

Data publication and dissemination of interactive keys under the open access model

ZooKeys working example

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Abstract

The concepts of publication, citation and dissemination of interactive keys and other online keys are discussed and illustrated by a sample paper published in the present issue (doi: 10.3897/zookeys.21.271). The present model is based on previous experience with several existing examples of publishing online keys. However, this model also suggests ways to publish, cite, preserve, disseminate and reuse the original data files to the benefit of future workers, the authors, and society in general. To be regarded as a “formal scientific publication,” an online key should satisfy the same criteria of peer review, registration, persistence, bibliographic description, etc., as with conventional publications. Keys can be published as either “static” or “dynamic” publications. We define a “static” publication as a discrete unit of information preserved in a persistent and unchangeable way on the publisher’s Web site and/or on paper and consequently in con-

ventional/electronic libraries and archives. This contrasts with the nature of the Internet, which allows and tends to encourage updating and improvement on a continuing basis. We call “dynamic” a publication of an interactive key on a Web site where its contents can be continuously updated. “Dynamic” publications meet some of the criteria of a “formal scientific publication” (identification, citation and location), while they lack other important features of it (persistence, archiving, indexing, science metric and citation metric services). Dynamic Web-based interactive keys may benefit from publishing the first version of their underlying datasets in a form of “formal scientific publication”. We define here the minimum set of data files to be published for several different platforms (Intkey, Lucid2, Lucid3, MX) to ensure both (1) priority, identification, location and citation of the first published work and (2) future use and re-use of the keys.

Introduction

“What is it?” is the fundamental question which begins most biological inquiries. The answer is provided by the identification process, that is, a sequence of observations of a specimen until a matching taxon is selected on the basis of a unique combination of attributes (character states). The identification process has been an integral part of biology since Linnaeus first developed his *Systema Naturae* (1758, 10th edition). In his *Systema*, the attributes were directly embedded in his hierarchical classification. Lamarck, in 1788, was the first to separate the identification process from the classification by making keys: hierarchical sets of choices between character states (Walter and Winterton 2007). These are usually called “dichotomous keys” (although strictly speaking this term should be restricted to keys having only two choices at each branching point), and sometimes “conventional keys”, “single-access keys”, or “pathway keys”. They are still the mainstay of taxonomy today, although they have many deficiencies (Dallwitz et al. 2000), the most fundamental of which is that the sequence of attributes used is predetermined by the author.

“Multi-access keys” or “polyclaves” were developed to overcome these deficiencies. They allow users to select, from a set of attributes, the ones that they think are best for their particular location on situation. For example, if one is identifying an angiosperm but the specimen has no flowers or fruits, other characters, such as those relating to habit and leaves, can be used. These keys may use punched cards (e.g. Archbald 1967) or computer programs (e.g. Goodall 1968; see also Pankhurst 1991). We shall refer to computerized, multi-access keys as “interactive keys”. Note that this definition excludes computerized dichotomous keys – e.g., keys in which each character is on a separate HTML page, and the paths to subsequent characters are implemented as hyperlinks.

Interactive keys are usually (but not always – see Dallwitz 1992) based on character-taxon matrices. These matrices can also be the basis of other taxonomic products, provided that the matrix format is sufficiently general, and suitable software is available. For example, Morse (1974) describes programs for interactive identification, construction of dichotomous keys, and description printing from matrices. DELTA (Dallwitz 1983; TDWG 2007) is a more powerful data-matrix format, which is also comparatively easy for humans (as opposed to computers) to read. DELTA data can be used to interact with cladistic software, as well as the products mentioned above

(DELTA Programs and Documentation: <http://delta-intkey.com/www/programs.htm>; Dallwitz 1993; Dallwitz et al. 1993). The latest TDWG standard for data matrices is Structured Descriptive Data (SDD) (TDWG 2007). Software is available to produce interactive keys and descriptions from SDD (e.g. Lucidcentral 2009).

Along with improvements in the identification process, improvements have been made in dissemination media. For most of the history of taxonomy, the medium was ink on paper, i.e., the traditional printed publication. The first multi-access keys were distributed on punched cards – either edge-punched cards or IBM 80-column punched cards. Computer programs and data were distributed on punched cards, punched paper tape, magnetic tape, magnetic (floppy) disks, optical disks (e.g. CD-ROM), and computer networks. With the development of a world-wide network, the Internet, this method of dissemination began to supplant the others, not only for computer programs and data, but also for traditionally paper-based publications. In particular, both dichotomous and interactive keys could now be made available online (Dallwitz et al. 2002). With this new medium, the traditional methods of scientific publication are becoming obsolete. The aims, which date back to the Royal Society and Henry Oldenberg (1660s), of recognition, priority, and peer review remain valid today, but the mechanisms need to be modified to adapt to the new online medium. Such modifications are outlined herein for online identification systems.

The present paper does not aim toward a thorough overview of interactive keys or at analyzing the advantages/shortcomings of the different software platforms; these are available elsewhere (e.g. Dallwitz 2000; Dallwitz et al. 2000; Farr 2006; Walter and Winterton 2007). Rather, we discuss and offer a model for *open data publishing* that allows a wider dissemination and reuse of data and interactive keys, and proper publication credit. The model adheres to the principles of open access to biodiversity information proclaimed in the opening editorial paper of ZooKeys (Penev et al. 2008), and recently illustrated by publishing occurrence datasets underlying taxonomic revisions (Miller et al. 2009; Penev et al. 2009).

“Formal scientific”, “static”, and “dynamic” publication

In this time of revolutionary changes in the way scientific information is being disseminated, the concepts of publication must be clearly defined. The process for “formal scientific” publication involves several steps, the most distinct of which are:

- (i) peer-review (not mandatory but desirable) and editorial quality control;
- (ii) registration of the publishing media in international registries through ISBN or ISSN numbers;
- (iii) long-stranding persistence and supply of the published information (on paper or in digital form) through libraries, trade, digital repositories (all recently facilitated by the presence of digital object identifiers (DOIs));
- (iv) accurate bibliographic description (metadata) of each scientific publication, which facilitates a proper identification, location and citation;

- (v) registration, distribution and dissemination of relevant parts of the published information through specialized indexing and harvesting aggregators (e.g., Global Biodiversity Information Facilities (GBIF), Encyclopedia of Life (EOL), Catalogue of Life, ITIS and Species 2000, Zoological Record, CABI Abstracts, Current Contents and many others);
- (vi) registration in citation, bibliometric and science metric indices (e.g., Thompson-Reuters Institute of Scientific Information (ISI), Google Scholar, Scopus);
- (vii) distribution through established supply channels, i.e., book trade, journal subscriptions, or in a form of free open access publications.

Online keys displayed on a Web site are not formal scientific publications unless the above requirements are met. This does not mean that such keys are without merit; rather, authors generously provide data for other researchers, typically without obtaining publication credit from their superiors for their efforts.

A traditional definition of “publication” includes the concept of “a discrete unit of information published in a persistent and unchangeable way”; usually such publications are called “static” or “fixed.” This contrasts with the nature of the Internet, which allows and tends to encourage updating and improvement of the published information on a continuing basis; such publications can be termed “dynamic.” The contradiction between the traditionally static nature of scientific publications and the new opportunities to change and update their contents online may be partially overcome by citing the version and date of access of a website. However, this does not fully identify the information being cited unless the Web site is systematically archived with version numbers (in which case the versions become static publications). The possibility of accurately citing a Web resource, however, does not transform it automatically into a formal scientific publication because other steps of the publishing process (see i–vii above) must also be applied during creation of the particular Web resource.

We offer a solution to formalize publication of dynamic interactive keys. The first version of datasets underlying a Web-based interactive key may be published in an online journal or book as data files, complete with title, authors, abstract, possibly introduction and other relevant text material. Such a practice would bring benefit to the authors ensuring their priority, publication and citation credit, as well as a proper dissemination, archiving and indexing of the first published work through the established channels the scholarly publishing.

Publishing keys

In the context of identification, examples of reconciliation between the dynamic nature of the Internet, and the static nature of conventional publications, are the pioneering models of Flora Online (<http://www.mobot.org/plantscience/ResBot/FO/FloraOnline.htm>) and the Canadian Journal of Arthropod Identifications (CJAI) (Marshall 2008;

see journal's Web site at: <http://www.biology.ualberta.ca/bsc/ejournal/ejournal.html>). Flora Online was the first electronic journal to receive an ISSN number from the Library of Congress. It published several interactive keys, as well as checklists, etc., in the period 1987–1993. It was available online (but the keys could not be *used* online – they had to be downloaded, and used offline), and was also distributed on floppy disks. Once published, material could not be altered, although new versions could be (and were) published.

CJAI offers at least two versions of each key: a dichotomous key is embedded in a conventional PDF publication, and a separate and possibly enhanced HTML version of this key is made available online. A limited number of printed copies of the PDF file are distributed to libraries. Despite the advances the CJAI model has provided, one limitation is that CJAI does not include the raw data files that were used to generate the keys. Unless the data files are obtained from the original authors, future revisers will be forced to duplicate much of the work that went into the original publication. For example, adding a single species to an already published key often requires substantial time and effort.

Here we suggest criteria for a more complete static publication model for keys, utilizing the resources we have at the present time (see also Fig. 1):

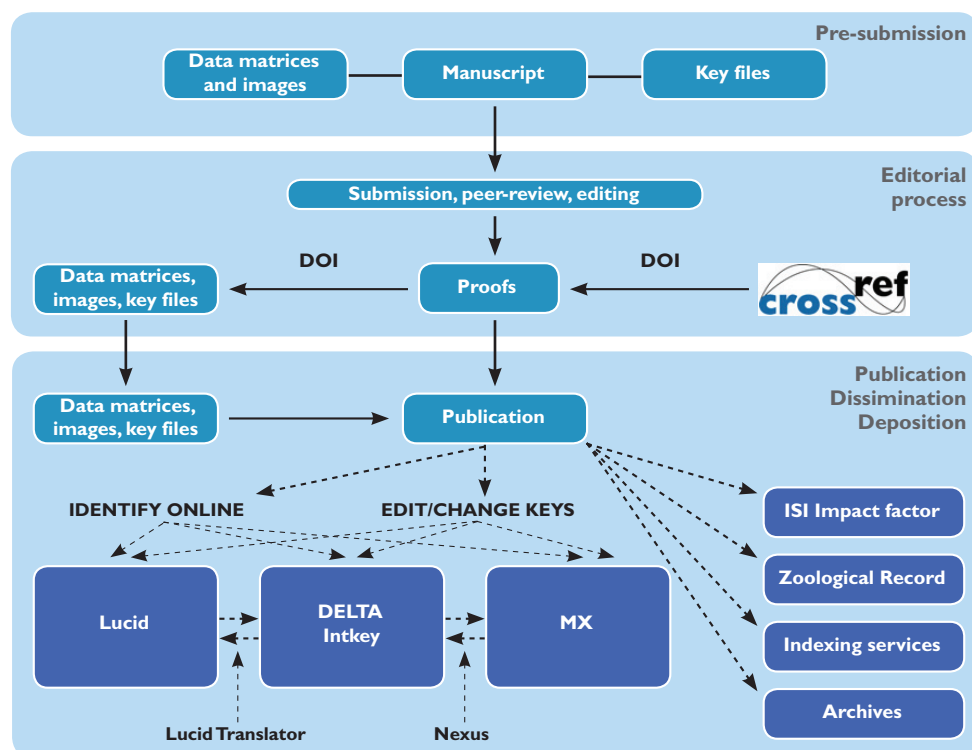


Fig. 1. The ZooKeys model for data publication and dissemination of interactive keys.

1. **Publication of keys in the traditional, dichotomous form on paper in a journal, report, or book, normally with an ISSN or ISBN.** The journal article or book might include, or be closely associated with, supplementary material such as full descriptions, interactive keys, images, and the data from which the keys, descriptions, etc. were generated. This material might be on microfiche, floppy disk, CD, or DVD. Some examples are: Watson and Dallwitz (1981) (supplementary material on microfiche); Britton (1986) (DELTA data included in the paper publication); Watson and Dallwitz (1988) (supplementary material, including interactive key, on microfiche and floppy disks; Pirchegger (1998) (supplementary material on CD-ROM).
2. **Publication of keys in the traditional, dichotomous form in an online (or both online and print) journal or book.** The article might be closely associated with supplementary online material such as full descriptions, interactive keys, images, and the data from which the keys, descriptions, etc. were generated. The article and the associated material are associated with a single DOI, if a key is published stand-alone. In case a key or keys is/are published as a part of larger paper, e.g., taxonomic revision, their datasets can be published as supplementary files under separate DOIs (usually semantically related to the DOI of the article). Examples that include such supplementary material under a single DOI are the first 8 issues of CJA (http://www.biology.ualberta.ca/bsc/ejournal/ejournal.html, accessed 6 September 2009). The DOI of each issue resolves to a HTML file containing the author, title, and abstract, and also containing links to the article in PDF form, and links, direct and indirect, to the supplementary material.
3. **Stand-alone publication, under separate DOIs, of interactive keys or dichotomous HTML keys.** This type of publication should comprise the necessary program and data files and/or HTML pages; title, authors, date, and abstract; and possibly associated material such as an introduction. The interactive keys would usually work online, but might also (or sometimes only) be available for downloading and use offline.
4. **Stand-alone publication, as a downloadable set of files under a separate DOI, of all primary data files related to the keys (e.g., data matrices and images).** This type of publication should contain title, authors, date, and abstract; and possibly associated material such as an introduction. The data files will be preserved primarily on the publisher's server and secondarily through leading international e-publication archives, such as LOCKSS, Portico, e-depot and others. This option will allow the updating of the data, and generation from the data of new keys (to be republished statically or dynamically) by researchers other than the original authors (naturally, provided that the original author and source are credited). For the data files, adoption of standards developed and supported by the Biodiversity Information Standards (TDWG) (http://www.tdwg.org) community is recommended to ensure maximum interchangeability and persistence. The latest TDWG standard is Structured

Descriptive Data (SDD); however, the earlier DELTA standard is still widely used, and neXML (NEXUS file format, <http://www.nexml.org>) may reach maturity in the near future.

Any or all of criteria 1–4, applied together with criteria i–vii for formal publication, will ensure that authors of the publication(s) get credit through peer review, registration, citation, distribution, dissemination, long-term preservation, and bibliometry. This will incorporate all of the advantages of the traditional and open access models, while allowing wide dissemination and reuse of original data, multiplying the benefits to both authors and the end users.

Well-referenced primary data files are encouraged, with literature citations and information on voucher specimen material provided for each couplet, Operational Taxonomic Unit (OTU), image, or matrix coding

To provide maximum dissemination and use, a key potentially may be published as a combination of some or all 4 forms listed above, as it is partly illustrated in the paper of Sharkey et al. (2009) in the present issue.

Key data files, key program files, primary data files

The different software packages for implementing interactive keys have different folder and file structures for their data and programs. As examples, we illustrate these structures using the fruit-fly package at <http://delta-intkey.com/ffa/> (Carroll et al. 2002). The package is generated from DELTA data files, and consists of natural-language descriptions, with links to images of the taxa, and interactive keys using Intkey, Lucid2, and Lucid3.

The contents of the folder <http://delta-intkey.com/ffa/> is shown in the listing `ffadir.txt`, which is published with the present paper (Appendix 1, doi: 10.3897/zookeys.21.274.app.1.ik.).

Publishing of MX data files is illustrated on the example of the paper of Sharkey et al. (2009, doi of the data files: 10.3897/zookeys.21.271.app.4.ik)

“Key data files” and “key program files” are the files required for running an interactive key. The “basic” key data files are the minimum set of files required to run the key, such as the character list, taxon names, and data matrix. The “supplementary” key data files are the other files used by the key, such as images and descriptions. As published, the keys would normally be run online, that is, via an Internet connection. Some keys can *only* be run online, because the key program is designed to run on a Web server rather than on a personal computer. In other cases, it may be possible, at least in principle, to download the keys and run them offline. However, such keys may not be downloadable in practice because of restrictions imposed by the Web site. Some kinds of interactive key may work *only* by downloading and running them offline, but this is rare nowadays.

“Primary data files” are the data files from which the key data files and other products (e.g., dichotomous keys, descriptions, classifications) are generated. The “basic” primary data files contain data such as the character list, taxon names, and data matrix.

The “supplementary” primary data files are associated files such as images and descriptions (if the latter are not generated from the basic data). The basic primary data files are usually different from the basic key data files. However, some key programs use the primary data files directly, e.g. NaviKey (NaviKey 2009), which runs directly from DELTA data files (plus other files).

Intkey

The *Intkey program files* must be downloaded and installed on the user’s computer before the interactive keys can be run. The program requires MS-Windows. Later versions of Intkey have more features, and these features have often required corresponding enhancements of the Intkey data files. Nevertheless, all recent program versions and data versions are intended to be compatible, and new program versions have bug fixes, as well as enhancements. It is therefore recommended that the latest version of Intkey (see <http://delta-intkey.com/www/programs.htm>) should always be used, rather than storing older versions of the program on journal Web sites.

The *basic key data files* are ffa.ink and ffai.zip; ffa.ink is a “startup file”, containing information about the locations of various files:

```
: To run the Intkey identification package from this file
; you need Intkey5 and Windows 95/NT or later
;
InkFile=http://delta-intkey.com/ffa/ffa.ink
; Name of this file
DataFile=http://delta-intkey.com/ffa/ffai.zip
; Name of the compressed data file
InitializationFile=intkey.ink
; Name of the Intkey initialization file within the compressed data file
ImagePath=http://delta-intkey.com/ffa/images
; Image path
InfoPath=http://delta-intkey.com/ffa/info
; Information path
```

Two folders, “images” and “info”, contain images and RTF descriptions that may be accessed by the key. (“www” contains the same descriptions in HTML format. These are not used by Intkey; they are linked from the main contents page (<http://delta-intkey.com/ffa/index.htm>) so that users can view them *without* using Intkey.)

When the user follows the link to ffa.ink (from the Web page “Pest Fruit Flies of the World - Interactive Keys”: www/_wident.htm), this file is read by Intkey (which must already be installed on the user’s PC). Intkey then uses this information to download (to a temporary file) and read the file ffai.zip, which contains all of the information necessary for the basic key. If and when the user asks to see an image or descrip-

tion, that image or description is downloaded to a temporary file and displayed (i.e., the same way that image and HTML files are handled when viewed in a browser).

When the user exits from the key, Intkey asks “*Do you want to save the data set you have just downloaded and used on your own disk?*” If the user clicks “Yes”, the temporary copies of ffa.ink and ffai.zip are copied to permanent files in a folder of the user’s choosing, and ffa.ink is modified to point to this copy of ffai.zip. Thus, when the user later opens this local ffa.ink, Intkey gets the basic key files from the local copy of ffai.zip, and doesn’t need to access the Web. However, the Web will still be accessed if and when the user asks for an image or description, because ffa.ink is still pointing to the Web folders for those files. The user can, if he wishes, download the complete “images” and “info” folders (e.g., by ftp), and modify ffa.ink to point to the local copies. Then the key will never access the Web (unless, of course, it happens to contain links to other Web resources, e.g., in citations of publications).

If the user clicks “No” in response to the “*save the dataset?*” prompt, Intkey asks “*Do you want to add the URL for the data set to the index file?*”. If the user clicks “Yes”, Intkey adds the URL to its own index file. This index is displayed whenever Intkey is started, and the user can choose any of the datasets in the index (which may include local keys, as well as ones on the Web).

To summarize, all the user normally has to do is click on the link to the key, and then choose whether to save and/or index the key on exit.

The **basic primary data files** from which the key and other products are generated comprise (normally) three DELTA text files: specs, chars, and items. In addition, there are other “directives” files which describe the links from characters and taxa to the images, and how the data are to be processed into other forms (e.g. where to put new paragraphs in descriptions), and subsidiary files such as the introduction and references. The author would normally keep all of these in a single folder. The **primary data files** comprise a zipped version of this folder, and the folder containing the images. (The descriptions that accompany Intkey packages are not normally part of the primary data files; they are generated from those files.)

The DELTA Editor has its own binary data files, but these are not recommended for data exchange. The Editor imports and exports DELTA text files.

Lucid2

The **Lucid2 key program files** must be downloaded and installed on the user’s computer before the interactive keys can be run. The program requires MS-Windows. There may be incompatibility between program and data versions, but any newly published key will presumably use the latest version, which is available at <http://lucidcentral.org>, or Lucid3 (see below).

The **basic key data file**, to which the Web page links, is “pest fruit flies.lcd”. When the user follows the link to this file, it is read by the Lucid2 Player (which must already be installed on the user’s PC). The key links to images in the folder “images” (shared

with Intkey), descriptions in the folder “html”, and macros in the folder “macros”. The descriptions in the “html” folder are almost the same as the ones in the “www” folder, except that the latter contain a link back to the contents page, which is not appropriate in the Lucid context. Both forms are generated automatically from the DELTA data.

The key file can be downloaded by the usual browser mechanism, and run locally. It will access images and descriptions from the Web as required.

Although the “images” and “html” folders can be downloaded (e.g., by ftp), the downloaded key won’t be able to access them. This is because the paths are built into the binary key file (unlike Intkey, where they are in easily modified text files). To access the images etc. locally, it would be necessary to download the LIF data file (see below), and rebuild the key.

The **basic primary data file** from which the key is generated is a Version 2 LIF file. The **primary data files** comprise this file and folders containing the images, descriptions, and macros.

The Lucid Builder Version 2 has its own binary data files, which are not normally used for data exchange. The Builder imports and exports LIF files.

Lucid3 applet keys

Lucid3 applet keys will run under MS-Windows, Solaris, Linux, and Mac OS X. All of the **Lucid3 key files**, comprising the key data files and the key program files, are packaged for Web deployment by the Lucid Builder, as follows.

```
l3\ffa.html
l3\key\ffa.lkc3
l3\key\ffa\ffa\ffa.* (i.e. ffa.dep, .fil, .sco, and .xml)
l3\key\ffa\media\images\* (the images)
l3\key\ffa\media\html\* (the descriptions)
l3\lucid_player\* (the program)
```

This directory structure is rigidly imposed by the Lucid3 Builder. It is a little awkward to share the images with Intkey and/or Lucid2, but it could be done by using the greater flexibility of the latter programs.

Before using the key, the Java Runtime Environment (JRE) must be installed on the user’s local (client) computer. When the user follows a link to “l3\ffa.html”, the applet in the “l3\lucid_player” folder is downloaded and run. The applet then downloads the rest of the key files.

The basic key will work locally if the directory tree containing the basic key files is downloaded, but it won’t access the images etc. from the Web. The key will work locally if the *whole* directory tree is downloaded (i.e., including the “media” tree); however some Web sites may not support downloading.

The **basic primary data file** from which the key is generated is a Version 3.x LIF3 file. These are XML files, and the later versions at least are supposed to conform

to SDD. The **primary data files** of a static publication comprise this file and folders containing the images and descriptions.

The Lucid Builder Version 3.x has its own binary data files, which are not normally used for data exchange. The Builder imports LIF and LIF3 files, and exports LIF3 files (export is only in the latest LIF3 format, which can't be read by earlier 3.x Builders).

Lucid3 keys can now be implemented by a program running on the server (instead of by an applet on the client) (Lucidcentral 2009).

MX

MX (Yoder et al. 2006) keys are Web based. To build new keys a user must either obtain an account with an existing instance of MX or a new installation on a machine that runs a Web server. Basic installation instructions are found on the MX wiki (<http://purl.oclc.org/net/mx-installation>) and presently require fairly advanced technical experience. The project is open source with the code base available on SourceForge (<http://sourceforge.net/projects/mx-database/develop>). MX is coded in Ruby on Rails with a MySQL database.

There is not a specific **key file** for MX, however, **data files** are downloadable as text. Present examples of these files are linked in the Revision of the Oriental genera of Agathidinae (Sharkey et al. 2009) and contain database-generated output describing components of the key. These include: a character/character state list, and NEXUS file. Images are also made available and linked to character state and Operational Taxonomic Unit (OTU) descriptions. These output files are adequate to properly recreate the key, but the format of these files (except the NEXUS file) are presently under review and should not be considered standardized output at the present time.

To run the key a user needs Internet access and the key URL (<http://purl.oclc.org/NET/oriental-agathidinae>). MX is optimized for Firefox Web browser.

To summarize, Table 1 provides a list of minimum set of files to be published for each platform.

