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DATA PAPER

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A geographic distribution database of *Mononychellus* mites (Acari, Tetranychidae) on cassava (*Manihot esculenta*)

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Abstract

The genus *Mononychellus* is represented by 28 herbivorous mites. Some of them are notorious pests of cassava (*Manihot esculenta* Crantz), a primary food crop in the tropics. With the exception of *Mononychellus tanajoa* (Bondar), their geographic distribution is not widely known. This article therefore reports observational and specimen-based occurrence data of *Mononychellus* species associated with cassava. The dataset consists of 1,513 distribution records documented by the International Center for Tropical Agriculture (CIAT) between 1975 and 2012. The specimens are held at CIAT's Arthropod Reference Collection (CIATARC). Most of the records are from the genus' native range in South America and were documented between 1980 and 2000. Approximately 61% of the records belong to *M. tanajoa*, 25% to *M. caribbeanae* (McGregor), 10% to *M. mcgregori* (Flechtmann and Baker) and 2% to *M. planki* (McGregor). The complete dataset is available in Darwin Core Archive format via the Global Biodiversity Information Facility (GBIF).

Keywords

Cassava Green Mite, Cassava Green Mite Complex, International Center for Tropical Agriculture (CIAT), CIAT's Arthropod Reference Collection (CIATARC)

Data published through GBIF

http://www.gbif.org/dataset/785cf038-7b79-4c2f-9e9e-eb940fcd4c0c

Project details

Project title: Management of RTB Critical Pests and Diseases under Changing Climates, through Risk Assessment, Surveillance and Modeling

Project personnel: Aymer Andrés Vásquez-Ordóñez (Data Manager, Data Publisher), Rodrigo Zúñiga (Data Manager), Soroush Parsa (Principal Investigator, Data Publisher).

***Mononychellus* collectors:** Collectors who have deposited more than 50 specimens include: Julio Bonilla, Daniel González, José María Guerrero, Carlos Julio Herrera, Jorge Ivan Lenis, Nora Cristina Mesa, Jesús Antonio Reyes, César Rodríguez and Miguel Santiago Serrano.

Funding: This project was supported by the Roots, Tubers and Bananas (RTB) Research Program of the Consultative Group on International Agricultural Research (CGIAR).

Design description: The purpose of this dataset is to significantly increase the geographic distribution data publicly available for the genus *Mononychellus*. This genus includes several species of herbivorous mites that are major pests of cassava (*Manihot esculenta* Crantz), most notoriously *Mononychellus tanajoa* (Bondar). We report 1,513 distribution records of the genus, documented by the International Center for Tropical Agriculture (CIAT) between 1975 and 2012. Most of the records (53%) correspond to specimens preserved at CIAT's Arthropod Reference Collection (CIATARC). Prior to this contribution, only 30 distribution records of *Mononychellus* were accessible through the Global Biodiversity Information Facility (GBIF) data portal (accessed 1/13/2014). Accordingly, the CIATARC *Mononychellus* dataset should facilitate a much better understanding of the genus' geographic association with cassava.

Taxonomic coverage

General taxonomic coverage description: Most records were identified to species level (98%) with the help of expert input (José María Guerrero, Pilar Hernandez). Only four species of the genus are reported. Approximately 61% of the records belong to *M. tanajoa*, 25% to *M. caribbeanae* (McGregor), 10% to *M. mcgregori* (Flechtmann and Baker) and 2% to *M. planki* (McGregor).

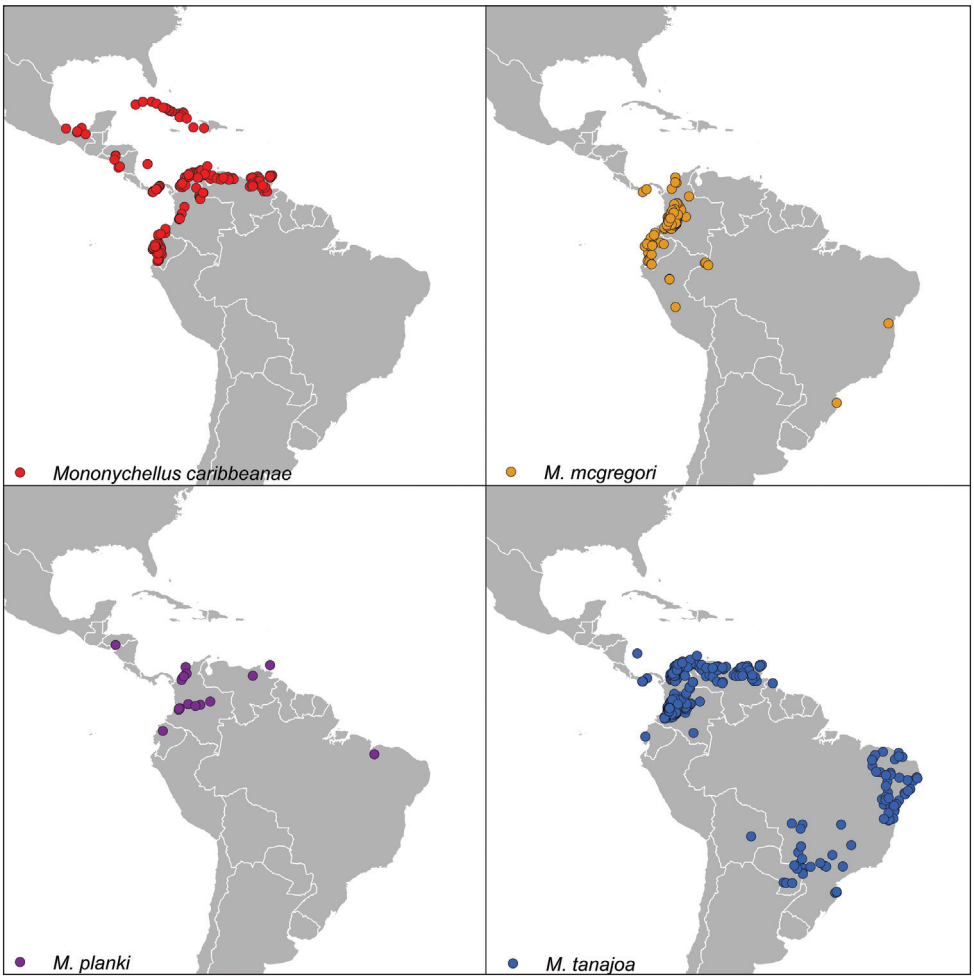

Figure 1. Native geographic distribution of records of the CIATARC *Mononychellus* dataset in the American continent.

Taxonomic ranks

Kingdom: Animalia.
Phylum: Arthropoda.
Class: Arachnida.
Order: Trombidiformes.
Family: Tetranychidae.
Genus: *Mononychellus*.
Species: *Mononychellus caribbeanae*, *M. mcgregori*, *M. planki*, *M. tanajoa*.
Common name: Cassava Green Mite (for *M. tanajoa*), Cassava Green Mite Complex (for *M. caribbeanae*, *M. mcgregori*, *M. planki* and *M. tanajoa*)

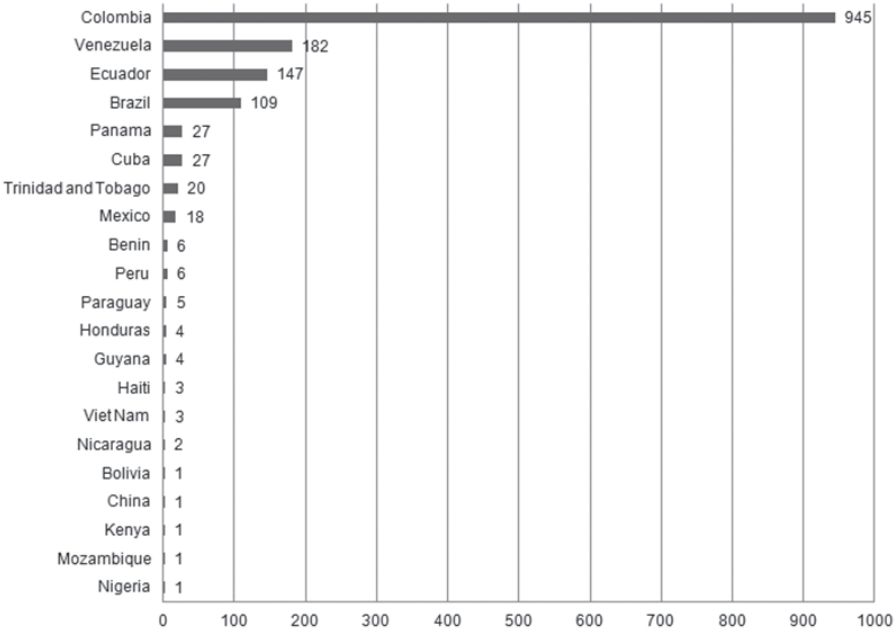

Figure 2. Records by country in the CIATARC *Mononychellus* dataset.

Spatial coverage

General spatial coverage: The *Mononychellus* specimens and observations of CIATARC are from South America (14 countries) and Central America (Cuba, Haiti, Honduras, Mexico, Nicaragua, Trinidad and Tobago), which represent the 99% of records, with Colombia and Venezuela are the best represented countries, followed by Brazil and Ecuador (Fig. 2). These countries are considered the center of origin of our focal species. The remaining records belong to Africa (0. 6%; Benin, Kenia, Mozambique, Nigeria) and Asia (0.3%; Vietnam, China).

Coordinates: 22.904301 and -27.098576 latitude; -95.2174947 and 109.580811 longitude.

Temporal coverage

1975–2012.

Natural Collections descriptions

Collection name: CIAT Arthropod Reference Collection (CIATARC).

Specimen preservation method: Specimens are preserved as microslide preparations in microscope slide boxes within cabinet drawers maintained at 21.0 ± 0.4 C and 47.6 ± 8.6 relative humidity. They are sorted numerically by species and country of origin.

Curatorial unit: 3,510 with an uncertainty of 0 (microslide preparation).

Methods

Method step description: The dataset integrates two data flows: observational records and specimen-based records, identified either to genus or to species. The former were digitized from field diagnostic forms completed by personnel extensively trained in mite identification. These identifications, however, were likely conducted on site without mounting and preserving samples. Alternatively, these observations may correspond to properly-mounted but lost specimens. In either case, our confidence in the identification of observational records is high to the genus level, but moderate to the species level. On the other hand, specimen-based records belong to verifiable samples properly-preserved at CIATARC following the guidelines of Krantz (1978). Unique accession numbers were assigned to all records.

All biodiversity data available (i.e. specimen, species identification, name of determiner, sex, biological phase, locality, date, habitat, host, collector and observations) was digitized in a Microsoft Excel 2010 spreadsheet adopting the Darwin Core Archive format v1.2 (Wieczorek et al. 2012). We updated locality fields (e.g., district, municipality) using the most current names and classifications of administrative divisions used by each country (e.g. http://www.dane.gov.co/Divipola/ for Colombia, http://www.inec.gob.ec/estadisticas/?option=com_content&view=article&id=80 for Ecuador, etc. [accessed 2013/11/14]). Based on their locality names, we then geocoded the records using Google Maps (https://maps.google.com/), GeoNames (http://www.geonames.org/) or Amézquita et al. (2013). GPS coordinates were converted to decimal degrees. The dataset with metadata was uploaded to the Integrated Publishing Toolkit (IPT) of the Colombia node of Global Biodiversity Information Facility (GBIF) (http://www.gbif.org/dataset/785cf038-7b79-4c2f-9e9e-eb940fcd4c0c).

Sampling description: The records in the dataset have been documented in three ways:

1) Records from CIAT's initial field explorations to document pests in cassava (Guerrero and Bellotti 1981; 4.4% records, between 1975-1983).
2) Records documented during the "Cassava Green Spider Mite Biological Control Project," led by CIAT, International Institute of Tropical Agriculture (IITA), Commonwealth Institute of Biological Control (CIBC) and Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) (Bellotti et al. 1987, 1996, 1998, 2000, Byrne et al. 1983, Braun et al. 1993, CIAT 1984, 1985, 1986, 1990, 1992, 1993, 1995, Guerrero et al. 1993, CIAT et al. 1998; 89.6%, 1983–1999).

Their locations were systematically selected based on their climatic homology to *M. tanajoa*-affected areas in Africa (Bellotti et al. 1987, CIAT 1993, Guerrero et al. 1993).

3) Records from other sources; including field inspections and collections conducted during routine farm visits by CIAT personnel, and from specimens submitted to CIATARC by fellow institutions and researchers (Bellotti et al. 2000; CIAT 2001, 2002, 2003; 6%, 2000-2012).

The sampling process typically involved scouting cassava fields for infested plants, identified by speckling of their terminal leaves, followed by a close-up inspection for green mites using a 10× magnifying glass. To collect specimens, mites were then brushed off from leaves into collection vials containing a lactophenol solution (Krantz 1978) and maintained in ice chests until reaching the laboratory for proper mounting and identification (Bellotti et al. 1987, CIAT 1993, Guerrero et al. 1993).

Quality control description: Record validation and cleaning was incorporated at several steps of the documentation process, following guideless by Chapman (2005 a,b). The scientific names on labels were checked with a taxonomic thesaurus developed by AAV. This thesaurus compiled all known synonyms and spelling variants of the scientific names used for our focal species. We assigned scientific names in accordance to current taxonomy trends. Geographic coordinates were verified using the "Check Coordinates" function in DIVA-GIS (Hitmans et al. 2001). For this last step, we relied on the Global Administrative Unit Layers (GAUL) shape file developed by the Food and Agriculture Organization of the United Nations (FAO, http://www.fao.org/geonetwork/srv/en/metadata.show?id=12691, [accessed 2013/11/14]).

Datasets

Dataset description

Object name: Darwin Core Archive *Mononychellus* distribution: data of the CIAT Arthropod Reference Collection of International Center for Tropical Agriculture (CIAT).
Character encoding: UTF-8.
Format name: Darwin Core Archive format.
Format version: 1.0.
Distribution: http://www.gbif.org/dataset/785cf038-7b79-4c2f-9e9e-eb940fcd4c0c
Publication date of data: 2014-03-14.
Language: English.
Licenses of use: This dataset [*Mononychellus* Collection of CIAT Arthropod Reference Collection (CIATARC)] is made available under the Creative Commons Zero (CC0) 1.0.

Acknoledgements

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RESEARCH ARTICLE

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A new species of shrimp of the genus *Anachlorocurtis* Hayashi, 1975 from the Red Sea, with range extension of *A. commensalis* Hayashi, 1975 (Crustacea, Decapoda, Pandalidae)

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§ *http://zoobank.org/0CF5D3F9-9663-4B76-BF91-713D9BE50BC3*

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Abstract

A new species of pandalid shrimp *Anachlorocurtis occidentalis* **sp. n.**, associated with antipatharian corals, is described and illustrated from the north-eastern Red Sea. This new species is closely related to *Anachlorocurtis commensalis* Hayashi, 1975, the only other species in the genus, and can be distinguished by the more slender body and appendages; the carapace with 3 large, and one small, subtriangular lobes in the middorsal line; a flattened dorsal outline of the third abdominal segment; the sixth abdominal segment twice as long as fifth one; propodi of the ambulatory pereiopods bearing only a single posterior spinule; and harbouring 3–5 pairs of dorsolateral spines on the telson. A revised generic diagnosis is provided here to accommodate the present new species. The genetic divergence of mitochondrial gene cytochrome c oxidase subunit I (COI) between *Anachlorocurtis occidentalis* sp. n., and *A. commensalis* is 15.2–15.4%. Molecular analysis also confirmed a sister position of the genus *Anachlorocurtis* to *Miropandalus.* The present records of *A. commensalis* from Taiwan constitute an extension of the known range of the species.

Keywords
Caridea, Pandalidae, *Anachlorocurtis occidentalis*, new species, *Antipathes*, Antipatharia, Red Sea

Introduction

Shrimps of the family Pandalidae include 23 genera and 190 species (De Grave and Fransen 2011, Komai and Tsuchida 2014), with their greatest diversity occurring in boreal to temperate Atlantic and Pacific waters, especially in low-latitudinal areas of the Indo-West Pacific, and with relatively few species at similar latitudes in the southern hemisphere. In tropical regions, numerous pandalid species are known, but largely restricted to deeper, colder water (Bauer 2004). Overall, this is a diverse group of medium to large-sized, mainly epibenthic shrimps with a typical natant body form possessing well-developed rostra and long slender or robust legs (Bruce 1983, Bauer 2004). With almost no exception, species of Pandalidae are free-living and the association with other invertebrates is restricted to three species: *Chlorotocella gracilis* Balss, 1914, *Anachlorocurtis commensalis* Hayashi, 1975, and *Miropandalus hardingi* Bruce, 1983. *Chlorotocella gracilis* has been reported in association with a jellyfish and gorgonarian corals (Hayashi and Miyake 1968, Li and Davie 2006, Hayashi 2007), although those associations are perhaps best regarded as accidental, as numerous reports exist on free-living specimens (Bruce 1972). The other two species are obligate symbionts of antipatharian black corals (Anthozoa, Antipatharia) *Antipathes* spp., *Myriopathes japonica* (Brook, 1889) and *Cirrhipathes* spp. (Hayashi 1975, Bruce 1983, 1991).

The genus *Anachlorocurtis* Hayashi, 1975 has, up to now, only included a single species, *A. commensalis* known from Japan (Hayashi 1975, 2007) and recorded herein from Taiwan. The new species *A. occidentalis* sp. n. was found in the Red Sea, thus considerably extending the genus' geographical range, equally associated with antipatharian corals. The external morphology of both *Anachlorocurtis* and *Miropandalus* are unique, with their body being well adapted to life with their hosts. They are small, slender, and compressed animals with a cryptic colour pattern (Kawamoto and Okuno 2003, Minemizu 1996, 2013), short (*Anachlorocurtis*), or fully reduced (*Miropandalus*) rostra, specialised mouth-parts, and comparatively large and few eggs (Hayashi 1975, Bruce 1983, 1991).

The following abbreviations are used: COI, mitochondrial gene cytochrome c oxidase subunit I; fcn, field collection numbers for Aqaba (Aq), Eilat (ISR) and Taiwan (Tw, TAI); SEM, scanning electron microscope; PoCL, post orbital carapace length; spm(s), specimen(s); RL, rostrum length (measured from the posterior orbital margin to the distal edge of the most anteriorly advanced tooth of the rostrum); TL, total length of the body (measured from tip of the rostrum to the distal end of the telson, posterior telson spines not included); MSS, Marine Science Station, Aqaba, Jordan; NTOU, National Taiwan Ocean University; OUMNH.ZC, Zoological Collection, Oxford University Museum of Natural History, Oxford; RMNH, Naturalis Biodiversity Center, Leiden; UO, University of Ostrava.

Material and methods

Specimens of *Anachlorocurtis occidentalis* sp. n. were collected in the Red Sea (Aqaba, Jordan, in 2008 and 2009; Eilat, Israel, in 2011), and *A. commensalis* in the South China Sea (southern Taiwan, in 2009, 2011, 2012), respectively, from antipatharian corals using hand nets and SCUBA equipment. Samples were preserved in 80% ethanol for morphological studies and in 96–99% ethanol for molecular analysis.

The terminal segments of the first and second pereiopods of both species examined were photographed under SEM. One specimen of each species (*A. occidentalis* sp. n. UO Aq09-30A and *A. commensalis* UO Tw12-79) was dehydrated by a series of acetone/ethanol solutions of concentrations 30, 50, 70, 80, 90, 95 and 100% acetone in incremental 30 minute steps. Acetone was removed by the CO_2 critical point method (POLARON E3000 Critical Point Drying Apparatus) with dried specimens gold-coated (Automatic Sputter Coater: JEOL JFC-1300) and examined under a scanning electron microscope (SEM-JEOL JSM-6610LV).

Total genomic DNA was extracted from abdominal muscle tissue or eggs using the DNeasy Blood & Tissue isolation Kit (QIAGEN) according to the manufacturer's instructions. For amplifying the segment of mitochondrial protein-coding gene COI, with a polymerase chain reaction, the universal pair of primers LCO1490/HCO2198 was used (Folmer et al. 1994). The PCR was conducted in 25–30 µl reaction volume containing: 2–3 µl DNA template, 0.3 µM each primer, 0.15 mM dNTP, 0.7 units of *Taq* polymerase, distilled water, 10 × PCR buffer and 2.5 mM of $MgCl_2$. PCR cycling profile was as follows: 2.5 min at 94 °C for initial denaturation, followed by 40 cycles of 30 s at 90 °C, 1 min at 48 °C, 1 min at 72 °C and the final extension step at 72 °C for 10 min. PCR products were purified using GenElute PCR clean-up kit (Sigma). Sequencing reactions were carried out using the ABI3730XL DNA Sequencer at Macrogen, Inc. Sequences obtained were deposited in GenBank (Table 1), from

Table 1. Species used in the molecular analysis. Sampling location is given, as is GenBank accession numbers (COI), and voucher identification numbers of specimens examined. (ii, v) – see Material; * - Sequences obtained from GenBank.

