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Asteroids, ophiuroids and holothurians from the southeastern Weddell Sea (Southern Ocean)

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Abstract

Until the early 1980s, the composition and distribution of the asteroid (starfish), ophiuroid (brittle star) and holothurian (sea cucumber) bottom fauna of the southeastern Weddell Sea was virtually unknown. This southernmost part of the Atlantic sector of the Southern Ocean is a typical high-latitude Antarctic region located in the circumpolar permanent pack-ice zone. It became accessible for large-scale scientific surveys only through the availability of modern ice-breaking research vessels, such as the German RV "Polarstern". Here, we describe a dataset of the faunal composition and abundance of starfish, brittle star and sea cucumber assemblages in this area, based on collections from trawl catches carried out during three "Polarstern" cruises in 1983, 1984 and 1985. The set comprises a total of 4,509 records of abundances of 35 asteroid species (with a total of 2,089 specimens) and 38 ophiuroid species (with a total of 18,484 specimens) from 34 stations, as well as of 66 holothurian species (with a total of 20,918 specimens) from 59 stations including zero-abundances (absences). A synthesizing zoogeographical community analysis confirms the presence of three distinct assemblages of asteroids, ophiuroids, and holothurians with highest species richness on the eastern shelf. Overall, starfishes, brittle stars and sea cucumbers were present at all sites investigated in the study area but composition and abundance of asterozoan (asteroids and ophiuroids together) and holothurian fauna varied considerably. A synthesizing zoogeographical community analysis confirms the presence of three distinct assemblages of asteroids, ophiuroids, and holothurians with highest species richness on the eastern shelf. In the case of asterozoans, water depth and latitude seemed to be the most important drivers of assemblage distribution and composition. One of the holothurian assemblages was part of the rich macrozoobenthic community dominated by a diverse and abundant epifauna, mainly sponges and gorgonians. Another one was mainly composed of vagrant deposit-feeding species inhabiting a predominantly non-colonised substratum. In addition, a mixed holothurian assemblage was identified.

Keywords

Asterozoa, Asteroidea, Ophiuroidea, Holothuroidea, southern and southeastern Weddell Sea, Antarctic, whole-assemblage approach, abundances, community analysis

Introduction

The southeastern Weddell Sea in the Atlantic Sector of the Southern Ocean is a typical high-latitude Antarctic region. It is located in the circumpolar permanent pack-ice zone (Hempel 1985a), characterized by summerly polynyas (areas of open water surrounded by sea ice). Due to its remoteness and persistent sea-ice cover, it was not accessible for extensive scientific surveys before the availability and support of modern research platforms that are capable to operate independently in sea-ice covered waters.

The first multidisciplinary marine research was carried out in this area in the 1980s during the first Antarctic cruises of the German icebreaking research and supply vessel "Polarstern”. Embedded in a broad ecological research programme, addressing a range of evolutionary, systematic, zoogeographical and ecological issues, first comprehensive faunistic inventories of the asteroid (starfish), ophiuroid (brittle star) and holothurian (sea cucumber) bottom fauna were conducted, based on field sampling efforts (Fig. 1) during “Polarstern” cruises ANT-I/2 (PS01), ANT-II/04 (PS04), and ANT-III/3 (PS06) (for cruise reports see Hempel 1983, Drescher et al. 1983, Kohnen 1984, and Hempel 1985b, respectively).

The major objective of this collection work was to provide material for subsequent zoogeographical and ecological studies on the asterozoan (asteroid and ophiuroids together; Voß 1988, Piepenburg et al. 1997) and holothurian fauna (Gutt 1988, Gutt 1991), as well as for analyses of entire macrozoobenthos communities (Gutt 2000; for a compilation: Gutt et al. 2013). Here, we publish the complete original dataset of asteroid, ophiuroid and holothurian abundances, including zero-abundances (= absences in the catches) that formed the basis of the scientific findings published in the research papers mentioned above, to allow for the general accessibility to such data associated with starfishes, brittle stars and sea cucumbers from the southeastern Weddell Sea.

In addition to making data and metadata available in the public database ANTABIF (www.biodiversity.aq), a robust community and diversity analysis for holothurians and asterozoans combined was carried out to synthesize results already published for holothurians and asterozoans separately (Voß 1988, Gutt 1991, Piepenburg et al. 1997).

Study area, material and methods

Asteroid, ophiuroid, and holothurian specimens were sampled at a total of 59 sites distributed across the southeastern Weddell Sea at water depths between 160 and 1,180 m (Fig. 1; for more detailed information see section on “Geographic coverage” below). In

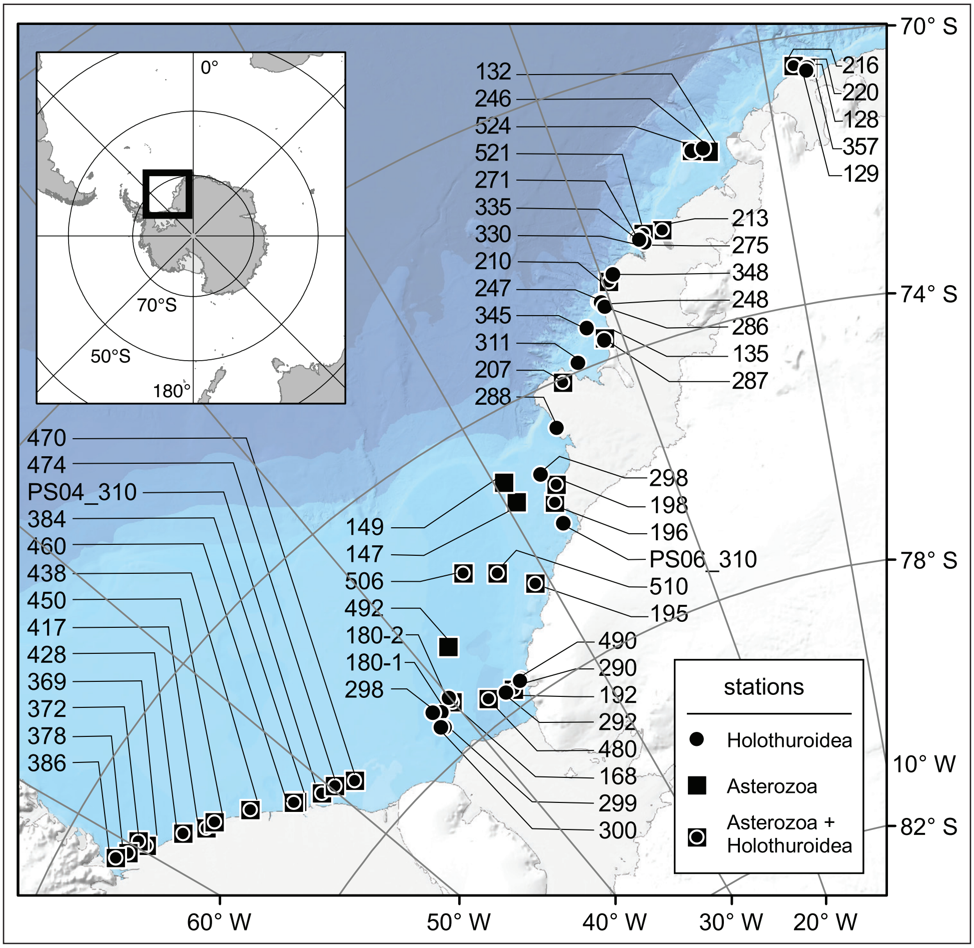


Figure 1. Map of stations in the southeastern Weddell Sea (Southern Ocean) where either asterozoans and holothurians separately or both asterozoans and holothurians together were sampled during „Polarstern“ cruises PS01, PS04, and PS06. In case of station number 310 that occurred during two cruises, cruise numbers are included in the station labels.

general, this region is characterized by a relatively homogenous physical environment, especially in terms of water masses, poorly sorted sediments, persistent sea-ice cover and hardly predictable occurrence of coastal polynyas. As such, it is representative for the entire high-latitude Antarctic habitat. Some drivers of faunistic heterogeneity, in addition to biological interactions and unknown unpredictable factors, are briefly summarized in the section on “Project Data – Study area description” below.

The field samples were mainly taken by means of an Agassiz trawl, but also with a commercial bottom trawl and, in one case, a smaller dredge. During the cruises, GPS positions were available approximately each six hours. Between the GPS fixes, the ship's positions were death reckoned (ship's track calculated by means of ship's speed and course starting from a satellite fix). Swept areas were estimated for each haul as described in Voß (1988) and Gutt (1988). Water depths were measured by a DWD echo sounder. For more detailed information see section on "Sampling methods – Sampling description" below.

Specimens were collected from either total catches or, in some cases subsamples, counted and preserved on board. Using the swept-area estimates, individual counts were standardized to abundance values (ind m^{-2}). After the cruises, the preserved specimens were identified to species in the lab. Some holothurian species, which were assumed to be new to science, were formally described (Gutt 1990a, b). Some of these new descriptions were later revised. The specimens were not integrated into a museum's collection, and original data were never published at that time when electronic data bases did not yet exist.

The quality of the data and metadata published here was enhanced prior to publication following the best practices suggested in the literature during the digitalization and geo-referencing processes. Moreover, the current accurate spelling of scientific names – except for the ophiuroid *Theodoria conveniens* ("nomen dubium") – was reviewed based on the World Register of Marine Species (www.marinespecies.org/). For more information see "Sampling methods – Quality control" below.

For 26 stations, at which both holothurians and asterozoans were sampled from Agassiz trawl catches, a simple multivariate community analysis of combined holothurian and asterozoan data were carried out, using the PRIMER 6.1.6 software (Clarke and Warwick 2001, Clarke and Gorley 2006). Abundance values (ind m^{-2}) were standardized to percentages per catch, to eliminate bias possibly introduced by differences between-haul catchability. Between-station resemblances were quantified by means of the Bray-Curtis similarity coefficient. The overall pattern of taxonomic resemblances was investigated using cluster analysis (average linkage) and Multidimensional Scaling (MDS).

Results

The dataset comprises a total of 4,509 records of abundances of 35 asteroid species (with a total of 2,089 specimens) and 38 opiuroid species (with a total of 18,484 specimens) from 34 stations, as well as of 66 holothurian species (with a total of 20,918 specimens) from 59 stations including zero-abundances.

Asteroid, ophiuroid and holothurian species were present at all sites investigated in the study area but composition and abundance of the asterozoan and holothurian assemblages varied considerably. The synthesizing community analysis shows four holothurian-asterozoan clusters. Since the cluster "Overdeepened Basins II" shows an affinity to "Overdeepened Basins I" rather than to "Eastern Shelf" (Fig. 2a), these two clusters were merged for analyzing the family-level composition. The "Eastern Shelf" assemblage was richest in species, "Overdeepened Basins II" was poorest, and the others were similar to each other, with intermediate species numbers (Fig. 2b). The class-level relative abundances were similar in all clusters, with highest values for ophiuroids followed by holothurians and lowest for asteroids (Fig. 3). However, on a family

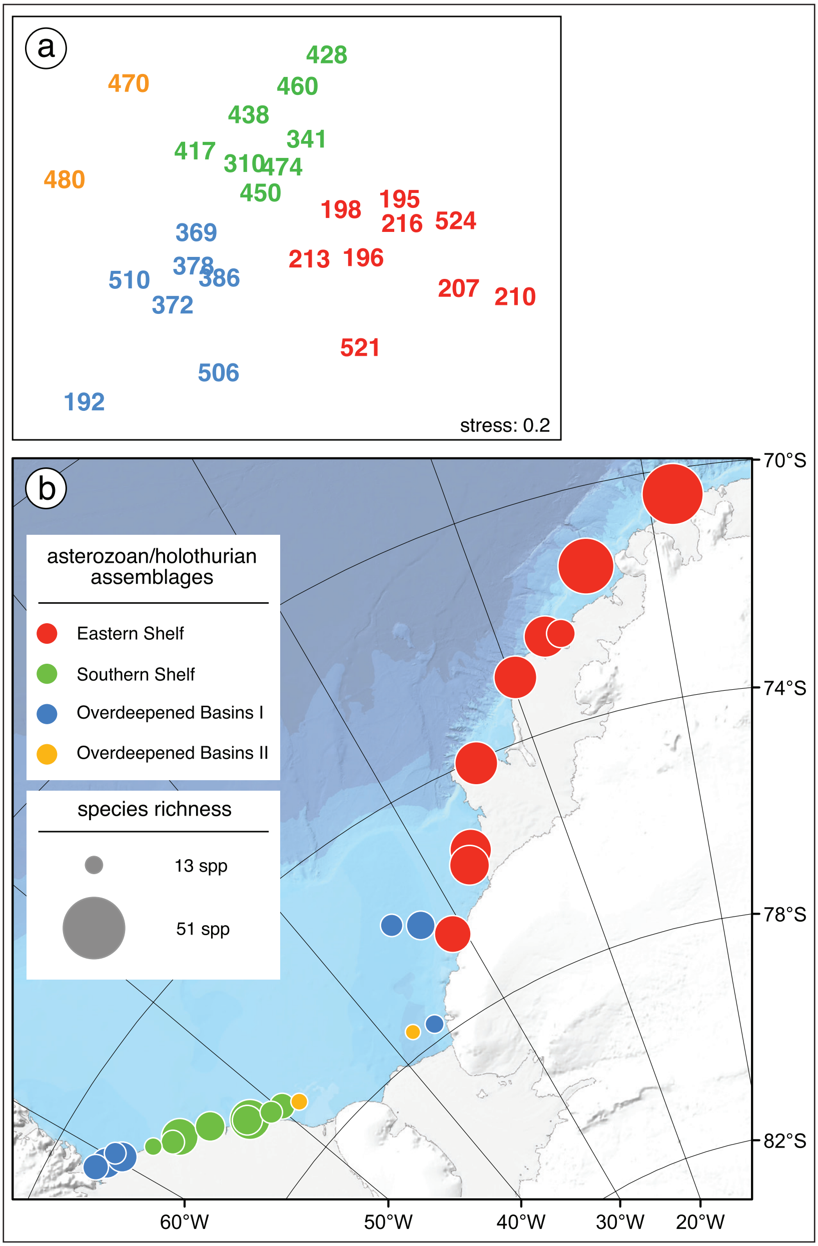
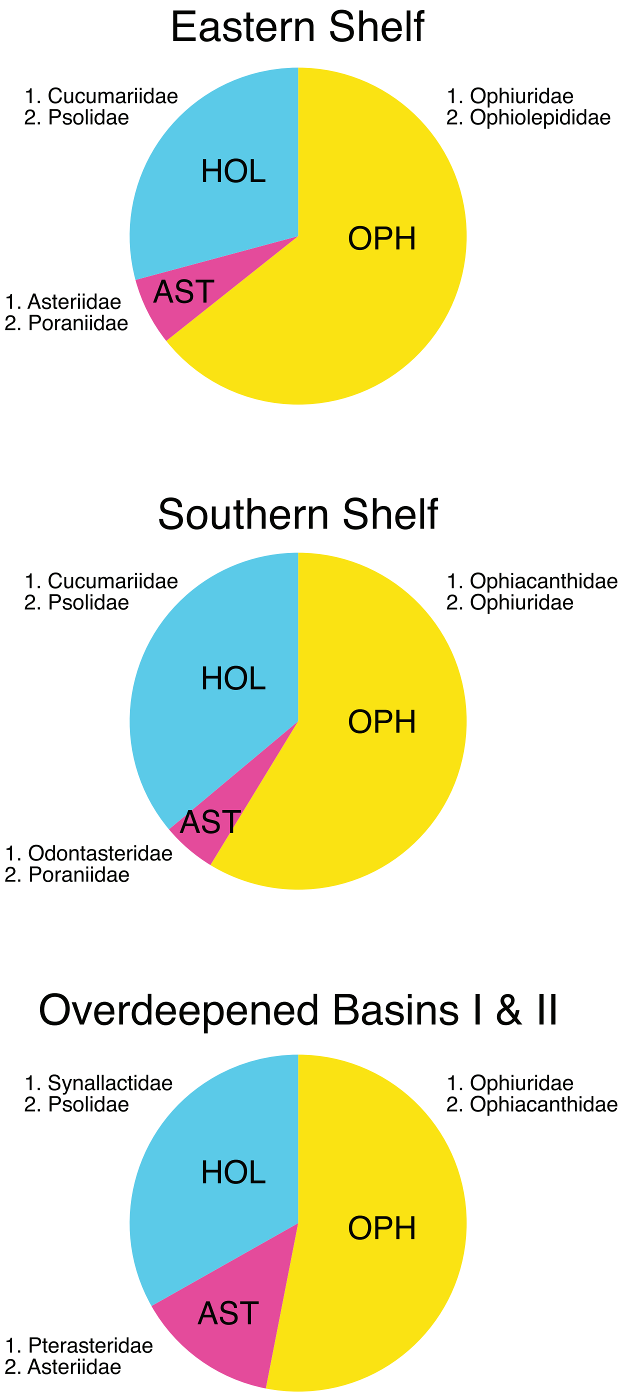


Figure 2. Faunal resemblance pattern (**a**) and geographic distibution (**b**) of stations where both asterozoans and holothurians were sampled during „Polarstern" cruises PS01, PS04, and PS06. **a** Multidimensional Scaling (MDS) plot showing the faunal between-station resemblance pattern. The numbers are station numbers, the affiliation of stations to asterozoan-holothurian assemblages, based on cluster analysis (complete linkage, threshold of 21% Bray-Curtis similarity), are indicated by color codes. According to cluster analysis, stn 213 belongs to cluster "Overdeepened Basins II" but based on MSD ordination it was assigned to cluster "Eastern Shelf" **b** Geographic map of stations. Symbol color denotes assemblage affiliation according to cluster analysis and Multidimensional Scaling (see Fig. 2a), symbol size is scaled according to the number of species at each station (ranging from 13 to 51).



Eastern Shelf

Southern Shelf

Overdeepened Basins I & II

Figure 3. Relative abundance proportions of Asteroidea (AST), Ophiuroidea (OPH) and Holothuroidea (HOL) within the three assemblages (Eastern Shelf, Southern Shelf, and Overdeepened Basins I & II) defined by cluster analysis and multidimensional scaling. In addition, the two most abundant families are given for each echinoderm class.

level, major differences became visible between the assemblages, whilst in the "Overdeepened Basins I & II" deposit-feeding holothurians (Synallactidae) were dominant. Filter feeders (Psolidae and Cucumariidae) were most abundant in "Eastern Shelf" and "Southern Shelf". Among asteroids, *Hymenaster* spp., of the family Pterasteridae, a typical deep-sea form, were most abundant at basin sites at water depths down to almost 1,200 m. The genus *Odontaster*, being generally abundant in the Antarctic, was dominant in the assemblage "Southern Shelf"; apart from that the evenness among the asteroids was more obvious than among holothurians and ophiuroids. A major difference between ophiuroid assemblages was the second dominance of Ophiolepididae in the "Eastern Shelf" assemblage, with *Ophioceres incipiens* being generally rare but occurring locally in relatively high abundances. It is a diatom feeder (Dahm 1996) and the smallest species in the entire area. The obvious high abundance of Ophiuridae across all clusters is due to the dominance of various species: the omnivorous large-sized *Ophionotus victoriae* in the assemblage "Overdeepened basins II", the crustacean feeder *Ophioplinus gelida* in "Southern Shelf" and the shallower shelf prefering *Ophioplinthus martensi* and the deeper *O. brevirima* in "Eastern Shelf". Since *Ophiacantha antarctica* was by far the most abundant ophiuroid in "Southern Shelf" Ophiacanthidae was the dominant family in this assemblage.

In the case of the separate analysis of asterozoan patterns (Voß 1988, Piepenburg et al. 1997), water depth and latitude seemed to be the most important drivers of assemblage distribution and composition. At shallow shelf sites rare asteroid and ophiuroid predators, such as, e.g., *Acodontaster conspicuus* and *Odontaster validus*, respectively, as well as epibiotic ophiuroids, e.g., *Astrotoma agassizii*, occurred in addition to the common and widely distributed opportunistic feeders. In the case of the separate analysis of holothurians (Gutt 1988, Gutt 1991), one assemblage co-occurred with the rich macrozoobenthic community dominated by dense epifauna consisting of, e.g., sponges and gorgonians, which are often used as substratum by epibiotic filter feeders. Others live mainly as vagrant deposit feeders on the predominantly non-colonised substratum, such as typical deep-sea species, e.g., *Elpidia glacialis* and *Protelpidia murrayi* (Gutt and Piepenburg 1991). In addition, a mixed holothurian assemblage was identified.

General significance

Virtually nothing was known about echinoderms in the southeastern Weddell Sea before the field sampling work, in the course of which the data published here was recorded. Also from other Antarctic regions only sporadic information on the three echinoderm classes, especially holothurians, was available at that time, mainly found published in the taxonomic literature. However, the application of a whole-assemblage approach was novel, and comparable surveys are even nowadays rare.

The unique dataset encompasses some of the first observations of asteroids, ophiuroids and holothurians in this area and represents a significant contribution of primary data about Antarctic benthos assemblages. Moreover, it provides unique baseline data for future faunistic, ecological and conservation studies to evaluate the effects of climate change and possible future fishing activities in this area. At present and in the future these faunistic data can gain further importance in the context of a number of further applications:

(1) More comprehensive circumpolar analyses and comparative studies with other large taxa become possible if these data are merged with similar datasets from other regions, see e.g., http://ipt.biodiversity.aq/resource.do?r=asteroidea_zoogeography and http://ipt.biodiversity.aq/resource.do?r=biopearl_asteroida. Data on these three echinoderm classes can also be compared within the same region with other taxa or environmental parameters, as compiled, e.g., by De Broyer et al. (2014).
(2) At the time of sampling in the 1980s, the study area was almost pristine and hardly affected by any anthropogenic activities. In the meantime, exploratory fishing started on the deeper shelf, and the knowledge on the fauna before the onset of these activities can serve as a valuable baseline for an assessment of the impact of further fishing.
(3) The same holds true for the study of the effects of climate change. The area is so far climatologically relatively stable but an increase of bottom-water temperatures is expected during the 21st century (Hellmer et al. 2012).
(4) The data can also be used for nature conservation initiatives (Teschke et al. 2013). They are especially suited for such applied ecological comparative studies, since all specimens – with few well-defined exceptions – were sorted from the catches, meaning that not only the presence of the species were registered but also very valuable absence data and the even more informative abundances. In general, the latter data are known to be more sensitive indicators of environmental change than binary presence-absence data.
(5) The community analysis of the combined holothurian-asterozoan data largely confirms the findings of the previous separate analyses of holothurians and asterozoans (Voß 1988, Gutt 1991, Piepenburg et al. 1997). There are basically three assemblages, the composition of which are quite similar on the level of classes but strongly differing on the level of families and species, as well as with regard to trophic guilds. These resemblance patterns can be attributed to geographic and bathymetric conditions.

General description

Purpose: The publication of the complete dataset of asteroid, ophiuroid and holothurian abundances (and absences) in the southeastern Weddell Sea, which formed the basis of the scientific findings already published in a number of original research papers, shall allow for the general accessibility to such data associated with starfishes, brittle stars and sea cucumbers from this high-Antarctic region. The unique dataset encompasses some of the first observations of asteroids, ophiuroids and holothurians in the study area and represents a significant contribution of primary data about Antarctic benthos assemblages. Moreover, it provides unique baseline data for future faunistic, ecological and conservation studies to evaluate the effects of climate change and possible future fishing activities in this area.

Project details

Project title: Asteroids, ophiuroids and holothurians from the southeastern Weddell Sea (Southern Ocean)

Funding: The sampling of all asterozoan and holothurian specimens in the course of the cruises ANT-I/2 (PS01), ANT-II/04 (PS04), ANT-III/3 (PS06) of the German R/V "Polarstern" and the subsequent analysis of asteroids and ophiuroids was financed by the Alfred Wegener Institute Helmholtz, Centre for Polar and Marine Research, Bremerhaven, Germany. The study on holothurians was also supported by a grant of the Deutsche Forschungsgemeinschaft (He 89/49).

Study area descriptions/descriptor: The study area included regions characterized by almost permanent pack-ice cover in the southernmost Weddell Sea as well as regions featuring coastal polynyas in the eastern Weddell Sea (Gutt 2000). The shelf plateau is mostly rather narrow, only a few 10 km wide, in some areas even "disappearing" beneath the floating ice shelf, but can also be much broader in the southern Weddell Sea (Arndt et al. 2013). Consequently, near-coast habitats can be affected by larger and smaller floating ice shelves or by a glaciated coast. As there is no "true" (i.e., non-glaciated) coast, shallow littoral habitats (<50 m water depth) are not known from this area.

The shelf seabed is usually rather level, and especially habitats on banks and their flanks are disturbed with varying intensity by grounding or scouring icebergs (Gutt and Starmans 2001). In addition to the shelf below 160 m water depth sampling included the upper slope and stations in the Filcher depression, an overdeepened trough with water depths of up to 1,180 m.

The hydrography of the study area is characterized by a southwestward flowing coastal current, which is part of the large Weddell Gyre (Fahrbach et al. 1992) and flows with a velocity of up to 0.14 m/s above the shelf edge. Different water masses dominated by the "Eastern Shelf Water" close to the sea floor are mainly characterized by low temperatures close to the freezing point and high salinities. However, occasionally upwelling "Warm Deep Water", with an average temperature of 0.4 °C, can be found on the deeper shelf (Fahrbach et al. 1992, Schröder and Fahrbach 1999). In the South, the current regime shows water flow from beneath and under the Filchner-Ronne Ice Shelf, with both northward and southward directions (Grosfeld et al. 2001). This difference is potentially of high relevance for the food supply to the benthos and also shapes species compositions along the eastern coast with smaller ice shelves.

Surface sediments are generally poorly sorted. However, clear differences in the sand-silt proportion exist, with mainly soft sediments in the deep areas and coarser sediments on the shelf. In some areas, biogenic particles, such as bryozoan debris and sponge spicules, are important components of the sediments, sometimes forming dense mat-like structures (Voß 1988).

Design description: Asteroid, ophiuroid, and holothurian specimens were sampled during the cruises ANT-I/2 (PS01), ANT-II/04 (PS04), ANT-III/3 (PS06) of the German R/V "Polarstern" at a total of 59 sites distributed across the southeastern Weddell Sea at water depths between 160 and 1,180 m (for more detailed information see section on “Geographic coverage”). The field samples were mainly taken by means of an Agassiz trawl, but also with a commercial bottom trawl and, in one case, a smaller dredge (for more detailed information see section on “Sampling methods - Sampling description”). During the cruises, GPS positions were recorded approximately every six hours. Between the GPS fixes, the ship's positions were death reckoned. Water depths were measured by a DWD echo sounder. Specimens were collected from either total catches or, in some cases subsamples, counted and preserved on board. They were later identified in the lab. Some holothurian species, which were assumed to be new to science, were formally described. Some of these new descriptions were later revised. The specimens were not integrated into a museum's collection, and original data were never published at that time when electronic data bases did not yet exist. The quality of the data and metadata published here was enhanced prior to publication following the best practices suggested in the literature during the digitalization and geo-referencing processes.

Taxonomic coverage

General taxonomic coverage description: All asteroids, ophiuroids, and holothurians caught by the gear mentioned in the section on “Sampling Methods" were considered in this study, with the exception of the very rare species *Amphiura deficiens* Koehler, 1992 and *A. atlantica* Ljungman, 1867. The taxonomic and morphological range even covers two holothurian species, which are assumed or known to be able to swim occasionally, *Rhipidothuria racovitzai* and *Peniagone vignioni*. Due to the mesh size used, not only adult but also juvenile specimens of all three classes are included in the collections. However, their abundance values are likely more biased than those of the adults. The trawls predominantly caught epifaunal species in a semi-quantitative way, the Agassiz trawl obviously with a higher catchability of macro-epibenthic invertebrates than the bottom trawl. Therefore, the swept-area approach is most useful for within-gear comparisons and only with less precision between-gear. The presence of typical infaunal species in the catches, such as the holothurian *Molpadia* and the asteroid *Hymenaster*, suggests that endobenthic species were also sampled to a considerable degree. Overall, organisms from a broad variety of ecological guilds among all three classes, such as deposit, sediment and filter feeders, infaunal, epifaunal and epibiotic (symbiotic) species, predators spezialized on various prey items, and scavengers, are present in the samples.

Taxonomic ranks

Class: Asteroidea; species: *Bathybiaster loripes*, *Macroptychaster accrescens*, *Leptychaster flexuosus*, *Psilaster charcoti*, *Cheiraster* (*Luidiaster*) *gerlachei*, *Acodontaster capitatus*, *Acodontaster conspicuus*, *Acodontaster hodgsoni* f. *hodgsoni*, *Acodontaster hodgsoni* f. *stellatus*, *Acodontaster marginatus*, *Odontaster meridionalis*, *Chitonaster johannae*, *Notioceramus anomalus*, *Cycethra verrucosa*, *Perknaster aurorae*, *Perknaster sladeni*, *Porania* (*Porania*) *antarctica*, *Kampylaster incurvatus*, *Pteraster affinis*, *Pteraster stellifer*, *Hymenaster* spp., *Peribolaster macleani*, *Remaster gourdoni*, *Solaster regularis*, *Lophaster densus*, *Lophaster gaini*, *Lophaster tenuis*, *Paralophaster antarcticus*, *Paralophaster godfroyi*, *Paralophaster* sp., *Cuenotaster involutus*, *Henricia parva*, *Henricia smilax*, *Rhopiella hirsuta*, *Diplasterias brucei*, *Kenrickaster pedicellaris*, *Lysasterias digitata*, *Lysasterias perrieri*, *Notasterias armata*, *Notasterias bongraini*, *Notasterias haswelli*, *Notasterias stolophora*, *Pedicellaster hypernotius*, *Psalidaster mordax*.

Class: Ophiuroidea; species: *Astrotoma agassizii*, *Astrochlamys bruneus*, *Ophiacantha antarctica*, *Ophiacantha vivipara*, *Ophiacantha pentactis*, *Ophiocamax drygalskii*, *Ophiomitrella ingrata*, *Ophiomitrella* sp., *Ophiosparte gigas*, *Ophiolimna antarctica*, *Amphiura belgicae*, *Amphiura joubini*, *Amphiura proposita*, *Ophioleuce regulare*, *Ophioceres incipiens*, *Ophiocten dubium*, *Ophiocten doederleini*, *Ophiocten megaloplax*, *Ophionotus victoriae*, *Ophioperla koehleri*, *Ophioplinthus brucei*, *Ophiosteira debitor*, *Ophiosteira echinulata*, *Ophiosteira rotundata*, *Ophiura lymani*, *Ophiura* (*Ophiuroglypha*) *carinifera*, *Ophioplinthus brevirima*, *Ophioplinthus gelida*, *Ophioplinthus martensi*, *Ophioplinthus tumescens*, *Ophiogona doederleini*, *Ophiura flexibilis*, *Ophiura* (*Ophiuroglypha*) *irrorata*, *Ophiura rouchi*, *Theodoria conveniens*, *Ophioplinthus relegata*, *Anophiura* sp., *Amphiophiura* sp.

Class: Holothuroidea; species: *Cucumaria georgiana* s.l., *Psolidiella mollis*, *Cucamba psolidiformis*, *Microchoerus splendidus*, *Trachythyone parva*, *Trachythyone bouvetensis*, *Staurocucumis liouvillei*, *Staurocucumis turqueti*, *Heterocucumis steineni*, *Heterocucumis denticulata*, *Paracucumis turricata*, *Crucella scotiae*, *Crucella hystrix*, *Psolus dubiosus*, *Psolus charcoti*, *Psolus antarcticus*, *Psolicrux coatsi*, *Psolidium gaini*, *Psolidium poriferum*, *Echinopsolus acanthocola*, *Bathyplotes moseleyi* s.l., *Bathyplotes gourdoni*, *Bathyplotes bongraini*, *Pseudostichopus mollis*, *Molpadiodemas villosus*, *Mesothuria* (*Zygothuria*) *lactea*, *Laetmogone wyvillethomsoni*, *Rhipidothuria racovitzai*, *Peniagone vignoni*, *Protelpidia murrayi*, *Sigmodota contorta*, *Paradota weddellensis*, *Molpadia musculus*.

Common names: Starfish, Brittle stars, Sea cucumbers.

Spatial coverage

General spatial coverage: The study area extends northward to 70°27'S, a latitude which is typical for the northern shelf off East Antarctica, with the exception of the large embayments of the Weddell and Ross Seas, and for the more southerly situated West Antarctic shelf regions, with the exception of the Antarctic Peninsula area. The southernmost station in the study area was located at 77°44'S. With regard to its longitudinal extent, the study area ranged from 008°01'W in the eastern Weddell Sea to 061°08'W at the basis of the Antarctic Peninsula at 061°08'W.

With regard to water depth, the samples were taken along a gradient ranging from 160 m at the shelf to a maximum of 1,180 m at the upper slope, encompassing stations at relatively shallow banks as well as those in overdeepened basins, such as the Filchner Trough.

Coordinates: 78°0'0"S and 70°0'0"S Latitude; 62°0'0"W and 8°0'0"W Longitude.

Temporal coverage: February 4, 1983 – February 24, 1985.

Methods

Method step description: See "Sampling description".

Study extent description: See "Study area description".

Sampling description: Three sampling gears were used: An Agassiz trawl that was deployed most frequently consisted of a metal sled, with an opening of 3 m width and 1 m height, to which a net, which was 5 m long and had a mesh size of 20 mm in the front part and 10 mm in the cod end, was attached. In front of the opening a tickler chain was fixed to the rig of the sled. The average trawling speed was 0.5 to 0.7 knots (nm/h), and the haul duration was approx. 20-30 min, resulting in swept areas of approx. 1,700 to 3,000 m^2. This strategy was a compromise to gain comparable semi-quantitative information about both relatively poor Antarctic communities, based on catches that were, nevertheless, large enough to be representative, and rich communities without clocking the net.

The bottom trawl used was a 140 feet commercial otter trawl with a 22.5 m wide and approximately 3 m high opening. The mesh size of the net was 10 cm in the front part and 15 mm in the cod end. The bottom trawl was towed over ground at an average speed of 3 knots (nm/h), mostly for 0.5 hours, as it is standard for research fishing of demersal fish.

The dredge used has an opening of 100 × 30 cm and a mesh size of 10 mm. The swept areas were calculated according to Voß (1988) for the asterozoan study and according to Gutt (1988) for the holothurian study.

Due to technical constraints, only one position and time was provided for the catches and only in some cases information on the depths at the start and end of the hauls was available. Metadata (position and time) are available at www.pangaea.de for the expeditions PS01 and PS06. For cruise PS04, metadata were published by Voß (1988), with the exception of stn 490 (Gutt 1988). Metadata are based on the station lists published in the cruise reports (Hempel 1983, Drescher et al. 1983, Kohnen 1984).

Quality control description: Identifications were made by Joachim Voss under supervision of Ilse Bartsch for ophiuroids and by Julian Gutt for holothurians partly under supervision of David Pawson (comparison with material at the Smithsonian

Institution, Washington) and Bent Hansen (Elasipodida caught during the Galathea expedition). In addition, identifications were based on the taxonomic references cited by Voß (1988) and Gutt (1988). All species names in the dataset are in accordance with the World Register of Marine Species (www.marinespecies.org/), with the sole exception of the ophiuroid *Theodoria conveniens* ("nomen dubium"). Consequently, some species names have changed in comparison to the ones used in past publications, as these are synonyms that are not valid anymore.

Datasets

Dataset description

Object name: Darwin Core Archive Asteroids, ophiuroids and holothurians from the southeastern Weddell Sea (Southern Ocean)
Character encoding: UTF-8
Format name: Darwin Core Archive format
Format version: 1.0
Distribution: http://ipt.biodiversity.aq/archive.do?r=asteroids_and_ophiuroids_from_the_southeastern_weddell_sea
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RESEARCH ARTICLE

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Complementary description of *Colomerus novahebridensis* Keifer (Acari, Eriophyidae), with a discussion about the constitution of the genus and its economic importance, and a tentative key to *Colomerus* Newkirk & Keifer species

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Abstract

Colomerus Newkirk & Keifer, 1971 is an eriophyid genus described by Newkirk and Keifer about 43 years ago, that contains species from all continents, except Antarctica. They live mostly on dicotyledonous plants. *Colomerus novahebridensis* Keifer, 1977 was described from coconut (*Cocos nucifera* L., Arecaceae) fruits from Vanuatu. A description of a Thai population of this species is given in this paper. A revised characterization of *Colomerus* and a dichotomous key for the separation of the species presently considered to belong to this genus are provided, and a consideration about the importance of *Colomerus* species is presented.

Keywords

Taxonomy, Thailand, Eriophyoidea, Cecidophyinae

Introduction

Colomerus Newkirk & Keifer is a relatively small genus of eriophyid mites described about 43 years ago by Newkirk and Keifer (1971). The 27 species assigned to this genus have been described from all continents, except Antarctica.

All *Colomerus* species have been described from dicotyledonous plants, except *Colomerus novahebridensis* Keifer, described from coconut (*Cocos nucifera* L.; Arecaceae) (Keifer 1977). The latter species was originally collected from coconut fruits in Saraoutou, Vanuatu (mentioned in the original description as New Hebrides Islands, the former name of that archipelago). Specimens identified in the present paper as *C. novahebridensis* were found a few years ago by the authors of this paper while unsuccessfully searching for the possible presence of an economically important eriophyid species, *Aceria guerreronis* Keifer, 1965, on coconut in Thailand.

The objective of this paper is to present a morphological description of that Thai population (based on adult females and males), to discuss the constitution of the genus, to provide a tentative dichotomous key to *Colomerus* species worldwide and to summarize the economic importance of this genus.

Materials and methods

Specimens used for the complementary description of *C. novahebridensis* were collected in different coconut fields in the central and southern regions of Thailand. Coconut fruits with symptoms of eriophyid attack similar to that of *A. guerreronis* (whitish to brownish triangular scars starting at the edge of the bracts and progressively enlarging with fruit growth) were collected and taken to the laboratory for examination. The bracts were removed and their undersurfaces as well as the surface of the fruits covered by them were examined, collecting all eriophyid mites found.

The mites were mounted in modified Berlese medium (Amrine and Manson 1996) for later examination under an Olympus BX 43 microscope with phase contrast. Structures relevant for taxonomic purposes were measured using a graded eyepiece and illustrated using a camera lucida attached to the microscope. Both photographs and scanning electron micrographs of specimens from the collection of H.H. Keifer (ARS, USDA, Beltsville, Maryland, USA), were taken by Philipp Chetverikov (Biological Research Institute, St. Petersburg State University, Old Peterhof, Russia), who kindly made them available to us for comparison with specimens we collected (these were not included in this publication). Notes on the bag containing the dry specimens mounted by P. Chetverikov read "ex. coconut cap, *Cocos nucifera*; Thailand, at Los Angeles; July 8, 1975", probably referring to specimens intercepted at Los Angeles, California, USA, from coconuts imported from Thailand.

All terminology and measurements follow Lindquist (1996) and de Lillo et al. (2010). The measurements are given in micrometers. Opisthosomal dorsal annuli count starts at the posterior shield margin; ventral annuli count starts from the first lateral annulus at the lateral prodorsal shield margin; the length of each leg is measured from the trochanter base to the tip of tarsus, excluding empodium. All specimens examined are deposited in the Insect Museum of Department of Entomology, Kasetsart University, Bangkok, Thailand, and Museum of Department of Agriculture, Ministry of Agriculture and Cooperatives, Bangkok, Thailand.

The revised characterization of the genus and the dichotomous key were prepared by examining the original descriptions of each species, except for *C. novahebridensis*, collected in this work, *Colomerus bucidae* (Nalepa), whose characteristics were taken from Flechtmann et al. (2000) and from our examination of specimens collected in the Dominican Republic by L. Sánchez-Ramirez (unpublished), and for *Colomerus vitis* (Pagenstecher), whose characteristics were taken from an examination of specimens collected from grapevine buds in Candiota and Bento Gonçalves, both in the state of Rio Grande do Sul, Brazil by N.J. Ferla. The key should be considered as tentative, because it was not possible in the scope of this work to study the actual type specimens of the species involved. Given the limited information provided in the description of some of the species, some of the characters used in the key cannot be considered as robust as desirable. Thus, its use should always be associated with complementary examination of the original description of the species thus determined. The species considered in this study are those listed in Amrine and Stasny (1994), complemented by the unpublished computerized database of world eriophyoid species compiled by Amrine and de Lillo (pers. comm.).

