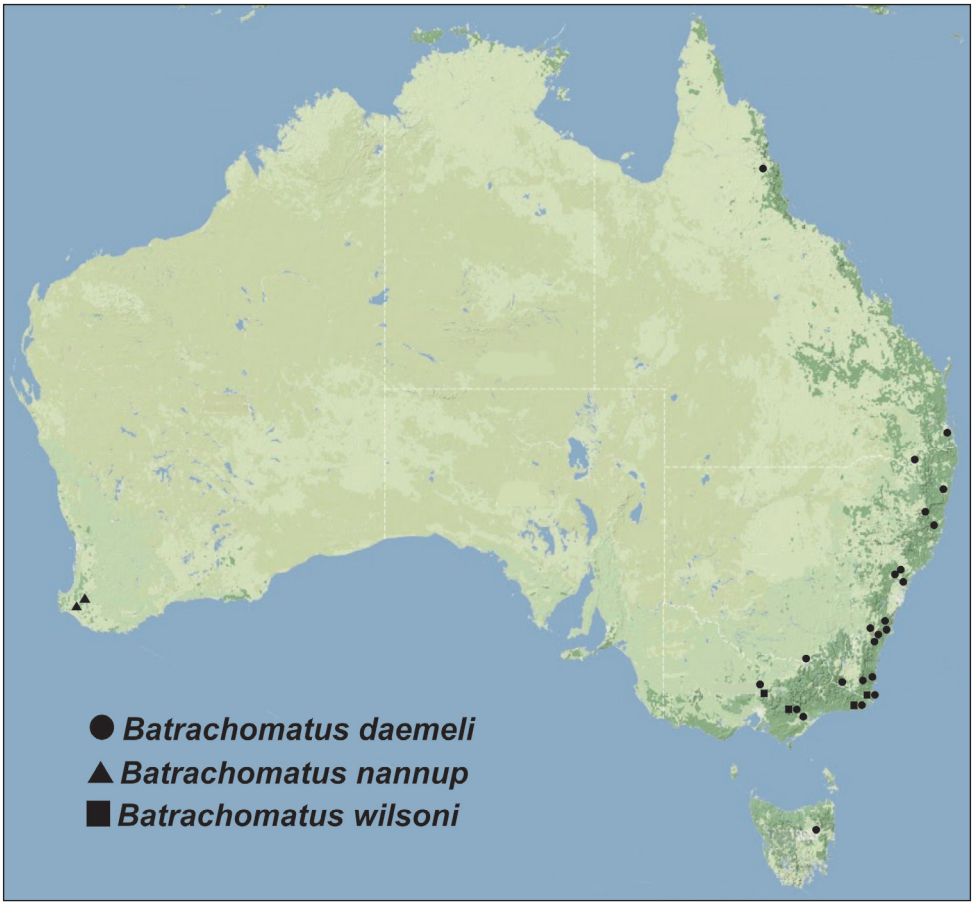


Figure 13. Distribution of *Batrachomatus*: *B. daemeli* (dots), *B. nannup* (triangles) and *B. wilsoni* (squares).

***Batrachomatus wingii* Clark, 1863**
http://species-id.net/wiki/Batrachomatus_wingii

Batrachomatus wingii Clark, 1863: 15 (orig. descr.); Mouchamps 1964: 138 (descr.); Watts 1978: 120 (descr.); Watts 1985: 23 (cat.); Lawrence et al. 1987: 351 (cat.); Larson 1993: 50 (cat.); Nilsson 2001: 261 (cat.); Watts 2002: 31, 46 (cat.).

Type locality. Northeast coast of Australia.

Holotype ♂: "N. Holl NE Aust 4412" [handwritten label], "Holotype", "Batrachomatus wingi" [sic!], [blue handwritten label by Clark] (BMNH).

Additional material (71 specimens). Western Australia: 1 ex., "Pilbara Region, De Grey River at Yarrie Station, 10.VII.1953, N.B.Tindale leg." (SAMA); 1 ex., "East Kimberley, Mitchell Plateau, Surveyors Pool, 150m, 17.VI.1999, Hendrich leg." (CLH). **Northern Territory**: 18 exs., "Kakadu N.P., Gungurul Lookout, 50 m,

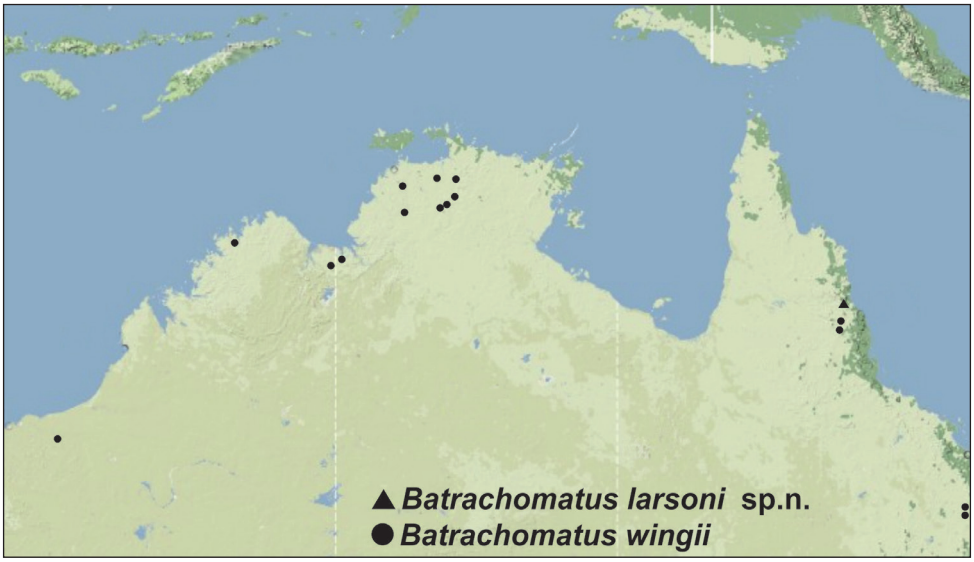


Figure 14. Distribution of *Batrachomatus*: *B. larsoni* sp. n. (squares) and *B. wingii* (dots).

13.59.359S, 132.19.904E, 1.XI.1996, L. Hendrich leg. (Lok.11)" (CLH); 3 exs., "Finnis River, 10 km W Batchelor, 43m, 20.VIII.2006, 13.01.278S, 130.57.217E, L. & E. Hendrich leg." (NT 2), provided with green printed labels "DNA M.Balke 2773", "DNA M.Balke 2774", "DNA M.Balke 2775" (ZSM, CLH); 4 exs., "Kakadu NP, Gunlom Waterfall Area, 72m, 25.VIII.2006, 13.26.026S, 132.25.141E, L. & E. Hendrich leg." (NT 17), one specimen with green printed label "DNA M.Balke 1659" (ZSM); 20 exs., "Magela Creek upstream, Jabiru East, 38m, 29.VIII.2006, 12.40.458S,132.55.853E, L. & E. Hendrich leg." (NT 21) (CLH, NMW, ZSM); 1 ex., "Magela Creek downstream, Jabiru East, 31m, 30.VIII.2006, 12.38.312S, 132.53.441E, L. & E. Hendrich leg. (NT 23)", "DNA M.Balke 2772" [green printed label] (ZSM); 1 ex., "Daly River, H. Wesselmann" (SAMA); 4 exs., "Kakadu N.P., Jim Jim District, Jim Jim Falls Camping Area, Jim Jim Creek, 60 m, 13.16.218S, 132.49.276E, low-gradient stream, 26. & 27.X.1996, Hendrich leg./loc. 2a" (CLH); 1 ex., "Kakadu N.P., Mary River District, 3 km ESE Gunlom Camping Area, South Alligator River, 50m, 2.XI.1996, 13.27.276S, 132.26.268E, L. Hendrich leg." (loc. 14) (CLH); 1 ex., "Fergusson River, 31 km SE by S of Pine Creek, 14.XI.1979, T.A.Weir leg." (ANIC). **Queensland**: 6 exs., "Foleyvale Aboriginal Reserve, 130 km W Rockhampton, 20.–25.I.1968, G. Hangay leg." (HNHM, CLH); 4 exs., "Boolburra, 95 km WSW Rockhampton, 12.I.1968, G. Hangay leg." (HNHM, CLH); 1 ex., "N Queensland, Bridge Creek, 20.XI.1992, water sweep, A. Calder & P. Zborowski leg." (ANIC); 1 ex., "N Queensland, Kennedy River Xing, dry river bed, sandy base, temporary pool, 16.VI.1992, T.A. Weir leg." (ANIC). Without any detailed locality label: 4 exs., "Australien", "Sammlung Clemens Müller", "Sammlung Zimmermann" (ZSM).