Taxa	Sampling location	GenBank accession #	Voucher ID
Pandalidae			
Anachlorocurtis occidentalis sp. n. (ii)	Jordan, Aqaba	KJ690257	RMNH.CRUS.D.56174
Anachlorocurtis occidentalis sp. n. (v)	Jordan, Aqaba	KJ690256	RMNH.CRUS.D.56177
Anachlorocurtis commensalis Hayashi, 1975	Taiwan, Nanvan	KJ690258	RMNH.CRUS.D.56182
Miropandalus hardingi Bruce, 1983	Taiwan, Nanvan	KJ690259	UO Tw11-20A
Heterocarpus ensifer A. Milne-Edwards, 1881	Guadeloupe	*AY612858	NTOU
Heterocarpus gibbosus Spence Bate, 1888	Philippines, Panglao	*GQ302742	NTOUM00797
Pandalus borealis Krøyer, 1838	Canada, Quebec	*FJ581839	PB01CN0406
Pandalus montagui Leach, 1814	Canada, New Brunswick	*FJ581840	GSL31-52
Stenopodidae (outgroup)			
Stenopus hispidus (Olivier, 1811)	Vietnam, Nhatrang Bay	KJ690260	UO V10-17

which additional sequences were used. Sequences were aligned using MUSCLE (Edgar 2004). The divergence of the analysed mitochondrial gene between both species was detected using the Kimura 2-parameter model. A further seven pandalid species (including *Miropandalus*, a morphologically closely related genus) and one stenopod shrimp (outgroup) were included in the phylogenetic analysis. The best-fit nucleotide substitution model under Bayesian Information Criterion (GTR+G+I, General Time Reversible) was selected. Phylogenetic reconstruction of COI data set was performed in a maximum likelihood (ML), bootstrap was done with 1,000 replicates. All analyses were conducted using MEGA v5.2.1 (Tamura et al. 2011).

Systematics

Superfamily Pandaloidea Haworth, 1825
Family Pandalidae Haworth, 1825

Genus *Anachlorocurtis* Hayashi, 1975
http://species-id.net/wiki/Anachlorocurtis

Generic diagnosis (modified from Hayashi 1975). Small-sized shrimps. Rostrum short, deep, not reaching end of eyes; anterior and dorsal margins with 2–6 small teeth in adult females; rostrum styliform, anteriad in adult males. Carapace with 2 large compressed dorsal lobes, with small epigastric tooth and one small lobe near posterior margin; anterior (i.e., postrostral) lobe just behind orbit, similar and subequal to rostrum, with 2–4 small teeth anteriorly and small epigastric lobe posteriorly; large posterior, anteriorly hooked lobe on distal third of dorsal midline; antennal tooth marginal, acute; supraorbital, hepatic and pterygostomial teeth absent. Abdomen smooth, without spines or spiniform processes, sixth segment elongate, with posterior lobes obtuse. Telson with 3–5 pairs of small dorsal spines on lateral margins; posterior margin rounded with 5 pairs of spines. Eyes well developed, cornea with apical tubercle, accessory pigment spot lacking, stalk slightly longer than corneal length. Antennular peduncle elongate; basal segment with deep medioventral keel; stylocerite short, anteriorly truncate with produced distolateral tooth and medial angle pointed; distal 2 peduncular segments short; upper and lower flagella uniramous, short. Scaphocerite well developed, distolateral spine not exceeding lamella. Mandible without palp. Maxillula with palp bearing 2 long setae, upper lacinia broader that lower lacinia. Maxilla with bi-setose palp, with simple, broad, distal endite and bilobed proximal endite, scaphognathite well developed, posterior lobe not particulary elongate. First maxilliped with large palp; exopod without flagellum but with elongate setose caridean lobe; endites feebly separated; podobranch lacking. Third maxilliped long, slender, with elongate lateral lobe; merus, basis and ischium (i.e., antepenultimate segment) fused; exopod, epipod and arthrobranch absent. Pleurobranchs present above all pereiopods. First pereiopods slender, not chelate, with dactylus reduced; ischium without

lamellar expansion. Second pereiopods slender, chelate, equal with small subspatulate fingers bearing irregularly denticulate cutting edges; carpus three-segmented. Ambulatory pereiopods with dactylus slender, simple; propodus with 1–2 spinules on ventral margin, distoventral spinules lacking or present, small; pereiopod 3–5 meral spinulation 2-2-(0-2), respectively. Endopod of first pleopod reduced to small setose lobe far overreached by functional appendix interna in males, and more reduced, without cincinnuli, in females. Uropod with elongate branches.

Generic distribution. Kii Peninsula to Ruykyus, Japan, at depths of 8–15 m (Hayashi 1975, Kawamoto and Okuno 2003); southern Taiwan, depths 10–27 m (this report), and northeastern Red Sea, depths 4–55 m (this report).

***Anachlorocurtis occidentalis* sp. n.**
http://zoobank.org/AA95EADC-5095-4590-A5D5-16B902C88249
http://species-id.net/wiki/Anachlorocurtis_occidentalis
Figs 1–4, 5A–F, 6A–C, 7A–D, 8

Material examined. Type series. (i) 1 female juvenile (paratype), PoCL 1.6 mm (OUMNH.ZC.2014.01.016), Marine Science Station area, Aqaba, Jordan, reef wall, 40 m depth, from *Antipathes* sp., leg. Z Ďuriš, 17.06.2008, (fcn-Aq08-25B); **(ii)** 2 ovigerous females (paratypes), PoCL 2.1 mm (RMNH.CRUS.D.56174, GenBank KJ690257), and 2.6 mm (dissected, UO Aq08-34B), Marine Science Station area, Aqaba, Jordan, from antipatharian coral in crevice among concrete blocks of pier, 5 m depth, leg. Z Ďuriš, 16.06.2008 (fcn Aq08-34B); **(iii)** 1 ovig. female **(holotype)**, PoCL 3.3 mm (RMNH.CRUS.D.56175), Marine Science Station pier, Aqaba, Jordan, from antipatharian corals in crevice among concrete blocks of pier, 4 m depth, leg. Z Ďuriš, 20.06.2008 (fcn Aq08-39); **(iv)** 1 ovigerous female (paratype), PoCL 2.4 mm (OUMNH.ZC.2014.01.017), Marine Science Station area, Aqaba, Jordan, reef wall, from *Antipathes* sp., 45 m depth, leg. Z Ďuriš & I Horká, 11.06.2009 (fcn Aq09-8); **(v)** 1 male **(allotype)**, PoCL 1.9 mm (RMNH.CRUS.D.56176), 1 ovigerous female (paratype), PoCL 2.2 (RMNH.CRUS.D.56177, Genbank KJ690256), 1 ovigerous female, PoCL 2.5 mm, 5 males PoCL 1.6–1.9 mm, 1 spm PoCL 1.6 mm (paratypes) (RMNH.CRUS.D.56179), Marine Science Station area, Aqaba, Jordan, rock on sandy bottom ca 15 m out of reef wall, from *Antipathes* sp., 47 m depth, leg. Z Ďuriš & I Horká, 21.06.2009 (fcn Aq09-28B); **(vi)** 1 ovigerous female (paratype), PoCL 3.1 mm (dissected, dried for SEM; UO Aq09-30A), Marine Science Station area, Aqaba, Jordan, reef wall, from *Antipathes* sp., 55 m depth, leg. Z Ďuriš & I Horká, 22.06.2009 (fcn Aq09-30A); **(vii)** 1 ovigerous female PoCl 2.5 mm, 2 females 1.9 mm, 1 male PoCL 1.5 mm (paratypes) (UO Aq09-65), Marine Science Station area, Aqaba, Jordan, sandy slope, antipatharian coral on rock, 50–55 m depth, leg. Z Ďuriš & I Horká, 01.06.2009 (fcn Aq09-65); **(viii)** 1 ovigerous female (paratype), PoCL 2.3 mm (RMNH.CRUS.D.56180), Marine Science Station area, Aqaba, Jordan, from *Antipathes* sp., 55 m depth, leg. Z Ďuriš & I Horká, 05.06.2009 (fcn Aq09-93).

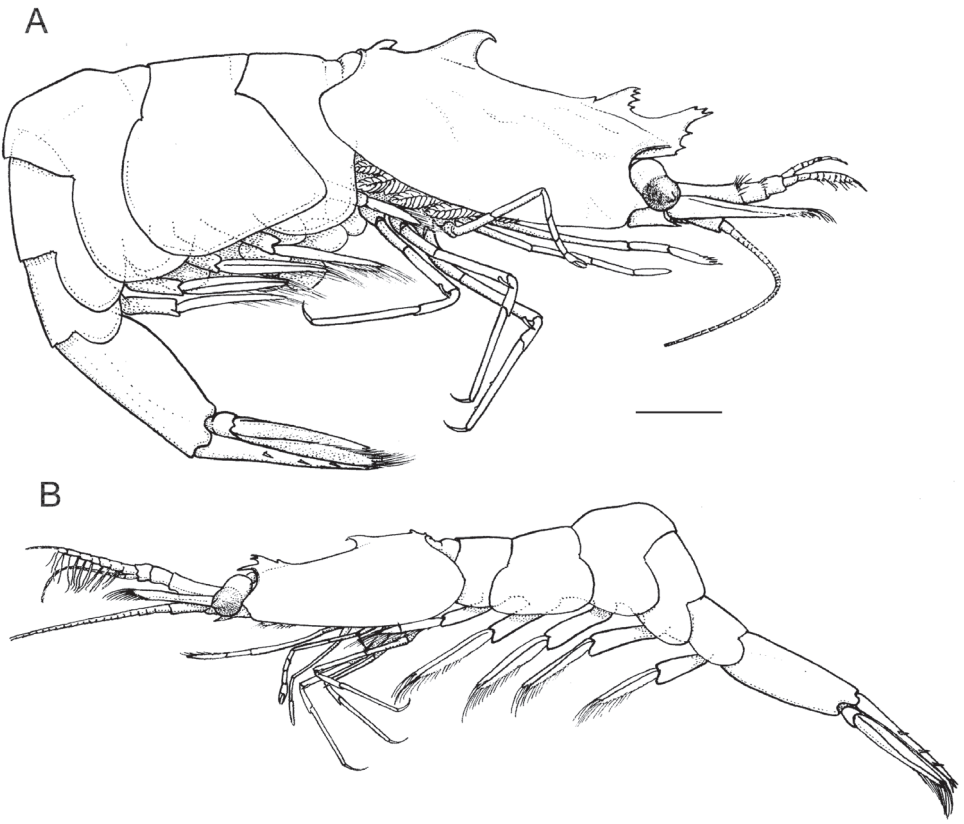

Figure 1. *Anachlorocurtis occidentalis* sp. n., total aspect. **A** holotype, ovigerous female (RMNH. CRUS.D.56175) **B** allotype, male (RMNH.CRUS.D.56176). Scale bar equals 1 mm.

Non-type material. (ix) 1 female, PoCL 3.3 mm (OUMNH.ZC.2011.05.078), Eilat, Israel, 29°30'07"N, 34°55'05"E, 40 m depth, from *Antipathes* sp., leg. S De Grave & ML Johnson, 04.04.2011 (fcn ISR-092); **(x)** 3 ovig. females (PoCL 2.6, 3.0, 3.2 mm) (OUMNH.ZC.2011.05.079), Eilat, Israel, 29'51"N, 34°55'39"E, 22 m depth, from *Antipathes* sp., leg. S De Grave & ML Johnson, 29°, 05.04.2011 (fcn ISR-112).

Diagnosis. Carapace dorsally trilobate in adults. Rostrum short, not reaching end of eyes; deep and anteriorly serrated with up to 6 small secondary teeth of which upper second or third tooth extending furthest forward; posterior margin smooth and convex; lower margin unarmed, slightly convex. Posterior dorsal lobe on carapace strongly hooked in adults. Posterior propodal spinule of ambulatory pereiopods small and single. Third abdominal segment distinctly angulated in lateral aspect, with dorsally straight outline. Sixth abdominal segment 2.5 times longer that deep. Mesial margin of endopod of male first pleopod with 9 mesial setae. Appendix masculina of second male pleopod longer than appendix interna. Telson with 3–5 pairs of dorsal spines.

Description of female holotype. Carapace (Fig. 1A) smooth, about twice as long as height, with 2 large triangular teeth on dorsal midline. Anterior tooth placed just behind posterior level of orbit, similar to but slightly smaller than rostrum, anteriorly serrated with 4 small teeth; small obtuse epigastric tooth placed posteriorly on base of anterior tooth. Large posterior tooth placed on posterior third of carapace, higher than anterior tooth and strongly hooked with apex pointed forwards, and with anterior and posterior margins convex, smooth, without serration; small acute anteriad directed tooth situated posterodorsally near margin of carapace. Dorsal margin of orbit continuous with short dorsal midrib extending to middle of rostrum near most anteroventrally tooth of rostrum; lower orbital angle broadly rounded, not produced. Antennal tooth well developed, marginal, acute; supraorbital, hepatic and pterygostomial teeth absent; pterygostomial angle subquadrate, obtuse.

Abdomen smooth and compressed, with all pleurae rounded posteriorly. Third segment produced posterodorsally, with straight dorsal outline. Sixth segment twice as long as fifth segment and more than twice as long as maximal depth; posterolateral and posteroventral angles obtusely produced. Abdominal sternites unarmed, sixth sternite with small preanal tubercle.

Telson (Fig. 2B) slender, as long as sixth abdominal segment and 4 times longer than maximal width at anterior fourth; with 5 pairs of small (less than 0.05 of telson length), irregularly placed dorsolateral spinules, first pair placed at 0.35 of telson length; the following 4 pairs distributed along distal half of telson. Posterior margin broadly rounded, with 5 pairs of spines, lateral shorter than dorsal spines, remaining spines longer, with submedian pair longest but not reaching 0.1 of telson length.

Eyes (Fig. 5F) long and cylindrical; cornea well pigmented, shorter than stalk, with a distinct pointed apical tubercle; without accessory pigment spot.

Antennular peduncle (Fig. 2A) with basal segment long, more than twice as long as distal 2 segments combined, with several long plumose seta on distal dorsal margin; mesial margin with deep and thin ventral keel along whole segment. Stylocerite reaching about middle of basal segment; outer margin nearly straight, ending in acute spine far overreaching transverse anterior margin; inner distal angle angulate, pointed. Distal 2 segments subequal, short and broad. Upper flagellum short, composed of about 9 segments with 4 basal segments swollen, and with about 6 groups of aesthetascs on distal segments; lower flagellum slightly longer than upper flagellum.

Antenna (Fig. 2C) with basicerite bearing well developed distolateral tooth; carpocerite cylindrical, reaching middle of scale. Scaphocerite distinctly exceeding antennular peduncle, about 3 times as long as broad; outer margin straight, ending in a stout spine, far overreached by angulate distomesial part of lamina. Flagellum slender, long, about half as long as body.

First pereiopod (Fig. 2D–E) slender, not chelate, reaching apex of rostrum; dactylus fully reduced, possibly indicated only as part of terminal spinulation of propodus; propodus about 7.0 times longer than basal depth, slightly tapering to apex; carpus, merus and ischium elongate, unarmed, almost uniformly wide, and about 0.8, 1.3 and 0.8 of propodus length, respectively.

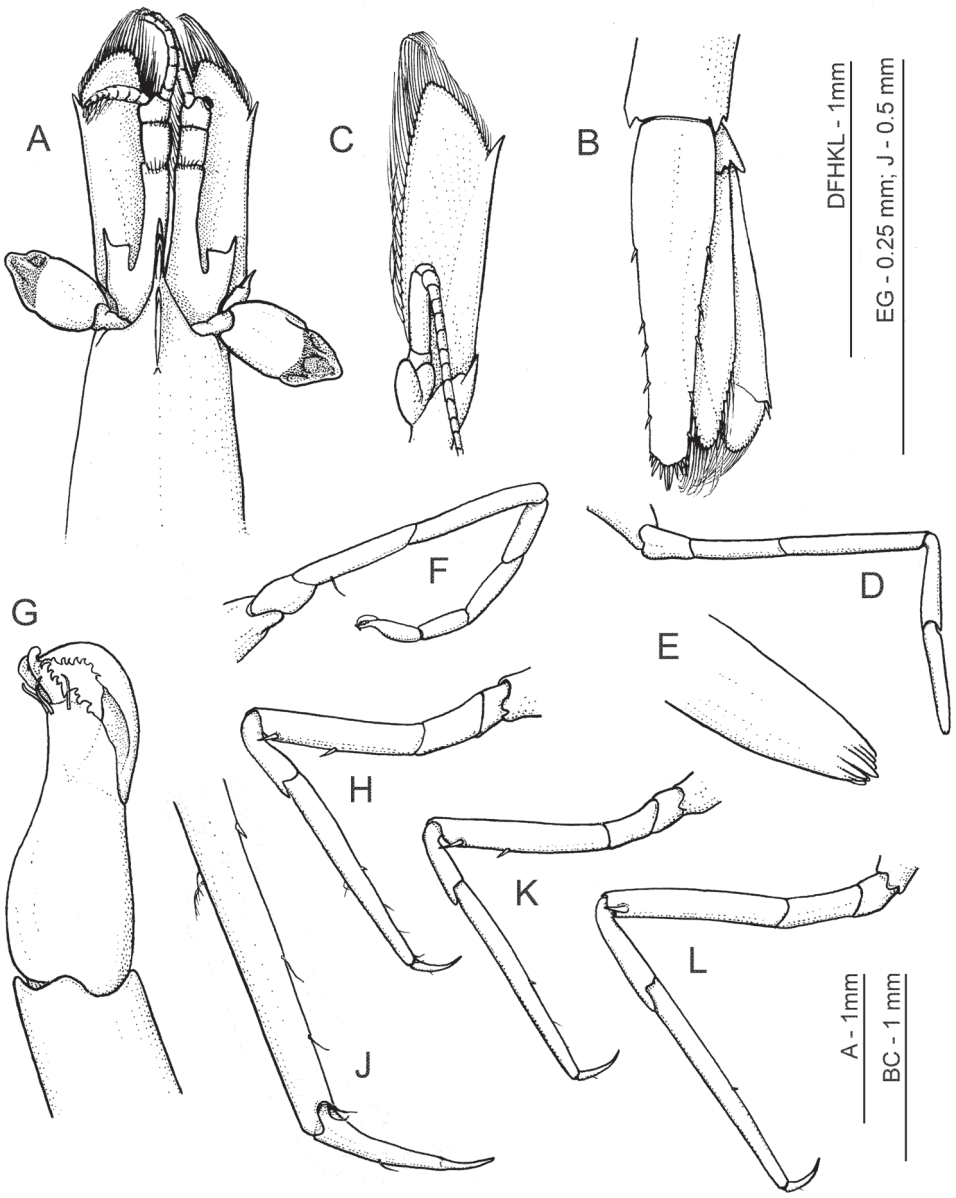

Figure 2. *Anachlorocurtis occidentalis* sp. n., holotype, ovigerous female (RMNH.CRUS.D.56175). **A** anterior carapace, antennae and eyes, dorsal **B** telson and uropod, dorsal **C** antenna, ventral **D** right first pereiopod **E** same, terminal segment **F** right second pereiopod **G** same, chela, ventrolateral aspect **H** third pereiopod, lateral **J** same, dactylus and distal propodus **K** fourth pereiopod **L** fifth pereiopod.

Second pereiopod (Fig. 2F–G) slender, chelate, not reaching distal end of eye; chela small, spatulate, with large gap between fingers, dactylus curved, with distally denticulate lateral cutting edge, fixed finger short, stout, with several irregular distal teeth

on cutting margin, with pair of large denticulate spines with hooked apices on apex, and with several simple setae subterminally; palm slightly longer than dactylus, swollen proximally; carpus about 3 times as long as chela, three-jointed, with length ratios 1.0 : 1.7 : 1.4 (distal to proximal), proximal segment obliquely articulating intermediate one; merus two-thirds length of carpus; ischium as long as merus.