Results and discussion

Colomerus novahebridensis Keifer

Colomerus novahebridensis Keifer, 1977: 23–24

Diagnosis. Frontal lobe of prodorsal shield rounded, broad-based, short; with parallel microtuberculate lines around lateral margin of ocellar gibbosities; median and admedian lines between anterior shield margin and region slightly anterior to shield center usually broken (indistinct in some specimen), and then continuous to posterior shield margin (broken in some specimens); with several incomplete submedian lines; empodia entire, 5-rayed; opisthosoma with 67–85 microtuberculate annuli; coverflap with longitudinal ridges arranged in two transverse rows. Genital apodeme usually visible as a narrow dark band in ventral view, but sometimes appearing to constitute a pair of subtriangular structures, depending on the position of the focus; spermathecal apparatus moderate distance from apodeme; with 4 coxigenital semiannuli anterior to coverflap, with genital opening somewhat appressed to coxisternum II.

Description. Female (Figs 1–3) (n= 9). Body wormlike, 187–238, 41-47 wide, 47–49 thick, whitish. **Gnathosoma** (Fig. 1)**:** 16–18, projecting slightly downwards, pedipalp coxal seta (*ep*) 2–3, dorsal pedipalp genual seta (*d*) 5–7, subapical pedipalp

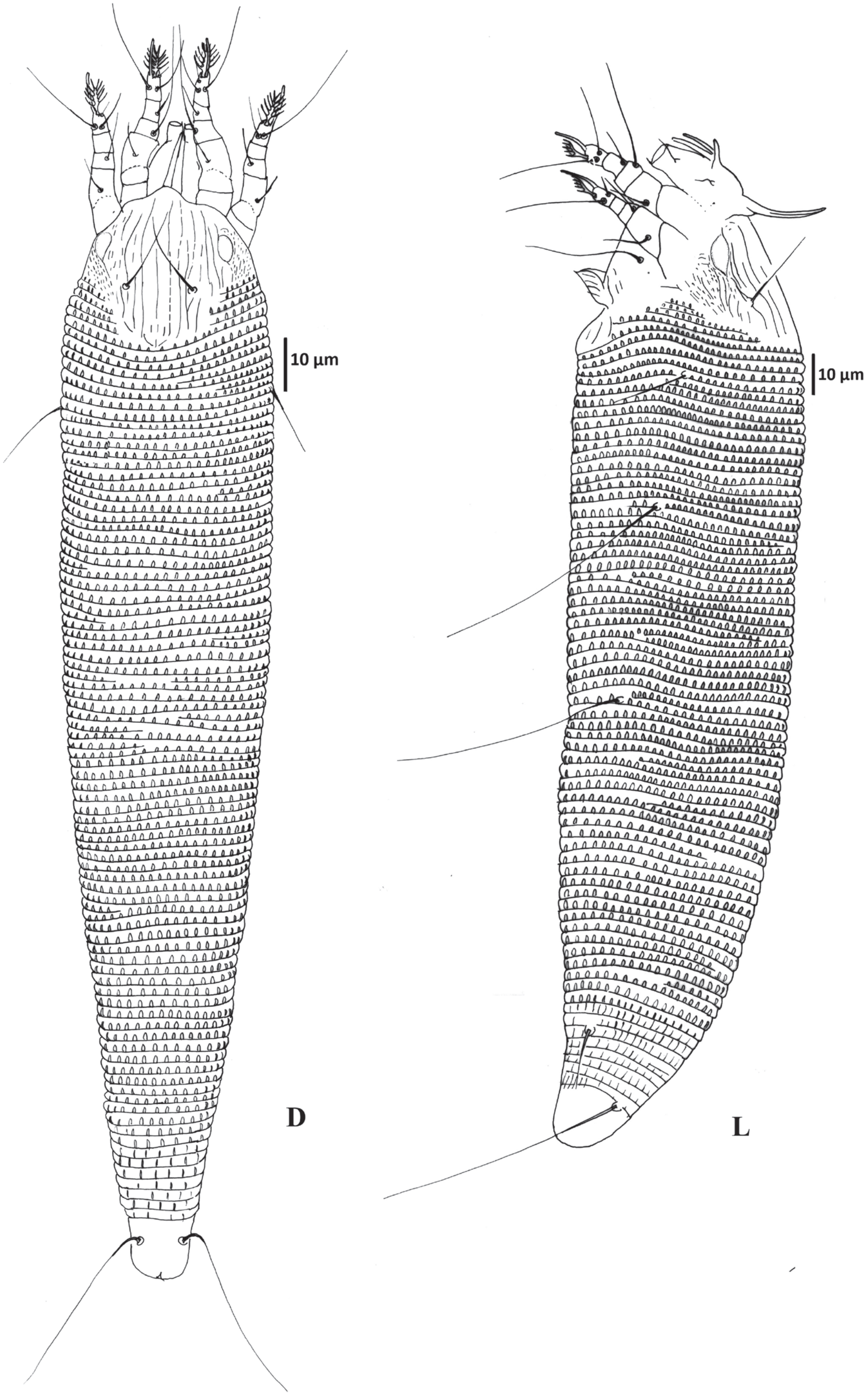

Figure 1. *Colomerus novahebridensis* Keifer. Female: **D** = dorsal view, **L** = lateral view. Specimens collected in Thailand.

tarsal seta (*v*) 2, cheliceral stylets 14–21. **Prodorsal shield** (Figs 1–3)**:** 28–41, 34–41 wide, semi-oval; prodorsal shield frontal lobe rounded, broad-based, short, 2–3; posterior shield margin convex, interrupting first 4–5 dorsal annuli. Prodorsal shield design with parallel microtuberculate lines around lateral margin of ocellar gibbosities. Line pattern variable (Fig. 3); median and admedian lines usually broken (indistinct in some specimens) between anterior shield margin and region slightly anterior to shield center and then continuous to posterior shield margin (broken in some specimens); some specimens with 1–2 short lines between median and admedian lines near posterior margin of prodorsal shield. Submedian lines variously broken, typically in four pairs running from anterior to posterior margins and four incomplete submedian lines running from anterior to posterior margin; 2 – 3 submedian lines posteriad or mesad of scapular tubercles; ocellar gibbosities prominent. Scapular tubercles situated 7–11 ahead of posterior shield margin, plicate, 12–14 apart, scapular setae (*sc*) 16–19, directed upward or forward. **Coxigenital region:** with 4 coxigenital semiannuli, microtuberculate. **Coxisternal plates** (Fig. 2 GF)**:** coxisternum I with several longitudinal lines, coxisternum II smooth, anterior seta on coxisternum I (*1b*) 5–6, 9–10 apart; proximal seta on coxisternum I (*1a*) 15–22, 8–9 apart; proximal seta on coxisternum II (*2a*) 28–39, 19–21 apart; tubercles of *1b* and *1a* 8–10 apart. Internal coxisternal apodeme 9–12. **Legs** (Fig. 2 L1, L2, E, S)**:** with all usual setae. Leg I 23–29, femur 8–10, ventral basifemoral seta (*bv*) 6–8; genu 4–5, antaxial genual seta (*l″*) 17–22; tibia 4–5, paraxial tibial seta (*l′*) 4–6; tarsus 5–6, antaxial fastigial tarsal seta (*ft″*) 16–18, paraxial fastigial tarsal seta (*ft′*) 10–16, paraxial unguinal tarsal seta (*u′*) 3, tarsal empodium 6–8, entire, 5-rayed, tarsal solenidion (*ω*) 6–10, slightly curved, blunt. Leg II 22–26, femur 6–10, ventral basifemoral seta (*bv*) 5; genu 3–4, antaxial genual seta (*l″*) 5–8; tibia 3–4; tarsus 4–6, antaxial fastigial tarsal seta (*ft″*) 18–23, paraxial fastigial tarsal seta (*ft′*) 4–6, paraxial unguinal tarsal seta (*u′*) 2–5, tarsal empodium 6–8, entire, 5-rayed, tarsal solenidion (*ω*) 8–9, slightly curved, blunt. **Opisthosoma** (Fig. 1D and L, Fig. 2 ES, CV)**:** dorsum evenly rounded, dorsal annuli 67–83, ventral annuli 71–85, both with elongate, oval microtubercles situated on or near posterior margin of each annulus. Microtubercles more elongate on the last 5–7 ventral annuli and slightly longer, sparser on the last 7-8 dorsal annuli. Seta *c2* 17–22, 39–46 apart, on ventral annulus 10–12; seta *d* 43–50, 33–39 apart, on ventral annulus 21–27; seta *e* 44–64, 19–24 apart, on ventral annulus 37–49; seta *f* 10–13, 11–13 apart, on ventral annulus 66–80 or annulus 5th from the rear. Seta h_1 absent, h_2 38–53. **Female genitalia** (Fig. 2 GF, IG)**:** 8–9, 18–20 wide, coverflap with 8–12 longitudinal ridges in each of two transverse rows, setae *3a* 4–6, 11–13 apart. Internal genital apodemes usually visible as a narrow dark band in ventral view (Fig. 2 IG), but sometimes appearing to constitute a pair of subtriangular structures (Fig. 2 IG), depending on the position of the focus; spermathecal apparatus at moderate distance from apodeme.

Male (Fig. 2 GM) (n =3)**:** smaller than female, 150–170, 40–48 wide, 44 thick. **Gnathosoma:** 16–18; pedipalp coxal seta (*ep*) 2, dorsal pedipalp genual seta (*d*) 5–6, subapical pedipalp tarsal seta (*v*) 2, cheliceral stylets 15–17. **Prodorsal shield:** 30–34, 34–35 wide, prodorsal shield frontal lobe rounded, broad-based, 2–3, shield design

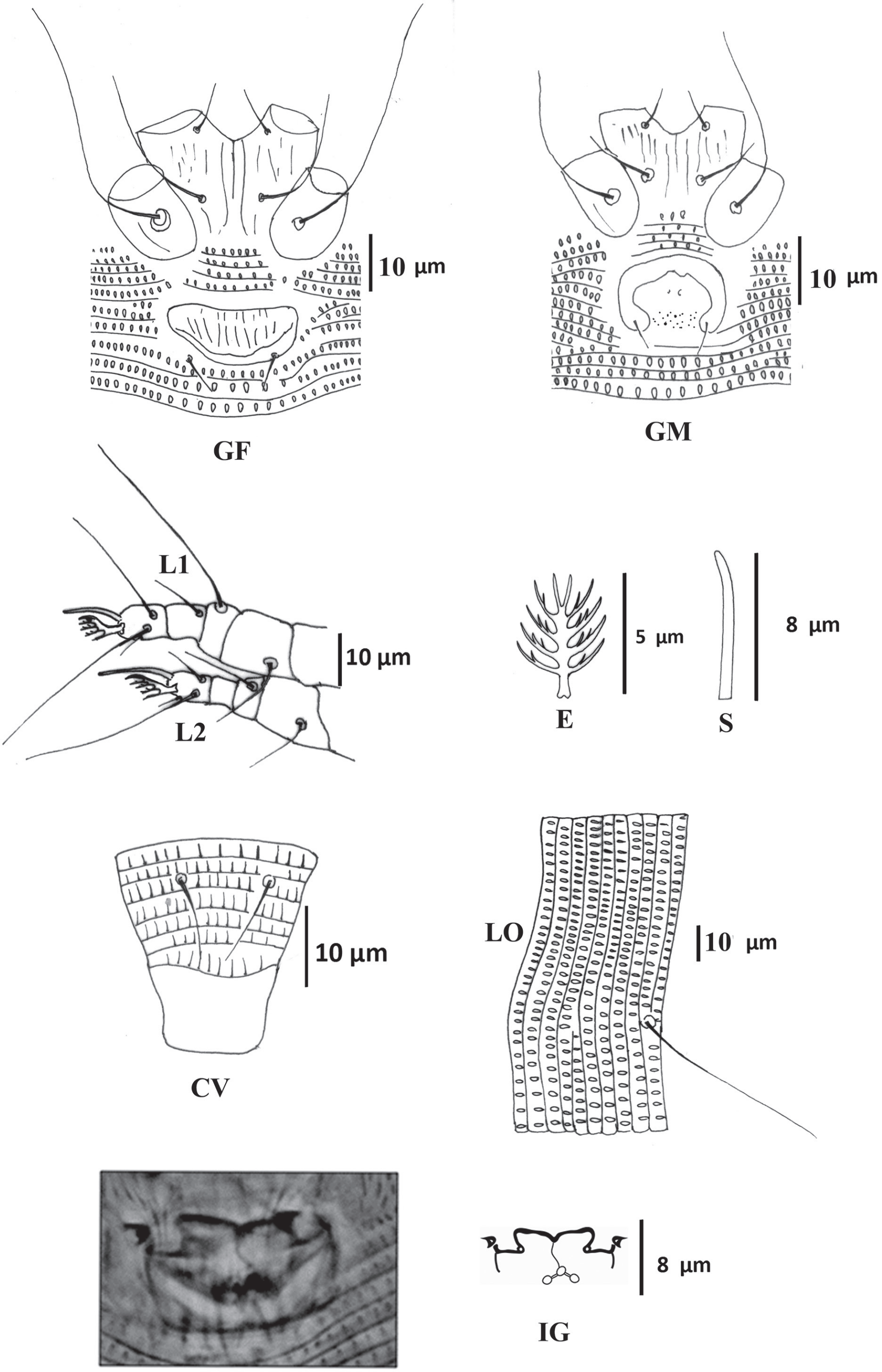

Figure 2. *Colomerus novahebridensis* Keifer. Female: **CV** ventral view of caudal region **E** empodium **GF** external female genitalia **IG** internal genitalia **L1** leg I **L2** leg II **LO** lateral opisthosoma **S** solenidion. Male: **GM** external male genitalia. Specimens collected in Thailand.

similar to that of the female; ocellar gibbosities prominent. Scapular tubercles situated 6–8 ahead of posterior shield margin, plicate, 14–15 apart; scapular setae (*sc*) 10–12, directed upward or forward. **Coxigenital region:** with 4 coxigenital semiannuli, microtuberculate. **Coxisternal plates** (Fig. 2 GM)**:** coxisternum I with several longitudinal lines, coxisternum II smooth, anterior seta on coxisternum I (*1b*) 5–6, 9–10 apart; proximal seta on coxisternum I (*1a*) 14–16, 8–9 apart; proximal seta on coxisternum II (*2a*) 24–26, 18–19 apart, tubercles *1b* and *1a* 8 apart. Internal coxisternal apodeme 8–11. **Legs:** with usual setae. Leg I 21–24, femur 7–8, ventral basifemoral seta (*bv*) 5–8; genu 4–5, antaxial genual seta (*l"*) 15–24; tibia 4–5, paraxial tibial seta (*l'*) 4–5; tarsus 4–5, antaxial fastigial tarsal seta (*ft"*) 14–18, paraxial fastigial tarsal seta (*ft'*) 12–13, paraxial unguinal tarsal seta (*u'*) 2–3, tarsal empodium 5–6, entire, 5-rayed, tarsal solenidion (*ω*) 6–8, slightly curved, blunt. Leg II 18–20, femur 7, ventral basifemoral seta (*bv*) 6–7; genu 3, antaxial genual seta (*l"*) 4–5; tibia 3; tarsus 5–6, antaxial fastigial tarsal seta (*ft"*) 16–19, paraxial fastigial tarsal seta (*ft'*) 4–6, paraxial unguinal tarsal seta (*u'*) 2–3, tarsal empodium 5–6, entire, 5-rayed, tarsal solenidion (*ω*) 10, slightly curved, blunt. **Opisthosoma:** dorsum evenly rounded, dorsal annuli 59–63 and ventral annuli 63–66. Seta *c2* 16, 40–47 apart, on annulus 9–10; seta *d* 30–32, 26–29 apart, on annulus 19–20; seta *e* 40–45, 16–21 apart, on annulus 34–36; seta *f* 10, 12–13 apart, on annulus 56–61 or annulus 5th from the rear. Seta h_1 absent, h_2 28–35. **Male genitalia** (Fig. 2 GM) 10–14, 18–19 wide, seta *3a* 4–6, 10–12 apart.

Material examined. 12 adult females and 5 adult males on 14 slides labeled # 2874, from Mueang Samut Songkhram District, Samut Songkhram Province, 13°24.834'N; 100°0.198'E, 14-II-2011, coll. P. Vichitbandha and G. J. de Moraes; 5 adult females on 5 slides labeled # 2875, from Chumporn Province, 10°15.2'N; 99°5.7'E, 14-II-2011, coll. P. Vichitbandha and G. J. de Moraes; 3 adult females on 2 slides labeled # 2876, Ban Phaeo District, Samut Sakhon Province,13°35.433'N; 100°6.466'E, 15-II-2011, coll. P. Vichitbandha and G. J. de Moraes; 7 adult females on 7 slides labeled # 2878 and 5 adult females and 1 adult male on 6 slides labeled # 2879, Kanchanadit District, Surat Thani Province, 9°9.933'N; 99°28.266'E, 15-II-2011, coll. P. Vichitbandha and G. J. de Moraes; 8 adult females on 7 slides labeled # 2883, Kanchanadit District, Surat Thani Province, 9°9.933'N; 99°28.266'E, 23-II-2011, coll. Yingniyom Riyaphan; 3 adult females, 1 adult male and 1 nymph on 5 slides labeled # 2911, Kanchanadit District, Surat Thani Province, 9°9.933'N; 99°28.266'E, 12-IX-2011, coll. Yingniyom Riyaphan; 72 adult females, 6 adult males and 5 nymphs on 23 slides labeled # 2912, Kanchanadit District, SuratThani Province, 9°9.933'N; 99°28.266'E, 28 IX 2011, coll. Yingniyom Riyaphan.

Host. Coconut (*Cocos nucifera* L. var. *nucifera*, Ma phrao; Arecaceae)

Relation to host. All specimens were collected from under the bracts of coconut fruit, causing usually the appearance of scanty triangular brown patches of damaged tissue on the fruit surface next to the bracts under which the colonies of the mites developed. In a few occasions damage was slightly more extensive, and the mite apparently caused premature fruit drop.

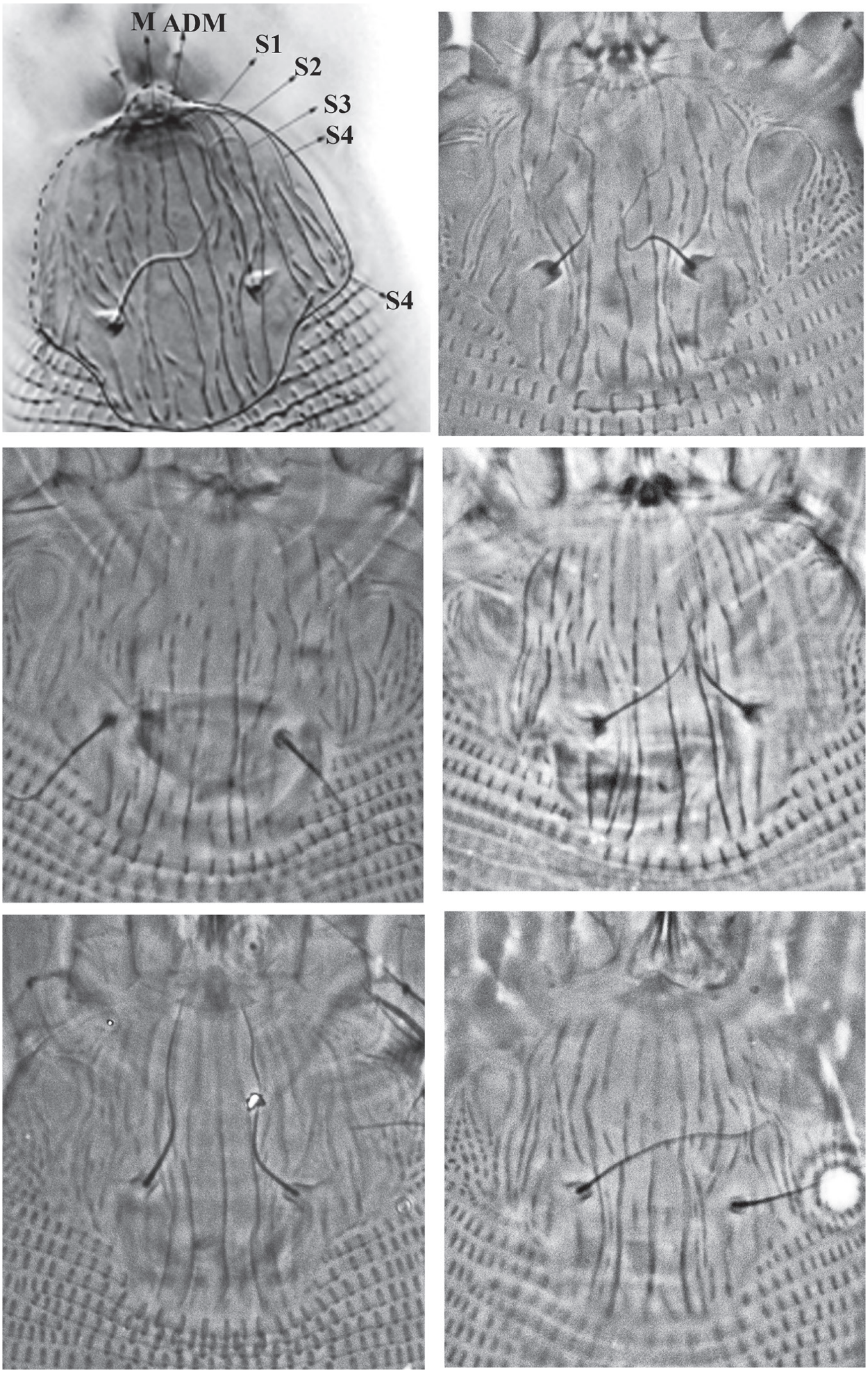

Figure 3. Variation of prodorsal shield sculpture of *Colomerus novahebridensis* Keifer. The top left figure highlights the prodorsal shield lines: from center to lateral margin, lines running from anterior to posterior margin are interpreted as median (**M**), admedian (**ADM**) and submedian lines (**S1–S4**). Specimens collected in Thailand.

Remarks

The morphological characteristics described generally fit the original description of the species, which was much less detailed. Slight differences, subsequently referred to, are considered to represent intraspecific variations. In the original description, admedian lines were mentioned as being complete, which was not the case with the specimens collected in this study. The illustration provided in the original description of the species indicates the presence of a few more submedian lines than observed in the specimens from Thailand. The original description mentioned frontal lobe of prodorsal shield to be truncate. The illustration of prodorsal shield design in the original description shows six partial rings antero-laterally, which is not seen in our specimens; internal coxisternal apodeme is also present in some Thai specimens, but it is not shown in the original description.

Revised characterization of *Colomerus*

Type species: *Eriophyes gardeniella* Keifer, by original designation.

As stated by Newkirk and Keifer (1971), this genus was erected to include species until then considered to belong to *Eriophyes* von Siebold (subfamily Eriophyinae), but that had genitalia and coxal structures typical for Cecidophyinae, namely *Colomerus gardeniella* (Keifer), *Colomerus holodisci* (Keifer) and *C. vitis*.

Keifer (1977) assumed the following characteristics as essential for the placement of species in this genus: a) genital opening somewhat appressed to hind coxae [in our concept, with a maximum of 4 coxigenital semiannuli anterior to coverflap]; b) genital apodemes appearing narrow [mentioned as "always shortened in ventral view, but somewhat variable" in the original description and mentioned as shortened by Keifer (1977)] in ventral view; c) scapular seta [named dorsal seta by Keifer (1977)] directed diagonally ahead or straight ahead; d) genital coverflap with longitudinal ridges arranged in two uneven transverse rows.

An evaluation of the species assigned to this genus leads to the conclusion that the first of those characteristics (position of genital opening) holds true for all of them. In relation to the second characteristic, the majority of the species placed in this genus has been mentioned to have narrow genital apodemes. However, nothing has been mentioned in the literature about the shape of the genital apodemes of *Colomerus oculivitis* (Attiah 1967). In a personal communication to the authors of the present publication (January 2014), C. Craemer kindly informed that in her evaluation of the specimens of the *C. vitis* – *C. oculivitis* complex (see Craemer and Saccaggi 2013), some specimens showed the typical narrow genital apodemes, whereas others showed genital apodemes as a pair of twisted leaf-like structures, similarly to what was observed in the present study for the specimens from Thailand identified as *C. novahebridensis*. Subtriangular apodemes were observed in specimens identified as *C. vitis* from southern Brazil.

Available illustrations of *Colomerus codiaeum* Keifer, 1979 and *Colomerus trichodesmae* Chakrabarti & Pandit, 1997 do not show the typical (narrow) apodemes illustrated by

Keifer for the type species of the genus. The inclusion of *C. codiaeum* in this genus is intriguing, given that it was described by Keifer, just two years after he published the items he considered essential for *Colomerus* species. Did he make a mistake in accepting that species as *Colomerus*? Did he then decided that species with different shape of genital apodeme could still be included in that genus, even without explicitly saying so, as could be assumed from his statement in the original description "always shortened in ventral view, but somewhat variable?". In this publication, we will accept the second option to be the case. This statement by Keifer reflects the assumed variability of the observed shape of these internal structures viewed under phase or interference contrast microscopy. Attempts to determine the real format of these structures could greatly benefit from observations under confocal microscopy, as used by Chetverikov (2014) for the study of other eriophyoids.

Nothing has been reported about the shape of the genital apodemes for the following species transferred to or originally described in *Colomerus*: *C. bucidae* (Nalepa, 1904), *C. lepidaturi* (Farkas, 1960), *C. pruni* Kuang & Luo, 2005 (in Kuang et al. 2005), *C. robaticus* Xue, Sadegui & Hong, 2012 and *C. spathodeae* (Carmona, 1967). Examination of the specimens redescribed by Flechtmann et al. (2000) and of the specimens from the Dominican Republic did not allow the verification of the shape of the genital apodeme.

An evaluation of the species referred to *Colomerus* suggested that it is not convenient to consider the orientation of the scapular seta as characteristic for species to be placed in this genus, given that it may vary when a specimen is slide mounted, although the species referred to this genus in the literature have been rarely mentioned or illustrated as having the scapular seta directed backward [only some *C. bucidae*, according to Flechtmann et al. (2000) and according to our examination of specimens from the Dominican Republic]. Also, it is not considered essential that the ridges of the coverflap be arranged in two uneven transverse rows, given that a continuous variation was observed (as subsequently detailed) from one to two transverse rows in species that otherwise resemble other species placed in this genus, as characterized later in this paper.

In the original description, *C. pruni* has been mentioned to have *h1* [rarely reported in other *Colomerus* (see characterization below)]; this species as well as *C. robaticus* have non-microtuberculate dorsal annuli and genital coverflap without ridges. Thus, they are not considered for the new characterization subsequently proposed for this genus, as they probably belong to a different genus (genera). Conversely, *C. trichodesmae*, *C. bucidae*, *C. lepidaturi* and *C. spathodeae* are provisionally retained in *Colomerus*, despite the reportedly non-typical genital apodeme of the first species or the absence of information about the shape of genital apodemes for the others.

A revised characterization of *Colomerus* could be stated as follows.

Idiosoma: wormlike, with opisthosomal annuli subequal dorsoventrally and microtuberculate; in some species smooth on the few posterior-most opisthosomal annuli (in the original description of *C. gardeniella*, type species of the genus, microtubercles very faint or absent dorsally on the six posterior-most dorsal annuli); opisthosomal setae *h1* absent [except, either reduced or completely absent in *Colomerus neopiperis* (Wilson, 1970), according to Wilson (1970) and usually absent in *Colomerus nudi* Manson, 1984, according to Manson (1984)]; mentioned and illustrated as present in the original description of *Eriophyes buceras* Cromroy, 1958, but not seen in specimens reported by Flechtmann et al. (2000) as *Colomerus bucidae* (Nalepa 1904), considered in that paper to be the senior synonym of the former species. Seta *h1* was also absent in the specimens of this species collected in the Dominican Republic and examined in this study.

Prodorsal shield: anterior lobe varying from indistinguishable to distinctly triangular or round and broad-based [absent according to original description of the genus]; scapular tubercles positioned variably from very near posterior shield margin to well anterior to posterior shield margin [slightly anterior to posterior shield margin according to original description of the genus, directing scapular setae diagonally forward or straight ahead (occasionally backward or laterally) [directing setae up and ahead in some degree according to original description of the genus]; gnathosoma short.

Legs: coxae I widely separate, with moderate or short internal coxisternal apodeme (in some species, anterior coxisternal regions totally separated and internal coxisternal apodeme not seen); legs with all usual setae, empodia entire, 4–6 rayed [only species with 5 rayed included in the original description].

Female genitalia: genital opening somewhat appressed to coxisternum II (4 coxigenital semiannuli anterior to genital coverflap); coverflap with longitudinal ridges distinctly arranged in one or two transverse rows, or with some (shorter) ridges in two rows and some (longer) ridges running along most of the length of genital coverflap, constituting a single row [arranged in uneven double rows according to original description of the genus]; genital apodemes usually visible as a narrow dark band in ventral view, but sometimes appearing to constitute a pair of subtriangular structures, depending on the position of the focus.

Key for the separation of the world *Colomerus* species (based on adult protogyne females)

Eriophyes buceras Trotter, 1929 should not be confused with *E. buceras* Cromroy, 1958. As there is no satisfactory description of the first of these species, a confirmation of its generic placement cannot be done. The second species was considered by Flechtmann et al. (2000) to be a junior synonym of *C. bucidae*. Some differences are observed between the redescription of *C. bucidae* given by Flechtmann et al. (2000) and the original description of *E. buceras* Cromroy, including the absence of seta *h1* in the specimens reported by Flechtmann et al. (2000) (also in the types of *C. bucidae*, as apparently mentioned in the original description: "s.a.fehlen") and the presence in the types of *E. buceras* Cromroy. Carlos Flechtmann considers however that those differences could correspond to misinterpretation of structures when Cromroy described his specimens. According to Cromroy (1958), *C. buceras* causes 4 distinct types of injury to its host, namely a deformation of fruits, erinea on the leaves, and 2 different types of galls. However, it seems that these symptoms are not the same as those reported by

Trotter (1929) for the species he had described as *Eriophyes buceras*, mentioned to consist of distinctive elongated, slender, hollow, horn-shaped flower outgrowths, reaching about 19 cm in length (very long, thin galls produced instead of the normal fruit measuring only 5–6 mm) and about 2–4 mm thick; some galls may develop into witches' brooms type of deformation. In the original description of *C. bucidae*, symptoms are mentioned as erineum-like structures in depressions of the undersurface of the leaves. Thus, these differences, although caused to the same host plant (*Terminalia buceras*, senior synonym of *Bucida bucera* and *Buchenavia buceras*), suggest *E. buceras* Trotter to be different from *C. bucidae* and *C. buceras* Cromroy. In the original description of *C. buceras* Trotter, the author mentioned it to be similar to *C. bucidae*. *Eriophyes buceras* Trotter needs to be redescribed.

In a recent publication, Craemer and Saccaggi (2013) reported an extensive evaluation of eriophyid mites intercepted on grape berries and grapevine budwood imported to South Africa from various countries. The authors reported their uncertainty in relation to the reliable separation of *C. vitis* and *C. oculivitis*, given the high variability of characters considered important in the characterization of those species, observed in their examination of specimens and available redescriptions of *C. vitis*. They reported that the only discrete and unambiguous distinguishing character was the number of empodial rays (5 in *C. vitis* and 6 in *C. oculivitis*), with a possible additional difference related to the shape and density of opisthosomal tubercles (rounded and more widely spaced in *C. vitis* as opposed to elongate and closer together in *C. oculivitis*). Despite those cited differences, the authors claimed that *Colomerus* mites from grapevine worldwide could not be accurately identified to species, given the possible (but not detected) variation in the number of empodial rays in those species. Regardless of that uncertainty, those species are placed separately in the key subsequently provided in this publication.

Eriophyes vitigineusgemmae Mal'chenkova, 1970 may also belong to *Colomerus*. However it is not included in the subsequent key because, according to the original description, its coverflap does not seem appressed to coxisternum II and because nothing has been mentioned about its genital apodemes.

Colomerus pruni and *C. robaticus* are also not included in the key because they probably belong to a different genus (genera), as previously discussed in this publication.

1 Without evident ocellar gibbosities; empodia 4-rayed **2**
1' With or without evident ocellar gibbosities; empodia 5- or 6-rayed **3**
2 Prodorsal shield without frontal lobe; region between admedian lines with many short lines; on *Trichodesma khasianum*... ....***C. trichodesmae* Chakrabarti & Pandit, 1997**
2' Prodorsal shield with frontal lobe; region between admedian lines with few short lines; on *Gardenia volkensii* subsp. *volkensii*... ....***C. volkensiae* Meyer & Ueckermann, 1990**
3 With evident ocellar gibbosities; empodia 6-rayed; all opisthosomal annuli microtuberculate..**4**

3’ With or without ocellar gibbosities; empodia 5-rayed; posterior-most opisthosomal dorsal annuli with or without microtubercles.......................... **6**

4 Opisthosomal seta *e* slightly over half as long as opisthosomal seta *d* and about as long as opisthosomal seta *f*; on *Woodfordia floribunda* .... ***C. woodfordis*** **Ghosh & Chakrabarti, 1989**

4’ Opisthosomal seta *e* at least 1.2 times as long as opisthosomal seta *d* and at least 3.5 times as long as opisthosomal seta *f*.......................... **5**

5 Scapular seta *sc* 21 µm; opisthosomal seta *d* 36 µm; opisthosoma with 70 annuli; microtubercles very narrow (linear); on *Vitis vinifera* .... ***C. oculivitis*** **(Attiah, 1967)**

5’ Scapular seta *sc* 10 µm; opisthosomal seta *d* 25 µm; opisthosoma with 55–62 annuli; microtubercles ovoid to rounded; on *Piper jaliscanum*.......................... ***C. neopiperis*** **(Wilson, 1970)**

6 Prodorsal shield smooth, except for few curved broken bases of admedian lines restricted to region between scapular tubercles and a tiny remnant of median line; without evident ocellar gibbosities; most posterior dorsal opisthosomal annuli without microtubercles; on *Baloghia inophylla* (G.Forst.) P.S. Green (mentioned as *Codiaeum inophyllum*, junior synonym) .... ***C. codiaeum*** **Keifer, 1979**

6’ Prodorsal shield with more extensive lines; with or without evident ocellar gibbosities; most posterior dorsal opisthosomal annuli with or without microtubercles; on other hosts.......................... **7**

7 Median line on prodorsal shield only distinguishable posteriorly, joined by broken arched lines to admedian lines, so as to form a pair of roundish cells at the base of the admedian lines; genital coverflap with longitudinal ridges arranged in two distinct transverse rows, those of the anterior row much shorter, fine and less evident than those of the posterior row; on *Gardenia jasminoides* .... ***C. gardeniella*** **(Keifer, 1964)**

7’ Median line on prodorsal shield not joined by broken arched lines to admedian lines; longitudinal ridges of genital coverflap not characteristically arranged in two transverse rows or, if so, then anterior row not composed of distinctly shorter, fine and less evident ridges than those of the posterior row.................. **8**

8 Prodorsal shield with frontal lobe (sometimes barely distinguishable) **9**

8’ Prodorsal shield without frontal lobe **19**

9 Prodorsal shield with lateral granulation; without evident ocellar gibbosities... **10**

9’ Prodorsal shield without lateral granulation; with or without evident ocellar gibbosities.......................... **11**

10 Opisthosomal setae *d* and *e* 30 and 8 µm, respectively; opisthosoma with 48 microtuberculate annuli; on *Holodiscus microphyllus*.......................... ***C. holodisci*** **(Keifer, 1970)**

10’ Opisthosomal setae *d* and *e* 18–25 and 18–30 µm, respectively; opisthosoma with 55–70 annuli; microtubercles missing on posterior 6–7 dorsal annuli; on *Phebalium nudum* .... ***C. nudi*** **Manson, 1984**

11 Opisthosoma with 60–85 annuli **12**

11’ Opisthosoma with less than 60 annuli (except *C. coplus*, with 53–63) **14**

12 With evident ocellar gibbosities; with 67–85 microtuberculate annuli; on *Cocos nucifera* ...... ***C. novahebridensis* Keifer, 1977**

12’ Without evident ocellar gibbosities; with 61–75 annuli, all microtuberculate or posterior ten dorsal annuli with few microtubercles **13**

13 Opisthosoma with 61–68 annuli; posterior 10 dorsal annuli with few microtubercles; on *Tricalysia junodii* var. *junodii* and *Sericanthe andongensis* ...... ***C. tricaseri* Meyer & Ueckermann, 1990**

13’ Opisthosoma with 75 microtuberculate annuli; on *Diospyros mespiliformis* ...... ***C. mespiliformae* Meyer & Ueckermann, 1990**

14 Admedian lines on prodorsal shield well defined and complete; ocellar gibbosities absent; all opisthosomal annuli microtuberculate **15**

14’ Admedian lines on prodorsal shield generally not well defined (or broken), may be distinct on posterior half of prodorsal shield; microtubercles may be absent on posterior opisthosomal dorsal annuli **16**

15 Median line totally distinct; opisthosoma with 53–63 microtuberculate annuli; opisthosomal setae *d* and *e* 19–24 and 14–26 µm, respectively; on *Melicope simplex* A. Cunn. ...... ***C. coplus* Manson, 1984**

15’ Median line distally indistinct; opisthosoma with 48–50 microtuberculate annuli; microtubercles fading dorsally on posterior 10 annuli; opisthosomal setae *d* and *e* 36 and 40 µm, respectively; on *Vitex wilmsii* ...... ***C. vitexi* Meyer & Ueckermann, 1990**

16 Without evident ocellar gibbosities; opisthosoma with 50–57 microtuberculate annuli; microtubercles rectangular dorsally, fading on posterior 10 annuli; on *Antidesma venosum*.... ***C. antidesmae* Meyer & Ueckermann, 1990**

16’ With or without evident ocellar gibbosities; opisthosoma with 50–59 microtuberculate annuli; microtubercles oval dorsally, may be missing on posterior-most annuli; on other hosts **17**

17 Frontal lobe of prodorsal shield much broader than long; with ocellar gibbosities (sometimes not well distinct); opisthosoma with 54–59 microtuberculate annuli; microtubercles fading dorsally on posterior 15 annuli; on *Tinnea barbata* ...... ***C. tinneae* Meyer & Ueckermann, 1990**

17’ Frontal lobe of prodorsal shield about as broad as long or slightly broader than long; with or without evident ocellar gibbosities; opisthosoma with 50–55 microtuberculate annuli; posterior-most opisthosomal dorsal annuli with or without microtubercles; on other hosts **18**

18 Region between admedian lines on prodorsal shield with many short lines; with prominent ocellar gibbosities; opisthosoma with 55 microtuberculate annuli; on *Alangium saviifolium* ...... ***C. alangii* Keifer, 1978**

18’ Region between admedian lines on prodorsal shield only with median line; without prominent ocellar gibbosities; opisthosoma with 50–55 microtuberculate annuli; posterior dorsal 15 annuli without microtubercles; on *Ziziphus mucronata* ...... ***C. mansus* Meyer & Ueckermann, 1990**

19 Opisthosoma with 70–94 annuli; with evident ocellar gibbosities............**20**

19’ Opisthosoma with at most 66 annuli; with or without evident ocellar gibbosities...**21**

20 Opisthosomal setae *d* and *e* 40–46 and 38–60 µm, respectively; opisthosoma with 76–89 microtuberculate annuli; posterior 6 dorsal annuli sparsely microtuberculate (all microtuberculate according to Mathez 1965 and Newkirk and Keifer 1971); on *V. vinifera* .... ***C. vitis*** **(Pagenstecher, 1857)**

20’ Opisthosomal setae *d* and *e* 31 and 27 µm, respectively; opisthosoma with 75–94 microtubertulate annuli; on *Ribes nigrum* .... ***C. riberini*** **Shi & Boczek, 2002**

21 Ocellar gibbosities absent; genital coverflap with longitudinal ridges arranged in a single row... ***C. lepidaturi*** **(Farkas, 1960)**

21’ Ocellar gibbosities well evident, ill-defined or absent; genital coverflap with longitudinal ridges arranged in two transverse rows **22**

22 With evident ocellar gibbosities; opisthosoma with about 62 microtuberculate annuli; microtubercles broadly oval; on *Spathodea campanulata*............. .... ***C. spathodeae*** **(Carmona, 1967)**

22’ With ill defined ocellar gibbosities; opisthosoma with 49–61 microtuberculate annuli, of which the 8–10 posterior-most without microtubercles; microtubercles elongate dorsally and ventrally, shorter and more rounded laterally; on *Terminalia* (syn. *Buchenavia*, *Bucida*) *buceras*........***C. bucidae*** **(Nalepa, 1904)**

Genera close to *Colomerus*

Ectomerus Newkirk & Keifer is the genus that most closely resembles *Colomerus* morphologically. It was described as a monotypic genus by Newkirk and Keifer (1975) in a dichotomous key to the genera of Cecidophyinae, with *Stenacis anysis* Keifer as the type species, described by Keifer (1970). Presently, three other species (*E. chebulae* Mohanasundaram, 1980; *E. systenus* Meyer, 1990; *E. triquetrus* Flechtmann & Etienne, 2002) are also included in this genus (Amrine and Stasny 1994, Amrine and de Lillo 2013 pers. comm.). The main characteristic used by Newkirk & Keifer to separate *Ectomerus* from *Colomerus* was its narrow and “basally flexible” anterior lobe; the flexibility of the anterior lobe was probably assumed by the observed variability of the angle between the lobe and the gnathosoma in lateral view of mounted specimens, although the authors also state seta *h1* to be present (though minute) and female genitalia not to be strongly appressed to the coxisternum II.