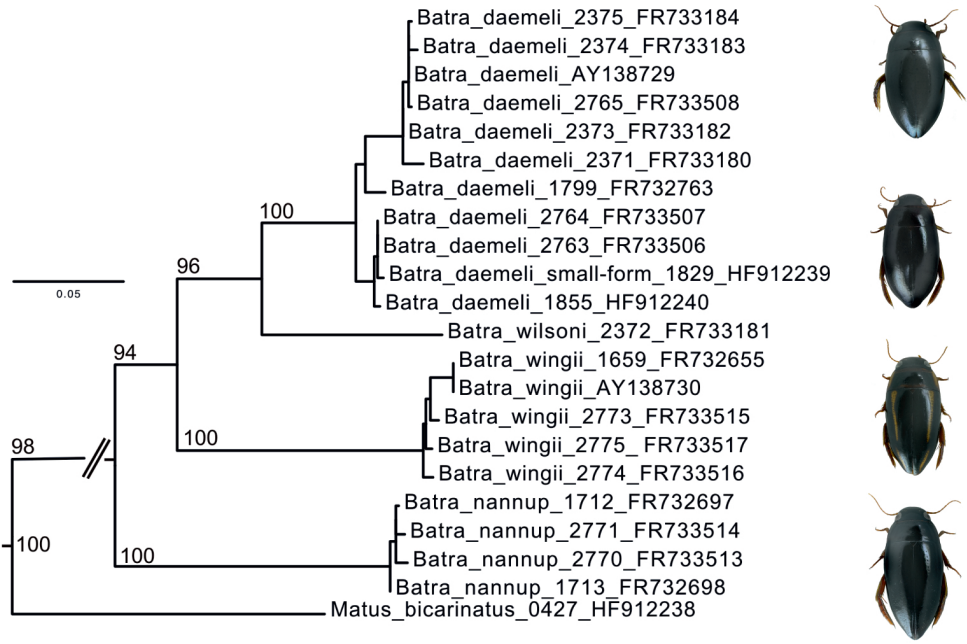


Figure 15. Maximum likelihood tree for Australian *Batrachomatus*. Node support are GARLI bootstrap values and only given for major nodes, numbers following taxon names are our extraction codes as well as Genbank accession numbers.

Literature records: Australia, Western Australia, Weaber Plain, Keep River east of Milligans, 15°37'11S, 129°02'00 E, May 2009, A.W. Storey leg. (WRM 2010); Australia, Northern Territory, Sandy Creek downstream of Keep River at Legune Road Crossing, 23.VII.–1.VIII.2004, 15°22'54S, 129°11'43E, A.W. Storey leg., site code SE 1, idem, Sandy Creek upstream of Keep River Road, 23.VII.–1.VIII.2004, 15°24'30S, 129°11'33 E, A.W. Storey leg., site code SR 2 (NCTWR 2005).

Description. Measurements. TL = 6.9–7.8 mm, TL-H = 6.2–7.2 mm; MW = 3.2–3.7 mm.

Colour. Black, anterior part of head reddish brown, pronotum with broad yellow lateral margins, elytron with a narrow yellow band of which apical 1/3 close to side and basal 2/3 some distance from side (Fig. 7). Underside and parts of head reddish brown, appendages reddish brown.

Structure and sculpture. Body outline elongate oval, flattened, pointed apically. Dorsal surface shiny, head, pronotum and elytral surface densely and evenly covered with small punctures, reticulation absent. Serial punctures on elytron sparse, weakly impressed, indistinct. Sides of pronotum moderately curved and convergent anteriorly. Ventral surface very densely and minutely punctured. Prosternal process flat, broad, parallel-sided, weakly and narrowly grooved in midline, and weakly margined at side, tip bluntly pointed, apex pointed. Metacoxal lines well separated, subparallel, reaching almost to hind margin of metaventrite.

Male. Pro- and mesotarsi stouter than in female, furnished beneath with dense, short, stout setae arranged in groups, many of the setae ending in minute suction cups. Aedeagus: median lobe (Fig. 12 a, b); paramere (Fig. 12 c).

Affinities. A very characteristic species and one of the most beautiful dytiscids in Australia (Fig. 7). *B. wingii* differs from all other species of the genus in the narrower and more flattened shape of body, the dorsal yellowish longitudinal stripes on the elytra, the subparallel metacoxal lines and the shape of the median lobe.

Distribution. Tropical northern Australia. Occurring from the northern Pilbara and the Kimberley region in the northwest, the Daly River, Darwin area and Kakadu National Park in the north, to the Atherton Tableland in northern Queensland, and along the east coast south to Rockhampton (Fig. 14).

Habitat. *Batrachomatus wingii* occurs in seasonal and permanent lowland streams, creeks and slow flowing smaller rivers at an altitude from about 20 to almost 150 m, at least partly shaded by eucalypt woodland or monsoonal forest. Most specimens were found in low-gradient stream sections where the substratum was entirely coarse sand and smaller pebbles yet the current was strong enough to clear the bottom of silt and leaves (Figs 24, 25, 27). In this habitat the beetles were found in areas of medium, laminar flow, generally in deeper water (50 cm depth and more), along the outside curve of stream bend, among floating gum roots, under larger logs and stones. In the Northern Territory, at the end of the dry season, a larger series of the species was collected in the deepest, coldest and most oxygen rich part (50–80 cm depths) of a rest pool (10 m^2), situated in a broad and almost dry and sandy creek bed. The pool was without any vegetation but rich in rotten leaves and partly shaded (Fig. 26). As mentioned by Larson (1993), who collected the species in northern Queensland at three different sites, the sub-surface seepage and local water temperatures could also be factors responsible for the local aggregation of beetles. In the Northern Territory larvae have been collected after the rainy season in February by Watts (Alarie et al. 2001).

Habitats and faunistics

All Australian *Batrachomatus* species are strongly lotic and restricted to streams, creeks and rivers with sand, pebble and cobble beds, often situated in woodland or closed-canopy forest sites (Figs 16–27). It is probable that at least the larvae are sensitive to low levels of dissolved oxygen and require cooler temperatures. If this is so the occurrence of any *Batrachomatus* species can be considered a good indicator of a running water´s health, habitat and water quality.

The currently known altitudinal distribution and ecology of *Batrachomatus* species is shown in Table 1. Most species occur in lowland regions from almost sea level to 500 m. Only *B. daemeli* has been collected in the Atherton Tableland and the Great Dividing Range up to at least 950 m. In Queensland *B. daemeli*, *B. wingii* and *B. larsoni* sp. n. are sympatric. In eastern Victoria *B. daemeli* and *B. wilsoni* are known from the same area and in three rivers they are also syntopic. *Batrachomatus*

Figures 16–21. Habitats: **16, 17** Blackwood River upstream the village Nannup, habitat of *B. nannup* in south-western Australia **18** Wallagaraugh River SW of Eden, southern New South Wales and **19** Thurra River at Highway 1 in south-eastern Victoria, habitats of *B. wilsoni* **20** Coffs Harbour street, Flaggy Creek Nature Reserve, northern New South Wales and **21** Glouchestershire, Barrington River at Barrington, central New South Wales, habitats of *B. daemeli* (Photos: L. Hendrich).

daemeli is widespread along the east coast and south-eastern Australia, including the northeast of Tasmania, and *B. wingii* occurs all over the tropical north of Australia. Two species, *B. nannup* in the south west and *B. larsoni* sp. n. in NE Queensland, have a very restricted distribution and are only known from one stream or river system (Blackwood River, Windsor Tableland). The rarity and limited distribution

Figures 22–27. Habitats: **22** 3 km W Albion Park, North Macquarie Road at creek crossing, central New South Wales and **23** Hughes Creek at Avenel, Central Victoria, habitat of *B. daemeli* **24** Finnis River, 10 km W Batchelor, Northern Territory **25** Magela Creek, Jabiru East, Northern Territory **26** Kakadu NP, Gunlom Waterfall Area, Northern Territory and **27** Kakadu N.P., Jim Jim District, Jim Jim Falls Camping Area, Jim Jim Creek, Northern Territory, habitats of *B. wingii* (Photos: L. Hendrich).

of the south-eastern *B. wilsoni* might be the result of human impacts (irrigation, increasing of salinity, clearing of riverine forests) on almost all river systems in Victoria in the last five decades. All species seem to be capable of flight but none was ever obtained by operating light traps. The larvae of *B. daemeli* and *B. nannup* were recently described by Alarie et al. (2001). The larvae of *B. wilsoni*, *B. larsoni* sp. n. and *B. wingii* remain unknown.

Table 1. Habitat information and altitudinal distribution of Matini in Australia.

Species	Altitude	Habitat
Batrachomatus daemeli	5–950 m	Large rivers, creeks and streams, side pools
B. larsoni sp. n.	500 m	Small rainforest stream
B. nannup	79 m	Large permanent river and side pools (adults)
B. wilsoni	54–138 m	Larger permanent rivers
B. wingii	30–150 m	Seasonal and permanent rivers, streams and creeks

When in a net and out of the water specimens of *Batrachomatus* move very rapidly and are easily to recognise and to collect. In contrast, Larson et al. (2000) noted that the related Nearctic *Matus* are all lentic and occur along the margins of rather eutrophic ponds, often amongst *Typha* or decaying deciduous leaves. They are often slow to move and with their brownish colour are easily overlooked and consequently are not well collected. Despite the fact that all Australian species are capable of flight, none was obtained by operating light traps.

Key to *Batrochomatus*

1 Dorsal surface covered with a strong double reticulation of irregular and polygonal meshes. Punctures absent or only at the intersections of all larger meshes **2**

– Dorsal surface densely and evenly covered with small punctures, reticulation absent or very fine almost obsolete with larger meshes **4**

2 Pronotum totally black **3**

– Pronotum black, with reddish broad lateral margins. Dorsal surface covered by a polygonal double reticulation with punctures at the intersections of all larger meshes. Elytra with a narrow longitudinal reddish band..... ..... ***B. larsoni* sp. n.** (NE Queensl.)