Third pereiopod (Fig. 2H, J) more robust than first 2 pereiopods, reaching end of basal antennular segment; dactylus slender, 5.0 times longer than basal depth, curved, with a distinct unguis; propodus 3.5 times as long as dactylus and about 10 times longer than basal width, tapering distally, with one distinct spinule in middle of ventral margin, without distoventral spines near articulation with dactylus; carpus about 0.4 of propodus length and slightly deeper distally than propodus, distodorsal end extending over base of propodus as flat expansion; merus about 0.8 of propodus length and about 6.0 times longer than uniform width, with 2 distinct ventrolateral spines, one subterminal and one at midlength of segment; ischium, basis and coxa short, unarmed.

Fourth and fifth pereiopods (Fig. 2K, L) subequal to third pereiopod, fifth slightly longer and more slender than fourth; fourth pereiopod similar to third pereiopod in spination of both propodus and merus, with proximal spine placed more forwards (distal 0.6 of ischium length); fifth pereiopod merus armed with one subterminal spine only.

Endopod of first pleopod reduced, triangular, appendix interna without cincinnuli, with marginal plumose setae.

Uropod (Fig. 2B) with branches slightly shorter than telson; outer margin of exopod almost straight, terminating in short fixed spine and with more mesial movable spine about twice overreaching fixed tooth; diaeresis well developed, unarmed mesially from lateral movable spine.

Description of mouthparts (paratype – ovigerous female PoCL 2.6 mm; UO Aq08-34B). Mandible (Fig. 3A–C) without palp; molar process with broadly truncate distal end densely covered by sharp tubercles and some slightly larger marginal teeth and subequal stout setae; incisor process basally broad, tapering distally, with obliquely truncate distal end comprised of 4 subquadrate, distally serrate, proximal teeth, and 2 slender simple teeth, terminal one more produced.

Maxillula (Fig. 3D) with palp truncate distally and bearing 2 long pappose setae; broad distal lacinia armed with numerous strong pappose setae; basal lacinia elongate, slender, tapering distally, with about 6 pappose or simple setae terminally.

Maxilla (Fig. 3E) with short palp about 2.5 times longer than broad basally, with 2 pappose setae distally; scaphognathite well developed, anterior lobe produced, almost twice longer than broad basally, posteriorly rounded, marginal setae densely plumose. Distal endite divided into 2 parts with plumose setae marginally; basal endite not divided and with single apical pappose seta.

First maxilliped (Fig. 3F) with elongate palp, more than 3.0 times longer than wide basally, with 3 simple setae distally; exopod composed of caridean lobe with long plumose marginal setae, flagellum absent; endites separated by faint incision, with sparsely distributed pappose setae; epipod broadly triangular, faintly bilobed.

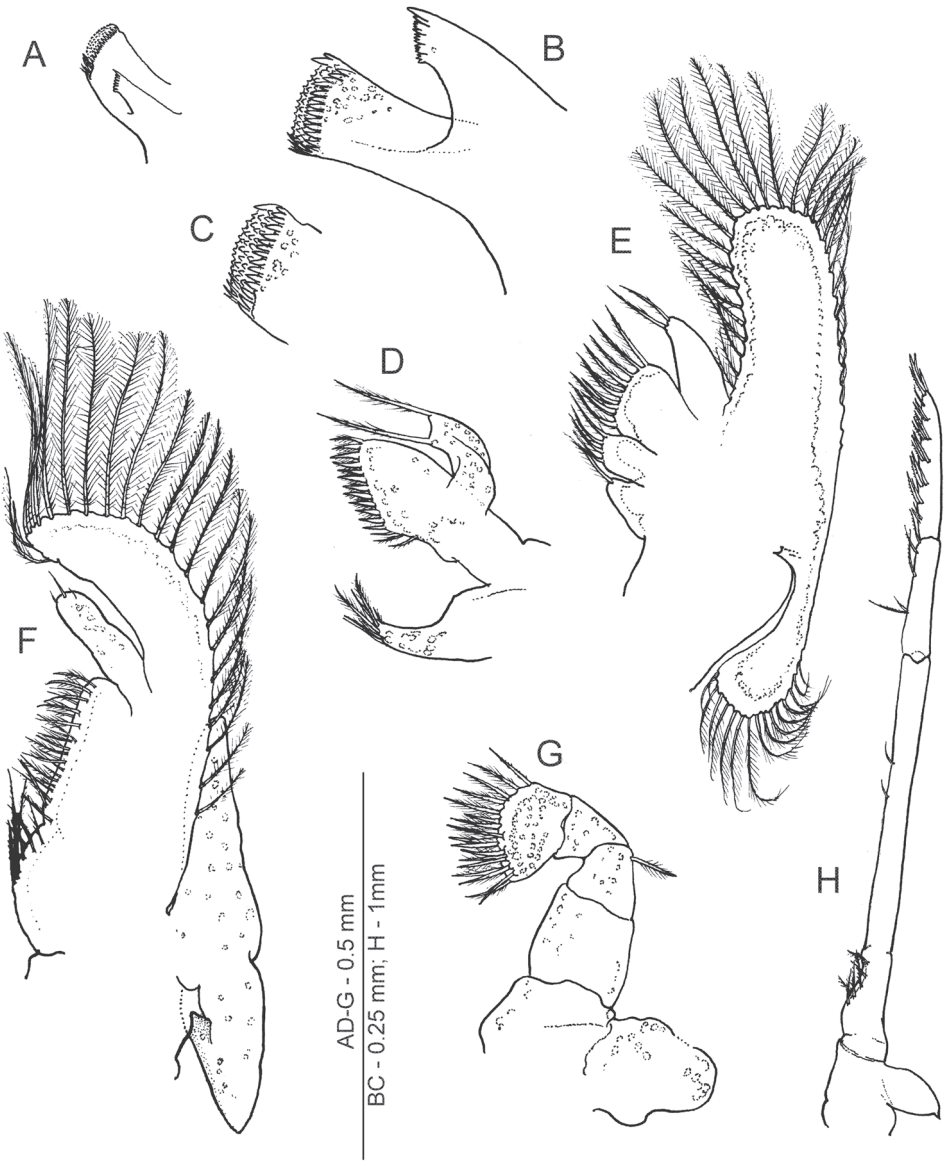

Figure 3. *Anachlorocurtis occidentalis* sp. n., mouthparts (ovigerous female, PoCL 2.6 mm, UO Aq08-34B). **A** mandible, anterior aspect **B** same, molar and incisor processes, anteroventral **C** same, apex of molar process, anteromesial **D** maxillula **E** maxilla **F** first maxilliped **G** second maxilliped **H** third maxilliped.

Second maxilliped (Fig. 3G) with dactylar segment completely fused to propodus, mesial margin with more than 15 stout pappose setae; single pappose seta situated distolaterally on merus; ischium broader and longer than carpus; basis and coxa fused, with division faintly indicated; exopod absent; epipod large, broadly ovate.

Third maxilliped (Fig. 3H) slender and long, failing to reach end of basal antennular segment; lateral coxal plate ovate, with small spiniform apex; antepenultimate segment (i.e., merus, ischium and basis fused) with subdivisions feebly indicated, about 12 times longer than uniform width and 1.5 times as long as distal 2 segments combined; setose concavity present on ventral margin of ischium; penultimate segment (i.e., carpus) about 4.0 times longer than wide basally and 0.4 of preceding segment length, with several serrulate setae ventrally; ultimate segment about 1.2 times longer than penultimate segment, furnished with about 8 dorsomesial rows of serrulate setae.

Other specimens. Males generally similar to adult females but distinctly smaller and more slender in lateral aspect (see Fig. 1). Allotype male (Figs 1B, 5D) with rostrum simple, styliform, with anteriad directed, bifid, dorsal tooth placed just above level of posterior orbital margin, and with obtuse epigastric tooth more posteriorly; posterior hooked tooth well developed at posterior third of carapace, posterior submarginal tooth small but distinct. Upper antennular flagellum with basal swollen part (corresponding to fused flagella) more elongate than in adult females, with stronger developed aesthetascs. Endopod of first pleopod (Fig. 4A, B) reduced to small setose lobe with bilateral setae and pair of pappose terminal setae, appendix interna far overreaching reduced endopod but falling short of midlength of exopod, elongate triangular, with 9 simple hooked spiniform setae on mesial margin, and with group of about 8 cincinnuli on oblique apex. Endopod of the second pleopod (Fig. 4C) almost as long as exopod, with pair of appendices emerging from proximal third of mesial margin; appendix masculina slender, more than 6.0 times longer than basal width, reaching midlength of endopod; with 4 stout simple setae on apex. Appendix interna reaching 0.75 of appendix masculina length, with about 8 terminal cincinnuli (Fig. 4D).

Variation. The main morphological variation observed within the samples of the new species is in the dorsal armament of the carapace and rostrum (Fig. 5A–E). While in adult and subadult females the carapace is trilobate, comprised of 2 high, anteriorly denticulate, similar "lobes", i.e., the rostrum and the anterior carapacial lobe, and a large posterior hooked tooth, in males only the postrostral lobe is developed, being small and bidentate, in addition to a short styliform rostrum and the posterior hooked tooth. In juveniles, the posterior hooked tooth is absent, and the anterior ornamentation generally consists of a short simple rostrum with a single posterior dorsal tooth. The rostral formula (number of anterior dentition of the postorbital lobe + same for rostrum) is 3-4 + 2-6 for adult females, 2-3 + 1-3 for subadult females, 2 + 1 (i.e., simple rostrum) for males, and 1 + 1-3 for juveniles.

The small epigastric tooth is placed some distance from the posterior end of the base of the small anterior tooth on the carapace in juveniles, not on the base of the lobe as in adults. The posterior dorsal submarginal tooth, well developed in adult females, is small but distinct in males and subadult females, and may present also in juveniles.

The dorsal telson dentition generally consists of 3 pairs of spinules, with the first pair situated anteriorly to the midlength of the telson. Some females possess 4 pairs of those spinules, e.g., in a subadult female (UO Aq09-30A), or 5 pairs (ovigerous female holotype, RMNH.CRUS.D.56175).

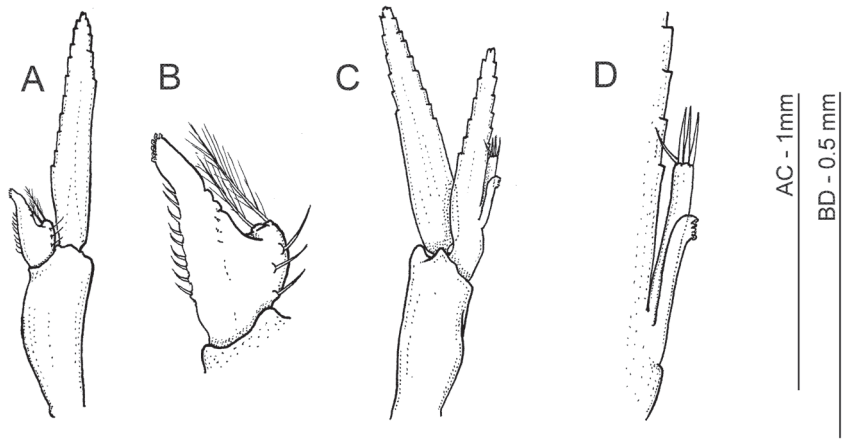

Figure 4. *Anachlorocurtis occidentalis* sp. n., allotype, male (RMNH.CRUS.D.56176). **A** first pleopod **B** same, endopod **C** second pleopod **D** same, mesial margin of endopod with appendices interna and masculina.

The specimens are consistent in the number of the meral spines on the 3rd-5th pereiopods, 2-2-1, respectively. A limited variation is present in the propodal ventral spinulation in the ambulatory pereiopods. In the females examined, the spinulation is 1-1-1, respectively, with the spinules very minute, while in adult males the spinules are stronger, numbering 2-2-1/2, respectively.

Colour in life (Fig. 6A–C). Cryptic, mimicking antipatharian host, ventral part of body reddish brown (similar to axial coral branch pattern), dorsal part of body transparent with yellowish to light reddish stripes emerging from internal axis of body (similar to host polyps), with narrow lighter band across carapace; antennulae light brown, scaphocerites with 2 light brown patches (distal and proximal), connected by narrow medial stripe; abdomen with irregular narrow light bands across each segment; tail fan (Fig. 6C) with 3 wide light brown transverse bands across uropods, with colour merged along mesial margin of endopod. Ovigerous females with greyish-brown finely marbled pattern on abdominal pleurae covering egg mass.

Measurements. Holotype ovigerous female: PoCL 3.3 mm, RL 0.8 mm, TL about 12 mm, eggs (without eye-spots) diameters 0.58 × 0.42 mm. Allotype male: PoCL 2.0 mm, RL 0.23 mm, TL 8.7 mm. Paratypes: males (5 spms) PoCL 1.6–1.8 mm, TL 7.1–8.2 mm; ovigerous females (8 spms) PoCL 2.2–3.1 mm, TL 8.7–11.5 mm; subadult females (2 spms) PoCL 1.9 mm; juveniles (2 spms) PoCL 1.5-1.6 mm; eggs without eyespots diameters (7 spms) 0.44–0.56 × 0.36–0.40 mm, eggs with eyespots (1 spm) 0.62 × 0.48 mm.

Host and habitat. Specimens were caught on black corals (*Antipathes* sp.), found in deeper waters along the reef wall and on a boat wreck at 22–55 m, but also in dark crevices in shallow waters, only 4–5 m deep.

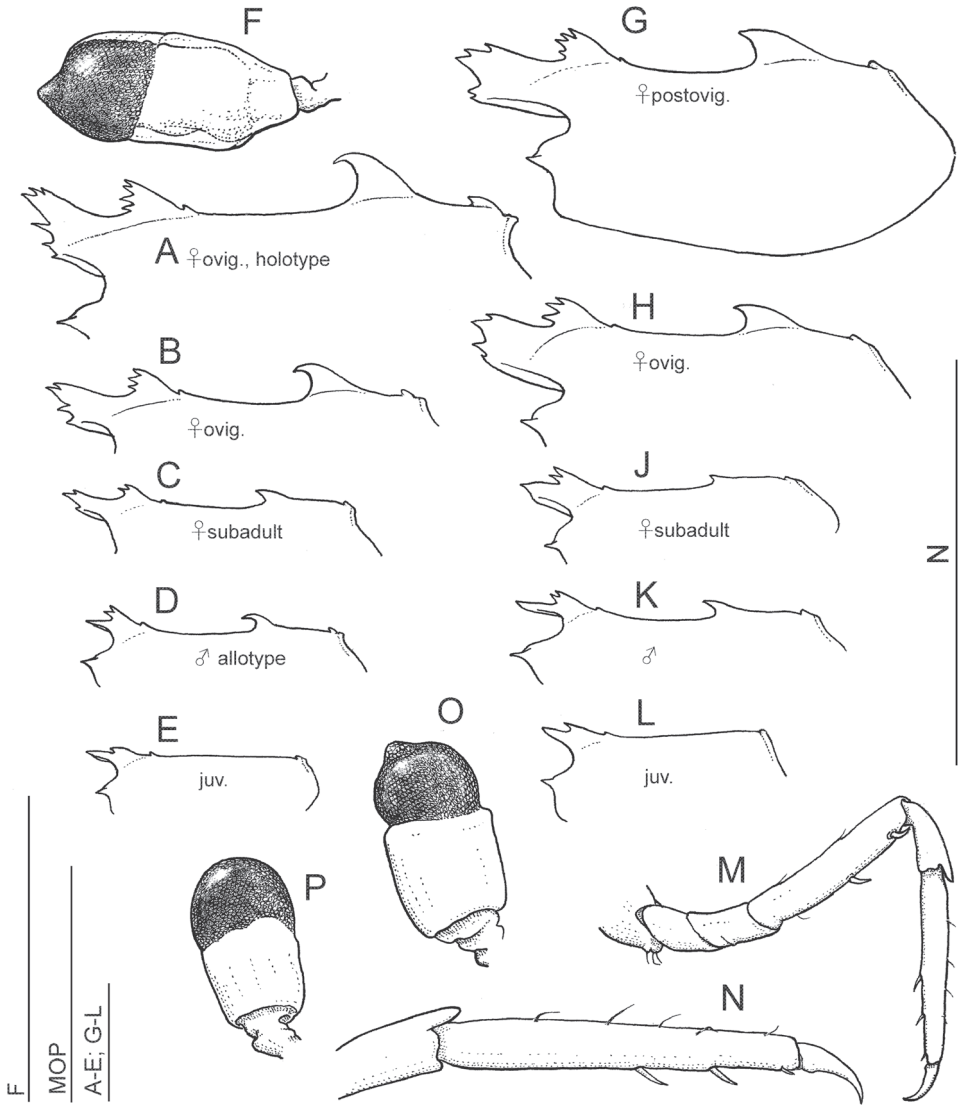

Figure 5. *Anachlorocurtis occidentalis* sp. n., (**A–F** Aqaba, 2009) and *A. commensalis* Hayashi, 1975 (**G–P** Taiwan, 2009), outline of carapace, lateral aspect (**A–E, G–L**), third pereiopod (**M–N**), and eye (**F, O–P**). **A** holotype, ovigerous female PoCL 3.3 mm (RMNH.CRUS.D.56175) **B** ovigerous female PoCL 2.5 mm (RMNH.CRUS.D.56179) **C** subadult female PoCL 1.9 mm (UO Aq09-65) **D** allotype, male PoCL 1.9 mm (RMNH.CRUS.D.56176) **E** juvenile specimen PoCL 1.6 mm (RMNH.CRUS.D.56179) **F** ovigerous female PoCL 2.5 mm (RMNH.CRUS.D.56179) **G** post-ovigerous female PoCL 2.6 mm (OUMNH.ZC.2010-02-010) **H** ovigerous female PoCL 2.6 mm **J** subadult female PoCL 1.9 mm **K** male PoCL 2.2 mm **L** juvenile specimen PoCL 1.6 mm (OUMNH.ZC.2010.02.061) **M–O** post-ovigerous female PoCL 2.6 mm (OUMNH.ZC.2010-02-010) **P** male PoCL 2.2 mm. Scale bars equal 1 mm.

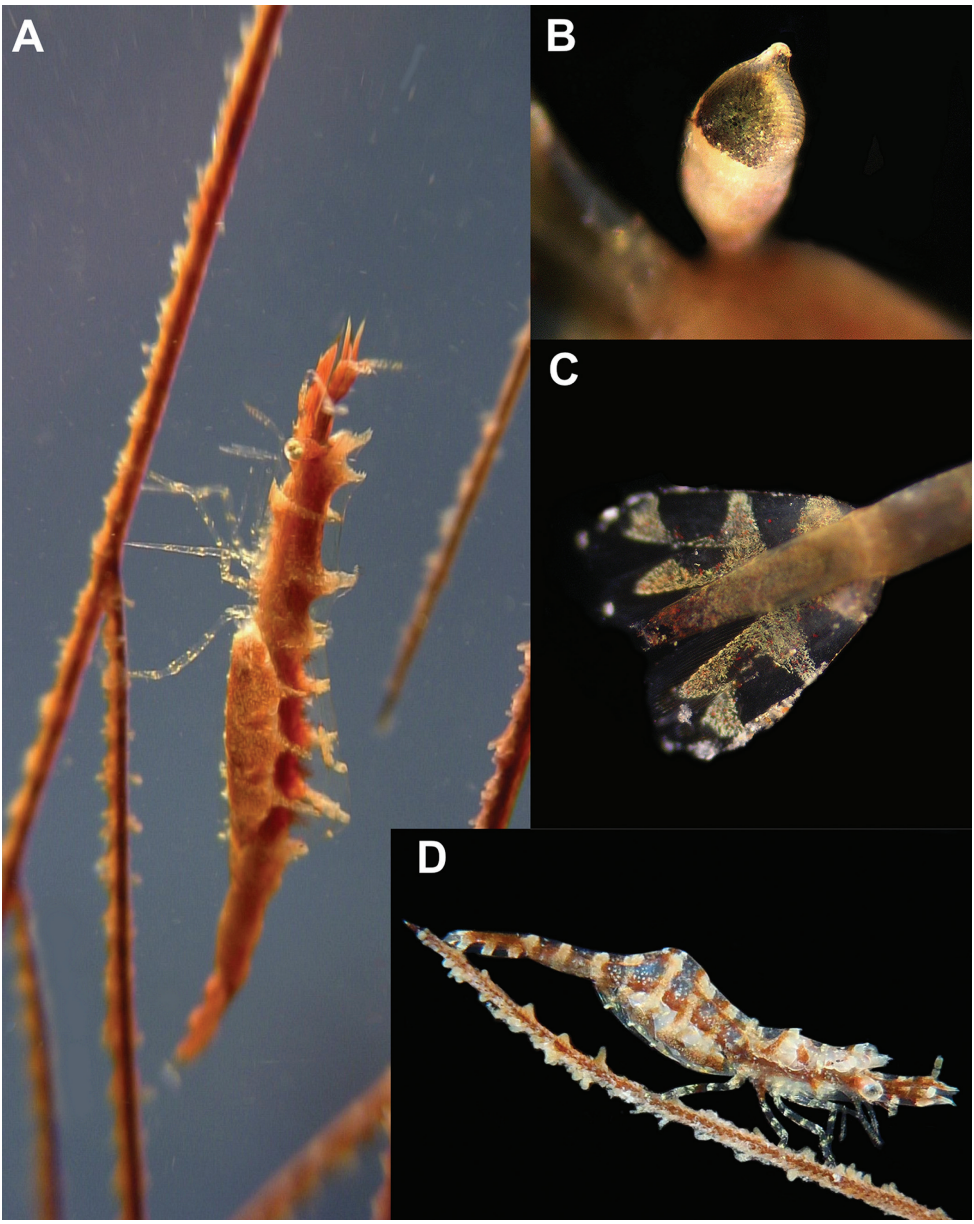

Figure 6. Colour patterns. *Anachlorocurtis occidentalis* sp. n. **A** ovigerous female holotype (RMNH. CRUS.D.56175) on antipatharian host **B** detail of the eye with produced apical tubercle **C** colour patterns of the tail fan. *Anachlorocurtis commensalis* Hayashi, 1975 **D** ovigerous female (UO Tw12-79).