Palmiphytoptus Navia & Flechtmann is also similar to this genus. It was described (Navia and Flechtmann 2002) based only on the type species, *P. oculatus* Navia & Flechtmann, 2002. This genus was described in Phytoptidae. Amrine et al. (2003) suggested the possibility that these mites could belong to Eriophyidae (probably *Eriophyes*), assuming the possibility that the setae interpreted as *ve*, could refer to *sc*, located much anterior to their usual position. *Palmiphytoptus barbosae* Navia & Flechtmann was described more recently (Navia and Flechtmann 2005). The genital apodemes of species of this genus seem similar to that of *Colomerus* and although in the type species the coverflap is not appressed to the coxisternum II, in *P. barbosae* it is appressed. We consider that regardless of the placement of this genus at the family and subfamily level, the placement of the prodorsal shield setae would make it different from *Colomerus*.

Economic importance of *Colomerus*

The kinds of injury caused by *Colomerus* species are very diverse, with some species causing more than one type of damage. The main types of damage are mentioned as: disturbance to development of new leaves, by damaging buds (*C. oculivitis*, *C. vitis*, *C. woodfordis*), fruit deformation (*C. bucidae*), formation of leaf erinea (*C. alangii*, *C. bucidae*, *C. coplus*, *C. holodisci*, *C. mespiliformae*, *C. nudi*, *C. riberini*, *C. spathodeae*, *C. tricaseri*, *C. vitexi*, *C. vitis*, *C. volkensiae*), leaf outgrowth (*C. tricaseri*), "witch´s broom", by damaging inflorescences (*C. antidesmae*), formation of leaf galls (*C. bucidae*, *C. lepidaturi*, *C. neopiperis*, *C. tinneae*, *C. trichodesmae*), leaf distortion (*C. mansus*, *C. spathodeae*, *C. trichodesmae*, *C. vitis*) and fruit necrosis (*C. novahebridensis*). The following species were not associated with any type of damage on plants from which type specimens were collected: *C. codiaeum* and *C. gardeniella*.

While several of these species are known to attack ornamental plants, only 3 species have been reported from major crops: *C. oculivitis* and *C. vitis* from grapevine and *C. novahebridensis* from coconut. *Colomerus oculivitis* and *C. vitis* have been mentioned to cause economic damage to their host, especially *C. vitis*, which has a wide distribution (Jeppson et al. 1975; Duso and De Lillo 1996; Craemer and Saccaggi 2013). *Colomerus novahebridensis* is usually not considered a pest, although West African cultivars growing in the Philippines and Malaysia are mentioned to be sometimes significantly damaged (Howard et al. 2001). As reported previously in this paper, this species was usually found in this study at very low levels, causing little damage; in a few occasions, damage was slightly more extensive, and the mite apparently caused premature fruit drop (see further details under "relation to host" in the complementary of the species based on the Thai population).

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Two new species of harvestmen (Opiliones, Eupnoi, Neopilionidae) from Waitomo, New Zealand

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Abstract

Two new species of harvestman (Opiliones: Neopilionidae: Enantiobuninae) are described from the Waitomo region of the North Island, New Zealand, *Forsteropsalis bona* **sp. n.** and *F. photophaga* **sp. n.** Both have been collected within caves in the region, where predation on glow-worms *Arachnocampa luminosa* has been previously recorded for one or both species (misidentified as '*Megalopsalis tumida*'). However, both are regarded as troglophiles rather than strict troglobites due to the presence of specimens outside the cave systems, and the absence of troglobitic adaptations. *Megalopsalis tumida* (Forster, 1944) is identified as a junior synonym of *Forsteropsalis fabulosa* (Phillipps & Grimmett, 1932).

Keywords

Taxonomy, arachnids, cave biota

Introduction

The Waitomo region of the North Island, New Zealand, has become internationally renowned as a tourist attraction owing to its extensive cave systems. The primary reason for their fame is their large population of glow-worms *Arachnocampa luminosa*

(Keroplatidae). These luminescent fly larvae construct silken nests on the roof of the cave from which they hang sticky threads to capture flying insects attracted to their light (Richards 1960). They are themselves predated upon by harvestmen (Opiliones), which are able to avoid entanglement by the glow-worms' threads and pull the larvae from their nests (Richards 1960; Meyer-Rochow and Liddle 1988).

Richards (1960) recorded two species of harvestmen feeding on glow-worms at Waitomo. One, *Hendea myersi cavernicola* Forster, 1954 (Triaenonychidae), was originally described from Waitomo. The second species was identified by both Richards (1960) and Meyer-Rochow and Liddle (1988) as *Megalopsalis tumida* (Forster, 1944) (Neopilionidae). Richards (1960) recorded this species feeding only on mature glow-worm gnats; Meyer-Rochow and Liddle (1988) recorded it also feeding on pupae and late-instar larvae. *Megalopsalis tumida* is a junior synonym of *Forsteropsalis fabulosa* (Phillipps & Grimmett, 1932) (see below), and was originally described from near Wellington. Examination of specimens collected from caves in the Waitomo region revealed the presence of two species of Neopilionidae, both of them described as new below. Which of these was the species mentioned by Richards (1960) and Meyer-Rochow and Liddle (1988) is unknown. *Forsteropsalis bona* sp. n. is the more similar to *F. fabulosa*, but a photograph of *'Megalopsalis tumida'* in Meyer-Rochow and Liddle (1988) may show *F. photophaga* sp. n. It is not impossible that the two were confused.

While Meyer-Rochow and Liddle (1988) regarded *Hendea myersi cavernicola* as a true troglobite, and did not find it outside the cave entrance, the collection of small numbers of *'M. tumida'* outside the cave led them to regard it as troglophilic rather than troglobitic. Similar habits were inferred by Taylor (2013) for *Megalopsalis suffugiens* Taylor, 2013, described from caves in Western Australia. Further epigean specimens are recorded herein for *Forsteropsalis bona*, while specimens collected in the cave were only a short distance from the entrance. *Forsteropsalis photophaga* has not yet been conclusively recorded outside the caves, but troglophily is also suggested for this species by the absence of strong adaptations for troglobitism.

Methods

Specimens were sourced from the collection of Te Papa Tongarewa, Wellington, New Zealand (MONZ) or collected by hand by A. Probert and associates. Specimens collected by A. Probert will be deposited at the New Zealand Arthropod Collection, Landcare Research, Auckland, New Zealand (NZAC). All specimens are assigned to the area code WO (Waikato) by the system established by Crosby et al. (1998). Photographs and measurements were taken using a Nikon SMZ1500 stereo microscope and the NIS-Elements D 4.00.03 programme, and a Leica DM2500 compound microscope. Measurements are given in millimetres (mm). Coloration is described as in alcohol (live coloration is given in parentheses).

Taxonomic descriptions

Forsteropsalis bona **sp. n.**
http://zoobank.org/32F7E0A3-1CE0-41EF-B7AA-48DDAE2A529A
Figure 1

Holotype male. WO. Lucky Strike Cave, Te Kuiti, on wall near entrance, 14 Feb 1959, K. A. J. Wise (MONZ).

Paratypes. WO. 2 males, Waitomo Valley, in stream crevice outside cave entrance (shady), specimens intertwined and sluggish, 30 Mar 1959, L. G. Watson (MONZ); 1 male, Weir Cave, Stubbs Farm, Waitomo, ca. 2 m from cave entrance within a 15 cm radius of *Arachnocampa luminosa* larvae, 23 Aug 2010, A. Probert (NZAC).

Etymology. From the Latin *bonus*, good, in contrast to the related *Forsteropsalis fabulosa*.

Male (n=4). Total body length 4.8–6.6; prosoma length 2.5–2.8, width 4.0–4.2. Prosoma (including ocularium) unarmed (Fig. 1A); ground colour in alcohol orange-brown with longitudinal yellow stripes on either side of ocularium (live coloration very dark brown [almost black] with orange-yellow stripes; appendages also black). Ozopores elongate, with small flanking lobes. Opisthosoma grey-yellow. Mouthparts cream-coloured; medial side of pedipalpal coxa with dense array of sharp denticles; cervix unarmed. Coxae yellow. *Chelicerae* (Fig. 1B): Segment I length 6.2–8.4; segment II 9.4–10.4. Elongate; segment I orange with lighter yellow patch at distal end, segment II dark orange-brown. Segment I denticulate, with denticles concentrated along dorsal, proventral and retroventral margins. Segment II massively inflated, evenly denticulate. Cheliceral fingers elongate, widely bowed apart; setae present on distal half of mobile finger. *Pedipalps*: Femur length 5.4–5.7; patella 2.2–2.4; tibia 2.8–3.1; tarsus 5.8–6.5. Distinctly elongate, yellow. Femur dorsally denticulate on proximal two-thirds; remainder of pedipalp unarmed. Setae sparse except for small concentration at prodistal end of patella; microtrichia present on tarsus and distal half of tibia; prodorsal end of patella with distinct protrusion but without definite finger-like apophysis (Fig. 1C). Tarsal claw without ventral tooth-row. *Legs*: Legs I femur length 8.6–9.9, patella 1.9–2.5, tibia 8.3–9.8; leg II femur 14.3–17.2, patella 2.2–2.8, tibia 14.4–17.8; leg III femur 7.5–8.7, patella 1.7–2.3, tibia 5.3–8.2; leg IV femur 8.5–10.7, patella 1.8–2.7, tibia 10.2–10.8. Femora sparsely denticulate, particularly in proximal half; remainder of legs unarmed. Distitarsus I with strong ventral tooth at distal end of each of first five or six pseudosegments (Fig. 1D). Tibia II with nine to fifteen pseudosegments; tibia IV with two pseudosegments. *Penis* (Fig. 1E–F): Shaft subquadrate; tendon long. Bristle groups relatively long, posterior bristle group with longest bristles reaching dorsal margin in lateral view. Glans short, subtriangular in ventral view, narrowing rapidly in lateral view.

Comments. Females of this species are currently unknown. *Forsteropsalis bona* can be distinguished from most other *Forsteropsalis* species by its unarmed prosoma

Figure 1. *Forsteropsalis bona* sp. n. **A** dorsal view of body, holotype **B** lateral view of body, pedipalps and chelicerae, holotype **C** dorsal view of right pedipalpal patella and tibia, holotype **D** proximal pseudosegments of right distitarsus I (venter upwards), holotype, showing ventrodistal teeth **E** penis, ventral view, specimen from Waitomo Valley **F** penis, right lateral view, specimen from Waitomo Valley.

and enormous, sub-globose cheliceral segment II with widely bowed cheliceral fingers (Taylor 2011). In these features it strongly resembles *F. fabulosa*, and would key out to either *F. fabulosa* or *F. tumida* in the key to *Forsteropsalis* species provided by Taylor (2011). These two species are synonymised below. *Forsteropsalis bona* can be distinguished from *F. fabulosa* by the form of the pedipalpal patella: *F. fabulosa* has a distinct finger-like prodistal apophysis on the patella (Phillipps and Grimmett 1932: Fig. C p. 732), while the patellar apophysis is almost absent in *F. bona* (Fig. 1C). *Forsteropsalis fabulosa* also has denticles both dorsally and ventrally on the pedipalpal femur, while *F. bona* has denticles dorsally only.

An interesting feature of *Forsteropsalis bona* is the presence of a strong ventrodistal tooth on the end of each of the proximal pseudosegments of the distitarsus. This tooth sits between the two spinose setae generally present on each tarsal pseudosegment in all Enantiobuninae (Fig. 1D). Such a feature has not previously been recorded for this subfamily, though it is also present in *F. fabulosa* (specimens from MONZ, details given in Taylor 2011). This may represent a distinct synapomorphy of these two species.

The glans of both *Forsteropsalis fabulosa* (Taylor 2011) and *F. bona* is relatively short compared to other *Forsteropsalis* species, and converges in shape on that of the Australian genus *Megalopsalis* (Taylor 2011, 2013). Nevertheless, the remaining features of these two species support a direct relationship with other New Zealand species of *Pantopsalis* and *Forsteropsalis*, and with *Forsteropsalis* in particular. These features include dorsal papillae on the glans (Taylor 2011), setae on the mobile finger of the chelicera (absent in *Megalopsalis* except *M. caeruleomontium*; Taylor 2011, 2013), and an array of denticles on the medial side of the pedipalpal coxa (Fig. 3A; Taylor 2011).

Forsteropsalis fabulosa (Phillipps & Grimmett, 1932)

Macropsalis fabulosa Phillipps & Grimmett, 1932: 731–733, fig. p. 732.
Megalopsalis fabulosa (Phillipps & Grimmett) – Forster 1944: 186–187, figs 10–11 (misidentification of *Forsteropsalis inconstans*).
Megalopsalis tumida Forster 1944: 188–189, figs 4–6 syn. n.
Forsteropsalis fabulosa (Phillipps & Grimmett) – Taylor 2011: 51, figs 99–101, 2012: 49.
Forsteropsalis tumida (Forster) – Taylor 2011: 60–61, figs 124–127.

Comments. *Forsteropsalis fabulosa* and *F. tumida* were distinguished in Taylor (2011) solely by the degree of dilation of the second cheliceral segment, with the latter supposedly more inflated in *F. tumida* than in *F. fabulosa*. A number of species of *Forsteropsalis* and its sister genus *Pantopsalis* are now known to vary in cheliceral dilation (Taylor 2004, 2011, 2013, and see *Forsteropsalis photophaga* below). *Forsteropsalis fabulosa* and *F. tumida* were both described from the Wellington district, and there seems to no longer be any justification for separating them as different species. *Forsteropsalis tumida* is therefore regarded herein as a junior synonym of *F. fabulosa* (syn. n.).

Forsteropsalis photophaga sp. n.

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Figure 2

Holotype male. WO. Waitomo, Gardners Gut Cave System, 200 yards from Zweihöllen entrance, 25 June 1977, W. L. Blundell (MONZ).

Paratypes. WO. 1 male, Giants Cavern, Hollow Hill Cave, Te Kuiti, in 'Crows Nest', 60–70 ft high, 12 January 1958, coll. R. W. Taylor (MONZ); 1 male, Aussie

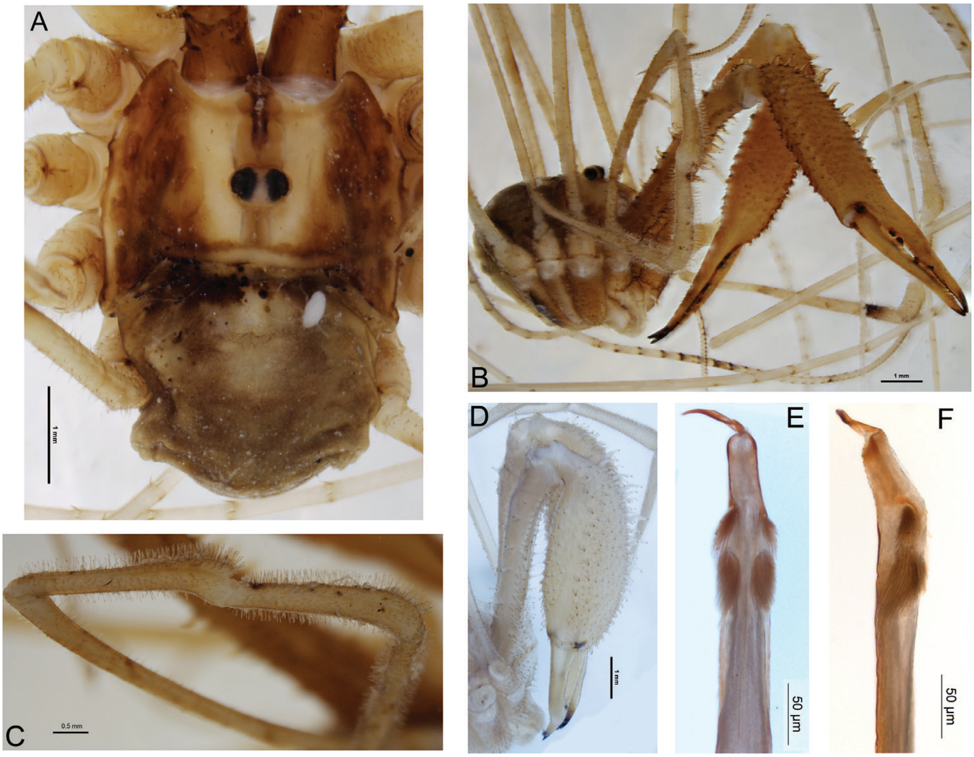

Figure 2. *Forsteropsalis photophaga* sp. n. **A** dorsal view of body, holotype, with parasitic mite attached **B** anterolateral view of body, pedipalps and chelicerae, holotype **C** dorsal view of right pedipalpal patella and tibia, holotype **D** anterolateral view of chelicerae of specimen from Aussie Cave, showing more inflated chelicerae **E** penis, ventral view, holotype **F** penis, right lateral view, holotype.

Cave, Taumatamaire Rd, Waitomo County, 50 ft, 16 May 1966, K. A. J. Wise (MONZ); 2 males, Stubbs Farm, Waitomo, on rocky cave substrate, February 2013, G. Holwell et al. (NZAC); 2 males, Mangapohue Cave, Stubbs Farm, Waitomo, on rocky cave substrate, 21 Oct 2013, A. Probert & D. Townsend (NZAC).

Etymology. From the Greek *phos*, light, and *phagein*, to eat, in reference to this species' predation of the glow-worm *Arachnocampa luminosa*.

Male (n=7). Total body length 3.5–6.1; prosoma length 1.9–2.1, width 2.5–3.9. Prosoma (including ocularium) unarmed except for few black setae (Fig. 2A); ground colour orange-brown with longitudinal yellow stripes on either side of ocularium (live colouration light to mid-brown with pale yellow stripes). Ozopores elongate, with small flanking lobes. Opisthosoma grey-brown. Mouthparts cream-coloured; medial side of pedipalpal coxa with array of sharp denticles; cervix with single pair of denticles laterally. Coxa I orange; remaining coxae and venter of opisthosoma yellow. *Chelicerae* (Fig. 2B, D): Segment I length 3.4–6.5, segment II 4.9–9.1. Elongate; orange except for lighter yellow patch at distal end of first segment. First segment dorsally with scattered denticles, becoming more elongate retrolaterally, ventrally with longitudinal prolateral and retrolateral rows of elongate denticles and some scattered median denticles proximally. Second segment mildly to notably inflated, sub-conical, evenly denticulate with longitudinal rows of more elongate denticles dorsally and retrolaterally. Cheliceral fingers elongate, slightly bowed apart; setae present along central third of mobile finger. *Pedipalps*: Femur length 4.6–6.5, patella 2.8–3.2, tibia 2.2–2.8, tarsus 4.8–5.7. Distinctly elongate; yellow. Median side of coxa with array of sharp denticles. Femur with few denticles dorsally in proximal half; remainder of pedipalp unarmed. Patella, tibia and proximal half of tarsus densely covered with plumose setae; microtrichia present over entirety of patella, tibia and tarsus; patella with small, rounded, prodistal apophysis (Fig. 2C). Tarsal claw without ventral tooth-row. *Legs*: Leg I femur length 8.1–11.0, patella 1.9–2.2, tibia 8.4–10.7; leg II femur 14.0–17.7, patella 1.9–2.5, tibia 16.0–19.0; leg III femur 7.1–9.4, patella 1.6–1.9, tibia 7.6–9.8; leg IV femur 9.0–12.2, patella 1.8–2.2, tibia 10.3–12.4. Yellow. Proximal half of femur I with few scattered dorsal denticles; remainder of legs unarmed. Tibia II with 12 pseudosegments; tibia IV with three pseudosegments. *Penis* (Fig. 2E–F): Shaft subquadrate; tendon long. Bristle groups relatively long, posterior bristle group with longest bristles reaching dorsal margin in lateral view. Glans relatively long, subrectangular in ventral view, remaining relatively deep to distal end but with dorsodistal end rounded.

Comments. Females of this species are currently unknown. The holotype of *Forsteropsalis photophaga* when first examined had a parasitic mite attached to the opisthosoma (Fig. 2A). This mite is a representative of the Microtrombidiidae, a family that has not previously been recorded as parasitic on Opiliones; a more detailed description is currently being prepared by C. Taylor.

The genera *Pantopsalis* and *Forsteropsalis* have hitherto been regarded as well distinguished by the morphology of the cheliceral fingers (crescent-shaped in *Pantopsalis* vs bowed in *Forsteropsalis*), pedipalpal patellar apophysis (hypersetose and rounded in *Pantopsalis*, sparsely setose and triangular in *Forsteropsalis*) and penile bristle groups (shorter in *Pantopsalis* than in *Forsteropsalis*) (Taylor 2004, 2011). The current species blurs this distinction: in its hypersetose and rounded pedipalpal apophysis it resembles *Pantopsalis*, but its elongate cheliceral fingers and penile bristle groups are more characteristic of *Forsteropsalis*. It also possesses an array of denticles on the medial side of the pedipalpal coxa as found in *Forsteropsalis* species (Fig. 3A; Taylor 2011). We therefore assign it to the latter genus herein. A hypersetose, rounded patella is also present in the female of *F. grimmetti*, though the male of that species possesses a more typical *Forsteropsalis*-type patella (Taylor 2011). It is possible that the hypersetose patella is in fact a symplesiomorphy of *Pantopsalis* and *Forsteropsalis*, with *F. photophaga* being a basal member of the latter genus.

Forsteropsalis photophaga can be readily distinguished from all other Neopilionidae in New Zealand by the hypertrophied denticle rows on the second cheliceral segment. The only other neopilionid with comparable chelicerae is the major male of the Tasmanian species *Megalopsalis nigricans* (Hickman 1957). This, however, is a much smaller species, with very different genital morphology and with small ozopores unlike those of any *Forsteropsalis* species (Hickman 1957, Taylor 2013).

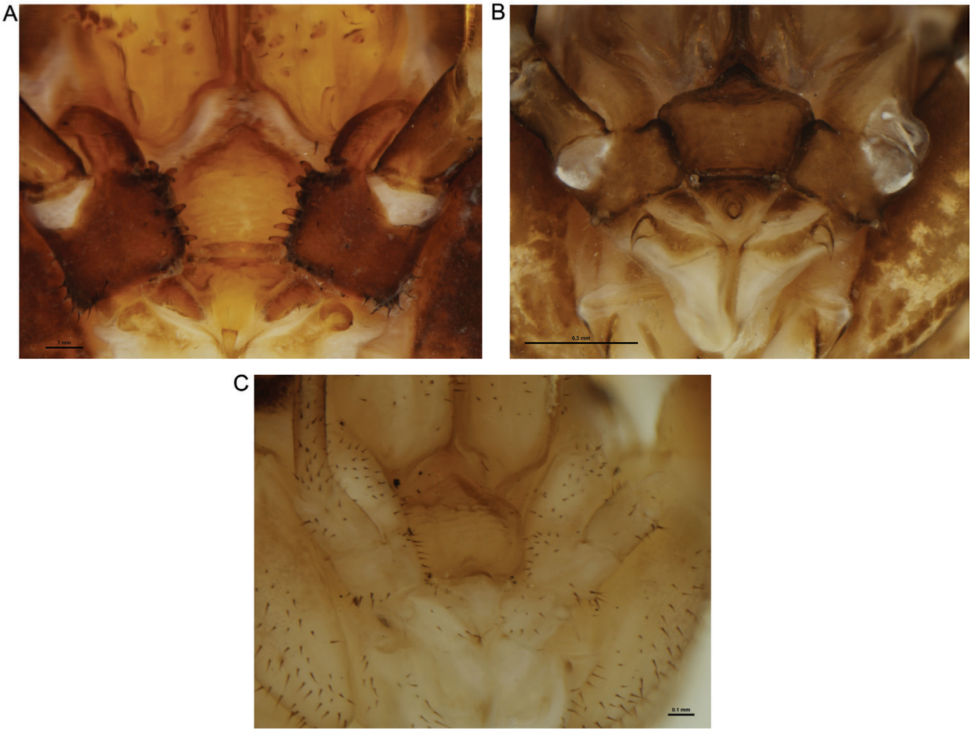

Figure 3. Mouthparts of selected New Zealand Neopilionidae, showing morphology of pedipalpal coxae. **A** *Forsteropsalis chiltoni*, with medial denticles **B** *Pantopsalis albipalpis*, with sclerotised medial flange overhanging cervix **C** *Mangatangi parvum*, with unarmed, simple coxae.

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RESEARCH ARTICLE

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Three new species of the leafhopper genus *Tambocerus* Zhang & Webb (Hemiptera, Cicadellidae) from southern China

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Abstract

Three new species, *Tambocerus dentatus*, *T. longicaudatus* and *T. robustispinus* **spp. n.** from southern China, are described and illustrated. A checklist and distribution to the *Tambocerus* species from China is provided together with a key for their separation.

Keywords

Auchenorrhyncha, taxonomy, morphology, China

Introduction

The Oriental leafhopper genus *Tambocerus* was established by Zhang and Webb (1996) with *Selenocephalus disparatus* (Melichar, 1903) from Sri Lanka as its type species. It was placed in the tribe Selenocephalini (Zhang and Webb 1996) due to the transverse striations on the fore margin of the head but was assigned to the tribe Athysanini in the subfamily Deltocephalinae by Viraktamath (2012) according to the key to tribes of the subfamily Deltocephalinae (Zahniser and Dietrich 2008).

Zhang and Webb (1996) originally described the genus *Tambocerus* for two species, *Tambocerus disparatus* (Melichar) and *T. plumbeus* (Distant) from Sri Lanka. Rao (1996) added one new species from Indian, Shen et al. (2008) described four more species from China and Viraktamath (2012) described seven new species from the Indian subcontinent. So far, the genus *Tambocerus* contains 14 known species.

In this paper, we describe three new species, *Tambocerus dentatus* Qu & Dai, sp. n., *T. longicaudatus* Qu & Dai, sp. n. and *T. robustispinus* Qu & Dai, sp. n. from China, are described and illustrated. A checklist along with distribution records and a key to distinguish species of the genus from China are provided.

Material and methods

Classification system follows that by Zahniser and Dietrich (2013), morphological terminology follows that by Zhang and Webb (1996), Shen et al. (2008) and Viraktamath (2012).

Type specimens of the new species are deposited in the Institute of Entomology, Guizhou University, Guiyang, China (GUGC) and one specimen of *Tambocerus robustispinus* sp. n. is deposited in the British Museum (Natural History), London, U.K. (BMNH).

Taxonomy

Genus *Tambocerus* Zhang & Webb

Tambocerus Zhang & Webb, 1996: 8–9; Shen et al. 2008: 242–249; Viraktamath 2012: 43–61.

Type species. *Selenocephalus disparatus* (Melichar, 1903).

Remarks. This genus can be differentiated from other genera by the following combination of characters: ocelli on margin close to eye, vertex slightly produced medially with anterior margin transversely striate, antennae located at level near to middle of eyes, connective Y-shaped with stem as long or longer than arms and aedeagal shaft laterally serrate.

Distribution. Palearctic and Oriental region: Sri Lanka, Indian and China.

Checklist of the genus *Tambocerus* in China

Tambocerus dentatus Qu & Dai, sp. n.
Distribution. China (Guizhou Province).

Tambocerus elongatus Shen, 2008: 243–246, figs 1–7.
Distribution. China (Hubei, Hunan, Henan, Shaanxi, Guangxi, Hainan, Guangdong, Fujian, Sichuan, Anhui Provinces).

Tambocerus furcellus Shang & Zhang, 2008: 247–248, figs 15–21.
Distribution. China (Hunan Province).

Tambocerus longicaudatus Qu & Dai, sp. n.
Distribution. China (Guizhou Province).

Tambocerus quadricornis Shang & Zhang, 2008: 248, figs 22–28.
Distribution. China (Guangxi Province).

Tambocerus robustispinus Qu & Dai, sp. n.
Distribution. China (Guangxi and Yunnan Provinces).

Tambocerus triangulatus Shen, 2008: 246–247, figs 8–14.
Distribution. China (Shaanxi and Hainan Provinces).

Key to species of the genus *Tambocerus* from China (males)

1 Pygofer caudal lobe rounded with dorsoposterior margin dentate (Fig. 10)... .... ***T. dentatus* Qu & Dai, sp. n.**

– Pygofer caudal lobe produced (Figs 16, 23) **2**

2 Pygofer lobe produced process-like (Figs 16, 23); apophysis of style not or slightly exceeding apex of connective (Shen et al. 2008: Fig. 27)................ **3**

– Pygofer lobe produced triangular shaped in lateral view, with caudal sclerotised cape-like region (Shen et al. 2008: Fig. 3); apophysis of style exceeding well beyond apex of connective (Shen et al. 2008: Fig. 6)........... ***T. elongatus* Shen**

3 Posterior process of pygofer curved dorsally (Shen et al. 2008: Figs 17, 24)..... **4**

– Posterior process of pygofer either directed posteriorly or posteriorly and then ventrally (Figs 16, 23).. **5**

4 Aedeagal shaft without bifurcate apex, with pair of lateral subapical process (Shen et al. 2008: Fig. 28) .... ***T. quadricornis* Shang & Zhang**

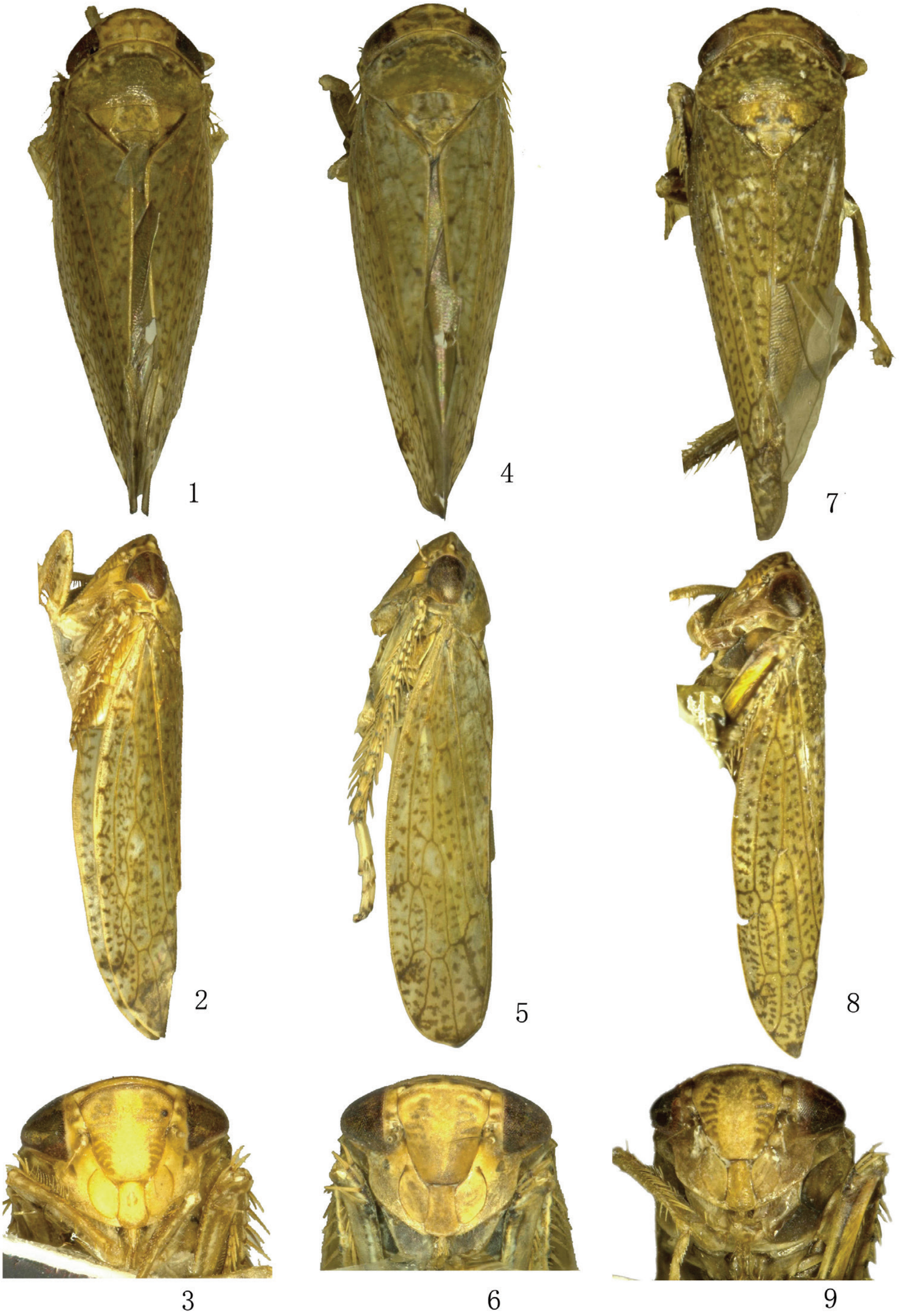
– Aedeagal shaft with bifurcate apex, without processes (Shen et al. 2008: Fig. 23).. ***T. furcellus* Shang & Zhang**

5 Pygofer posterior process with acute apex (Fig. 23); aedeagal shaft with bifurcate apex (Figs 27–28).................... ***T. robustispinus* Qu & Dai, sp. n.**

– Pygofer posterior process with apex digitate and curved ventrally (Fig. 16); aedeagus with pair of lateral processes (Fig. 20).. **6**

6 Aedeagal shaft with processes distinctly longer than width of shaft (Figs 20–21) .... ***T. longicaudatus* Qu & Dai, sp. n.**

– Aedeagal shaft with processes similar in width to shaft (Shen et al. 2008: Fig. 14).. ***T. triangulatus* Shen**



Figures 1–9. 1–3 *Tambocerus dentatus* Qu & Dai, sp. n. **4–6** *T. longicaudatus* Qu & Dai, sp. n. **7–9** *T. robustispinus* Qu & Dai, sp. n. **1, 4, 7** Dorsal view **2, 5, 8** Lateral view **3, 6, 9** Facial view.

Tambocerus dentatus **Qu & Dai, sp. n.**

http://zoobank.org/814B98D5-DE3F-428A-AF16-36DAB803E210

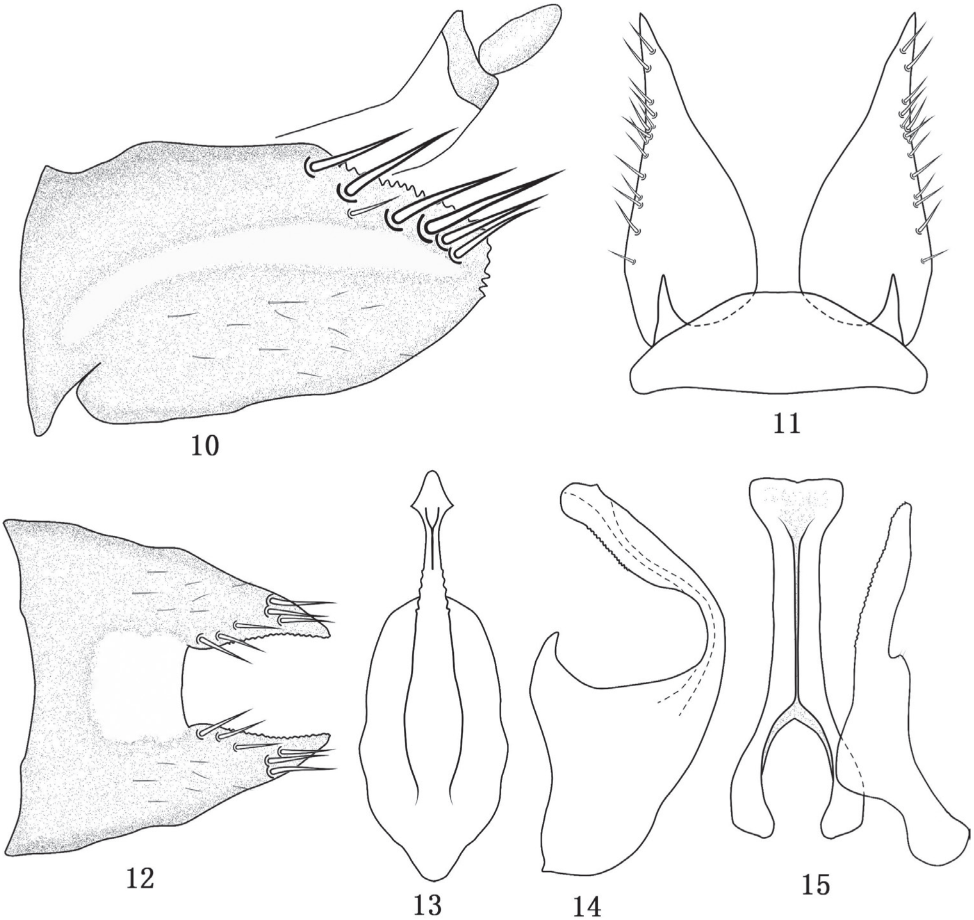
Figs 1–3, 10–15

Body length. (including tegmina), ♂, 5.7 mm.

Description. *Body colour*. Yellow-brown with dark brown markings and eyes fuscous. Vertex and pronotum with several light yellow blotches.

Morphology. Head (Fig. 1) including eyes nearly as wide as pronotum; vertex produced anteriorly with midlength 1.5 times length next to eyes. Fore tibia with dorsal setal formula 1+4.

Male genitalia. Pygofer (Figs 10, 12) with elongate lateral hyaline band and quadrate hyaline area on dorsal bridge; lobe with several long macrosetae dorsally and dor-



Figures 10–15. *Tambocerus dentatus* Qu & Dai, sp. n. **10** Pygofer in lateral view **11** Valve and subgenital plate in ventral view **12** Pygofer in dorsal view **13** Aedeagus in caudal view **14** Aedeagus in lateral view **15** Connective and style in dorsal view.

sal margin and apex serrated; valve (Fig. 11) semicircular; subgenital plate (Fig. 11) evenly tapered from base to acute apex with several short stout setae laterally; style (Fig. 15) relatively slender, with short and narrow lateral lobe, apophysis long, half length of style, serrate over inner margin; connective (Fig. 15) with stem twice length of arms; aedeagal shaft (Figs 13–14) abruptly constricted and curved dorsally near base in lateral view, distally laterally compressed with a medial subapical keel on the ventral surface, lateral margins serrate, with a short subapical processes on each side of ventral surface; phallobase well developed; dorsal apodeme short without lateral arms.

Female. Unknown.

Material examined. Holotype, ♂, CHINA: Guizhou Province, Libo County, Wuyanqiao, 20. VII. 2011, collected by Zheng Weibin.

Distribution. China (Guizhou Province).

Remarks. This species externally resembles *Tambocerus elongatus* Shang and Zhang but can be separated from the latter by the male pygofer (Figs 10, 12) without process; the subgenital plate (Fig. 11) tapering from base to end; the aedeagal shaft (Figs 13–14) without depression at subapex in lateral view.

Etymology. This species name is derived from the Latin word "*dentatus*", referring to the dentate dorsal margin of the pygofer lobe.

Tambocerus longicaudatus Qu & Dai, sp. n.

http://zoobank.org/0BF009FF-5B6F-4BD1-B621-725C088A06D5

Figs 4–6, 16–22

Body length. (including tegmina), ♂, 6.3–6.5 mm.