Table 1. Minimum set of files to publish for Intkey, Lucid and MX to ensure a proper data use and re-use

Platform	Key data files	Primary data files	Software
Intkey	.ink startup file, .zip data file, images, descriptions	specs, chars, items, other directives files, images	Intkey5
Lucid2	.lcd file, images, descriptions, macros	Version2x .LIF, images, descriptions, macros	Lucid2 Player
Lucid3	.html, .lkc3, .dep, .fil, .sco, and .xml; images, descriptions	Version3x .LIF3, images, descriptions	Lucid3, Java Runtime Environment (JRE)
MX	none	NEXUS, Character list with image ids, OTU list with image ids, images	MX, Web-based

Flexibility of data use

It is desirable to have software to convert between the different formats for primary data, so that users can use take advantage of the capabilities of a variety of programs.

The program Confor (a component of the DELTA software package available at <http://delta-intkey.com/www/programs.htm>) translates basic DELTA data (the “specifications,” character list, taxon names, and matrix, i.e. the “specs,” “chars,” and “items” files) into Nexus format, but important information may be lost because of the limitations of the Nexus format, at least in the version targeted by this conversion (see Dallwitz 1999). The program NDE (<http://taxonomy.zoology.gla.ac.uk/rod/NDE/nde.html>) can convert NEXUS data to DELTA.

The Lucid Translator (<http://www.lucidcentral.org/Software/Lucid3/LucidBuilder/LucidTranslator/tabid/189/Default.aspx>, accessed 30th of June 2009) translates between basic DELTA data and Lucid Interchange Format Version 2 (.LIF files), in both directions. However, the capabilities of these formats differ, and important information may be lost in both directions of translation (see Dallwitz 1999). For example, LIF does not support text characters or characters with more than 15 states, and DELTA does not directly support the Lucid “by misinterpretation” coding (though a workaround is available – see DELTA Programs - Test Versions and Utilities: <http://delta-intkey.com/testp/>). Later versions of Lucid Interchange Format support more of the DELTA features, but there is no direct route between these versions and DELTA. Version 2 LIF files can be imported into later versions of Lucid, and thus provide a pathway from DELTA (with the associated information loss already mentioned), but conversion in the other direction is currently not possible.

The key to Oriental agathidine genera (Sharkey et al. 2009) in the present issue was originally produced using DELTA and subsequently converted to Lucid. The Lucid Translator was used to import the basic DELTA data into the Lucid Builder, as described above. However, the taxon and character images had to be linked manually to the Lucid key.

A complete translator is not at present available to convert DELTA to MX. The basic DELTA data was acquired from a Nexus file produced by Confor, as described above. Images were associated with character states using information in the DELTA cimages file. The images were manually associated with character states and needed reformatting before entering them into MX. Multiple images illustrating character states were combined into one image in the Oriental Agathidinae DELTA data. These had to be broken apart back into individual images before importing them to MX for illustrating character states. Import scripts for images, OTU names and characters were used after the data was manipulated into a format MX handles.

Previously publications also allowed comparison of interactive keys using different software with the same data: Carroll et al. (2002) for Intkey, Lucid2 and Lucid3 and Watson and Dallwitz (2004) for Intkey and NaviKey; and the DELTA data are available from the authors on request. However, Sharkey et al. (2009), in addition to including a MX key, provide a solution for a formal, static publication of the keys.

Copyright

Copyright law is complex, varying between countries and content type. Different legal tools exist to attempt to simplify the process allowing easy application of licenses for creative and scientific products, ensuring future open access to these products.

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Identification, location and citation

There is at least one good reason to identify data separately from the publication they are related to. Published data may be incorporated into larger datasets and should be identified properly so that the original author and source may be traced in consequent uses. The DOI number assigned to a published dataset serves as such an identifier; moreover, it holds the function not only of *identifier* but also as a bibliographic metadata *descriptor* (through CrossRef, <http://www.crossref.org>), as well as a locator (through CrossRef's domain <http://dx.doi.org>). Moreover, the number of downloads of data files can be tracked separately and automatically and further exposed on the site so that authors will gain additional credits for use of their data.

Another reason to provide separate citation details for datasets implies in cases where several interactive keys of different taxa are published as datasets within one and the same paper, e.g., in a large taxonomic revision.

The DOIs of the publication and datasets/keys related to it can be described in a form of a “parent-child” relationship. It seems convenient DOIs of datasets/keys to be semantically related to the DOI of the “parent” publication to facilitate harvesting and indexing through machine-generated methods. Datasets related to interactive keys can be identified with the acronym “ik” (from “interactive keys”) within its DOI, which is a semantic extension of the paper’s DOI (worked examples from the paper of Sharkey et al. (2009) in the present issue):

if a DOI of a paper is: 10.3897/zookeys.21.271

then the DOI of the dataset will have the form:

doi: 10.3897/zookeys.21.271.app.1.ik

which means that the downloadable file is published as Appendix 1 of the paper.

Naturally, in most cases of stand-alone publications of interactive keys, there is no need to imply a “child” DOI, because it can’t identify the key as a separate digitally published object. In such cases, it would be enough to assign a DOI to the publication itself and a link to either associated data files or to the external Web platform where the key is hosted.

To summarize, we describe the following combinations to identify and cite online keys, in correspondence with criteria 1–4 listed in the “Publishing Keys” section above:

1. Interactive keys are published stand-alone and contain bibliographic metadata descriptors (author, title, publication date, publication details, abstract), possibly introduction, as well as supplementary files published and hosted on the journal’s platform:

<Author> <(Year)> <Title of the publication> <Journal, volume, issue, pages>
<Doi of the publication>.

2. Interactive keys are published dynamically and hosted on an external Web platform; their first-version datasets are published stand-alone in an online journal or book and contain bibliographic metadata descriptors (author, title, publication date, publication details, abstract), possibly introduction, as well as a Web link to the key:

<Author> <(Year)> <Title of the publication> <Journal, volume, issue, pages>
<Doi of the publication>. Interactive key: <Interactive key format > <Link to the external Web site>. Version (if applicable), day of accession.

3. Interactive keys are published as datasets accompanying either a conventional dichotomous key or a paper of a wider scope (e.g., taxonomic revision):

<Author> <(Year)> <Legend of the dataset>. <File format> DOI of the dataset
<DOI> Dataset published in: <Journal, volume, issue, pages> < DOI of the publication>

Dissemination and use

Publishing the datasets underlying a taxonomic paper under the open access model benefits everyone, from the authors to other researchers, as well to publishers and society in general. The social and psychological constraints, benefits, and incentives are being actively discussed (i.e., Costello 2009; Smith 2009). We believe that publishing online keys in a variety of forms (conventional dichotomic, interactive dichotomy or matrix, static or dynamic) within one and the same publication will visibly enhance their use and citation rates. By opening the possibility to modify and update keys, a long-standing perpetuity of a key's life is facilitated, bringing all of the deserved credits to the original and subsequent authors.

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Appendix I.

Listing of directory containing key files for the fruit-fly interactive keys package at <http://delta-intkey.com/ffa/> (Carroll et al. 2002). doi: 10.3897/zookeys.21.274.app.1.ik.

See section *Key data files, key program files, primary data files* for details.

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Revision of the Oriental genera of Agathidinae (Hymenoptera, Braconidae) with an emphasis on Thailand including interactive keys to genera published in three different formats

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§ [urn:lsid:zoobank.org:author:7CCD166F-F1FA-43DA-B582-4E84EAF59AD1](https://zoobank.org/urn:lsid:zoobank.org:author:7CCD166F-F1FA-43DA-B582-4E84EAF59AD1)

| [urn:lsid:zoobank.org:author:35527E46-D787-49B4-B7B4-C4A0A81E4661](https://zoobank.org/urn:lsid:zoobank.org:author:35527E46-D787-49B4-B7B4-C4A0A81E4661)

¶ [urn:lsid:zoobank.org:author:1DC4B249-A873-4ACF-AA8F-5FF3AE56803A](https://zoobank.org/urn:lsid:zoobank.org:author:1DC4B249-A873-4ACF-AA8F-5FF3AE56803A)

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[urn:lsid:zoobank.org:pub:4ED41545-BCA4-4F84-B4C6-647F7DE849EB](https://zoobank.org/pub:4ED41545-BCA4-4F84-B4C6-647F7DE849EB)

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Abstract

The genera of Oriental Agathidinae are revised and a fully illustrated dichotomous key is presented. New generic concepts are proposed for *Basus* Fabricius, 1804 and *Hypsoctypus* Baltazar, 1963. *Basus* is restricted to a clade with an Old World distribution and the remaining members are divided amongst the resurrected genera *Camptothlipsis* Enderlein, 1920, *Lytopylus* Förster, 1862, and *Therophilus* Wesmael, 1837. The concept of *Hypsoctypus* is restricted and the new genus *Amputostypus* Sharkey, **gen. n.** is proposed to include species formerly included in *Hypsoctypus* that do not have raised antennal bases. *Troticus* Brullé, 1846 is reported from the Oriental region for the first time. Eighteen genera are recognized for Thailand and neighboring areas, i.e., *Agathis* Latreille, 1804, *Amputostypus*, *Aneurobracon* Brues, 1930, *Bassus*, *Biroia* Szépligeti, 1900, *Braunsia* Kriechbaumer, 1894, *Camptothlipsis*, *Coccygidium* Saussure, 1892, *Cremnops* Förster, 1862,

Disophrys Förster, 1862, *Earinus* Wesmael, 1837, *Euagathis* Szépligeti, 1900, *Gryochus* Enderlein, 1920, *Hypsostypus*, *Lytopylus* Förster, 1862, *Therophilus*, *Cremnoptoides* van Achterberg & Chen, 2004, and *Troticus*. Identification keys to the genera are provided as a standard textual dichotomous key, as well as online keys in three different formats (conventional dichotomous, DELTA/Intkey, Lucid, and MX) to enable users to choose their preferred platform and to allow direct comparisons of the technologies for producing online keys. Publication of underlying data (data matrices, character states table, and images) under the OpenData-Commons license (ODbl) (<http://www.opendatacommons.org/licenses/odbl/1.0/>) for DELTA/Intkey files (doi: 10.3897/zookeys.21.271.app.1.ik), primary DELTA files (10.3897/zookeys.21.271.app.2.ik) Lucid3 (LIF3) and Lucid SDD key data files (doi: 10.3897/zookeys.21.271.app.3.ik) and MX MySQL database files (doi: 10.3897/zookeys.21.271.app.4.ik) allows future workers to edit keys and to add newly described taxa. The data files for the keys published and stored on the publisher's website and in e-archives have the rights of "first publication" identified by its bibliography data, location and citation. Readers should cite the first published version and the day of accession in case they use future online versions of the same key. The concept of publication, citation, preservation, and re-use of data files to interactive keys under the open access model is discussed in a forum paper published in the present issue (doi: 10.2897/zookeys.21.274).

Keywords

Ichneumonoidea, Braconidae, new genus, new combination, new synonym, new status, identification key, interactive keys, data publishing

Introduction

Agathidinae is a moderately large subfamily of Braconidae with 1,061 described species worldwide and 238 in the Oriental Region (Yu et al. 2005). Though there are an estimated 2,000–3,000 species awaiting description worldwide (Sharkey et al. 2006). The subfamily has a worldwide distribution and members are found in most terrestrial habitats. Though all known species are koinobiont endoparasitoids of lepidopteran larvae, life history traits vary considerably. Depending on the species, they may be nocturnal or diurnal, gregarious or solitary, attack exposed or concealed hosts, and attack any larval instar. In general they are solitary, attack first-instar Lepidoptera larvae in concealed microhabitats such as leaf-rolls or stems, and emerge from the last larval instar of the host after it has spun its cocoon. Detailed studies of life history have been conducted for a few species (e.g., Simmonds 1947, Dondale 1954, Odebiyi and Oatman 1972, 1977, Janzen et al. 1998) and a few have been used in classical biological control efforts. Currently there are about 50 genera recognized (Sharkey 1992). The history of higher classification of the Agathidinae was summarized by Sharkey (1992) who also proposed a tribal-level classification based on groundplan coding.

Sharkey et al. (2006) conducted phylogenetic analyses based on morphology and the D2–3 regions of 28S rDNA. Perhaps their most noteworthy result was a clear demonstration of the polyphyletic nature of the genus *Bassus*, however it was beyond the scope of the paper to adjust generic classification. Here we begin to correct this problem by resurrecting two junior synonyms of *Bassus* and restricted *Bassus* s.s. to a relatively small Old World clade.

The Oriental fauna of Agathidinae were revised by Bhat and Gupta (1977) and they provided a detailed history of taxonomic research for the area. Many of the generic

concepts have changed since their publication and here we revise and update the generic concepts and provide a key to genera. This is a prelude to a complete revision of all of the species of Agathidinae found in Thailand funded by a USA, NSF grant to explore the terrestrial insect fauna of Thailand. As part of the inventory of Thai insects we have run 3 Malaise traps at 30 different localities throughout Thailand since 2007, comprising approximately 90 Malaise trap years.

Materials and methods

Material for this study was primarily collected in Malaise traps operated throughout Thailand since 2007. Raw Malaise trap samples were sent to the Queen Sirikit Botanic Gardens (QSBG) in Chaing Mai, Thailand, where the Agathidinae and many other taxa were separated. These were then sent to the Sharkey lab in Lexington, Kentucky where they were treated in hexamethyldisilazane, mounted, and labeled. Most species have been sequenced for COI and the D2–3 regions of 28S. Holotypes of all material will be returned to QSBG. For more details on the Thai inventory visit <http://sharkeylab.org/tiger/>.

Images for this study were taken with an Automontage© imaging system mounted on a Leica MZ16 stereomicroscope. The taxonomic decisions were based primarily on the analyses published in Sharkey et al. (2006) many of which have been confirmed by more recently obtained unpublished sequence data.

Following the key to genera, below, each genus is treated in alphabetical order. Included in these treatments are discussions of distribution, diversity, phylogeny, biology, and diagnosis. Where warranted, a section on taxonomic decisions is included. Each generic treatment includes a full lateral habitus and an image of a forewing. There are also three published interactive keys available. They are in the following formats: Intkey, Lucid, and MX.

The dichotomous key was generated using DELTA software (<http://delta-intkey.com>). Data, species names, characters and character states were entered into Delta Editor (Dallwitz 1980; Dallwitz et al. 1999). The “tokey” file was edited to select and weight the characters used for the dichotomous key, and the modified file was exported from DELTA to produce the key which was then lightly edited to produce the final version (Dallwitz 1974; Dallwitz 1980; Dallwitz, Paine, and Zurcher 1993). The Intkey was produced in a similar manner using the DELTA file “toint” and the software Intkey (Dallwitz 1980; Dallwitz, Paine, and Zurcher 1993; Dallwitz, Paine, and Zurcher 1995). All source files and images used in this publication are available at <http://sharkeylab.org/sharkeylab/Misc/datasets/DeltaFiles/AgathidinaeThaiDeltaFiles.zip> and in Appendices 1 and 2 of the present paper (doi: 10.3897/zookeys.21.271.app.1.ik and doi: 10.3897/zookeys.21.271.app.2.ik). These files are open to the public and future researchers are welcome to download them if they wish to modify, correct, or add newly described taxa for identification.

Online interactive matrix and dichotomous keys were also produced using Lucid (www.lucidcentral.org), and are available on Waspweb at: <http://www.waspweb.org/Ichneumonoidea/Braconidae/Keys/index.htm>. Users can choose between three different key formats depending on their personal preference: a standard dichotomous key, a Lucid Phoe-

nix key or a Lucid matrix key. Lucid Phoenix keys are interactive but still dichotomous and a choice needs to be made at each key couplet to continue. Lucid matrix keys, on the other hand, use a different approach where relevant states from multiple character features can be selected independently until identification is achieved. For more information concerning Lucid keys visit <http://www.lucidcentral.org>. Files are provided in two formats enabling conversion of the Lucid matrix key to other platforms: 1. Lucid Interchange Format version 3 (LIF3) files are XML based files that store all the Lucid3 key data, allowing exchange of the key with other key developers, and 2. SDD files are XML-based files structured using the internationally agreed SDD (Structure of Descriptive Data) Schema. SDD files may be used to exchange Lucid keys with other SDD-compliant applications. Lucid files are published in Appendix 3 of the present paper (doi: 10.3897/zookeys.21.271.app.3.ik).

A third interactive key to Oriental Agathidinae was generated using MX (Yoder et al. 2006-present) and is available at <http://purl.oclc.org/NET/oriental-agathidinae>. The MX MySQL database files are published in Appendix 4 (doi: 10.3897/zookeys.21.271.app.4.ik). The MX is optimized for viewing in Firefox. MX is an open source, web-based content management tool and workbench for systematists. The images, dynamically generated matrix in Nexus format, and specimen data from the key are available for download. The online key has the utility of dynamically updating from database additions. MX has a wide range of functionality beyond multi-entry and dichotomous key generation, information captured from other activities such as managing specimen data, images, phylogenetic characters, and ontologies may be incorporated into key content. The key to Oriental Agathidinae is dynamically linked to the Hymenoptera Anatomy Ontology (<http://hymao.org>), which provides a glossary of terminology for the key. More information regarding MX software is found at <http://purl.oclc.org/NET/mx-database>.

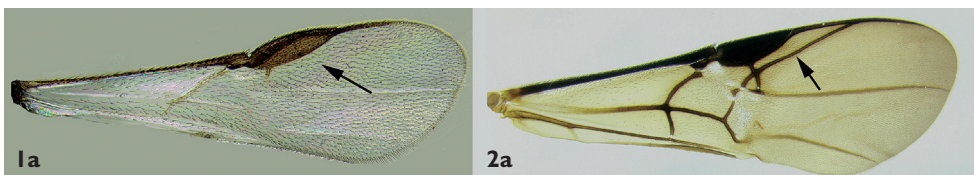
The key data files are published under the conditions of the OpenDataCommons license (ODbl) (<http://www.opendatacommons.org/licenses/odbl/1.0/>)

All new species have been registered with Zoobank (Polaszek et al. 2005).

The concept of data publication and dissemination of interactive keys under the open access model is discussed in a forum paper published in the present issue (Penev et al. 2009).

Key to Oriental Genera of Agathidinae

- 1 – Forewing venation greatly reduced, last abscissa (segment) of RS vein completely absent (1a) ***Aneurobracon* Brues, 1930**
- Forewing more complete, last abscissa of RS vein present though sometimes weak (1b) **2**



- 2(1). – Fore and mid claws cleft (2a) 3
 – Fore and mid claws with a basal lobe (2b) 12
 – Fore and mid claws simple (2c) *Bassus* Fabricius, 1804



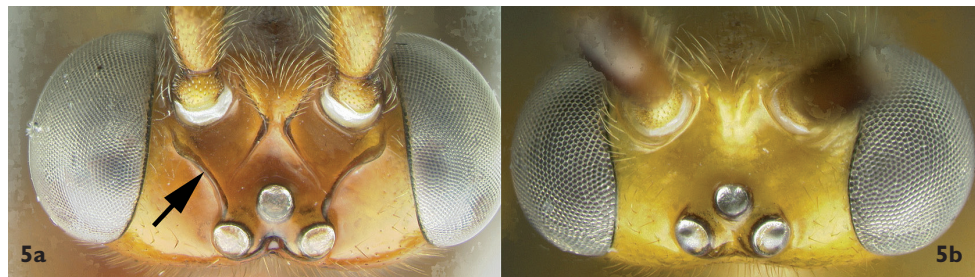
- 3(2) – Hind trochantellus with one or two distinct carinae (3a) 4
 – Hind trochantellus lacking carinae (3b) 7



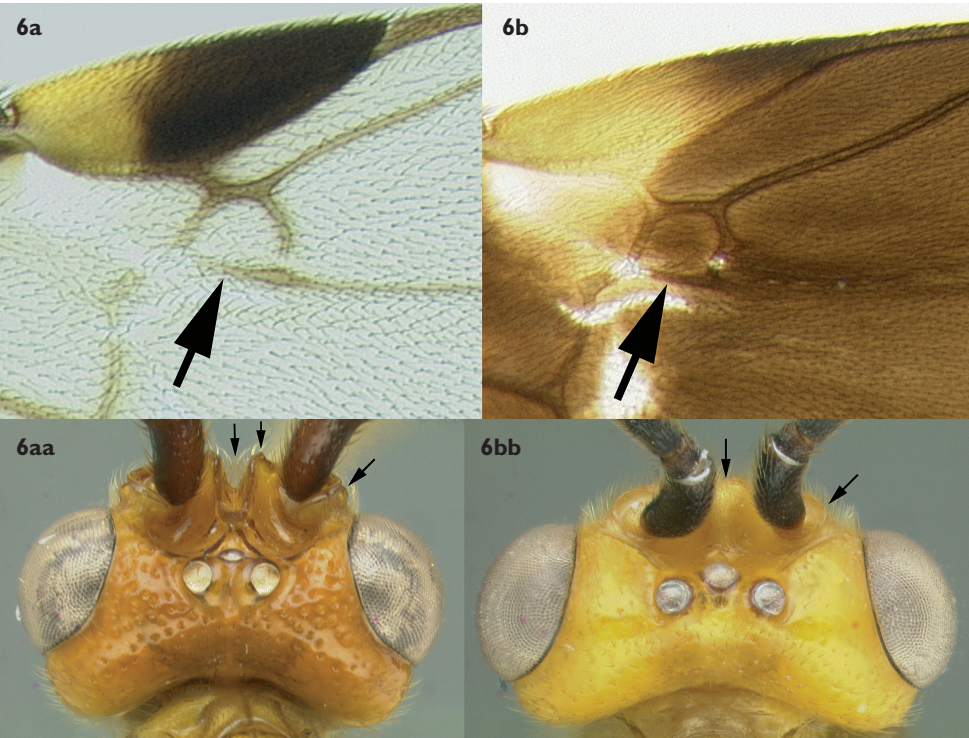
- 4(3) – Foretibial spurs about as long as basitarsus and ending in a long thin style (4a) *Coccygidium* Saussure, 1892
 – Foretibial spurs less than 3/4 length of fore basitarsus and ending more abruptly (4b) 5



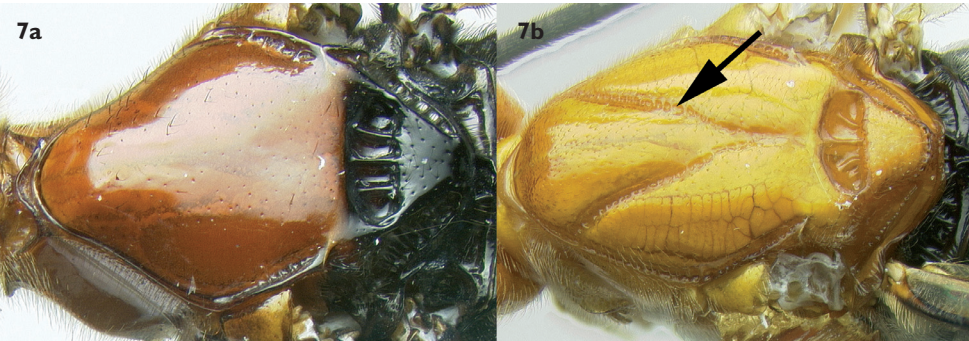
- 5(4) – Posterolateral margins of frons bordered with carinae (5a) 6
 – Posterolateral margins of frons not bordered with carinae (5b)
 *Amputostypos* Sharkey, gen. n.