Associated fauna. The specimens of the present new species were collected from their hosts together with specimens of the pontoniine shrimps, *Manipontonia psamathe* (De Man, 1902) and *Periclimenes* cf. *lepidus* Bruce, 1978, both not previously reported from the Red Sea.

Etymology. The specific name is from the Latin *occidentalis*, western, reflexing the geographic range of the new species in the westernmost region of the Indo-West Pacific area, the Red Sea, as opposed to the East Asian distribution of the type species of the genus.

Distribution. Currently only known from the type locality, Gulf of Aqaba, in the north-eastern Red Sea.

Anachlorocurtis commensalis Hayashi, 1975

http://species-id.net/wiki/Anachlorocurtis_commensalis
Figs 5G–P, 6D, 7E–G, 8

Anachlorocurtis commensalis Hayashi 1975: 172–182, figs1–3.; Hayashi 2007: 147–150, figs 538–539.; Kawamoto and Okuno 2003: 64, colour photo.; Minemizu 2013: 129, colour photo.

Material examined. (i) 8 spms (1 ovigerous female PoCL 2.6 mm, 1 female subadult PoCL 2 mm, 3 males PoCL 1.8–2.1 mm, 3 juveniles PoCL 1.6–1.8 mm) (OUMNH.ZC.2010.02.061), Gudanshr reef, Namwan Bay, Pingtung County, Taiwan, 21°56.531'N, 120°45.546'E, from bushy black coral, 10 m depth, leg. S De Grave, 07.12.2009 (fcn TAI-244); **(ii)** 10 spms (4 females ovigerous PoCL 2.5–2.6 mm, 1 female post ovigerous PoCL 2.6 mm, 1 female PoCL 2.3 mm, 1 female subadult PoCL 1.9 mm, 3 males PoCL 1.9–2.2 mm) (OUMNH.ZC.2010-02-010), Gudanshr reef, Namwan Bay, Pingtung County, Taiwan, 21°56.531'N, 120°45.546'E, from *Cirrhipathes* sp., 27 m depth, leg. S De Grave, 12.12.2009 (fcn TAI-327); **(iii)** 1 juvenile PoCL 1.8 mm (RMNH.CRUS.D.56181), Gudanshr reef, Namwan Bay, Pingtung County, Taiwan, from antipatharian on overhanging rock wall, 10.9 m depth, leg. Z Ďuriš, 11.11.2011 (fcn Tw11-11); **(iv)** 1 juvenile (damaged) PoCL 1.8 mm (OU Tw11-20B), Gudanshr reef, Namwan Bay, Pingtung County, Taiwan, upper side of rocky reef, from yellow branching antipatharian, 18.6 m depth, leg. Z Ďuriš, 03.11.2011 (fcn Tw11-20B); **(v)** 1 ovigerous female PoCL 2.3 (RMNH.CRUS.D.56182, Genbank KJ690258), 1 ovigerous female, PoCL 2.4 mm, 1 male PoCL 2.1 mm (NTOU M01305), Gudanshr reef, Namwan Bay, Pingtung County, Taiwan, upper side of reef, from dense bushy antipatharian, 22.1 m depth, leg. Z Ďuriš , 03.11.2011 (fcn Tw11-21); **(vi)** 1 ovigerous female PoCL 2.5 mm (dissected, dried for SEM; UO Tw12-79), Gudanshr reef, Namwan Bay, Pingtung County, Taiwan, reef slope, from antipatharian, 25.3 m depth, leg. Z Ďuriš & I Horká, 12.09.2012 (fcn Tw12-79).

Remarks. The specimens examined agree well with the original description by Hayashi (1975). As in *A. occidentalis* sp. n., the specimens examined of *A. commensalis* vary in the dorsal armament of the carapace and rostrum (Fig. 5G–L). In adult and subadult females the carapace with the rostrum is triple lobate, in contrast in males only the anterior, bidentate, lobe is developed, in addition to the posterior hooked tooth and a short styliform rostrum. In juveniles the posterior hooked is absent and the

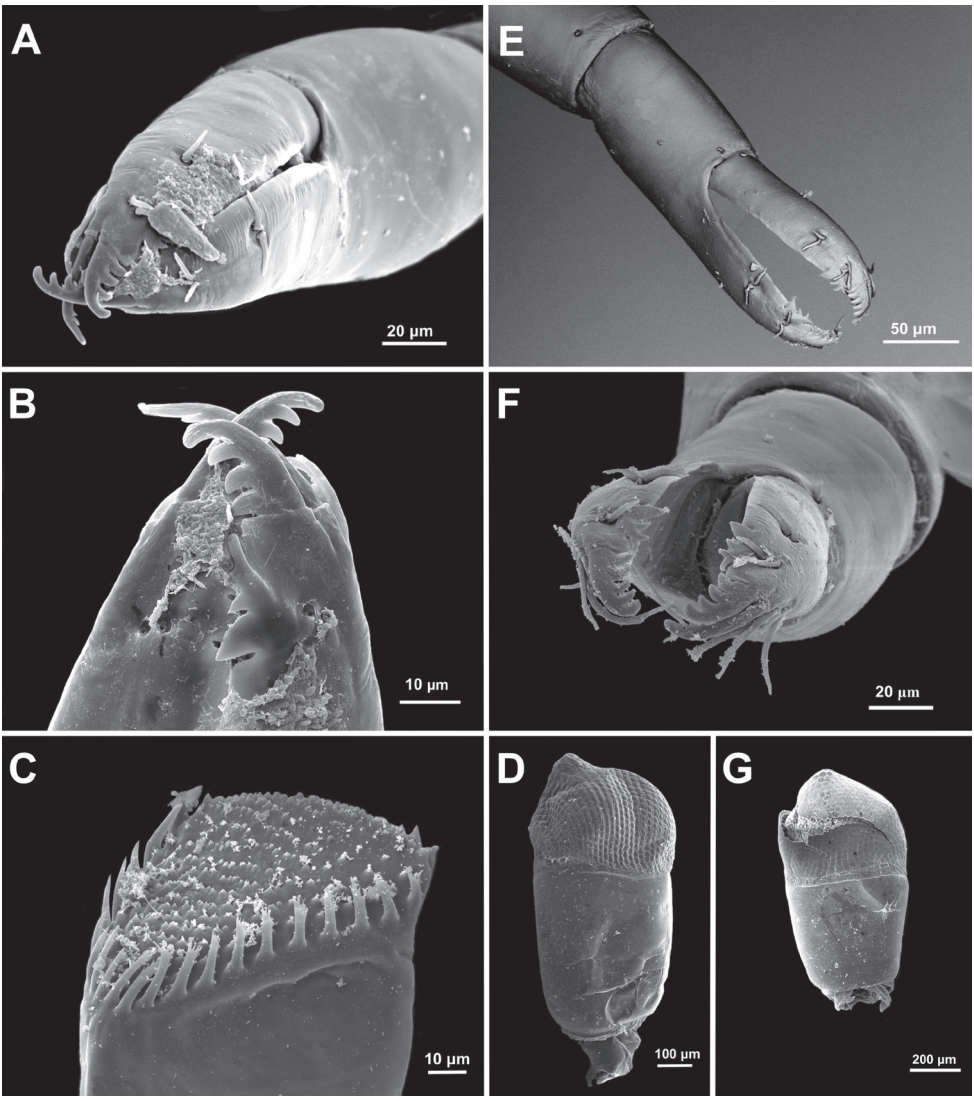

Figure 7. *Anachlorocurtis occidentalis* sp. n., ovigerous female paratype, PoCL 3.1 mm (UO Aq09-30A). **A** second pereiopod chela **B** same, tips of fingers **C** mandible, molar process, antero-mesial aspect (from side of incisor process) **D** eye. *Anachlorocurtis commensalis* Hayashi, 1975, ovigerous female PoCL 2.5 mm (UO Tw12-79) **E** second pereiopod chela **F** same, tips of fingers **G** eye.

anterior ornamentation generally consists of a short simple rostrum with a single posterior dorsal tooth. The posterior dorsal submarginal tooth is small in adults and subadults, and is absent in juveniles. The rostral formula (see above) is 2-4 + 4-5 for adult females, 2-3 + 1-2 for subadult females, 2 + 1 (i.e. simple rostrum) for males, and 1-2 + 1 for juveniles. Cornea in males is almost globular, with the apical tubercle indistinct, in females the tubercle is more produced but not as developed as *A. occidentalis* sp. n.

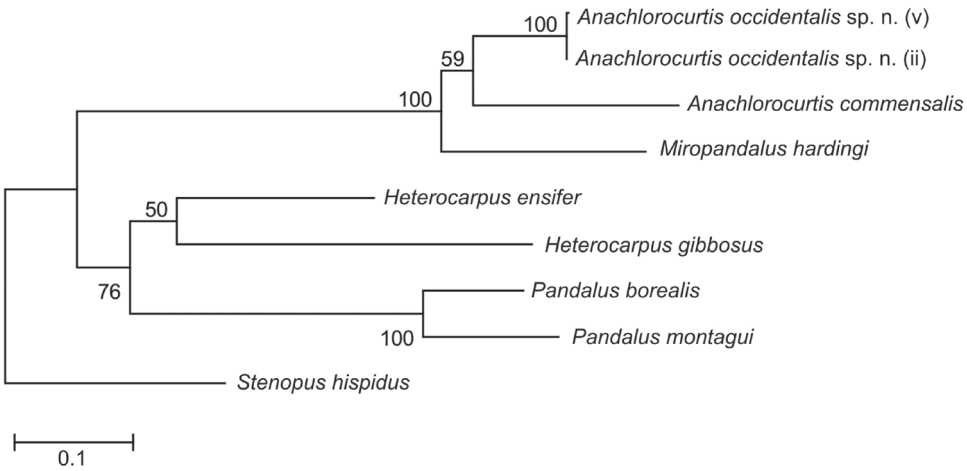

Figure 8. Phylogenetic tree obtained by maximum likelihood analysis (GTR+G+I substitution model) of partial sequence of COI (658 bp).

Colour in life. Generally similar to that of *A. occidentalis* sp. n., but the light transverse bands are greyish, more wide and distinctive in *A. commensalis* (Fig. 6D); also see colour photos in Minemizu (1996: 8; 2000: 113; 2013: 129), Kato and Okuno (2000: 58) and Kawamoto and Okuno (2003: 64).

Distribution. Kii Peninsula (type locality), Izu-Oshima and Hachijyo-jima, Izu Islands, and Kume-jima, Ryukyus, Japan (Minemizu 1996, 2000, 2013, Kato and Okuno 2000), Kawamoto and Okuno (2003); South (Namwan) Bay, Taiwan (present report).

Molecular data

Molecular analysis (Maximum Likelihood, Fig. 8) supports a sister position of *Anachlorocurtis occidentalis* sp. n. (Red Sea) to *A. commensalis* (Taiwan). Both species form a monophyletic clade with *Miropandalus hardingi*. The maximum Kimura 2-parameter distance between *A. occidentalis* sp. n. and *A. commensalis* reached 15.4% (for more details see Table 2).

Discussion

Anachlorocurtis occidentalis sp. n. is morphologically closely related to the only other species in the genus, *A. commensalis*. Both species have a small, slender body and ambulatory legs. The third to fifth pereiopods have the propodi about 10 times longer than deep basally *A. occidentalis*, whilst 8 times longer in *A. commensalis*, and the dactyli are 5.5 times longer than deep basally in the new species, and 3 times longer than

Table 2. Kimura's 2-parameter distances of COI gene sequences among species studied.

	***A. occidentalis* sp. n.**	***A. occidentalis* sp. n.**	***A. commensalis***	***M. hardingi***	***H. ensifer***	***H. gibbosus***	***P. borealis***	***P. montagui***	***S. hispidus***
Anachlorocurtis occidentalis sp. n. (RMNH. CRUS.D.56177)	–								
A. occidentalis sp. n. (RMNH.CRUS.D.56174)	0.002	–							
A. commensalis	0.154	0.152	–						
Miropandalus hardingi	0.156	0.154	0.192	–					
Heterocarpus ensifer	0.254	0.252	0.267	0.268	–				
H. gibbosus	0.300	0.297	0.295	0.272	0.211	–			
Pandalus borealis	0.278	0.275	0.286	0.293	0.221	0.236	–		
P. montagui	0.268	0.266	0.276	0.270	0.220	0.246	0.123	–	
Stenopus hispidus	0.253	0.251	0.237	0.248	0.219	0.226	0.251	0.230	–

deep in *A. commensalis*. The new species also differs from *A. commensalis* by the posterior dorsal lobe on the carapace being strongly hooked in adults (vs. feebly hooked), and more developed posterior submarginal tooth dorsally on the carapace in adults; by a more elongate apical tubercle on cornea; by a small and single posterior propodal spinule on the 3rd - 5th pereiopods (vs. stronger, with their number 2-2-2, respectively, in *A. commensalis*); by the distinctly angulated third abdominal segment in lateral aspect, with dorsally straight outline (vs. rounded); by the more elongated sixth abdominal segment (2.5 times longer that deep in *A. occidentalis* vs. 2.0 in *A. commensalis*); by the greater number of setae on the mesial margin of the endopod of the first pleopod of the male (9 versus 3, respectively); by the length of the appendix masculina of the second male pleopod (longer than the appendix interna versus shorter), and possibly a higher number of dorsal telson spines (3–5 pairs in *A. occidentalis*, versus 3 pairs in *A. commensalis*).

The morphological distinction between the two species is further supported by small differences in their colour pattern, but more importantly by their COI divergence being 15.2–15.4%.

Acknowledgements

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project possibilities to examine the Red Sea and Taiwanese shrimps, and two referees for valuable comments. This study was partially supported by the US-Jordan Project 'Summer 2009' (NSF-IRES), projects of University of Ostrava (sgs05/PřF/2012 and sgs/29PřF/2014) (IH), the project IET (CZ.1.05/2.1.00/03.0100) financed by the Structural Funds of the European Union and Project LO1208 of the National Feasibility Programme-I of the Czech Republic, the Czech National Committee for cooperation with IOC UNESCO (ZĎ), and the EU-FP7 ASSEMBLE program (SDG).

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RESEARCH ARTICLE

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The genus *Omalus* Panzer, 1801 (Hymenoptera, Chrysididae) from China, with descriptions of four new species

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Abstract

The Chinese species of the genus *Omalus* Panzer, 1801 are revised and keyed for the first time. Eight species are recorded, of which four are new to science and one is new to China: *Omalus aeneus* (Fabricius, 1787), *Omalus berezovskii* (Semenov-Tian-Shanskij, 1932), *Omalus potanini* (Semenov-Tian-Shanskij, 1932), *Omalus imbecillus* (Mocsáry, 1889) (new to China), *Omalus helanshanus* **sp. n.**, *Omalus probiaccinctus* **sp. n.**, *Omalus pseudoimbecillus* **sp. n.**, and *Omalus tibetanus* **sp. n.**

Keywords

Chrysididae, *Omalus*, new species, Palaearctic, Oriental, China

Introduction

The genus *Omalus* Panzer, 1801 belongs to the chrysidid tribe Elampini (Chrysidinae). This genus is differently interpreted by different authors, and the complex history of this genus was summarised by Rosa (2006). In this study, we follow the system used

for Fauna Europaea (Rosa and Soon 2013), which is slightly altered according to the system of Kimsey and Bohart (1991).

Currently *Omalus* includes 26 species (Kimsey and Bohart 1991; Rosa 2005, 2006, 2009). In China, only three species of *Omalus* were known before this study, *Omalus aeneus* (Fabricius, 1787), *Omalus berezovskii* (Semenov-Tian-Shanskij, 1932) and *Omalus potanini* (Semenov-Tian-Shanskij, 1932). In this paper, four new species of *Omalus*, *Omalus helanshanus* sp. n., *Omalus probiaccinctus* sp. n., *Omalus pseudoimbecillus* sp. n., and *Omalus tibetanus* sp. n., and one new to China, *Omalus imbecillus* (Mocsáry, 1889) are described, and a key to all eight species is also provided.

Materials and methods

All specimens were examined and described under a stereomicroscope (Olympus SZ61). All photos were taken with a digital camera (CoolSNAP) attached to a Zeiss Stemi 2000-CS stereomicroscope. Images were processed using Image-Pro Plus software.

Morphological terminology follows Kimsey and Bohart (1991). Abbreviations used in the descriptions are as follows: F-I, F-II, F-III, etc. = flagellum I, flagellum II, flagellum III and so on; L/W = relative length to width; MOD = midocellar diameter; MS = malar space, the shortest distance between the base of the mandible and the margin of the compound eyes; Notaulic pit = the pit on the posterior margin of mesoscutum where notauli originate; PD = puncture diameter; T-I, T-II, T-III, etc. = metasomal tergum I, tergum II, tergum III and so on.

Types and other specimens have been examined from the following institutions:

HNHM Hungarian Natural History Museum, Budapest, Hungary.
SCAU Hymenopteran Collection, South China Agricultural University, Guangzhou, China.
SHEM Shanghai Entomological Museum, Chinese Academy of Sciences, Shanghai, China.
ZMUC Zoological Museum, University of Copenhagen, Copenhagen, Denmark.

Systematics

Genus *Omalus* Panzer, 1801
http://species-id.net/wiki/Omalus

Omalus Panzer, 1801: 13. Type species: *Chrysis aenea* Fabricius, 1787. Bohart and Campos 1960: 235 (partim, *Omalus* s. s.); Bohart and Kimsey 1982: 36 (partim, *Omalus* s. s.); Kimsey and Bohart 1991: 243; Rosa 2005: 8; 2006: 100.

Diagnosis. This genus is close to *Holophris* Mocsary, 1890, *Philoctetes* Abeille, 1879, and *Pseudomalus* Ashmead, 1902, but can be distinguish by mesoscutum impunctate

and transpleural carina reaching the apex of propodeal angle. Other diagnostic characteristics are: scapal basin deep, smooth and glabrous, rarely with weak striae; malar space equal to or longer than 1 MOD, rarely less than 1 MOD, and horizontally bisected by the genal carina; mandibles tridentate; pronotum impunctate medially or nearly so; mesopleuron with scrobal sulcus horizontally, and with a single carina dorsally; transpleural carina reaching the apex of propodeal angle; scutellum with two flattened foveae on anterior margin; metanotum round or hemispherical; tarsal claw with three to six teeth; apex of T-III usually with small medial notch, rarely absent.

Biology. Species of *Omalus* have been reported as parasitoids of some crabronid wasps (Mocsáry 1889; Tsuneki 1952; Krombein 1963, 1967; Parker and Bohart 1966; Nozaka 1969; Bohart and Kimsey 1982; Tormos et al. 1996; Rosa 2006).

Distribution. *Omalus* occurs in all zoogeographic regions, except Australia. There are 26 valid *Omalus* species, of which 19 are found in the Palaearctic, one in both the Holarctic and the Oriental, three in the Nearctic, two in the Afrotropical, and one in the Neotropical Regions.