3 Body outline oval, slightly convex. Humeral angle of elytron reddish. Punctures at the intersections of a very few larger meshes. Metacoxal lines separating metacoxal plate into three unequal parts; the median sparsely punctured, the lateral almost smooth with an extremely sparse and scarcely visible microreticulation. Aedeagus: median lobe (Fig. 11 a, b)..... ..... ***B. wilsoni*** (SE Australia)

– Body outline narrowly oval, flattened and only slightly convex, pointed apically. Elytron uniformly black, reticulation virtually impunctate. Metacoxal lines well separated, subparallel in anterior 2/3, moderately diverging posteriad, area between lines with many small punctures. Aedeagus: median lobe (Fig. 10 a, b)..... ***B. nannup*** (SW Australia)

4 Pronotum totally black. Elytra with or without a red humeral angle. Body outline oblong oval. Dorsal surface with a very fine almost obsolete close reticulation with larger meshes. Metacoxal lines raised, well separated, reaching

almost to hind margin of metaventrite, diverging a little anteriorly. Aedeagus: median lobe (Fig. 8 a, b) ..... ***B. daemeli*** (SE Australia)

– Pronotum with broad yellow lateral margins, elytron with a narrow yellow band of which apical 1/3 is close to side and basal 2/3 some distance from side. Body outline elongate oval, flattened, pointed apically. Reticulation on dorsal surface absent. Metacoxal lines subparallel. Aedeagus: median lobe (Fig. 12 a, b) ..... ***B. wingii*** (N. Australia)

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Description of *Phradonoma blabolili* sp. n. (Coleoptera, Dermestidae, Megatominae), with notes on the dermestid beetles from Angola

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Abstract

Phradonoma blabolili **sp. n.** from Angola is described and illustrated. Key to the Afrotropical "*Phradonoma nobile* species group" to which the newly described species belongs, as well as key to genera of dermestid beetles occurring in Angola is given. List of all species of Dermestidae known to occur in Angola hitherto is provided.

Keywords

Taxonomy, new species, Coleoptera, Dermestidae, *Phradonoma*, Angola

Introduction

The family Dermestidae (Coleoptera: Bostrichoidea) contains about 1440 species and subspecies worldwide (Háva 2003a, Háva and Solervicens 2012). Its members are "mainly scavengers on dried proteinaceous material and are of economic importance because the family includes species that are pests of stored products or natural-history enemies" (Lawrence and Ślipiński 2005). Despite their species richness, only 14 species have been

reported from Angola hitherto (Erichson 1843, Ferreira 1965, Háva 2003a,b, Kadej 2006, 2010, Mroczkowski 1968, Pacavira *et al.* 2006, Pic 1931, 1937). This doubtlessly small number is perhaps largely due to the 27 years of Angolan civil war (1975–2002) which was a serious impediment to entomological research; the actual number of species is undoubtedly much higher. After the end of the conflict, and especially in the recent years, specialists carrying out entomological research seem to be returning to Angola. The genus *Phradonoma* Jacquelin du Val, 1859 is distributed largely in Palaearctic and Afrotropical regions and one species has been introduced into the U.S.A. In this contribution to the taxonomy of Angolan Dermestidae (Coleoptera) we describe one new species of *Phradonoma* and provide a summary of the dermestid taxa occurring there.

Material and methods

The type specimen of this new species has been collected using flight intercept trap in open savannah near Catabola, in the central Angolan province of Bié, in altitude 1300 m. The FIT trap has been placed near a small pond, and cow dung, rotting bananas as well as rotting fish were all used to attract insects. The attractants were placed in small plastic containers around the trap. When removing the male terminalia from the specimen, the entire abdomen was first severed from the rest of the body, subsequently macerated in KOH heated up to 90°C for a short while, cleared in 96% ethanol and thence the male genitalia was removed from the cleared abdomen. The habitus photographs of *P. blabolili* was taken by macroscope Leica 216 APO. The dissected male genitalia was macerated in 10 % solution of KOH heated up to 90 °C for a few minutes, cleared in Xylene and transferred into glycerin in small glass dish where it was observed. The photograph of the male genitalia has been taken with Olympus BX 41 camera. The map on Fig.5 depicting the type locality of *P. blabolili* was downloaded from the Internet and subsequently re-drawn using Adobe Illustrator CS4. The type specimen is deposited in the collection of the senior author (JHAC).

Standard measurements have been made according to Háva (2006) and are as follows:

BL Body length - linear distance measured from anterior margin of pronotum to apex of elytra;
BW Body width - measured between two anterolateral humeral calli;
PL Pronotum length - measured from the top of the anterior margin to scutellum;
PW Pronotum width - measured between the two posterior angles of pronotum;
EL Elytral length- linear distance measured from shoulder to apex of elytron.

Abbreviation

JHAC Private Entomological Laboratory & Collection, Únětice u Prahy, Prague-west, Czech Republic

Results

Subfamily Megatominae Leach, 1815
Tribe Megatomini Leach, 1815

***Phradonoma blabolili* sp. n.**
urn:lsid:zoobank.org:act:93246F10-2B76-4573-9771-C6F3C84E7538
http://species-id.net/wiki/Phradonoma_blabolili
Figs 1–5

Type material. Holotype, male, with printed label "Angola, Bié province, Catabola env., 15–27.11.2012, FIT trap, T. Lackner lgt." (JHAC).

Description. Male. Body measurements: BL 2.20 mm; BW 1.30 mm; PL 0.60 mm; PW 1.10 mm; EL 1.70 mm. Body (Fig. 1) dark brown and black, elongate oval. Head entirely black, coarsely punctuate, with decumbent light brown setae; maxillary palpi dark brown. Eyes large, with short microscopic setae. Antennae with 11 antennomeres, antennal club consisting of 3 antennomeres; antennomeres I-VIII brown, antennomeres IX-XI black, furnished with short setae (Fig. 2). Frons with small dark brown ocellus. Pronotum entirely black, shiny, sparsely and finely punctuate, with dark and semi-erect setae medially, white setae increase in number towards the lateral margins, posterior edges and in ante-scutellar area; lateral pronotal margins not visible from above. Scutellum small, black and triangular, asetose and impunctate.

Elytra black in anterior half, dark brown on posterior half, sparsely and coarsely punctuate; sparsely covered with semi-erect dark setae. Each elytron bears four transverse fasciae formed by intermixed white and yellow setae: the first situated near scutellum; second present anteriorly, reaching elytral suture; third fascia situated sub-medially reaching elytral suture; and the fourth fascia situated sub-apically, reaching elytral suture. Elytral epipleuron short, black, with dark setae.

Metaventrite finely punctuate with white, short, recumbent setae. Mesoventrite coarsely punctuate laterally, medially finely punctuate, and covered by white, short, recumbent setae.

All abdominal ventrites black, covered by short, white, recumbent setae; first abdominal ventrite with distinct oblique discal striae.

Legs. Tibiae and tarsi brown, femora anteriorly darkened and sparsely covered with fine white setae. Anterior tibiae with black spines along shaft.

Male genitalia. Parameres widely 'open' connected anteriorly by a 'bridge', parameres apically with pseudopores and short setae; basal piece strongly sclerotized; penis apically with downward pointing 'hook'. Penis has been slightly damaged during the manipulation with the aedeagus and therefore we decided to show the photograph as well as the drawing of the aedeagus depicting a reconstructed penis. (Figs 3-4).

Female unknown.

Differential diagnosis. This new species belongs to the genus *Phradonoma* Jacquelin du Val, 1859, and can be placed into the "*P. nobile* species group" (sensu Háva 2006;

Figure 1. *Phradonoma blabolili* sp. n., habitus, dorsal view.

see also below). *Phradonoma blabolili* sp. n. is visually most similar to *P. cornelli* Háva & Hermann, 2009 and can be differentiated from it by the characters given in the key.

Distribution. Known only from the vicinity of Catabola, Bié province, central Angola (Fig. 5).

Etymology. Patronymic, dedicated to Martin Blabolil, (Kuito, Angola) who has been instrumental in providing all kinds of help during the visit of Tomáš Lackner in Angola.