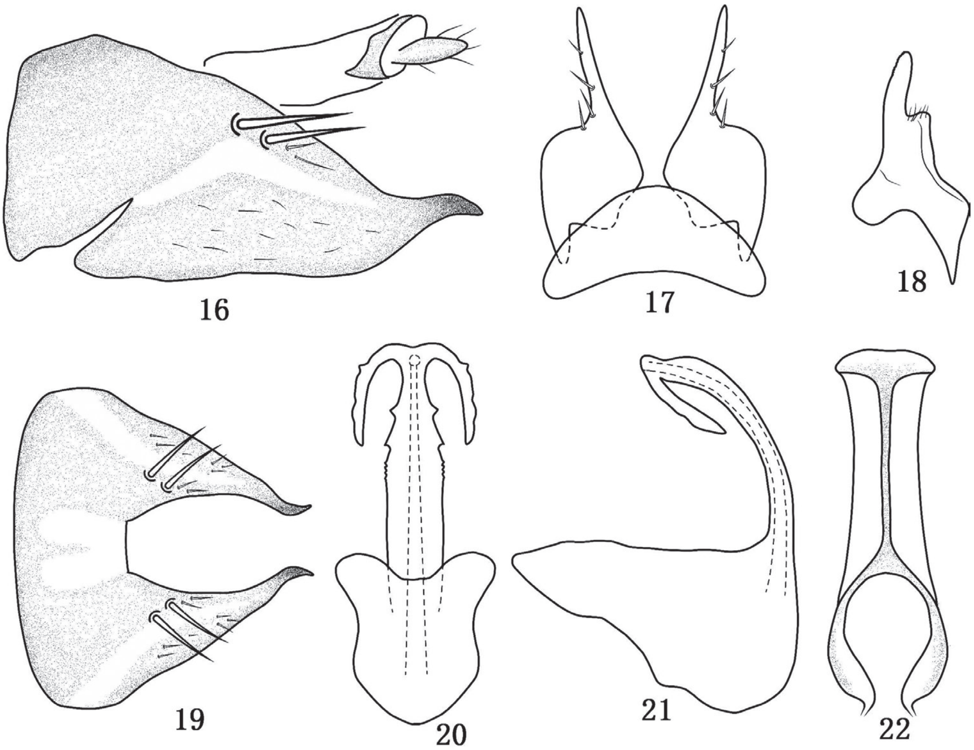
Description. *Body colour*. Body yellow-brown with dark brown patches and eyes fuscous or black.

Morphology. Head (Fig. 4) including eyes slightly narrower than pronotum; vertex with midlength 1.5 times length next to eyes. Fore tibia with dorsal setal formula 1+6.

Male genitalia. Pygofer (Figs 16, 19) with elongate lateral hyaline band and pair of lobe-like hyaline areas on dorsal bridge (Fig. 19), lobe with few long macrosetae dorsally at base, lobe well produced process-like with apex digitate and curved ventrally; valve (Fig. 17) triangular; subgenital plate (Fig. 17) abruptly narrowing at midlength, apical half slender with few short setae; style (Fig. 18) with short and broad subapical lobe, apophysis moderately long, digitate with inner margin dentate subapically; connective (Fig. 22) Y-shaped with stem one and a half times length of arms; aedeagal shaft (Figs 20–21) compressed dorsoventrally, dentate laterally over distal half to near apex, with pair of apical dorsolateral serrated processes approximately half length of shaft; phallobase well developed; dorsal apodeme with short robust arms.

Female. Unknown.

Material examined. Holotype, ♂, CHINA: Guizhou Province, Suiyang County, Kuankuoshui National Natural Reserve, 5. VI. 2010, collected by Xing Jichun;



Figures 16–22. *Tambocerus longicaudatus* Qu & Dai, sp. n. **16** Pygofer in lateral view **17** Valve and subgenital plate in ventral view **18** Style in dorsal view **19** Pygofer in dorsal view **20** Aedeagus in front view **21** Aedeagus in lateral view **22** Connective in dorsal view.

Paratype, 1 ♂, CHINA: Guizhou Province, Suiyang County, Kuankuoshui National Natural Reserve, 8. VI. 2010, collected by Dai Renhuai and Li Hu.

Distribution. China (Guizhou Province).

Remarks. This species can be recognized by the extended and ventrally curved pygofer lobe (Figs 16, 19), sharply constricted subgenital plates (Fig. 17) at midlength and aedeagus (Figs 20–21) with pair of moderately long processes on apex.

Etymology. The new species name is derived from the Latin words "*longus*" (long) and "*caudatus*" (tail), indicating the long pygofer extension.

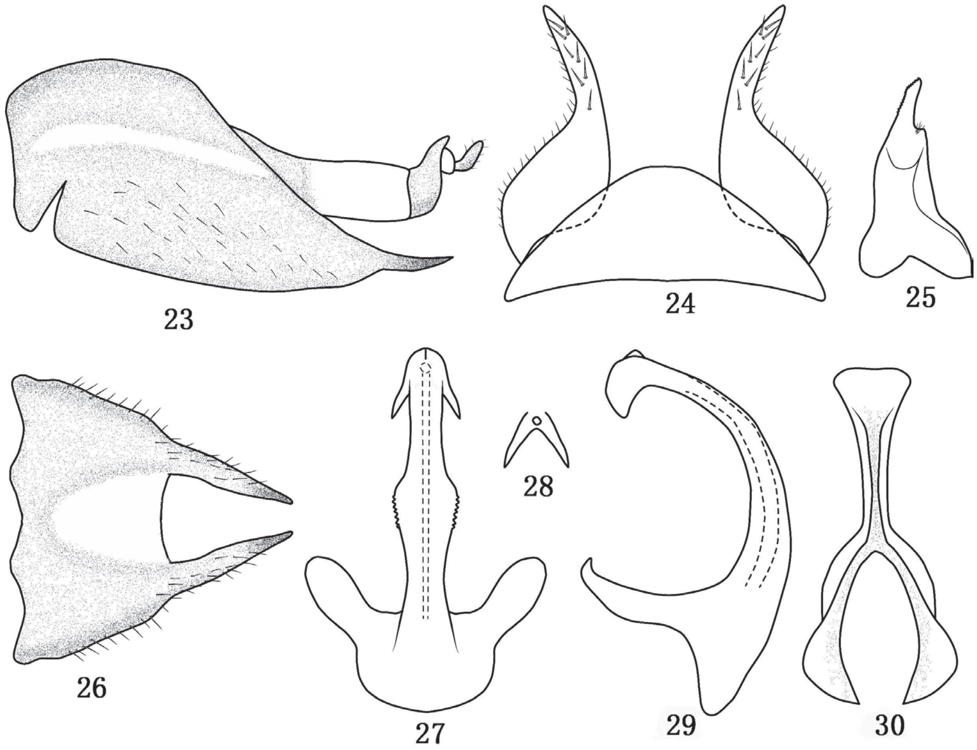
Tambocerus robustispinus Qu & Dai, sp. n.

http://zoobank.org/4A27CF3B-F210-4BFC-A96A-FF2EC926A6E2

Figs 7–9, 23–30

Body length. (including tegmina), ♂, 6.1–7.0 mm.

Description. *Body colour*. Yellow with dark brown spots and eyes fuscous or black. Pronotum with several light yellow irregular blotches in dorsal view.



Figures 23–30. *Tambocerus robustispinus* Qu & Dai, sp. n. **23** Pygofer in lateral view **24** Valve and subgenital plate in ventral view **25** Style in dorsal view **26** Pygofer in dorsal view **27** Aedeagus in caudal view **28** Apex of aedeagus **29** Aedeagus in lateral view **30** Connective in dorsal view.

Morphology. Head (Fig. 7) including eyes slightly wider than or nearly equal to pronotum; vertex slightly produced anteriorly with midlength 1.2 times length next to eyes. Fore tibia with dorsal setal formula 1+5 or 1+6.

Male genitalia. Male pygofer (Figs 23, 26) with elongate lateral hyaline band and semi crescent-shaped hyaline area on dorsal bridge, lobe (Figs 23, 26) with fine dorsal setae, lobe produced and tapered to acute apex with fine dorsal setae; valve (Fig. 24) triangular; subgenital plate (Fig. 24) gradually tapered to midlength thereafter with finger-like apex, with several short setae; style (Fig. 25) with short and narrow lateral lobe and moderately long apophysis dentate apically; connective (Fig. 30) with arms and stem similar in length; aedeagal shaft (Figs 27–29) cylindrical with serrated flange at midlength on each side, with bifurcate apically, short apical keel medially on ventral surface; phallobase narrow in lateral view; basal apodeme with moderately long widely spaced digitate arms.

Female. Unknown.

Material examined. Holotype, ♂, CHINA: Guangxi Province, Wuming County, Damingshan National Natural Reserve, 15. V. 2012, collected by Li Hu; Paratypes, 6 ♂♂, same data as holotype; 7 ♂♂, CHINA: Guangxi Province, Wuming County, Damingshan National Natural Reserve, 19. V. 2012, collected by Fan Zhihua (one specimen deposited in BMNH); 2 ♂♂, CHINA: Guangxi Province, Longsheng County, Huaping National Natural Reserve, 19. V. 2012, collected by Yang Nannan and Fan Zhihua; 1 ♂, CHINA: Yunnan Province, Yuanyang County, Shangjiupai, 2. VIII. 2013, collected by Liu Yangyang.

Distribution. China (Guangxi and Yunnan Provinces).

Remarks. This species is similar to *Tambocerus furcellus* Shang and Zhang but can be distinguished by the male pygofer (Figs 23, 26) with acuminated and smooth process; the aedaeagus (Figs 27–29) with short spine ventrally.

Etymology. This species is named for the stout apical processes of the aedeagal shaft.

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Keys to the blow flies of Taiwan, with a checklist of recorded species and the description of a new species of *Paradichosia* Senior-White (Diptera, Calliphoridae)

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Abstract

Blow flies (Diptera: Calliphoridae) show a great diversity in behavior and ecology, play important roles in ecosystems, and have medical and forensic importance to humans. Despite this, the taxonomy and classification of Taiwan's Calliphoridae have rarely been studied. In this study, specimens of Taiwanese calliphorids were collected and carefully studied, and all 76 species recorded in Taiwan are listed following the identification keys. Dichotomous keys to all subfamilies, tribes, genera, and species of blow flies recorded in Taiwan are provided, including 16 species that are newly recorded from Taiwan. In addition, one new species of the genus *Paradichosia* Senior-White is described and illustrated. We also discuss the morphological differences between the specimens of *Silbomyia hoeneana* Enderlein collected from China and Taiwan, a species that has only been found previously in Southern China.

Keywords

Calliphoridae, diagnostic key, new species, taxonomy

Introduction

Calliphorids show great diversity in behavior and ecology. Some species parasitize terrestrial vertebrates and invertebrates such as insects, snails, amphibians, mammals, and others rely on animal carcasses or excrement for survival (Kano and Shinonaga 1968). Some calliphorid species are regarded as serious pests because they carry pathogens or parasitize livestock or humans, causing myiasis (Tumrasvin et al. 1979; Sawabe et al. 2006). Other species called carrion flies are considered important scavengers due to their necrophagous feeding behaviors (Singh et al. 1979). Some species also provide an alternative way to estimate the minimum post-mortem interval of a victim or an animal in forensic investigations (Catts and Goff 1992). Adult blow flies often visit flowers, and some species like *Chrysomya megacephala* (Fabricius) are pollinators of fruits (Dag and Gazit 2001). The Calliphoridae are thus important in many different fields. In this article, keys to the subfamilies, tribes, genera, and species recorded from Taiwan are provided, hopefully to help in the understanding and identification of these useful flies in studies of medical entomology, forensic entomology, agricultural pollination, and other related fields.

Only fragmentary studies have been done on the taxonomy of Taiwanese Calliphoridae. Hennig (1941) listed 46 species of Calliphoridae from Taiwan. James (1977) mentioned 34 Taiwanese species in “A Catalog of Diptera of the Oriental Region.” Kurahashi (1987a) published a key to the species of Taiwan’s Calliphorini and Luciliini tribes. Fan (1992) published a key to the common calyptrate flies of China, including 40 Taiwanese species. Recently, a new *Lucilia* species, *L. taiwanensis*, was described by Kurahashi and Kano (1995).

Materials and methods

Adult specimens of Taiwanese calliphorids examined in this study were collected and pinned by the authors and colleagues, and additional specimens were collected by K. Kanmiya, R. Kano, K. Matsuki, and S. Ueno. Systematics and nomenclature adopted in this paper mainly follows Rognes (1991, 1997, 2002, 2009a, 2009b, 2011a), Fan (1992), and Kurahashi and Bunchu (2011). Specimens collected by the first author were mostly deposited in the Insect Museum of National Taiwan University (NTU). Other specimens were deposited in the National Museum of Nature and Science, Tsukuba (NSMT), Bishop Museum, Honolulu (BPBM), Carnegie Museum of Natural History, Pittsburgh (CMNH), and International Department of Dipterology, Tokyo (IDD). Some specimens are personal collection of Mr. K. Harusawa (PCKHa) as noted in the text. The terminology used in this study mainly follows that of Senior-White et al. (1940), Fan (1992), Triplehorn and Johnson (2005). Frons measurement and the calculation of the frons index follows Fan (1992).

Results and discussion

Examined specimens are classified into nine subfamilies: Ameniinae, Bengaliinae, Calliphorinae, Chrysomyinae, Luciliinae, Melanomyinae, Rhiniinae, Phumosiinae, and Polleniinae. In total, 76 calliphorid species are listed herein based on our direct examinations and the literature. Among them, 16 species are newly recorded from Taiwan, with an asterisk (*) preceding each of them in the checklist. The names in this checklist include mainly the species examined in this research and partially also the species recorded in the literature. Some species that have not yet been recorded in Taiwan are also included in this key with a footnote [e.g., 'not recorded from Taiwan']. We believe these latter species have the potential to be found in future Taiwan surveys because they occur in nearby areas of the Orient.

Widespread Oriental elements share the highest proportion (53.9%, 41/76) of Taiwan's calliphorid fauna, while endemic species have the second-highest (15.8%, 12/76). Australasian and Oriental-Australasian elements share 14.5% (11/76), cosmopolitan elements 6.6% (5/76), pantropical elements 2.6% (2/76), Holarctic species 1.3% (1/76), and Palaearctic species 5.3% (4/76).

Practical keys

Key to the subfamilies of Taiwanese Calliphoridae

1 Posterodorsal side of R stem vein of wing setose **2**

– Posterodorsal side of R stem vein of wing not setose **3**

2 Upper occiput with setulae and pollinose, without glossy submarginal band; lower facial margin not protruding much; prealar knob with erect hairs (except for tribe Phormiini); thoracic squama hairy on dorsal surface, largely lobulate, subtruncate at apex, concave on outer margin ... **Subfamily CHRYSOMYINAE**

– Upper occiput often without setulae, with bare glossy submarginal band; lower facial margin often protruding in front of vibrissal corners obviously; prealar knob bare or pubescent, without distinct hairs; thoracic squama (lower calypter) bare or pubescent on dorsal surface, usually tongue-like, narrowly rounded at apex, straight on outer margin, rarely lobulate in some species of *Isomyia* .... **Subfamily RHINIINAE**

3 Anterior lappet of metathoracic spiracle with conspicuous backward-pointing tuft of long hairs; postscutellum forming definite convex swelling which is micro-rugose and sometimes shows a slight trace of a shallow median incision; female postabdomen non-telescopic, modified for deposition of grown larvae; large tachinid-like flies .... **Subfamily AMENIINAE**

– Anterior lappet of metathoracic spiracle bare or at most with very few inconspicuous hairs; postscutellum not at all convex or at most with a rudimentary trace of swelling, not as above; female postabdomen forming telescopic ovipositor, but sometimes short in larviparous species for deposition of first instar larvae **4**

4 Propleuron hairy **5**

– Propleuron bare **8**

5 Posterior part of suprasquamal ridge with tuft of setulose erect hairs (posterior parasquamal tuft) on small well-defined black sclerite .... **Subfamily LUCILIINAE**

– Posterior parasquamal tuft absent **6**

6 Supraspiracular convexity clothed with long, upstanding fine hairs; anterior part of suprasquamal ridge bare; distance between right and left presutural acrostichal bristles (*ac*) rather large, almost equal to distance between presutural *ac* and dorsocentral bristles (*dc*); mesothoracic spiracle rather large, sometimes swollen; thoracic squama bare .... **Subfamily PHUMOSIINAE, *Caiusa* Surcouf**

– Supraspiracular convexity bare or pubescent 7

7 Hairs on thoracic squama widely distributed .... **Subfamily CALLIPHORINAE**

– Thoracic squama bare, or only few hairs fragmentarily distributed .... **Subfamily MELANOMYINAE**

8 Prosternum usually hairy; thorax not clothed in golden curly hairs; eyes dichoptic, eyes widely separated in both male and female; proboscis short and stout, boat-shaped; body at least partly yellowish .... **Subfamily BENGALIINAE, *Bengalia* Robineau-Desvoidy**

– Prosternum bare; thorax usually with golden curly hairs, sometimes lacking; head usually holoptic or subholoptic in males, sometimes dichoptic .... **Subfamily POLLENIINAE**

Subfamily AMENIINAE

Key to the tribes and genera of AMENIINAE

1 Head almost always with a very large facial carina; propleuron and prosternum almost always hairy; hind tibia with apical posteroventral bristle (*pv*); outer posthumeral bristle (*ph*) situated mesad of presutural bristle (*prs*); ventral surface of costa setulose between apices of subcostal (Sc) and first longitudinal (R_1) veins .... **Tribe Ameniini, *Silbomyia* Macquart**

– Head without facial carina; propleuron bare; prosternum bare, sometimes hairy; hind tibia without apical *pv*; outer *ph* situated laterad of *prs*; ventral surface of costa bare between apices of veins Sc and R_1 .... **Tribe Catapicephalini, *Catapicephala* Macquart**

Tribe Ameniini

Key to the species of *Silbomyia*

1 Facial carina longer and distinctly fusiform, slightly longer than distance from lunule to anterior ocellus; male antennae longer than in female, third segment of antenna (AS_3; first flagellomere) in male at least 4 times as long as AS_2 (pedicel); postorbits yellow or silvery yellow..... ***S. cyanea* (Matsumura)**

– Facial carina short, and roof-like, shorter than distance from lunule to anterior ocellus; antennae about equal in length in both sexes, AS_3 not more than 3.9 times as long as AS_2; postorbits silvery white.. **2**

2 One or both of third tergite (T_3) and T_4 almost always with one pair or more of strong median discal setae; color usually dark blue to violet, sometimes green; male frontal stripe (interfrontal area) no more than 3 times as wide as one parafrontal; distance between eyes at lower margin subequal or slightly broader than that at vertex in frontal view in male; lobe of fifth sternite (ST_5) shorter than basal part .... ***S. sauteri* Enderlein**

– Third tergite and T_4 without or only T_3 with one pair of very weak discal setae; color green to blue; male interfrontal area about 3.5 times as wide as one parafrontal; distance between eyes at lower margin slightly narrower than that at vertex in frontal view in male; lobe of ST_5 longer than basal part ... ***S. hoeneana* Enderlein**

Tribe Catapicephalini

Key to the species of *Catapicephala*

1 Eyes hairy .... ***C. dasyophthalma* Villeneuve**

– Eyes bare.. **2**

2 Antenna orange; tomentum on face golden .... ***C. ruficornis* Villeneuve**

– Antenna entirely fuscous; tomentum on face grey; T_4, T_5 brilliant metallic blue; silver white pollinosity on lateral and ventral sides of T_5 extending to dorsal side, visible in dorsal view; fronto-orbital bristles (*ors*) 0+1 in male, 2+1 in female.. ***C. splendens* Macquart**

Subfamily CALLIPHORINAE

Key to the genera of CALLIPHORINAE

1 Presutural *ac* usually 1, rarely absent; facial carina more or less developed..... .... ***Polleniopsis* Townsend**

– Presutural *ac* 2; facial carina absent **2**

2 Head dichoptic in both male and female; AS_3 elongate, more than 4 times as long as AS_2; presutural intra-alar bristles (*ia*) absent ..... *Tainanina* Villeneuve

– Head holoptic or subholoptic in male, dichoptic in female; AS_3 variable in length; presutural *ia* present or absent **3**

3 Presutural *ia* absent; eyes in male subholoptic; male hypopygium prominently swollen, metallic ..... ***Aldrichina* Townsend, *A. grahami* (Aldrich)**

– Presutural *ia* present; eyes in male holoptic; male hypopygium not remarkably developed **4**

4 Body small- to medium-sized; distance between rows of right and left presutural *ac* rather small (*fig. 1b* in Kurahashi 1970); male paraphallus with wide, sickle-like tip ..... ***Bellardia* Robineau-Desvoidy** (Kurahashi (1987b) treat it in genus *Onesia*)

– Body large-sized; distance between rows of right and left presutural *ac* rather large (*fig. 1a* in Kurahashi 1970); male paraphallus with slender tip ..... ***Calliphora* Robineau-Desvoidy**

Key to the species of *Calliphora*

1 Postgena clothed with orange or pale yellow hairs, or intermixed with black ones; mesothoracic spiracle fuscous black ..... ***C. vomitoria* (Linnaeus)**

– Postgena clothed wholly with black hairs **2**

2 Mesothoracic spiracle yellowish brown to orange ..... ***C. nigribarbis* Vollenhoven**

– Mesothoracic spiracle black or blackish brown ..... ***C. pattoni* Aubertin**

Key to the species of *Bellardia*

1 Body length less than 6 mm; R_5 cell closed at wing margin; vein M_{1+2} gently curved, with dull angle ..... ***B. menechma* (Séguy)**

– Body length longer than 8 mm; R_5 cell open at wing margin; vein M_{1+2} bent with a right angle ..... ***B. pubescens* (Macquart)**

Key to the species of *Tainanina*

1 Fronto-orbital bristles 0 in male, 2+1 in female ..... ***T. sarcophagoides* (Malloch)**

– Fronto-orbital bristles 1+1 in both sexes ..... ***T. pilisquama* (Senior-White)**

Key to the species of *Polleniopsis*

1 Presutural *ia* present, abdomen black, densely covered with yellowish gray or golden dusting, strongly tessellated; facial carina well developed; outer *ph* present .... ***P. toxopei* (Senior-White)**

– Presutural *ia* absent, abdomen black, with bluish or bronzy tinge, silver-gray dusted; facial carina poorly developed; outer *ph* absent .... ***P. dalatensis* Kurahashi**

Subfamily MELANOMYINAE

Key to the genera of MELANOMYINAE

1 Eye bare; *ia* 0 (male) or 1 (female) +2; outer *ph* present; *ac* 2+3; *dc* 3+3; sternopleural bristle (*st*) 1+1; body yellowish brown, thorax with gray dusting; pronotum with 5 black vertical stripes; meso- and metathoracic spiracle yellowish white; leg yellowish, with blackish tarsus; 6.5–7.5 mm .... ***Tricycleopsis* Villeneuve, *T. paradoxa* Villeneuve**

– Eye hairy, or with sparse short hairs, or bare; *st* usually 2+1; other characters not as above **2**

2 Eye with distinct, dense hairs; body almost all black .... ***Paradichosia* Senior-White**

– Eye with sparse short hairs or bare **3**

3 At least part of body yellow; scutellum with at least apex yellowish; T_{1+2} and T_3 testaceous yellow; legs testaceous except for fuscous tarsi......................... .... ***Gymnadichosia* Villeneuve, *G. pusilla* Villeneuve**

– Body blackish; scutellum entirely black; abdomen and legs black except for brownish tibia.................................***Pollenomyia* Séguy, *P. sinensis* Séguy**

Key to the species of *Paradichosia*

1 Scutellum entirely black... **2**

– Scutellum with at least apex yellowish... **3**

2 Hind tibia with submedian anterodorsal bristle (*ad*) more than 3 times as long as tibial diameter; hind tarsus with dorsal hairs longer than usual, forming a short fringe; third sternite (ST_3) of male with tuft of long hairs........... ....***P. dubia* Malloch [not recorded from Taiwan]**

– Submedian *ad* of hind tibia no more than 3 times as long as tibial diameter; dorsal hairs of hind tarsus not longer than usual; male ST_3 with tuft of very short hairs.. ***P. lui* sp. n.**

3 Fore coxa yellow in front; femora entirely fulvous yellow; none of the hind tibial bristles exceptionally long or slender in both sexes .... ***P. crinitarsis*** **Villeneuve**

– Fore coxa fuscous in front; femora fulvous yellow or dark brown; 1 or 2 of the hind tibial bristles in male 2–3 times as long as tibial diameter .... ***P. nigricans*** **Villeneuve**

Subfamily LUCILIINAE

Key to the genera of LUCILIINAE

1 Supraspiracular convexity bare or pubescent .... ***Lucilia*** **Robineau-Desvoidy**

– Supraspiracular convexity clothed with long, erect, fine hairs... ***Hemipyrellia*** **Townsend,** ***H. ligurriens*** **(Wiedemann)**

Key to the species of *Lucilia*

1 Postsutural *ac* 3–4 .... **2**

– Postsutural *ac* 2 .... **5**

2 Basicosta yellow **3**

– Basicosta fuscous to black **4**

3 Abdomen usually metallic green, more or less oval, not arched in profile, without tuft of long hairs on sternites in male; female having metallic green to gold tinged abdomen with sparse pruinosity; 5–8 occipital hairs (*occ*) in female .... ***L. sericata*** **(Meigen)**

– Abdomen coppery, elongate, arched in profile, with tufts of long hairs on sternites in male; hypopygium prominent; female having coppery abdomen with dense pruinosity; 1 *occ* in female .... ***L. cuprina*** **(Wiedemann)**

4 Body metallic purple or blue .... ***L. taiwanica*** **Kurahashi & Kano**

– Body metallic green .... ***L. hainanensis*** **Fan**

5 Anterior pair of postsutural *ac* usually more advanced than second pair of postsutural *dc*; T_3–T_5 without dark marginal band posteriorly; mid tibia with 1 *ad* in both sexes .... ***L. porphyrina*** **(Walker)**

– Anterior pair of postsutural *ac* level with or slightly posterior to second pair of postsutural *dc*; T_3–T_5 with dark marginal band posteriorly; mid tibia with 1 *ad* in male, 2 *ad* in female **6**

6 First postsutural *ac* more posterior, on posterior 2/5 part of postsutural area; distance between first postsutural *dc* and second postsutural *dc* twice as long as distance between second postsutural *dc* and third postsutural *dc*; large size flies, body length usually more than 10.0 mm .... ***L. sinensis*** **Aubertin**

– First postsutural *ac* normal, on anterior 3/5 part of postsutural area; distance between first postsutural *dc* and second postsutural *dc* as long as distance between second postsutural *dc* and third postsutural *dc* **7**

7 Alar squama (upper calypter) creamy, with tuft of yellowish white hairs at inner lower margin; thoracic squama pale, brownish on disc............***L. bazini* Séguy**

– Alar squama fuscous brown, sometimes more or less paler at inner 1/2, but usually with tuft of blackish-brown, sometimes brown, hairs at inner lower margin.. **8**

8 Posterior surface of postgena clothed with yellow hairs; parafacilia narrow, invisible in profile, about 1/2–2/3 of the width of AS$_3$, golden yellow dusted, often darkened above..***L. calviceps* Bezzi**

– Posterior surface of postgena clothed with black hairs; parafacilia rather broad, at least as broad as the width of AS$_3$, gray dusted, rarely with yellow tinge ....***L. papuensis* Macquart**

Subfamily BENGALIINAE

Key to the species of *Bengalia*

1 Prealar knob pointed; fourth sternite (ST$_4$) with 1 pair of long and strong median marginal bristles (*mb*) in male; abdomen very slightly pollinose; body small- to medium-sized; mesonotum blackish on disc....***B. calilungae* Rueda**

– Prealar knob rounded; ST$_4$ without strong *mb* in male; abdomen slightly to heavily tessellated; body medium- to large-sized.. **2**

2 Fifth tergite without discal bristles; hind tibia never fringed in male **3**

– Fifth tergite with 1 pair of discal bristles; hind tibia more or less fringed in male, sometimes not very dense, covered with row of 3–7 fine long anteroventral bristles (*av*) on apical 1/2 .... **6**

3 Vibrissa far above oral margin, distance between vibrissa and oral margin larger than wide of AS$_3$; clypeus strongly projecting forward; posterior margin of eye somewhat concave at middle; fore tibia in male with 5+2 ventral spines; hairs on pteropleuron wholly yellowish (Fig. 1) ....***B. torosa* (Wiedemann)**

– Vibrissa level with oral margin; clypeus less strongly projecting; posterior margin of eye straight, not concave at middle; fore tibia in male with 3 ventral spines; hairs on pteropleuron wholly whitish yellow or with some black hairs present at least on upper part... **4**

4 Epaulet (tegula) blackish, with hind margin yellowish; pteropleuron hairs totally whitish yellow (Fig. 2) .... ***B. chekiangensis* Fan**

– Epaulet yellowish; pteropleuron hairs not totally yellowish......................... **5**

5 Fifth tergite black, tessallated; mesopleuron bicolored, yellow on upper 1/3, yellow upper part distinct from lower 2/3 blackish; pteropleuron largely

Figure 1. Pteropleuron (pt) of *Bengalia torosa* (Wiedemann), hairs on pteropleuron are wholly yellowish.

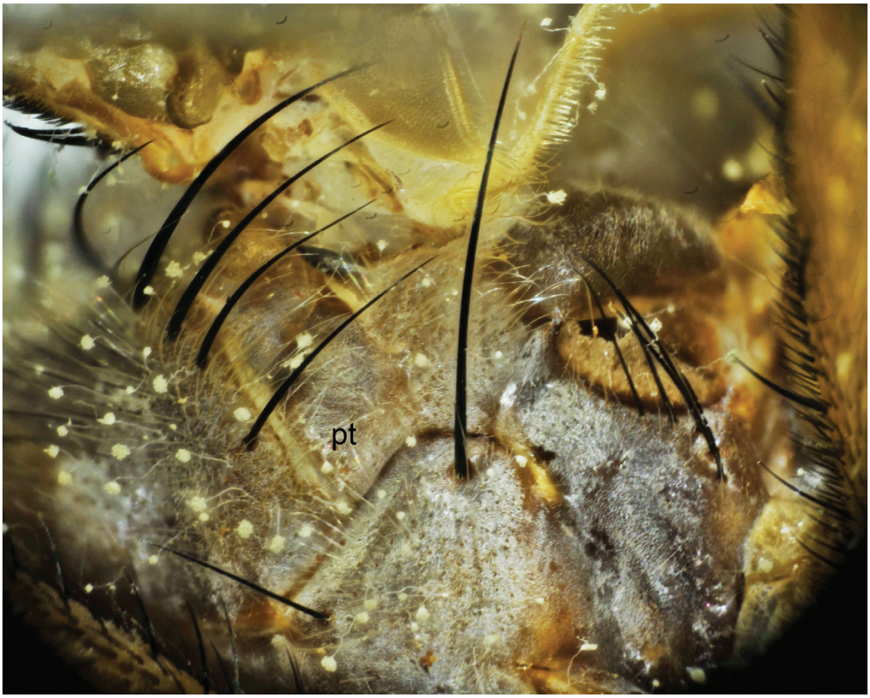

Figure 2. Pteropleuron (pt) of *Bengalia chekiangensis* Fan, hairs on pteropleuron are totally whitish yellow.

covered with black hairs (Fig. 3); stenopleuron also mostly blackish haired; femora largely fuscous.. ***B. escheri* Bezzi**

– Fifth tergite yellowish brown with black marginal band; mesopleuron yellowish, but more or less brownish on lower part; pteropleuron largely covered with yellow hairs except for tuft of several blackish hairs (Fig. 4); sternoplerual hairs yellow except for a tuft of black ones; femora yellow.................. .... ***B. fuscipennis* Bezzi**

6 Pteropleuron mostly clothed in yellow hairs, less than 15 black hairs present on upper part (Fig. 5); *dc* 2+4; mid tibia not typically fringed in male; fore tibia with 2–3 long and 2–5 short stout spines on anteroventral surface in male; body 8–11 mm.. ***B. varicolor* (Fabricius)**

– Pteropleuron mostly or largely clothed in black hairs, at least 20 hairs on upper part black (Fig. 6); *dc* 1–3+4; mid tibia with or without fringe in male; fore tibia without spines, at most with several small spines on anteroventral surface; body 11–15 mm 7

7 Projection of male ST_5 rounded with small indentation; mid tibia double-fringed on apical 2/3 of posteroventral surface in male; T_5 in female without indentation in median part of posterior margin; *dc* 3+4................... ***B. emarginata* Malloch**

– Fifth sternite in male with two–branched projection; mid tibia not typically fringed in male; T_5 in female with small indentation in median part of posterior margin; *dc* 1–2+4 .... ***B. taksina* (Lehrer)**

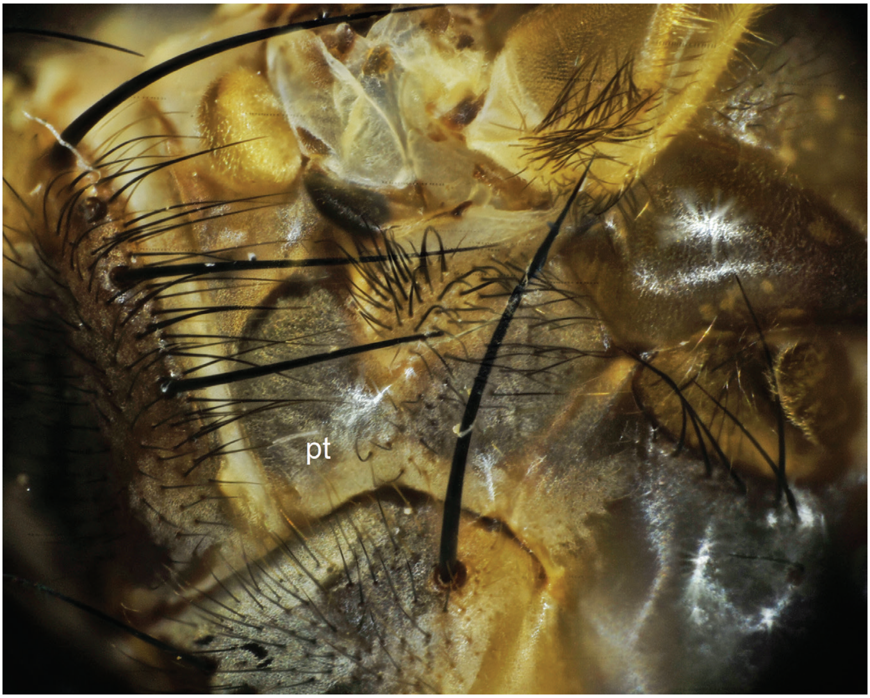

Figure 3. Pteropleuron (pt) of *Bengalia escheri* Bezzi, hairs on pteropleuron are largely blackish.

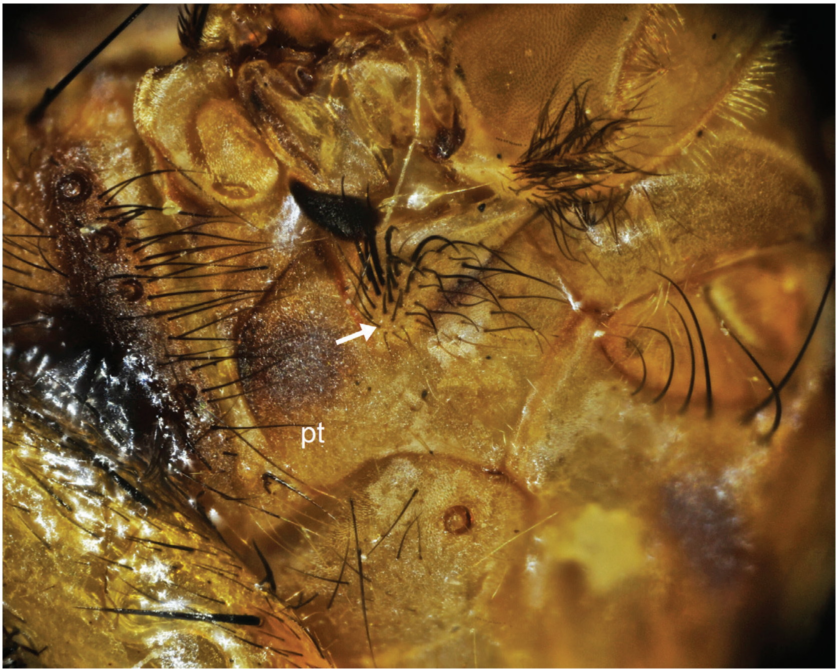

Figure 4. Pteropleuron (pt) of *Bengalia fuscipennis* Bezzi, which is largely covered with yellow hairs except for a tuft of blackish hairs. Arrow shows the blackish hair tuft.

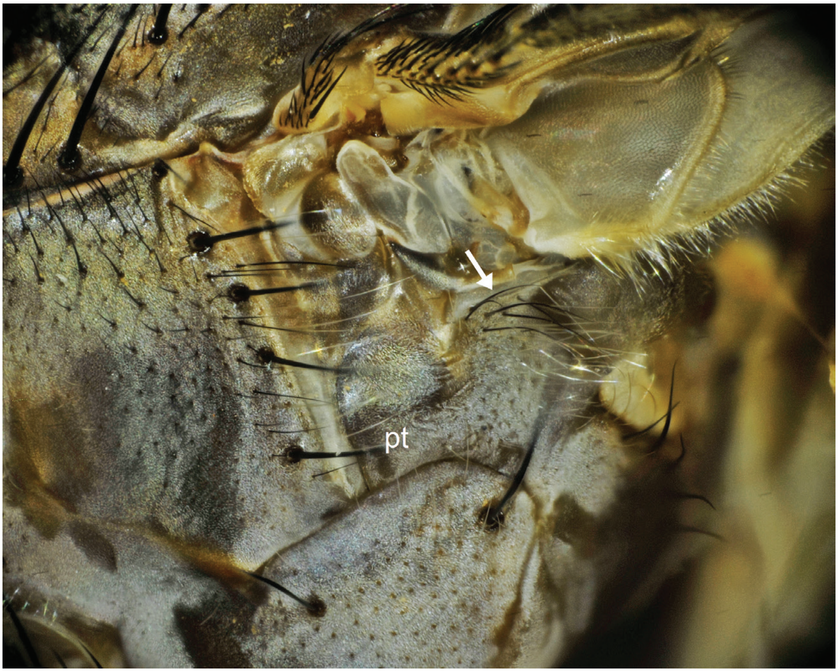

Figure 5. Pteropleuron (pt) of *Bengalia varicolor* (Fabricius), which is mostly clothed in yellow hairs, with a few black hairs present on upper part. Arrow shows the blackish hairs.

Figure 6. Pteropleuron (pt) of *Bengalia emarginata* Malloch, which is mostly clothed in black hairs.

Subfamily PHUMOSIINAE

Key to the species of *Caiusa*†

1 Mesonotum with fuscous median stripe or spots; male cercus much shorter than surstylus.. ***C.* sp. ‡**

– Mesonotum largely fuscous black; male cercus as long as surstylus............... .... ***C. indica* Surcouf**

† Species *C. testacea* Senior-White is excluded from this key, since the morphological characters that used to recognize *C. testacea* (e.g., mesonotum all pale testaceous yellow) is not autapomorphies of this species (Rognes, personal communication), and we did not have Taiwanese *C. testacea* specimens to examine for building a new couplet.

‡ The taxonomic status of this species is not clear at present. Its external morphology is similar to that of *C. coomani* Séguy (Rognes 2011b), while the hypopygium and genitalia are quite different. It might be an undescribed species or only a variation in *C. testacea* Senior-White (Rognes, personal communication).