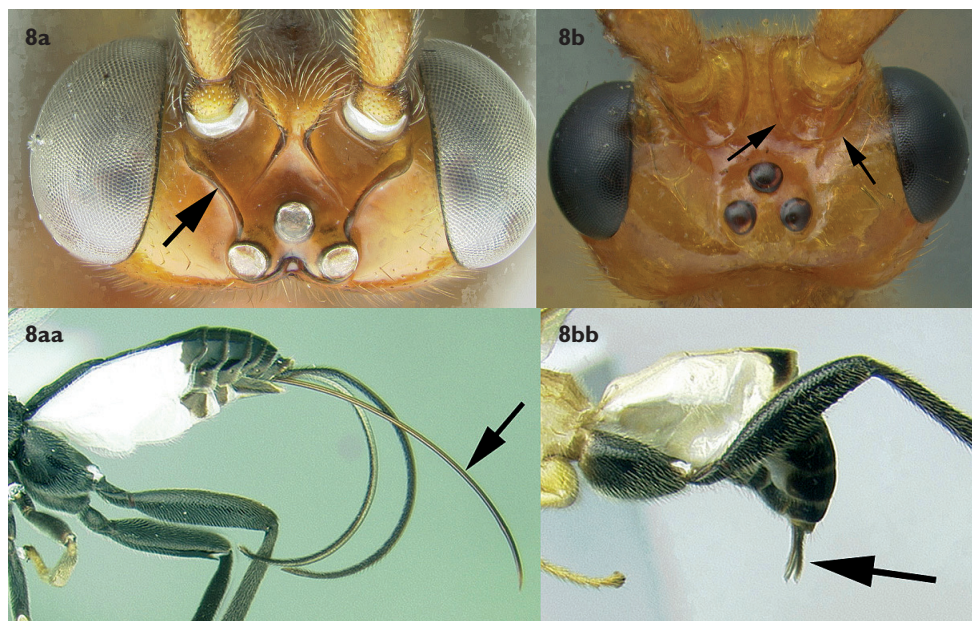
- 6(5) – 2nd submarginal cell of forewing triangular or at least anterior side distinctly shorter than posterior side (6a); base of antenna surrounded by pronounced medial, posterolateral, and anterior ridges; deep groove between antennae (6aa) *Hypsostypos* Baltazar, 1963
- 2nd submarginal cell of forewing quadrate, as wide anteriorly as posteriorly (6b); base of antenna surrounded by weak posterolateral, and anterior ridges; lacking deep groove between antennae (6bb) *Cremnoptoides* van Achterberg & Chen, 2004



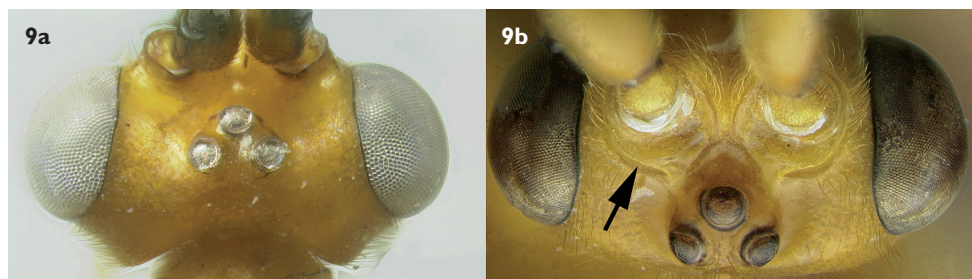
- 7(3) – Notauli absent (7a) 8
- Notauli present but not necessarily complete (7b)..... 9



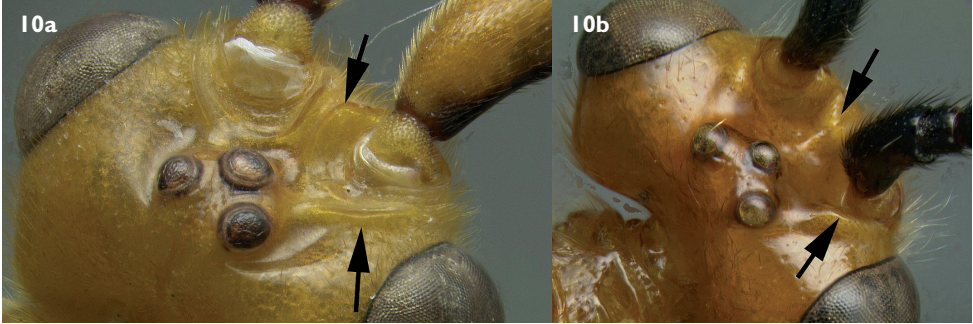
- 8(7) – Lateral carina of frons directed towards lateral ocellus and not fused with medial carina (8a); ovipositor at least as long as metasoma (8aa) *Biroia* Szépligeti, 1900
- Lateral carina of frons fused with medial carina forming a circular border around antennal base (8b); ovipositor barely exerted (8bb) *Gyrochus* Enderlein, 1920



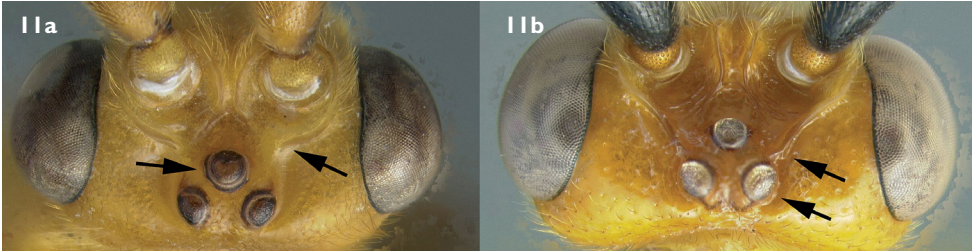
- 9(7) – Posterolateral margins of frons not bordered with carinae (9a) *Euagathis* Szépligeti, 1900
- Posterolateral margins of frons bordered with carinae (9b) 10



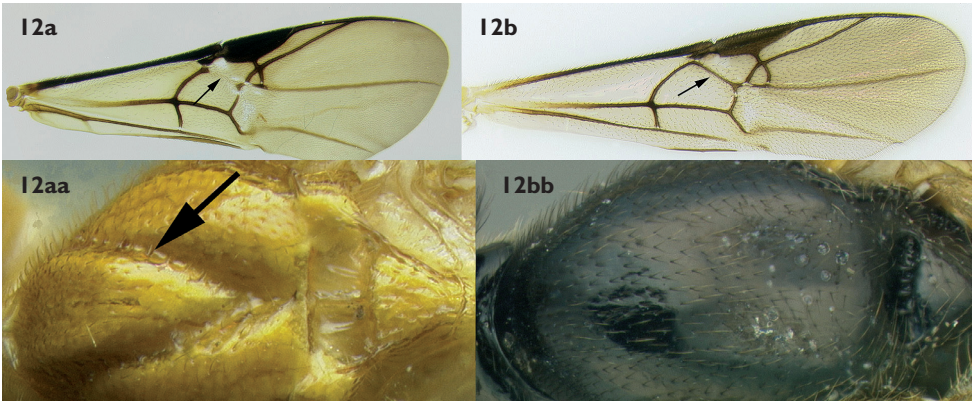
- 10(9) – Medial and lateral carinae of frons lamellate (high and thin) (10a); ovipositor barely exerted, much shorter than half length of metasoma (see Fig 8bb) . **11**
– Medial and lateral carina of frons in the form of blunt ridges, not lamellate (10b); ovipositor at least as long as the metasoma (see Fig. 8aa)
..... ***Cremnops* Förster, 1862**



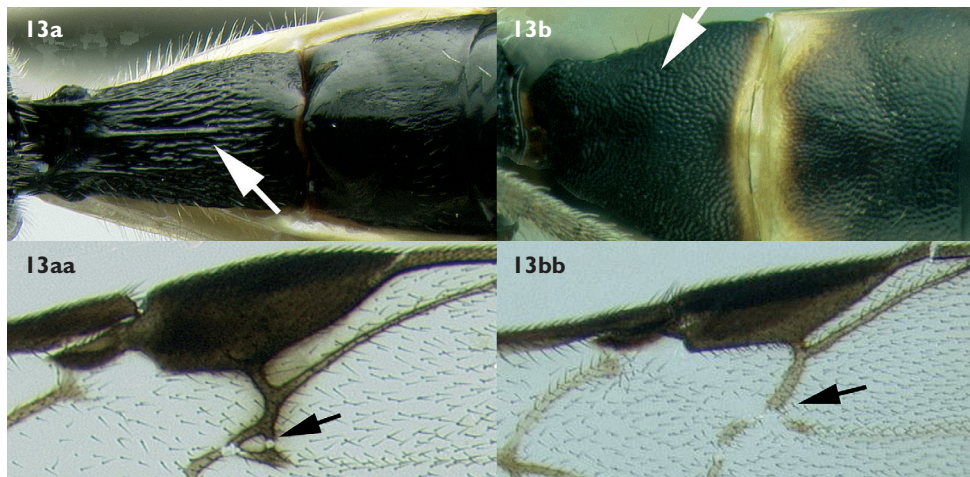
- 11(10) – Lateral carina of frons with posterior ends directed towards median ocellus (11a) ***Troticus* Brullé, 1846**
– Lateral carina of frons with posterior ends directed towards lateral ocelli (11b)..... ***Disophrys* Förster**



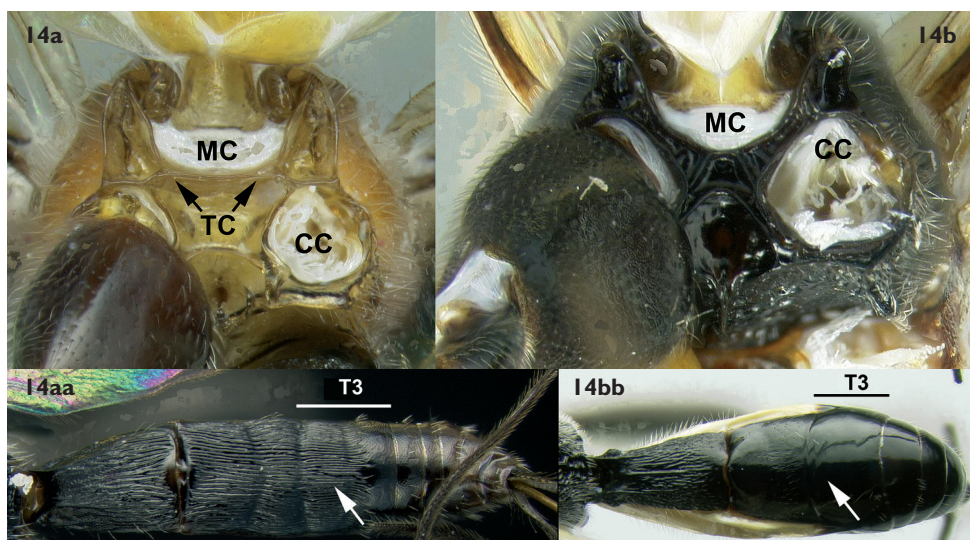
- 12(2) – RS+M vein of forewing mostly or entirely absent (12a); notauli present but not necessarily complete (12aa)..... **13**
– RS+M vein of forewing present and complete (12b); notauli absent (12bb) ***Earinus* Wesmael, 1837**



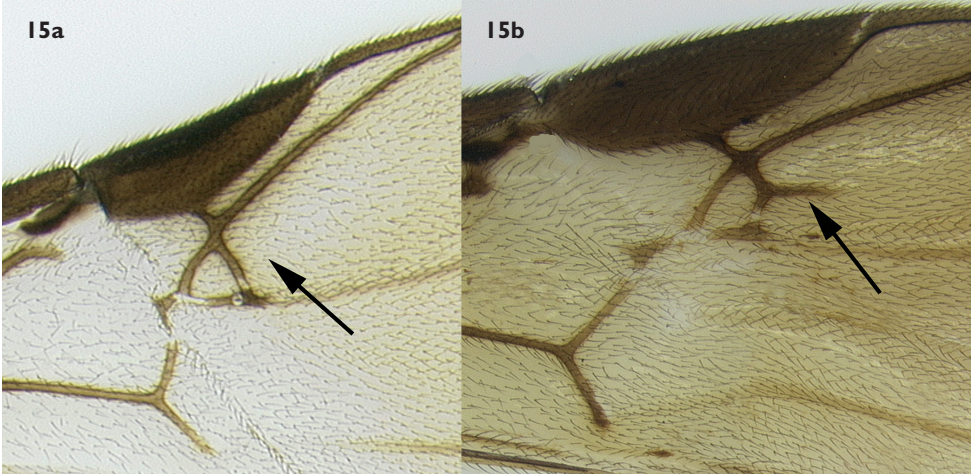
- 13(12) – First median tergite mostly striate (13a) or (rarely) smooth; 2nd submarginal cell of forewing usually present (13aa)..... **14**
 – First median tergite mostly granulate or coriaceous (13b); 2nd submarginal cell of forewing absent (13bb) *Camptothlipsis* Enderlein, 1920



- 14(13) – Metasomal cavity (MC) situated entirely dorsal to coxal cavities (CC) (14a); a wide, high, straight, transverse carinae (TC) present between metasomal cavity (MC) and coxal cavities (CC) (14a); median tergite 3 usually extensively striate in anterior half or more (14aa), sometimes with other sculpture, rarely smooth... **15**
 – Metasomal cavity (MC) situated partly between coxal cavities (CC) (14b); wide, high, straight, transverse carinae (TC) between metasomal (MC) and coxal cavities absent, usually curved and relatively shallow if present (14b); median tergite 3 smooth or (rarely) coriarious (14bb) **16**



- 15(14) – Adventitious vein (2RS) on r-m crossvein of forewing absent or indicated only by slight swelling (15a).....*Lytopylus* Förster, 1862
– Adventitious vein (2RS) on r-m crossvein of forewing present and distinct (15b)..... *Braunsia* Kriechbaumer, 1894



- 16(14) – Mouthparts long, galea significantly longer than wide; gena usually elongate (16a)*Agathis* Latreille, 1804
– Mouthparts short (normal), galea not longer than wide; gena not elongate (16b)..... *Therophilus* Wesmael, 1837



Generic Treatments

Agathis Latreille, 1804

Type species: *Agathis malvacearum* Latreille, 1805.

Cenostomus Förster, 1862, first synonymized by Muesebeck and Walkley (1951) and confirmed by Baltazar (1966), De Santis (1967), Shenefelt (1970), Bhat and Gupta (1977) and Marsh (1979). Type species: *Cenostomus lugubris* Förster, 1862.

Aenigmostomus Ashmead, 1900, first synonymized by Sharkey and Mason (1986) and confirmed by Chou and Sharkey (1989) and Sharkey (1998). Type species: *Microdus longipalpus* Cresson, 1865.

Rhamphagathis Tobias, 1962, synonymized by Sharkey (1998). Type species: *Agathis nasicornis* Telenga, 1955.

Distribution: Holarctic, with more diversity in cool temperate regions. No species of *Agathis* has been collected in Thailand or in the Oriental Region, but the occurrence of the genus in northern high-altitude areas is likely. Bhat and Gupta (1977) reported 45 species of *Agathis* for the Oriental region but they used a different generic concept that included *Bassus* s.s., *Therophilus*, and *Lytopylus* as they are defined in the present study. None of the species treated by Bhat and Gupta (1977) correspond to *Agathis* s.s., as it is interpreted here.

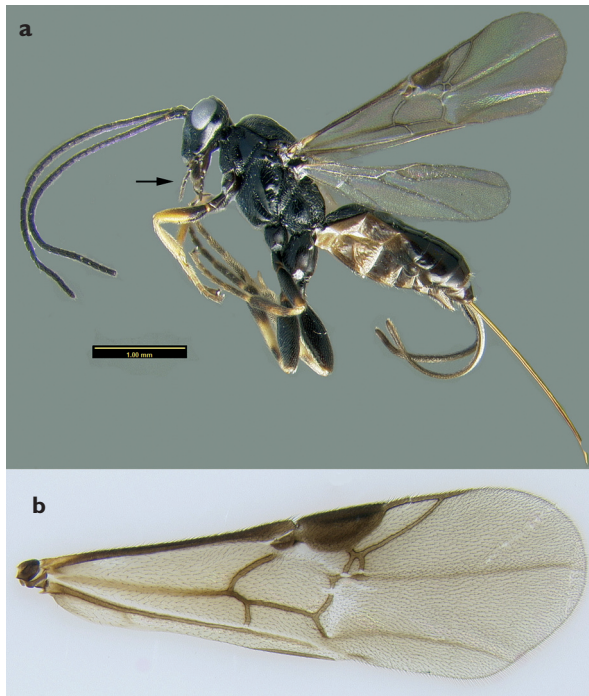


Figure 17. *Agathis* sp. **a** lateral habitus **b** forewing

Diversity: Highly diverse in cool north-temperate climates.

Biology: Species generally attack lepidopterous larvae feeding in flower heads. There are numerous host records many of which are likely to be incorrect; host families that are reasonably certain include: Gelechiidae, Coleophoridae, Oecophoridae, Tortricidae, and Prodoxidae.

Phylogenetic Information. Sister to the clade composed of *Lytopylus* + *Braunsia* (*Lytopylus* corresponds to *Bassus* s.s. in Sharkey et al. 2006).

Diagnosis: Head rostriform or subrostriform (Fig. 17a); tarsal claws not bifid and with a basal lobe (as in Fig. 2b).

***Amputostypos* Sharkey, gen. n.**

urn:lsid:zoobank.org:act:83935652-A2F4-4F55-91D3-86BE3DBE7AF4

Type species: *Disophrys concolor* Szépligeti, 1908.

Lectotype of *D. concolor* designated by van Achterberg, 1974.

Amputostypos concolor **comb. n.**

Etymology: From the Greek words *Amputo* and *stypos*, meaning short and stem respectively. These refer to the close relationship with the genus *Hypsostypos*, meaning high stem. *Amputostypos* differs from *Hypsostypos* primarily in lacking high ridges surrounding the antennal bases.

Taxonomy: Sharkey et al. (2006) included this generic concept under *Hypsostypos*, mistakenly thinking that the type species of *Hypsostypos* lacked posterolateral carinae on the frons.

Distribution: Oriental, East Palaearctic, Oceanic, Australian, African (rare), primarily tropical and warm-temperate, but reasonably represented in moderate temperate localities. No specimens are recorded from Thailand but we have collected 83 specimens representing 10 species.

Diversity: It is difficult to estimate the number of species due to recent changes in generic concepts. Sharkey et al. (2006) divided *Coccygidium* s.l. into *Hypsostypos*, *Zelomorpha*, and *Coccygidium* s.s., however few new combinations were made. Members of *Amputostypos* are restricted to the Old World and there are about 12 species recorded for the Oriental region. Bhat and Gupta (1977) included 10 species. *Amputostylos* corresponds to what they referred to as the Sulana species group of *Zelomorpha*.

Biology: There are no reliable host records available. The short ovipositor suggests that they attack exposed hosts. Many species are pale colored with rather large ocelli and presumably nocturnal.

Phylogenetic Information: Probable sister to *Euagathis* (Sharkey et al. 2006).

Diagnosis: Members are very similar to *Coccygidium* and *Euagathis*. Unlike *Coccygidium* they have relatively short foretibial spurs (Fig. 4b) and the frons lacks lateral carinae (Fig. 5b). Unlike *Euagathis* they have one or two carinae ventrally on the hind trochantellus (Fig. 3a). Members differ from *Hypsostypos* in lacking the high ridges surrounding the antennal insertions.

Description: Head: Lateral carina of frons lacking (Fig. 5b); interantennal space usually with two weak prominences separated by shallow groove (never high as in *Hypsostypus*); gena not extended ventroposteriorly into sharp prominence; labial palp with four segments, third segment not reduced, more than half length of apical segment; apical antennomere acute. **Mesosoma:** Mesoscutum with sculptured notauli; posteroscutellar depression absent; median areola of metanotum surrounded by well defined carinae laterally and posteriorly; propodeum areolate carinate; posterolateral corners of propodeum elongate; propleuron mildly convex to flat; propodeal pseudosternite well developed, separating hind coxal cavities from metasomal foramen. **Legs:** Foretibial spur not elongate, about $\frac{1}{2}$ length of basitarsus (Fig. 4b); foretibial spur with setae extending to its apex or nearly so (Fig. 4b); foretibia lacking pegs; tarsal claws bifid (Fig. 2a); midtibia with apical pegs but lacking pegs at midlength; hind femur usually rugose ventrally; hind tibia with 2 apical pegs, posterior peg larger than anterior peg. **Wings** (Fig. 18b): Rs+Ma vein of forewing incomplete and not tubular throughout; second submarginal cell of forewing triangular and sessile; forewing 3RSb straight to slightly sinuate; hind wing crossvein r absent; hind wing crossvein r-m weakly indicated as a short nebulous or spectral thickening, i.e., as a depressed line that may or may not be pigmented, near the base of Rs; hind wing Cub present as nebulous or spectral vein. **Metasoma:** All terga smooth, lacking sculpture; median tergite 1 lacking pair of longitudinal carinae;

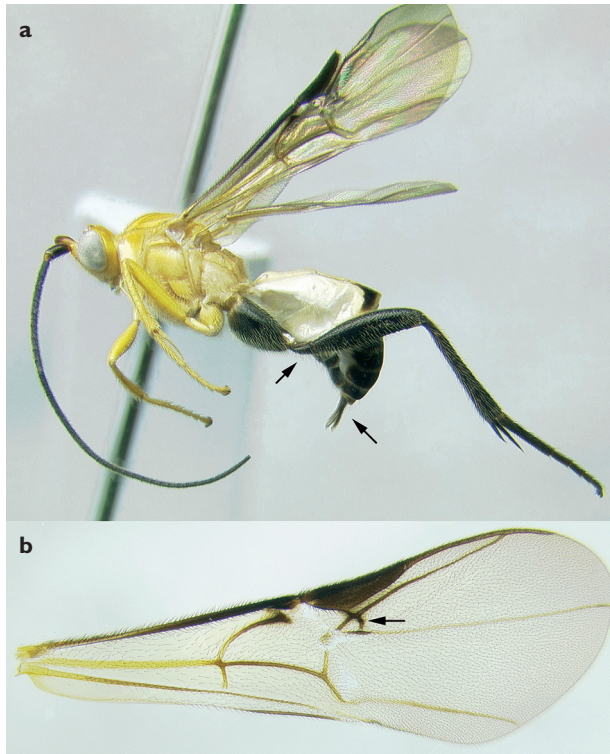


Figure 18. *Amputostypus* sp. **a** lateral habitus **b** forewing

median syntergum 2+3 lacking transverse depression separating terga 2 and 3 or with depression barely indicated; ovipositor, decurved, shorter than half the length of the metasoma when fully extended (Fig. 18a).

Aneurobracon Brues, 1930

Type species: *Aneurobracon bequaerti* Brues, 1930.

Distribution: Oriental, East Palaearctic, Oceanic, Australian, tropical to warm-temperate.

Diversity: Five species described world-wide, two recorded for the Oriental region (India, Philippines), and none for Thailand. No specimens of *Aneurobracon* have been collected in Thailand but it is likely that this rare genus occurs in the country.

Biology: There are two host records both on members of the family Gracillariidae.

Phylogenetic Information: Sister to *Mesocoelus*, which is confined to the neotropics.

Diagnosis: The lack of venation (Fig. 19b), long legs and long setae on the hind tibia (Fig. 19a) are all unique for the Oriental agathidine fauna.



Figure 19. *Aneurobracon* sp. **a** lateral habitus **b** forewing

***Biroia* Szépligeti 1900**

Type species: *Biroia elegans* Szépligeti, 1900.

Isoptronotum Enderlein, 1920, synonymized by Sharkey et al. (2006). Type species: *Isoptronotum taeniocauda* Enderlein, 1920.

Distribution: Old world tropical, including African, Oriental, and Australian regions. Bhat and Gupta (1977) used the name *Isoptronotum* for the same concept, and it here considered a junior synonym (following Sharkey et al. 2006). Bhat and Gupta (1977) included 10 species (of the present concept of *Biroia*) in the Oriental Region. No specimens have been recorded from Thailand but we have collected one or two species; that is, one polymorphic species or two closely related species.

Diversity: 29 species are known of which 12 are recorded from the Oriental region.

Biology: Unknown, the long ovipositors suggest concealed hosts.

Phylogenetic Information. Sister to *Zacremnops*, a small genus with a Neotropical distribution (Sharkey et al. 2006).

Taxonomic Information. Most authors treated species under *Isoptronotum* prior to Sharkey et al. (2006).

Diagnosis: Mesoscutum smooth, lacking notauli (Fig.7a); fore and mid claws bifid (Fig. 2a), lateral carina of frons lamellate (high and thin) (Fig. 8a); ovipositor more than half length of metasoma (Fig.20a).



Figure 20. *Biroia* sp. **a** lateral habitus **b** forewing

***Braunsia* Kriechbaumer, 1894**

Type species: *Braunsia bicolor* Kriechbaumer, 1894.

Metriosoma Szépligeti, 1902, synonymized by Sharkey et al. (2006). Type species: *Metriosoma munda* Szépligeti, 1902.

Lissagathis Cameron, 1911, synonymized by Sharkey et al. (2006). Type species: *Lissagathis bicarinata* Cameron, 1911.