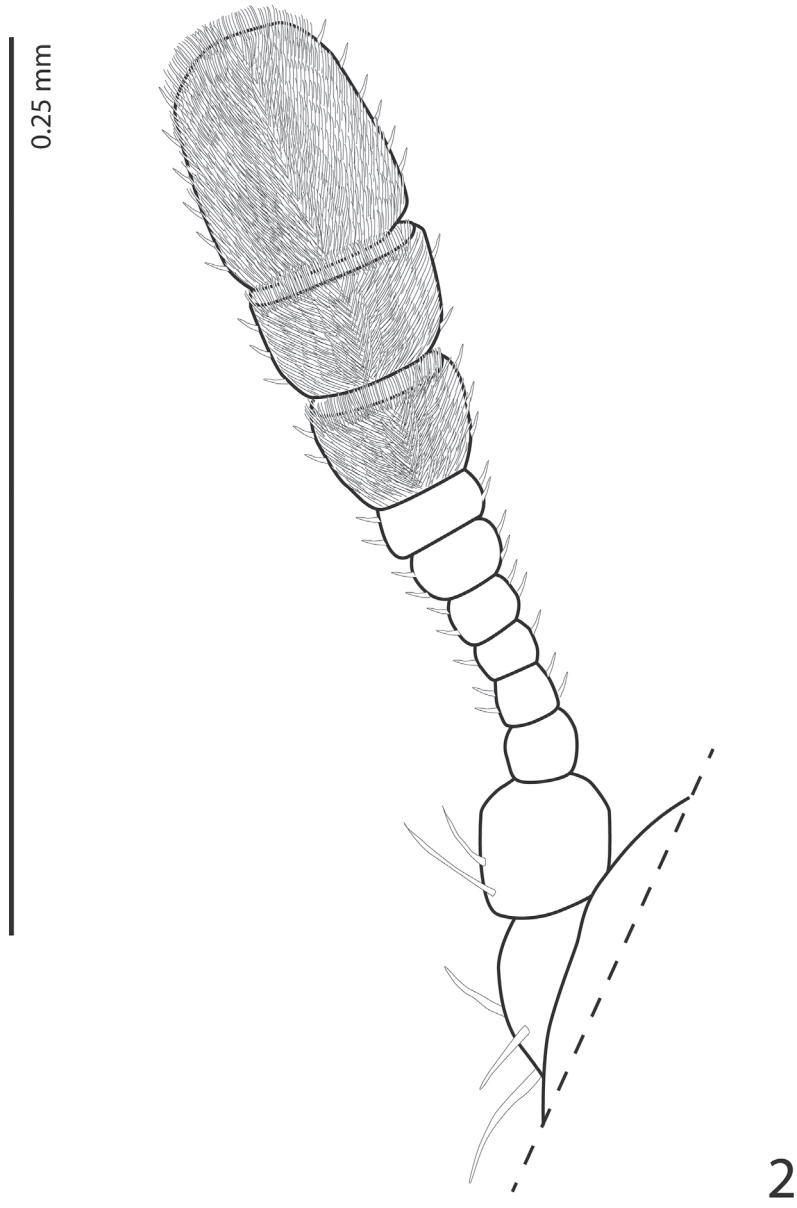

Figure 2. *Phradonoma blabolili* sp. n., antenna, dorsal view.

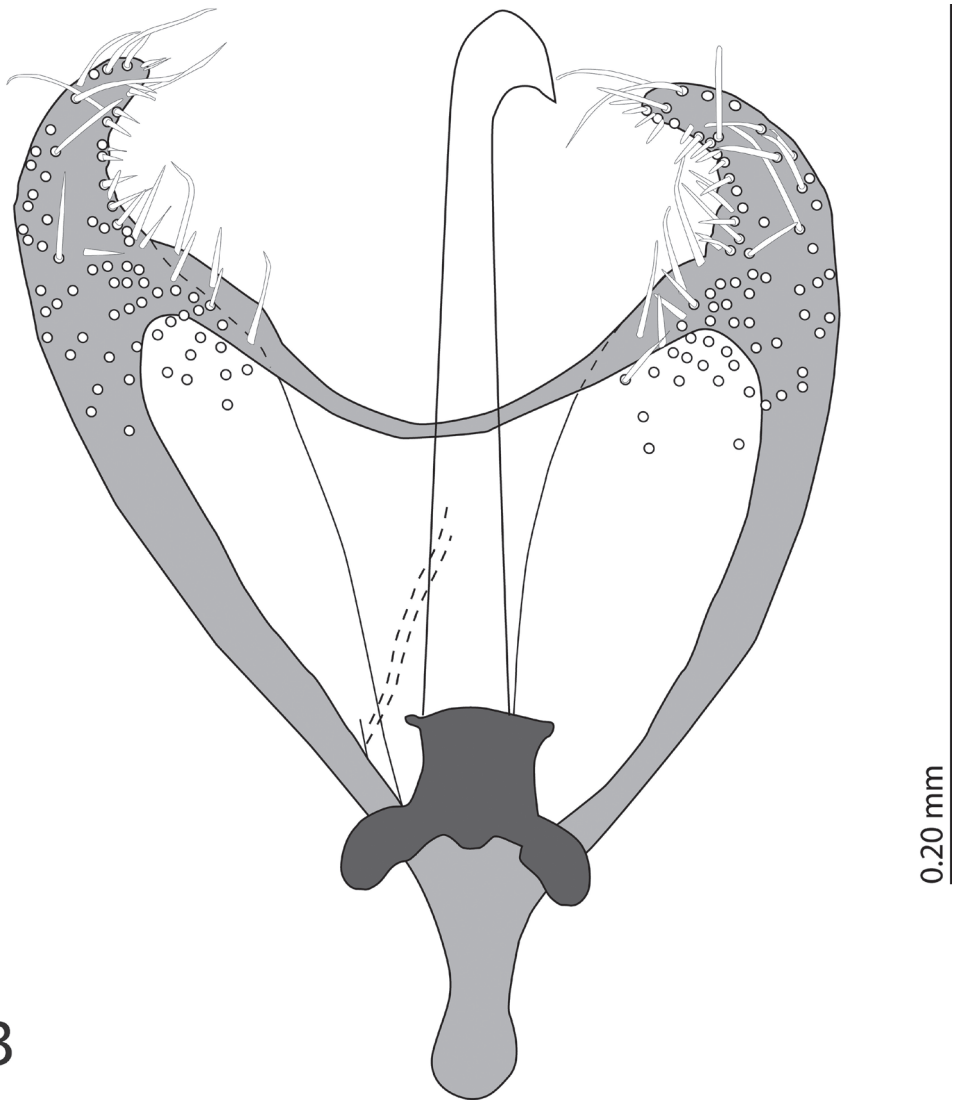

Figure 3. *Phradonoma blabolili* sp. n., aedeagus, dorsal view, showing the reconstructed penis.

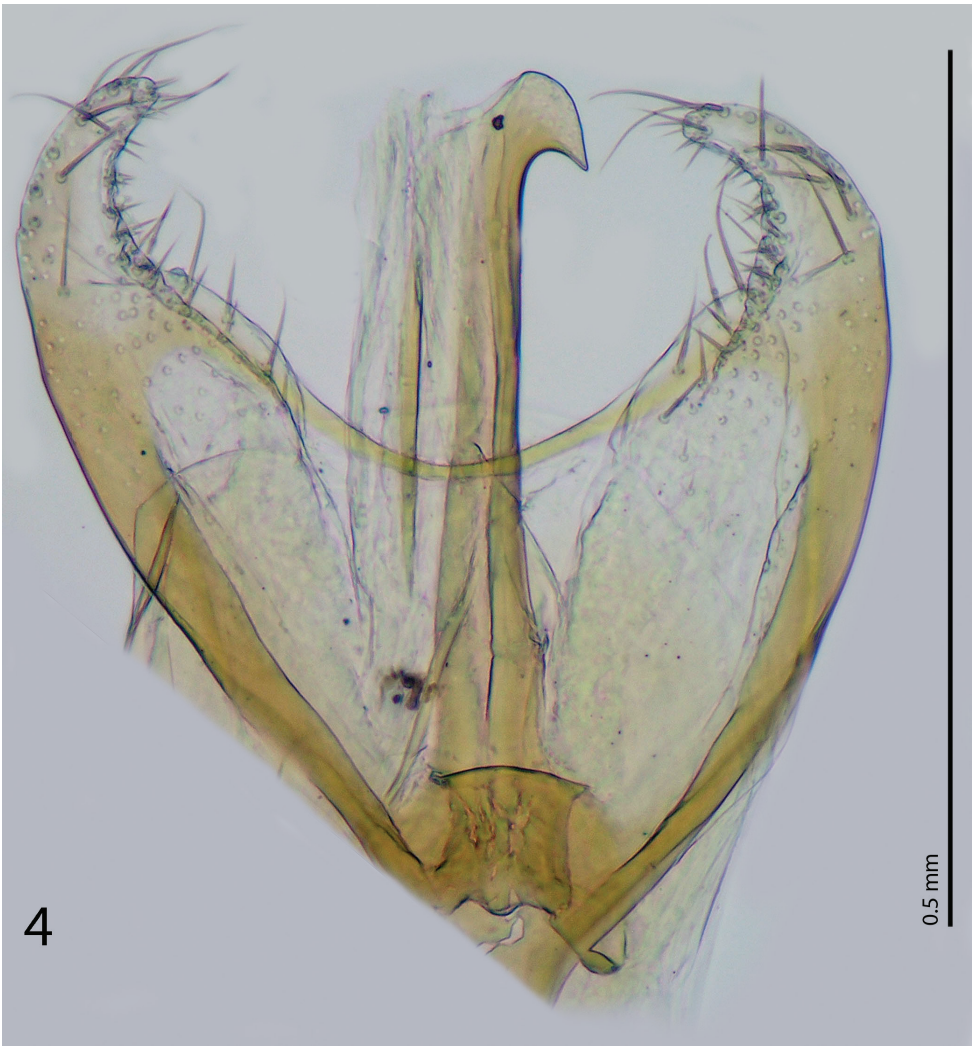

Figure 4. *Phradonoma blabolili* sp. n., aedeagus, depicting the damaged penis.

Figure 5. Map of Angola showing the type locality of *Phradonoma blabolili* sp. n.