Subfamily POLLENIINAE

Key to the genera of POLLENIINAE

1 Parafacial hairy; body mainly black .... ***Pollenia* Robineau-Desvoidy [not recorded from Taiwan]**

– Parafacial bare; body entirely or largely testaceous yellow, rarely entirely black .... ***Dexopollenia* Townsend**

Key to the species of *Dexopollenia*

1 Presutural *ac* absent ....***D. luteola* Villeneuve**

– Presutural *ac* present **2**

2 Thorax yellow to dark brown; abdomen entirely yellow, sometimes with black spots on T_4 and T_5; leg almost entirely yellow except for fuscous tarsus; AS_3 largely yellow ....***D. flava* (Aldrich)**

– Thorax entirely black; abdomen with blackish median stripe; male femora and tibia entirely fuscous black, and entirely orange in female; AS_3 entirely brown .... ***D. maculata* Villeneuve**

Subfamily CHRYSOMYINAE

Key to the tribes of CHRYSOMYINAE

1 Prealar knob with erect hairs..**Tribe Chrysomyini**

– Prealar knob without erect hairs ... **Tribe Phormiini, *Protocalliphora* Hough**

Key to the genera of Chrysomyini

1 Sternopleural bristle (*st*) 0+1; head dichoptic in both sexes .... ***Ceylonomyia* Fan, *C. nigripes* (Aubertin)**

– Sternopleural bristles 1+1; head holoptic to dichoptic in male, dichoptic in female **2**

2 Outer vertical bristle (*ov*) developed in both sexes; no proclinate *ors* developed in female (*ors* 0+1); T_5 in female with cleft on median part of posterior margin [larvae facultative predacious species, body with fleshy tubercles]...... .... ***Achoetandrus* Bezzi**

– Outer vertical bristle absent in male, developed in female; 2 proclinate *ors* (*ors* 2+1) developed in female; T_5 in female without median cleft, truncate posteriorly... ***Chrysomya* Robineau-Desvoidy**

Key to the species of *Achoetandrus*

1 Mesothoracic spiracle white or yellow; femora normal in both sexes; head holoptic in male, dichoptic in female; facial ridge not remarkably high; T5 with some pale hairs laterally among black ones..... ***A. rufifacies* (Macquart)**

– Mesothoracic spiracle fuscous black to dark brown; femora swollen in both sexes, more noticeably so in male; head dichoptic in both sexes; facial ridge well developed, high .... ***A. villeneuvi* (Patton)**

Key to the species of *Chrysomya*

1 Gena and postgenal area entirely orange-yellow, clothed with pale yellow hairs, except immediately around vibrissa **2**

– Gena and postgenal area entirely fuscous or somewhat rufous anteriorly, entirely clothed in black hairs or with some pale hairs posteriorly...... ***C. pinguis* (Walker)**

2 Alar and thoracic squama entirely white except for yellowing of fringe; mesothoracic spiracle small, not longer than length of AS_3; upper eye facets not conspicuously larger than lower in male; parafrontal not obliterated in male; eyes separated by slightly less than width of AS_3 in male [myiasis-producing species rarely found except by rearing from hosts].... ***C. bezziana* Villeneuve**

– At least thoracic squama distinctly infuscated posteriorly; mesothoracic spiracle large, much longer and broader than AS_3 in profile; male with upper eye facets conspicuously enlarged and with sharp transition to small facets in lower 1/3; parafrontal almost obliterated and eyes virtually touching above in male [common synanthropic species]............... ***C. megacephala* (Fabricius)**

Subfamily RHINIINAE

Key to the tribes and genera of RHINIINAE

1 Arista pectinate; *ac* and *dc* not distinguishable from general vestiture, prescutellar bristles at most weakly developed; suprasquamal ridge bare .... **Tribe Rhiniini, 2**

– Arista pubescent or plumose, not pectinate .... **Tribe Cosminini, 5**

2 Outer *ph* absent; cell R_5 petiolate; male head holoptic, female dichoptic; body metallic green or dark blue ... ***Chlororhinia* Townsend [not recorded from Taiwan]**

– Outer *ph* present; cell R_5 variable; male head variable, female dichoptic; body variable in color **3**

3 Hind tibia without conspicuous row of *ad*, but with 2–3 *ad* as long as or longer than tibial diameter; cell R_5 open; body slender, parallel-sided; abdomen mostly testaceous .... ***Idiella* Brauer & Bergenstamm**

– Hind tibia with conspicuous row of subequal setae on anterodorsal surface, longer than general vestiture, sometimes 2–3 rather strong *ad* developed among them; fore tibia with 1 *pv*; body rather stout with ovate abdomen, usually of dark coloration.......... **4**

4 Cell R$_5$ petiolate; stenopleuron brassy, without pollinosity; mesopleuron without setigerous spots; legs entirely yellow.... ***Rhinia* Robineau-Desvoidy**

– Cell R$_5$ open at wing margin or closed; if petiolate then sternopleuron heavily dusted.......... ***Stomorhina* Rondani**

5 Arista plumose, rays at least as long as width of AS$_3$ in anterior view; fore tibia without or with 1 posterior bristle (*p*).......... **6**

– Arista pubescent, longest hairs never exceeding 1.5 times width of AS$_3$ in anterior view; fore tibia with 1 *p*.......... ***Rhyncomya* Robineau-Desvoidy**

6 Outer *ph* absent; fore tibia without *p*.......... **7**

– Outer *ph* present; fore tibia with 1 *p*, rarely lack in *Malayomyza*.......... **8**

7 Prostigmatal bristles (*pst*) absent; two longitudinal silver white stripes present on dorsum.......... ***Borbororhinia* Townsend, *B. bivittata* (Walker)**

– Prostigmatal bristles present; yellowish brown dorsum with or without three fuscous longitudinal stripes, or fuscous dorsum with two longitudinal silver white to grey stripes.......... ***Sumatria* Malloch**

8 Presutural *ac* absent or indistinct; *dc* and postsutural *ac* usually indistinct except for prescutellars; if 1–2 postsutural *ac* developed as prescutellars, then propleuron hairy.......... ***Cosmina* Robineau-Desvoidy [not recorded from Taiwan]**

– Presutural *ac* well developed at least in one pair; *dc* also well developed; propleuron bare.......... **9**

9 Fore tibia without *p*; small fly, less than 4 mm in length, blackish and shiny, with bronzy tinge; humerus, propleuron, upper and anterior part of mesopleuron reddish brown; abdomen reddish brown in part on T$_{1+2}$ and T$_3$; male head dichoptic.......... ***Malayomyza* Malloch [not recorded from Taiwan]**

– Fore tibia with 1 *p*; medium- to large-sized fly having thorax usually metallic green, blue and purple, more or less pollinose; humerus, propleuron, and mesopleuron concolorous with thoracic dorsum; abdomen concolorous with thoracic dorsum, also pollinose, sometimes tessellated; male head usually holoptic to subholoptic.......... **10**

10 Mesopleuron with group of bristles on its upper part; bend of vein M$_{1+2}$ regularly curved or angulose; male hypopygium of normal size, scarcely visible on abdomen in profile; female last sternite not projecting posteriorly..... ***Isomyia* Walker**

– Mesopleuron without bristle on its upper part next to first notopleural bristle; bend of vein M$_{1+2}$ gently curved; male hypopygium and ST$_5$ very strongly developed, altogether almost same size as rest of abdomen; female last sternite widely uncovered by corresponding tergites, its posterior border projecting outwards.......... ***Strongyloneura* Bigot**

Tribe Rhiniini

Key to the species of *Stomorhina*

1 Mesopleuron with 1–2 bristles on upper corner of posterior margin 2

– Mesopleuron with complete row of black bristles along posterior margin; wing strongly infuscated along costal border and with distinct apical suffusion; fore tibia blackish .... ***S. veterana*** **Villeneuve**

2 Mesopleuron without distinct piliferous spots **3**

– Mesopleuron with distinct piliferous spots **5**

3 Sternopleuron as densely yellow pollinose as mesopleuron **4**

– Sternopleuron and hypopleuron glossy black, not pollinose; cell R_5 open; abdomen blackish, with violet tinge .... ***S. melastoma*** **(Wiedemann) [not recorded from Taiwan]**

4 Thoracic squama with lobulate inner border; cell R_5 closed, petiolate .... ***S. xanthogaster*** **(Wiedemann)**

– Thoracic squama without lobulate inner border; cell R_5 open .... ***S. lunata*** **(Fabricius)**

5 Hind femur yellowish at base; cell R_5 open narrowly; anterior lower part of mesopleura and anterior part of sternopleuron glossy, black; male abdomen not pollinose, without piliferous spots; T_{1+2} with only narrow fuscous posterior marginal band, without median stripe .... ***S. discolor*** **(Fabricius)**

– Hind femur entirely dark brown; cell R_5 open; anterior lower part of mesopleuron and anterior part of sternopleuron black, weakly gray pollinose, not glossy; male abdomen with piliferous spots; T_{1+2} with both fuscous anterior and posterior marginal band, with median stripe .... ***S. obsoleta*** **(Wiedemann)**

Key to the species of *Idiella*

1 Basicosta black; occipital dilatation, mesopleuron and sternopleuron with distinct piliferous spots **2**

– Basicosta brown; occipital dilatation, mesopleuron and sternopleuron without distinct piliferous spots **3**

2 First visible tergite without lateral bristle among fine yellow general vestiture; hind tibia in male with fine long hairs on posteroventral surface, length of hairs more than tibial diameter .... ***I. divisa*** **(Walker)**

– First visible tergite with 1 to several black lateral bristles among fine yellow general vestiture; hind tibia in male without fine long hairs on posteroventral surface, tibial hairs not exceeding tibial diameter .... ***I. euidielloides*** **Senior-White**

3 Second antennal segment reddish; mid tibia with 2 *p* and brush of hairs in male; male frons usually broader than width of ocellar triangle .... ***I. mandarina*** **(Wiedemann)**

– Second antennal segment fuscous; mid tibia with 1 *p*, but without brush of hairs on inner surface of apex in male; male frons variable in width .... ***I. tripartita*** **(Bigot) [not recorded from Taiwan]**

Tribe Cosminini

Key to the species of *Isomyia*

1 Thoracic squama strongly lobulate; body very stout **2**

– Thoracic squama generally not lobulated, not reaching base of scutellum, its longitudinal diameter longer than transverse; body usually slender; antenna yellow; *ac* 2+4; alar and thoracic squama yellowish white........... ***I. tibialis*** **(Villeneuve)**

2 Mesopleural hairs and hairs of other pleural areas as well, soft and yellow to golden, except for usual black setulae just below notopleural suture; mesothoracic spiracle yellow **3**

– Mesopleural hairs more extensively black than indicated above, with some soft black hairs on mesopleuron, sometimes remote from notopleural suture, and on sternopleuron... **4**

3 Basicosta bright yellow; epaulet yellowish; pleura and abdomen densely pollinose in male, less so in female, but dorsum of T_5, when viewed laterally at angle, with tessellated pattern of pollinosity; black lateral bristles on T_{1+2} surrounded, at least on three sides, by pale yellow hairs .... ***I. viridaurea*** **(Wiedemann)**

– Basicosta black; epaulet black; T_3 and T_4 without marginal band; wing hyaline, sometimes slightly infuscated apically in female; parafrontal in female subequal to frontal stripe at middle of frons; hind tibia without *av* in male .. .. ***I. electa*** **(Villeneuve)**

4 Marginal scutellar bristles (*msc*) 4, the last three spaced at closer intervals than basal bristle; both alar and thoracic squama pale yellow; posterior mesopleural fringe yellow; some hairs on notopleuron, lower part of mesopleuron, and part of sternopleuron yellow to yellowish brown .... ***I. pseudolucilia*** **(Malloch)**

– Marginal scutellar bristles 3, spaced at approximately equal intervals **5**

5 Pleura with extensive yellow hairs, at least around *pst* and propleural bristles (*pp*) and on part of sternopleuron; posterior mesopleural fringe golden **6**

– Pleural hairs entirely black or virtually so; posterior mesopleural fringe brown to black; alar and thoracic squama wholly dark brown to black.................... .... ***I. oestracea*** **(Séguy)**

6 Mesothoracic spiracle entirely bright yellow to golden; T_3 and T_4 without marginal band; wing hyaline, sometimes slightly infuscated apically in female; parafrontal in female subequal to frontal stripe at middle of frons; hind tibia without *av* in male .... ***I. electa*** **(Villeneuve)**

– Mesothoracic spiracle dark brown to black .... ***I. delectans* (Walker)**

Key to the species of *Rhinia*

1 Mesopleura, and usually occipital dilatation too, with distinct piliferous spots; sternopleura pruinose; cell R_5 open .... ***R. sauteri* Peris**

– Mesopleura without distinct piliferous spots; male scutellum with long and fine hair; interfrontalia width twice each parafrontal in female...................... .... ***R. apicalis* (Wiedemann)**

Key to the species of *Rhyncomya*

1 Propleuron hairy; T_3 and T_4 with black median stripe; T_4 with dark marginal band; T_5 blackish ....***R. notata* (van Der Wulp)**

– Propleuron bare; antenna yellowish fuscous, AS_3 brownish; posterior mesopleural bristles 6–7; hind tibia with 2 fine *av*. Female frons as wide as 0.67 eye wide; interfrontal area reddish brown, not wider at lunule; femur entirely black .... ***R. setipyga* Villeneuve**

Key to the species of *Strongyloneura*

1 Male sternite without brush-like tuft of hairs or bristles except ST_5; anteroventral side of hind coxa with yellow fine hairs and black hairs....***S. prasina* Bigot**

– Male with brush-like tuft of hairs or bristles on each sternite **2**

2 Third sternite with large brush-like tuft of hair ...... ***S. diploura* Fang & Fan**

– Third sternite without tuft of hair; ST_4 with tuft of hair... ***S. prolata* (Walker)**

Key to the species of *Sumatria*

1 Dorsum of thorax orange, with paired narrow longitudinal brownish stripes separated by a median silvery gray-dusted area.............***S. flava* (Villeneuve)**

– Dorsum of thorax testaceous, with three dark longitudinal stripes **2**

2 Dorsum of thorax with three dark longitudinal stripes separated by silvery gray-dusted areas.................................***S. chiekoae* Kurahashi & Tumrasvin**

– Dorsum of thorax with three dark longitudinal stripes, without gray pruinosity... .... ***S. vittata* (Peris)**

New taxon

Paradichosia lui sp. n.

http://zoobank.org/23029B64-E9A8-4A44-B292-E88E08201588
Figs 7, 9

Description. Male. Head: Holoptic, eyes hairy; frons index < 0.01; frontal stripe dark brown to black, obliterated at narrowest point of frons; parafrontal dark brown to black, silver pollinose, setulose, with about 7 pairs of orbital bristles (*ori*); parafacial dark brown to black, silver pollinose, setulose, about as wide as width of AS3; face dark brown to fuscous, slightly gray pollinose, facial carina not developed; facialia dark brown to fuscous, gray pollinose, with several hairs above vibrissa; mediana dark brown, slightly pollinose, with some hairs below; vibrissaria brown, with several bristles; vibrissa developed; epistome yellowish, slightly projecting forward, not obviously demarcated from face; gena blackish, gray pollinose, clothed with black hairs; postgena concolorous with gena, not demarcated from gena, with mostly black hairs but yellowish hairs posteriorly; occiput concolorous with gena, whitish gray-dusted, clothed in yellowish soft hairs at inner part and black hairs along outer margin, epicephalon and upper parts along posterior eye margins black, slightly dusted; AS_2 fuscous, reddish to brown, at joint of AS_3 pale apically; AS_3 fuscous, somewhat reddish to brown at joint of AS_2, yellowish white pollinose, about 3 times as long as AS_2; arista dark brown, long plumose on basal 2/3; palpus orange, with black setulae.

Thorax: blackish, thinly whitish gray pollinose on dorsum and pleura; humerus, postalar callus and scutellum concolorous with thoracic dorsum; prosternum black, with brown hairs below; propleuron yellowish to blackish, whitish pollinose posteriorly, with yellowish brown hairs; mesopleuron and sternopleuron clothed with black hairs and bristles; supraspiracular convexity pubescent, without long upstanding hairs; hypopleuron clothed in black hairs and bristles; other pleural hairs also blackish; mesothoracic spiracle blackish brown on upper part, lower part brown; metathoracic spiracle fuscous; postalar declivity fuscous black, with black hairs; tympanic tuft present; anterior parasquamal tuft present.

Chaetotaxy: *ac* 2+3; *dc* 2+3; *ia* 1+2; humeral bristles (*h*) 3; *ph* 2-3, 2 strong, 1 fine bristle present in front of strong inner *ph*; *prs* 1; supraalar bristles (*sa*) 3; postalar bristles (*pa*) 3; *st* 2+1; *msc* 5; discal scutellar bristle (*dsc*) 1; notopleural bristles (*n*) 2; propleural bristles (*pp*) more than 5; *pst* 1.

Wings: Brownish hyaline; veins brown; epaulet black, with black setulae and bristles; basicosta blackish; subcostal sclerite dark brown, yellowish pubescent; node of 2nd (R_{2+3}) and 3rd (R_{4+5}) longitudinal veins with a few black setulae above and below; 4th longitudinal vein (M_{1+2}) forming right angle; cell R_5 open in wing margin; section of 4th vein from bend to wing margin slightly curved inward; alar squama fuscous, paler at base with golden brown pubescence, semitransparent on apical part, with tuft of dark brown hairs at inner lower margin; thoracic one fuscous, lobulate bare on dorsal surface. Halter brownish, with yellowish apex.

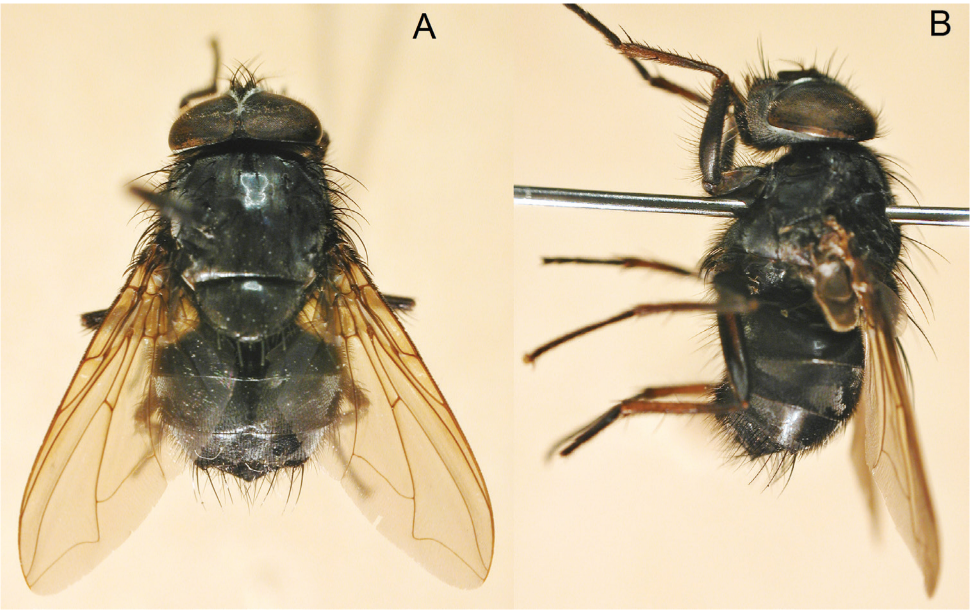

Figure 7. *Paradichosia lui* sp. n., ♂. **A** dorsal view **B** lateral view.

Legs: Femora dark brown to black, tibia brownish, tarsi blackish; fore coxa dark brown to black, more or less whitish grey pollinose; mid and hind coxae brownish black, more or less whitish grey pollinose; fore tibia with 1 *p* and row of several short *ad*; mid tibia with 1 *ad*, 1 *p*, 2 *pv*, and 1 *v*; hind tibia with 3 *ad*, 2–3 *pd*, and 2–3 *av*.

Abdomen: Blackish, submetallic, with bronze tinge, slightly whitish grey pollinose, fine black median stripe more or less distinct on T_3; hairs and bristles black; T_{1+2} with 2–4 lateral marginal bristles; T_3 with lateral and median *mb*; T_4 with row of *mb*; T_5 with row of *mb* and several discal bristles; ST_2 large, elongated, blackish, whitish gray pollinose except for margin, clothed in black hairs only; ST_3 and ST_4 with tuft of short hair as shown in Fig. 9G, H. ST_5 with lobes narrower and bended inward at tip as shown in Fig. 9C.

Hypopygium small in size, withdrawn from sight; genitalia as shown in Fig. 9A, B, D, E, F, aedeagus with fine and slender paraphallus and acrophallus.

Female. Unknown.

Length: 9.5 mm

Holotype ♂, TAIWAN, Yilan, Datong Township, Jiuliao River, *ca*. 158 m, riverside, 26.i.2013, S. T. Yang (NTU). Paratypes, 1♂, Tatung, 28.xii.1991, C. L. Chung (NSMT); 1♂, Tatung, Chilanshan, Chihtuan, 15.xi.1961, J. C. Lien (NSMT).

Etymology. The specific epithet *lui* is named after Mr. I-Tse Lu, who guided the first author to the collecting site and helped collect specimens.

Type depository. Holotype (♂) is deposited in the Insect Museum of National Taiwan University (NTU); two paratypes (type series NSMT-I-Dip6958, 6959) are deposited in the National Museum of Nature and Science, Tokyo (NSMT).

Diagnosis. This new species, which has hairy eyes and a blackish scutellum, is similar to *P. dubia* (Malloch) from Java, Indonesia in general morphology. Nevertheless, it can be easily distinguished from *P. dubia* by having very short hairs on the tuft of ST_3 in the male.

Bionomics. Adults were found on the bush near the stream side.

Distribution. Taiwan (Yilan).

New Record from Taiwan

Silbomyia hoeneana Enderlein

Figs 8, 10

Redescription. Male. Head: Eyes dichoptic; frons index 0.42; frontal stripe yellow to yellowish-orange, very wide, about 4 times as wide as a parafrontal, black setulose on outer part; parafrontal yellow, silvery-yellow pollinose, with about 9 pairs of *ori*, reclinate *ors* 1, proclinate *ors* 2; parafacial yellow, silvery-yellow pollinose, bare, about 2 times as wide as width of AS_3; face yellow, slightly yellowish pollinose; facial carina developed, rather short and broad, shorter than distance from lunule to median ocellus, more or less ridge-like, not fusiform, facialia yellow, slightly yellowish pollinose, with several black hairs above vibrissa; mediana yellow, silvery-yellow pollinose; vibrissaria yellow, with several strong bristles; vibrissa well developed; epistome yellow, not obviously demarcated from face; gena yellow, silvery-yellow pollinose, covered with yellowish-fuscous to brown hairs; peristomal bristles black and stout; postgena concolorous with gena, not demarcated from gena, with yellowish hairs; postorbits dark brown, bright silver pollinose; upper occiput dark brown to black, slightly silvery-gray pollinose, with black hairs, lower occiput yellow, silvery-yellow pollinose, with golden-yellow hairs; upper epicephalon yellow, concolorous with frontal stripe, lower part brown; AS_2 yellowish to pale orange; AS_3 yellowish to pale orange, yellowish white pollinose, about 3 times as long as AS_2; arista fuscous brown, almost entirely long plumose; palpus pale orange, with black setulae.

Thorax: Metallic bluish-green to blue, with somewhat purplish tinge, slightly silvery-gray pollinose on dorsum and pleura; humerus, postalar callus, and scutellum concolorous with thoracic dorsum; outer prosternum yellowish, inner part dark brown, with rather long black hairs; propleuron dark brown, silvery-gray pollinose, with metallic greenish tinge, covered with brown hairs; supraspiracular convexity brownish pubescent, without long upstanding hairs; hypopleural with row of long black bristles; other pleural hairs black; mesothoracic spiracle dark brown; metathoracic spiracle dark brown; postalar declivity fuscous black, with black hairs; tympanic tuft absent; anterior parasquamal tuft absent.

Chaetotaxy: *ac* 3+4–5; *dc* 3+4; *ia* 1+2–4, sometimes 2 weaker postsutural *ia* present; *h* 4–5; *ph* 3; *prs* 1; *prealar* 1; *sa* 2; *pa* 2; *st* 2+1; *msc* 3–4; *dsc* 2–4; *n* 2; *pp* 2; *pst* 1–3.

Wings: Dark brown infuscate, most strongly brown along veins, paler in cells and to hind margin; veins dark brown; epaulet black, with black setulae and bristles; basi-

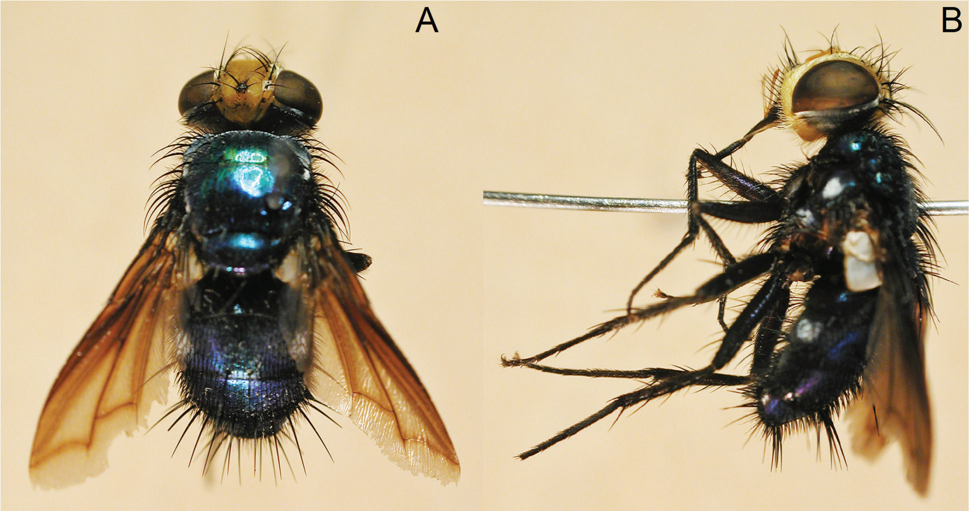

Figure 8. *Silbomyia hoeneana* Enderlein, ♂. **A** dorsal view **B** lateral view.

costa black, with brown pubescence; subcostal sclerite dark brown; node of R_{2+3} and R_{4+5} veins with several black setulae extending to R_{4+5} above and below; vein M_{1+2} forming right angle; Cell R_5 open at wing margin; section of vein M_{1+2} from bend to wing margin slightly curved inward; alar squama whitish, with pale yellow edge and white fringe; thoracic squama whitish, bare on dorsal surface, with dark brown edge and dark brown fringe. Halter fuscous, darkened on apex.

Legs: Femora dark brown to blackish, with metallic violet tinge; tibiae brown; tarsi dark brown; coxa dark brown to blackish, covered with black hairs and bristles anteriorly; fore tibia with row of several strong *ad*, 3 short *pd*, 2–3 strong *p*; mid tibia with row of several strong *ad*, several short *pd*, 2–3 strong *p*, 1 strong *av*; hind tibia with 2 *av*, row of several strong *ad*, 4 long *pd*.

Abdomen: Metallic bluish-green to blue, with somewhat purplish tinge, slightly silvery-gray pollinose; hairs and bristles black; T_{1+2} with 1 lateral marginal bristle; T_3 with lateral and 1 pair of strong median *mb*, sometimes with 1 or a pair of median discal bristles weakly developed; T_4–T_5 with row of *mb*; sternites dark brown with metallic violet tinge, covered with black bristles and hairs. Fifth sternite with long and wide lobes, longer than basal part, as shown in Fig. 10C.

Hypopygium not prominent; genitalia as shown in Fig. 10A, B, D, E, F, paraphallus stout, strongly ossified; hypophallus and acrophallus stout.

Female. Head: Eyes dichoptic; frons index 0.54; frontal stripe yellow to yellowish-orange, broad, about 2.8 times as wide as one parafrontal, black setulose laterally; parafrontal yellow, silvery-yellow pollinose, broader than that of male, with about 9 pairs of *ori*, reclinate *ors* 1, proclinate *ors* 2; parafacial yellow, silvery-yellow pollinose, bare, broader than that of male, about 3 times as broad as width of AS_3; *ors* 2+1; ocellar bristle (*oc*) 1; postocellar bristles (*pooc*) 3–4; *ov* 1; inner vertical bristle (*iv*) 1; postoccipital bristle (*poc*) 1; occipital bristle (*occ*) 1.

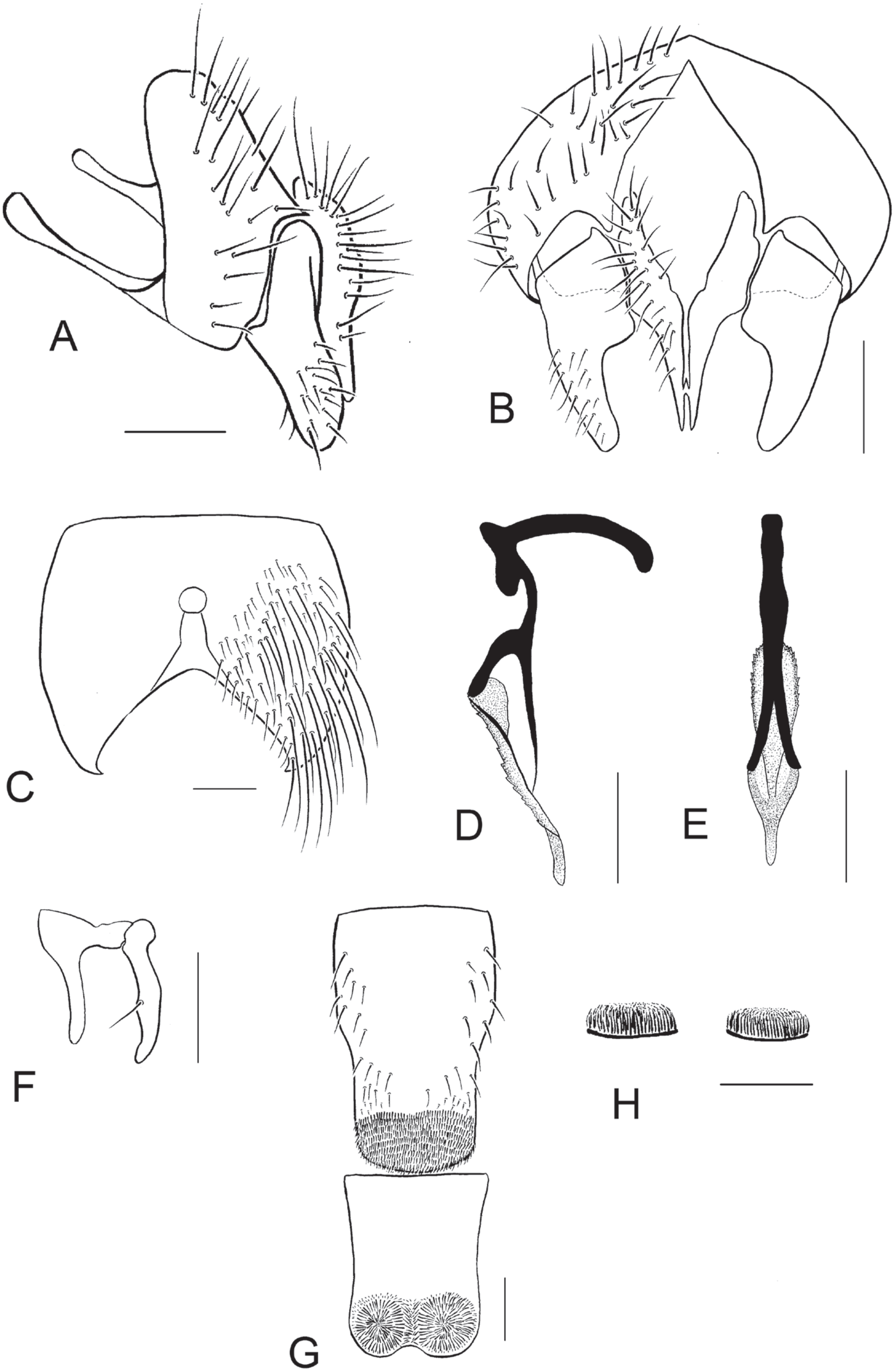

Figure 9. Sternites and genitalia of *Paradichosia lui* sp. n., ♂. **A** Epandrium, cercus, and surstylus, lateral view **B** Cercus and surstylus, caudal view **C** Fifth abdominal sternite, ventral view **D** Aedeagus, lateral view **E** Aedeagus, posterior view **F** Anterior and posterior parameres **G** Third and fourth abdominal sternites, ventral view **H** Tufts on the third (left) and fourth (right) abdominal sternites. Scale bars: 0.2 mm.

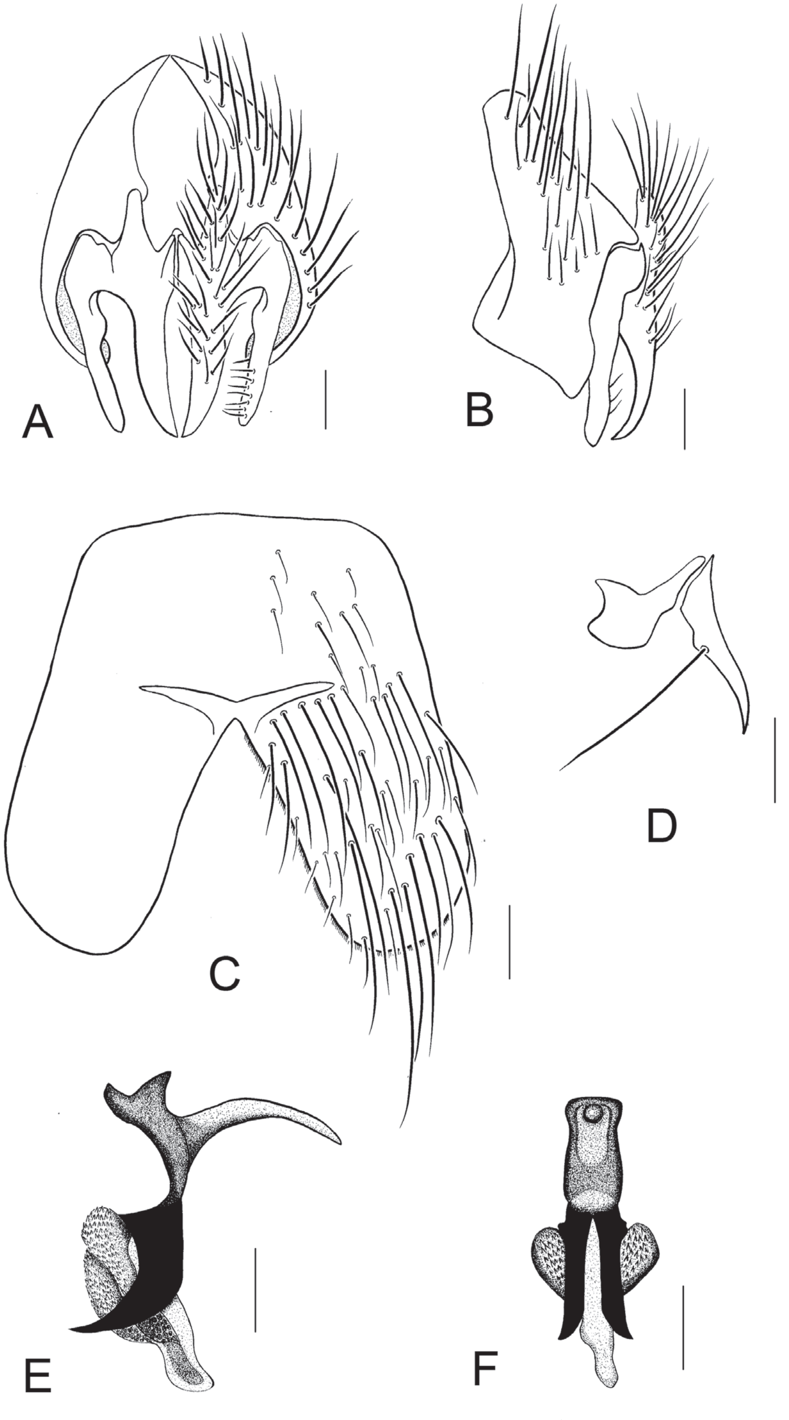

Figure 10. Sternite and genitalia of *Silbomyia hoeneana* Enderlein, ♂. **A** Cercus, and surstylus, caudal view **B** Epandrium, cercus, and surstylus, lateral view **C** Fifth abdominal sternite, ventral view **D** Anterior and posterior parameres **E** Aedeagus, lateral view **F** Aedeagus, posterior view. Scale bars: 0.2 mm.

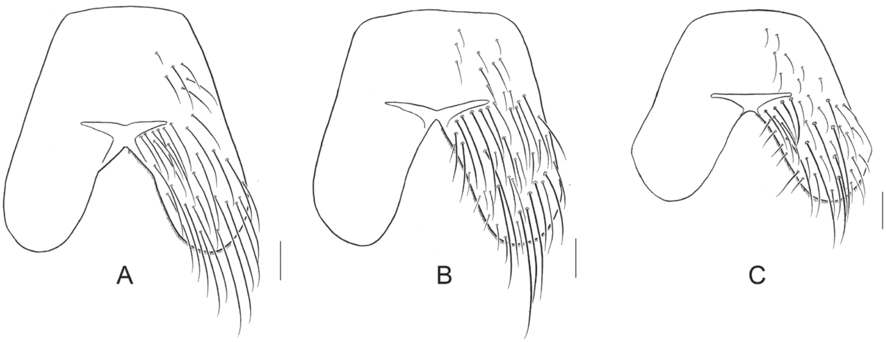

Figure 11. The male fifth abdominal sternites of *Silbomyia* species. **A** *S. sauteri* **B** *S. hoeneana*, Taiwan **C** *S. hoeneana*, China. Scale bars: 0.2 mm.

Legs: Fore tibia with row of several strong *ad*, 4 *pd*, 2 strong *p*; mid tibia with row of several strong *ad*, 3 *pd*, 2 strong *p*, 1 strong *av*; hind tibia with 2 *av*, row of several strong *ad*, 4 long *pd*. Otherwise same as for male.

Length: 12.0–17.0 mm.

Diagnosis. The specimens of this species collected in Taiwan are slightly different in external morphology from those collected in China. Taiwanese specimens are more bluish when compared to the greener Chinese individuals, and the shape of the ST_5 is different (Fig. 11) (A, *S. sauteri*; B, *S. hoeneana*, collected in Taiwan; C, *S. hoeneana*, collected in China), the lobes of the ST_5 of *S. hoeneana* collected in Taiwan are longer than the basal part, while those of *S. hoeneana* collected in China are almost equal to the basal part.

Bionomics. Adults are frequent flower visitors.

Distribution. Taiwan and Southern China (Jiangsu Province, Zhejiang Province, Sichuan Province, Jiangxi Province, Hainan Province, Guangdong Province, Yunnan Province).

Checklist

The following list of Taiwanese Calliphoridae is based mainly on the specimens examined and to a lesser extent on the published records. Names of the collecting localities are based on the original spelling on the collecting labels of specimens.

Subfamily AMENIINAE
Tribe Ameniini
Silbomyia Macquart, 1843

Silbomyia cyanea (Matsumura, 1916)

Materials. 1♂, Kaohsiung City, Liugui Dist., Tsaidie Valley, 366 m, secondary forest, 31.iii.2013, S. T. Yang (NTU); 1♀, P'ing-tung Hsian, K'en-ting-kung-yuan, 2.iv.1965, R. Kano (NSMT); 1♂, P'ing-tung Hsien, Kuei-chiao-liu, 3.iv.1965, S. Ueno (NSMT); 2♀, T'ai-nan Hsien, Kuan-tzu-ling, 250 m, 6.iv.1965, Rokuro Kano (NSMT); 1♀, Chia-I Hsien, Ch'-hsin-liao, 15.iv.1965, S. Ueno (NSMT); 1♀, Jiji (Chichi), 30.iv.2006, H. Kurahashi (NSMT); 1♀, Kuan-tzu-ling, 250 m, 6.iv.1965, R. Kano (NSMT); 3♀, Puli, 26.ix.1965, K. Kaneko (NSMT); 1♂, Chihpen, 20.vii.1985, S. Shinonaga (NSMT); 1♂, Nanshanchi, 26.vii.1985, S. Shinonaga (NSMT); 1♂, Kenting Park, 15.vii.1985, S. Shinonaga (NSMT); 2♂ 1♀, Chihpen hot spring, 3–4.vi.1992, R. Kano and H. M. Lin (NSMT); 1♂, Kenting, 11.x.1965, K. Kaneko (NSMT); 1♀, Janai (Mushia), 28.ix.1965, K. Kaneko (NSMT); 1♂, Chuchi, 5.x.1965, K. Kaneko (NSMT); 1♂ 1♀, Shanpin, Kaohsiung Co., 6.iv.1996, R. Matsumoto (NSMT); 3♀, Puli, Nanshanhsi, 23-24.v.1992, R. Kano (NSMT); 2♂, Kentin, 15.ii.1972(1♂), 10.iii.1972(1♂), K. Matsuki (NSMT); 2♀, Liuknei, 12.vii.1985, S. Shinonaga (NSMT).

Silbomyia sauteri Enderlein, 1936

Materials. 1♂, Tainan City, Baihe Dist., Guanziling, Red-Leaf Park, 357 m, secondary forest, 21.iii.2013, S. T. Yang (NTU); 2♀, Santimen, 13.vii.1985, S. Shinonaga (NSMT); 2♀, Kentin, 15.ii.1972(1♀), 10.iii.1972(1♀), K. Matsuki (NSMT); 1♀, Taipei Fushan Botanical Garden, 700 m, 24–26.x.2002, M. Owada (NSMT); 1♀, Kuan-tzu-ling, 7.iv.1965, S. Miyamoto (NSMT); 1♀, Jih-yueh-tan, 24.ix.1965, K. Kaneko (NSMT); 1♀, Lushan, 1,000 m, 24–25.vii.1985, S. Shinonaga (NSMT); 2♂, Shannpin, Nantou Co., 7.iv.1996, R. Matsumoto (NSMT); 1♂, Jiji (Chichi), 30.iv.2006, H. Kurahashi (NSMT); 1♀, Fushan B. G., 600 m, 3–6.v.2006, H. Kurahashi (NSMT); 1♀, Kuanzuling, 7.x.1965, K. Kaneko (NSMT); 1♂, Paling, Taoyuen, 9–11.vi.1992, R. Kano (NSMT).