Key to the Chinese species of the genus *Omalus* Panzer

1 Tarsal claw with four teeth **2**
– Tarsal claw with three teeth **3**
2 Scapal basin with weak, transverse striae (Plate 12A); mesoscutum transversally rugulose, with notauli distinct, deep and complete (Plate 12D); metasoma distinctly elongate (Plate 12E); apex of T-III with faint median notch (Plate 12F) ..... ***Omalus probiaccinctus* sp. n.**
– Scapal basin smooth, without transverse striae (Plates 2A, 4A); mesoscutum polished, with notauli indistinct but complete, impressed as fine lines (Plates 2D, 4D); metasoma oval (Plates 2E, 4E); apex of T-III with distinct median notch (Plates 2F, 4F) ..... ***Omalus aeneus* (Fabricius)**
3 Notauli distinct and deep (Plates 6D, 16D) **4**
– Notauli indistinct, impressed as fine lines (Plates 8D, 10D, 14D) **5**
4 Pronotum with scattered (1–2 PD), shallow punctures medially (Plate 6B); metasoma pear-shaped, T-II notably wider than T-I; apex of T-III with median notch V-shaped (Plate 6F) ..... ***Omalus berezovskii* (Semenov-Tian-Shanskij)**
– Pronotum almost impunctate medially (Plate 16B); metasoma distinctly elongate, T-II not wider than T-I; apex of T-III with median notch shallowly indented (Plate 16F) ..... ***Omalus tibetanus* sp. n.**
5 Scutellum with two flattened and semi-elliptical foveae on anterior margin (Plates 10D, 14D) **6**
– Scutellum without foveae on anterior margin (Plate 8D) **7**
6 Tegula fully metallic blue (Plate 10B); mesopleuron without striae between punctures (Plate 10C); propodeal angle indistinct ..... ***Omalus imbecillus* (Mocsáry)**
– Tegula transparent brownish, with faint metallic reflections anteriorly (Plate 14B); mesopleuron with striae between punctures (Plate 14C); propodeal angle distinct and stout ..... ***Omalus pseudoimbecillus* sp. n.**

7 Body metallic bluish-purple, with green reflections; apex of T-III with brownish transparent rim (Plate 8F) ..... ***Omalus helanshanus* sp. n.**

– Body metallic green-bronzy, with more or less golden-green reflections; apex of T-III with colourless transparent rim ..... ***Omalus potanini* (Semenov-Tian-Shanskij)**

***Omalus aeneus* (Fabricius, 1787)**
http://species-id.net/wiki/Omalus_aeneus
Plates 1–4

Chrysis aenea Fabricius, 1787: 284.
Omalus aeneus (Fabricius, 1787): Panzer 1801: 13; Kimsey and Bohart 1991: 245; Kunz 1994: 74; Mingo 1994: 78; Rosa 2006: 101.
Elampus chevrieri Tournier, 1877: 105 (synonymized by Kimsey and Bohart 1991).
Omalus aeneus var. *pygialis* du Buysson, 1887: 170 (synonymized by Kimsey and Bohart 1991).
Philoctetes japonicus Bischoff, 1910: 438 (synonymized by Kimsey and Bohart 1991).
Ellampus sauteri Mocsáry, 1913: 613 (synonymized by Kimsey and Bohart 1991).

Material examined. Type material: 1 ♀ (ZMUC), *aenea* [handwritten by Fabricius] [specimen considered as Type by Zimsen (1964) and Kimsey and Bohart (1991)]; 1 ♀ (HNHM), "Formosa Sauter", "Taihorinsho, 1909. XI.", "sauteri Mocs. type, det. Mocsáry", "Holotypus Ellampus sauteri, ♀, Mocsáry, (L. D. French)", "id nr. 134845, HNHM, Hym. coll.". Other material: 1 ♀ (SCAU), Inner Mongolia, Helanshan, Gulaben, Dayanggou (39°5'24.90"N, 106°3'32.35"E), 27.VII.2010, Hong-fei Chai, No. SCAU-O0001; 2 ♀♀ (SCAU), Inner Mongolia, Helanshan, Halawuchagou (38°51'33.33"N, 105°53'28.67"E), 10.VIII.2010, Hong-fei Chai, No. SCAU-O0002, SCAU-O0003; 2 ♀♀ (SCAU), Inner Mongolia, Helanshan, Shuimogou (38°57'25.97"N, 105°52'22.90"E), 30.VII.2010, Jie Zeng, No. SCAU-O0004, SCAU-O0005; 1 ♂ (SCAU), Inner Mongolia, Helanshan, Shuimogou, 30.VII.2010, Jie Zeng, No. SCAU-O0006; 1 ♂ (SCAU), Inner Mongolia, Helanshan, Qianggangling (38°53'N, 105°59'E), 3.VIII.2010, Jie Zeng, No. SCAU-O0007; 1 ♂ (SCAU), Inner Mongolia, Helanshan, Halawuchagou 10.VIII.2010, Hong-fei Chai, No. SCAU-O0008; 1 ♀ (SHEM), Inner Mongolia, Helanshan, Gulaben (38°53'N, 105°59'E), 2700 m, 27.VIII.2010, Xu-feng Zhang and Feng-li Cui, No. 34020542.

Diagnosis. Scapal basin deep, smooth and glabrous. Mesoscutum polished, with notauli indistinct but complete, impressed as fine lines. Propodeum with lateral margin distinctly concave before propodeal angle. Tarsal claw with four teeth. Metasoma oval; apex of T-III with distinct median notch.

Description. *Female* (n = 12). Body length 4.5–5.4 mm (Plate 1). Fore wing length 3.3–4.2 mm. MS = 0.9 MOD.

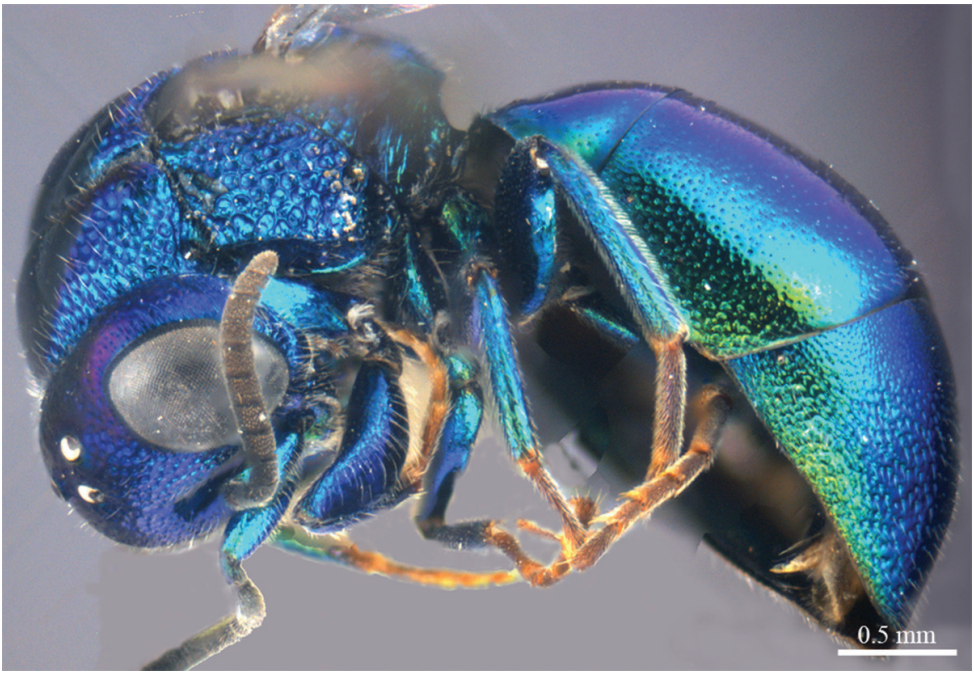

Plate 1. *Omalus aeneus* (Fabricius, 1787), female from Inner Mongolia. Habitus lateral.

Head. Face with large, round, dense (0–0.5 PD), shallow punctures (Plate 2A). Scapal basin deep, smooth and glabrous (Plate 2A). Ocellar triangle isosceles. Postocellar line absent (Plate 2B). Gena with fine and oblique wrinkles.

Mesosoma. Pronotum almost impunctate medially, with small, deep pits on anterior margin; with large, dense (0–0.5 PD) punctures laterally and anteriorly towards the collar (Plate 2B). Mesoscutum polished, almost impunctate (Plate 2D); notauli indistinct but complete, impressed as fine lines; notaulic pit elongate; parapsidal lines indistinct, similar to notauli (Plate 2D). Scutellum without flattened fovea on anterior margin; with small, triangular and impunctate area antero-medially, with deep, round, dense (0–0.5 PD) punctures, and becoming larger towards alar foveae (Plate 2D). Mesopleuron without striae between punctures (Plate 2C). Metanotum evenly round, with large, deep, areolate-reticulate punctures (Plate 2D). Propodeum with lateral margin distinctly concave before propodeal angle (Plate 2D); propodeal angle distinct and stout, pointing posterolaterally (Plate 2D). Tarsal claw with four teeth.

Metasoma. Oval (Plate 2E), L/W = 11/7. T-I almost impunctate. T-II with fine, dense punctures. T-III with fine, much denser punctures than those on T-II (Plate 2E); apex of T-III with narrow (1/3 MOD), brownish transparent rim, with distinct median notch (Plate 2F).

Colouration. Face metallic blue. Vertex and mesosoma metallic bluish-purple, with medial pronotum and mesoscutum blackish. Antenna black, with scape and pedicel

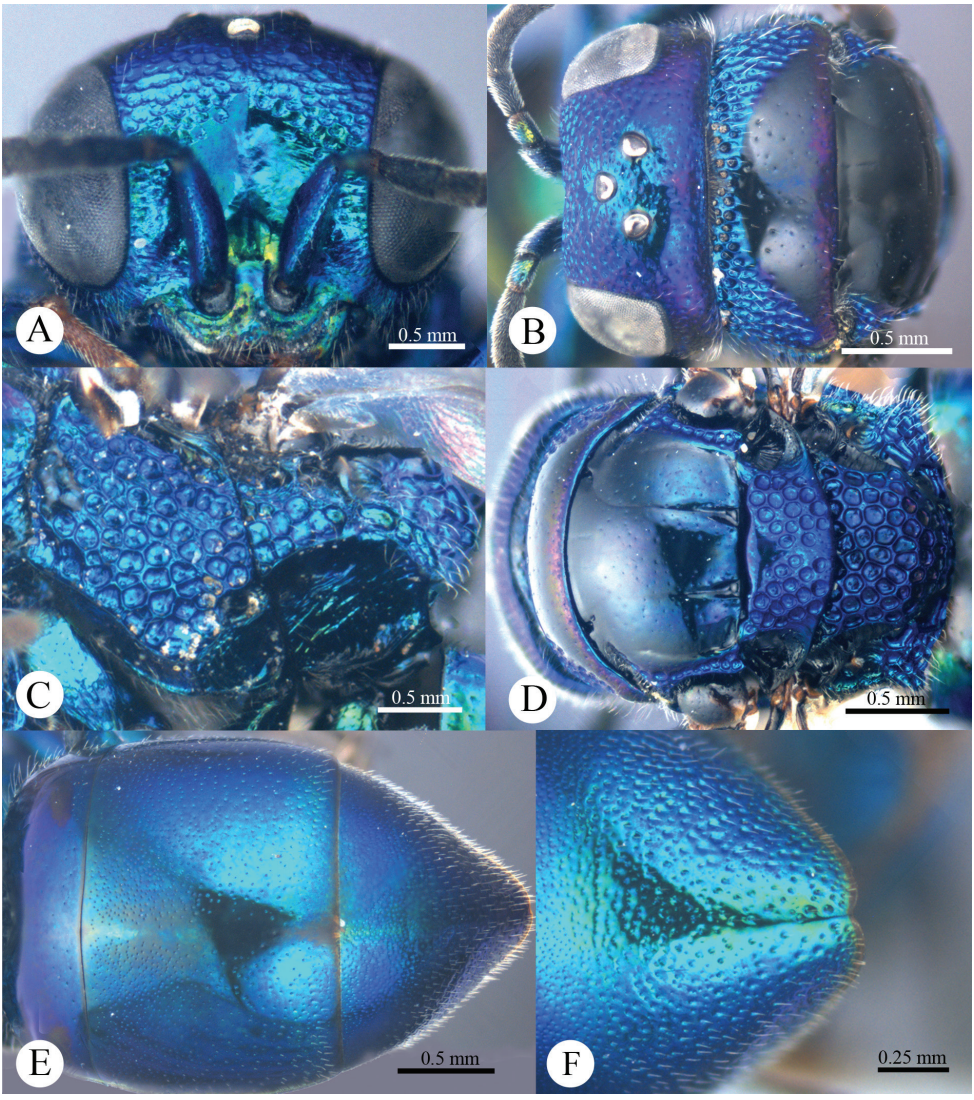

Plate 2. *Omalus aeneus* (Fabricius, 1787), female from Inner Mongolia. **A** Head anterior **B** Head and pronotum dorsal **C** Mesopleuron and metapleuron lateral **D** Mesoscutum, scutellum, metanotum and propodeum dorsal **E** Metasoma dorsal **F** Apex of T-III dorsal.

metallic green. Tegula blackish-brown. Leg metallic bluish-green, with tarsus brown. Metasoma metallic greenish-blue, with blackish tints.

Male (n = 3). Body length 4.4–5.0 mm (Plate 3). Forewing length 3.2–3.9 mm. POL : OOL : OCL = 6.2 : 6.4 : 6.0. MS = 1.0 MOD. Differing from female as follows: face metallic greenish blue; vertex, medial pronotum, mesonotum, metanotum and propodeum blackish (Plate 4B, 4D); with antero-lateral corners of pronotum, mesopleuron, metapleuron, and lateral part of propodeum metallic green; metasoma

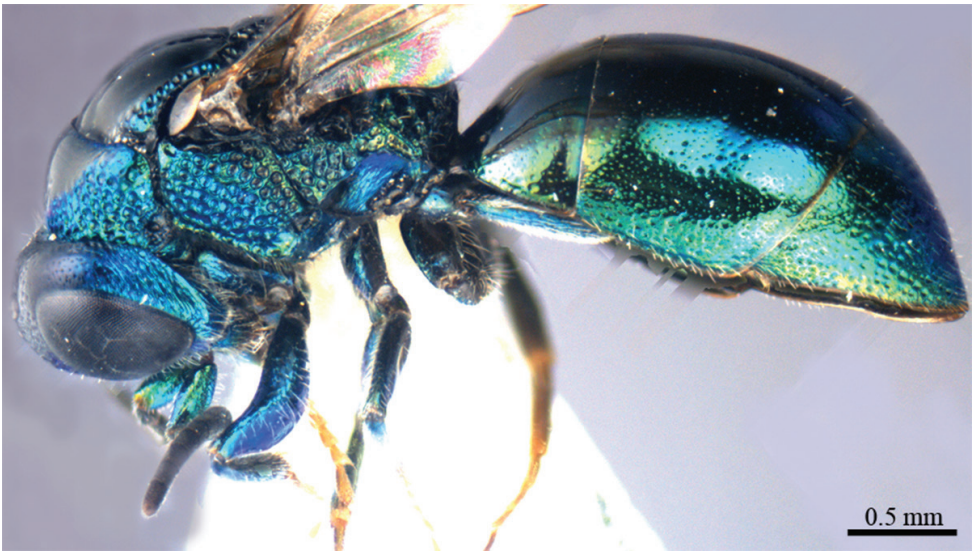

Plate 3. *Omalus aeneus* (Fabricius, 1787), male from Inner Mongolia. Habitus lateral.

blackish with metallic green on posterior T-II and T-III (Plate 4E); apex of T-III with median notch deeper than that of female (Plate 4F).

Distribution. China (Inner Mongolia, Taiwan); Japan; widespread in Holarctic (Kimsey and Bohart 1991; Kunz 1994; Mingo 1994; Rosa 2006).

Biology. Collected from June to November (Tsuneki 1970; Rosa 2006). Two or more generations are observed in South Europe in one year (Rosa 2006). Hosts include species in the genera *Pemphredon*, *Passaloecus* and *Psenulus* (Crabronidae) (Mocsáry 1889; Grandi 1961; Kunz 1994; Strumia 1997).

***Omalus berezovskii* (Semenov-Tian-Shanskij, 1932)**
http://species-id.net/wiki/Omalus_berezovskii
Plates 5, 6

Ellampus berezovskii Semenov-Tian-Shanskij, 1932: 12.
Omalus berezovskii (Semenov-Tian-Shanskij, 1932): Kimsey and Bohart 1991: 247.

Material examined. 2 ♀♀ (SCAU), Ningxia, Liupanshan Forest Park (35°22'54.76"N, 106°18'51.22"E), 3–4.VII.2009, Hua-yan Chen, No. SCAU-O0009, SCAU-O0010.

Diagnosis. Pronotum with scattered (1–2 PD), shallow punctures medially. Mesoscutum with notauli distinct, deep, complete. Mesopleuron with distinct striae between punctures. Metasoma pear-shaped, T-II notably wider than T-I. Apex of T-III with median notch V-shaped.

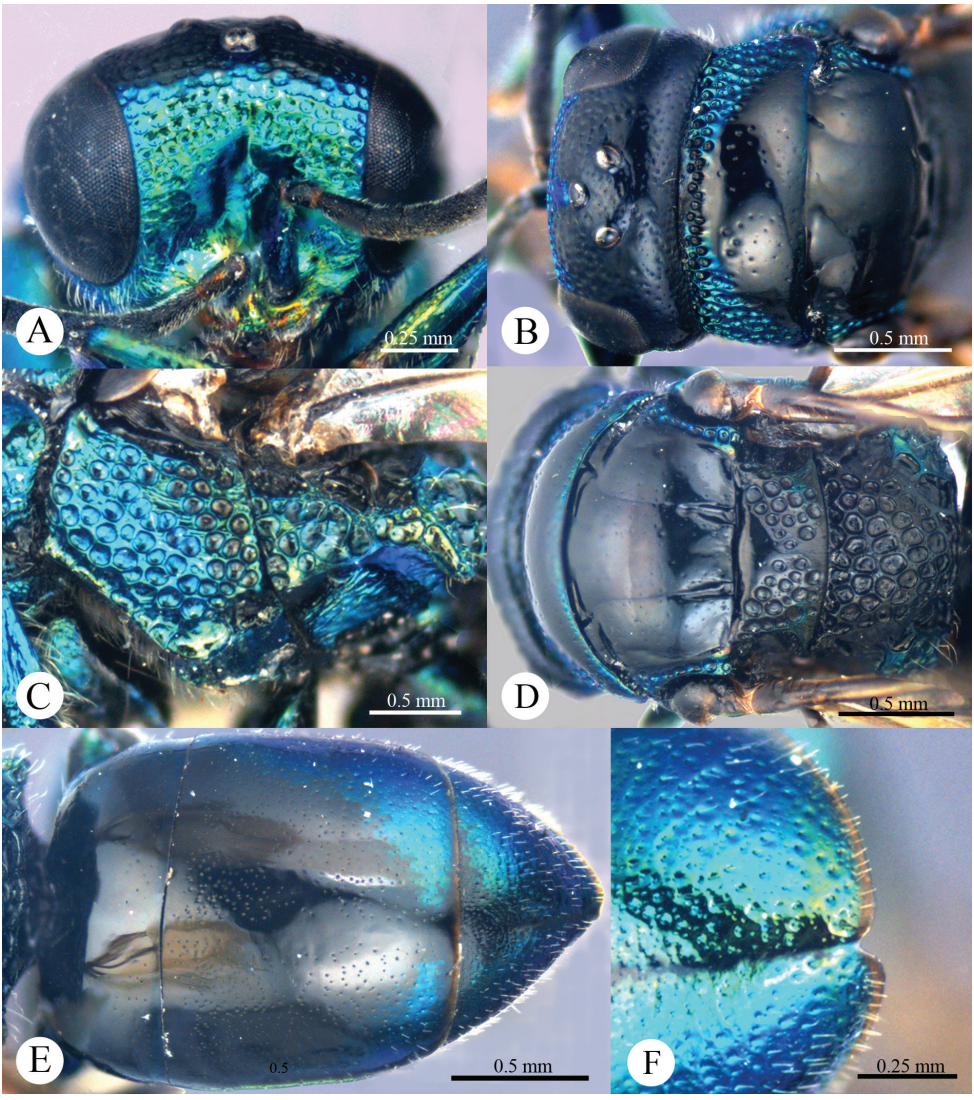

Plate 4. *Omalus aeneus* (Fabricius, 1787), male from Inner Mongolia. **A** Head anterior **B** Head and pronotum dorsal **C** Mesopleuron and metapleuron lateral **D** Mesoscutum, scutellum, metanotum and propodeum dorsal **E** Metasoma dorsal **F** Apex of T-III dorsal.

Description. *Female* (n = 2). Body length 4.1–4.6 mm (Plate 5). Fore wing length 3.3–4.0 mm. MS = 1.7 MOD.