Laccagathis Watanabe, 1934, synonymized by Sharkey et al. (2006). Type species: *Laccagathis formosana* Watanabe, 1934.

Pholeocephala van Achterberg, 1988, synonymized by Sharkey et al. (2006). Type species: *Pholeocephala lieftincki* van Achterberg, 1988.

Distribution: Old world tropical, including African, Oriental, and Australian regions. Bhat and Gupta (1977) separated the genus *Laccagathis*, which is here considered a junior synonym (following Sharkey et al. 2006). No specimens are recorded from Thailand, but we have collected two species.

Diversity: 68 species are described world-wide and 26 are known from the Oriental region (Yu et. al. 2005).

Biology: Most host records are on Pyralidae, with one record each for Lasiocampidae and Noctuidae that need confirmation.

Phylogenetic Information. Sister to *Lytopylus* (as *Bassus* s.s. in Sharkey et al. 2006).

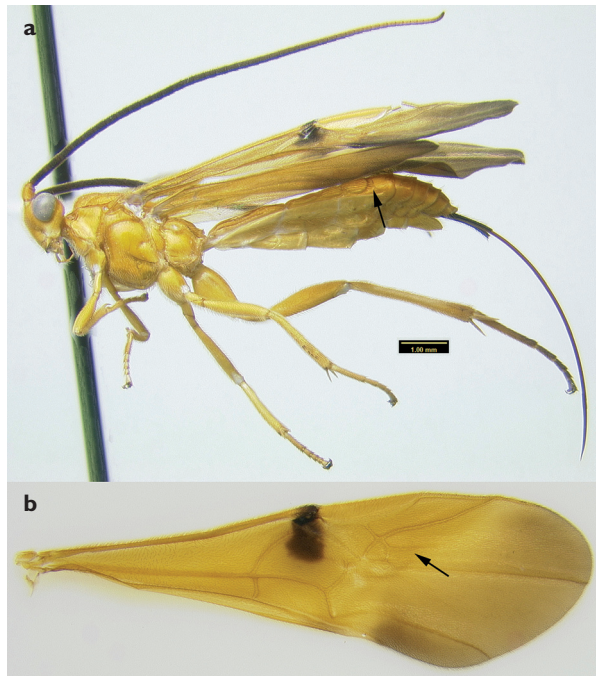


Figure 21. *Braunsia* sp. **a** lateral habitus **b** forewing

Diagnosis: Metasomal median tergite 3 with longitudinal striae (as in Fig. 14a), first median tergite with prominent lateral longitudinal carinae; second submarginal cell with an adventitious 2RS vein (Figs. 15b, 21b).

Camptothlipsis Enderlein, 1920

Type species: *Camptothlipsis costalis* Enderlein, 1920.

Distribution: Old World, including Palearctic, African, Oriental, and Australian regions; far more diverse in tropical areas. Related taxa occur in the New World and continued research will determine whether or not these should be considered congeneric. Often included with *Bassus* s.l. in keys.

Diversity: 17 species have been described, 6 from the Oriental region all of which were included by Bhat and Gupta (1977). No specimens have been recorded from Thailand but we have collected two species. The genus is especially diverse in the Ethiopian region where there are more than 100, mostly undescribed, species.

Biology: The three host records are all on Gelechiidae.

Phylogenetic Information. In a clade that includes *Zacremnops*, *Plesiocoelus* and some taxa presently placed in the polyphyletic *Therophilus* (as *Bassus* s.l. in Sharkey et al. 2006).

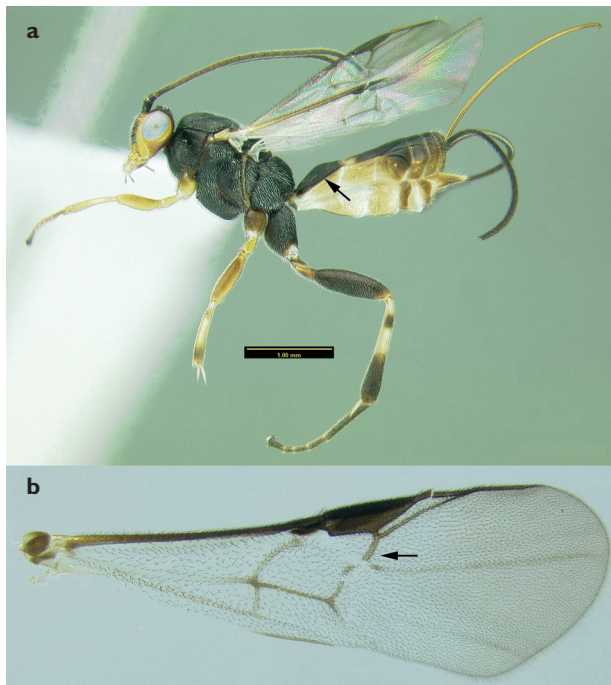


Figure 22. *Camptothlipsis* sp. **a** lateral habitus **b** forewing

Taxonomic Information. Treated as a synonym of *Bassus* in many recent publications, e.g., Simbolotti and van Achterberg (1992), Papp (1998).

Diagnosis: Second submarginal cell absent (Fig. 22a); median tergite 1 coriaceous or granulate (Fig. 13b).

***Coccygidium* Saussure, 1892**

Type species: *Coccygidium luteum* Saussure, 1892.

Brachyropalum Kriechbaumer, 1894, first synonymized by Chou and Sharkey (1989) and confirmed by Sharkey (1996) and Sarmiento and Sharkey (2005). Type species: *Brachyropalum pallidum* Kriechbaumer, 1894.

Brachyrhopalum Dalla Torre, 1898, synonymized by Chou and Sharkey (1989). Emendation for *Brachyropalum*.

Neophylax Ashmead, 1900, first synonymized by Chou and Sharkey (1989) and confirmed by Sharkey (1996) and Sarmiento and Sharkey (2005). Type species: *Neophylax snyderi* Ashmead, 1900.

Ahngeria Kokujev, 1902, first synonymized by van Achterberg and Maeto (1990) and confirmed by Sharkey (1996, 1998) and Sarmiento and Sharkey (2005). Type species: *Ahngeria transcaspica* Kokujev, 1902.

Lisitheria Cameron, 1904, first synonymized by Chou and Sharkey (1989) and confirmed by Sharkey (1996); Sarmiento and Sharkey (2005). Type species: *Lisitheria nigricornis* Cameron, 1904.

Xanthomicrodus Cameron, 1904, first synonymized by Chou and Sharkey (1989) and confirmed by Sharkey (1996) and Sarmiento and Sharkey (2005). Type species: *Xanthomicrodus iridipennis* Cameron, 1904.

Caenophylax Schulz, 1911, first synonymized by Chou and Sharkey (1989) and confirmed by Sharkey (1996) and Sarmiento and Sharkey (2005). New name for primary homonym *Neophylax* Ashmead, 1900, nec *Neophylax* McLachlan, 1871.

Distribution: Oriental, Palaearctic, Oceanic, Australian, African, primarily tropical and warm-temperate, but reasonably represented in moderate temperate localities. No species are recorded from Thailand but we have collected 18 specimens representing 3 or 4 species in Thailand.

Diversity: It is difficult to estimate the number of species due to recent changes in generic concepts. Sharkey et al. (2007) divided *Coccygidium* s.l. into *Hypsostypos*, *Zelomorpha*, and *Coccygidium* s.s., but did not include a list of new combinations so the generic concepts have not been incorporated into the Taxapad database (Yu et al. 2005). Members of *Coccygidium* are restricted to the Old World and there are about 10 species recorded for the Oriental region; Bhat and Gupta (1977) included 8 species. *Coccygidium* corresponds to what they referred to as the Fuliginosa species group of *Zelomorpha*.

Biology: There are five host records, all on members of the family Noctuidae. Many species are pale colored with rather large ocelli and are nocturnal. The short ovipositor suggests that they are attacking exposed hosts.

Phylogenetic Information. Sister to *Zelomorpha* which is New World and primarily tropical in distribution (Sharkey et al. 2006).

Taxonomic Information. Chou and Sharkey (1989) treated *Zelomorpha* as a junior synonym; however the monophyly of both *Coccygidium* and *Zelomorpha* were confirmed by Sharkey et al. (2006).

Diagnosis: The long, style-like, foretibial spur (Fig. 4a) is unique amongst Agathidinae. Members are otherwise very similar to those of *Amputostypus*, which are more commonly collected in Malaise traps in the Oriental Region.

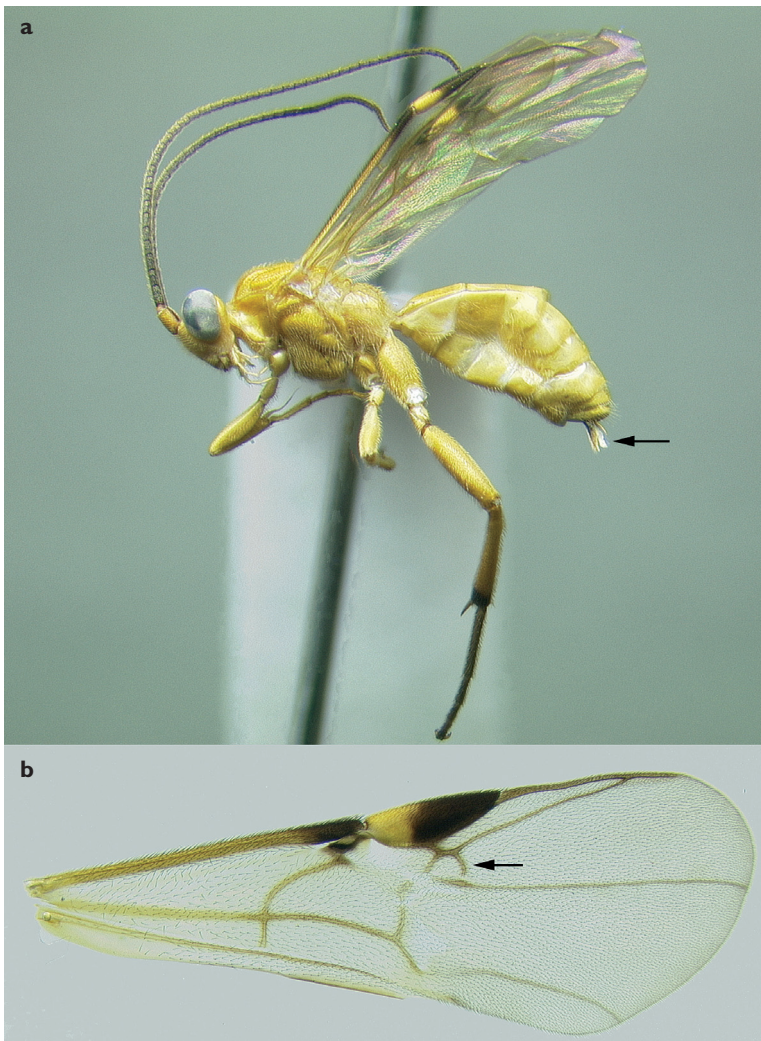


Figure 23. *Coccygidium* sp. **a** lateral habitus **b** forewing

***Cremonops* Foester, 1862**

Type species: *Bracon deflagrator* Spinola, 1808.

Distribution: Cosmopolitan, with similar representation in tropical and temperate habitats. No specimens are recorded from Thailand but we have collected one or two species represented by less than 10 specimens. They are similar to the widespread Palearctic species *C. desertor*, and may be conspecific.

Diversity: 73 species described world-wide, 16 recorded for the Oriental region (all treated by Bhat 1979).

Biology: Host families include Pyralidae (10 spp.), Noctuidae (4 spp.), Tortricidae (2 spp.) Sesiidae (1 sp.). The relatively long ovipositor suggests that members attack concealed hosts. The coloration of the Oriental species indicates that they are diurnal, however nocturnal species are known from other areas.

Phylogenetic Information. Sister to *Cremonoptoides* (unpublished, based on COI and 28S sequence data).

Diagnosis: Ovipositor longer than half length of metasoma (Fig. 24a); fore and mid tarsal claws cleft (Fig. 2a); notauli impressed (as in Fig. 7b); hind trochantellus lacking ventral carinae (as in Fig. 3b).

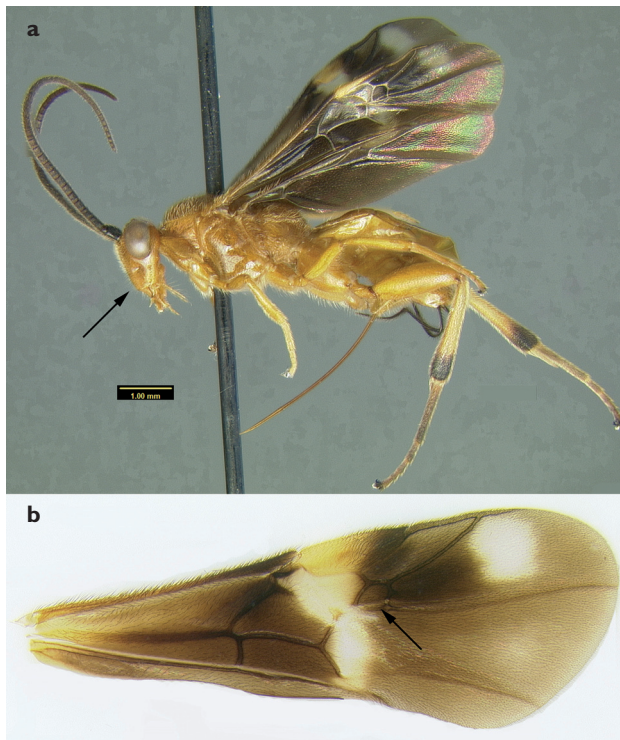


Figure 24. *Cremonops* sp. **a** lateral habitus **b** forewing

***Cremnoptoides* van Achterberg & Chen, 2004**

Type species: *Cremnops pappi* Sharkey, 1996.

Distribution and Diversity: Only represented in the literature by two species from Japan and Korea (Sharkey 1996) and China (Henan) (van Achterberg & Chen 2004). We have five specimens representing a new species from Thailand.

Biology: Unknown; the long ovipositor suggests that it attacks concealed hosts.

Phylogenetic Information. *Cremnoptoides* is a member of the tribe Cremnoptini but exemplars have not been included in published phylogenetic analyses. Our unpublished analyses of COI and D2–3 28S sequence data place it as sister to *Cremnops*.

Diagnosis: Fore and midtarsal claws bifid (Fig. 2a); ovipositor as long as metasoma (Fig. 31a); notauli complete (as in Fig. 12aa); lateral carina of frons acute and directed towards lateral ocellus (Fig. 6bb); gena and mouthparts slightly elongate (Fig. 31a); sternaulus complete to epicnemium, composed of a series long, shallow, vertical grooves (Fig. 31a); hind trochantellus with a pair of longitudinal carinae.

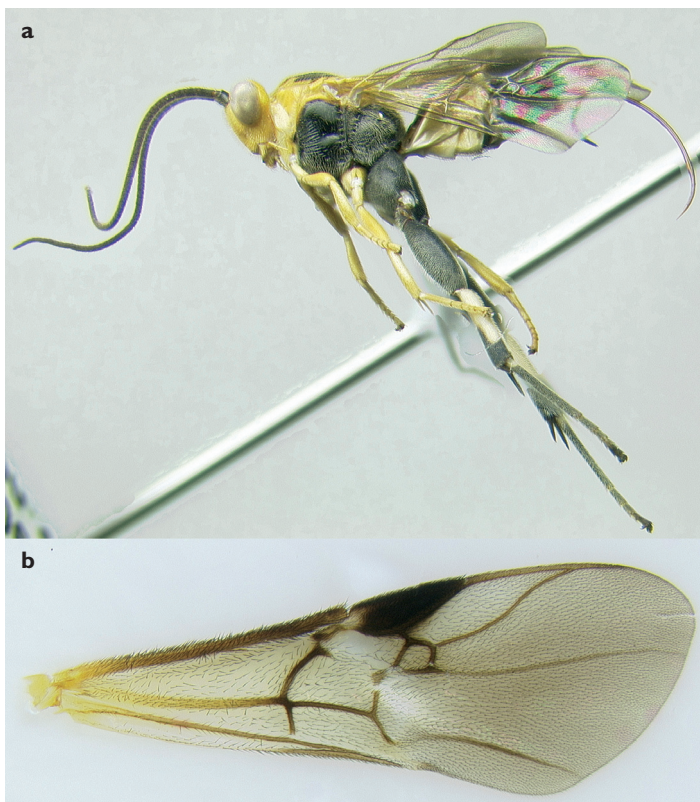


Figure 31. *Cremnoptoides* sp. **a** lateral habitus **b** forewing

***Disophrys* Foester, 1862**

Type species: *Agathis caesa* Klug, 1835.

Megagathis Costa, 1888, first synonymized by Marshall (1900), and confirmed by Papp (1993), Simbolotti and van Achterberg (1999) and Belokobyskij et al. (2003).

The type of *Megagathis*, *Agathis imperialis* Costa, 1888, was treated by Marshall (1900) as a junior synonym of *Disophrys caesa* (Klug, 1835), thereby effectively synonymizing the genera.

Pseudagathis Kriechbaumer, 1894, first synonymized by Szépligeti (1904) and confirmed by Brues (1926), Watanabe (1937), Shenefelt (1970) and Chou and Sharkey (1989). Type species: *Pseudagathis calabarica* Kriechbaumer, 1894.

Diophrys Kriechbaumer, 1898. Unjustified emendation for *Disophrys* Foerster.

Pseudocremonops Szépligeti, 1915, synonymized by Sharkey et al. (2006). Type species: *Pseudocremonops atripennis* Szépligeti, 1915.

Distribution: Old World, primarily tropical: African, Oriental, and Australian regions, with a few Palearctic species. No specimens have been recorded from Thailand but we have collected four species represented by 5 specimens, suggesting that there are considerably more.

Diversity: Bhat and Gupta (1977) recorded 23 species from the Oriental region and Bhat (1978) added 2 new Oriental species.



Figure 25. *Disophrys* sp. **a** lateral habitus **b** forewing

Biology: Most host records are on Noctuidae and the short ovipositors suggest that exposed hosts are attacked.

Phylogenetic Information. Sister to all other Disophrini that were included in the Sharkey et al. (2006) analyses.

Diagnosis: Lateral carina of frons lamellate (high and thin) (Fig. 11b); ovipositor barely exerted or sometimes hidden by hypopygium (Fig. 25a); second cubital cell quadrate, not narrowed anteriorly (Fig. 25b); foretibial spur not as long as basitarsus (as in Fig. 4b); hind trochantellus lacking carinae ventrally (as in Fig. 3b).

Earinus Wesmael, 1837

Type species: *Microdus delusor* Wesmael, 1837.

Diatmetus Förster, 1862, first synonymized by Szépligeti (1904) and confirmed by Muesebeck (1927), Watanabe (1937), Muesebeck and Walkley (1951), Shenefelt (1970), Gupta and Bhat (1974), Bhat and Gupta (1977), Marsh (1979), Chou and Sharkey (1989) and Braet (2002). Type species: *Microdus gloriator* Nees, 1812.

Distribution: Holarctic, Oriental, austral region of South America, especially diverse in cold temperate areas. Species described from Chile as *Earinus* are sister to the Hol-

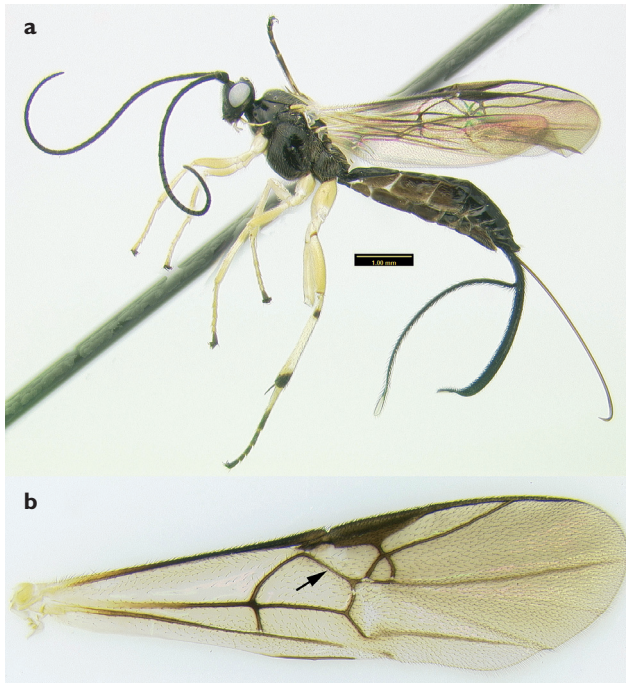


Figure 26. *Earinus* sp. **a** lateral habitus **b** forewing

arctic and Oriental clade (Sharkey et al. 2006). There are no records from Thailand but we have captured one specimen.

Diversity: 15 species are described world-wide, and 3 from the Oriental region. Bhat and Gupta (1977) recorded only one species from the Oriental region. There are many undescribed species in Austral South America.

Biology: Most host records are on Noctuidae and Tortricidae.

Phylogenetic Information. Sister to all other Earinini (Sharkey et al. 2006; and new unpublished data).

Diagnosis: This is the only agathidine genus in the Oriental region with a complete RS+M vein in the fore wing (Fig. 26b).

Euagathis Szépligeti, 1900

Type species: *Euagathis bifasciata* Szépligeti, 1900.

Chromomicrodus Ashmead, 1900, first synonymized by Baltazar (1961) and confirmed by Shenefelt (1970), Bhat and Gupta (1977), Chou and Sharkey (1989), Simbolotti and van Achterberg (1995), Sharkey (1996, 1998), van Achterberg and Chen (2002), van Achterberg (2004a, b) and van Achterberg and Raychaudhuri (2004).

Type species: *Chromomicrodus abbotti* Ashmead, 1900.

Holcotroticus Cameron, 1902, first synonymized by Simbolotti and van Achterberg (1995) and confirmed by van Achterberg and Chen (2002), van Achterberg (2004a, b) and van Achterberg and Raychaudhuri (2004). Type species: *Holcotroticus ruficollis* Cameron, 1902.

Balcemena Cameron, 1903, synonymized by van Achterberg and Chen (2002), confirmed by van Achterberg (2004a, b) and van Achterberg and Raychaudhuri (2004). Type species: *Balcemena longicollis* Cameron, 1903.

Distribution: Old World, primarily tropical: African, Oriental, and Australian regions, with a few incursions into the East Palaearctic. We have collected about 10 species in Thailand represented by 152 specimens.

Diversity: Bhat and Gupta (1977) recorded 46 species from the Oriental region, they also reported 6 species of *Balcemena* which is now considered a junior synonym, making the total 52. Four species have been recorded from Thailand, viz., *E. abbotti* (Ashmead 1900), *E. chinensis* (Holmgren 1868) (as *E. semiflava* Szépligeti, 1908), *E. forticarinata* (Cameron 1899) and *E. longicollis* (Cameron, 1903) (Bhat and Gupta 1977, Simbolotti and van Achterberg 1995, Quicke et al. 2008).

Biology: Most host records are on Lymantriidae and the short ovipositors suggest that exposed hosts are attacked.

Phylogenetic Information. Rather unplaced within the Disophrini based on Sharkey et al. (2006) although many analyses placed it as sister to *Amputostypos* (as *Hypsostypos* in Sharkey et al (2006)) and unpublished COI and 28S sequence data support this placement.



Figure 27. *Euagathis* sp. **a** lateral habitus **b** forewing

Diagnosis: Claws cleft (Fig. 2a); frons lacking lateral carinae (Fig. 9a); hind trochantellus lacking ventral carinae (Fig. 3b); ovipositor much shorter than metasoma (Fig. 27a).

***Gyrochus* Enderlein, 1920**

Type species: *Gyrochus helvus* Enderlein, 1920.

Distribution: Recorded from Sumatra, Peninsular Malaysia, and Yunnan Prov. China. Not recorded from Thailand but this rare genus undoubtedly occurs there.

Diversity: 4 described species, 3 species were included in Bhat & Gupta (1977).

Biology: No host records but the short ovipositors suggest that exposed hosts are attacked.

Phylogenetic Information: A member of the Disophrini, but not included in any phylogenetic analyses.



Figure 28. *Gyrochus* sp. **a** lateral habitus **b** forewing

Diagnosis: Tarsal claws bifid (Fig. 2a); notauli lacking (as in Fig. 7a), ovipositor short (Fig. 28a), hind trochantellus lacking ventral carinae (Fig. 3b); lateral and medial carinae of frons joined posteriorly completely surrounding base of antennae (Fig. 8b).