Key to the Afrotropical "*Phradonoma nobile* species group"

"*Phradnonoma nobile* species group" of the genus *Phradonoma* can be defined by the combination of the following putative synapomorphies: cuticle bicolored, dorsal body surface with bi- or tri-colored setae and antennal club consisting from three antennomeres (see also Háva 2006).

1 Body form narrow, parallel, elytra without white setae, black with orange apex; antennal club with 5 antennomeres (Kenya, Namibia, Tanzania) ..... ***P. babaulti* (Pic, 1921)**

– Body form oval, elytra with brown and white or grey setae, antennal club with 3 antennomeres **2**

3 Berminal antennal antennomere triangular; elytra brownish-black except for three (sometimes only two) red, transverse bands and small circular spots; (Cyprus, England (intr.), Greece, Portugal, Spain, Algeria, Egypt, Eritrea, Libya, Morocco, Namibia, Nigeria, South Africa, South Sudan, Sudan, Tanzania, Tunisia, Zimbabwe, Afghanistan, „Caucasus", India: Madhya Pradesh, Rajasthan, Uttar Pradesh, Iran, Iraq, Israel, Jordan, Pakistan, Qatar, Saudi Arabia, Syria, Tajikistan, Turkmenistan, United Arab Emirates, Uzbekistan, USA: Arizona (intr.)) ..... ***P. nobile*** **(Reitter, 1881)**

– Terminal antennal antennomere oval **4**

4 Elytra with light fasciae of setae and apical spot **5**

– Elytra with isolated light spots of setae **7**

5 Elytra with one orange transverse fasciae, small median orange patches and orange apical spot all covered by white setae; body length 2.30–2.70 mm; antennal club with 3 antennomeres (Botswana, Congo, Namibia, South Africa, Tanzania, Zambia, Zimbabwe) ..... ***P. eximium*** **(Arrow, 1915)**

– Elytra dark brown or black and dark brown without median, orange or brown patches **6**

6 Elytra dark brown, each elytron covered by slightly erected dark setae with three or four fasciae and small apical spot from light brown and white setae; body length 2.10–2.60 mm; antennal club with 3 antennomeres (Cameroon) ..... ***P. cornelli*** **Háva & Herrmann, 2009**

– Elytra black in anterior half, dark brown posteriorly, each elytron with four distinct transverse fasciae from grey setae; body length 2.20 mm; antennal club with 3 antennomeres (Angola: Bié province) ..... ***P. blabolili*** **sp. n.**

7 Elytra with isolated light spots of setae **8**

8 Elytra black, without red, orange or brown parts. Body length 2.60–2.70 mm; antennal club with 3 antennomeres; each elytron with very small isolated 13–14 white spots (Kenya, Madagascar) ..... ***P. albonotatum*** **(Pic, 1927)**

– Elytra with red, orange or brown parts **9**

9 Pronotum with 5 isolated white patches, two in lateral parts, two medially and one near scutellum; body length 2.30–3.30 mm; antennal club with 3 antennomeres; elytra black with orange-brown apical part and with small white spots (Botswana, South Africa) ..... ***P. borowieci*** **Háva & Kadej, 2006**

– Pronotum with two lateral white patches **10**

10 Elytra near scutellum coarsely punctured with small humeral bump; body length 2.80 mm; antennal club with 3 antennomeres; elytra black, each elytron with 12 small, distinct spots of white setae on three or four very blurred fasciae and an apical spot (Cameroon) ..... ***P. angelusi*** **Háva & Herrmann, 2009**

– Elytra near scutellum finely punctured with very large humeral bump; body length 2.40–3.20 mm; antennal club with 3 antennomeres; elytra black with orange apex, each elytron intermixed in brown setae with small patches of white setae (Namibia) ..... ***P. namibicum*** **Háva, 2005**

Key to genera of Dermestidae hitherto known to occur in Angola

1 Head without frontal ocellus .... **subfamily Dermestinae, genus *Dermestes*, 2**
– head with frontal ocellus **3**
2 visible abdominal sternites with white and black pubescence .... **subgenus *Dermestinus* Zhantiev, 1967**
– visible abdominal sternites with concolorous pubescence .... **subgenus *Dermestes* Linnaeus, 1758**
3 prosternum not forming a "collar"; mouthparts free .... **subfamily Attageninae, genus *Attagenus* Latreille, 1802**
– prosternum forming a "collar" under which mouthparts fit when the head is retracted ..... **subfamily Megatominae, 4**
4 dorsal and ventral surfaces covered by flat scales..... **genus *Anthrenus*, 5**
– dorsal and ventral surfaces covered by pubescence..... 7
5 antenna with 11 antennomeres **6**
– antenna with 10 antennomeres ..... **subgenus *Anthrenodes* Chobaut, 1898**
6 eyes with median margin broadly and deeply emarginate at about anterior 1/3..... **subgenus *Anthrenus* Geoffroy, 1762**
– eyes with median margins complete..... **subgenus *Nathrenus* Casey, 1900**
7 anterior tibiae with spines along shaft; antennal club with 3 antennomeres... ..... **genus *Phradonoma* Jacquelin du Val, 1859**
– anterior tibiae without spines..... **8**
8 antennal club with 2 antennomeres, terminal antennomere of male big, flat and slightly vaulted..... **genus *Orphinus* Motschulsky, 1858**
– antennal club with 3-8 antennomeres ..... **genus *Trogoderma* Dejean, 1821**

List of the dermestid beetles reported from Angola so far:

Subfamily Dermestinae Latreille, 1804
Tribe Dermestini Latreille, 1804

Dermestes (*Dermestes*) *ater* DeGeer, 1774
= *Dermestes cadaverinus* Fabricius, 1775
= *Dermestes domesticus* Germar, 1824
= *Dermestes cinereus* Motschulsky, 1848

Dermestes (*Dermestes*) *lardarius* Linnaeus, 1758
Dermestes (*Dermestinus*) *maculatus* DeGeer, 1774
= *Dermestes vulpinus* Fabricius, 1781
= *Dermestes senex* Germar, 1824
= *Dermestes lupinus* Eschscholtz in Mannerheim, 1843

Subfamily Attageninae Laporte, 1840
Tribe Attagenini Laporte, 1840

Attagenus donckieri Pic, 1916
Attagenus fasciatus (Thunberg, 1795)
= *Anthrenus gloriosae* Fabricius, 1798
Attagenus hargreavesi Pic, 1935
Attagenus havai Kadej, 2006
Attagenus vestitus Klug, 1855
= *Attagenus rhodesianus* Pic, 1927

Subfamily Megatominae Leach, 1815
Tribe Anthrenini Gistel, 1848

Anthrenus (*Anthrenodes*) *endroedyi* Háva, 2003b
Anthrenus (*Anthrenus*) *flavipes flavipes* LeConte, 1854
Anthrenus (*Nathrenus*) *maltzi* Kadej, 2010
Anthrenus (*Nathrenus*) *verbasci* (Linnaeus, 1767)

Tribe Megatomini Leach, 1815

Orphinus (*Orphinus*) *aethiops* Arrow, 1915
Orphinus (*Orphinus*) *incognitus* Háva, 2003b
Phradonoma blabolili sp. n.
Trogoderma granarium Everts, 1898

Acknowledgements

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RESEARCH ARTICLE

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Did the genus *Parandrocephalus* Heller, 1916 (Coleoptera, Cerambycidae, Callichromatini) cross the Wallace line? The taxonomic status of *Parandrocephalus blairi* Bentanachs & Vives 2009 and a new subgenus of *Hexamitodera* Heller, 1896, with notes on convergent evolution and secondary sexual characters

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Abstract

The genera *Parandrocephalus* Heller, 1916 and *Hexamitodera* Heller, 1896 are reviewed and redescribed. Based on the combination of chromatic sexual dimorphism, velvety pubescence on the whole dorsal body and distinctly developed carina on the elytra, *Parandrocephalus blairi* Bentanachs & Vives, 2009 is transferred to *Hexamitodera*.

A new subgenus, *Sulcognatha* Perger, is instituted to accommodate mandible, head and metasternal modifications in *H. blairi* **comb n.**. that are lacking in the type species of *Hexamitodera*, *H. semivelutina*. As indicated by fundamental structural differences in the mandibles of *Parandrocephalus* and *H.* (*Sulcognatha*) *blairi* **comb. n.**, the exaggerated secondary sexual traits and open procoxal cavities in both taxa are presumably the result of convergent evolution. Contrary to Bentanachs and Vives (2009), the presence of the two *Parandrocephalus* species in Sundaland and the endemism of *Hexamitodera* on Sulawesi agree well with the zoogeographical separation of both areas by the Wallace line.

Keywords
Longhorn beetles, Malaysia, Indonesia, Sulawesi, Wallacea, taxonomy, biogeography

Introduction

The discovery and description of two distinct zoogeographical realms in South East Asia by Alfred Russel Wallace was the birth of biogeography and inspired the naturalist to formulate fundamental principles of the evolution theory, at the same time with Charles Darwin (Sarkar 1998). Like Darwin, Wallace was genuinely interested in beetles, however, both never pursued beetle taxonomy (see Beutel et al. 2009), nor did Wallace compare the beetle faunas of the zoogeographical realms he discovered, likely because of the enormous and difficult manageable diversity of this taxon.

A beetle group that has attracted the attention of following generations of collectors and taxonomists and is mainly speciose in the tropical regions of the Austral hemisphere is the heterogeneous tribe Callichromatini (Schmidt 1922).