**Silbomyia hoeneana* Enderlein, 1936

Materials. 2♀, T'ai-nan Hsien, Kuan-tzu-ling, 250 m, 06.iv.1965, Rokuro Kano (NSMT); 1♂, Taoyuen, Paling, 09-11.vi.1992, R. Kano (NSMT); 1♀, Kentin, 15.ii.1972, K. Matsuki (NSMT).

Tribe Catapicephalini

Catapicephala Macquart, 1851

Catapicephala dasyophthalma Villeneuve, 1927

Note. See to James (1977: 532).

Catapicephala ruficornis Villeneuve, 1927

Materials. 1♂, Kaohsiung, Shanping, 640 m, 21–30.iv.1988, C. Young, R. Davidson & J. Rawlins (CMNH); 1♀, Kaohsiung, Shanping, 640 m, 1-10.iv.1988, C. Young, R. Davidson & J. Rawlins (CMNH); 1♀, Chihpen Hot Spring, 3–4.vi.1992, R. Kano (NSMT).

Catapicephala splendens Macquart, 1851

Note. See to James (1977: 532).

Subfamily CALLIPHORINAE

Aldrichina Townsend, 1934

Aldrichina grahami (Aldrich, 1930)

Materials. 1♂ 1♀, Nantou County, Ren'ai Township, Songgang, 2049 m, secondary forest, 16.iv.2013, S. T. Yang (NTU); 2♂ 1♀, Taichung Ctiy, Heping Dist., Huanshan Tribe, Ssuchiehlan Stream, 1832 m, riverbed, 26.i.2013, S. T. Yang (NTU); Mazu, Beigan Is.: 2♂, Lienchiang County, Beigan Township, 100 m, seashore, 12.v.2013, S. T. Yang (NTU); 1♂ 2♀, Alishan, 28–29.v.1992, R. Kano (NSMT); 1♀, nr Huanshan, 2.v.2006, H. Kurahashi (NSMT); 2♂, Alishan-Yushan, 2,600-2,700 m, 31.x.1985, M. Iwasa (NSMT); 1♀, Taoyuen, Paling, 9–11.vi.1992, R. Kano (NSMT); 4♂ 7♀, Oiwake, 4.V.1965, T. Shirozu (NSMT); 6♂ 4♀, Mt. Alishan, 10–13.VII.1964, S. Asahina (NSMT); 2♀, Tattaka, 24.VI.1965, T. Shirozu (NSMT); 1♂, Taichung, Pilushi, 2,200 m, 22–23.v.1988, R. Davidson, C. Young & J. Rawlins (CMNH); 2♂, Alishan-Yushan, 2,600-2,700 m, 31.x.1985, M. Iwasa (NSMT).

Bellardia Robineau-Desvoidy, 1863

Bellardia menechma (Séguy, 1934)

Materials. 1♂, Hualien Hsien, Juisui, 11.xi.1985, K. Kanmiya (NSMT); 1♂, Chihpen, 10.vi.1972, R. Kano (NSMT); 7♂ 6♀, Juisui, 10–11.xi.1985, K. Kanmiya (NSMT); 2♀, Chihpen, 10.vi.1973, H. M. Lin (IDD); 2♀, Fenchifu, 1,405 m, 2.xi.1985, M. Iwasa (IDD); 1♀, Taichung Hsien, Chichiawanchi, Huanshan, 6.xi.1985, K. Kanmiya (IDD).

Bellardia pubescens (Macquart, 1851)

Materials. 1♂, Chia-i Hsien, Fenchi-Hu, 8.vii.1985, H. Shima (NSMT); 1♀, Nantou Hsien, Janai (Mushia), 28.ix.1965, K. Kaneko (IDD); 1♀, Lishan, 16.ix.1970, S. C. Lien (IDD); 1♀, Chihpen, 10.vi.1972, R. Kano (IDD).

Calliphora Robineau-Desvoidy, 1830

Calliphora nigribarbis Vollenhoven, 1863

Note. See to James (1977: 531).

Calliphora pattoni Aubertin, 1931

Materials. 1♂, Taichung City, Heping Dist., Wuling Farm, Taiwan Salmon Observatory Deck, 1800 m, river bed, 23.xii.2012, T. R. Tsai (NTU); 1♀, Taichung Ctiy, Heping Dist., Huanshan Tribe, Ssuchiehlan Stream, 1832 m, riverbed, 26.i.2013, S. T. Yang (NTU); 3♀, Taichung Ctiy, Heping Dist., Siaosyue Mt., Tianchi, 2626 m, coniferous forest, 12.ii.2013, S. T. Yang (NTU); 1♀, Alishan-Yushan, 2,600–2,700 m, 31.x.1985, M. Iwasa (NSMT); 1♂ 2♀, Alishan Mts., 2,270m, 9.IV.1965, R. Kano, Yoshimoto & Parkins (NSMT); 1♂, Tzuchung, 2,370m, 10.IV.1965, S. Ueno (NSMT); 13♂ 5♀, Alishan, 28-29.v.1992, R. Kano & H. M. Lin (NSMT); 1♂, Taichung, Anmashan, 2,230 m, 30.iv–4.v.1990, A. Smetana (CMNH); 1♀, Ren-Ai- He-Huan-Shan, LuoYing Inn, 2,830 m, 22.iii.2011, C. Young (CMNH); 1♀, Alishan-Yushan, 2,600–2,700 m, 31.x.1985, M. Iwasa (NSMT).

Calliphora vomitoria (Linnaeus, 1758)

Materials. 14♂ 10♀, Nantou County, Ren'ai Township, Songgang, 2049 m, secondary forest, 16.iv.2013, S. T. Yang (NTU); 6♀, Taichung Ctiy, Heping Dist., Wuling Farm, Taiwan Salmon Observatory Deck, 1800 m, river bed, 23.xii.2012, T. R. Tsai (NTU); 1♂ 3♀, Taichung City, Heping Dist., Huanshan Tribe, Ssuchiehlan Stream, 1832 m, riverbed, 26.i.2013, S. T. Yang (NTU); 3♀, Taichung Ctiy, Heping Dist., Siaosyue Mt., Tianchi, 2626 m, coniferous forest, 12.ii.2013, S. T. Yang (NTU); 2♂ 1♀, Chiayi County, Alishan Township, Leye Village, Dinghu, 1657 m, secondary forest, 23.ii.2013, S. T. Yang (NTU); 1♂ 1♀, Alishan-Yushan, 2,600-2,700 m, 31.x.1985, M. Iwasa (NSMT); 1♂ 4♀, Taichung, Anmashan, 2,230 m, 30.iv–4.v.1990, A. Smetana (CMNH); 1♂, Anmashan, 2,230 m, 30.iv.–4.v.1990, A. Smetana (CMNH); 1♀, nr Alishan, Hishan, 2,300 m, 30.iv.2006, H. Kurahashi (NSMT); 4♀, Kuanshan trail at Kuanshanchi River, 2,400 m, 20–23.

vii.1993, A. Smetana (CMNH); 6♂ 10♀, Alishan, 28–29.v.1992, R. Kano & H. M. Lin (NSMT); 1♂ 1♀, Alishan-Yushan, 2,600–2,700 m, 31.x.1985, M. Iwasa (NSMT); 3♀, Ren-Ai- He-Huan-Shan, LuoYing Inn, 2,830 m, 22.iii.2011, C. Young (CMNH).

Polleniopsis Townsend, 1917

**Polleniopsis dalatensis* Kurahashi, 1972

Materials. 1♂, Nantou County, Ren'ai Township, Jianqing Farm, 26.vii.1961, J. K. Nii (NSMT); 1♂1♀, Fanshan, 1650 m, 6.xi.1985, M. Iwasa (NSMT).

Polleniopsis toxopei (Senior-White, 1926)

Note. See to James (1977: 540).

Tainanina Villeneuve, 1926

Tainanina pilisquama (Senior-White, 1925)

Materials. 1♂, Juisui, 10.xi.1985, K. Kanmiya (NSMT); 2♂, Tienshiang, 8.x.1965, K. Kanmiya (NSMT); 1♂, Juisui, 10.xi.1985, K. Kanmiya (NSMT).

**Tainanina sarcophagoides* (Malloch, 1931)

Materials. 2♀, Tienshiang, 8.x.1965, K. Kanmiya (NSMT)

Subfamily MELANOMYINAE

Gymnadichosia Villeneuve, 1927

Gymnadichosia pusilla Villeneuve, 1927

Materials. 1♂ 1♀, Mt. Alishan, Chun-shan, 2,400 m, 9–10.vii.1985, S. Shinonaga and H. Shima (NSMT);1♂, Chichiawanchi, Huanshan, 6.xi.1985, K. Kanmiya (NSMT).

Paradichosia Senior-White, 1923

Paradichosia crinitarsis Villeneuve, 1927

Materials. 1♂, Nantou County, Ren'ai Township, Gaofeng, Guantou Mt. (Northeast), 20.v.2013, K. Harusawa (PCKHa); 1♂ 1♀, Pingtung County, Shizi Township, Shuangliu, 189–300 m, secondary forest, 11.v.2013, S. T. Yang (NTU); 1♀, Tsuifeng-Shunkan, 24.vii.1985, H. Shima (NSMT); 1♀, Shanpaling, 26.x.1985, K. Kanmiya (NSMT); 1♂, Hsinchu, Wufeng, 24.xii.1993, C. L. Chung (NSMT).

Paradichosia lui sp. n.

Paradichosia nigricans Villeneuve, 1927

Materials. 1♀, Nantou County, Lugu Township, Xitou, 1156 m, secondary forest, 08.iii.2013, S. T. Yang (NTU); 1♂, Taoyuen, Paling, 9-11.vi.1992, R. Kano (NSMT); 1♀, Alishan, 28-29.v.1992, R. Kano (NSMT); 1♀, Fanlu, Kungtien village, 15.iv.1958, S. Y. Liu (NSMT); 1♂, Shihtsao, 24.v.1972, R. Kano (NSMT); 2♂ 1♀, Hohuan-shan, Tsuifeng, 2,400 m, 23-24.vii.1985, S. Shinonaga (NSMT); 1♂, Hsitou, 1,000 m, 1.v.2006, H. Kurahashi (NSMT); 1♀, Alishan, 28-29.v.1992, R. Kano (NSMT).

Pollenomyia Séguy, 1935

Pollenomyia sinensis (Séguy)

Materials. 1♂, Miaoli, Nanchung, 22.xii.1993, C. L. Chung (NSMT).

Tricycleopsis Villeneuve, 1927

Tricycleopsis paradoxa Villeneuve, 1927

Note. See to James (1977: 540).

Subfamily BENGALIINAE

Bengalia Robineau-Desvoidy, 1830

**Bengalia calilungae* Rueda, 1985

Materials. 1♂, Penpuchi (Honbukei), 21.viii.1980, K. Hara (NSMT).

******Bengalia chekiangensis* **Fan, 1965**

Materials. 3♂ 2♀, Nantou, Wushe, 24.v.1988, C. Young, J. Rawlins & R. Davidson (CMNH); 1♀, Kaohsiung, Shanping, 640 m, 11–20.v.1988, J. Rawlins, C. Young, & R. Davidson (CMNH); 7♂ 9♀, Nantou, Wushe, 24.v.1988, C. Young, J. Rawlins & R. Davidson (CMNH).

Bengalia emarginata **Malloch, 1927**

Materials. 1♂, Nantou County, Ren'ai Township, Aowanda, 18.v.2013, K. Harusawa (PCKHa); 1♂, Pingtung County, Shizi Township, Shuangliu, 189-300 m, secondary forest, 11.v.2013, S. T. Yang (NTU); 3♂, Taiton, Tsupun, 21.iii.1981, M. Iwasa (NSMT); 1♀, Hotso (Roshan), 30.ix.1965, K. Kaneko (NSMT); 1♀, Kaohsiung, Shanping, 640 m, 11–20.iv.1988, C. Young, J. Rawlins & R. Davidson (CMNH); 1♂, Kotzulin, 850m, 4.IV.1965, S. Ueno (NSMT); 1♂, Alishan, 10–13. VII.1964, S. Asahina (NSMT); 1♂, Fenchihu, 1,370m, 11.IV.1965, B. D. Parkins (NSMT); 1♂, Wulai, 130m, 17.IV.1965, T. Saigusa (NSMT); 2♂, Kentingkungyuan, 2-3.IV.1965, R. Kano (NSMT); 1♀, Kuantzuling, 250m, 6.IV.1965, R. Kano (NSMT); 3♂ 1♀, Nanzan-kei, 30.IV.1965, 8.V.1965, T. Shirozu (NSMT); 1♂, Chihpen Hot Spring, 3–4.vi.1992, R. Kano (NSMT); 1♂, Chung-Hsien University, Huei-sun Forest, 21.v.1992, R. Kano (NSMT); 1♂, Kenting Park, 1–2. vi.1992, R. Kano (NSMT); 1♀, Nantou, Wushe, 24.v.1988, C. Young, J. Rawlins & R. Davidson (CMNH).

Bengalia escheri **Bezzi, 1913**

Materials. 1♀, Nantou County, Ren'ai Township, Aowanda, 18.v.2013, K. Harusawa (PCKHa); 3♂, Taipei City, Neihu Dist., Daluntou Mt., 352 m, secondary forest, 19.v.2013, S. T. Yang (NTU); 1♂, New Taipei City, Wulai Dist., Hsiaoi Village, Tonghou, 233 m, dump (at light), 30.v.2012, S. T. Yang (NTU); 1♀, Kaohsiung, Shanping, 640 m, 21–30.iv.1988, C. Young, R. Davidson & J. Rawlins (CMNH); 1♂, Fenchihu, 1,370m, 10.IV.1965, R. Kano (NSMT); 1♂ 1♀, Fenchihu, 4.IV.1965, 12.IV.1965, R. Kano (NSMT); 1♀, Ten-chih, 23-04-03 N, 120-45-13 E, 1,550 m, 23.viii.1996, C. W. Young (CMNH); 1♂, Taoyuen, Paling, 9–11.vi.1992, R. Kano (NSMT); 2♀, Lushan, 1,000m, 24-25.VII.1985, S. Shinonaga (NSMT); 1♂ 1♀, Kukan, 3.XI.1985, K. Kanmiya (NSMT); 1♂, Nanshanchi, 31.iii.1996, R. Matsumoto (BLKU); 1♀, Wulai-hsiang, Fushan, 400–600 m, 28.xi.1997, T. Tachi (BLKU); 8♂ 1♀, Fushan B. G., 600 m, 3–6.v.2006, H. Kurahashi (NSMT); 1♂, Chiapaotai Park, 4.x.1985, K. Kanmiya (NSMT).

Bengalia fuscipennis Bezzi, 1913

Materials. 1♂, Nantou County, Puli Township, Shizitou, at light, 20.v.2013, K. Harusawa (PCKHa); 1♀, Nantou County, Ren'ai Township, Gaofeng, Guantou Mt. (Northeast), 20.v.2013, K. Harusawa (PCKHa); 2♂, New Taipei City, Wulai Dist., Hsiaoi Village, Tonghou, 233 m, dump (at light), 30.v.2012, S. T. Yang (NTU); 16♂ 7♀, Fushan B. G., 600 m, 3-6.v.2006, H. Kurahashi (NSMT); 2♀, Wulai, 150m,17. IV.1965, 20.X.1985, R. Kano & K. Kanmiya (NSMT); 1♀, Lafu, 350m, 27.X.1985, R. Kano (NSMT); 1♂ 3♀, Fenchifu, 1,400m, 5.VII.1985, 8.VII.1985, S. Shinonaga & H. Shima (NSMT); 5♂ 2♀, Lenai, 1,000m, 23.VII.1985, S. Shinonaga (NSMT); 1♀, Tattaka, 29.VI.1965, T. Shirozu (NSMT); 2♀, Kaohsiung, Shanping, 640 m, 21–30.iv.1988, C. Young, J. Rawlins & R. Davidson (CMNH); 2♂, Chiapaotai Park, 4.x.1985, K. Kanmiya (NSMT); 1♂ 5♀, Kaohsiung, Shanping, 640 m, 21-30.iv.1988, C. Young, R. Davidson & J. Rawlins (CMNH); 2♀, Kaohsiung, Shanping, 640 m, 11–20.iv.1988, C. Young, R. Davidson & J. Rawlins (CMNH); 2♂ 1♀, Chung-Hsien University, Huei-sun Forest, 21.v.1992, R. Kano (NSMT).

Bengalia taksina (Lehrer, 2005)

Materials. 1♀, Nanshanchi, 31.iii.1996, R. Matsumoto (BLKU); 5♂ 5♀, Nantou, Wushe, 24.v.1988, C. Young, J. Rawlins & R. Davidson (CMNH); 1♂, Kaohsiung, Shanping, 640 m, 21–30.iv.1988, C. Young, R. Davidson & J. Rawlins (CMNH); 1♂, Nantou, Wushe, 640 m, 24.v.1988, C. Young, J. Rawlins & R. Davidson (CMNH); 2♀, Taoyuen, Paling, 9–11.vi.1992, R. Kano (NSMT); 3♂ 1♀, Kuantzuling, 28.v.1992, R. Kano (NSMT); 2♂ 1♀, Puli, Nanshanhsi, 23–24.v.1992, R. Kano (NSMT); 2♂ 1♀, Chung-Hsien University, Huei-sun Forest, 21.v.1992, R. Kano (NSMT).

Bengalia torosa (Wiedemann, 1819)

Materials. 2♀, Kaohsiung, Shanping, 640 m, 1–10.iv.1988, R. Davidson, J. Rawlins & C. Young (CMNH); 1♂, Kaohsiung, Shanping, 640 m, 21-30.iv.1988, C. Young, J. Rawlins & R. Davidson (CMNH).

Bengalia varicolor (Fabricius, 1805)

Materials. 1♂ 1♀, Nantou County, Ren'ai Township, Aowanda, 18.v.2013, K. Harusawa (PCKHa); 2♀, Nantou County, Ren'ai Township, Aowanda, 21.v.2013, K. Harusawa (PCKHa); 13♂ 24♀, Jenai, Chinglin, 27.V.1972, R. Kano (NSMT); 1♂, Nanzan-kei, 26.VI.1965, T. Shirozu (NSMT); 1♂, Kenting-kung-yuan, 2.IV.1965, R. Kano (NSMT); 1♀, Tienshiang, 8.X.1985, K. Kanmiya (NSMT); 2♂ 1♀, Hotso (Roshan), 30.IX.1965, K. Kaneko (NSMT).

Subfamily LUCILIINAE
Hemipyrellia Townsend, 1918

Hemipyrellia ligurriens (Wiedemann, 1830)

Materials. 1♂, Nantou County, Puli Township, Qianxi, 20.v.2013, K. Harusawa (PCKHa); 3♂ 7♀, Yilan County, Nan'ao Township, 22 m, secondary forest; eggs collected, 7.iii.2013 eclosion, 16.ii.2013, S. T. Yang (NTU); 4♀, Tainan City, Baihe Dist., Guanziling, Lingding Park, 322 m, secondary forest, 21.iii.2013, S. T. Yang (NTU); 1♀, New Taipei City, Shimen Dist., Linshan Cape, 20 m, seashore, 29.xii.2012, S. T. Yang (NTU); 1♀, New Taipei City, Xindian Dist., Zhitan Dam, 57 m, riverside, 27.xii.2012, S. T. Yang (NTU); 1♀, Hualien County, Xiulin Township, Fushi, Changuang Temple, 120 m, monsoon rainforest, 09.v.2013, S. T. Yang (NTU); Orchid Is.: 1♂, Taitung County, Lanyu Township, Hongtou, Weather Station, 231 m, tropical rainforest, 01.vi.2013, S. T. Yang (NTU); Orchid Is.: 1♀, Taitung County, Lanyu Township, Zhong'ai Bridge, 53 m, tropical rainforest, 01.vi.2013, S. T. Yang (NTU); 18♂ 22♀, Hualien County, Shoufeng Township, Pinghe, 41 m, plain; eggs collected, 7.iii.2013 eclosion, 16.ii.2013, S. T. Yang (NTU); Mazu, Beigan Is.: 3♂ 3♀, Lienchiang County, Beigan Township, 100 m, seashore, 12.v.2013, S. T. Yang (NTU); 2♂ 1♀, Kaohsiung City, Liugui Dist., Tsaidie Valley, 366 m, secondary forest, 31.iii.2013, S. T. Yang (NTU); 5♂ 12♀, New Taipei City, Wulai Dist., Zhongzhi, 109 m, riverside; eggs collected, 18.i.2013 eclosion, 27.xii.2012, S. T. Yang (NTU); 10♂ 5♀, Hualien County, Xincheng Township, Qixingtan, Sihba Height, 41 m, grassland, 09.v.2013, S. T. Yang (NTU); 5♀, Hualien County, Xincheng Township, Qixingtan, 14 m, seashore, 09.v.2013, S. T. Yang (NTU); 5♂ 4♀, Pingtung County, Sangdimen Township, Sandi Village, 381 m, secondary forest, 2.iv.2013, S. T. Yang (NTU); 1♀, New Taipei City, Zhonghe Dist., Yuantong Temple, 173 m, secondary forest, 25.v.2013, S. T. Yang (NTU); 2♂ 2♀, Yilan County, Toucheng Township, Beiguan, 34 m, seashore, 04.iv.2013, S. T. Yang (NTU); 2♂ 1♀, Chiayi County, Alishan Township, Shanmei, Tanayiku, 450 m, secondary forest, 24.ii.2013, S. T. Yang (NTU); 11♂, Taitung County, Haiduan Township, Xinwulu, 390 m, secondary forest, 30.v.2013, S. T. Yang (NTU); 1♂ 3♀, Taitung County, Luye Township, Ruiyuan, 198 m, farmland, 30.v.2013, S. T. Yang (NTU); 2♂, Taitung County, Luye Township, Luye High Terrace, 353 m, grassland, 30.v.2013, S. T. Yang (NTU); 2♂ 2♀, Taitung County, Dawu Township, Dawu, 85 m, secondary forest, 18.iv.2013, S. T. Yang (NTU); Liuqiu Is.: 2♂ 1♀, Pingtung County, Liuqiu Township, Geban Bay, 10 m, seashore, 04.v.2013, S. T. Yang (NTU); Liuqiu Is.: 8♂ 2♀, Pingtung County, Liuqiu Township, Shanfu, 25 m, seashore, 04.v.2013, S. T. Yang (NTU); Liuqiu Is.: 3♂ 6♀, Pingtung County, Manzhou Township, Qikong Waterfall, 40–125 m, secondary forest, 24.i.2013, S. T. Yang (NTU); 5♂ 2♀, Kaohsiung City, Jiaxian Dist., Jiaxian, 278 m, secondary forest, 12.v.2013, S. T. Yang (NTU); 4♂ 13♀, Taipei City, Da'an Dist., NTU Agricultural Entomology Building, 12 m, orchard; eggs collected, 05.ii.2013 eclosion, 22.i.2013, S. T. Yang (NTU); 1♀, Taipei

City, Da'an Dist., NTU Agricultural Entomology Building, 12 m, orchard, 22.i.2013, S. T. Yang (NTU); 1♂, Taipei City, Da'an Dist., NTU Agricultural Entomology Building, 12 m, orchard, 01.iv.2013, S. T. Yang (NTU); 19♂ 11♀, Taipei City, Da'an Dist., NTU Agricultural Entomology Building, 12 m, orchard; eggs collected, 20.xii.2012 eclosion, 19.viii.2009, S. T. Yang (NTU); 7♂ 1♀, Taipei City, Da'an Dist., Fuzhoushan Park, 71 m, secondary forest, 17.iii.2013, S. T. Yang (NTU); 2♀, Taipei City, Da'an Dist., Fuzhoushan Park, 100 m, secondary forest, 17.iii.2013, S. T. Yang (NTU); LANHSU IS.: 1♂ 1♀, 17–19.VII.12985, S. Shinonaga (NSMT); 1♀, Wulai, 4.VII.1985, S. Shinonaga (NSMT); 1♂, Kenting Park, 1–2.vi.1992, R. Kano (NSMT); 1♂ 1♀, Kuatsuling, ll.VII.1985, S. Shinonaga (NSMT); 1♂, Shu Lin, 16.VIII.1987, I. Togashi (IAC); 1♂ 1♀, Santimen, 13.VII.1985, S. Shinonaga (NSMT); 1♂, Juisui, 10.XI.1985, K. Kanmiya (NSMT); 1♂ 1♀, Taipei City, 20–17.III.1965, R. Kano (NSMT); 3♂, Liuknei, 12.VII.1985, H. Shima (NSMT); 1♂ 1♀, Kuatsuling, 10–11.VII.1985, H. Shima (NSMT); 8♂ 1♀, Chihpen, 15.XI.1985, K. Kanmiya (NSMT); 5♂ 3♀, Antung, 12.XI.1985, K. Kanmiya (NSMT); 1♂ 2♀, Chihpen Hot Spring, 3–4.vi.1992, H. M. Lin (NSMT); 1♂, Jiji (Chichi), 30.iv.2006, H. Kurahashi (NSMT); 3♂, Kuantzuling, 26.v.1992, R. Kano (NSMT).

Lucilia Robineau-Desvoidy, 1830

Lucilia bazini Séguy, 1934

Materials. Mazu, Beigan Is.: 1♀, Lienchiang County, Beigan Township, 100 m, seashore, 12.v.2013, Y. C. Yu (NTU); 1♀, Kaohsiung, Shanping, 640 m, 23–31.iii.1988, R. Davidson, J. Rawlins & C. Young (CMNH); 1♂ 1♀, Kaohsiung, Shanping, 640 m, 21–30.iv.1988, R. Davidson, J. Rawlins & C. Young (CMNH).

Lucilia calviceps Bezzi, 1927

Materials. 2♂, Chihpen, 20.VII.1985, 15.XI.1985, S. Shinonaga (NSMT); 1♂, Chuchi, 120m, 14.IV.1965, R. Kano (NSMT); 1♀, Yuankan-Tsuifen, 23.VII.1985, H. Shima (NSMT).

Lucilia cuprina (Wiedemann, 1830)

Materials. 1♂, Hualien County, Xincheng Township, Qixingtan, 14 m, seashore, 09.v.2013, S. T. Yang (NTU); 1♀, Hualien County, Xincheng Township, Qixingtan, Sihba Height, 41 m, grassland, 09.v.2013, S. T. Yang (NTU); 1♀, Chiayi County, Alishan Township, Shanmei, Tanayiku, 450 m, secondary forest, 24.ii.2013, S. T. Yang (NTU); 1♀, Fenchifu, 1,400m, 8.VII.1985, S. Shinonaga (NSMT); 1♂, Kwantyling, 11.VII.1985, S. Shinonaga (NSMT); 1♀, Shanpaling, 27.x.1985, K. Kanmiya (NSMT); 1♀, Taipei, 30.III.1965, R. Kano (NSMT); 1♀, Taipei, 4.III.1981, M. Iwasa (NSMT); 1♀, Laanung, 11.VII.1985, S. Shinonaga (NSMT); 1♂ 1♀, San Palin, 1,100m, 25.X.1985, R. Kano (NSMT); 1♂, Pinton, 6.III.1981, M. Iwasa (NSMT); 2♂ 2♀, Shanpaling, 27.X.1985, K. Kanmiya (NSMT); 1♂, Kwantyling, 11.VII.1985, S. Shinonaga (NSMT); 1♀, Shanpaling, 27.x.1985, K. Kanmiya (NSMT).

Lucilia hainanensis Fan, 1965

Materials. 2♂, Nantou County, Ren'ai Township, Gaofeng, Guantou Mt. (Northeast), 20.v.2013, K. Harusawa (PCKHa); 2♂ 3♀, Pingtung County, Shizi Township, Shuangliu, 189-300 m, secondary forest, 11.v.2013, S. T. Yang (NTU); 4♀, Taitung County, Haiduan Township, Xinwulu, 390 m, secondary forest, 30.v.2013, S. T. Yang (NTU); 5♀, Taitung County, Dawu Township, Dawu, 85 m, secondary forest, 18.iv.2013, S. T. Yang (NTU); 2♀, Taitung County, Haiduan Township, Xiama, 790 m, secondary forest, 30.v.2013, S. T. Yang (NTU); 1♀, Chiayi County, Alishan Township, Shanmei, Tanayiku, 450 m, secondary forest, 24.ii.2013, S. T. Yang (NTU); 2♂ 30♀, Kaohsiung City, Liugui Dist., Tsaidie Valley, 366 m, secondary forest, 31.iii.2013, S. T. Yang (NTU); 2♂ 17♀, Pingtung County, Sangdimen Township, Sandi Village, 381 m, secondary forest, 2.iv.2013, S. T. Yang (NTU); 20♂ 10♀, Kaohsiung, Shanping, 640 m, 11-20.iv.1988, 21–30.iv.1988, 1–10.v.1988, R. Davidson, J. Rawlins & C. Young (CMNH); 1♀, Taichung, Anmashan, 2,230 m, 30.iv–4.v.1990, A. Smetana (CMNH); 1♂, Anmashan, 2,230 m, 30.iv.–4.v.1990, A. Smetaana (CMNH).

Lucilia papuensis Macquart, 1842

Materials. 1♀, Nantou County, Lugu Township, Xitou, 1156 m, secondary forest, 08.iii.2013, S. T. Yang (NTU); 1♀, Taitung County, Beinan Township, Jhihben, 209 m, secondary forest, 15.ii.2013, S. T. Yang (NTU); 1♀, Nantou County, Yuchi Township, Sun Moon Lake, 803 m, lakeside, 20.i.2013, S. T. Yang (NTU); 1♀, Taitung County, Beinan Township, Jhihben, 209 m, secondary forest, 15.ii.2013, S. T. Yang (NTU); 1♀, Juisui, 11.XI.1985, K. Kanmiya (NSMT); 3♀, Lushan, 1,000m, 24–25.VII.1985, S. Shinonaga (NSMT); 2♀, Chihpen, 15.XI.1985, K. Kanmiya (NSMT); 2♀, Tenchih, 23-04-03 N, 120-45-13 E, 1,550 m, 23.viii.1996, C. W. Young (CMNH); 1♀, Kuantzuling, 250m, 6.IV.1965, R. Kano (NSMT); 1♀, Lenai, 1,000m, 23.VII.1985, S. Shinonaga (NSMT); 1♀, Fushan B. G., 600 m, 3–6.v.2006, H. Kurahashi (NSMT); 1♀, Nanshanchi, 1.v.2006, H. Kurahashi (NSMT); 6♀, Kaohsiung, Shanping, 640 m, 1–10.v.1988, R. Davidson, J. Rawlins & C. Young (CMNH); 1♀, Kaohsiung, Shanping, 640 m, 11–20.iv.1988, J. Rawlins, C. Young, R. Davidson (CMNH); 3♀, Meifeng, 2,130 m, 10–17.vii.1993, A. Smetana (CMNH); 6♀, Taoyuen, Paling, 9–11.vi.1992, R. Kano (NSMT); 1♀, Taichung, Anmashan, 2,230 m, 30.iv.1990, A. Smetana (CMNH).

Lucilia porphyrina (Walker, 1857)

Materials. 1♂, Nantou County, Ren'ai Township, Aowanda, 21.v.2013, K. Harusawa (PCKHa); 4♀, Nantou County, Ren'ai Township, Aowanda, 18.v.2013, K. Harusawa (PCKHa); 2♀, Nantou County, Ren'ai Township, Gaofeng, Guantou Mt. (Northeast), 20.v.2013, K. Harusawa (PCKHa); 21♂ 23♀, Yilan County, Datong Township, Cilan, 394 m, secondary forest; eggs collected, 11.ii.2013 eclosion, 27.i.2013, S. T. Yang (NTU); 1♂ 3♀, Chiayi County, Alishan Township, Shanmei, Tanayiku, 450 m, secondary forest, 24.ii.2013, S. T. Yang (NTU); 3♀, Taipei City, Neihu Dist., Daluntou Mt., 352 m, secondary forest, 19.v.2013, S. T. Yang (NTU); 9♂ 46♀, Nantou County, Lugu Township, Xitou, 1156 m, secondary forest, 08.iii.2013, S. T. Yang (NTU); 19♂ 28♀, Nantou County, Lugu Township, Xitou, 1156 m, secondary forest; eggs collected, 26.iii.2013 eclosion, 08.iii.2013, S. T. Yang (NTU); 2♂ 2♀, Taipei City, Beitou Dist., Yangmingshan Anbu, 837 m, arrow bamboo forest, 31.i.2013, S. T. Yang (NTU); 8♂ 19♀, New Taipei City, Wulai Dist., Xinxian Village, 219 m, riverside, 16.iii.2013, S. T. Yang (NTU); 7♀, New Taipei City, Wulai Dist., Hsiaoi Village, Tonghou, 233 m, riverside, 27.xii.2012, S. T. Yang (NTU); 6♂ 7♀, New Taipei City, Wulai Dist., Hsiaoi Village, Tonghou, 233 m, riverside; eggs collected, 18.i.2013 eclosion, 27.xii.2012, S. T. Yang (NTU); 9♀, Taoyuan County, Fuxing Township, Baling, 640 m, secondary forest, 07.i.2013, S. T. Yang (NTU); 1♀, Nantou County, Ren'ai Township, Meifeng Farm, 2100 m, secondary forest, 24.x.2009, S. T. Yang (NTU); 1♂, Tainan City, Baihe Dist., Guanziling, Red-Leaf Park, 357 m, secondary forest, 21.iii.2013, S. T. Yang (NTU); 12♂ 9♀, New Taipei City, Wugu Dist., Guanyin Mt., Yinghan Peak, 359-611 m, secondary forest, 30.iv.2013, S. T. Yang (NTU); 2♀, Taichung City, Heping Dist., Guguan, Songhe Tribe, 700 m, secondary forest, 14.iv.2013, S. T. Yang (NTU); 1♂, Taichung City, Heping Dist., Huanshan Tribe, Ssuchiehlan Stream, 1832 m, riverbed; larvae collected, 09.ii.2013 eclosion, 26.i.2013, S. T. Yang (NTU); 1♂, Nantou County, Ren'ai Township, Qingjing Farm, 1911 m, secondary forest, 16.iv.2013, S. T. Yang (NTU); 2♀, New Taipei City, Xindian Dist., Zhitan Dam, 57 m, riverside, 27.xii.2012, S. T. Yang (NTU); 7♀, Pingtung County, Shizi Township, Shuangliu, 352 m, secondary forest, 11.v.2013, S. T. Yang (NTU); 34♂ 35♀, Yilan County, Su'ao Township, 28 m, rural area; eggs collected, 7.iii.2013 eclosion, 16.ii.2013, S. T. Yang (NTU); 11♂ 12♀, Yilan County, Nan'ao Township, 22 m, secondary forest; eggs collected, 7.iii.2013 eclosion, 16.ii.2013, S. T. Yang (NTU); 2♀, Yilan County, Nan'ao Township, 22 m, secondary forest, 16.ii.2013, S. T. Yang (NTU); 4♀, New Taipei City, Wulai Dist., Zhongzhi, 109 m, riverside,27.xii.2012, S. T. Yang (NTU); 5♂ 24♀, New Taipei City, Wulai Dist., Zhongzhi, 109 m, riverside; eggs collected, 18.i.2013 eclosion,27.xii.2012, S. T. Yang (NTU); 10♀, Chiayi County, Alishan Township, Leye Village, Dinghu, 1657 m, secondary forest, 23.ii.2013, S. T. Yang (NTU); 21♂ 25♀, Chiayi County, Alishan Township, Leye Village, Dinghu, 1657 m, secondary forest; eggs collected, 18.iii.2013 eclosion, 23.ii.2013, S. T. Yang (NTU); 14♂ 19♀, Taipei City, Wenshan Dist., Saint's Alp, 144 m, secondary forest; eggs collected, 08.i.2013 eclosion, 21.xii.2013, S. T. Yang (NTU); 2♂ 19♀, Taipei City, Wenshan Dist., Saint's Alp, 144 m, secondary forest, 21.xii.2013, S. T. Yang (NTU); 1♀, Taipei City, Wenshan Dist., Saint's Alp, 144 m, secondary forest, 20.xii.2013, S. T. Yang (NTU); 2♀, New Taipei City, Ruifang Dist., Jinguashih, 360 m, house, 05.ii.2013, T. H. Wu (NTU); 9♂ 22♀, Taipei City, Da'an Dist., NTU Agricultural Entomology Building, 12 m, orchard; eggs collected, 05.ii.2013 eclosion,22.i.2013, S. T. Yang (NTU); 1♂ 20♀, Yilan County, Toucheng Township, Beiguan, 34 m, seashore, 04.iv.2013, S. T. Yang (NTU); 1♂ 9♀, New Taipei City, Shimen Dist., Linshan Cape, 20 m, seashore, 29.xii.2012, S. T. Yang (NTU); 13♂ 17♀, New Taipei City, Shimen Dist., Linshan Cape, 20 m, seashore; eggs collected, 21.i.2013 eclosion, 29.xii.2012, S. T. Yang (NTU); 1♂ 17♀, Yilan County, Toucheng Township, Yingzi Mt., 936 m, bush, 27.v.2013, S. T. Yang (NTU); 1♀, Taitung County, Haiduan Township, Xiama, 790 m, secondary forest, 30.v.2013, S. T. Yang (NTU); Mazu, Beigan Is.: 1♂ 1♀, Lienchiang County, Beigan Township, 100 m, seashore, 12.v.2013, Y. C. Yu (NTU); 9♂ 10♀, New Taipei City, Pingxi Dist., Lingjiao, 213 m, secondary forest; eggs collected, 19.iii.2013 eclosion, 28.ii.2013, S. T. Yang (NTU); 2♂ 15♀, Chiayi County, Alishan Township, Leye Village, Zhunghu, 1383 m, secondary forest, 23.ii.2013, S. T. Yang (NTU); 1♂, Taitung County, Beinan Township, Jhihben, 209 m, secondary forest, 15.ii.2013, S. T. Yang (NTU); 1♂, New Taipei City, Shiding Dist., Tanyao, 300 m, lakeshore, 2.ii.2013, S. T. Yang (NTU); 2♂ 3♀, Taipei City, Da'an Dist., Fuzhoushan Park, 71 m, secondary forest, 17.iii.2013, S. T. Yang (NTU); 2♂ 9♀, New Taipei City, Ruifang Dist., Jinguashih, Chahu Mt., 416 m, bush, 01.ii.2013, S. T. Yang (NTU); 21♀, New Taipei City, Ruifang Dist., Jinguashih, Chahu Mt., 343 m, bush, 01.ii.2013, S. T. Yang (NTU); 15♂ 36♀, New Taipei City, Ruifang Dist., Jinguashih, Chahu Mt., 343 m,bush; eggs collected, 19.ii.2013 eclosion,01.ii.2013, S. T. Yang (NTU); 30♂ 28♀, Taipei City, Wenshan Dist., Saint's Alp, 144 m, secondary forest; eggs collected, 08.i.2013 eclosion, 20.xii.2013, S. T. Yang (NTU); 20♂ 17♀, Yilan County, Datong Township, 144 m, secondary forest; eggs collected, 11.ii.2013 eclosion, 27.i.2013, S. T. Yang (NTU); 1♀, Hualien County, Guangfu Township, 143 m,plain,16.ii.2013, S. T. Yang (NTU); 3♂ 8♀, Chiayi County, Zhuqi Township, Shizhao, 774 m, secondary forest; eggs collected, 18.iii.2013 eclosion, 23.ii.2013, S. T. Yang (NTU); 4♀, New Taipei City, Gongliao Dist., Shuangyu, 16 m, secondary forest; eggs collected, 19.iii.2013 eclosion, 28.ii.2013, S. T. Yang (NTU); 2♀, Chiayi County, Alishan Township, Dingshizhao, 1446 m, secondary forest, 24.ii.2013, S. T. Yang (NTU); 6♂ 10♀, New Taipei City, Sanzhi Dist., Beixinzhuang, 327 m, secondary forest, 31.i.2013, S. T. Yang (NTU); 9♀, New Taipei City, Gongliao Dist., Santiago Cape, 97 m, bush, 28.ii.2013, S. T. Yang (NTU); 21♂ 18♀, Yilan County, Su'ao Township, Nanfang'ao, 336 m, seashore; eggs collected, 7.iii.2013 eclosion, 16.ii.2013, S. T. Yang (NTU); 1♂ 2♀, New Taipei City, Xindian Dist., Qingtan, Sishifen, 419 m, secondary forest, 07.ii.2013, S. T. Yang (NTU); 16♂ 22♀, Chiayi County, Fanlu Township,

Xiding, 1247 m, secondary forest; eggs collected, 18.iii.2013 eclosion, 23.ii.2013, S. T. Yang (NTU); 6♂ 2♀, Hualien County, Xiulin Township, Chongde, 73 m, seashore, 16.ii.2013, S. T. Yang (NTU); 4♀, Hualien County, Xiulin Township, Fushi, Changuang Temple, 120 m, monsoon rainforest, 09.v.2013, S. T. Yang (NTU); 1♂ 4♀, nr Huanshan, 2.v.2006, H. Kurahashi (NSMT); 8♂ 14♀, Fushan B. G., 600 m, 3-6.v.2006, H. Kurahashi (NSMT); 3♂ 4♀, Nanshanchi, 1.v.2006, H. Kurahashi (NSMT); 1♂, Kaohsiung, Shanping, 640 m, 21-30.iv.1988, C. Young, R. Davidson & J. Rawlins (CMNH); 1♂ 7♀, Kaohsiung, Shanping, 640 m, 21-30.iv.1988, 11-20.v.1988, R. Davidson, J. Rawlins & C. Young (CMNH); 3♂ 5♀, Hsito, 1,000 m, 1.v.2006, H. Kurahashi (NSMT); 2♂ 6♀, Taichung, Anmashan, 2,230 m, 30.iv–4.v.1990, A. Smetana (CMNH); 2♂, Meifend, 2,130 m, 10–17.vii.1993, A. Smetana (CMNH); 1♂ 2♀, Kaoshiung, Shanping, 640 m, 11–20.iv.1988, J. Rawlins, C. Young and R. Davidson (CMNH); 1♀, Kuanshan trail at Kuanshanchi River, 2,400 m, 20–23.vii.1993, A. Smetana (CMNH); 1♂, Anmashan, 2,230 m, 30.iv.–4.v.1990, A. Smetaana (CMNH); 2♂ 2♀, Ten-chih, 23-04-03N, 120-45-13E, 1,550 m, 23.viii.1996, C. W. Young (CMNH); 1♀, Puri, 27.III.1981, M. Iwasa (NSMT); 2♂ 1♀, Hohuan-shan, Tsuifeng, 2,400m, 23-24.VII.1985, S. Shinonaga (NSMT); 1♂, Tsuifeng, 19.vi.1970, H. Kurahashi (NSMT); 3♂ 1♀, Fenchifu, 1,400m,12.IV.1965, 8.VII.1985, 20.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 1♀, Hohuan-shan, Yuankang, 2,700m, 23.VII.1985, S. Shinonaga (NSMT); 2♀, Huanshan, Chichiawanchi, 4.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 7♀, Alishan, 2,400m, 9-10.VII.1985, H. M. Lin & H. Shima (NSMT); 3♀, Mt. Yangming shan, 450m, 28.III.1965, 8.VII.1985, R. Kano & S. Shinonaga (NSMT); 1♀, Chiapaotai, 4.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 3♂ 15♀, Lala shan, 1,400–1,600m, 25-26.X.1985, R. Kano & H. M. Lin (NSMT); 1♀, Puri, Rushan, 26.III.1981, M. Iwasa (NSMT); 1♂ 4♀, Shanpaling, 26.X.1985, K. Kanmiya (NSMT); 1♀, Taiton, Tsupun, 21.III.1981, M. Iwasa (NSMT); 1♀, Paling, Taoyuen, 9–11.vi.1992, R. Kano (NSMT); 1♂ 8♀, Alishan, 28–29.v.1992, R. Kano (NSMT); 2♂ 17♀, Chung-Hsien University, Huei-sun Forest, 21.v.1992, R. Kano (NSMT); 3♂ 4♀, Puli, Nanshanhsi, 23–24.v.1992, H. M. Lin (NSMT); 5♂ 24♀, Taoyuen, Paling, 9–11.vi.1992, R. Kano (NSMT); 1♀, Kenting Park, 1–2.vi.1992, R. Kano (NSMT); 2♂ 6♀, Taoyuen, Lalashan, 12.vi.1992, H. M. Lin (NSMT); 1♀, Tattaka, 1.VI.1965, T. Shirozu (NSMT).