Hypsostypus Baltazar, 1963

Type species: *Agathis rugifrons* Smith, 1860.

Distribution and Diversity: The genus is only represented in the literature by the type species from Sulawesi, though we have seen another specimen representing an undescribed species from Sulawesi. Due to its rarity and proximity to Thailand it may occur there as well.

Taxonomy: See the Taxonomy section under *Amputostypus*.

Biology: The short ovipositor suggests that exposed hosts are attacked.

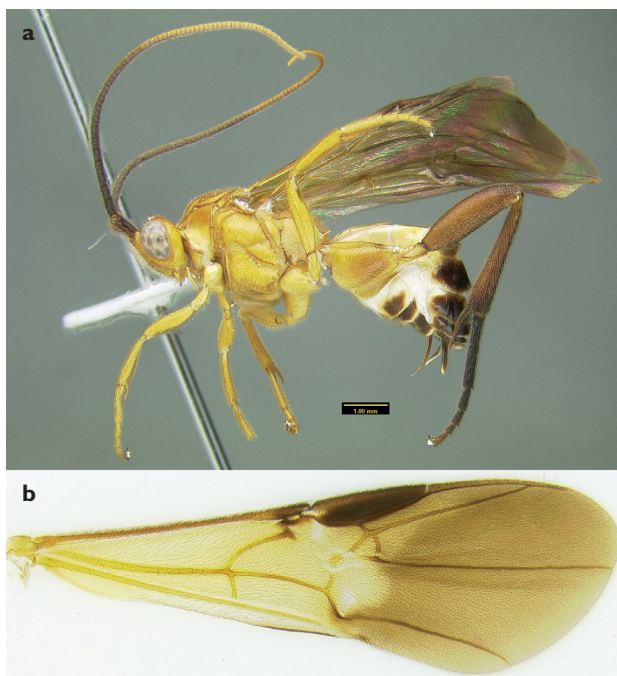


Figure 29. *Hypsostypus* sp. **a** lateral habitus **b** forewing

Phylogenetic Information. Member of the tribe Disophrini but exemplars have not been included in phylogenetic analyses.

Diagnosis: Tarsal claws bifid (Fig. 2a); ovipositor short, barely exerted (Fig. 29a); antennal sockets surrounded on three sides by tubular shaped projection (Fig. 6aa); hind trochantellus with strong pair of carinae ventrally (Fig. 3a).

Lytopylus Förster 1862, stat. n.

Type species: *Lytopylus azygos* Viereck, 1905.

Aerophilina Enderlein, 1920, syn. n. Type species: *Aerophilina bicristata* Enderlein, 1920.

Aerophilopsis Viereck, 1913, syn. n. Type species: *Bassus erythrogaster* Viereck, 1913.

Facilagathis van Achterberg & Chen, 2004, syn. n. Type species: *Facilagathis spinulata* van Achterberg & Chen, 2004.

Hormagathis Brues, 1926, syn. n. Type species: *Hormagathis mellea* Brues, 1926.

Ioxia Enderlein, 1920, syn. n. Type species: *Ioxia faceta* Enderlein, 1920.

Neomicrodus Szépligeti, 1908, syn. n. Type species: *Neomicrodus boliviensis* Szépligeti, 1908.

Obesomicrodus Papp, 1971, syn. n. Type species: *Obesomicrodus niger* Papp, 1971.

Taxonomy. Sharkey et al. (2006) demonstrated the polyphyly of the generic concept *Bassus* as it has been used over the past few decades (Nixon 1986, Simbolotti and van Achter-

berg 1992, Sharkey 1997), and further showed that a stricter sense of *Bassus* was a monophyletic group and sister to *Braunsia*. However they did not examine the type specimen of *Bassus* which does not happen to belong to the same clade as the specimens included in their analyses. Here we have selected the oldest available name for what was referred to as *Bassus* s.s. in Sharkey et al. (2006). *Lytopylus* was first proposed by Förster 1862 but no species were assigned to the genus until Viereck (1914) included *L. azygos* as the type.

Distribution: Cosmopolitan, with more diversity in temperate regions. Only one species of *Lytopylus* has been collected in Thailand but the occurrence of more members of the genus is likely. Bhat and Gupta (1977) included members of *Lytopylus* under *Agathis*. These include *L. aequoreticulatus* (Bhat & Gupta, 1977), *L. astioles* (Nixon, 1950), *L. burmensis* (Bhat & Gupta, 1977), *L. phillipinensis* (Bhat & Gupta, 1977) and *L. romani* (Shestakov, 1940) all new combinations.

Diversity: Highly speciose.

Biology: Most commonly attacking species of Tortricidae and Pyralidae, other reliable records include: Elachistidae, Gelechiidae, and Thyrididae. Undoubtedly many other host families will be confirmed or discovered.

Phylogenetic Information. Sister to *Braunsia* (as *Bassus* s.s. in Sharkey et al. 2006).

Diagnosis: Metasomal median tergites 1–3 sculptured (Fig.14a), first median tergite with prominent lateral longitudinal carinae defining a median elevated area;

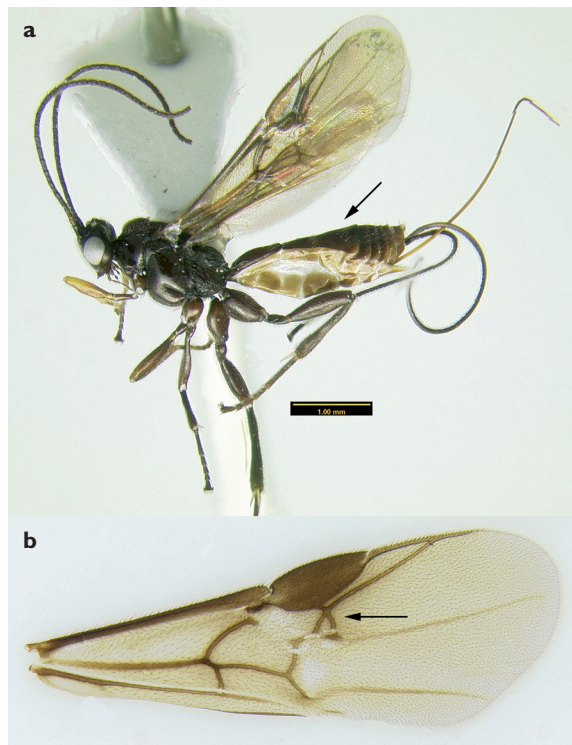


Figure 30. *Lytopylus* sp. **a** lateral habitus **b** forewing

second submarginal cell lacking adventitious 2RS vein (Fig. 30b). This diagnosis does not work well for other regions.

***Therophilus* Wesmael 1837, stat. n.**

Type species: *Microdus* (*Therophilus*) *conspicuous* Wesmael, 1837

Aerophiliodes Strand, 1911, syn. n. Type species: *Aerophiliodes testaceator* Strand, 1911.

Agathiella Szépligeti, 1902, syn. n. Type species: *Agathiella pedunculata* Szépligeti, 1902.

Baeognatha Kokujev, 1903, syn. n. Type species: *Baeognatha turanica* Kokujev, 1903.

Orgiloneura Ashmead, 1900, syn. n. Type species: *Orgiloneura antipoda* Ashmead, 1900.

Taxonomy. Based on the results of Sharkey et al. (2006) we have broken the former concept of *Bassus* into several large monophyletic genera, e.g., *Lyptopylus*, *Camptothlipsis*, however not all of the problems with the old concept of *Bassus* are solved and *Therophilus* is here used to contain the polyphyletic assemblage that remains. Clearly there is improvement to be made however it seems better to recognize large monophyletic groups within the former concept of *Bassus*. If monophyly were the only criterion many agathidine genera would need be lumped into one genus.

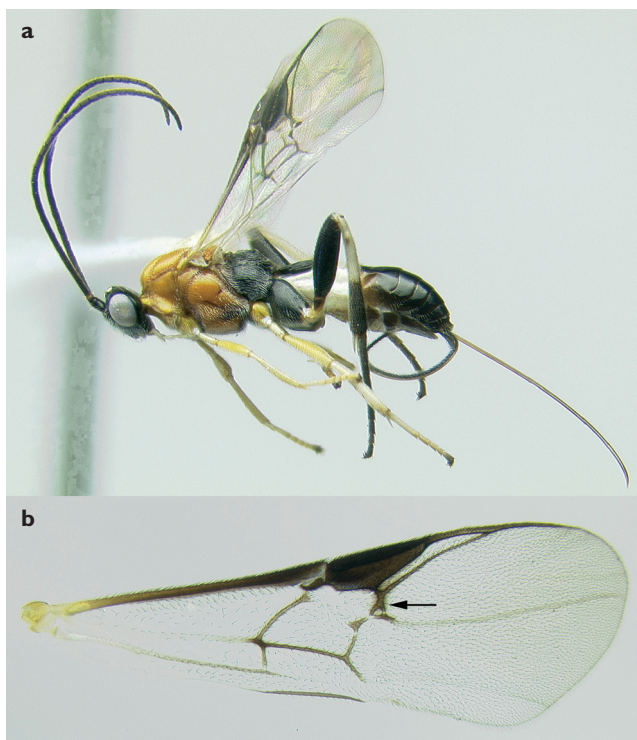


Figure 32. *Therophilus* sp. **a** lateral habitus **b** forewing

Distribution: Cosmopolitan. No species have been recorded for Thailand but we have collected 35 species.

Diversity: This polyphyletic genus is very rich and contains about as many species as all other genera combined.

Biology: Attacking a wide assortment of primarily micro-Lepidoptera, mostly in concealed microhabitats. Undoubtedly many other host families will be confirmed or discovered.

Phylogenetic Information. Polyphyletic (Sharkey et al. 2006).

Diagnosis: Ovipositor longer than metasoma (Fig. 32a); gena and mouthparts not elongate (Figs. 16b, 32a); tarsal claws with a basal lobe (Fig. 2b); metasomal cavity positioned partly between hind coxal cavities (Fig. 14bb); median tergite 3 lacking sculpture (Fig. 14b).

Troticus Brullé, 1846

Type species: *Troticus ovatus* Brullé, 1846.

Distribution: Most species are recorded from sub-Saharan Africa (Braet 2001) although a few specimens have been captured in Egypt and one in Italy, Sicily (Fahringer

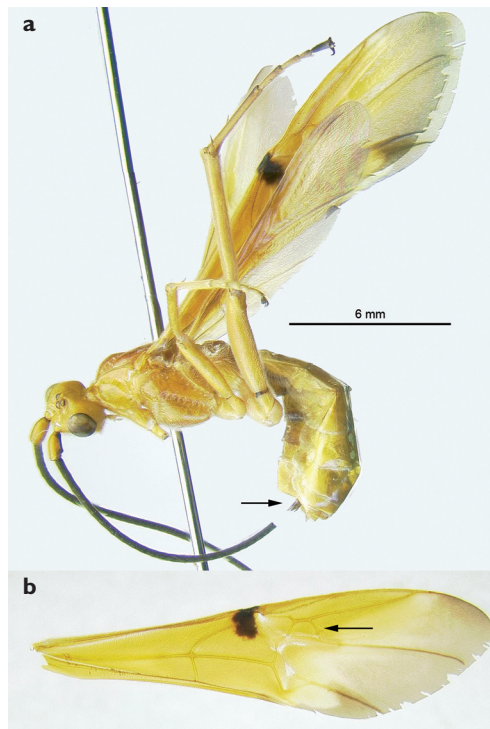


Figure 33. *Troticus* sp. **a** lateral habitus **b** forewing

1937, van Achterberg 2008). We have collected one specimen from Thailand. It is the first record from the Oriental region.

Diversity: 13 species are described, one Palaearctic and 12 Ethiopian.

Biology: Recorded from Lasiocampidae (van Achterberg et al. 2008).

Phylogenetic Information. Member of the tribe Disophrini but exemplars have not been included in phylogenetic analyses.

Diagnosis: Tarsal claws bifid (Fig. 2a); ovipositor short, barely exerted (Fig. 33a); notauli complete (as in Fig. 12aa); lateral carina of frons acute and directed towards median ocellus (Fig. 11a); epicnemial carina with an acute angle (Fig. 33a).

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We thank all of the staff at Queen Sirikit Botanic Garden in Chaing Mai for sorting the many hundreds of samples that have passed through their hands and for the Thai park staff for running Malaise traps and other collection devices. We especially thank Chawee-wan Hutacharern for managing the Thai end of the TIGER project. Stephanie Clutts processed the Thai samples as they arrived at the Hymenoptera Institute at the University of Kentucky. Funding was provided by NSF grants DEB-0542864 and EF-0337220.

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Appendix 1.

Interactive key, in Intkey format, to the Oriental genera of Agathidinae (Hymenoptera, Braconidae). doi:10.3897/zookeys.21.271.app.1.ik.

Note: To run the identification key, you will need Windows 95/NT or a later version. You also need to download Intkey software and reboot your computer, if it is not already installed. The software package, Intkey, can be downloaded from <http://delta-intkey.com/www/programs.htm>. Once Intkey is installed you need only click on the .ik link (above) and the key will open. Click on any character on the left to begin. More details on how to use Intkey efficiently are found at http://florabase.calm.wa.gov.au/help/keys/intkey_tutorial.pdf.

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Citation: Sharkey MJ, Yu DS, van Noort S, Seltmann K, Penev L (2009) Interactive key, in Intkey format, to the Oriental genera of Agathidinae (Hymenoptera, Braconidae). doi:10.3897/zookeys.21.271.app.1.ik. Dataset published in: Zookeys 21: 19–54. doi:10.3897/zookeys.21.271.

Appendix 2.

DELTA data matrix, images, and other files to the key to the Oriental genera of Agathidinae (Hymenoptera, Braconidae). doi:10.3897/zookeys.21.271.app.2.ik.

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Appendix 3.

Lucid Interchange Format version 3 (LIF3) and Lucid SDD files to the key to the Oriental genera of Agathidinae (Hymenoptera, Braconidae). doi:10.3897/zookeys.21.271.app.3.ik.

Note: The LIF3 file is an XML-based file that stores all the Lucid3 key data, allowing exchange of the key with other key developers. The Lucid SDD file is a XML-based file structured using the internationally agreed SDD (Structure of Descriptive Data) Schema. The SDD file may be used to exchange the Lucid key with other SDD-compliant applications.

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Citation: Sharkey MJ, Yu DS, van Noort S, Seltnmann K, Penev L (2009) Lucid Interchange Format version 3 (LIF3) and Lucid SDD files to the key to the Oriental genera of Agathidinae (Hymenoptera, Braconidae). doi:10.3897/zookeys.21.271.app.3.ik. Dataset published in: Zookeys 21: 19–54. doi:10.3897/zookeys.21.271.

Appendix 4.

MX data files (NEXUS, Character list with image ids, OTU list with image ids, images) to the key to the Oriental genera of Agathidinae (Hymenoptera, Braconidae). doi:10.3897/zookeys.21.271.app.4.ik.

Note: MX keys are Web based. To build new keys a user must either obtain an account with an existing instance of MX or a new installation on a machine that runs a Web server. Basic installation instructions are found on the MX wiki (<http://purl.oclc.org/net/mx-installation>) and presently requires fairly advanced technical experience. MX is coded in Ruby on Rails with a MySQL database.

Present files contain MySQL database-generated output describing components of the key. These include: a character/character state list, and NEXUS file. Images are also made available and linked to character state and Operational Taxonomic Unit (OTU) descriptions. These output files are adequate to properly recreate the key, but the format of these files (except the NEXUS file) are presently under review and should not be considered standardized output at the present time.

To run the key a user needs Internet access and the key URL (<http://peet.tamu.edu/projects/36/public/multikey/show/199>). MX is optimized for Firefox Web browser.

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Citation: Sharkey MJ, Yu DS, van Noort S, Seltnmann K, Penev L (2009) MX data files (NEXUS, Character list with image ids, OTU list with image ids, images) to the key to the Oriental genera of Agathidinae (Hymenoptera, Braconidae). doi:10.3897/zookeys.21.271.app.4.ik. Dataset published in: Zookeys 21: 19–54. doi:10.3897/zookeys.21.271.

Two new species of *Utetheisa* Hübner (Lepidoptera, Noctuidae, Arctiinae) from the Galapagos Islands, Ecuador

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‡ [urn:lsid:zoobank.org:author:CDF35F55-5E73-4FC5-8D83-D1A169A4ABB5](https://doi.org/urn:lsid:zoobank.org:author:CDF35F55-5E73-4FC5-8D83-D1A169A4ABB5)

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[urn:lsid:zoobank.org:pub:0B417B36-BB5D-481C-A2CD-E8FFACEA10DD](https://doi.org/urn:lsid:zoobank.org:pub:0B417B36-BB5D-481C-A2CD-E8FFACEA10DD)

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Abstract

Two new species, *Utetheisa connerorum* and *Utetheisa henrii* (Lepidoptera, Noctuidae, Arctiinae) are described from the Galapagos Islands, Ecuador. The latter inhabits the highlands of San Cristobal Island while the former is widely distributed on most of the islands of the archipelago. Their habitus and genitalia are illustrated. Based on a study of the holotype, *Utetheisa galapagensis* (Wallengren) was found to be restricted to San Cristobal Island, contrary to previous reports, and is redescribed here. A key is provided to separate all six Galapagos species of *Utetheisa* based on external characters.

Keywords

Lepidoptera, Noctuidae, Arctiinae, moths, *Utetheisa*, taxonomy, species descriptions, diagnoses, key, endemism, Galapagos archipelago

Introduction

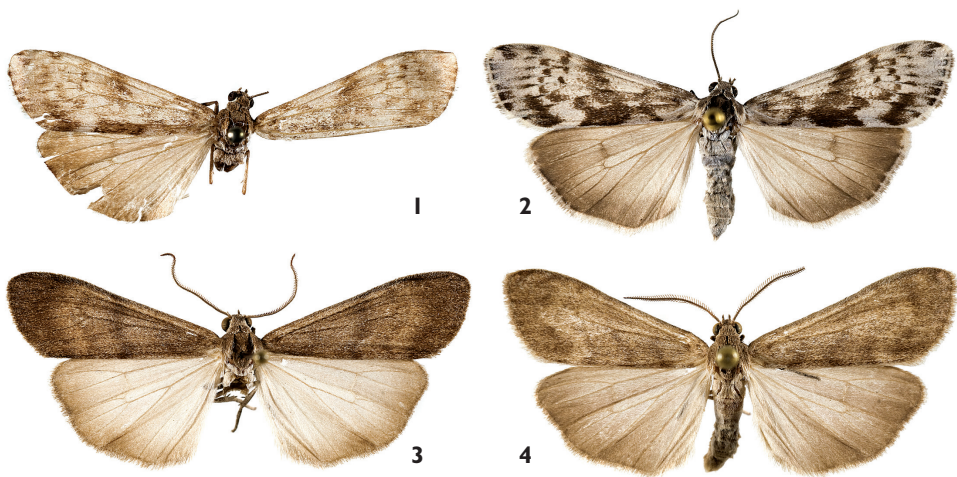
Surveys of Lepidoptera on the Galapagos Islands during the past two decades have generated numerous records of undescribed species and new distribution records for previously reported species (e.g., Landry and Gielis 1992; Roque-Albelo and Landry 2002; Causton et al. 2006; Razowski et al. 2008).

Utetheisa Hübner is the only genus of the subfamily Arctiinae occurring on the Galapagos Islands. Six species have been found on the archipelago: the widely distributed Neotropical *U. ornatrix* (L., 1758) and five endemic species, two of which are described in this paper. The original three endemic species are *U. galapagensis* (Wallengren, 1860) and *U. perryi* and *U. devriesi*, described by Hayes (1975). *Utetheisa galapagensis* has long been regarded as the widespread member of the endemic *Utetheisa* in the Galapagos. However, our study of the holotype showed that it is in fact restricted to San Cristobal Island. The widespread species is actually new and described below as *U. connerorum*.

Genus *Utetheisa* represents the third most speciose radiation of endemic Galapagos Lepidoptera following that of the Autochistidae genus *Galagete* Landry, with 12 species described (Landry 2002; Landry and Schmitz 2008) and that of the Scythrididae, yet undescribed. The Galapagos *Utetheisa* were reviewed taxonomically by Forbes (1941), Hayes (1975), and Roque-Albelo et al. (2009). Their ecology was treated by Perry and de Vries (2003), Roque-Albelo et al. (2002, 2009), and Garrett et al. (2008).

Material and methods

Field work was conducted on San Cristóbal Island by BL in 1989 and by LR-A in 2008 as part of a survey of the Galapagos lepidopteran fauna that we carried out between 1989 and 2008 on all islands of the archipelago except Darwin. Moths were collected at light (mercury vapor lamps (MVL) and ultraviolet lights (UVL)). In addition, eggs were obtained from females collected at UVL and confined to plastic cups. The females began to lay eggs during the second night of confinement. Larvae were reared to last



Figures 1–4. Habitus of Galapagos *Utetheisa* species **1** *U. galapagensis* (Wallengren), holotype female **2** *U. galapagensis*, female collected in 2008 **3** *U. henrii* sp. n., holotype **4** *U. connerorum* sp. n., holotype.

instar on *Tournefortia pubescens* Hooker f. (Boraginaceae) by Sarah Garrett at the insect containment facility of the Charles Darwin Research Station, Santa Cruz Island.

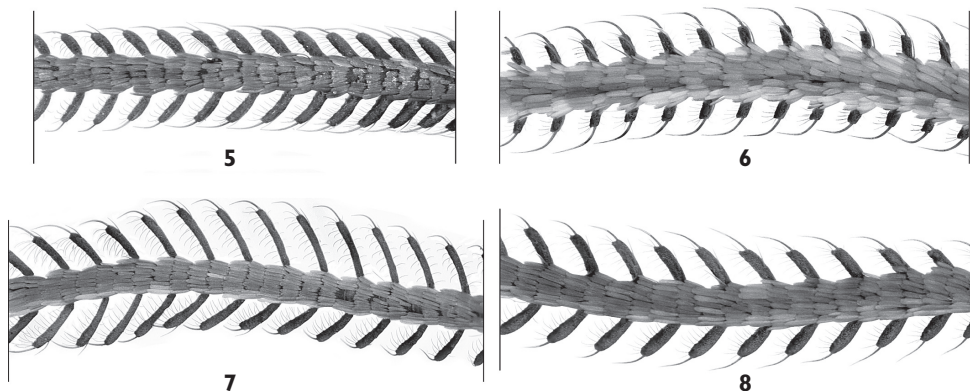
The specimens and genitalia preparations discussed here are deposited in the American Museum of Natural History, New York, New York (AMNH), the California Academy of Sciences, San Francisco, California (CAS), the Canadian National Collection, Ottawa, Ontario (CNC), the Invertebrates Collection of the Charles Darwin Research Station, Santa Cruz Island (IC-CDRS), and the Muséum d'histoire naturelle, Geneva, Switzerland (MHNG). The single female type specimen of *Utetheisa galapagensis* (Wallengren, 1860) was borrowed from the Naturhistoriska riksmuseet, Stockholm (NHRS). It was dissected to insure that we correctly interpreted the identity of the species.

Images of adults were taken using a Nikon® D300 equipped with a 60 mm AF Micro Nikkor® lens. Genitalia were dissected following the methodology mentioned in Landry (2006). The illustrations of the genitalia and antennae were made with the AutoMontage® system using a JVC® video camera mounted on a Leica MZ APO® stereomicroscope. Morphological terminology follows de Vos (2007).

Results

Key to the Galapagos species of *Utetheisa* based on external characters

- 1 Forewing and thorax whitish pink with pink along forewing costa and outer margin, and black dots on thorax, on forewing costa and outer margin..... *U. ornatrix* (L.)
- Forewing variable shades of brown, usually with some darker brown markings 2
- 2 Forewing buff brown, usually with contrasting markings, at least with two dots at end of discal cell, the dorsal one sometimes obscured by conspicuous dark brown shading; hindwing with dark brown bar at end of discal cell, often with darker shading along costa and apex; male antenna strongly bipectinate *U. perryi* Hayes
- Forewing various shades of greyish brown (Figs 1–4), rarely with two dots at end of cell; hindwing without dark brown bar at end of discal cell and without shading on costa and apex, but with shading usually along outer margin; male antenna bipectinate, with length of pectination variable 3
- 3 Forewing background (Fig. 2) colour light greyish brown, with contrasting variable pattern usually with outwardly slanted subapical thick line from dorsum changing into series of spots at CuA1, rarely with two dots at end of cell, usually with postbasal, median, and postmedian lines also present and slanted toward apex from dorsal margin, forewing maximal length 15 mm; hindwing usually with darker broad band along outer margin, sometimes with faint bar at end of discal cell; male antenna with bipectination of medium length (Fig. 5) *U. galapagensis* (Wallengren)



Figures 5–8. Male antenna Galapagos *Utetheisa* species **5** *U. galapagensis* (Wallengren) **6** *U. henrii* sp. n. **7** *U. connerorum* sp. n. **8** *U. devriesi* Hayes.