Head. Face with round, dense (0–0.5 PD), shallow punctures (Plate 6A). Scapal basin deep, smooth, glabrous, weakly striae laterally near antennal sockets (Plate 6A). Ocellar triangle isosceles. Postocellar line absent (Plate 6B). Gena with fine, transverse wrinkles.

Plate 5. *Omalus berezovskii* (Semenov-Tian-Shanskij, 1932), female from Ningxia. Habitus lateral.

Mesosoma. Pronotum with scattered (1–2 PD), shallow punctures medially (Plate 6B); with small, deep pits on anterior margin; with large, dense (0–0.5 PD) punctures laterally (Plate 6B). Mesoscutum polished, with fine, scattered punctures between notauli; with dense, deep punctures between parapsidal lines and notauli (Plate 6D); notauli distinct, deep, complete; notaulic pit elongate; parapsidal lines shallower than notauli (Plate 6D). Scutellum without flattened fovea on anterior margin; with triangular and impunctate area antero-medially (Plate 6D); with shallow punctures laterally, and becoming larger and deeper towards alar foveae (Plate 6D). Mesopleuron with distinct striae between the punctures (Plate 6C). Metanotum evenly round, with large, deep, areolate punctures (Plate 6D). Propodeum with lateral margin slightly concave before propodeal angle; propodeal angle distinct, long, pointing posterolaterally. Tarsal claw with three teeth.

Metasoma. Oval, T-II notably wider than T-I, T-III distinctly constrict laterally towards the apex (Plate 6E), L/W = 9/5. T-I and T-II almost impunctate dorsally, with fine, scattered punctures laterally. T-III with finer, denser punctures than those on T-II (Plate 6E); apex of T-III with narrow (2/3 MOD) and brownish rim, with median notch V-shaped, 1/2 MOD deep (Plate 6F).

Colouration. Head and mesosoma mostly metallic bluish-purple, with face, mesopleuron and metapleuron metallic green. Antenna black, with scapes and pedicel metallic greenish-blue. Tegula metallic green, with apex brown. Leg metallic bluish-

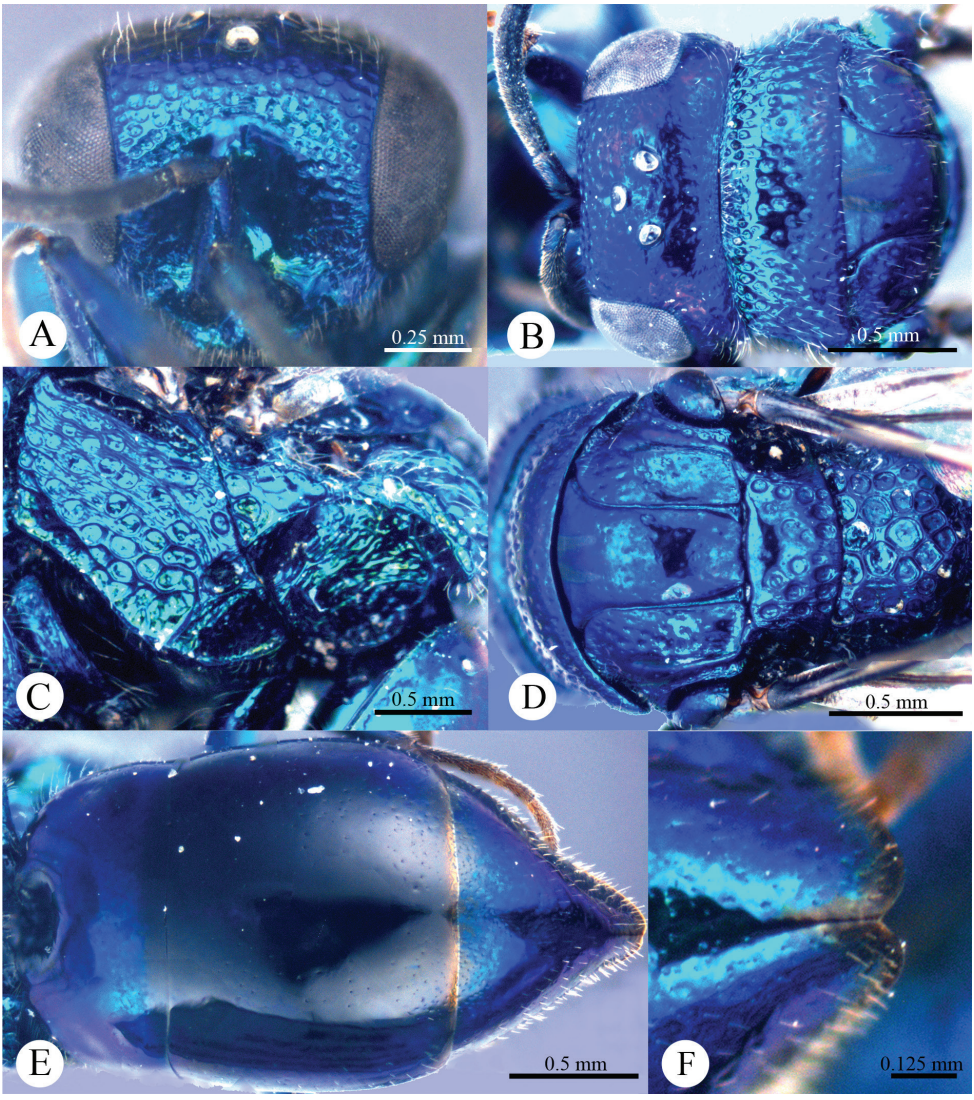

Plate 6. *Omalus berezovskii* (Semenov-Tian-Shanskij, 1932), female from Ningxia. **A** Head anterior **B** Head and pronotum dorsal **C** Mesopleuron and metapleuron lateral **D** Mesoscutum, scutellum, metanotum and propodeum dorsal **E** Metasoma dorsal **F** Apex of T-III dorsal.

purple, with tarsus brown. Metasoma metallic blue with purple reflections, with T-II blackish dorsally.

Male. Unknown.

Distribution. China (Ningxia, Sichuan) (Semenov-Tian-Shanskij 1932).

Biology. Unknown. Collected from May to July (Semenov-Tian-Shanskij 1932; Kimsey and Bohart 1991).

***Omalus helanshanus* sp. n.**
http://zoobank.org/B6E18E24-218C-41F2-A6ED-028CA872C119
http://species-id.net/wiki/Omalus_helanshanus
Plates 7, 8

Material examined. Holotype, ♀ (SCAU), Inner Mongolia, Helanshan, Gulaben, Dayanggou (39°5'24.90"N, 106°3'32.35"E), 27.VII.2010, Hong-fei Chai, No. SCAU-O0011. Paratypes: 3 ♀♀ (SCAU), Inner Mongolia, Helanshan, Gulaben, Dayanggou, 27.VII.2010, Hong-fei Chai, No. SCAU-O0012–0014; 2 ♀♀ (SCAU), Inner Mongolia, Helanshan, Shuimogou (38°57'25.97"N, 105°52'22.90"E), 30.VII.2010, Hong-fei Chai, No. SCAU-O0015, SCAU-O0016; 1 ♀ (SCAU), Inner Mongolia, Helanshan, Shuimogou, 30.VII.2010, Jie Zeng, No. SCAU-O0017; 3 ♀♀ (SCAU), Inner Mongolia, Helanshan, Habeigou, Huangliangzi (38°51'49.22"N, 105°53'17.40"E), 9.VIII.2010, Jie Zeng, No. SCAU-O0018–O0020; 5 ♀♀ (SCAU), Inner Mongolia, Helanshan, Halawuchagou (38°51'40.66"N, 105°52'10.49"E), 10.VIII.2010, Hong-fei Chai, No. SCAU-O0021–O0025; 1 ♀ (SCAU), Inner Mongolia, Helanshan, Halawuchagou, 10.VIII.2010, Cheng-jin Yan, No. SCAU-O0026; 11 ♀♀ (SCAU), Inner Mongolia, Helanshan, Halawubeigou (38°51'33.33"N, 105°53'28.67"E), 9.VIII.2010, Hong-fei Chai, No. SCAU-O0027–0037; 1 ♀ (SHEM), Inner Mongolia, Helanshan, Halawu (38°52'5.39"N, 105°45'29.34"E), 2250 m, 10.VIII.2010, Xu-feng Zhang and Feng-li Cui, No. 34020573; 1 ♀ (SHEM), Inner Mongolia, Helanshan, Halawu, 2800 m, 9.VIII.2010, Xu-feng Zhang and Feng-li Cui, No. 34020592; 1 ♀ (SHEM), Inner Mongolia, Helanshan, Halawu, 2250 m, 10.VIII.2010, Xu-feng Zhang and Feng-li Cui, No. 34020129.

Diagnosis. *Omalus helanshanus* sp. n. is similar to *O. potanini* Semenov-Tian-Shanskij based on the indistinct notauli and scutellum without flattened fovea on anterior margin; it also resembles *O. tibetanus* sp. n. based on the elongate metasoma and the similar sculpture. However, *O. helanshanus* sp. n. can be distinguished by the combination of the following characters: postocellar line present, apex of T-III with brownish transparent rim and median notch faint. Comparison with *O. potanini* Semenov-Tian-Shanskij is based on the description of the male, since the female of *O. potanini* is unknown.

Description. *Female* (n = 30). Body length 3.9–4.9 mm (Plate 7). Forewing length 3.1–4.4 mm. MS = 0.9 MOD.

Head. Face with large, round, dense (0–0.5 PD), shallow punctures (Plate 8A). Scapal basin deep, smooth, glabrous (Plate 8A). Ocellar triangle isosceles. Postocellar line shallowly impressed (Plate 8B). Gena without wrinkles or with very fine wrinkles.

Mesosoma. Pronotum almost impunctate medially, with small, deep pits on anterior margin; with large, dense (0–0.5 PD) punctures laterally (Plate 8B). Mesoscutum polished, almost impunctate (Plate 8D); notauli indistinct, almost complete, impressed as fine lines, with notaulic pit round and short; parapsidal lines indistinct (Plate 8D).

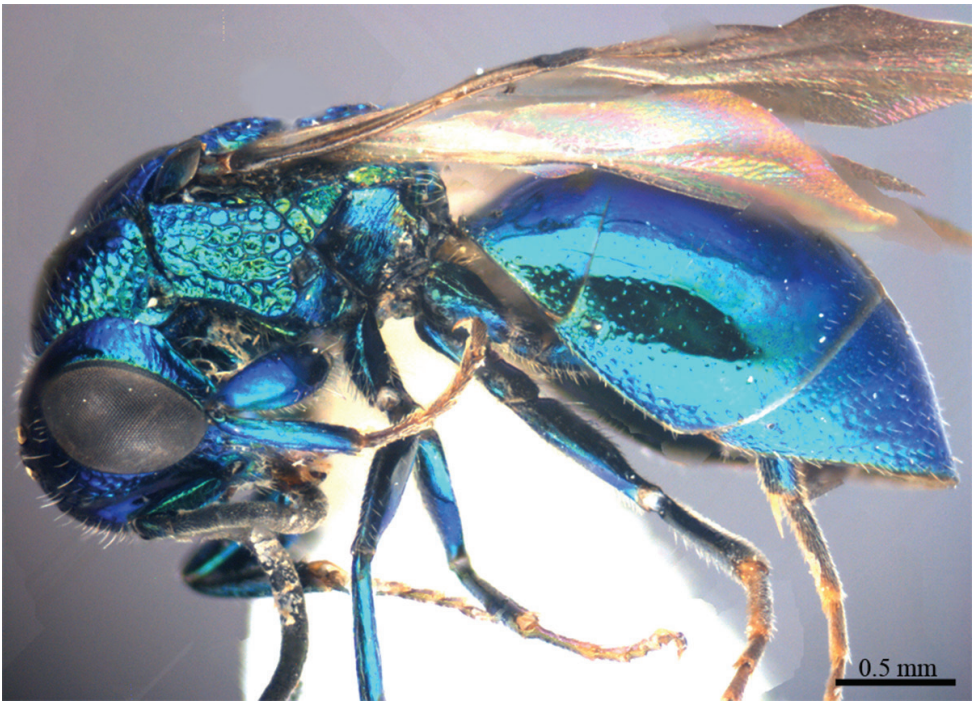

Plate 7. *Omalus helanshanus* sp. n., holotype, female. Habitus lateral.

Scutellum without flattened fovea on anterior margin; with broad, impunctate median area extending along its length, slightly convergent posteriorly (Plate 8D); with shallow, areolate punctures laterally, becoming larger and deeper towards alar foveae. Mesopleuron without striae between punctures (Plate 8C). Metanotum evenly round, with large, deep, areolate-reticulate punctation (Plate 8D). Propodeum with lateral margin concave before propodeal angle; propodeal angle small, short, pointing backwards (Plate 8D). Tarsal claw with three teeth.

Metasoma. Elongate (Plate 8E), L/W = 10/7. T-I and T-II almost impunctate dorsally, with fine, scattered punctures towards the margins and laterally (Plate 8E). T-III with fine, denser punctures than those on T-II; apex of T-III with narrow (1/2 MOD), brownish transparent rim, with faint median notch (Plate 8F).

Colouration. Head and mesosoma mostly metallic bluish-purple, with distinct or faint metallic green reflections on mesopleuron, metanotum, metapleuron, and propodeum. Antenna black, with scape and pedicel metallic green. Tegula purple, with apex brownish. Leg metallic bluish-purple, with tarsus brown. Metasoma metallic bluish-purple, with some metallic green reflections.

Male. Unknown.

Distribution. China (Inner Mongolia).

Biology. Unknown. Collected from July to August.

Etymology. The species is named after the type locality.

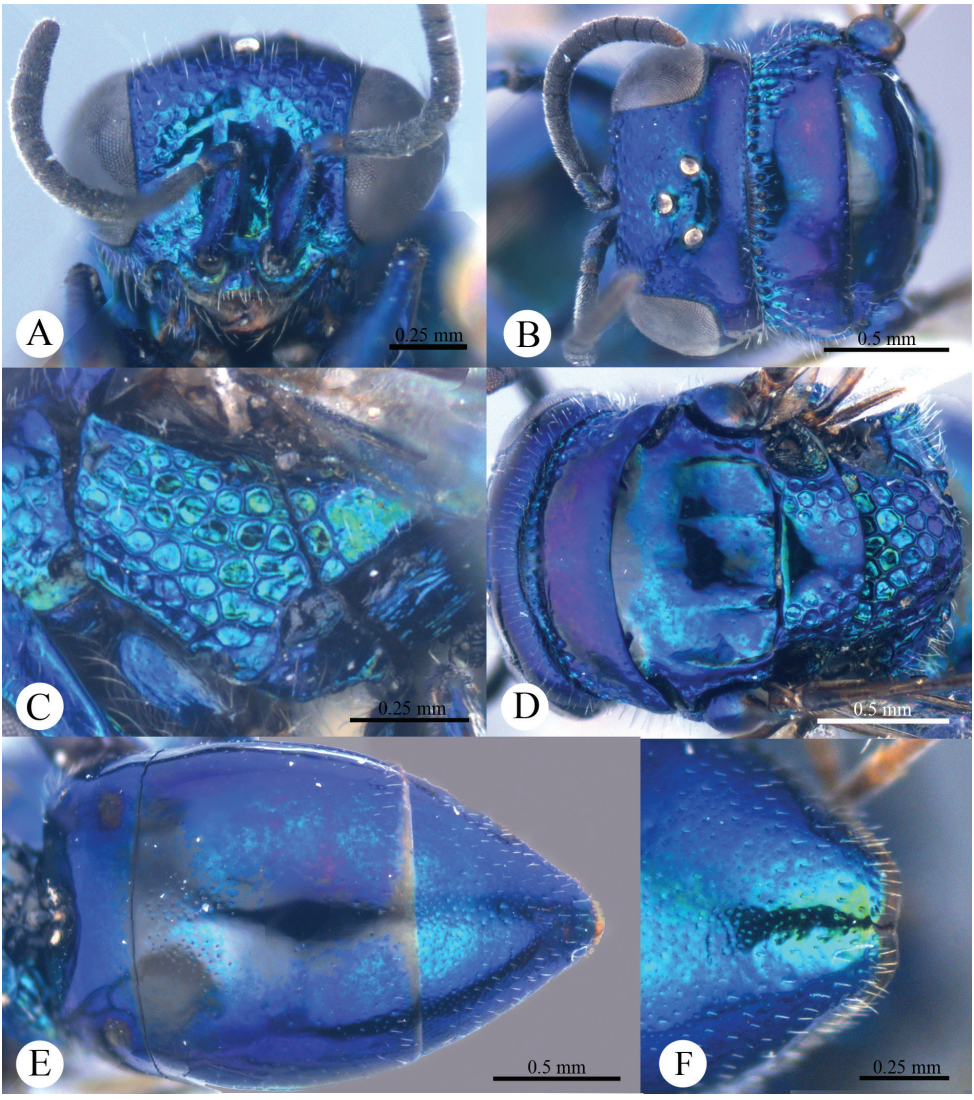

Plate 8. *Omalus helanshanus* sp. n., holotype, female. **A** Head anterior **B** Head and pronotum dorsal **C** Mesopleuron and metapleuron lateral **D** Mesoscutum, scutellum, metanotum and propodeum dorsal **E** Metasoma dorsal **F** Apex of T-III dorsal.

***Omalus imbecillus* (Mocsáry, 1889) (new to China)**
http://species-id.net/wiki/Omalus_imbecillus
Plates 9, 10

Ellampus imbecillus Mocsáry, 1889: 98.
Holophris imbecillus (Mocsáry, 1889): Kimsey and Bohart 1991: 225.
Omalus imbecillus (Mocsáry, 1889): Rosa 2005: 12.

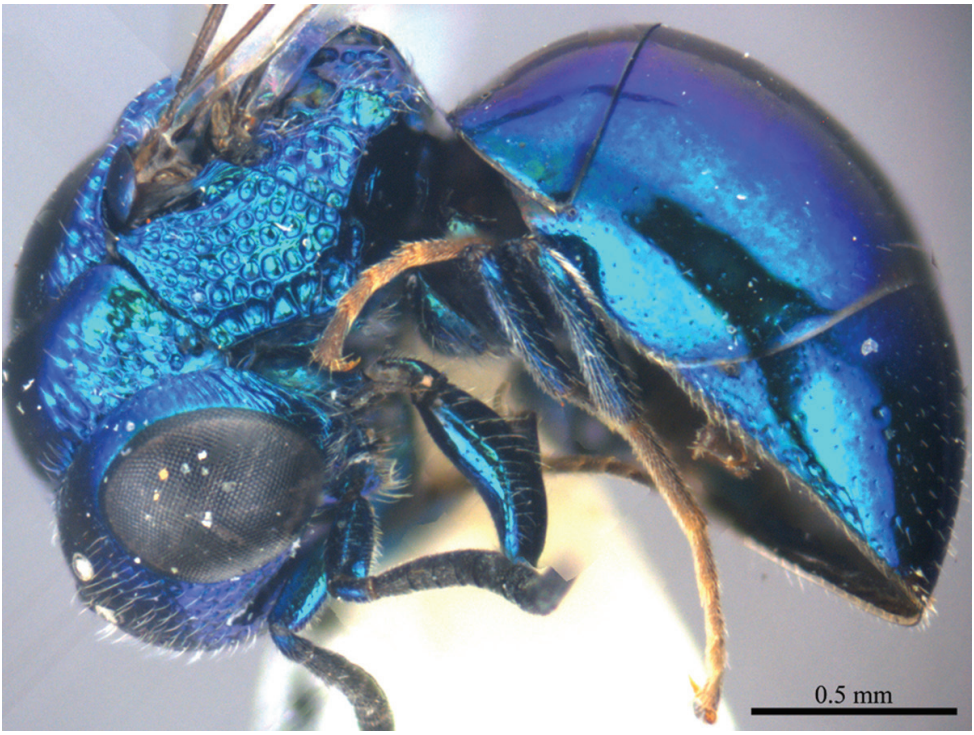

Plate 9. *Omalus imbecillus* (Mocsáry, 1889), female from Yunnan. Habitus lateral.

Material examined. Lectotype: 1 ♀ (HNHM), "Turkestan", "*imbecillus* Mocs, type, det. Mocsáry", "Lectotypus, *Ellampus imbecillus*, ♀, (L. D. French), Mocsáry", "id nr. 135046, HNHM, Hym. coll.". Other material: 3 ♀♀ (HNHM), Laos, Vientiane, 19.III.1990, E. Kondorosy; 1 ♀ (SCAU), Yunnan, Kaiyuannan River (23°42'N, 103°16'E), 16.VII.2003, Long Hu, No. 20048184; 1 ♀ (SCAU), Yunnan, Gaoligongshan National Nature Reserve (25°50'23"N, 98°51'23"E), 16–17.VII.2006, Jie Zeng, Juan-juan Ma, and Bin Xiao, No. SCAU-O0038.