Taxa with a combination of chromatic sexual dimorphism and velvety pubescence on the whole dorsal body are exceptional for this tribe. Only three Asian Callichromatini species share this combination: *Hexamitodera semivelutina* Heller, 1896, *Parandrocephalus blairi* Bentanachs & Vives, 2009 and *Niisatochroma celebiana* Vives & Bentanachs, 2010, all occurring on Sulawesi.

Particularly *P. blairi* with the con-generics *Parandrocephalus eversor* Heller, 1916 and *P. drescheri* Blair, 1938 on the Sunda Islands represents an interesting case as it belongs to one of the few Cerambycidae genera that occur on both sides of the Wallace line (Bentanachs and Vives 2009).

In this study I review generic characters to test the hypothesis of whether the genus *Parandrocephalus* indeed crossed the Wallace line or alternatively, the Sulawesian taxa share characters that rather indicate vicariance processes and support the Wallace line as an effective zoogeographical boundary.

Materials and methods

Specimens examined for this study are from the following institutions / private collections**:**

BMNH Natural History Museum, London, U.K.;
JA Dr. Joachim Adolphi, Private collection, Dresden, Germany;
RMNH National Museum of Natural History in Leiden, The Netherlands;
RP Robert Perger, Private collection, Santa Cruz, Bolivia;
RV Robert Vigneault, Private collection, Quebec, Canada;
SNSD Senckenberg Naturhistorische Sammlungen Dresden,Germany;
TN Tatsuya Niisato, Private collection, Tokyo, Japan;
UN Ulf Nylander, Private collection, Valbo, Sweden.

Morphological characters were examined with a stereomicroscope and specimens were photographed with a Canon 450D reflex camera fitted with macro lenses.

The following specimens were examined:

***Parandrocephalus eversor* Heller, 1916**

Sumatra, Padangsche Bovenlanden: holotype 1 ♂, RMNH, ex coll. Dr. H. J. Veth; Malaysia, Cameron Highlands, Kampong Rajah: 1 ♂, RP, VI-2000; Borneo, Sabah, Mt. Trus Madi: 1 ♀, UN, 19-VI-05, S.Chew coll.

***Parandrocephalus drescheri* Blair, 1938**

Java, G. Tangkoeban Prahoe, 4000-5000 voet [= ft.]: holotype,1♂, BMNH,VI-1937, F.C. Drescher coll.[G. Tangkoeban Prahoe, 4000-5000 voet [= ft.], Dreanger, Java, VI.1937 / type / Parandroceph. drescheri Blr., ♂ type det. K.G. Blair / Brit.Mus., 1937-662]

***Parandrocephalus blairi* Bentanachs & Vives, 2009**

Indonesia, Sulawesi, Puncak near Palolo: holotype, 1 ♂, TN, II-1990; Indonesia, Sulawesi, Palolo Palu: allotype, 1 ♀, TN, IV-1991; Indonesia, Central Sulawesi, Palolo Palu: 2 ♂ RP, 1 ♂ JA, III-1999; Indonesia, Central Sulawesi, Puncak: 1 ♂, RP, IV-1999.

***Hexamitodera semivelutina* Heller, 1896**

Indonesia, North Sulawesi: holotype, 1 ♀, SNSD [semivelutina Hh. / N.Celebes, 9389 / Typus / Staatl. Museum für Tierkunde, Dresden]; Indonesia, Sulawesi, Minado: 1 ♂, BMNH, 1781, Wallace coll., ex coll. Fry; Indonesia, Sulawesi: 1 ♀, BMNH, 1922; Indonesia, Sulawesi, Pulu Pulu: 1♂, RV, 19-XII-1997, A. Audureau coll.

Results

***Parandrocephalus* Heller, 1916**
http://species-id.net/wiki/Parandrocephalus

Type species. *Parandrocephalus eversor* Heller, 1916

Redescription. Body relatively large, elongated, parallel-sided, flattened, without chromatic sexual dimorphism. Head and mandibles with pronounced sexual dimorphism, abnormally enlarged in male, vertex glabrous. Male mandible sickle-shaped, flattened vertically, with dorsomedian carina, median longitudinal concave. Antennae slightly surpassing the basal elytral half (not the apical third of the elytra as diagnosed by Bentanachs and Vives 2009). Pronotum transverse, glabrous, obtusely toothed

at each side, deeply constricted anteriorly and posteriorly; anterior margin strongly projected forward. Procoxal cavities open posteriorly. Elytra covering the abdomen, sparsely pubescent, with scarcely elevated costae. Female abdominal sternites1–4 distally margined with whitish pubescence. Metatibia apically distinctly flattened and broadened, about as wide as metafemora.

Parandrocephalus eversor Heller, 1916

http://species-id.net/wiki/Parandrocephalus_eversor
Fig. 1A, B

Redescription. Male. Body 4.2 times as long as wide. Head and pronotum (Fig. 2B) glabrous. Head dorsally polished, coarsely wrinkled, vertex strongly convex, not carinated dorsally; frons strongly concave, with a deep longitudinal furrow. Temple in dorsal view strongly convex; distance between temples wider than anterior border of pronotum and as wide as widest width of pronotum. Gena apically rounded, externally thickened. Width between genae as wide as width of head. Mandible sickle-shaped, curved, forming an elongated ellipse in closed position, with dorsomedian carina; apex conical, unidentate; molar margin without basal tooth. Antenna sparsely pubescent, bicolored. Elytra 2.2 times as long as prothorax and head excluding mandibles.

Female. Vertex and temples straight, distance between temples narrower than anterior pronotal margin and widest pronotal width, vertex setose, with longitudinal furrow reaching anterior pronotal margin. Mandible horizontally flattened, dorsal surface convex, with dorso-lateral carina, externally straight. Pronotal disc setose. Elytra 3.43 times as long as prothorax and head excluding mandibles. Abdomen bordered with yellowish pubescence at the base of all ventrites.

Geographical distribution. Sumatra, Borneo, Malaysia Peninsula.

Hexamitodera Heller, 1896

http://species-id.net/wiki/Hexamitodera

Type species. *Hexamitodera semivelutina* Heller, 1896 (monotypic)

Redescription. Body relatively large, elongated, flattened, dorsally covered with dense velvety pubescence (could be partially abrased, particularly in females), with chromatic sexual dimorphism. Mandible horizontally flattened, dorsal surface straight, without dorsomedian carina, dorso-lateral border, externally straight or with shallow to deep concavity. Antenna relatively short, reaching or slightly projecting above basal half of elytra. Pronotum transverse, obtusely to acutely toothed laterally; apical margin not constricted. Procoxal cavity open posteriorly. Sternum and epimeron of meso- and metathorax densely pubescent. Elytra covering abdomen, parallel-sided, with three distinctly elevated longitudinal costae, the inner two converging in about the apical