- Forewing background colour light to dark greyish brown, usually with diffuse pattern of usually complete transverse lines mostly medially and subapically, sometimes pattern absent, lines slanted towards apex or not, never with dots at end of discal cell, forewing length variable; hindwing often with darker broad band along outer margin, never with faint bar at end of discal cell; male antenna with bipectination length variable..... **4**
- 4** Forewing pattern (Fig. 3) dark greyish brown, with darker median and post-median lines at right angle from dorsal margin, with darker terminal 1/5 entirely darker, forewing length 14–16 mm in males; male antenna (Fig. 6) shortly bipectinate ***U. henrii* sp. n.**
- Forewing pattern light to dark greyish brown, with darker lines generally slanted towards apex from dorsal margin, with terminal 1/5 darker or not, forewing length 13.5–20.5 mm in males; male antenna bipectination of medium length or long..... **5**
- 5** Forewing pattern light greyish brown, with transverse lines consisting of median band thicker on dorsal margin and slightly slanted toward apex, and subapical line delimiting darker terminal 1/5, forewing length 17–20.5 mm in males; male antenna (Fig. 8) with bipectination of medium length..... ***U. devriesi* Hayes**
- Forewing pattern (Fig. 4) dark greyish brown, with usually four transverse lines slanted towards apex from dorsal margin postbasally, sub- and postmedially, and subapically, pattern sometimes obscure or absent, forewing length 12–15 mm in males; male antenna (Fig. 7) strongly bipectinate ***U. connerorum* sp. n.**

***Utetheisa galapagensis* (Wallengren, 1860)**

Figs 1, 2, 5, 9, 12

Euchelia galapagensis [sic] Wallengren, 1860: 161. Unused original spelling.*Euchelia gallopagensis* [sic] Wallengren, 1861: 370, 389. Incorrect subsequent spelling.*Utetheisa galapagensis* (Wallengren); Justified emendation: Hampson, 1901: xvi, 488, pl. 50 fig. 12; Forbes, 1917: 340; Seitz, 1919–1925: 301, pl. 38; Schaus, 1923: 23; Forbes, 1941: 101, fig. 3; Linsley and Usinger, 1966: 158 (with original genus misspelled as *Euchalia*); Parkin et al., 1972: 103; Hayes, 1975: 161, figs 22, 23; Linsley, 1977: 29; Silberglied, 1978: 275; Hickin, 1979: 176; McMullen, 1993: 99; Roque-Albelo et al., 2002: 153; Perry and de Vries, 2003: 152; Garrett et al., 2008: 2–6; Roque-Albelo et al., 2009: 207 et seq.**Note on above citations.** Most of these citations, except that of Wallengren (1860, 1861), and probably that of Seitz (1919–1925) given the illustration provided, actually refer to *U. connerorum*, described below.**Material examined.** Holotype ♀: 1- ‘Ins. | Gallop.’ [printed black on white paper]; 2- ‘12’ [printed on lavender paper]; 3- ‘Euchelia | gallopagensis | Wallengr’ [handwritten in faded black ink on white paper]; 4- ‘BL 1655 ♀’ [handwritten in black ink on green paper]. Deposited in NHRS.**Other specimens.** 2 ♂, 11 ♀: 2 ♂ (dissected, slides BL 1666, LR 192), 4 ♀, ‘ECU. GALAPAGOS. San Cristóbal | Sendero las tijeretas | Arid Zone 17m altitude | S 00 53’ 29.9 W 089 36’ 34.8 | 10 IV 2008 UVL | L. Roque’ (IC-CDRS); 1 ♀ (dissected, slide LR 191), ‘ECU. GALAPAGOS. San Cristóbal | Cerro Colorado | Arid Zone 123 m altitude | S 00 54’ 53.5 W 089 26’ 06.4 | 8 IV 2008 UVL | L. Roque’ (IC-CDRS); 6 ♀ in CAS as follows: 1 ♀, 1- ‘Chatham I. | GalapagosIs. | II-1-[19]06’, 2- Coll. by | F. X. Williams’, 3- ‘Utetheisa | galapagensis | Wallengren | det. A.H. Hayes 1973’; 1 ♀, same data except date (II-9-[19]06); 1 ♀ (dissected, slide BL 1665), same data except date (II-9-[19]06) and additional label ‘Sappho | Cove’; 1 ♀ (dissected, slide BL 1661), same data except date (II-22-[19]06); 1 ♀, same data except date (X-14-[19]05); 1 ♀, same data except date (X-15-[19]05).**Note on type.** The specimen is in rough condition (Fig. 1). The legs and antennae are all broken and the right hindwing is broken off and in a gelatin capsule on the pin. The dissected genitalia are in good condition (Fig. 12).**Diagnosis.** As opposed to most of the other Galapagos *Utetheisa* species, except *U. perryi* Hayes, *U. galapagensis* usually has complex, though variable forewing markings in the form of more or less complete postbasal, median, postmedian, and subapical lines. The ground colour in this species is greyish brown, with darker brown markings whereas the ground colour of *U. perryi* is often a warmer buff brown. The male antenna of *U. galapagensis* has pectination of medium length, as in *U. devriesi*, while that of *U. perryi* has strong pectination similar to that of *U. connerorum* (Fig. 7). The male genitalia of *U. perryi* differ most markedly from those of *U. galapagensis* by the much shorter and broader cucullus (see Hayes, 1975: fig. 171). Regarding the shape of the cucullus *U. galapagensis*

mostly resembles *U. connerorum*, but the male genitalia of *U. galapagensis* differ in having less strongly developed coremata, a more swollen uncus, and the vesica has the dorsodistal narrower extension shorter, curved back only to the row of sclerotized bumps, and it has 4 small spine-like cornuti on the right side at the level of the row of sclerotized bumps whereas *U. connerorum* has 0–3 spines in the two specimens examined. The female genitalia are distinguished from those of *U. perryi* (See Roque-Albelo et al. 2009: fig. 14–2, I) by the apically wider and blunt extensions of sternum VII with a broader gap in between and a much more strongly developed section between the compressed sclerotized part of the ductus bursae and the membranous corpus bursae; they are similar to those of *U. connerorum* but differ especially by the apically rounded, longer and narrower lateral extensions, by the narrower U-shaped gap between them, with the anterior end (bottom) often slightly wider, and by the less strongly developed anterior section of the ductus bursae.

Redescription: MALE (n=2) (Figs 5, 9). Head smooth scaled, with thinner scales on lower part of frons converging medially, with ocelli, mostly greyish brown, with few scattered white scales on vertex and occiput, and white to pale beige along eye margin; frons very lightly rounded, without protuberances; eye about 3/10 width of whole head in frontal view. Labial palpus small, projected slightly forward and upward; basal segment mostly white; second segment laterally pale greyish brown with white at base and apex; apical segment darker greyish brown, with or without few paler scales apically. Antenna (Fig. 5) bipectinate; scape mostly greyish brown dorsally, white to pale beige and greyish brown ventrally; flagellum greyish brown with 1–2 beige scales laterally on basal

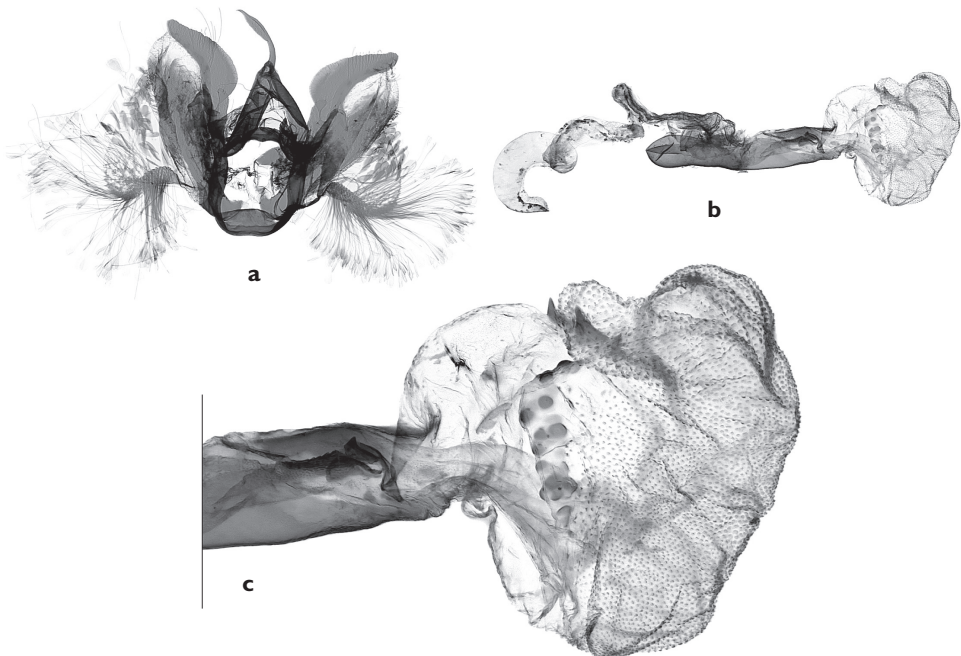


Figure 9. Male genitalia of *Uretheisa galapagensis* (Wallengren), slide LR 192 (a), slide BL 1666 (b, c).
a Whole genitalia without phallus b Phallus c Enlarged vesica.

flagellomeres; some flagellomeres with one thin seta sticking out of scale cover laterally or medially (or both) and about as long as one flagellomere, flagellomeres ventrally covered with short hyaline cilia; longest pectinations slightly longer (by $1/5$ of length) than width of corresponding flagellomere, each flagellomere distally adorned with thick, curved seta about $1/5$ shorter than longest pectination, most pectinations except lateral ones on basal flagellomeres also adorned dorsally with shorter, curved seta.

Thorax: Patagia greyish brown with few pale beige scales laterally, with pale beige or white all around each patagia; tegulae concolorous with patagia, with more or less intense white scaling in middle and toward base, with white or pale beige thin and hair-like scales laterally and mediodistally; mesothorax mostly concolorous with tegulae, white to pale beige laterally and toward apex; metathorax white with medium-length hair-like scaling laterally and short scales in middle. Foreleg greyish brown with white ventrally on coxa and femur, and beige ventrally on tibia and tarsomeres except last. Middle leg as foreleg except coxa mostly white with little pale greyish brown ventrally. Hindleg mostly white to pale beige from coxa to femur, with some pale greyish brown scaling; tarsomeres greyish brown, speckled with pale beige. Forewing length: 13–15 mm; background colour pale (almost silver) greyish brown, usually with darker greyish brown pattern of postbasal outwardly curved line often fading toward costa, thicker slanted line from middle of dorsum to shortly before middle of costa, postmedian line starting perpendicular from $2/3$ dorsum then outwardly curved and becoming series of spots from CuA2 until reaching costa at $3/5$, and outwardly slanted subapical thick line from dorsum changing into series of spots at CuA1 and slightly curving back toward costa; often with additional spots at base on costa, apex of discal cell, on outer margin especially in cubital sector, and on costa before apex; also some specimens mostly greyish brown between median and postmedian lines on dorsal half, and one specimen mostly greyish brown before postmedian line except along dorsum, only spotted at bases of lines, and with thicker and more complete subapical line and more prominent marginal spots; fringe with first row of scales white, second row mostly white but greyish brown at location of marginal spots; underside greyish brown with indication of upperside lines, with darker, wide outer margin band. Hindwing greyish brown, often with darker marginal band and small bar at apex of discal cell, with fringe often appearing contrastingly white, but usually greyish brown in medial sector; underside as upperside.

Abdomen: Greyish brown. Genitalia (n=2) (Fig. 9). Uncus of rather narrow girth at base, moderately long, with sparse, short setation on most of length except distally, swollen from before middle to before apex, with curved, sharply pointed, downturned apex. Cucullus with median section produced dorsally, rounded, with margin wrinkled, slightly narrowing into broadly rounded apex. Corema moderate in size, not reaching apex of cucullus, with numerous long spatulated androconial scales on narrow base, and fewer, short-stalked, bulbous ones on distal $2/3$. Ampulla short, thumb-like, with mostly short setation especially at apex. Phallus straight, cylindrical, with slightly angled, short and bulbous coecum penis, with lateral walls partly unsclerotized, ventral and dorsal sclerotized areas adorned with scobination on distal $1/3$ dorsally and distal end ventrally, left lateral wall distally with narrow sclerotized and scobinated band ending in short spined

crest; coecum penis without ventral incline, not enlarged, slightly bent to left; vesica with row of about 13 sclerotized rounded bumps dorsally on left side before middle, with 4 small spine-like cornuti on right side at level of row of sclerotized bumps, with dorsodistal narrower extension rather short, curved back to row of sclerotized bumps.

FEMALE (n=11) (Figs 1, 2, 12). Similar to male in most respects, but antennal flagellomeres biserrate, dorsally covered with grey-brown scales, some flagellomeres with seta sticking out dorsally, ventrally with short hyaline cilia, with thick seta at distal end of each serration about 1/4 longer than corresponding flagellomere, also with one lateral seta on each serration about half as long as distal seta. Forewing length: 12–15 mm (holotype: 14 mm). Frenulum with 2 acanthae. Genitalia (n=3) (Fig. 12). Papillae anales short, squarish in lateral view, with apical margin straight or only slightly rounded, rather well sclerotized, with short setation along apical margin and as thick cluster at base dorsally, with long setae sparsely distributed on most of surface. Apophyses of moderate length and thickness; anteriores about 2/3 length of posteriores, latter approximately reaching edge of ostium in extension. Segment VIII narrow, sternum desclerotized medially. Apex of sternum VII forming pair of posterior extensions of medium length, apically wide and blunt, separated by broad U with lateral margins straight for most of length, enlarging only apically; ventral margin of U normally scaled; with descaled, scobinated surface on dorsal side of lateral extensions. Antrum wide, about 1/2 as wide as tergum VIII, thickly sclerotized, scobinated. Ductus bursae with posterior section dorsoventrally compressed, rather short, about as wide as antrum, thickly sclerotized, scobinated, posteriorly curved at right angle dorsally then curved at right angle anteriorly; anterior section enlarged laterally and dorsoventrally, less thickly sclerotized, slightly shorter than posterior section, with few sclerotized ridges, with spinulose zones on left and right sides. Appendix bursae dextrally curved, narrowing before connecting with ductus seminalis. Corpus bursae circular, membranous, with pattern of small hexagons, about 1/2 as long as ductus bursae; signa a pair of small, short-spined, limpet-shaped low internal projections.

Biology. The species was reared on *Tournefortia pubescens* Hook. f. (Boraginaceae) under laboratory conditions. This plant, along with the other two species of *Tournefortia* present on San Cristobal is probably the host in the field.

Distribution. Currently known only from the Galapagos island of San Cristobal; presumed to be endemic to the archipelago.

Remarks. The original spelling of the name of this species is '*galapagenis*' (Wallengren, 1860), which would appear to be a misspelling for '*galapagensis*'. The next appearance of the name, also by Wallengren (1861), was published as '*gallopagensis*' without demonstration of intentional name change, hence it is here considered an incorrect subsequent spelling. Following these, all authors have used '*galapagensis*', here considered a justified emendation and adopted as the valid name.

The species was apparently described from a unique female specimen, although the number of females is not specifically mentioned. The NHRS holds this type only.

Forbes (1941) cites *U. galapagensis* as having been reported by Hampson (1920: pl. 68), but this appears to be an error as M. Honey (pers. comm.) checked this publication and couldn't corroborate Forbes' citation.

In a preliminary analysis of 688 base pairs of the mitochondrial gene cytochrome oxidase I (COI) by Michelle DaCosta *U. galapagensis* placed as sister to *U. connerorum* collected on Santa Cruz, suggesting a close relationship between the two species. Genetic distances (corrected) between these species ranged from 1.06% to 2.26%.

Inside the corpus bursae of one dissected female (slide BL 1665) there were five spermatophores.

***Utetheisa connerorum* Roque-Albelo & B. Landry, sp. n.**

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Figs 4, 7, 11, 14

Utetheisa galapagensis (misidentifications): Schaus, 1923: 23; Forbes, 1941: 101, 106, fig. 3; Linsley and Usinger, 1966: 158 (with original genus misspelled as *Euchalia*); Parkin et al., 1972: 103; Hayes, 1975: 161, figs 22, 23; Linsley, 1977: 29; Silberglied, 1978: 275; Hickin, 1979: 176; McMullen, 1993: 99; Roque-Albelo et al., 2002: 153; Perry and de Vries, 2003: 152; Garrett et al., 2008: 2–6; Roque-Albelo et al., 2009: 207 et seq.

Material examined. Holotype ♂: 1- 'ECU[ADOR]., GALAPAGOS | Isabela, V[olcan]. Darwin | 630 m elev[ation]., 17.v.1992 | M[ercury]V[apour]L[amp], leg. B. Landry' [printed black on white card stock]; 2- 'HOLOTYPE | *Utetheisa* | *connerorum* | Roque-Albelo & | Landry [handwritten in black ink on red card stock]. Deposited in MHNG. Paratypes: 41 ♂, 36 ♀, from Ecuador, Galapagos Islands. Baltra: 2 ♂, 3 ♀ (one dissected, slide [AMNH] MD296), South Seymour, 23.IV.1923 (W. Beebe expedition). Fernandina: 2 ♀, Arid zone, Altitud [sic] 850 m, S 00 35453 W 091 58912, 10.II.2005 U[ltra]V[iolet]L[ight] (L. Roque, B. Landry). Floreana: 1 ♀ (dissected, slide MHNG ENTO 5770), close to Loberia, G[lobal]P[ositioning]S[ystem]: elev[ation]. 6 m, S 01° 17.102' W 090° 29.460', 11.IV.2004, uvl (P. Schmitz); 3 ♂ (one dissected, slide MHNG ENTO 5085), 9 ♀ (one dissected, slide MHNG ENTO 5086), Punta Cormoran, 21.IV.1992, M[ercury]V[apour]L[amp] (B. Landry); 1 ♂, 1 ♀, Arid zone, 130 ms[obre el]n[ivel del]m[ar], 01 17.053S/ 090 28.295W, in black light trap, 24.III.1996 (L. Roque). Genovesa: 1 ♀, Bahia Darwin, 10.III.1992, MVL (B. Landry). Isabela: 2 ♂, 1 ♀, Volcán Alcedo Top, 1.100 msnm, LS0°26'25.5" LW91°05'22", IV.1998 (L. Roque); 1 ♀, Albermarle, Tagus Cove, 6.IV.1923 (W. Beebe expedition); 2 ♂, Tagus Cove, 13.V.1992, MVL (B. Landry); 1 ♂, V[olcan]. Darwin, 300 m elev[ation]., 15.V.1992 (B. Landry); 1 ♂, 2 ♀, V[olcan]. Darwin, 300 m elev., 20.V.1992, MVL (B. Landry); 1 ♂, ± 15 km N P[uer]to Villamil, 25.V.1992, MVL (B. Landry); 1 ♀, Alcedo, Guaya-billos, 900m, 30.X.2000, UVL-W[hite]L (L. Roque). Marchena: 1 ♂ (dissected, slide MHNG ENTO 5978), [no precise locality] 12.III.1992, MVL (B. Landry). Pinta: 3 ♂ (one dissected, slide MHNG ENTO 5769), Playa Ibbeston [sic], 14.III.1992, MVL (B. Landry); 4 ♂, arid zone, 15.III.1992, MVL (B. Landry); 1 ♂, 3 ♀ (one dissected, slide MHNG ENTO 5087), 200 m elev., 16.III.1992, MVL (B. Landry); 2 ♂, 400 m elev.,

17.III.1992, MVL (B. Landry); 2 ♂ (one dissected, slide MHNG ENTO 5084), 400 m elev., 18.III.1992, MVL (B. Landry); 1 ♂, \pm 50 m elev., 20.III.1992, MVL (B. Landry). San Cristobal: 1 ♂ (dissected, BL 1652), 4 km SE Pto Baquarizo [sic], 12.II.1989, MVL (B. Landry); 1 ♀ (dissected, BL 1662), 22.II.[19]06 (F. X. Williams). Santa Cruz: 1 ♂ (dissected, slide [AMNH] MD259), Indefatigable, 9.I.1936 (W. von Hagen); 1 ♀, same data except 12.I.1936; 1 ♂, 1 ♀, same data except 28.I.1936; 1 ♂, Finca Vilema, 2 km W Bella Vista, 1.IV.1992, MVL (B. Landry); 1 ♂, Los Gemelos, 27.V.1992, MVL (B. Landry); 1 ♀, Barranco, Arid zone, 20 msnm, 00 44' 34S-090 18' 21W, 13.IX.1996, in fluorescent light (L. Roque); 1 ♂, same locality, 8.X.1996, in fluorescent light tramp [sic] (L. Roque); 2 ♀, Santa Cruz, 30.X.1935 (W. von Hagen); 1 ♀, same data except 7.XI.1935; 1 ♂ (dissected, slide [AMNH] MD258), 1 ♀ (dissected, slide BL 1664), same data except 25.XI.1935. Santa Fé: 2 ♂, Tourist Trail, 28.V.1992, MVL (B. Landry). Santiago: 2 ♂ (one dissected, slide MHNG ENTO 5083), Bahia Espumilla, 4.IV.1992, MVL (B. Landry); 1 ♂, 200 m elev., 5.IV.1992, MVL (B. Landry); 1 ♂, 1 ♀ (dissected, slide MHNG ENTO 5755), Aguacate, 520 m elev., 6.IV.1992, MVL (B. Landry); 1 ♂, same data but 7.IV.1992; 1 ♀, Central, 700 m elev., 9.IV.1992, MVL (B. Landry); 1 ♀, 3 km E Playa Espumilla, 200 mts, 4.IX.1998, UVL (L. Roque). Deposited in AMNH, BMNH, CAS, CNC, IC-CDRS, and MHNG.

Diagnosis. This species may or may not have a pattern of up to four more or less lightly contrasted transverse lines; in this respect it differs most notably from the usually

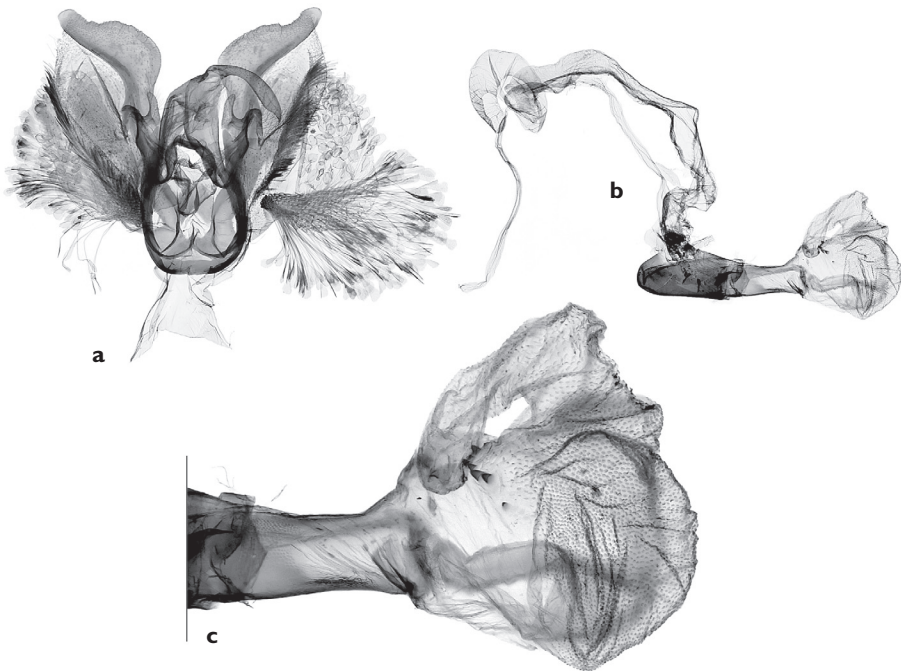


Figure 10. Male genitalia of *Utetheisa henrii* sp. n., slide BL 1654. **a** Whole genitalia without phallus **b** Phallus **c** Enlarged vesica.

more strongly marked *U. galapagensis* (Fig. 2) and *U. perryi* (see Hayes, 1975: Figs 20, 21). It differs from the larger *U. devriesi* (17–20.5 mm male forewing length) and *U. henrii* (14–16 mm male forewing length) in the submedian and postmedian lines slanted towards the apex, whereas *U. henrii* has the median and postmedian lines starting at right angle from the dorsal margin (Fig. 3), while in *U. devriesi* there is just one median line that is thickened on the dorsal margin (see Hayes, 1975: Figs 24, 25). Moreover, the male of *U. connerorum* has the most strongly pectinate antenna of the three species (Figs 6–8). In male genitalia *U. connerorum* (Fig. 11) has a moderately developed cucullus as in *U. galapagensis* (Fig. 9), but it has more strongly developed coremata than *U. galapagensis*, a less strongly swollen uncus, the vesica has the dorsodistal narrower extension longer, curved back almost to the sclerotized end of the phallus shaft, and it has 0–3 small spine-like cornuti on the right side at the level of the row of sclerotized bumps whereas *U. galapagensis* has 4 spines in the two specimens examined. In female genitalia *U. connerorum* mostly resembles *U. galapagensis* as they share a similar apex of sternum VII with a U-shaped median gap, but the posterior extensions of sternum VII in *U. connerorum* are narrower, longer, and apically rounded, whereas they are apically blunt in *U. galapagensis*.