Diagnosis. Scutellum with two flattened and semi-elliptical foveae on anterior margin, with numerous fine, short, longitudinal striae on posterior margin. Propodeal angle indistinct. Apex of T-III with narrow, colourless semi-transparent rim, without medial notch.

Description. Described from a female from Yunnan. Body length 3.3 mm (Plate 9). Forewing length 2.6 mm. MS = 1.0 MOD.

Head. Face with large, round, dense (0–0.5 PD), shallow punctures (Plate 10A). Scapal basin deep, smooth, glabrous (Plate 10A). Ocellar triangle isosceles. Postocellar line very weak, broadly interrupted medially (Plate 10B). Gena with distinct, oblique wrinkles.

Mesosoma. Pronotum impunctate medially, with small, deep pits on anterior margin; with large, dense (0–0.5 PD) punctures laterally (Plate 10B). Mesoscutum polished, impunctate (Plate 10D); notauli indistinct but complete, impressed as fine lines, with

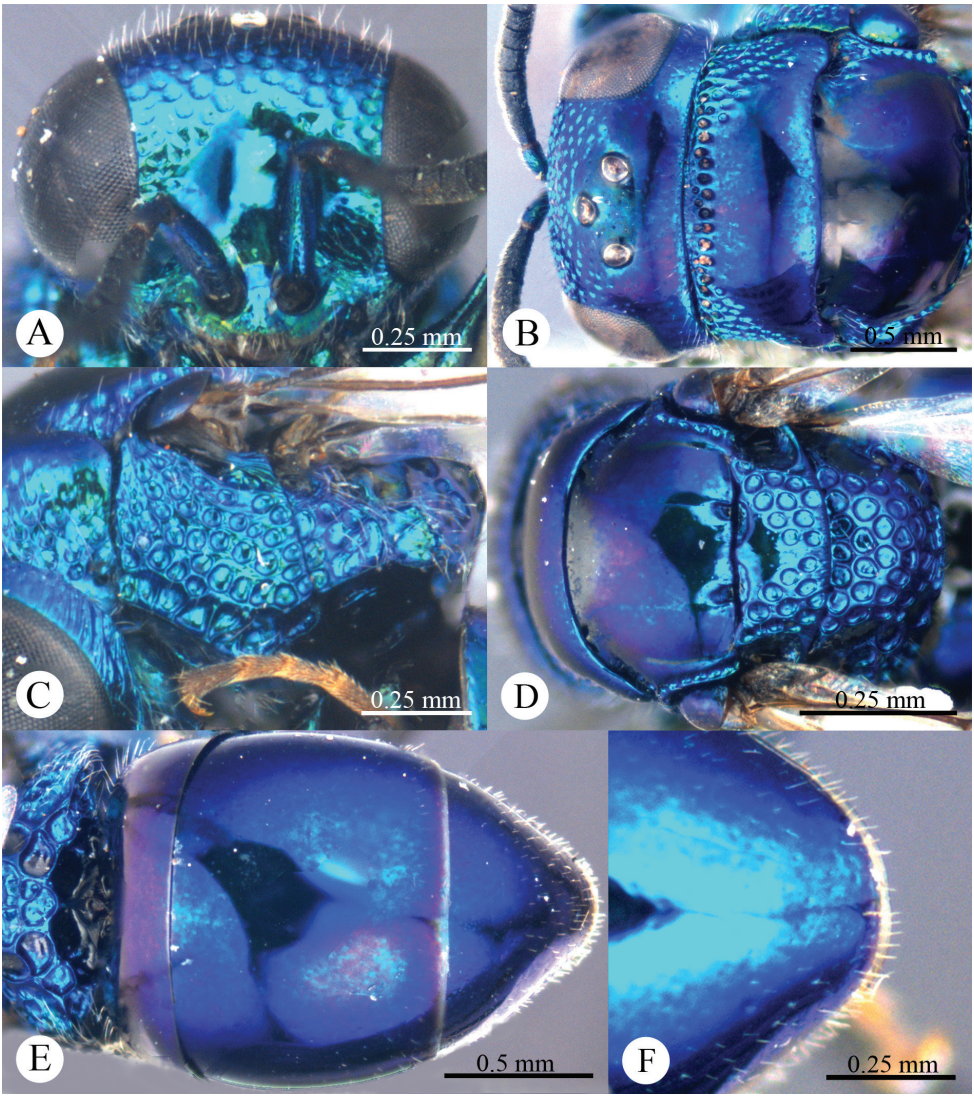

Plate 10. *Omalus imbecillus* (Mocsáry, 1889), female from Yunnan. **A** Head anterior **B** Head and pronotum dorsal **C** Mesopleuron and metapleuron lateral **D** Mesoscutum, scutellum, metanotum and propodeum dorsal **E** Metasoma dorsal **F** Apex of T-III dorsal.

notaulic pit oval; parapsidal lines indistinct (Plate 10D). Scutellum with two flattened, semi-elliptical foveae on anterior margin (Plate 10D); with triangular, impunctate area antero-medially (Plate 10D); with numerous fine, short, longitudinal striae on posterior margin; with deep punctures, becoming larger towards alar foveae (Plate 10D); Mesopleuron without striae between punctures (Plate 10C). Metanotum gibbous, with large, deep, areolate-reticulate punctures (Plate 10D). Propodeum with lateral margin very slightly concave before propodeal angle; propodeal angle indistinct. Tarsal claw with three teeth.

Metasoma. Oval (Plate 10E), L/W = 15/11. T-I and T-II almost impunctate. T-III with fine, scattered punctures (Plate 10E); apex of T-III with narrow (1/3 MOD), colourless semi-transparent rim, without median notch (Plate 10F).

Colouration. Face metallic green. Head and mesosoma metallic blue, with purple reflections on vertex, median pronotum, and mesoscutum. Antenna black, with scape and pedicel metallic greenish-blue. Tegula metallic blue. Leg metallic greenish-blue, with tarsus brown. Metasoma purple, with metallic blue.

Variation. Female (n = 6). Body length 3.3–3.9 mm. Forewing length 2.6–3.2 mm.

Male. Chinese male specimens are not available for this study.

Distribution. China (Yunnan), Laos, Russia, Turkey, Iran (Kimsey and Bohart 1991; Rosa et al. 2013).

Biology. Unknown. Collected in March and July.

***Omalus potanini* (Semenov-Tian-Shanskij, 1932)**
http://species-id.net/wiki/Omalus_potanini

Ellampus potanini Semenov-Tian-Shanskij 1932: 11.
Philoctetes (*Holophris*) *potanini* (Semenov-Tian-Shanskij, 1932): Tsuneki 1953: 55.
Omalus potanini (Semenov-Tian-Shanskij, 1932): Kimsey 1986: 107 (♂ lectotype designation); Kimsey and Bohart 1991: 249.

Material examined. No material available for this study.

Diagnosis. Body fully green-bronzy, with scutellum, metanotum, mesopleuron and lateral sides of the metasoma more or less golden-green. Tegula black, with faint metallic blue reflections. Mesoscutum smooth, polished, with notauli indistinct. Scutellum without flattened fovea on anterior margin; with broad, impunctate median area. Tarsal claw with three teeth. Metasoma oval. Apex of T-III with faint median notch (Semenov-Tian-Shanskij 1932).

Distribution. China (Liaoning, Sichuan) (Semenov-Tian-Shanskij 1932; Tsuneki 1953; Kimsey and Bohart 1991).

Biology. Unknown. Collected in July and August (Semenov-Tian-Shanskij 1932; Kimsey and Bohart 1991).

***Omalus probiaccinctus* sp. n.**
http://zoobank.org/92EB6218-3545-4859-85C5-3F4DC7ED9B3C
http://species-id.net/wiki/Omalus_probiaccinctus
Plates 11, 12

Material examined. Holotype: ♀ (SCAU), Guizhou, Suiyang, Kuankuoshui National Nature Reserve (27°55'24"N, 107°11'8"E), 4.VI.2010, Jie Zeng, No. SCAU-O0039. Paratype: 1 ♀ (SCAU), Guizhou, Suiyang, Kuankuoshui National Nature Reserve, 4.VI.2010, Jie Zeng, No. SCAU-O0040.

Plate 11. *Omalus probiaccinctus* sp. n., holotype, female. Habitus lateral.

Diagnosis. *Omalus probiaccinctus* sp. n. is related to *O. biaccinctus* based on the similar and peculiar punctures on the mesoscutum, which is unique in the West Palaearctic species. However, *Omalus probiaccinctus* sp. n. can be separated from the latter by having the body mostly metallic greenish-blue (body dark metallic blue or green, black medially on mesoscutum, metanotum, propodeum and metasoma in *O. biaccinctus*); tarsal claw with four teeth (three in *O. biaccinctus*); apex of T-III with faint median notch (apex of T-III with distinct, deep median notch in *O. biaccinctus*).

Description. *Female* (n = 2). Body length 4.8–5.7 mm (Plate 11). Fore wing length 4.1–4.4 mm. MS = 1.1 MOD.

Head. Face with large round, dense (0–0.5 PD), and shallow punctures (Plate 12A). Scapal basin deep, glabrous, with weak and transverse striae (Plate 12A). Ocellar triangle isosceles. Postocellar line absent (Plate 12B). Gena with fine, oblique wrinkles.

Mesosoma. Pronotum with fine, scattered (> 2 PD) punctures medially; with small, deep pits on anterior margin; with large and dense (0–0.5 PD) punctures laterally (Plate 12B). Mesoscutum transversally rugulose, with fine, sparse punctures evenly scattered (Plate 12D); notauli distinct, deep, complete; notaulic pit elongate; parapsidal lines distinct, shallower than notauli (Plate 12D). Scutellum without flattened fovea on anterior margin; with broad, almost impunctate median area extend along its length, slightly convergent posteriorly (Plate 12D); posterior margin of scutellum with numerous fine, short, longitudinal striae; with large, round, dense (0–0.5 PD) punctures laterally, becoming larger, deeper towards alar foveae (Plate 12D). Mesopleuron with very weak striae between punctures (Plate 12C). Metanotum evenly round, with large, deep, areolate-reticulate punctures (Plate 12D). Propodeum with lateral mar-

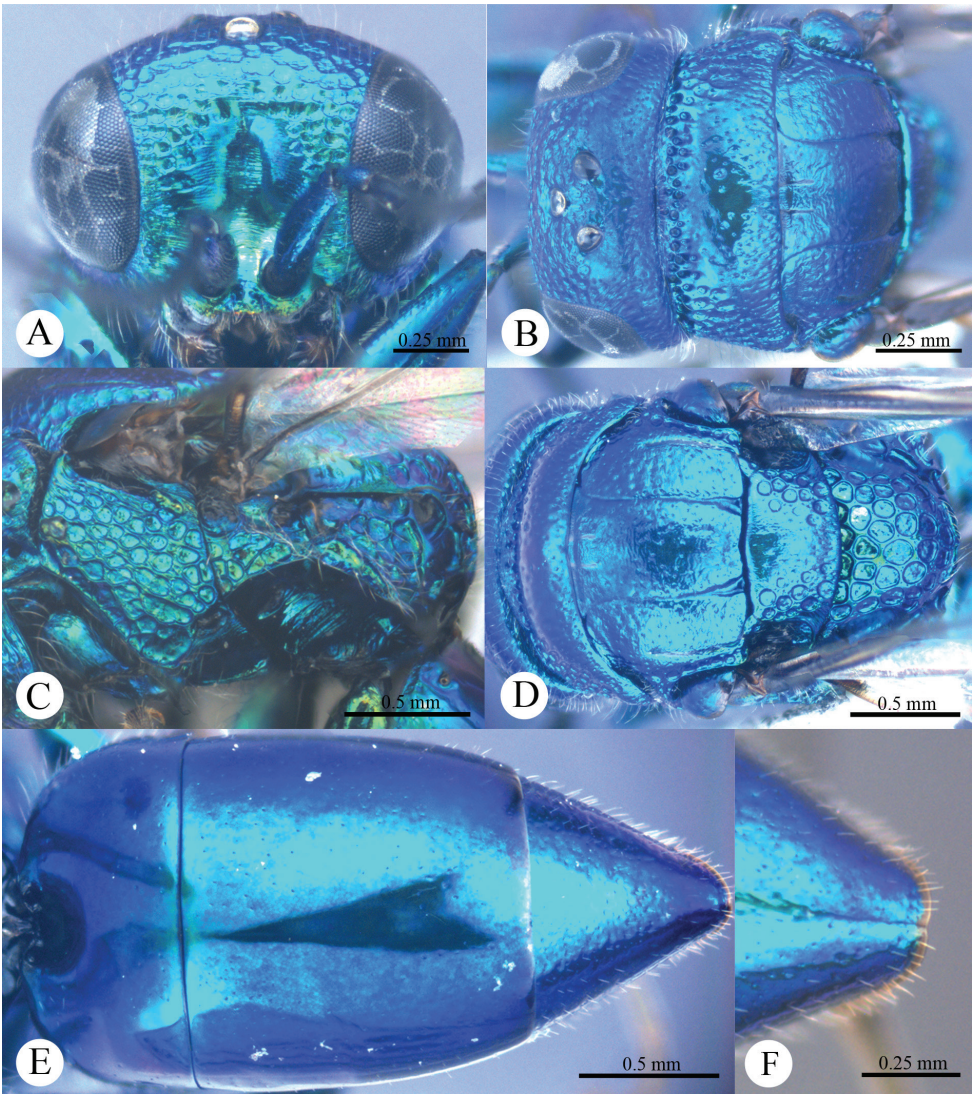

Plate 12. *Omalus probiaccinctus* sp. n., holotype, female. **A** Head anterior **B** Head and pronotum dorsal **C** Mesopleuron and metapleuron lateral **D** Mesoscutum, scutellum, metanotum and propodeum dorsal **E** Metasoma dorsal **F** Apex of T-III dorsal.

gin concave before propodeal angle; propodeal angle distinct, pointing posterolaterally (Plate 12D). Tarsal claw with four teeth.

Metasoma. Distinctly elongate, L/W = 2/1, with T-III slightly constrict laterally towards the apex (Plate 12E). T-I and T-II almost impunctate dorsally, with fine, scattered punctures laterally. T-III with slightly denser punctures than those on T-II (Plate 12E); apex of T-III with narrow (1/5 MOD), brownish rim, with faint median notch (Plate 12F).

Colouration. Head and mesosoma metallic greenish-blue, with purple reflections. Antenna black, with scape and pedicel metallic green. Tegula metallic greenish-blue, with apex brown. Leg metallic greenish-blue, with tarsus brown. Metasoma metallic greenish-blue, with purple reflections.

Male. Unknown.

Distribution. China (Guizhou).

Biology. Unknown. Collected in June.

Etymology. The name *probiaccinctus* is derived from the Latin preposition *pro-* and the chrysidid name *biaccinctus.*

***Omalus pseudoimbecillus* sp. n.**
http://zoobank.org/A2DABE4B-2BEF-4E28-8DD1-29D9D911A910
http://species-id.net/wiki/Omalus_pseudoimbecillus
Plates 13, 14

Material examined. Holotype: ♀ (SCAU), Yunnan, Yimen, Longquan Park (24°40'5"N, 102°9'2"E), 12.II.2005, He-sheng Wang, No. SCAU-O0041. Paratypes: 1 ♀ (SCAU), Yunnan, Yunlong, Tianchi National Nature Reserve (25°52'4"N, 99°17'25"E), 21.VIII.2003, Peng Wang, No. SCAU-O0042; 1 ♀ (SCAU), Yunnan, Jingdong, Jingping (24°27'14"N, 100°50'4"E), 28.IV.2005, He-sheng Wang, No. SCAU-O0043.

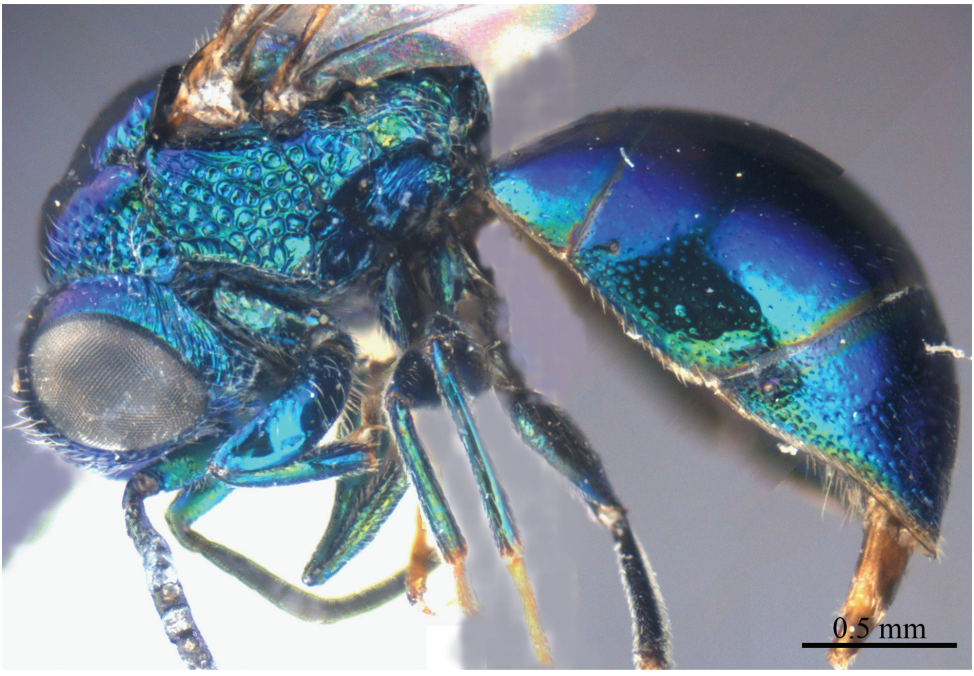

Plate 13. *Omalus pseudoimbecillus* sp. n., holotype, female. Habitus lateral.

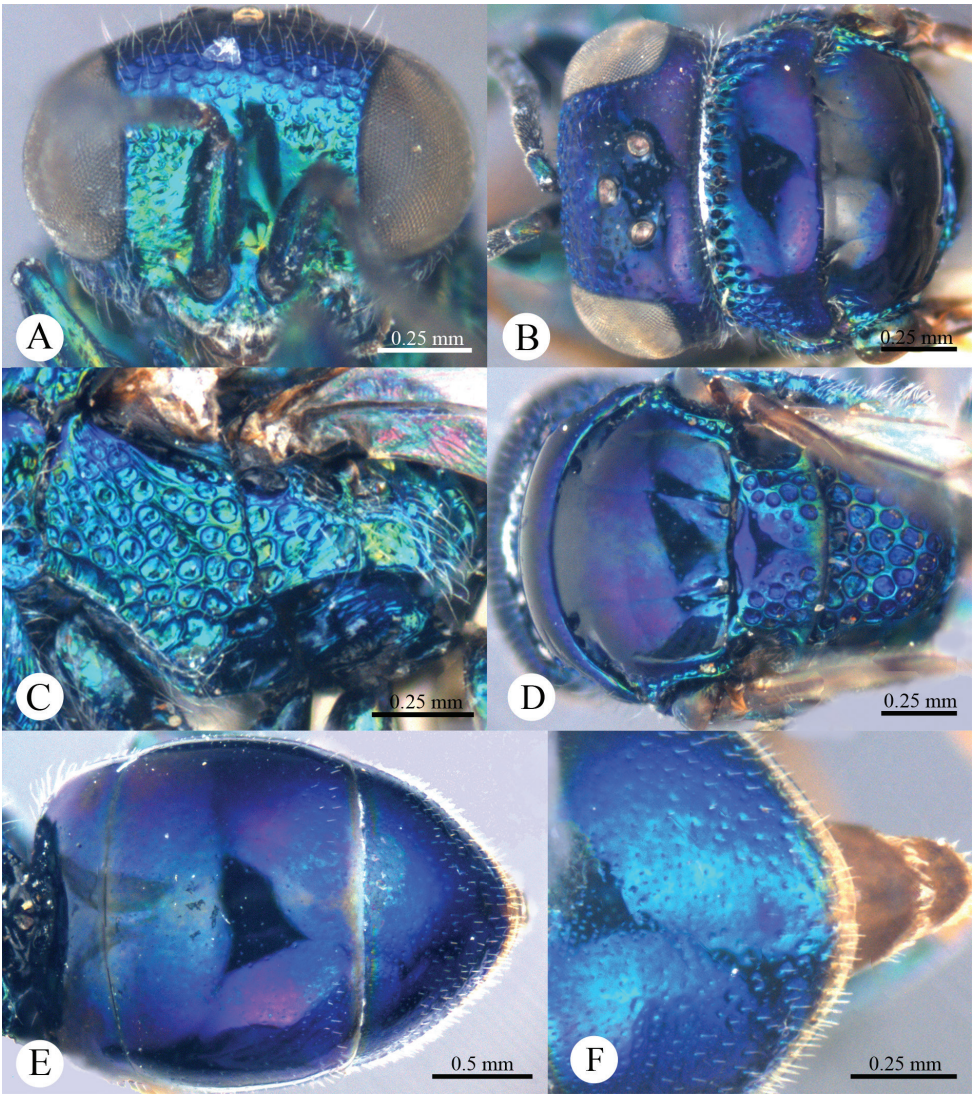

Plate 14. *Omalus pseudoimbecillus* sp. n., holotype, female. **A** Head anterior **B** Head and pronotum dorsal **C** Mesopleuron and metapleuron lateral **D** Mesoscutum, scutellum, metanotum and propodeum dorsal **E** Metasoma dorsal **F** Apex of T-III dorsal.