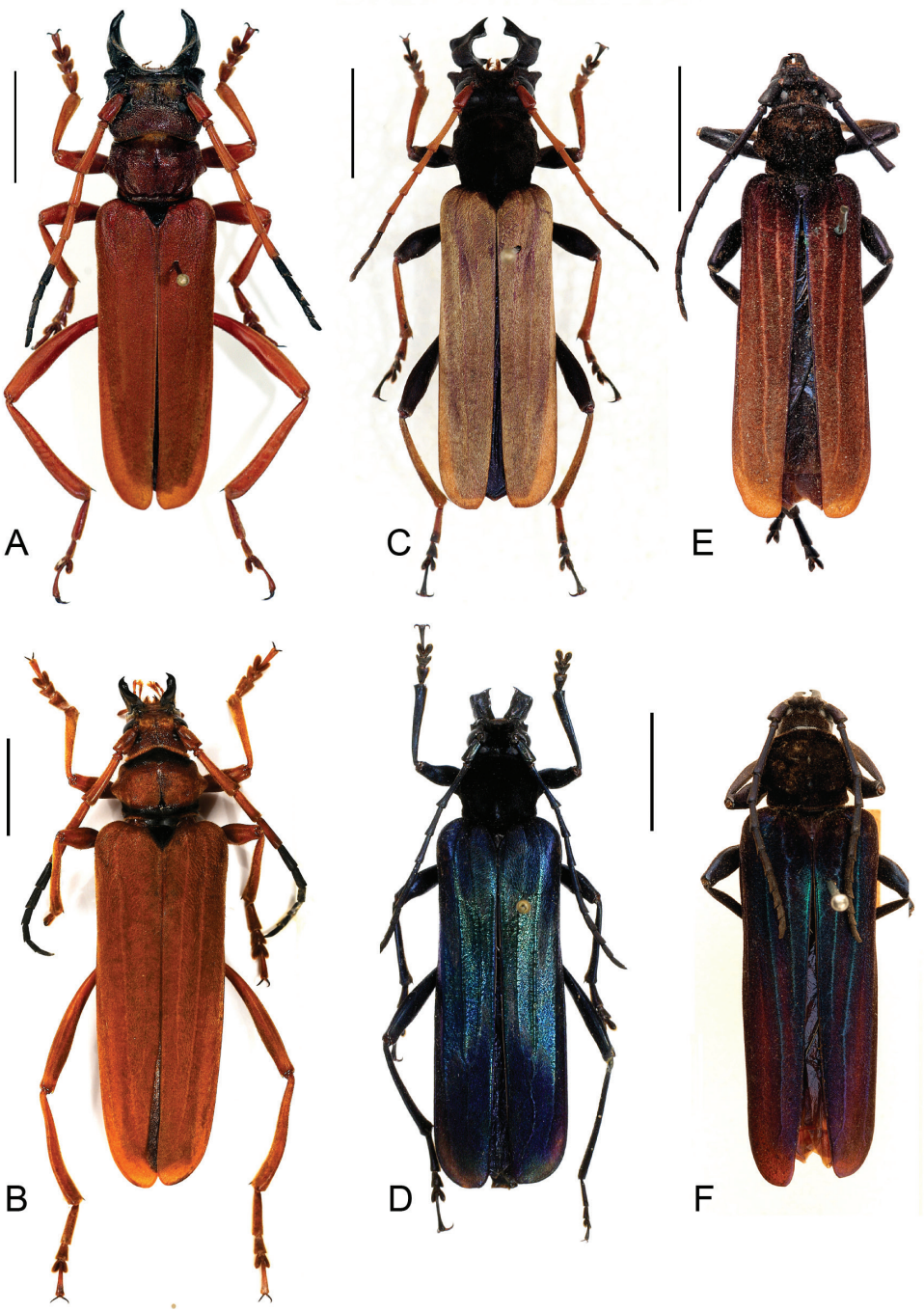

Figure 1. Dorsal view habitus, scale bars 10 mm **A** *Parandrocephalus eversor*, male, Malaysia, Cameron Highlands, Kampong Rajah **B** idem, female **C** *Hexamitodera* (*Sulcognatha*) *blairi* comb. n., male, Indonesia, Central Sulawesi, Puncak **D** idem, female, allotype, Indonesia, Sulawesi, Palolo Palu **E** *Hexamitodera semivelutina*, male, Sulawesi **F**, idem, female, holotype, Indonesia, North Sulawesi.

third of the elytra. First abdominal sternite of female distally bordered with white pubescence. Femur fusiform, comparably short, stout; metatibia moderately flattened and widened, narrower than metafemur.

Hexamitodera semivelutina Heller, 1896

http://species-id.net/wiki/Hexamitodera_semivelutina
Fig. 1E, F

Redescription. Male. Body 3.7–3.8 times as long as wide. Vertex and temples straight, distance between temples narrower than anterior margin of pronotum and widest pronotal width. Head dorsally uniformly finely punctured, with a fine longitudinal furrow reaching the base. Mandible without inner basal tooth, feebly curved or angulate (Fig. 3A). Mandible as long as one-half of the rest of the head, as long and wide as scape. Gena rounded apically; width between genae distinctly narrower than width between temples, the latter narrower than pronotal width. Antenna sparsely pubescent. Antennomeres 1–2 apically rounded, 3 straight, as 1.9 times as long as scape, 4–11 obtusely toothed. Antenna and legs unicolorous.

Prothorax 1.21 times as wide as long. Procoxal cavity opened posteriorly by a comparable small gap. Apex of mesosternal process not concealed by metasternum.

Elytra 2.9 times as long as prothorax and head excluding mandible and 2.8 times as long as elytra width, brownish.

Female. Head, mandible and pronotum as in male. Elytron 3.3 times as long as prothorax and head excluding mandible, metallic blue with purple brownish stripes and brown apices.

Geographical distribution. Sulawesi.

Sulcognatha Perger subgen. n.

Fig. 1C, D

Type species. *Hexamitodera* (*Sulcognatha*) *blairi* (Bentanachs & Vives, 2009) comb. n.

Description. Head and mandible enlarged in both sexes; gena acutely produced; clypeus strongly concave, very short; labrum reduced and not visible from dorsal view; mandible basally broadened, in male conspicuously, and distal half antero-laterally of mandible in both sexes with prominently developed concavity (Fig. 2A; 3D). Apex of mesosternal process concealed by metasternum; antenna and tibia with chromatic sexual dimorphism.

Etymology. The new subgenus name is a combination of the Latin word sulcus (meaning, "furrow") and the Greek word gnathus (meaning, "jaw"), and is a reference to the deep antero-lateral furrow in the mandible of both genders. The name is feminine.

Included species. This subgenus includes so far only the type species.

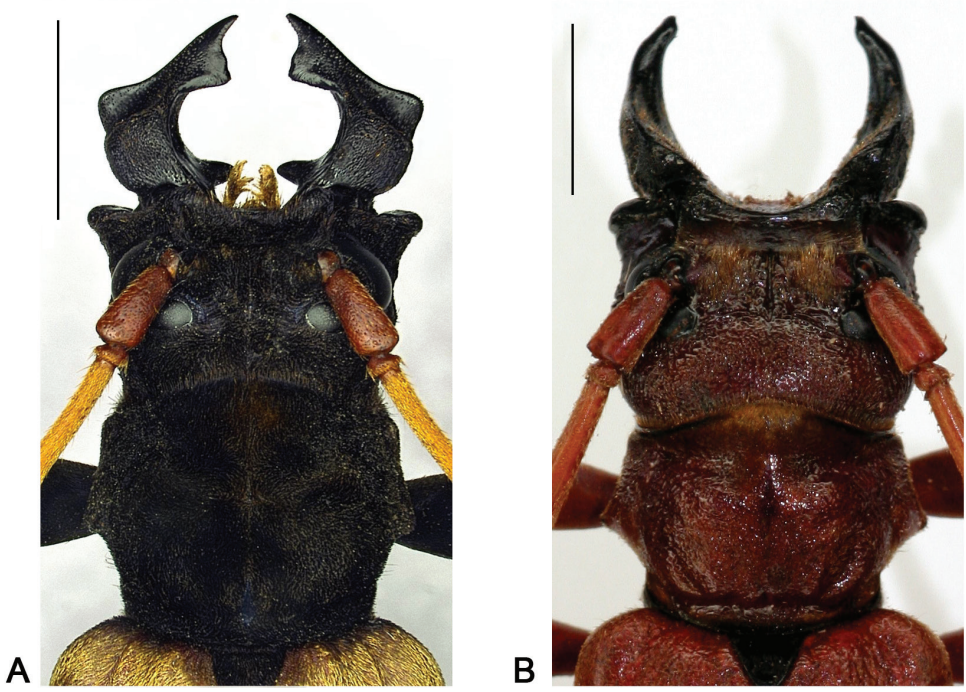

Figure 2. Dorsal view head and pronotum, scale bars 5 mm **A** *Hexamitodera* (*Sulcognatha*) *blairi* comb. n., male, Indonesia, Central Sulawesi, Puncak **B** *Parandrocephalus eversor*, male, Malaysia, Cameron Highlands, Kampong Rajah.

***Hexamitodera* (*Sulcognatha*) *blairi* (Bentanachs & Vives, 2009), comb. n.**
http://species-id.net/wiki/Hexamitodera_blairi
Fig. 1C, D

Redescription. Male. Head abnormally developed (Fig. 1C; 2A), dorsally uniformly finely punctured, with a fine longitudinal furrow reaching the base. Temple straight, not protruded under the forehead in dorsal view, distance between temples narrower than anterior pronotal margin. Gena elongate and acutely produced exteriorly, anterolaterally rounded, maximal width distinctly wider than forehead and as wide as pronotum. Mandible as long as head, twice as long as scape, maximal width as long as scape, strongly curved inwards, forming a transverse ellipse in closed position; apex flattened, shovel-shaped, bidentate, internal tooth obtuse; molar margin with strong basal tooth. Antenna slightly surpassing elytral half, articles 1–2 spineless, glabrous, red-brown, 3–6 with small apical spines, fine short pubescence, testaceous to brass-colored, 7–11 spineless, sparsely pubescent, dark-grey/brown, 11 apically rounded. Prosternal process projecting over posterior border of procoxae. Elytra 2.5 times as long as prothorax and head without mandibles, with brass-colored velvety pubescence. Femur dark-brown to black, tibia brass-colored to testaceous.

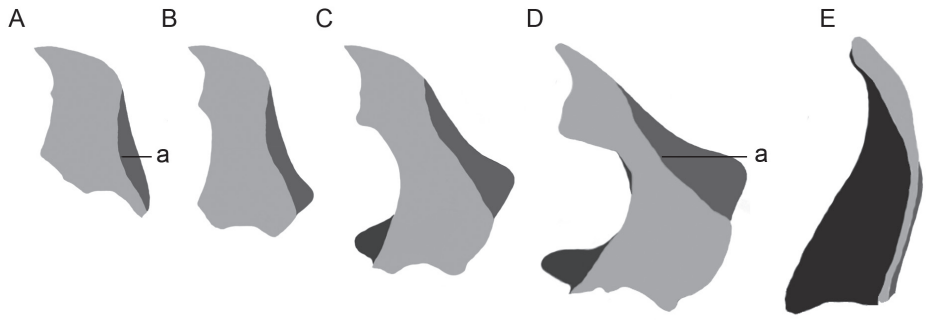

Figure 3. Dorsal view male mandibles; light grey, dorsal surface; dark grey, ventral external concavity; black, interior surface; a, dorso-lateral border; mandibles of **A** and **D** are drawn from specimens that were digitally scaled until they had similar body length **A** *Hexamitodera semivelutina* **B, C** hypothetical intermediate forms **D** *Hexamitodera* (*Sulcognatha*) *blairi* comb. n. **E** *Parandrocephalus eversor*.