Lucilia sinensis Aubertin, 1933

Materials. 1♀, Nanzan-kei, 27.V.1965, T. Shirozu (NSMT); 1♂, Hohuan-shan, Yuankang, 2,700m, 23.VII.1985, S. Shinonaga (NSMT); 2♀, Kenting Park, 17.X.1985, K. Kanmiya (NSMT); 1♀, Mt. Yuishan, 2,700-3,500m, 6-7.VII.1985, S. Shinonaga (NSMT).

Lucilia sericata (Meigen, 1826)

Materials. 6♂ 4♀, Taichung City, Heping Dist., Huanshan Tribe, Ssuchiehlan Stream, 1832 m, riverbed; larvae collected, 09.ii.2013 eclosion, 26.i.2013, S. T. Yang (NTU); 1♀, Fenchifu, 1,370m, 11.IV.1965, R. Kano (NSMT); 1♂, Huanshan, Chichiawanchi, 6.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 1♂, Taipei City, 30.III.1965, S. Miyamoto (NSMT).

Lucilia taiwanica Kurahashi & Kano, 1995

Materials. 2♂, Nantou County, Ren'ai Township, Aowanda, 18.v.2013, K. Harusawa (PCKHa); 2♂, Nantou County, Ren'ai Township, Songgang, 2049 m, secondary forest, 16.iv.2013, S. T. Yang (NTU); 1♀, Nantou County, Ren'ai Township, Meifeng Farm, 2100 m, secondary forest, 24.x.2009, S. T. Yang (NTU); 1♀, Nantou County, Lugu Township, Xitou, 1156 m, secondary forest, 08.iii.2013, S. T. Yang (NTU); 1♀, New Taipei City, Wugu Dist., Guanyin Mt., Yinghan Peak, 359–611 m, secondary forest, 30.iv.2013, S. T. Yang (NTU); 4♀, Fushan B. G., 600 m, 3–6.v.2006, H. Kurahashi (NSMT); 2♀, Ten-chih, 23-04-03 N, 120-45-13 E, 1,550 m, 23.viii.1996, C. W. Young (CMNH).

Subfamily PHUMOSIINAE

Caiusa Surcouf, 1919

Caiusa indica Surcouf, 1914

Materials. 1♂, Shanping, 640 m, 21-30.iv.1988, C. Young, R. Davidson and J. Rawlins (CMNH).

Caiusa testacea Senior-White, 1923

Note. See to Hennig (1941: 180).

Caiusa sp.

Materials. 7♂ 4♀, New Taipei City, Xindian Dist., Sikanshui, 500 m, secondary forest, 22.ii.2013, Y. R. Huang (NTU); 1♀, New Taipei City, Xindian Dist., Sikanshui, 500 m, secondary forest, 28.ii.2013, Y. R. Huang (NTU); 2♂, Taitung County, Haiduan Township, Xiama, 790 m, secondary forest, 30.v.2013, S. T. Yang (NTU).

Subfamily POLLENIINAE

Dexopollenia Townsend, 1917

Dexopollenia flava (Aldrich, 1930)

Materials. 1♂, Taichung, Pilushi, 2,200 m, 22-23.v.1988, R. Davidson, C. Young & J. Rawlins (CMNH); 1♂, Fanshan, 1,650 m, 5.xi.1985, M. Iwasa (IDD).

Dexopollenia luteola (Villeneuve, 1927)

Note. See to James (1977: 532).

**Dexopollenia maculata* Villeneuve, 1933

Materials. 1♂, Nantou County, Hohuan-shan, Tayulin, 2700 m, 23.vii.1985, S. Shinonaga (NSMT).

Subfamily CHRYSOMYINAE

Tribe Chrysomyini

Achoetandrus Bezzi, 1927

Achoetandrus rufifacies (Macquart, 1843)

Materials. Orchid Is.: 28♂ 59♀, Taitung County, Lanyu Township, Hongtou, Weather Station, 231 m, tropical rainforest, 01.vi.2013, S. T. Yang (NTU); Orchid Is.: 1♂ 9♀, Taitung County, Lanyu Township, Hongtou, 15 m, seashore, 01.vi.2013, S. T. Yang (NTU); Orchid Is.: 8♂ 9♀, Taitung County, Lanyu Township, Longmen Harbor, 5 m, seashore, 01.vi.2013, S. T. Yang (NTU); Orchid Is.: 4♂ 1♀, Taitung County, Lanyu Township, Dongqing, Qingrendong, 18 m, seashore, 01.vi.2013, S. T. Yang (NTU); Orchid Is.: 1♀, Taitung County, Lanyu Township, Zhong'ai Bridge, 53 m, tropical rainforest, 01.vi.2013, S. T. Yang (NTU); 10♂ 35♀, Chiayi County, Alishan Township, Shanmei, Tanayiku, 450 m, secondary forest, 24.ii.2013, S. T. Yang (NTU); 1♂ 2♀, Kaohsiung City, Jiaxian Dist., Jiaxian, 278 m, secondary forest, 12.v.2013, S. T. Yang (NTU); 4♂ 18♀, Taitung County, Haiduan Township, Xiama, 790 m, secondary forest, 30.v.2013, S. T. Yang (NTU); 3♂ 3♀, Taitung County, Haiduan Township, Xinwulu, 390 m, secondary forest, 30.v.2013, S. T. Yang (NTU); 2♂ 12♀, Taitung County, Luye Township, Ruiyuan, 198 m, farmland, 30.v.2013, S. T. Yang (NTU); 1♂, Taitung County, Beinan Township, Jhihben, 209 m, secondary forest, 15.ii.2013, S. T. Yang (NTU); 4♀, Taitung County, Dawu Township, Dawu, 85 m, secondary forest, 18.iv.2013, S. T. Yang (NTU); 7♂ 25♀, Hualien County, Xincheng Township, Qixingtan, Sihba Height, 41 m, grassland, 09.v.2013, S. T. Yang (NTU); 2♀, Hualien County, Xincheng Township, Qixingtan, 14 m, seashore, 09.v.2013, S. T. Yang (NTU); 1♀, Hualien County, Xiulin Township, Fushi, Changuang Temple, 120 m, monsoon rainforest, 09.v.2013, S. T. Yang (NTU); 2♀, Hualien County, Shoufeng Township, Pinghe, 41 m, plain, 16.ii.2013, S. T. Yang (NTU); 1♀, Hualien County, Yuli Township, 133 m, plain, 16.ii.2013, S. T. Yang (NTU); 4♂ 13♀, Pingtung County, Sangdimen Township, Sandi Village, 381 m, secondary forest, 2.iv.2013, S. T. Yang (NTU); 2♂, Pingtung County, Manzhou Township, Qikong Waterfall, 40-125 m, secondary forest, 24.i.2013, S. T. Yang (NTU); Liuqiu Is.: 2♂ 21♀, Pingtung County, Liuqiu Township, Geban Bay, 10 m, seashore, 04.v.2013, S. T. Yang (NTU); Liuqiu Is.: 1♂ 3♀, Pingtung County, Liuqiu Township, Shanfu, 25 m, seashore, 04.v.2013, S. T. Yang (NTU); 1♀, Pingtung County, Shizi Township, Shuangliu, 352 m, secondary forest, 19.v.2013, S. T. Yang (NTU); 2♀, Taipei City, Da'an Dist., Fuzhoushan Park, 71 m, secondary forest, 17.iii.2013, S. T. Yang (NTU); 7♀, Taipei City, Da'an Dist., Fuzhoushan Park, 100 m, secondary forest, 17.iii.2013, S. T. Yang (NTU); 8♂ 20♀, Taipei City, Da'an Dist., NTU Agricultural Entomology Building, 12 m, orchard; eggs collected, 05.ii.2013 eclosion, 19.viii.2009, S. T. Yang (NTU); 1♀, Taipei City, Wenshan Dist., Saint's Alp, 144 m, secondary forest, 21.xii.2012, S. T. Yang (NTU); 3♀, Taipei City, Neihu Dist., Daluntou Mt., 352 m, secondary forest, 19.v.2013, S. T. Yang (NTU); 1♀, Yilan County, Toucheng Township, Beiguan, 34 m, seashore, 04.iv.2013, S. T. Yang (NTU); 1♀, Kaohsiung, Shanping, 640 m, 21–30.iv.1988, C. Young, R. Davidson & J. Rawlins (CMNH); 1♂ 3♀, Puli, Nanshanhsi, 23-24.v.1992, H. M. Lin (NSMT); 2♂ 2♀, Taitung, Chihpen Hot Spring, 3-4.vi.1992, H. M. Lin (NSMT); 1♂ 4♀, Fushan B. G., 600 m, 3–6.v.2006, H. Kurahashi (NSMT); 1♂ 1♀, Chihpen, 15.XI.1985, K. Kanmiya (NSMT); 1♂ 5♀, Antung, 12.XI.1985, K. Kanmiya (NSMT); 2♀, Tainan, Kuantzling, 26.v.1992, R. Kano (NSMT); 1♀, Nanshanchi, 1.v.2006, H. Kurahashi (NSMT); 5♀, Liuknei, 12.VII.1985, S. Shinonaga (NSMT); 1♂ 3♀, Kenting Park, 18-19.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 2♂ 1♀, Chihpen, 15.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 2♂ 3♀, Santimen, 13.VII.1985, S. Shinonaga (NSMT); 1♀, Kuan-zu-ling, 250m, 6.IV.1965, R. Kano (NSMT); 1♀, Chiai, 7.IV.1965, C. M. Yoshimoto & B. D. Parkins (NSMT); 2♂ 8♀, Antung, 12.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT).

Achoetandrus villeneuvi **(Patton, 1922)**

Materials. 1♂ 5♀, Taitung County, Beinan Township, Jhihben, 209 m, secondary forest, 15.ii.2013, S. T. Yang (NTU); 2♀, Hualien County, Xiulin Township, Fushi, Changuang Temple, 120 m, monsoon rainforest,09.v.2013, S. T. Yang (NTU); 1♀, Hualien County, Wanrong Township, Wanrong, 1000 m, secondary forest, 08.iv.2013, W. H. Lin (NTU); 2♀, Chiayi County, Alishan Township, Shanmei, Tanayiku, 450 m, secondary forest, 24.ii.2013, S. T. Yang (NTU); 4♀, Taitung County, Haiduan Township, Xiama, 790 m, secondary forest, 30.v.2013, S. T. Yang (NTU); 2♀, Taipei City, Neihu Dist., Daluntou Mt., 352 m, secondary forest, 19.v.2013, S. T. Yang (NTU); 2♂, Luchan, 1,000 m, 24-25.vii.1985, S. Shinonaga (NSMT); 6♂ 2♀, Fushan B. G., 600 m, 3–6.v.2006, H. Kurahashi (NSMT); 2♂ 4♀, Kaohsiung, Shanping, 640 m, 21-30.iv.1988, C. Young, R. Davidson & J. Rawlins (CMNH); 1♂, Taoyuen, Paling, 9-11.vi.1992, R. Kano (NSMT); 1♂ 1♀, Nanshanchi, 1.v.2006, H. Kurahashi (NSMT); 1♂, Ten-chih, 23-04-03 N, 120-45-13 E, 1,550 m, 23.viii.1996, C. W. Young (CMNH).

Ceylonomyia Fan, 1965

**Ceylonomyia nigripes* (Aubertin, 1932)

Materials. Orchid Is.: 10♂ 16♀, Taitung County, Lanyu Township, Hongtou, Weather Station, 231 m, tropical rainforest, 01.vi.2013, S. T. Yang (NTU); Orchid Is.: 1♂ 1♀, Taitung County, Lanyu Township, Longmen Harbor, 5 m, seashore, 01.vi.2013, S. T. Yang (NTU); Orchid Is.: 1♀, Taitung County, Lanyu Township, Hongtou, 15 m, seashore, 01.vi.2013, S. T. Yang (NTU); 1♀, Hualien County, Xiulin Township, Fushi, Changuang Temple, 120 m, monsoon rainforest, 09.v.2013, S. T. Yang (NTU); 1♀, Kaohsiung City, Jiaxian Dist., Jiaxian, 278 m, secondary forest, 12.v.2013, S. T. Yang (NTU); 1♂, Fenchifu, 20.XI.1985, K. Kanmiya (NSMT); 12♂ 21♀, Kenting Park, 18–19.XI.1985, K. Kanmiya (NSMT); 2♂, Antung, 12.XI.1985, K. Kanmiya (NSMT); LANHSU IS.: 1♂ 1♀, 17–19.VII.1985, S. Shinonaga (NSMT); 1♂ 5♀, Santimen, 13.VII.1985, S. Shinonaga (NSMT); 10♂ 3♀, Liuknei, 12.VII.1985, S. Shinonaga (NSMT); 1♀, Kenting Park, 18–19.xi.1985, K. Kanmiya (NSMT); 3♀, Fushan B. G., 600 m, 3–6.v.2006, H. Kurahashi (NSMT); 1♂, Kaohsiung, Shanping, 640 m, 21–30.iv.1988, C. Young, R. Davidson & J. Rawlins (CMNH); 1♀, Juisui, 10.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 1♀, Juisui, 11.XI.1985, K. Kanmiya (NSMT); 3♂, Kenting Park, 18-19.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 1♀, Kenting Park, 18-19.xi.1985, K. Kanmiya (NSMT).

Chrysomya Robineau-Desvoidy, 1830

Chrysomya bezziana Villeneuve, 1914

Note. See to Fan (1992: 544).

Chrysomya megacephala (Fabricius, 1794)

Materials. 65♂ 87♀, Hualien County, Xincheng Township, Qixingtan, Sihba Height, 41 m, grassland, 09.v.2013, S. T. Yang (NTU); 4♂ 6♀, Hualien County, Xincheng Township, Qixingtan, 14 m, seashore, 09.v.2013, S. T. Yang (NTU); 1♀, Hualien County, Xiulin Township, Taroko, 81 m, canyon, 09.v.2013, S. T. Yang (NTU); 1♀, Hualien County, Guangfu Township, 143 m, plain,16.ii.2013, S. T. Yang (NTU); 2♂ 20♀, Hualien County, Shoufeng Township, Pinghe, 41 m, plain, 16.ii.2013, S. T. Yang (NTU); 2♂ 5♀, Taipei City, Neihu Dist., Daluntou Mt., 352 m, secondary forest, 19.v.2013, S. T. Yang (NTU); 1♂ 19♀, Taipei City, Da'an Dist., Fuzhoushan Park, 71 m, secondary forest, 17.iii.2013, S. T. Yang (NTU); 1♂ 1♀, Taipei City, Da'an Dist., NTU Agricultural Entomology Building, 12 m, orchard, 22.i.2013, S. T. Yang (NTU); 1♀, New Taipei City, Shimen Dist., Linshan Cape, 4 m, seashore, 21.xii.2012, S. T. Yang (NTU); 12♀, New Taipei City, Shimen Dist., Linshan Cape, 4 m, seashore, 29.xii.2012, S. T. Yang (NTU); 1♂, New Taipei City, Wulai Dist., Hsiaoi Village, Tonghou, 233 m, riverside, 27.xii.2012, S. T. Yang (NTU); 1♀, New Taipei City, Xindian Dist., Zhitan Dam, 57 m, riverside, 27.xii.2012, S. T. Yang (NTU); 1♂ 20♀, Taitung County, Luye Township, Ruiyuan, 198 m, farmland, 30.v.2013, S. T. Yang (NTU); 1♀, Taitung County, Beinan Township, Jhihben, 209 m, secondary forest, 15.ii.2013, S. T. Yang (NTU); 3♂ 31♀, Taitung County, Dawu Township, Dawu, 85 m, secondary forest, 18.iv.2013, S. T. Yang (NTU); 7♂ 3♀, Taitung County, Haiduan Township, Xiama, 790 m, secondary forest, 30.v.2013, S. T. Yang (NTU); 1♂, Taitung County, Haiduan Township, Xinwulu, 390 m, secondary forest, 30.v.2013, S. T. Yang (NTU); Orchid Is.: 13♂ 59♀, Taitung County, Lanyu Township, Hongtou, Weather Station, 231 m, tropical rainforest, 01.vi.2013, S. T. Yang (NTU); Orchid Is.: 3♂ 18♀, Taitung County, Lanyu Township, Hongtou, 15 m, seashore, 01.vi.2013, S. T. Yang (NTU); Orchid Is.: 2♀, Taitung County, Lanyu Township, Yeyou, 8 m, seashore, 31.v.2013, S. T. Yang (NTU); Orchid Is.: 2♀, Taitung County, Lanyu Township, Longmen Harbor, 5 m, seashore, 01.vi.2013, S. T. Yang (NTU); Mazu, Beigan Is.: 4♂ 2♀, Lienchiang County, Beigan Township, 100 m, seashore, 12.v.2013, Y. C. Yu (NTU); Liuqiu Is.: 6♂ 33♀, Pingtung County, Liuqiu Township, Shanfu, 25 m, seashore, 04.v.2013, S. T. Yang (NTU); Liuqiu Is.: 6♂ 5♀, Pingtung County, Liuqiu Township, Shanfu, 25 m, seashore; eggs collected, 17.v.2013 eclosion, 04.v.2013, S. T. Yang (NTU); Liuqiu Is.: 6♂ 7♀, Pingtung County, Liuqiu Township, Dafu Fishing Port, 8 m, seashore; eggs collected, 17.v.2013 eclosion, 04.v.2013, S. T. Yang (NTU); Liuqiu Is.: 1♂, Pingtung County, Liuqiu Township, Dafu Fishing Port, 8 m, seashore, 04.v.2013, S. T. Yang (NTU); Liuqiu Is.: 1♂ 4♀, Pingtung County, Liuqiu Township, White Lighthouse, 82 m, secondary forest, 04.v.2013, S. T. Yang (NTU); Liuqiu Is.: 2♂ 115♀, Pingtung County, Liuqiu Township, Geban Bay, 10 m, seashore, 04.v.2013, S. T. Yang (NTU); 5♂ 14♀, Pingtung County, Manzhou Township, Qikong Waterfall, 40-125 m, secondary forest, 24.i.2013, S. T. Yang (NTU); 1♂ 16♀, Pingtung County, Sangdimen Township, Sandi Village, 381 m, secondary forest, 02.iv.2013, S. T. Yang (NTU); 3♂ 3♀, Kaohsiung City, Jiaxian Dist., Jiaxian, 278 m, secondary forest, 12.v.2013, S. T. Yang (NTU); 1♂ 2♀, Tainan City, Baihe Dist., Guanziling, Lingding Park, 322 m, secondary forest, 21.iii.2013, S. T. Yang (NTU); 1♂ 2♀, Chiayi County, Alishan Township, Shanmei, Tanayiku, 450 m, secondary forest, 24.ii.2013,

S. T. Yang (NTU); 1♂ 3♀, Yilan County, Toucheng Township, Beiguan, 34 m, seashore, 04.iv.2013, S. T. Yang (NTU); 5♀, Fenchifu, 20.XI.1985, K. Kanmiya (NSMT); 2♂, Santimen, 13.VII.1985, S. Shinonaga (NSMT); 1♂, Hori, 2.VII.1965, T. Shirozu (NSMT); 1♂ 1♀, Honbukei, 2.V.1965, T. Shirozu (NSMT); 1♀, Chu-ch'i, 120m, 13.IV.1965, R. Kano (NSMT); 4♂ 5♀, Chichiwanchi, Huanshan, 5-6.XI.1985, K. Kanmiya (NSMT); 1♀, Chihpen, 15.XI.1985, K. Kanmiya (NSMT); 1♀, San Palin, 1,100m, 25.X.1985, R. Kano (NSMT); 2♂ 8♀, Antung, 12.XI.1985, K. Kanmiya (NSMT); 2♂, Yangmin-shan, 28.X.1985, K. Kanmiya (NSMT); 2♀, Juisui, 10.XI.1985, K. Kanmiya (NSMT); LAN HSU IS.: 1♂, Yehyin, 7.VII.1971, K. Mizusawa (NSMT); 1♀, Wulai, 4.VII.1985, S. Shinonaga (NSMT); LANHSU IS.: 4♂ 6♀, 17–19.VII.1985, S. Shinonaga (NSMT); 2♂ 2♀, Liuknei, 12.VII.1985, S. Shinonaga (NSMT); 2♂ 2♀, Fenchifu, 1,400m, 8.VII.1985, S. Shinonaga (NSMT); 3♂, Kenting Park, 15.VII.1985, S. Shinonaga (NSMT); 1♂, Taipei, 30.III.1965, R. Kano (NSMT); 2♂, Hohuan-sahn, Tsuifeng, 2,400m, 23–24.VII.1985, S. Shinonaga (NSMT); 1♂ 3♀, Antung, 12.XI.1985, K. Kanmiya (NSMT); 2♂, Kwantyling, 11.VII.1985, S. Shinonaga (NSMT); 1♀, Taihoku, 18.vii.1927, F. C. Hadden (BPBM); 2♀, Taoyuen, Paling, 9-11.vi.1992, R. Kano (NSMT); 3♀, Kenting Park, 1–2.vi.1992, H. M. Lin (NSMT); 1♂ 2♀, Chung-Hsien University, Huei-sun Forest, 21.v.1992, R. Kano (NSMT); 6♂ 18♀, Ten-chih, 23-04-03 N, 120-45-13 E, 1,550 m, 23.viii.1996, C. W. Young (CMNH); 1♂, Kuantzuling, 26.v.1992, R. Kano (NSMT); 5♂ 12♀, Kaohsiung, Shanping, 640 m, 21–30.iv.1988, C. Young, R. Davidson & J. Rawlins (CMNH); 1♀, Taihoku, 18.vii.1927, F. C. Hadden (BPBM); 1♂ 1♀, Fushan B. G., 600 m, 3–6.v.2006, H. Kurahashi (NSMT); 1♂ 1♀, Puli, Nanshahsi, 23–24.v.1992, H. M. Lin (NSMT).

Chrysomya pinguis **(Walker, 1858)**

Materials. 1♂ 1♀, Nantou County, Ren'ai Township, Aowanda, 18.v.2013, K. Harusawa (PCKHa); 1♀, Nantou County, Ren'ai Township, Gaofeng, Guantou Mt. (Northeast), 20.v.2013, K. Harusawa (PCKHa); 41♂ 119♀, Taitung County, Beinan Township, Jhihben, 209 m, secondary forest, 15.ii.2013, S. T. Yang (NTU); 2♂ 18♀, Taitung County, Haiduan Township, Xiama, 790 m, secondary forest, 30.v.2013, S. T. Yang (NTU); 1♀, New Taipei City, Gongliao Dist., Santiago Cape, 97 m, bushes, 28.ii.2013, S. T. Yang (NTU); 1♂ 7♀, Taipei City, Da'an Dist., Fuzhoushan Park, 71 m, secondary forest, 17.iii.2013, S. T. Yang (NTU); 1♀, Yilan County, Toucheng Township, Beiguan, 34 m, seashore, 04.iv.2013, S. T. Yang (NTU); 1♀, Hualien County, Xiulin Township, Taroko, 81 m, canyon, 09.v.2013, S. T. Yang (NTU); 3♀, Hualien County, Xiulin Township, Fushi, Chanɡuang Temple, 120 m, monsoon rainforest, 09.v.2013, S. T. Yang (NTU); Mazu, Beigan Is.: 1♂, Lienchiang County, Beigan Township, 100 m, seashore, 12.v.2013, Y. C. Yu (NTU); 3♀, New Taipei City, Xindian Dist., Qingtan, Sishifen, 419 m, secondary forest, 07.ii.2013, S. T. Yang (NTU); 44♂ 44♀, Taipei City, Neihu Dist., Daluntou Mt., 352 m, secondary forest, 19.v.2013, S. T. Yang (NTU); 1♂, Pingtung County, Manzhou Township, Qikong Waterfall, 40–125 m, secondary forest, 24.i.2013, S. T. Yang (NTU); 4♀, Pingtung County, Shizi Township, Shuangliu, 189-300 m, secondary forest, 11.v.2013, S. T. Yang (NTU); 27♂ 24♀, Nantou County, Ren'ai Township, Meifeng Farm, 2100 m, secondary forest; eggs collected, 23.i.2013 eclosion, 28.viii.2011, Y. J. Liu (NTU); 9♂ 19♀, Nantou County, Lugu Township, Xitou, 1156 m, secondary forest, 08.iii.2013, S. T. Yang (NTU); 1♂ 5♀, Nantou County, Ren'ai Township, Songgang, 2049 m, secondary forest, 16.iv.2013, S. T. Yang (NTU); 2♀, New Taipei City, Wugu Dist., Guanyin Mt., Yinghan Peak, 359-611 m, secondary forest, 30.iv.2013, S. T. Yang (NTU); 4♂ 9♀, Taichung City, Heping Dist., Huanshan Tribe, Ssuchiehlan Stream, 1832 m, riverbed; larvae collected, 09.ii.2013 eclosion, 26.i.2013, S. T. Yang (NTU); 39♂ 94♀, New Taipei City, Wulai Dist., Xinxian Village, 219 m, riverside, 16.iii.2013, S. T. Yang (NTU); 3♂ 16♀, Taipei City, Wenshan Dist., Saint's Alp, 144 m, secondary forest, 21.xii.2012, S. T. Yang (NTU); 5♂ 1♀, Yilan County, Toucheng Township, Yingzi Mt., 936 m, bush, 27.v.2013, S. T. Yang (NTU); 4♀, Chiayi County, Alishan Township, Shanmei, Tanayiku, 450 m, secondary forest, 24.ii.2013, S. T. Yang (NTU); 1♀, New Taipei City, Shimen Dist., Linshan Cape, 20 m, seashore, 21.xii.2012, S. T. Yang (NTU); 7♂ 12♀, New Taipei City, Wulai Dist., Hsiaoi Village, Tonghou, 233 m, riverside, 27.xii.2012, S. T. Yang (NTU); 4♀, New Taipei City, Xindian Dist., Zhitan Dam, 57 m, riverside, 27.xii.2012, S. T. Yang (NTU); 1♀, New Taipei City, Wulai Dist., Zhongzhi, 109 m, riverside, 27.xii.2012, S. T. Yang (NTU); 2♂ 6♀, New Taipei City, Ruifang Dist., Jinguashih, Chahu Mt., 343 m, bush, 01.ii.2013, S. T. Yang (NTU); 1♂ 11♀, New Taipei City, Ruifang Dist., Jinguashih, Chahu Mt., 416 m, bush, 01.ii.2013, S. T. Yang (NTU); 1♀, New Taipei City, Ruifang Dist., Jinguashih, 360 m, house, 05.ii.2013, T. H. Wu (NTU); 1♂, San Palin, 1,100m, 25.X.1985, R. Kano (NSMT); 3♂ 2♀, Lalashan, Taoyuen, 12.vi.1992, H. M. Lin (NSMT); 2♀, Chihpen, 15.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 6♂ 5♀, Huanshan, Chichiawanchi, 5-6.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 1♂, Lafu, 350m, 27.X.1985, R. Kano (NSMT); 2♂ 7♀, Fenchifu, 20.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 2♂ 6♀, Lala shan, 1,400-1,600m, 25–26.X.1985, R. Kano & H. M. Lin (NSMT); 2♂, Antung, 12.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 3♂ 2♀, Hohuan-shan, Yuankang, 2,700m, 23.VII.1985, S. Shinonaga (NSMT); 2♀, Chiapaotai, 4.XI.1985, K. Kanmiya, R. Kano & H. M. Lin (NSMT); 1♂ 1♀, Mt. Yang-ming Shan, 450m, 28.III.1965, R. Kano (NSMT); 1♂ 1♀, Lushan, 1,000m, 24–25.VII.1985, S. Shinonaga (NSMT); 1♀, Taichung, Pilushi, 2,200 m, 22-23.v.1988, R. Davidson, C. Young & J. Rawlins (CMNH); 4♀, Taitung, Chihpen Hot Spring, 3–4.vi.1992, H. M. Lin (NSMT); 4♂ 3♀, Taoyuen, Paling, 9-11. vi.1992, R. Kano (NSMT); 8♂ 4♀, Puli, Nanshanhsi, 23–24.v.1992, N. M. Lin (NSMT); 1♂ 5♀, Chung-Hsien University, Huei-sun Forest, 21.v.1992, R. Kano (NSMT); 1♂ 1♀, Alishan, 2,400m, 9-10.VII.1985, S. Shinonaga (NSMT); 4♂ 4♀, Mt. Alishan, 28–29.v.1992, R. Kano (NSMT); 22♂ 33♀, Kaohsiung, Shanping, 640 m, 21–30.iv.1988, C. Young, R. Davidson & J. Rawlins (CMNH); 2♂, Wulai, Taipei, 15.vi.1992, R. Kano (NSMT); 1♂, Anmashan, 2,230 m, 30.iv.–4.v.1990, A. Smetana (CMNH); 3♂ 7♀, Nanshanchi, 1.v.2006, H. Kurahashi (NSMT); 3♂ 7♀, nr Huanshan, 2.v.2006, H. Kurahashi (NSMT); 2♂ 3♀, Ten-chih, 23-04-03 N, 120-45-13 E, 1,550 m, 23.viii.1996, C. W. Young (CMNH); 17♂ 21♀, Fushan B. G., 600 m, 3–6.v.2006, H. Kurahashi (NSMT); 18♂ 4♀, Hohuan-sahn, Tsuifeng, 2,400m, 23–24.VII.1985, S. Shinonaga (NSMT).

Tribe Phormiini
Protocalliphora Hough, 1899

Protocalliphora sp.

Materials. 1♀, Mt. Alishan, 2,400 m, 9-10.vii.1985, S. Shinonaga (NSMT). [See to Kurahashi (2000: 27)]

Subfamily RHINIINAE
Tribe Rhiniini
Idiella Brauer & Bergenstamm, 1889

**Idiella divisa* (Walker, 1861)

Materials. 4♂ 5♀, Chihpen, 15.xi.1985, K. Kanmiya (NSMT); 1♂, Shui-tao, 220 m, 15.iv.1915, S. Ueno (NSMT); 1♀, Fenchifu, 20.xi.1965, K. Kanmiya (NSMT).

Idiella euidielloides Senior-White, 1923

Materials. 2♂, Nantou County, Ren'ai Township, Aowanda, 18.v.2013, K. Harusawa (PCKHa); 2♂ 1♀, Nantou County, Ren'ai Township, Gaofeng, Guantou Mt. (Northeast), 20.v.2013, K. Harusawa (PCKHa); 1♀, Chihpen, 15.xi.1985, K. Kanmiya (NSMT); 1♂, Chung-Hsien University, Huei-sun Forest, 21.v.1992, R. Kano (NSMT); 2♂ 4♀, Taoyuen, Paling, 9-11.vi.1992, R. Kano (NSMT); 3♀, Nanshanhsi, nr Puli, 23–24.v.1992, R. Kano & H. M. Lin (NSMT); 1♀, Meifeng, 2,130 m, 10–17.vii.1993, A. Smetana (CMNH); 1♀, Kaohsiung, Ten-chih, 23.04'03"N, 120.45'13"E, 1,550 m, 23.viii.1996, C. W. Young (CMNH); 1♀, Chihpen, 15.xi.1985, K. Kanmiya (NSMT); 8♂ 3♀, Fushan B. G., 600 m, 3-6.v.2006, H. Kurahashi (NSMT); 1♂ 1♀, Chihpen, 15.xi.1985, K. Kanmiya (NSMT); 1♀, Hsitou, 1,000 m, 1.v.2006, H. Kurahashi (NSMT); 3♀, Nanshanchi, 1.v.2006, H. Kurahashi (NSMT).

Idiella mandarina (Wiedemann, 1830)

Materials. 1♂, Kenting-kung-yuan, 3.iv.1965, R. Kano (NSMT).

Rhinia Robineau-Desvoidy, 1830

Rhinia apicalis (Wiedemann, 1830)

Materials. 1♀, Nantou County, Ren'ai Township, Lushan, 1000 m, 10.x.2010, S. T. Yang (NTU); 1♂, Hohuan-shan, Kunyan, 2,700 m, 23.vii.1985, S. Shinonaga (NSMT); 2♀, Hohuan-shan, Tsuifeng, 2,400 m, 23-24.vii.1985, S. Shinonaga (NSMT); 1♀, Lushan, 1,000 m, 24-25.vii.1985, S. Shinonaga (NSMT); 1♂ 4♀, Huanshan, Chichiawanchi, 6.xii.1985, K. Kanmiya (NSMT); 1♂, Tsuifeng-Shunkan, 24.vii.1985, H. Shima (NSMT); 1♀, Nanshanhsi nr Puli, 23-24.v.1992, R. Kano (NSMT); 1♂, Hohuan-shan, Tsuifeng-Shunkan, 24.vii.1985, H. Shima (NSMT); 1♂, Tsuifeng-Shunkan, 24.vii.1985, H. Shima (NSMT).

Rhinia sauteri Peris, 1951

Note. See to James (1977: 553).

Stomorhina Rondani, 1861

Stomorhina discolor (Fabricius, 1794)

Materials. 1♀, Pingtung County, Manzhou Township, Qikong Waterfall, 40-125 m, secondary forest, 24.i.2013, S. T. Yang (NTU); 1♂, Kentin, 1.II.1972, K. Matsuki (NSMT); 1♂, Kentin Park (Kontei Park), 13.viii.1980, K. Hara (NSMT); 2♀, Antung, 12.x.1985, K. Kanmiya (NSMT); 1♂, Juisui, 10.xi.1985, K. Kanmiya (NSMT); 1♀, Oluanpi (Galanpi), 13.viii.1980, K. Hara (NSMT); 1♂, nr Alishan, Shanmei, 1,300 m, 29.iv.2006, H. Kurahashi (NSMT); 1♂, Ch'-hsin-liao, 15.iv.1965, S. Ueno (NSMT); 1♂, Lushan, 1,000 m, 24-25.vii.1985, S. Shinonaga (NSMT).

Stomorhina lunata (Fabricius, 1805)

Note. See to Hennig (1941: 181).

******Stomorhina obsoleta*** (Wiedemann, 1830)**

Materials. 1♀, Lushan, 1,000 m, 24-25.vii.1985, S. Shinonaga (NSMT); 1♀, Fen-ch'i-hu, 12.iv.1965, R. Kano (NSMT); 1♂, Hotso (Roshan), 30.ix.1965, K. Kaneko (NSMT).

Stomorhina veterana **Villeneuve, 1927**

Materials. 1♂, Yingfeng (Gokansan), 19.viii.1980, K. Hara (NSMT); 1♀, Alishan-Yushan, 2,600-2,700 m, 31.x.1985, M. Iwasa (NSMT); 1♀, Hohuan-shan, Tsuifeng, 2,400 m, 23-24.vii.1985, S. Shinonaga (NSMT); 1♀, Hohuan-shan, Kunyan, 2,700 m, 23.vii.1985, S. Shinonaga (NSMT); 7♀, Meifeng, 2,130 m, 10-17.vii.1993, A. Smetana (CMNH); 1♂, Fenchihu, 4.iv.1965, R. Kano (NSMT); 1♀, Ten-chin, 23.04'03"N 120.45'13"E, 1,550 m, 23.viii.1996, C. W. Young (CMNH); 1♀, Tattaka, 10.iv.1965, T. Saigusa (NSMT); 1♂, Mt. Yui-shan, 2,700-3,500 m, 6-7.vii.1985, S. Shinonaga (NSMT); 1♀, Mt. Yui-shan, 2,700-3,500m, 6-7.VII.1985, S. Shinonaga (NSMT); 1♀, Hohuan-shan, Yuankang, 2,700m, 23.VII.1985, S. Shinonaga (NSMT); 12♀, Hohuan-shan, Tsuifeng, 2,400m, 23-24.VII.1985, S. Shinonaga (NSMT); 1♂, Fenchihu, 12.IV.1965, R. Kano (NSMT); 1♂ 1♀, Tatachia-anpu, 31.x.1985, K. Kanmiya (NSMT); 1♂, Tatachiaanpu-Paiyunshan-chuan, 6.vii.1985, H. Shima (NSMT); 1♀, Alishan-Yushan, 2,600-2,700 m, 31.x.1985, M. Iwasa (NSMT); 1♀, Alishan-Yushan, 2,600-2,700 m, 31.x.1985, M. Iwasa (NSMT).

Stomorhina xanthogaster **(Wiedemann, 1820)**

Materials. 9♂ 4♀, New Taipei City, Shimen Dist., Linshan Cape, 20 m, seashore, 29.xii.2012, S. T. Yang (NTU).

Tribe Cosminini

Borbororhinia **Townsend, 1917**

Borbororhinia bivittata **(Walker, 1857)**

Note. See to James (1977: 544).

Isomyia **Walker, 1860**

******Isomyia delectans*** (Walker, 1860)**

Materials. 1♀, Yilan County, Toucheng Township, Yingzi Mt., 936 m, bush, 27.v.2013, S. T. Yang (NTU).

Isomyia electa (Villeneuve, 1927)

Materials. 1♂, New Taipei City, Wulai Dist., Wulai, 500 m, secondary forest, 20.vi.2011, Y. C. Yu (NTU); 2♂ 8♀, Fushan B. G., 600 m, 3-6.v.2006, H. Kurahashi (NSMT).