Description. MALE (n=42) (Figs 4, 7, 11). Head smooth scaled, with thinner scales on frons converging medially, with ocelli, mostly greyish brown with some beige scales, sometimes slightly paler along eye margin and dorsal base of antenna; frons slightly rounded, without protuberances; eye about 1/4 width of whole head in frontal view. Labial palpus small, projecting slightly forward and upward, mostly white on basal segment, greyish brown mixed with beige on second, and greyish brown on third, sometimes with 1–2 white scales at apex. Antenna (Fig. 7) bipectinate; scape and pedicel mostly greyish brown; flagellum greyish brown with 1–3 pale beige scales on each flagellomere laterally, some flagellomeres with one thin seta sticking out of scale cover laterally or medially (or both) and about as long as one flagellomere, flagellomeres ventrally covered with short cilia; longest pectinations slightly longer than 2× width of corresponding flagellomere, each flagellomere distally adorned with curved, thick seta slightly less than half length of longest pectination, median pectinations also adorned dorsally with shorter, curved seta located near middle on shorter pectinations and subapically on longer pectinations. Thorax: Patagia greyish brown flecked with beige; tegulae concolorous with patagia, with elongate and thin white scales apically; mesothorax concolorous with tegulae anteriorly, with more beige scales toward apex; metathorax with long, whitish beige scales. Legs with coxa and femur greyish brown abundantly speckled with beige; fore- and midleg with tibia and tarsomeres darker greyish brown with few beige scales laterally on tibia and at apex of each tarsomere; hindleg tibia and tarsomeres paler, with more beige scaling than on other two legs, but also with distinct paler rings at apex of each tarsomere. Forewing length: 12–15 mm (holotype 14 mm). Coloration greyish brown with or without apparent pattern of up to 4 darker greyish brown lines slanted toward outer margin, starting on inner margin postbasally, submedially, postmedially, and subapically, curving back at median sector, and connecting with costa; under magnification scales from light to dark beige and brown; fringe concolorous, with some longer scales white. Hindwing pale greyish brown, rarely with marginal 1/5 slightly darker; fringe slightly contrasting, paler,

mixed white to pale brown. Underside of wings mostly pale greyish brown; forewing with costa, apex, and outer margin speckled with white to pale beige.

Abdomen: greyish beige. Genitalia (n=8) (Fig. 11). Uncus rather narrow, moderately long, with sparse, short setation mostly laterally except toward apex, setae slightly longer on slightly swollen section from middle to before apex, with curved, sharply pointed, downturned apex. Cucullus with rather wide median section slightly produced dorsally, with somewhat wrinkled edge, slightly narrowing distally to rounded apex. Corema very broad, not reaching apex of cucullus, with long spatulated androconial scales on broad base, and short-stalked, bulbous ones on distal 2/3. Ampulla short, thumb-like, with mostly short setae, mostly on dorsal surface and apex. Phallus cylindrical, distal third with lateral walls partly unsclerotized, ventral and dorsal sclerotized areas adorned with scobination on distal half dorsally and distal 1/4 ventrally, left lateral wall distally with narrow sclerotized and scobinated band ending in short spined crest; coecum penis with minimal ventral incline, not enlarged; vesica with row of about 6–10 sclerotized rounded bumps dorsally on left side before middle, with 0–3 small spine-like cornuti on right side at level of row of sclerotized bumps, with dorsodistal narrower extension moderately developed, curved back almost to apex of sclerotized phallus shaft.

FEMALE (n=36). Color and maculation as in male. Antenna with flagellomeres slightly biserrate, some with seta sticking out dorsally, ventrally with short cilia, with thick seta at distal end of each serration about 1/4 longer than one flagellomere, also with one lateral seta on each serration about half as long as distal seta. Forewing length: 12–14 mm. Frenulum with 2 acanthae. Genitalia (n=7) (Fig. 14). Papillae anales short, rounded, rather well sclerotized, with short setation along apical margin and especially as thick cluster at base dorsally, with long setae sparsely distributed on most of surface. Apophyses moderately long and thin; posteriores 1/3 to 2/3 longer than anteriores, approximately reaching ostium in extension. Segment VIII narrow, sternum desclerotized medially. Apex of sternum VII forming pair of rather long, narrow and apically rounded posterior extensions separated by narrow U with anterior end often slightly wider; ventral margin of U normally scaled; with descaled, scobinated surface on dorsal side of lateral extensions. Antrum wide, about 1/2 as wide as tergum VIII, thickly sclerotized, scobinated. Ductus bursae with posterior section dorsoventrally compressed, rather short, slightly wider than antrum, thickly sclerotized, scobinated, posteriorly curved at right angle dorsally and then again anteriorly; anterior section slightly wider, less thickly sclerotized, without scobination, not forming twist. Appendix bursae sclerotized and ridged, dextrally curved, of medium length, with or without spinules at base, narrowing before connecting with ductus seminalis. Corpus bursae circular, not much wider than anterior section of ductus bursae, membranous, with pattern of small pentagons or hexagons, about 1/4 longer than ductus bursae; signa a pair of small, limpet-shaped, oval, short-spined, low internal projections.

Larva. (From Perry and de Vries, 2003). 18 mm long. Head dark brown with white patches. Thorax and abdomen pale buff, heavily overlain dorsally and laterally with greyish and brownish black, these markings merging to more or less continuous black on either side of a pale median stripe.

Biology. The moths of *U. connerorum* are nocturnal and specimens have been attracted to light from sea level to the pampa zone. The following biological observations were given under the name *U. galapagensis* (Wallengren). Hayes (1975) reported the food plants as *Tournefortia psilostachya* HBK. and *T. pubescens* Hooker f. (Boraginaceae), that moths were often seen flying at dusk around plants of *Scalesia affinis* Hooker f. (Asteraceae), and that they fly in all months of the year. Silberglied (1978) reported moths being attracted to ship lights and thus being transported from island to island. McMullen (1993) observed moths visiting flowers of *Cordia lutea* Lamarck and *Tournefortia rufo-sericea* Hooker f. Roque-Albelo et al. (2002) treated the chemical defense and lack of aposematism of this species. They reported that the larva feeds on three species of *Tournefortia*: *T. rufo-sericea*, *T. psilostachya*, and *T. pubescens*. The moths of both sexes contain pyrrolizidine alkaloids as *U. ornatrix* (L.), which, in contrast, is diurnal and aposematically coloured. Perry and de Vries (2003) added *Heliotropium curassavicum* L. (Boraginaceae) as a food plant for this species. They added that the larva is solitary and draws leaves together, fastening their edges, for concealment, and that larval specimens were collected from May to November. During field experiments in the Galapagos, Garrett et al. (2008) demonstrated that the moths of this species were unpalatable to an orb-weaving spider (*Eustela vegeta* (L. Koch) Simon, Araneidae), which released moths given to them off their webs, but lava lizards (*Microlophus pacificus* Steindachner) ate the moths presented to them, which suggest that the endemic group of Galapagos *Utetheisa* lost their aposematic colouration to avoid diurnal lizard predation, but retained their chemical defenses to avoid nocturnal spider predation.

Etymology. We are pleased to name this species in honour of William and Mindy Conner in recognition of their many contributions to the study of arctiid moths, including Galapagos *Utetheisa*.

Distribution. This species is endemic to the Galapagos archipelago, where it is the most widespread of all *Utetheisa* species. We have examined specimens from Baltra, Fernandina, Floreana, Genovesa, Isabela, Marchena, Pinta, San Cristóbal, Santa Cruz, Santa Fé, and Santiago.

Remarks. This species and *U. galapagensis* apparently are the most closely related of the Galapagos *Utetheisa* based on the morphology of the female and male genitalia. This is corroborated by the mitochondrial sequence data mentioned above.

In one dissected female there was a tiny caterpillar (preserved on slide MHNG ENTO 5770) at the end of the oviduct. It was not enclosed in an egg capsule as the latter disintegrated during KOH treatment of the abdomen.

Utetheisa henrii Roque-Albelo & B. Landry, sp. n.

urn:lsid:zoobank.org:act:85B5B499-10E2-4526-A8E4-6130A90A7763

Figs 3, 6, 10, 13

Material examined: Holotype: ♂, 1- 'ECUADOR | GALÁPAGOS | San Cristóbal | pampa zone | 18.II.1989, M[ercury]V[apour]L[amp] | B. Landry' [printed black on

white card stock, with 'ECUADOR' sideways on left]; 2- 'HOLOTYPE | *Utetheisa* | *henrii* | Roque-Albelo & | B. Landry' [handwritten in black ink on red card stock]; 3- 'BL 1654 ♂' [handwritten in black ink on green paper]; 4- 'Database # | CNC LEP | 00041388' [printed in black on white card stock]. Deposited in the CNC.

Paratypes: 3 ♂, 2 ♀: – 1 ♀ (dissected, slide BL 1653), same data as holotype except date (15.II.1989) (CNC); 1 ♂, 'ECUADOR [sideways on left side] | GALAPAGOS | San Cristóbal, 4 | km SE P[uer]to Baquarizo [sic] | 20.II.1989, MVL | B. Landry' (MHNG); 1 ♂ (dissected, slide LR 177) 'ECU. GALAPAGOS. San Cristóbal | El Chino. (R. Criollo) | S 0° 54' 53.5" W 89° 27' 15.4" | 195msnm 2–3.XII.2002. L. Guamán | T. Luz. (Hortalizas Frutales)' (IC-CDRS); 1 ♀ 'ECU. GALAPAGOS. San Cristóbal | El Chino. (R. Criollo) | S 0° 54' 53.5" W 89° 27' 15.4" 195msnm | 2–3. XII.2002. L. Guamán | T. Luz. (Hortalizas Frutales)' (IC-CDRS); 1 ♂ (dissected, LR 179) 'ECU. GALAPAGOS. San Cristóbal | Goteras. (M. Davis [farm]) | S 0° 52' 17.1" W 89° 26' 18.8" 359msnm | 4–5.XII.2002. L. Guamán, J. Loaiza | T. Luz. (*Brachiaria* sp.)'. Deposited in CNC, IC-CDRS, and MHNG.

Diagnosis: Among the Galapagos endemic species of *Utetheisa*, *U. henrii* (Fig. 3) has a dull pattern similar to that of *U. connerorum* (Fig. 4) except that *U. henrii* has a wider and straighter median line and the apical 1/5 of the forewing is wholly darker brown. Also, the male flagellum of *U. henrii* has shorter and thicker pectinations (compare Figs 6 and 7), and in male genitalia (Fig. 10) the uncus is thicker and shorter, the median part of the cucullus is more strongly produced, the left side of the phallus subapically is without a spined, elongate, triangular projection, the vesica has a clear set of spines dorsally where *U. connerorum* (Fig. 11) has a series of circular, sclerotized knobs. *U. connerorum* also often has 1–3 additional spines dorsally at the level of the knobs on the right side (4 specimens examined, one without these spines, two with one spine), and the narrower, dorsodistal extension of the vesica is longer in *U. henrii*. In female genitalia the main difference lies in the shape of the apex of sternum VII which in *U. connerorum* (Fig. 14) is narrower and has the lateral extensions longer, apically rounded, with the gap between them forming a narrow U, and altogether supporting dorsally the lateral walls of the antrum. The signa, ductus bursae, and ventral extension connecting with the ductus seminalis in *U. henrii* (Fig. 13) are also more strongly developed.

Description: MALE (n=4) (Figs 3, 6, 10). Head: Smooth scaled, with thinner scales on frons converging medioventrally, with ocelli, scales mixed dark to light brown but white along margin of eye and base of antenna; frons slightly rounded, without frontal protuberances; eye as wide as 3/10 of width of whole head in frontal view. Labial palpus small, projected slightly forward and upward, brown with white scales on basal segment and base of second segment laterally. Antenna bipectinate (Fig. 6), light brown scaled dorsally, with white scales ventrally on scape and pedicel; some flagellomeres with one thin seta sticking out of scale cover and about as long as one flagellomere, flagellomeres ventrally covered with short cilia; longest pectinations slightly shorter than width of corresponding flagellomere; each pectination distally adorned with long, curved, thick seta 2× length of pectination, and shorter, thinner seta from base of pectination dorsally and reaching tip of pectination or beyond (absent of some lateral pectinations).

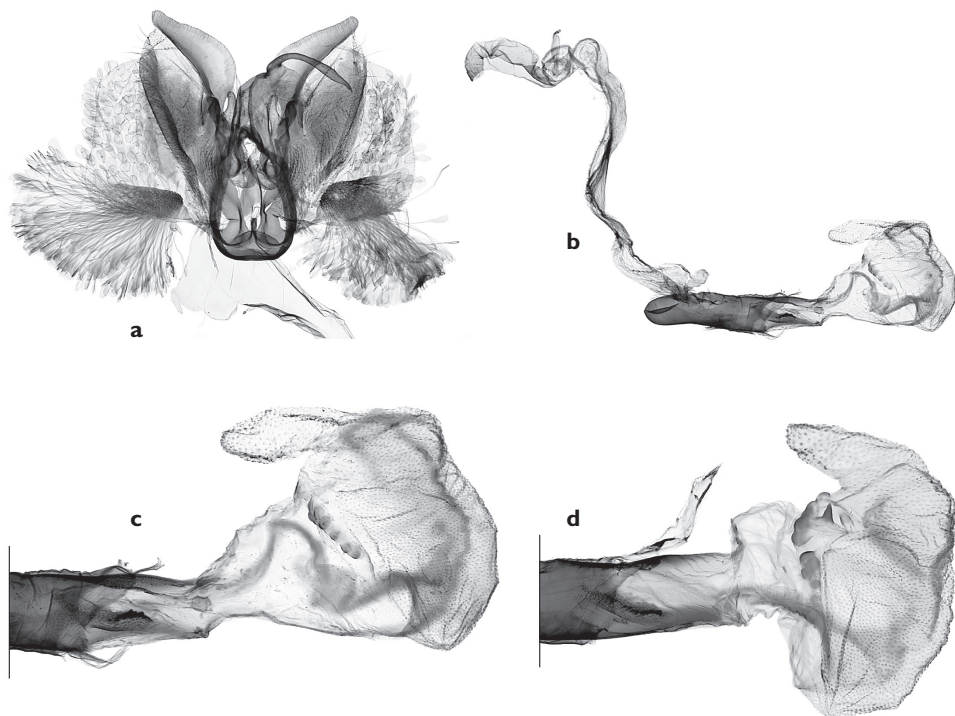


Figure 11. Male genitalia of *Utetheisa connerorum* sp. n., slide BL 1652. **a** Whole genitalia without phallus **b** Phallus **c** Enlarged vesica **d** Enlarged vesica from slide MHNG ENTO 5084.

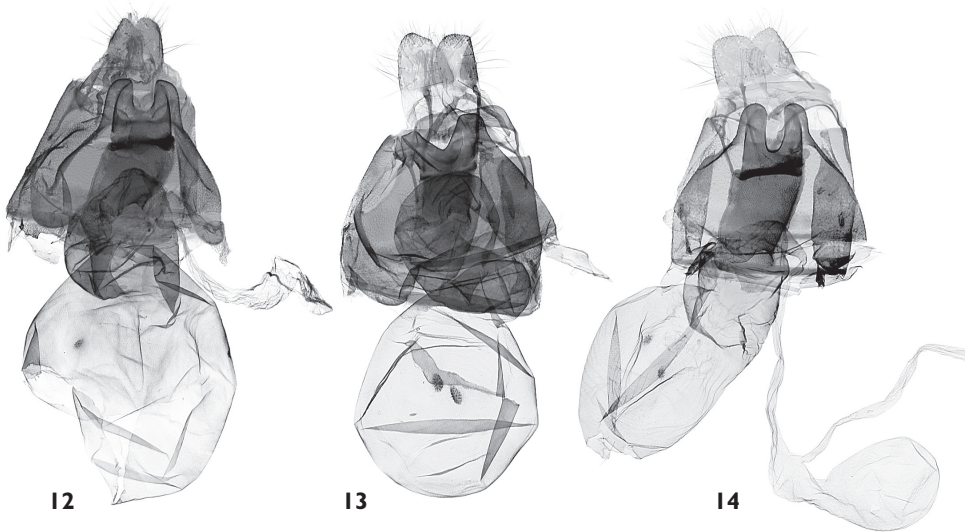
Thorax: Patagia brown flecked with beige; tegulae brown with hair-like whitish scales on edges and apex; mesothorax as collar; metathorax white-scaled. Legs mostly dark greyish brown on tibia and tarsi, flecked with pale beige especially on hindleg; coxae, trochanters, and femurs paler, white to beige, more or less flecked with brown. Forewing length: 14–16 mm (holotype: 16 mm). Coloration superficially brown with darker markings in faint postbasal, curved line, straight, well-marked, thick median fascia, faint, postmedian waved line, and well-marked, darker terminal 1/5; under magnification covered with mixture of light beige, dark brown, and brown scales. Hindwing light greyish brown; with diffuse brown marginal band slightly more apparent at apex of CuA2. Underside of wings less evidently marked than upperside and paler.

Abdomen: whitish brown. Genitalia (n=3) (Fig. 10). Uncus rather thick, moderately long, with short setae dorsally before distal 1/3 and ventrally before apex, swollen subapically, with curved, sharply pointed, downturned apex. Cucullus with median section broadly produced dorsally, with somewhat wrinkled edge, markedly narrowing into short, apical section with rounded apex. Corema broad, not reaching apex of cucullus, with long spatulated androconial scales on base of medium width and length, and short-stalked, bulbous ones on distal 2/3. Ampulla short, thumb-like, with mostly short setae, especially toward apex. Phallus cylindrical, distal third with lateral walls

unsclerotized, ventral and dorsal sclerotized areas adorned with scobination subapically; vesica with 5–8 small cornuti mediodorsally, dorsodistal narrower extension long, curved back almost to apex of sclerotized phallus shaft.

FEMALE (n=2) (Fig. 13). Color and maculation as in male. Antenna with flagellomeres slightly biserrate, some with seta sticking out dorsally, ventrally with short hyaline cilia, with thick seta at distal end of each serration about $\frac{1}{4}$ longer than one flagellomere, also with one lateral seta on each serration about half as long as distal seta. Forewing length: 16–17 mm. Frenulum with 2 acanthae. Genitalia (n=1) (Fig. 13). Papillae anales short, rounded, rather well sclerotized, with short setation along apical margin and especially as thick cluster at base dorsally, with long setae sparsely distributed on most of surface. Apophyses of moderate length and thickness; posteriores slightly more than 2× length of anteriores, approximately reaching edge of ostium in extension. Segment VIII narrow, sternum desclerotized medially. Apex of sternum VII forming pair of short, blunt posterior extensions separated by broad V; ventral margin of V with descaled, scobinated ‘collar’ anteriorly closed by narrow scaled rim. Antrum wide, $\frac{2}{3}$ as wide as tergum VIII, thickly sclerotized, scobinated. Ductus bursae with posterior section dorsoventrally compressed, rather short, slightly wider than antrum, thickly sclerotized, scobinated, posteriorly curved at right angle dorsally and then again anteriorly; anterior section slightly wider, less thickly sclerotized, without scobination, forming one twist. Appendix bursae sclerotized and ridged, dextrally curved, of medium length, with few spinules on right side, narrowing before connecting with ductus seminalis. Corpus bursae circular, membranous with pattern of small hexagons, about $\frac{1}{4}$ longer than ductus bursae; signa a pair of small, limpet-shaped, oval, short-spined, internal projections.

Biology. Unknown, found on the humid zone of San Cristobal. Host plants are probably members of the genus *Tournefortia* as in the other endemic species of *Utetheisa*.



Figures 12–14. Female genitalia of Galapagos *Utetheisa* species **12** *U. galapagensis* (Wallengren), holotype, slide BL 1655 **13** *U. henrii* sp. n., slide BL 1653 **14** *U. connerorum* sp. n., slide BL 1662.

Etymology. This species is named in honor of H.R.H. Grand-Duke Henri of Luxembourg for his most generous support to the Charles Darwin Foundation and the conservation of the Galapagos Islands.

Distribution. Presumed to be endemic. Currently known only from the Galapagos Island of San Cristóbal.

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A taxonomic study on the genus *Tectodamaeus* Aoki (Acari, Oribatida, Damaeidae), with description of two new species from China

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Abstract

Two new species of the genus *Tectodamaeus* from Yunnan and Anhui Province respectively, China are described, *Tectodamaeus daliensis* **sp. n.**, *Tectodamaeus longus* **sp. n.** Nine new combinations, *Tectodamaeus costanotus* (Wang & Norton) **comb. n.**, *Tectodamaeus exspinosus* (Wang & Norton) **comb. n.**, *Tectodamaeus wulongensis* (Wang & Cui) **comb. n.**, *Tectodamaeus brevisetus* (Wang) **comb. n.**, *Tectodamaeus spiniger* (Wang) **comb. n.**, *Tectodamaeus exsertus* (Wang) **comb. n.**, *Tectodamaeus yaoi* (Wang) **comb. n.**, *Tectodamaeus furcatus* (Wang & Lu) **comb. n.**, *Tectodamaeus cuii* (Wang & Lu) **comb. n.** are presented. The subgenus *Damaeus* (*Tectodamaeus*) as a genus in the oribatid mite family Damaeidae was reestablished. A key is given to distinguish all the species of the genus. The type specimens of the new species are deposited in the Institute of Entomology, Guizhou University (IEGU).

Keywords

Oribatida, Damaeidae, *Tectodamaeus*, *Damaeus*, new species, new combination, China

Introduction

The genus *Tectodamaeus* (Acari, Oribatida, Damaeidae), was established by Aoki (1984) for a single species, *Tectodamaeus armatus* Aoki, 1984, because there are only 2 setae on genu IV, while all the known genera of Damaeidae have 3–4 setae on the segment. In 1988, Enami and Aoki described the second species, *Tectodamaeus striatus*. In 1989, Wang and Norton described two species from South China, *Damaeus exspinosus*, *Damaeus costanotus*. Later, Wang and Hu (1992) described a new species *Damaeus wulongensis*. In 1994, Wang and Cui described another five species, proposed two new combinations and *Tectodamaeus* was treated as a subgenus of *Damaeus*.

In this paper, the subgenus *Damaeus* (*Tectodamaeus*) as a genus in the oribatid mite family Damaeidae was reestablished. Two new species of *Tectodamaeus* from China are described and illustrated and nine new combinations present. A key to all known species of this genus is also provided. The type specimens of new species are deposited in the Institute of Entomology, Guizhou University, Guiyang, Guizhou (IEGU).

Results

Genus *Tectodamaeus* Aoki

Tectodamaeus Aoki, 1984: 110–111; Enami and Aoki 1988:33–36

Damaeus (*Tectodamaeus*) Wang and Cui, 1994: 62–63; Lu and Wang, 1995: 81–82;

Lu and Wang, 1995:59–62

Type species: *Tectodamaeus armatus* Aoki, 1984.