Female. Mandible as long as scape, flattened, acutely pointed at the apex, between tooth of apex and base continuous, not strongly curved inwards, molar margin without tooth. Gena forming an obtuse angle, their maximal width narrower than width between eyes, nearly as wide as forehead. Antenna dark blue with metallic reflections, sparsely pubescent. Elytron 3.3 times as long as prothorax and head excluding mandibles, metallic blue.

Geographical distribution. Sulawesi.

Niisatochroma celebiana Vives & Bentanachs, 2010

http://species-id.net/wiki/Niisatochroma_celebiana

Discussion. In *N. celebiana*, the sole species in this genus, the chromatic gender dimorphism (brass brownish tones in male, bluish-green in female), dorsal body pubescence, prominent developed elytral costae and short limbs (see Vives and Bentanachs 2010) indicate a close relationship with *H. semivelutina* and *H.* (*Sulcognatha*) *blairi*. The thickened antenna and distinct apical spines on the antennomeres (Vives and Bentanachs 2010) however suggest that this species does not belong to the same lineage as *H.* (*Sulcognatha*) *blairi*. Like *H.* (*Sulcognatha*) *blairi*, *N. celebiana* might deserve subgeneric status within *Hexamitodera*, however, unfortunately no specimens of this rare species were available for a detailed study and therefore the generic status has to be retained for the moment.

Geographical distribution. Sulawesi.

Discussion

Taxonomy

Contrary to the generic characters provided for *Parandrocephalus* (Bentanachs and Vives 2009), the mandible of *H.* (*Sulcognatha*) *blairi* does not possess a dorsomedian

Table 1. Generic differences of *Parandrocephalus* and *Hexamitodera*

Character	***Parandrocephalus***	***Hexamitodera***
Body chromatic sexual dimorphism	absent	present
Shape male mandibular	vertically flattened, with dorsomedian carina, interiorly concave, distal portion interiorly with deep concavity	horizontally flattened, dorsally straight, dorsomedian carina absent, dorso-lateral border, externally with shallow to deep concavity
Pubescence male head + pronotum	absent	distinct
Elytral costae + pubescence	weak	distinct
Light pubescence at female abdominal sternites	first to fourth	first
Metatibia distally flattened and broadened	distinct	moderate
Width of metatibia distally	~ metafemora	<metafemora

carina (Fig. 2A; 3D) and the elytra have prominently (and not weakly) developed carina (Fig.1 C, D). Consequently the generic position of *H.* (*Sulcognatha*) *blairi* had to be reconsidered.

The separate treatment of sexual and non-sexual traits has revealed a suite of apomorphic characters (Table 1) that allows a more coherent interpretation of relationships of *H.* (*Sulcognatha*) *blairi*. Actually, the chromatic gender dimorphism (brownish tones in male, blue in female), body pubescence, prominent developed elytral costae, short legs and antennae of *H.* (*Sulcognatha*) *blairi* clearly belong to *Hexamitodera* (Table 1). The relationship becomes already evident in the comparison of the dorsal habitus of the females of *H.* (*Sulcognatha*) *blairi* and *H. semivelutina* (Fig. 1D, F).

The lacking sexual dimorphism in mandible and head of *H. semivelutina* suggests an ancestral relationship with *H.* (*Sulcognatha*) *blairi*, while the enlargement and complex structure of the mandible in *H.* (*Sulcognatha*) *blairi* indicate a more derived status. I hypothesise that the grades of differentiation in the mandible in the two *Hexamitodera* species represent the basal and terminal end of an evolutionary transformation series (Fig. 3A-D) of male adaptations to adjust on the female during the mating. The interior shape of the male mandible in *H.* (*Sulcognatha*) *blairi* fits well with the posterior constriction of the female prothorax, while the antero-distal mandibular concavity is perfectly suited to accommodate the female profemora. The large mandibles and their adjustment on the female during the mating are evolutionarily advantageous because they facilitate a successful (possibly prolonged) fertilization and contribution to the gene pool. In this context, the inclusion of *H.* (*Sulcognatha*) *blairi* into *Hexamitodera* provides an interesting hypothesis for testing evolutionary processes that select for large mandibles and co-adaptations.

It might be asked if the modifications in head and mandible of *H.* (*Sulcognatha*) *blairi* justify the establishment of a new genus, however, particularly on the basis of morphology it is difficult to assess at which point a phylogenetic distance passes a

subgeneric or generic boundary, and additionally there is no operational definition for such boundaries. Mayr (1969) pragmatically defined a genus as "a taxonomic category containing a single species, or a monophyletic group of species, which is separated from other taxa of the same rank (other genera) by a decided gap."

To my knowledge, *H. semivelutina* and *H.* (*Sulcognatha*) *blairi* are from other taxa of the same rank unambiguously distinguished by apomorphic characters (Table 1) and the lack of intermediate mandible and head forms, indeed representing a certain gap, at the very most justifies the institution of a new subgenus.

Convergence in secondary sexual characters

The extraordinarily developed mandibles in males of *Parandrocephalus* and *H.* (*Sulcognatha*) *blairi*, evidently showing distinct features (Table 1; Fig. 2; 3D, F), should be interpreted as convergent adaptations, possibly for mate-guarding and the fitting of the male mandible to the posterior constriction of the female prothorax. While the mandible structure might contain useful taxonomical information, the enlargement alone is not a good indicator for relationships since it has also independently evolved in males of other Callichromatini genera (e.g. *Aphrodisium niisatoi* Vives & Bentanachs, 2007 and *Huedepohliana superba* (Aurivillius, 1910)), and also in phylogenetically more distant beetle taxa, such as Prioninae (Cerambycidae), Manticorini (Carabidae) and Lucanidae.

Heller (1916) considered the opened procoxal cavity in *Parandrocephalus* and the African Callichromatini genus *Dictator* Thomson, 1878 (as well having enlarged mandibles) as atypical for this tribe and indicator for a closer relationship, however, such combination is also observed in the phylogenetically distant groups already mentioned before and might represent a convergent co-adaptation. The opened procoxal cavities possibly allow a greater deflection of the procoxa and the strong bend of forebody and abdomen while the mandibles and prolegs keep close contact with the female prothorax during the mating. There might be indeed a Gondwanian relationship between African and Asian Callichromatini taxa, however, I think a detailed phylogenetic analysis based on a larger set of morphological or/and biochemical features is needed to present a robust hypothesis of actual relationships.

Cerambycid-Geography and the Wallace line

Sundaland (including Borneo, Sumatra and Java) is assumed to be zoogeographically separated from 'Wallacea' (comprising Sulawesi and the Philippines except for Palawan) (Dickerson 1928) by the Wallace line (Huxley 1868), which is supported by distributional patterns e.g. in mammals and birds (Wallace 1859, 1860; Huxley 1868), cicadas (de Boer and Duffels, 1996), butterflies (see Vane-Wright and de Jong 2003 for a review) and hawkmoths (Beck et al. 2006).

The distribution of Cerambycidae taxa has been only sporadically treated in respect to the Wallace line and there is no statistical approach identifying geographical patterns.

Actually there are several closely related Cerambycidae taxa that occur on both sides of the Wallace line, e.g. the subspecies of *Xixuthrus microcerus* White, 1853 (Prioninae) (Komiya and Lorenc 2006), species of *Komiyandra* Santos-Silva, Heffern & Matsuda, 2010 (Parandrinae) (Santos-Silva et al. 2010) and *Chloridolum* Thomson, 1864 (Callichromatini) (Vives, in litt.), a pattern indicating more recent dispersal and colonization events.

The genera *Xystrocera* Blanchard, 1845 (Xystrocerini) (Martins 1960; Heffern 2005) and *Distenia* (Disteniinae) Lepeletier & Serville 1828 (Gressit 1959; Heffern 2005; Santos-Silva and Hovore 2007) occur not only on both sides of the Wallace line, but also on other continents (Africa and South America), suggesting Gondwanian relationships and longer vicariance processes.

However, in both, the South-East Asian taxa that occur on both sides of the Wallace line and pantropical taxa, distributional patterns might also be influenced by transoceanic dispersal of larvae in drifting logs (see Holzapfel and Harrell 1968; Peck 1994).

The Wallace line holds for the tribe Tmesisternini (Lamiinae), which is highly diversified in New Guinea and Sulawesi but nearly absent in Sundaland (Heffern 2005), and the Callichromatini. Only two (*Chloridolum* Thomson, 1864, and *Pachyteria* Audinet-Serville, 1833) (Niisato 2001; Vives and Bentanachs 2010) of the 20 Callichromatini genera that are listed for Borneo (Heffern 2005) are found in Sulawesi. While some of the *Chloridolum* species that occur on both sides of the Wallace line are morphologically very similar (Vives, in litt.), other species reported for Sulawesi differ from con-generics in Sundaland and might belong to another genus (Vives and Bentanachs 2010).

There appear to be clear trends in some Cerambycidae tribes supporting the Wallace line, nevertheless, the examples predating such line call for a proper statistical analysis of morphological or biochemical characters to clarify phylogeographical relationships.

According to the current state of knowledge, the genus *Parandrocephalus* did not cross the Wallace line, supporting the idea that *Parandrocephalus* and *Hexamitodera* are indeed examples for convergent evolutionary processes within two zoogeographically distinct realms.

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