**Isomyia oestracea* (Séguy, 1934)

Materials. 1♀, Taitung County, Haiduan Township, Xiama, 790 m, secondary forest, 30.v.2013, S. T. Yang (NTU); 4♂, Fushan B. G., 600 m, 3-6.v.2006, H. Kurahashi (NSMT); 1♀, Fushan Botanical Garden, 750 m, 28.vi.2010, K. Harusawa (PCKHa).

**Isomyia pseudolucilia* (Malloch, 1928)

Materials. 2♂ 1♀, Nantou County, Ren'ai Township, Aowanda, 18.v.2013, K. Harusawa (PCKHa); 1♂ 1♀, New Taipei City, Wugu Dist., Guanyin Mt., Yinghan Peak, 359–611 m, secondary forest, 30.iv.2013, S. T. Yang (NTU); 3♀, Taipei City, Neihu Dist., Daluntou Mt., 352 m, secondary forest, 19.v.2013, S. T. Yang (NTU); 2♀, Liuknei, 12.vii.1985, S. Shinonaga (NSMT); 17♂ 37♀, Fushan B. G., 600 m, 3-6.v.2006, H. Kurahashi (NSMT).

Isomyia tibialis (Villeneuve, 1927)

Materials. 1♂, Kukan, 3.xi.1985, K. Kanmiya (NSMT); 1♀, Tsuifen-Shunkan, 24.vii.1985, H. Shima (NSMT); 1♀, Paling, Taoyuen, 9–11.vi.1992, R. Kano (NSMT).

Isomyia viridaurea (Wiedemann, 1819)

Note. See to James (1977: 551).

Rhyncomya Robineau-Desvoidy, 1830

Rhyncomya notata (van Der Wulp, 1880)

Note. See to Fan (1992: 565).

Rhyncomya setipyga Villeneuve, 1927

Materials. 2♂ 1♀, New Taipei City, Shimen Dist., Linshan Cape, 20 m, seashore, 29.xii.2012, S. T. Yang (NTU).

Strongyloneura Bigot, 1886

**Strongyloneura diploura* Fang & Fan, 1984

Materials. Kinmen Is.: 2♂ 2♀, Shiahsintsuoh, 8.viii.1993, C. L. Chung (NSMT).

Strongyloneura prasina Bigot, 1886

Note. See to James (1977: 555).

**Strongyloneura prolata* (Walker, 1860)

Materials. 1♂, Kuantzuling, 26.v.1992, R. Kano (NSMT).

Sumatria Malloch, 1926

**Sumatria chiekoae* Kurahashi & Tumrasvin, 1992

Materials. 1♂, Lenai, 1,000 m, 23.vii.1985, S. Shinonaga (NSMT); 1♀, Lala Shan, 1,400 m, 25.x.1985, R. Kano (NSMT); 1♂, Lenai, 1,000 m, 23.vii.1985, S. Shinonaga (NSMT); 2♀, Taoyuen, Paling, 9-11.vi.1992, R. Kano (NSMT).

Sumatria flava (Villeneuve, 1927)

Materials. 1♀, Hsitou, 1,000 m, 1.v.2006, H. Kurahashi (NSMT); 1♀, Hsitou, 1,000 m, 1.v.2006, H. Kurahashi (NSMT).

**Sumatria vittata* (Peris, 1952)

Materials. 1♂, San Palin, 1,500 m, 26.x.1985, M. Iwasa (NSMT); 1♂, Sai Palin, 1,500 m, 25.x.1985, M. Iwasa (NSMT); 1♂, Sai Palin, 1,500 m, 25.x.1985, M. Iwasa (NSMT).

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RESEARCH ARTICLE

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Insects of French Guiana: a baseline for diversity and taxonomic effort

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Abstract

This paper analyzes the first checklist of insects from French Guiana. Compiled by a group of 70 experts based on published records, it comprises about 15 100 valid species names belonging to 20 orders and 322 families. Currently, about 17% of the species are only known from French Guiana or from the Guiana Shield region. Since Linné, the average rate of description has been 59 species per year, which has been increasing in the last 10 years. Based on a sample of recent taxonomic and faunistic papers covering 736 new species for French Guiana, 46% of the species came from new country records, the rest from new species descriptions. The rate of faunistic progress (new species or new records) is about 180 species per year over the last five years. Sixty-five percent of these faunal records came from non-professional entomologists and 74% of the holotypes of new species were collected by amateur entomologists. A rough extrapolation, using two different methods, provides a likely estimate of around 100 000 species, the most conservative estimate being 67 000 species and the highest 184 000. Therefore, an estimated 80% of the species remain to be recorded and, in a best-case scenario, at least 270 years would be needed to complete the biotic inventory, at the current rate of species descriptions and distribution records. Although no order is exhaustively inventoried, the most in need of study are Diptera, Hymenoptera, Hemiptera and Trichoptera; and in absolute numbers, Coleoptera. These results and the fundamental role of non-professional entomologists in collecting and describing new species are discussed.

Keywords

Regional checklist, Neotropics, species database, Guiana Shield, biodiversity, arthropods, taxonomic diversity, endemism, taxonomic effort, Linnean shortfall

Introduction

The total number of arthropod species in tropical forests has been the object of intense speculation and scientific debate since the extrapolation published by Erwin (1982). Although knowing how many species are present is not required for research and applied conservation of biodiversity (Magurran and Queiroz 2010), it is still a great intellectual challenge to evaluate the actual diversity of life on earth.

French Guiana is a small territory of 84 000 km^2 in northern South America. It is in the Guianan moist forest ecoregion (Dinerstein et al. 1995), and is 95% covered by relatively homogeneous lowland tropical rain forest (Guitet et al. 2013). A recent book dealing with French Guiana's biodiversity (Charles-Dominique 2011) indicates that 100 000 species of insects are known so far, with a total number probably between 400 000 and 1 million species. This estimation, without any published references, seems quite unlikely to entomologists studying the French Guianan fauna. However, it highlighted the fact that no global checklist was available to provide an accurate account of what was known so far. French Guiana, with its rich diversity, became a popular destination for entomologists worldwide and therefore is assumed to be better studied than some other tropical countries. Unfortunately, faunal lists are only available for a restricted number of groups (e.g. Coleoptera: Cerambycidae, Tavakilian and Chevillotte 2012).

There are at least three important objectives for this work on the compilation of regional species databases:

1) To enable data exchange, which makes data sharing possible between observational or collection databases from different users, as long as they use the same taxonomic list. This data sharing is the basis for filling the "Wallacean shortfall", which aims to study distribution, biogeographic questions and applied questions of conservation (Cardoso et al. 2011), such as defining priority areas in systematic conservation planning (Margules et al. 2002).
2) To have global indicators of diversity and to monitor taxonomic progress, which facilitates communication with the general public and the biodiversity policy makers about invertebrate biodiversity and the challenge of the "Linnean shortfall", that is to say that only fraction of the planet's species has been described by science (Whittaker et al. 2005).
3) To facilitate the work of taxonomists, by enabling them to easily check what is already known and to stimulate further taxonomic research and the publication of new country records.

For these reasons, we launched this project as a part of the national taxonomic database (TAXREF: Gargominy et al. 2013) on behalf of the natural heritage inventory of France (MNHN, online). The database will be available online (see Suppl. material 1) and will be updated on a yearly basis. This publication provides descriptive analysis of what is known so far, quantifies the description rates, discusses who supports the faunistic and taxonomic progress, which are the most and least studied orders, and tries to extrapolate a rough figure of the total species richness of insects in French Guiana.

Material and methods

Elaboration of the checklist of known species

Except for a few families that recently benefited from a regional checklist (e.g. Heiss and Moragues 2009, Faynel 2010, Brûlé 2011, Pauly et al. 2013) and some global species databases (e.g. Tavakilian and Chevillotte 2012), no list of species was available for French Guiana. In 2008, we started the French Guiana list, as a part of the French national taxonomic database (TAXREF: Gargominy et al. 2013), with the help of all our colleagues working on specimens collected by SEAG (Société entomologique Antilles-Guyane — Entomological Society of French Guiana and West Indies). At the end of 2012, we asked those experts to compile and transmit lists in their taxonomic groups of study, taking into account only published records for French Guiana up to the beginning of 2013. Eighty experts, listed in the acknowledgements section, took up the challenge and provided updated lists for 169 families, representing 53% of the total families and 90% of the total species in the final list. The other orders and families, not listed by a specialist but suspected to be present in French Guiana, were compiled by the authors. This was done by searching for relevant references on Google Scholar and the Zoological Record. It is likely that, for those groups, certain lists are incomplete and some species names are obsolete.

The lists were compiled in a spreadsheet with the taxonomic hierarchy of family, subfamily, tribe (occasionally), genus, species, subspecies (occasionally), and author's name for each taxon. For this first effort, we focused only on valid taxa. These lists were coded using the TAXREF format (Gargominy et al. 2013) in order to integrate the species database. This includes a "biogeographic status" field regarding the occurrence of the species in French Guiana. The following codes were used: P: taxa present in French Guiana (default status); G: taxa described and only known (so far) from French Guiana; E: endemic taxa (used only for well-known groups, otherwise G); S: sub-endemic taxa (well-known taxa ranging only in the Guiana Shield region); I: introduced taxa; J: introduced and invasive; B: vagrant; Q: taxa recorded from French Guiana in error.

Other insect baselines for comparison

To compare and extrapolate the total diversity of French Guiana, we first sought published checklists or available online databases for very well-known fauna, in all orders and families, in as close a biogeographical context (tropical America) as possible. We found no convincing resources corresponding to these criteria. We finally used for comparison three faunal references: total species richness of the global, Nearctic and French faunas.

The total number of known species per order worldwide (Zhang 2013) cannot be used to extrapolate total diversity, as it is dependent on the level of the taxonomic knowledge. However, it can be used to identify major gaps, by comparing the number of species known worldwide per order with the same figure from French Guiana.

The figures for the North American fauna from the Nomina Insecta Nearctica series (Poole and Gentili 1996) were used at the family level. Although compiled 15 years ago, this series provides a comprehensive reference for all orders. Knowing the total figure for North America (ca. 95 000 species), it was possible to estimate the diversity in French Guiana using cross-multiplication from a sample of well-known families. These figures are useful, but we assume that the total richness based on this projection is surely underestimated.

The Fauna Europeae project is a continent-wide data basing effort (De Jong 2013). Additional faunistic and taxonomic updates have been conducted on a subset of the TAXREF data limited to France and Corsica. The French fauna is one of the longest studied, and estimated to contain 36 000 insect species. This total can be considered accurate, however new species are added every year, especially restricted range species (Essl et al. 2013).

Extrapolating a rough estimate of total diversity

We use a method similar to the one use by Lewinsohn and Prado (2005) for Brazil, which consists of comparing some groups with a benchmark fauna and estimating the total using a rule of proportionality. Instead of using as a benchmark the extrapolated worldwide diversity, we use two well-known temperate faunas, one of the possible methods reviewed by Mora et al. (2011).

First, experts were asked to provide their best estimate of total number of species, by counting the number of unnamed « sp. » and by extrapolating the number of unseen species. Three estimates were calculated: the minimum, probable « best guess » and maximum number of species. The minimal number is a conservative figure, corresponding roughly to the number of different morphospecies seen from French Guiana by the expert, generally from a huge sample of localities and specimens. In a few cases (5 out of 68) the probable number extrapolates the unseen species from the number of singletons and doubletons as in Chao 1 estimator (Colwell and Coddington 1994). In most cases, this was performed by an educated guess corresponding to the rate of new taxa seen. We received answers for 68 taxonomic groups at the ordinal (Dermaptera, Ephemeroptera, Phasmatodea, Odonata), superfamily (Hymenoptera: Chalcidoidea; Hemiptera: Pentatomoidea) and mostly the family level (62 families or subfamilies). Most of them are included in the richest orders at the world level according to Zhang (2013). We consider these groups as representative "random" samples of the total insect taxa.

Secondly, we compiled figures of species richness for the same taxonomic groups in benchmark faunas of North America (based on Poole and Gentili 1996) and of France from TAXREF (Gargominy et al. 2013). A few taxa have a lower richness in French

Guiana (e.g. Coleoptera, Lucanidae; Hymenoptera, Apidae), but most show an equal or much higher diversity (see Suppl. material 2). All these groups were included in the analysis to avoid any bias towards more, or less diversified groups in French Guiana.

Thirdly, considering that the proportion of these 68 groups studied was representative of the ratio of richness between French Guiana and the benchmark fauna, we used a simple rule of proportionality to obtain rough estimates of the total diversity of species in French Guiana. For instance, consider that 1 000 species is the estimated total number of species in 10 well-known taxonomic groups in French Guiana; 500 is the reported number of species in the benchmark fauna for those same 10 groups and 100 000 species is the overall number of insect species in the benchmark well-known fauna, then the total extrapolation for French Guiana would be 200 000 species [(1000/500) × 100 000].

As there is no perfect method to assess species richness (Mora et al. 2011), we also used a second method to assess robustness of the estimate. Using the relatively scale-independent correlation found between vascular plant richness and arthropod richness in Panama (Basset et al. 2012), the minimum ratio between arthropods and plants is 17:1 and 20:1 is the most likely. For plant richness, we used the commonly admitted number of 5 750 species of vascular plants (Delnatte and Meyer 2012).

Assessing descriptive and faunistic work in recent years

Belonging to the large Guianan moist forest ecoregion, French Guiana shares a species pool with adjacent countries. Species cited from French Guiana can either be described from French Guiana or from another country and then published as a new record for French Guiana. These new country records may be important to assess the real progress of faunistic knowledge. Therefore, we investigate a large sample of 144 faunistic and taxonomic papers dealing with French Guiana, from 2008 to 2013. For each of these, we compute the following items: number of new species and new country records, professional status and nationality of authors and professional status of the collector of the holotype and of all the material cited from French Guiana. To assess how many species were described or cited by status of the authors, we divide the number of species treated by the number of authors (see Hołyński 2013) and then sum by categories of authors: professional taxonomist, non-professional and para-professional. By para-professional, we mean individuals affiliated with an institution or biologists whose job is not taxonomy. We had an “unknown” category, which we did not include as it contained just one author.

Results and discussion

Known taxa by order

Of the 29 orders of insects currently recognized, excluding fossils (Zhang 2013), 20 taxa appeared in the first checklist for French Guiana. The nine orders not represented are

Table 1. Overall number of taxa known by order in French Guiana.

Order	Subspecies	Species	Genera	Tribe	Subfamily	Family	Total
Blattodea		251	116		24	8	**399**
Coleoptera	66	5759	1863	343	167	81	**8301**
Dermaptera		45	21	1	9	3	**79**
Diptera	2	577	142	17	19	32	**789**
Ephemeroptera		20	15		1	4	**40**
Hemiptera	7	859	451	74	78	46	**1515**
Hymenoptera	32	1338	295	67	58	39	**1829**
Lepidoptera	561	5507	1541	52	91	48	**7800**
Mantodea		93	40	15	14	6	**168**
Megaloptera		5	2			1	**8**
Neuroptera		25	15		1	4	**45**
Odonata	13	237	84			14	**348**
Orthoptera	18	341	216	59	37	12	**683**
Phasmatodea		50	25	11	8	5	**99**
Plecoptera		1	1			**1**	**3**
Psocoptera		20	12			9	**41**
Siphonaptera	6	12	7			3	**28**
Strepsiptera		1	1			1	**3**
Thysanoptera		6	6		4	3	**19**
Trichoptera		36	14	2	6	2	**60**
Total	**705**	**15183**	**4867**	**641**	**517**	**322**	**22257**

Mecoptera, Archaeognatha, Zygentoma, Embioptera, Grylloblattodea, Mantophasmatodea (the latter two usually grouped in Notoptera in recent classifications), Zoraptera, Phthiraptera, and Raphidioptera. These are all minor orders regarding their species diversity, even if Phthiraptera reaches more than 5 600 species (Zhang 2013). The absence of species in the list could be either a genuine absence of these orders, a lack of publication on the subject or a lack of specific research in the literature on these groups.

Out of 22 257 taxa listed, about 30% were above the species level. Overall, 15 183 species are inventoried from French Guiana. The compilation and expertise for listing these species may not be comprehensive but the most diverse families are the focus of this work so there should not be too many species missed. At most, we estimate there could be 18 000 published species records from French Guiana.

Only 705 taxa at the subspecies level were mentioned from French Guiana. Lepidoptera accounts for 80% of these taxa, and of these most are Rhopalocera. This is probably due to the focus of entomologists on this well-known suborder.

Introduced species and endemism

The fauna of French Guiana is believed to hold few real endemics because, as pointed out for its flora (Granville et al. 1996), there are no strong geographical barriers between French Guiana and neighboring countries (Suriname and Brasilian state of Amapá).

Table 2. Repartition of French Guiana species among different biogeographical categories. "Described from French Guiana" represents taxa known only (so far) from French Guiana.

Order	Dubious records	Occasional, vagrant	Endemic or sub-endemic	Described from French Guiana	Introduced (not invasive)	Introduced (invasive)	Other "presence"
Blattodea	1	0	43	28	0	3	176
Coleoptera	78		812	844	5	5	4021
Dermaptera			3				42
Diptera	2		6	50			519
Ephemeroptera							20
Hemiptera			30	66			763
Hymenoptera	3		72	132			1131
Lepidoptera	11	1	49	265	3		5178
Mantodea			4	10			79
Megaloptera							5
Neuroptera							25
Odonata	2	1	14	2			218
Orthoptera				142			199
Phasmida							50
Plecoptera							1
Psocoptera							20
Siphonaptera							12
Strepsiptera							1
Thysanoptera							6
Trichoptera							36
Total	**97**	**2**	**1033**	**1539**	**8**	**8**	**12502**

However, we found about 17% of insect species are known only from French Guiana or the Guiana shield (considered as subendemics). This is a conservative figure, as this status has not been reported accurately for some orders or families. We considered 1 033 rather well known species (6.8% of the total) as likely endemics of the Guiana Shield. Of recently described species, 10.1%, are so far known only from their country of description, but may be considered subendemics or more widespread species as chorological knowledge progresses. A good example of a likely true subendemic is the large and attractive dynastine beetle *Ceratophileurus lemoulti* Ohaus, 1911, known only from French Guiana and Surinam (Gillett et al. 2010). We should be very cautious with levels of endemism, even at the level of the Guiana Shield, as many insects previously known only from French Guiana are also present in the Amazonian part of Andean countries, exhibiting what one botanist called a "peri-amazonian" distribution (Granville 1992). As an illustration, for Lepidoptera, probably the best studied group, less than 1% of the species are considered endemic. However, recently discovered species may be cryptic species, species from poorly studied groups or a truly restricted range species, making it difficult to assess real endemism in a context of incomplete inventories for South American insects.

The number of species reported as introduced in French Guiana is very low (16 species, about 0.1%), especially compared with checklists from the West Indies, which categorize about 5% of taxa as introduced (e.g. Peck 2011). This may come from a reporting bias, with either a lack of publication on agricultural pests in French Guiana or a lack of literature searching for existing papers. It is also probably genuine, due to the high integrity of the forest cover of French Guiana, which is generally not favorable for alien species establishment (Hooper et al. 2005, Delnatte and Meyer 2012).

Rate of description

The rate of species descriptions is, on average, 59 valid taxa per year being added to the French Guiana fauna during the 255 years between Linné and today (2013). The highest peak was during the early twentieth century, with 178 species per year between 1904 and 1908. In the last century, the lowest period was between 1960 and 1970. In the last five years (2008-2012) the rate is nearly twice this average, with 102 species per year.

Description curves cannot be used for estimating total species richness (Bebber et al. 2007), but provide a good way to compare taxonomic effort between taxa (Fig. 2). The rate is quite different among orders. Currently, the rate of description is robust for Coleoptera, Hymenoptera and Hemiptera, and significantly higher than for Lepidoptera (Kolmogorov-Smirnov test for Lepidoptera vs Coleoptera: $D = 0.19$; $p<0.001$). The description rate seems to have nearly reached a plateau for macro-Lepidoptera. The numerically smaller orders also exhibit a significantly different description rate pattern (Kolmogorov-Smirnov test for Hemiptera vs other orders: $D = 0.22$; $p<0.001$): the description effort was very low before 1900, quite intense between 1900 and 1960, and constant after 1960, nearly following the description rate for Coleoptera, Hemiptera and Hymenoptera.

The peak in the early 20th century was due to the publication of books, mainly on Lepidoptera, which yielded numerous new species at the same time, whereas now, new species are typically described in journal articles, which results in many more papers and authors than before, but fewer species per paper (as pointed at the global level by Costello et al. 2013b).

The overall rate observed in Figures 1 and 2 does not necessarily mean that species were described from French Guiana, but may be due to subsequent new faunal records. In our sample of 144 papers from the last six years, 344 species (47%) were new country records of species previously described from other countries, and 393 (53%) were new species descriptions based totally or partially on material from French Guiana. This implies that, in the last six years, more than 100 new species were described per year, with about the same number of new species records added. The overall rate of species addition may therefore be about 180 species per year, of which ca. 100 are new descriptions, another 90 are new records, minus 10 probable future synonyms.

Who is currently providing the taxonomic effort?

Sixty-five percent of new additions to the French Guiana fauna are made by non-professionals (Table 3). There is a significant difference ($Chi2=69.6$; $df=4$; $p<0.001$)

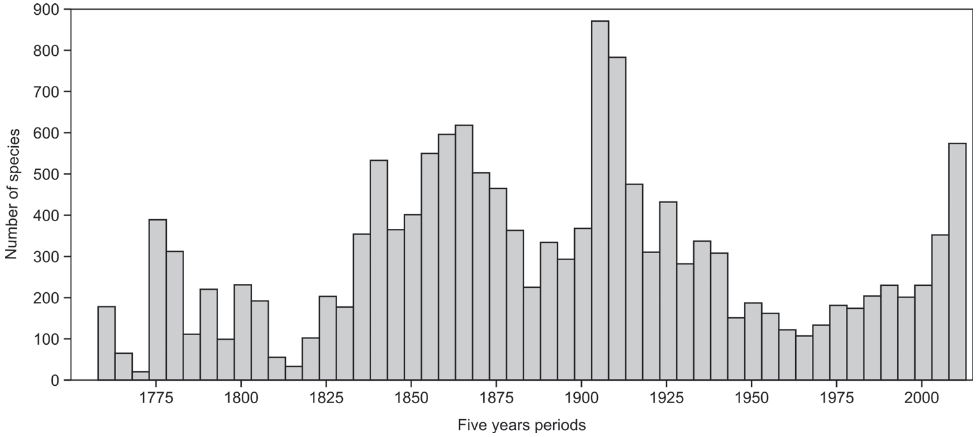

Figure 1. Number of described species from the French Guiana fauna by five year period from Linné to 2013.

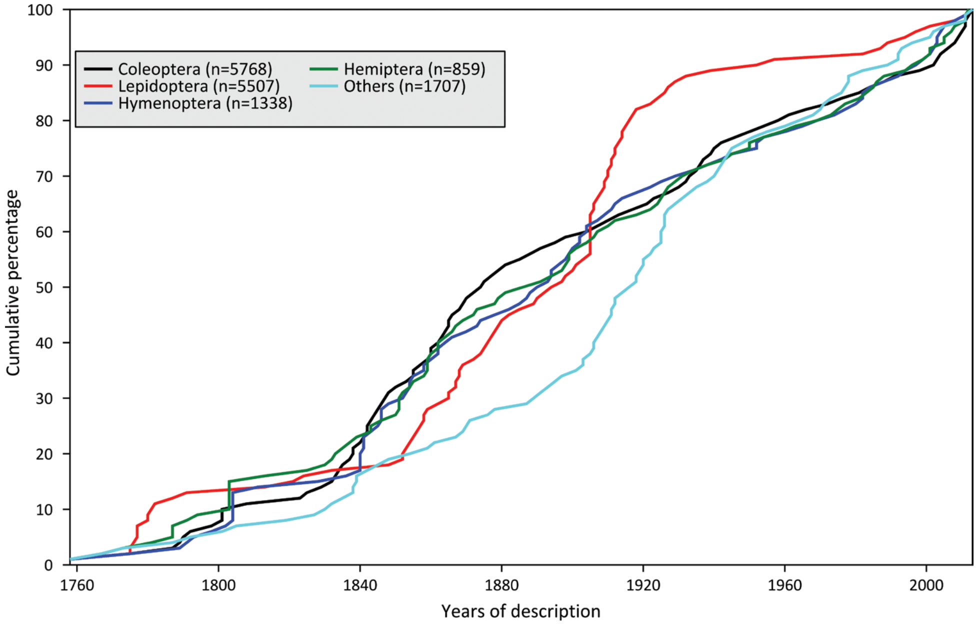

Figure 2. Cumulative rate of description of species belonging to the French Guiana fauna, for the four most diverse orders and for other excluded orders, from Linné to 2013.

between orders. Coleoptera and Lepidoptera are mainly studied by non-professionals, although both are also studied extensively by professional taxonomists. On the other hand, Diptera, Hemiptera and Hymenoptera are mainly studied by professionals. This is likely due to the fact the Lepidoptera and Coleoptera are very popular among collectors, whereas the other orders are traditionally less so.

Table 3. Number of taxonomic additions (new species or new records) to the French Guiana fauna by author type, for the 144 recent papers reviewed. Other orders (Diptera, Hymenoptera and Hemiptera), are pooled because they exhibit the same pattern.

Order	Non-professional	Para-professional	Professional
Coleoptera	407	83	134
Lepidoptera	64	1	8
Other orders	5	8	26
Total	476	92	169
Proportion	**65%**	**13%**	**23%**

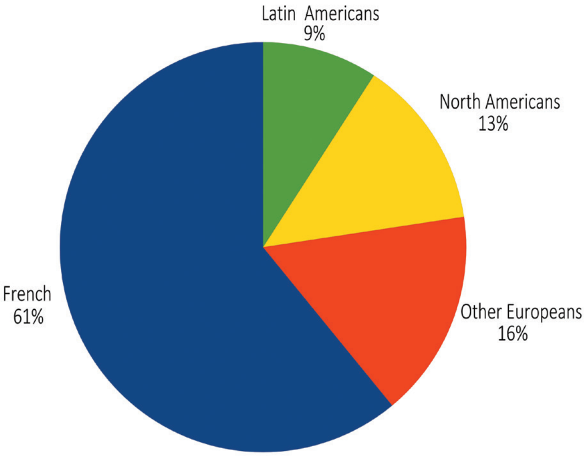

Figure 3. Repartition of the 393 new species according to the country of the authors.

French entomologists, including those from French Guiana, are, as expected, the most active at describing new species, followed by other Europeans, North Americans and entomologists from South and Central America (Fig. 3). In detail (Fig. 4), non-professionals are describing half of the new species, but are publishing 80% of the new country records. This is probably due to the low academic reward for faunistic records, whereas such records are considered of interest by amateur naturalists making a collection. The intermediate category of "para-professional" can be viewed as a higher level part of the non-professional as, strictly speaking, they are not professional taxonomists. This key role of non-professionals confirms the conclusions about taxonomic work within the European fauna (Fontaine et al. 2012). It might be argued that quality of the work done by amateur is much lower than the revisions and descriptions done by professional taxonomist. For instance, there may be publication of many synonyms and species publications that are inadequate, because species have not been studied on a comparative basis, or types were not compared, or the amateur may have a species concept that fails to take into consideration intraspecies morphological variation. Of some concern, also, is the availability of type material in private collections. What appears to be rapid progress because of the contribution of amateurs may not be if

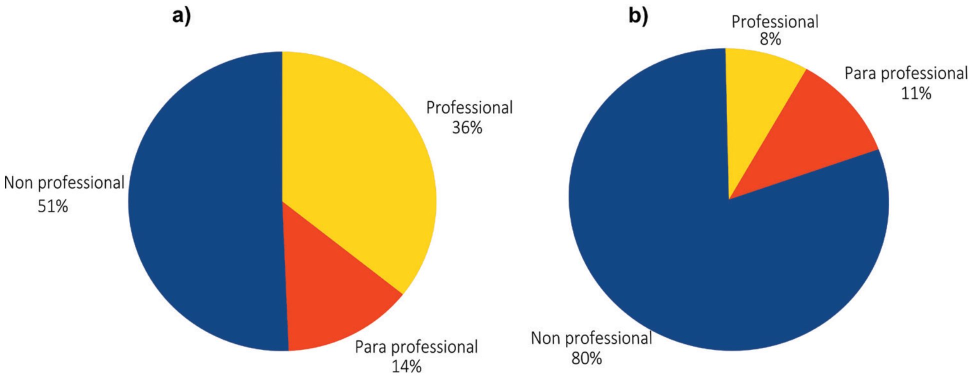

Figure 4. Proportion of taxonomic contributions according to the status of the authors. a) descriptions of new species (n= 393) and b) new country records of species described from another country (n=344).

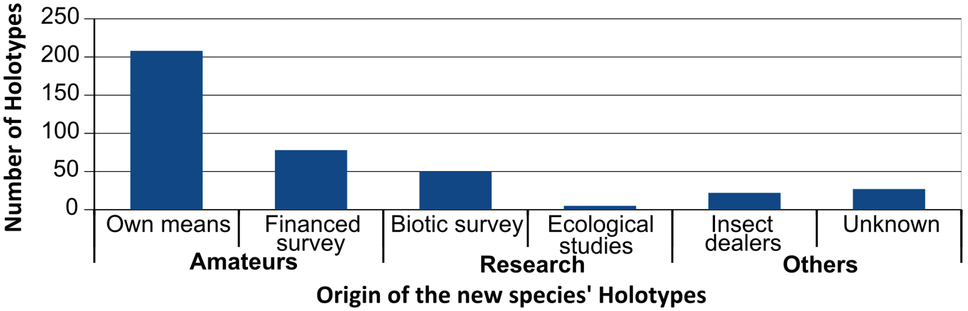

Figure 5. Origins of the holotypes of a sample of 393 species described from French Guiana between 2008 and 2013.

considered in the longer trajectory of the taxonomic hurdles subsequent workers may need to face. If this may be true in a few cases, most of the published work by amateurs we have checked was carefully done with comparisons to the types, proper keys, and holotypes were deposited in public institutions, mostly at the Muséum national d'Histoire naturelle (Paris).

By looking at the sources of the specimens treated in the 144 papers, the importance of amateur entomologists is even more obvious (Fig. 5). Seventy-four percent of the holotype specimens were collected by amateurs. Interestingly, a rather important part of these specimens comes from surveys made by amateurs for protected areas managers. Academic researchers yielded just 14% of the holotypes, few of which come from material collected during ecological studies not targeted at taxonomic discovery. A small but non negligible proportion (5%) of the holotypes came from insect dealers, who made material available for purchase and study.

Concerning French Guiana and contrary to common perceptions about the decline of taxonomy (Hopkins and Freckleton 2002), taxonomic work is much more vigorous now than it was 50 years ago (Costello et al. 2013a). As pointed out by

Costello et al. (2013b) at the global level, there are more taxonomists publishing fewer new taxa per paper than before. However, the publication of fewer species per author does not necessarily mean that a plateau has been reached in the discovery of species diversity (Hołyński 2013). The increase in species descriptions may also be quite specific to French Guiana for the following four reasons: 1) collecting insects is not strictly regulated, which favors a large collecting effort by many French and foreign entomologists; 2) protected areas managers have recently started faunal inventory programs; 3) a local group, the Entomological Society for West Indies and French Guiana (SEAG), has organized massive collecting efforts with intercept traps and have sent material to taxonomists (42% of the holotypes came from this single source); 4) a tradition of amateur entomology in France provides a pool of people, sometimes retired, focused on faunistics and descriptions, tasks that are not valued as much as others in professional biology (Hołyński 2013). All together, these are conditions specific to French Guiana, as compared to the majority of tropical countries, which are less favorable for sustained taxonomic progress (Hołyński 2013).

How many species might be there overall?

Using two well-known insect faunas, the extrapolation of species diversity for French Guiana, based on benchmark taxonomic groups, gives a probable number of species between 100 000 and 120 000, with a conservative estimate of 67 000 species and a highest estimate at 184 000 (Table 4). Estimates using the French fauna as a benchmark are consistently higher than those based on the Nearctic list. The ratio between the richness of the reference fauna and French Guiana is highly variable among groups (Suppl. material 2). Each reference fauna has a bias. The French fauna is quite well-known but belongs to a different continent with a different biogeographical history than French Guiana. For the Nearctic fauna, the 95 000 total species figure of Poole and Gentili (1996) is probably an underestimation. Therefore, these figures should not be considered more than rough estimates of insect richness in French Guiana.

The second method for extrapolating species richness, using an arthropod/plant ratio, which was found to be consistent in Panama (Basset et al. 2012), gives figures from 98 000 to 115 000 as the most likely estimates for all continental arthropods. Considering that insects represent 80 to 90% of the continental arthropods (88% in metropolitan France: Gargominy et al. 2013), the insect richness estimate would range between 85 000 and 104 000. Therefore, these two independent approaches yield comparable values of insect richness, with a likely estimate near 100 000 species. It may, however, still be conservative as an educated guess and non parametric estimators are likely to be conservative.

This estimation represents about 10% of the total insect diversity expected in Brazil by Lewinsohn and Prado (2005). It is difficult to assess if these results are coherent. Brazil is 101 times larger than French Guiana and hosts 13 terrestrial ecoregions, compared to one in French Guiana (Dinerstein et al. 1995). The diversity between

Table 4. Total insect diversity estimates for French Guiana. Calculation based on extrapolation of the richness of 68 taxonomic groups (Suppl. material 2) from two well-known temperate reference faunas, North America and France.

Reference fauna	Minimal estimate for French Guiana	Maximal estimate for French Guiana	Most likely estimate
Nearctic region (Poole and Gentili 1996): 95 000 species	67 000	156 000	**101 000**
Metropolitan France and Corsica (MNHN 2013): 36 000 species	81 000	184 000	**116 000**

ecoregions is likely to exhibit a high level of species turnover, as opposed to the relatively low beta diversity found in homogeneous lowland rainforest (Panama: Basset et al. 2012 and unpublished results from French Guiana). The world baseline used by Lewinsohn and Prado (2005) to extrapolate the Brazilian total is the one of Hammond et al. (1995), which predicts eight million insects worldwide. More recent estimates have lowered this total. For instance, Hamilton et al. (2013) calculate that the total number of species, including all arthropods, may be closer to 6.1 million, so the total for Brazil might be overestimated. Using a well-known temperate fauna as a basis for comparison, rather than an extrapolation based on a questionable estimate at the world level might give a more conservative estimate.

Although current taxonomic effort is higher than the historic average, at this rate, even in the most optimistic scenario (18 000 known species, 67 000 extrapolated species, 180 species added per year), an additional 270 more years would be needed to complete the taxonomic inventory! This is indeed optimistic as the description curve will tend to plateau when most of the easier, larger and more attractive groups have been studied (Gaston 1991), leaving an unknown number of cryptic species (Bickford et al. 2007) and neglected orders and families which are more difficult to collect or to study, or which generally to not receive much attention (Stork et al. 2008). We still have roughly 80-90% of species to discover, which is close to the overall estimate for global terrestrial diversity made recently by Mora et al. (2011).

Major gaps in taxonomic knowledge

We compared the richness by order in French Guiana with that expected from the richness compiled at the global level (Zhang 2013). Our knowledge at the global level is far from complete, and richness patterns are not similar worldwide, but this comparison may broadly highlight the status of knowledge in French Guiana compared to the overall situation (Fig. 6).

Five groups appeared to be relatively better studied (and/or possibly more diverse) in French Guiana, compared to the global level: Odonata, Mantodea, Lepidoptera, Blattodea, and to a lesser extent, Dermaptera. Four groups studied are at a comparable level between French Guiana and the world as a whole: Phasmatodea, Coleoptera, Orthoptera and Megaloptera. It should be noted that the known richness of the orders

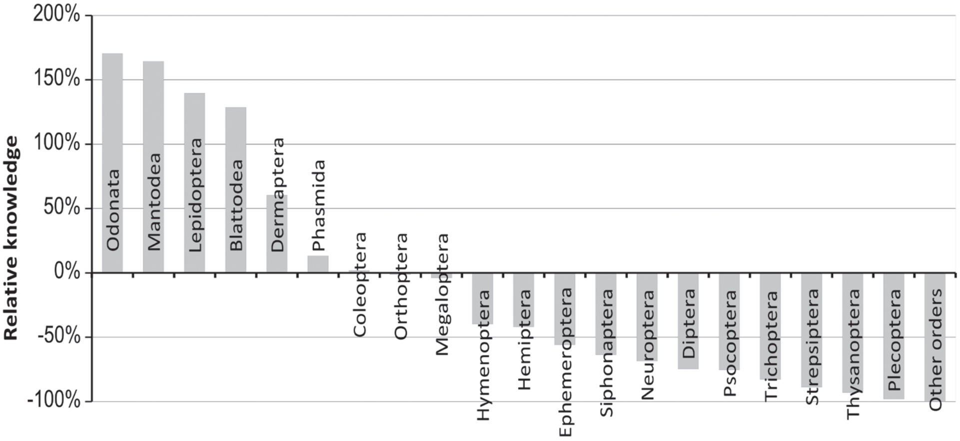

Figure 6. Ratio between the number of known and expected species richness in French Guiana. Ratios are based on the number of known species in French Guiana and the number described at the world level (Zhang 2013). Other orders on the right of the histogram with no known species in French Guiana comprise: Mecoptera, Archaeognatha, Zygentoma, Embioptera, Grylloblattodea, Mantophasmatodea, Zoraptera, Phthiraptera, Raphidioptera.

in these two categories is still far from being exhaustive, including Lepidoptera and Odonata (Suppl. material 2). The other 20 orders are underrepresented in the faunal list of French Guiana in comparison to the figures at the world level. They might be either genuinely poorly represented in French Guiana, for large scale biogeographical reasons, or perhaps they have not received as much taxonomic work as other taxa. Considering the rate of description in these groups (Hymenoptera, Hemiptera, and orders excluded, Fig. 2) the second hypothesis is overall more likely than the first. The highly diverse orders, which are obviously understudied in French Guiana, offer the largest opportunity for taxonomic discoveries, descriptions and new country records. The first four are: Diptera, Hymenoptera, Hemiptera and Trichoptera. The megadiverse order Coleoptera, although studied on average the same as at the world level, is certainly, in absolute number, the one where most species remain to be described.

Conclusion

Knowledge of French Guiana's insect diversity has been progressing at a relatively high rate in the past 10 years, mainly due to efforts of the large amateur community involved in collecting material for study and in taxonomic work. Demand for faunal surveys by protected areas managers has also opened the opportunity to obtain material from remote areas. However, the taxa inventory is far from complete. Even for longhorn beetles (Coleoptera: Cerambycidae), a well-known group in French Guiana, which has long been the focus of intense collecting and taxonomic work from amateurs and professionals, from France, US and Brazil, at least one third of the species remain to be described or revised (1 200 species known, 1 800 species are the lower estimate; Suppl. material 2). If we are to overcome the « Linnean shortfall » and start to fill the « Wallacean shortfall » (Cardoso et al. 2011), for both baseline knowledge and applied conservation, the contribution of amateur entomologists needs to be recognized and encouraged. The species collected and described by amateurs, as valuable as this may be, still need to be studied in an integrative context for taxonomic advances to be made. To tackle the taxonomic gap, it may be efficient to organize directed training for the amateur community about the use of the molecular genetic tools and to provide financial and technical help for this.

Interestingly, it should be mentioned that French Guiana is among the last countries in South America that has no constraining regulation on collecting insects over the whole territory. With no major impact on insect conservation, this has clearly favored contributions to the description of the fauna from the amateur community, and also the collection of material, including by insect dealers, a part of which has been the basis for many significant taxonomic works.

We consider the building and maintenance of a regional species database for insects as an opportunity to raise awareness of insect diversity and to measure the taxonomic gap. The initial checklist analyzed in this paper will be regularly supplemented and corrected, with updates made available from an online downloadable database (MNHN, online). Finally, we invite all our taxonomist colleagues to contribute to the insect list any missing taxa already described, corrections to existing records and to publish any new taxa and new records for French Guiana.

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Supplementary material 1

How to access, cite and contribute to the TAXREF species database?
Authors: Stéphane Brûlé, Julien Touroult
Data type: documentation (PDF file)
Explanation note: This file explains who contributed to the species database and give links for downloading the taxonomic database.

Link: doi: 10.3897/zookeys.434.7582.app1

Supplementary material 2

Total species richness estimations for 68 taxonomic groups in French Guiana
Authors: Stéphane Brûlé, Julien Touroult
Data type: Spreadsheet (xls file)
Explanation note: Estimated and extrapolated species richness for 68 taxonomic groups in French Guiana and comparative figures for two well-known faunas. These taxa are used to extrapolate the total number of species in French Guiana given in Table 4.

Link: doi: 10.3897/zookeys.434.7582.app2