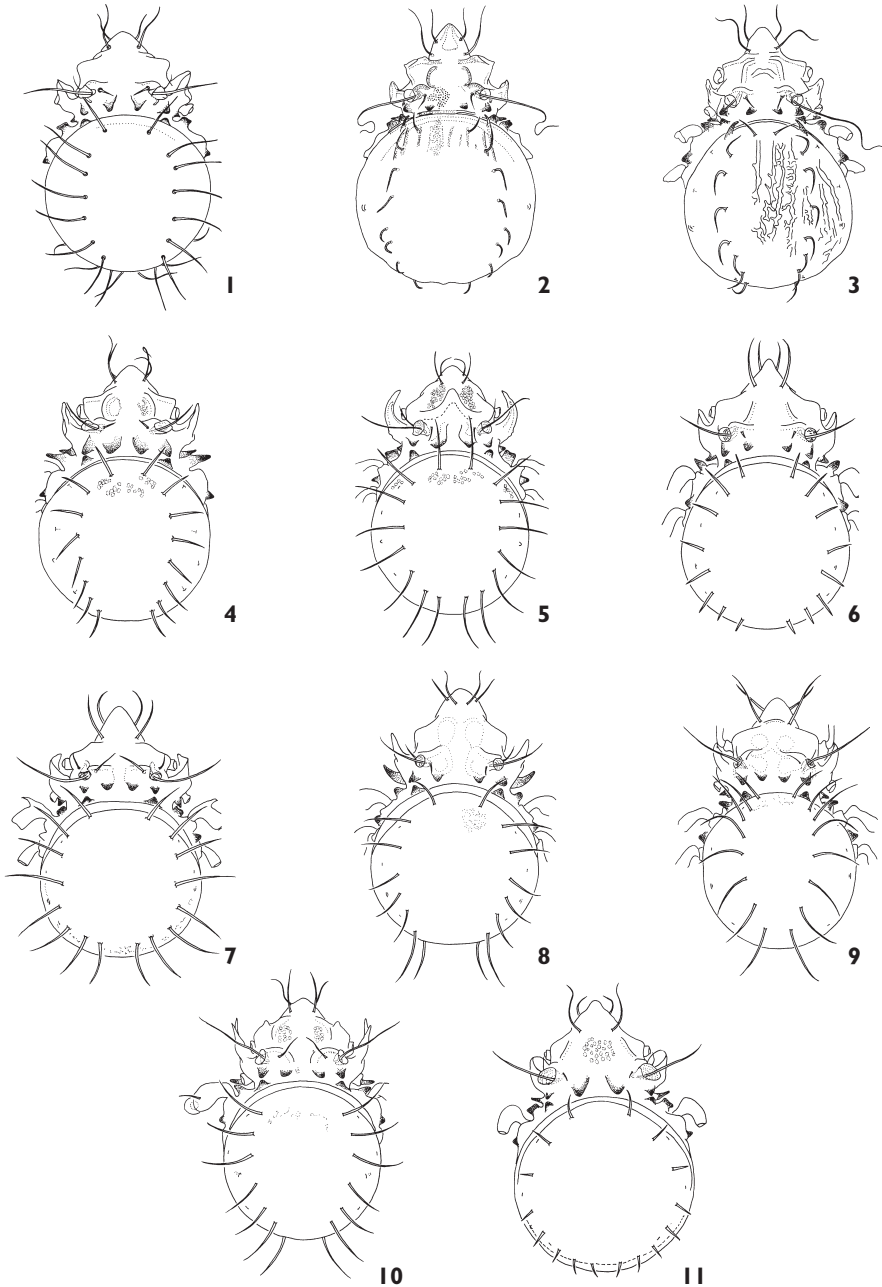
Description. Large, dark-colored damaeid mites with long legs. Three pairs of tubercles (Da, Ba and Bp) on prodorsum and 4 pairs of tubercles (E2a, E2p, Va and Vp) on ventral side well developed. Propodolateral apophysis (P) always present, Discidium present. Epimeral setation: 3–1–3–4. Leg IV always longer than total body length. Genu IV bearing only 2 setae. Setae *d* of genu present on legs I–III. Solenidion of tibia has no protecting seta *d* on legs I–IV.

Diagnosis. *Tectodamaeus* resembles *Damaeus* Koch, 1836 in general appearance, but can be distinguished from latter by having only 2 setae on genu IV and Setae *d* of genu present on legs I–III.

Distribution. Oriental Region, Palaearctic region.

Key to species of the genus *Tectodamaeus*

- | | | |
|---|--|---|
| 1 | Spinae adnatae present (Figs 2, 3, 18) | 2 |
| – | Spinae adnatae absent (Figs 1, 4–12) | 4 |



Figures 1–11. 1 *Tectodamaeus armatus* (Aoki) 2 *Tectodamaeus striatus* Enami & Aoki (after Enami and Aoki 1988) 3 *Tectodamaeus costanotus* (Wang & Norton); 4 *Tectodamaeus expinosus* (Wang & Norton) (after Wang and Norton 1989) 5 *Tectodamaeus wulongensis* (Wang & Cui) 6 *Tectodamaeus brevisetus* (Wang) 7 *Tectodamaeus spiniger* Wang (after Wang and Cui 1994) 7a unusually tubercles 8 *Tectodamaeus exsertus* Wang (after Wang and Cui 1994) 9 *Tectodamaeus yaoi* (Wang) 10 *Tectodamaeus furcatus* Wang & Lu (after Wang and Lu 1995a) 11 *Tectodamaeus cuii* Wang & Lu (after Wang and Lu 1995b).

- 2 Legs are very long, especially leg IV (Figs 20–23) *T. longus* sp. n.
 — Legs are not very long 3
- 3 Existing striation in the anterior part of notogaster (Fig. 2) *T. striatus*
 — Existing striation over all the surface of notogaster (Fig. 3)
 *T. costanotus* (Wang & Norton) comb. n.
- 4 Tubercle Sp slightly acute at tip, peach-shaped (Fig. 6)
 *T. brevisetus* (Wang) comb. n.
- Tubercle Sp rectangular, triangle or anvil-shaped (Figs 1, 4, 5, 7–12) 5
- 5 Tubercle Sp triangular (Fig. 9) *T. yaoi* (Wang) comb. n.
 — Tubercle Sp rectangular or anvil-shaped (Figs 1, 4, 5, 7, 8, 10–12) 6
- 6 Propodolateral apophysis(P) bowl-like (Fig. 11)
 *T. cuii* (Wang & Lu) comb. n.
- Propodolateral apophysis(P) not bowl-like (Figs 1, 4, 5, 7, 8, 10, 12) 7
- 7 Propodolateral apophysis(P) bent ventrad, horn-shaped (Fig. 5)
 *T. wulongensis* (Wang & Cui) comb. n.
- Propodolateral apophysis(P) bent anteriad (Figs 1, 4, 7, 8, 10, 12) 8
- 8 Femora and trochanter with unusually tubercles (Fig. 7)
 *T. spiniger* (Wang) comb. n.
- Femora and trochanter without unusually tubercles 9
- 9 The length of tubercle Sa larger than Sp (Fig. 8)
 *T. exsertus* (Wang) comb. n.
- The length of tubercle Sp larger than Sa (Figs 1, 4, 10, 12) 10
- 10 Propodolateral apophysis(P) furcated at the tip (Fig. 10)
 *T. furcatus* (Wang & Lu) comb. n.
- Propodolateral apophysis(P) not furcated at the tip (Figs 1, 4, 12) 11
- 11 Tubercle Sp somewhat anvil-shaped (Fig. 4)
 *T. exspinosus* (Wang & Norton) comb. n.
- Tubercle Sp rectangular at base (Figs 1, 12) 12
- 12 Notogastral setae acuminate, roughened with dense warts and distal half
 finely barbed, c_1 directed anteriad. (Fig. 12) *T. daliensis* sp. n.
- Notogastral setae thick, smooth. (Fig. 1) *T. armatus*

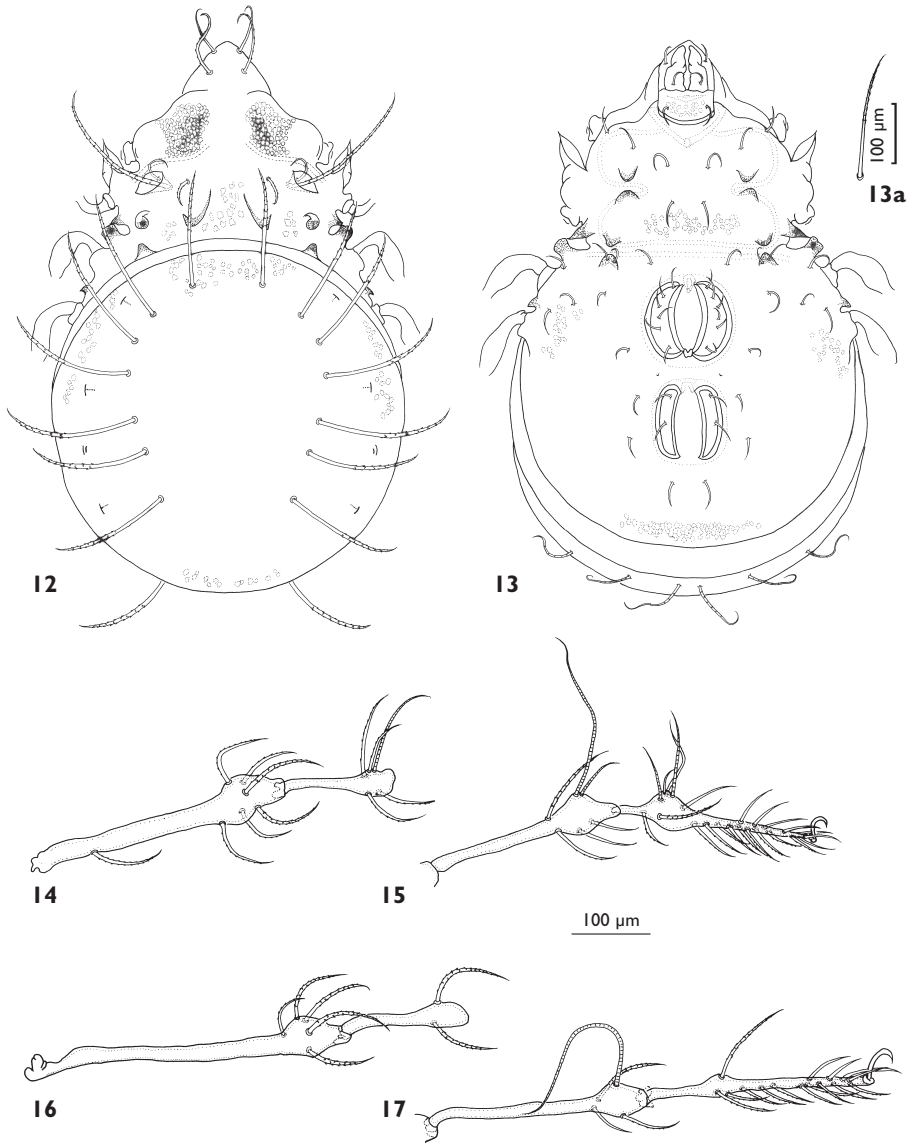
***Tectodamaeus daliensis* sp. n.**

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Figs 12–17

Measurements. Mean ventral length: 817 μ m (range 785–822); Mean notogastral width: 722 μ m (range 695–786).

Integument. Microtuberculate on all enantiophyses and apophyses, rostrum, lateral prodorsum and around leg acetabula. Cerotegument mostly filamentous, long, thick, dense on most of body and legs, except center of notogaster.



Figures 12–17. *Tectodamaeus daliensis* sp. n. **12** adult, dorsal view **13** adult, ventral view **13a** the setae of notogaster **14** femur and genu of leg I; **15** tibia and tarsus of leg I; **16** femur and genu of leg IV; **17** tibia and tarsus of leg IV.

Prodorsum. Three pairs tubercles (Da, Ba and Bp) well developed. Propodolateral apophysis (P) strongly developed, pedotectum-like. Setae *le* with small, coarse barbs, those of *ro* smooth, both setae attenuate, mutual distance of *ro* slightly less than that of *le*. Setae *in* short, dark brown, with small barbs and roughened. Exobothridial setae relatively long, undulating attenuate. Sensillus (about 329 μm) dark, attenuate, with sparse, fine, conspicuous barbs, tip acuminate.

Notogaster. Hemispherical, adherent debris, held away from notogastral surface. Notogastral setae of c -, l -, h - series inserted on distinct tubercles. Setae relatively large, thick, brown, acuminate, roughened with dense warts and distal half finely barbed. c_1 (about 150 μm) directed anterodorsad, c_2 (about 188 μm) dorsolaterad. l - and h -series (mostly 200–235 μm) erect from surface, slightly curved posterolaterad. Mutual distance of setae c_2 2 times that of c_1 . Pseudanal setae undulating attenuate, conspicuous barbed. ps_1 somewhat darkened and directed posterolaterad, ps_2 and ps_3 curved laterad. Order in length of the thicker setae: $c_1 < c_2 = h_2 = h_3 = la < lp < lm < h_1$.

Ventral region. Coxisterna I with medial pit and associated groove. Enantiophyses E2 and V present. E2a small, broadly curved tubercle, represented by low, broadly curved ridge, E2p and Va all represented by broad ridge. Vp carrying seta 3b, 4b. Lateral margin of coxisternum I and II strongly contoured giving appearance of ridge in transmitted light. Tubercle Sa broadly triangular with narrowly rounded tip, Sp broadly rounded or subquadrangular, in lateral aspect Sp twice as broad as Sa. Discidium small than Sp, directed posterolaterad. Ventral setae smooth. Coxisternal setation: 3 – 1–3 – 4. Anogenital region normal, seta ad_3 close to anal valves. Raised medial band of anal valve distinct, with undercut lateral margin, fissure *ian* minute, represented by small, inconspicuous pore in anterolateral corner of valve. Anal aperture appreciably narrower than genital one.

Legs. Relative lengths (I–IV) 1: 0.77: 0.85: 1.06. Leg IV 1.38 times ventral body length. Femur IV 2.5 times length of trochanter IV, proximal stalk 3 times length of bulb. Leg chaetotaxy (famulus included, solenidia in parentheses) – I: 1–7–4(1)–4(2)–21(2); II: 1–6–4 (1)– 4(1)–18 (2); III: 2–5–3(1)–3(1)–18; IV: 1–5–2–3(1)–15. Setae d of genu shorter than respective coupled solenidion δ . Tibia solenidia φ of leg IV is long, tibial solenidion φ_1 on leg I about 4 times as long as φ_2 .

Type Material. 1 Holotype and 14 Paratypes, leaf litter, Mt.Cang, Dali (25°43'18.19"N, 100°11'33.78"E), Yunnan province, China. 11 December 2007, coll. Yi Yan (IEGU).

Remarks. The new species is similar to *Tectodamaeus armatus* Aoki, but is easily distinguished from the latter mainly by the setae of notogaster, roughened with dense warts and distal half finely barbed. The shape of sensilluse and tubercles (Sp, Da and Ba) and leg chaetotaxy are also different. The new species is also similar to *T. spiniger* (Wang), but the former differs from the latter by different notogastral setae.

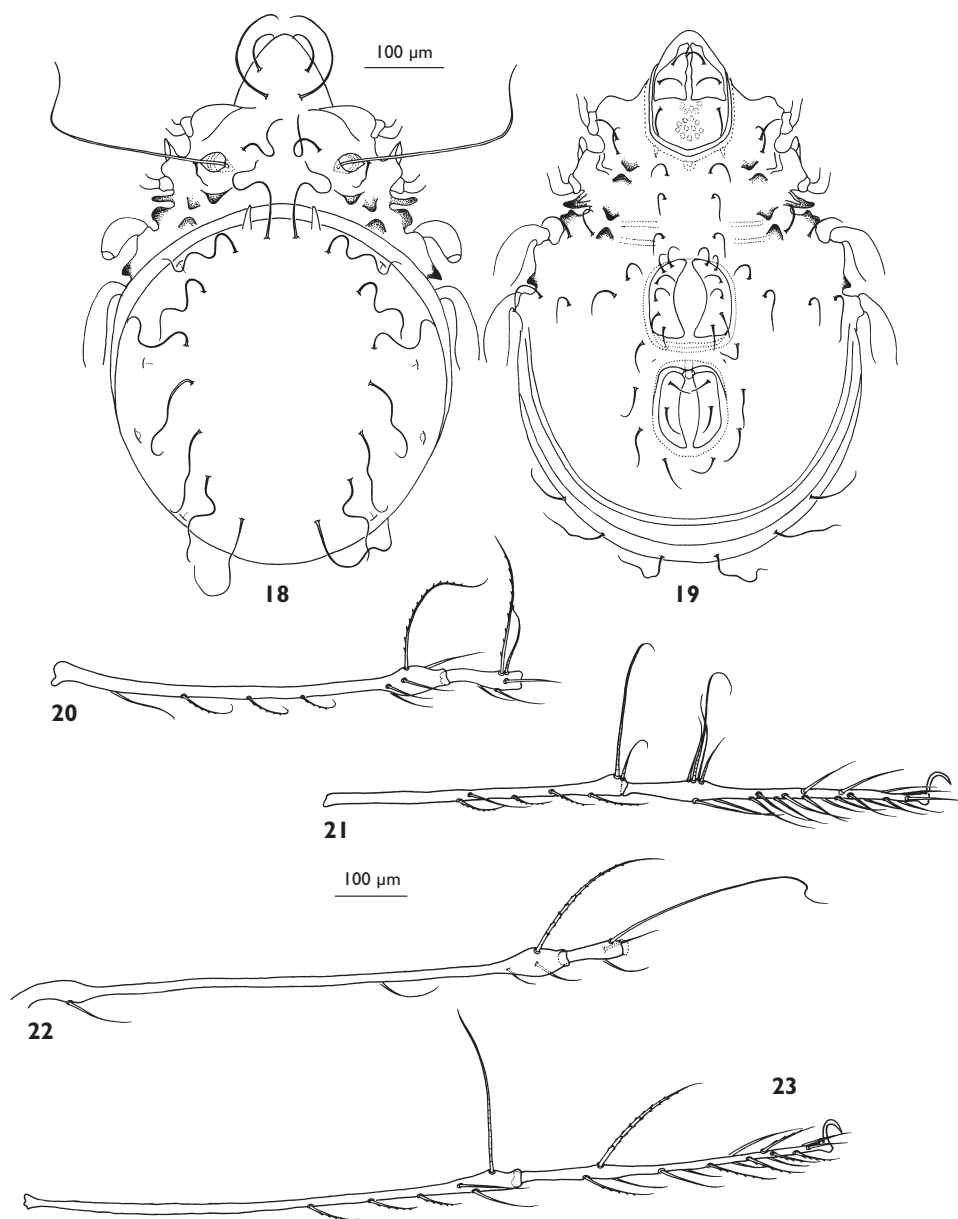
Etymology. The species name is derived from the name of type locality.

Tectodamaeus longus sp. n.

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Figs 18–23

Measurements. Mean ventral length: 686 μm (range 656–721); Mean notogastral width: 490 μm (range 465–514).



Figures 18–23. *Tectodamaeus longus* sp. n. **18** adult, dorsal view **19** adult, ventral view **20** femur and genu of leg I **21** tibia and tarsus of leg I **22** femur and genu of leg IV **23** tibia and tarsus of leg IV.

Integument. Yellowish-brown to reddish- brown in colour. Surface of body and basal part of leg segments except distal half of tarsi with rather thick cerotegument. Notogaster with triangular spinae adnatae and exuviae. Microtuberculate on all enantiophyses and apophyses, rostrum, lateral prodorsum and around leg acetabula. Noto-

gaster and leg segments with adherent debris. Distal parts of all tarsi, and bulb of tarsi III, IV smooth.

Prodorsum. Three pairs tubercles (Da, Ba and Bp) well developed. Propodolateral apophysis (P) strongly developed. Rostral seta (about 117 μ m) thin. Lamellar seta long (about 196 μ m), both setae attenuate, smooth, mutual distance of *le* slightly less than that of *ro*. Interlamellar setae (about 156 μ m) very long, smooth, flagellate, curling. Exobothridial setae short, undulating attenuate. Sensillus (about 392 μ m) long, smooth, flagellate, directed dorsolaterad.

Notogaster. Slightly ovate viewed perpendicular to circumgastric scissure, about 1.1 times as long as wide. Spinae adnatae medium in size (about 98 μ m), curved ventrad, distance between their bases almost equal to that between insertions of interlamellar setae. Notogastral setae very long (mostly 58–137 μ m), smooth, flagellate, curling. c_1 (about 117 μ m) directed anterodorsad, relatively thick, curling. c_2 (about 78 μ m) directed dorsolaterad. *l* and *h* series (mostly 68–137 μ m), curved posterolaterad. Mutual distance of setae c_2 3 times that of c_1 . Pseudanal setae undulating attenuate, ps_1 curved posterolaterad, ps_2 and ps_3 curved laterad. Order in length of the setae: $la = lm < lp < h_3 < c_2 < h_2 < c_1 < h_1$. Lyrifissures *ia*, *im*, *ih*, *ips* and *ip* and lateroopisthosomal gland opening gla well developed.

Ventral region. Coxisterna I with medial pit but without groove leading anteriorad from it. Enatiophyses E2 and V present, broadly curved tubercle, represented by low, broadly curved ridge. Enantiophysis V positioned laterally, seta *3b* not carried on tubercle Vp. Tubercle Sa broadly triangular with tip directed anterolaterad. Sp subquadrangular, in lateral aspect Sp twice as broad as Sa. Discidium smaller than Sp, directed posterolaterad. Ventral setae smooth. Coxisternal setation: 3–1–3–4. Anogenital region normal, seta ad_3 close to anal valves. Raised medial band of anal valve distinct, with undercut lateral margin, fissure *ian* minute, represented by small, inconspicuous pore in anterolateral corner of valve. Anal aperture appreciably narrower than genital one.

Legs. Relative lengths (I–IV) 1: 0.63 : 0.88 : 1.41. Leg IV is very long, about 3.21 times ventral body length. Leg chaetotaxy (famulus included, solenidia in parentheses) – I: 1–9–4(1)–5(2)–20(2); II: 1–7–4(1)–4(1)–18(2); III: 2–5–3(1)–4(1)–18; IV: 1–4–2–5(1)–15. solenidion δ of genu on legs I–III are shorter than respectively coupled protecting seta *d*. Tibia solenidia φ of leg IV is long, tibial solenidion φ_1 on leg I about 3 times as long as φ_2 . Femur I 12 times length of trochanter I and tibia I is equal to tarsus I. Femur IV 7 times length of trochanter IV, proximal stalk 6 times length of bulb.

Type Material. 1 Holotype and 3 Paratypes, leaf litter, Mt. Huang (30°16'22.26"N, 118°08'32.09"E), Anhui province, China. 25 May 2008, coll. Zhanyu Hu (IEGU).

Remarks. This new species is similar to *Damaeus flagellatus* (Wang), but is easily distinguished from the latter mainly by the length and chaetotaxy of legs. The present of tubercle (Da, Dp) and the shape of seta *in* are also different.

Etymology. The species name is derived from the latin word *longus*, indicating that legs are very long.

Dicussion

Tectodamaeus has many characters in common with *Damaeus*, but there are two differences by which these can be distinguished from each other (see Table 1). During our ongoing study of the Chinese Damaeidae and our examination of additional material, we discovered that there are many species that have only 2 setae on genu IV. Therefore it is reasonable, to reestablish the subgenus *Damaeus* (*Tectodamaeus*) as a genus in the family Damaeidae.

Table 1. Comparison of distinguishing characters between *Tectodamaeus* and *Damaeus*.

character	<i>Tectodamaeus</i>	<i>Damaeus</i>
Body size	Large	Large
Body color	Dark	Dark
Dorsosejugal tubercles(Da)	Present	Present
Postbothridial tubercles(Bp)	Present	Present
Epimeral tubercles(E2)	Distinct	Distinct
Leg IV	Longer than body	Longer than body
Protecting seta of tibia on	None of legs	None of legs
Protecting seta of genu on	Legs I, II, III	None of legs
The number of setae on genu IV	2	3

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