Diagnosis. *Omalus pseudoimbecillus* sp. n. is similar to *O. imbecillus* based on the colouration, polished mesoscutum, and oval metasoma. However, it can be distinguished from the latter by having the tegula transparent brownish, with faint metallic reflections anteriorly (fully metallic blue in *O. imbecillus*); mesopleuron with striae between punctures (without striae in *O. imbecillus*); propodeal angle distinct and stout (indistinct in *O. imbecillus*).

Description. *Female* (n = 3). Body length 3.9–4.4 mm (Plate 13). Fore wing length 3.3–3.6 mm. MS = 1.4 MOD.

Head. Face with large, round, dense (0–0.5 PD), shallow punctures (Plate 14A). Scapal basin deep, smooth, glabrous (Plate 14A). Ocellar triangle isosceles. Postocellar line absent (Plate 14B). Gena with oblique wrinkles.

Mesosoma. Pronotum almost impunctate medially, with small, deep pits on anterior margin; with large, dense (0–0.5 PD) punctures laterally (Plate 14B). Mesoscutum polished, almost impunctate (Plate 14D); notauli indistinct but complete, impressed as fine lines, with notaulic pit round and short; parapsidal lines indistinct (Plate 14D). Scutellum with two flattened, semi-elliptical foveae on anterior margin (Plate 14D); with broad, impunctate median area extending along its length (Plate 14D); areolate-punctate laterally, becoming deeper, larger towards alar foveae (Plate 14D). Mesopleuron with striae between punctures (Plate 14C). Metanotum gibbous, with large, deep, areolate-reticulate punctate (Plate 14D). Propodeum with lateral margin concave before propodeal angle; propodeal angle distinct, stout, pointing posterolaterally. Tarsal claw with three teeth.

Metasoma. Oval (Plate 14E), L/W = 15/11. T-I and T-II almost impunctate dorsally, with fine, scattered punctures laterally. T-III with fine, denser punctures than those on T-II (Plate 14E); apex of T-III with narrow (1/3 MOD), testaceous semi-transparent rim, without median notch (Plate 14F).

Colouration. Face metallic blue. Vertex and mesosoma purple, with mesoscutum blackish, and mesopleuron metallic bluish-green or green. Antenna black, with scape and pedicel metallic green. Tegula transparent brownish, with faint metallic reflections anteriorly. Leg metallic greenish-blue, with tarsus testaceous. Metasoma blackish-purple, with metallic blue reflections.

Male. Unknown.

Distribution. China (Yunnan).

Biology. Unknown. Collected in February, April, and August.

Etymology. The name *pseudoimbecillus* is derived from the Greek word psèydos (false) and the chrysidid name *imbecillus*. This name points to the morphological similarity between the two species.

***Omalus tibetanus* sp. n.**

http://zoobank.org/2DAB6611-C754-4092-8976-62D51990A738

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

Plates 15, 16

Material examined. Holotype: ♀ (SCAU), Tibet, Chayu, Cibagou (28°55'0.59"N, 97°27'2.22"E), 3200 m, 22.VI.2009, Jiang-li Tan, No. 200902083.

Diagnosis. *Omalus tibetanus* sp. n. is related to *O. probiaccinctus* sp. n. based on the distinctly elongate metasoma; to *O. berezovskii* Semenov-Tian-Shanskij based on the deep notauli. However, *Omalus tibetanus* sp. n. can be distinguished from them

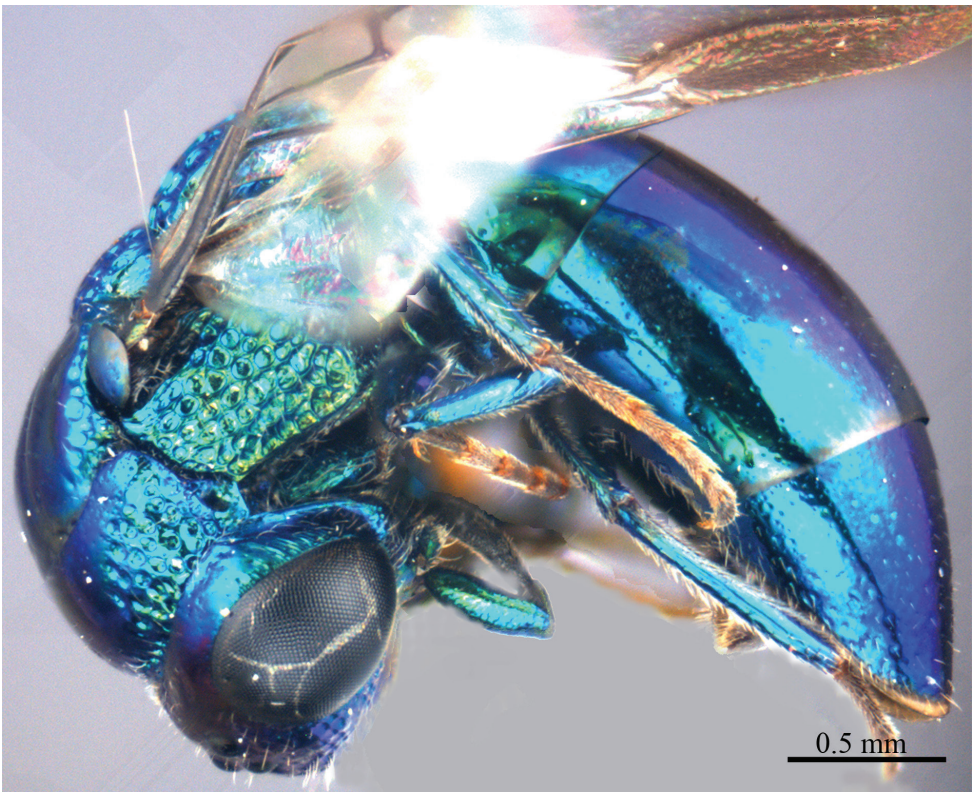

Plate 15. *Omalus tibetanus* sp. n., holotype, female. Habitus lateral.

by the combination of the following characters: mesoscutum polished (transversally rugulose in *O. probiaccinctus* sp. n.); T-III median notch shallowly indented (median notch deeply V-shaped in *O. berezovskii*, slightly in *O. probiaccinctus* sp. n.); metasoma distinctly elongate (pear-shaped in *O. berezovskii*).

Description. *Female.* Body length 4.5 mm (Plate 15). Forewing length 3.9 mm. POL : OOL : OCL = 2.0 : 2.7 : 2.5. MS = 0.9 MOD.

Head. Face with large, round, dense (0–0.5 PD), shallow punctures (Plate 16A). Scapal basin deep, with upper half smooth, glabrous; lower half weakly and obliquely striae laterally (Plate 16A). Ocellar triangle isosceles. Postocellar line absent (Plate 16B). Gena with oblique wrinkles.

Mesosoma. Pronotum almost impunctate medially (Plate 16B); with small, deep pits on anterior margin; with large, dense (0–0.5 PD) punctures laterally (Plate 16B). Mesoscutum polished, almost impunctate (Plate 16D); notauli distinct, deep, complete; notaulic pit elongate; parapsidal line shallower than notauli (Plate 16D). Scutellum without flattened fovea on anterior margin; with broad, impunctate median area extending along its full length (Plate 16D); shallowly areolate punctate laterally, becoming deeper, larger towards alar foveae (Plate 16D). Mesopleuron without striae between punctures (Plate 16C). Metanotum evenly round, large, deep,

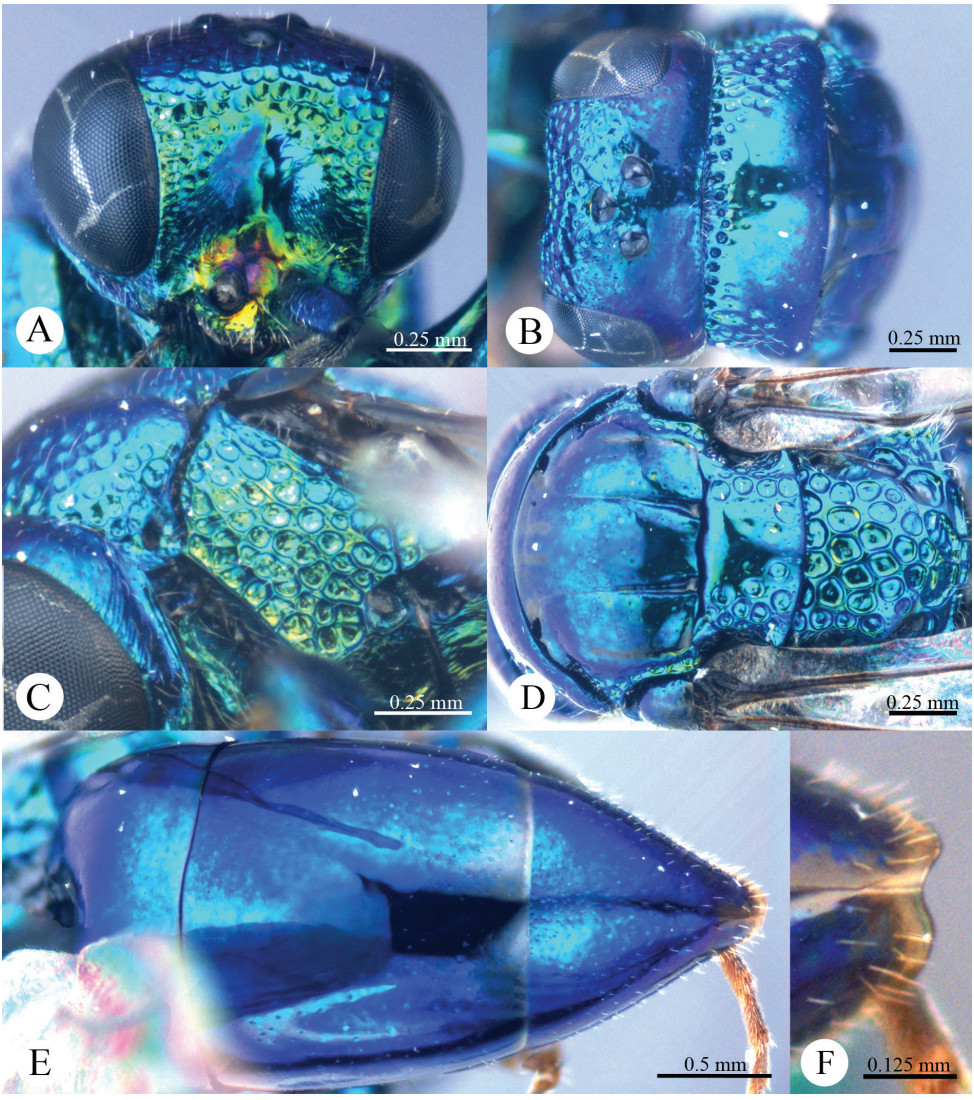

Plate 16. *Omalus tibetanus* sp. n., holotype, female. **A** Head anterior **B** Head and pronotum dorsal **C** Mesopleuron and metapleuron lateral **D** Mesoscutum, scutellum, metanotum and propodeum dorsal **E** Metasoma dorsal **F** Apex of T-III dorsal.

areolate-punctate (Plate 16D). Propodeum with lateral margin concave before propodeal angle; propodeal angle distinct, long, pointing posterolaterally (Plate 16D). Tarsal claw with three teeth.

Metasoma. Distinctly elongate, L/W = 13/9, with T-III slightly constrict laterally towards the apex (Plate 16E). T-I and T-II almost impunctate. T-III with fine, scattered punctures (Plate 16E); apex of T-III with narrow (1/2 MOD), testaceous transparent rim, with median notch shallowly indented (Plate 16F).

Colouration. Face metallic green, with some yellowish and violet tints on lower face between antennal socket. Vertex metallic blue, with purple laterally near the eye. Antenna black, with scape and pedicel metallic green. Mesosoma metallic bluish-green. Tegula metallic bluish-green, with apex blackish-brown. Leg metallic greenish-blue, with tarsus brown. Metasoma metallic blue, with purple reflections.

Male. Unknown.

Distribution. China (Tibet).

Biology. Unknown. Collected in June.

Etymology. The species is named after the type locality.

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RESEARCH ARTICLE

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Inventory of the carabid beetle fauna of the Gaoligong Mountains, western Yunnan Province, China: species of the tribe Zabrini (Coleoptera, Carabidae)

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Abstract

A ten-year multidisciplinary, multi-national and multi-institutional biodiversity inventory project in the Gaoligong Shan region of western Yunnan Province, China generated more than 35,000 specimens of the beetle (Coleoptera) family Carabidae. In this report, first of a planned series, we focus on diversity in tribe Zabrini. Our study of just over 1300 specimens of zabrine carabids from the project, all in genus *Amara* Bonelli, found a total of 13 species, all previously described, to occur in the study area, with none of them strictly endemic. We present a key for identification of adults of these species, as well as nomenclatural data, diagnoses, illustrations of dorsal habitus and male genitalia, and information about geographical, altitudinal and habitat distributions within the study area and overall geographical distribution for each species. Distributions of the species within the study area are compared, and broader geographical range patterns are characterized. We also discuss a possible role of the Gaoligong Shan region as one source area for the present-day fauna of the Himalaya and southern edge of the Qinghai-Xizang (Tibetan) Plateau.

Keywords

Coleoptera, Carabidae, Zabrini, *Amara*, China, Yunnan, Gaoligong Shan, Himalaya, Qinghai-Xizang (Tibetan) Plateau, distribution, biodiversity hotspot

Introduction

The Gaoligong Shan (Gaoligong Mountains) of extreme western Yunnan province, China, form the westernmost range of the Hengduan Mountains system of southeastern Xizang Autonomous Region (Tibet), northern and western Yunnan, and western Sichuan (Fig. 1). They extend north to south for more than 600 km, and, in the central part of the range, their crest forms the border between China and Myanmar. They also separate and form parts of the watersheds of two of Southeast Asia's major rivers, the Irrawaddy and the Salween (known in China as the Nujiang). Elevations within the region range from a low of about 650 m in the south to more than 5000 m in the north. Chaplin (2006) reviewed the physical geography of the region. Because of its geographic isolation and rugged topography, much of this area has remained less disturbed than most other parts of China; and previous biological exploration of the area over the past 150 years has revealed exceptionally high species richness, based almost exclusively on records for vertebrates (e.g., Stattersfield et al. 1998) and vascular plants (Li et al 2000). Because of these traits, two large nature reserves have been established in the area, and the region has been included in the Three Parallel Rivers of Yunnan World Heritage Site (UNESCO 2003).

In late 1997, the California Academy of Sciences was invited to participate in a joint project with the Kunming Institutes of Botany and Zoology of the Chinese Academy of Sciences to conduct a biodiversity inventory of the Gaoligong Mountains. Scientists from several additional institutions, including the Institute of Zoology, Beijing, and Royal Botanical Garden (Edinburgh) joined in the collaboration. Principal target groups for the inventory included bryophytes and vascular plants, all vertebrate groups, and arachnids, myriapods, and insects, especially the Neuropteroidea, Mecoptera, and Coleoptera (the Carabidae in particular). Multidisciplinary and multi-institutional teams carried out biotic sampling through more than 25 separate expeditions during the period 1998 to 2007. More than 100 reports on the project have been published to date, including partial results for bryophytes (e.g., Long 2006, Shevock 2005), plants (e.g., Fritsch et al. 2008, Zhou et al. 2006), birds (Dumbacher et al. 2011), amphibians (e.g., Liu et al. 2000), fishes (e.g., Chen et al. 2005), spiders (e.g., Miller et al. 2009, Wang et al. 2010), and carabid beetles (Kavanaugh and Liang 2004 and 2006; Kavanaugh and Long 1999; Liang and Imura 2003; Liang and Kavanaugh 2006 and 2007; and Liu et al. 2010 and 2011).

Prior to the start of the project the carabid beetle fauna of the region was very poorly known. The faunal for the entire Hengduan region included only about 50 species (Yu 1992), and most of these were widespread species from low elevation areas. The region in general and the higher elevations in particular were virtually unexplored with respect to the carabid fauna. As a result of our work on this project to date, we now recognize more than 525 species occurring in the Gaoligong Shan, with many additional species undoubtedly represented among materials for groups not yet fully studied. For several of the groups currently under study, (e.g., *Leistus* (Nebriini), *Broscosom*a (Broscini), *Amerizus* (*Tiruka*) (Bembidiini) and *Aristochroa*

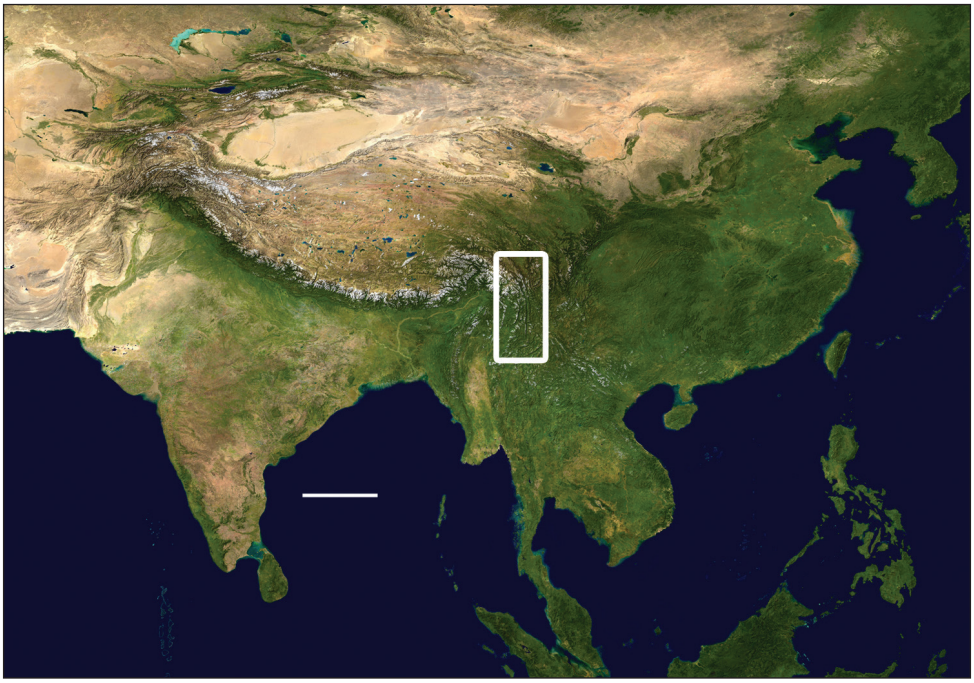


Figure 1. Map of Asia with study region outlined; scale line = 500 km. Modified from Wikimedia Commons, World Atlas of the World, at URL: http://upload.wikimedia.org/wikipedia/commons/8/8f/Whole_world_-_land_and_oceans_12000.jpg

(Pterostichini), species diversity is much higher in this area than is known anywhere else that these taxa occur.

This report, on the tribe Zabrini, represents the first of an intended series of treatments on the carabid beetle fauna of the Gaoligong Shan region, each dealing with one or more tribes or hyper-diverse genera represented in the fauna. These will appear as taxonomic work on each group is completed and not in any particular taxonomic or phylogenetic order.

Zabrini is a moderately diverse taxon, including nearly 700 described species (Lorenz 2005). It is principally Holarctic in distribution, with relatively few species occurring south of that region in the Neotropical (as far south as Costa Rica), Afrotropical (nine species in Ethiopia, Kenya, Somalia and Tansania) and Oriental (three or four species in northern parts only) Regions. The only zabrine genus represented in the study area is *Amara* Bonelli (1810), which is also the largest genus in the tribe, with just over 570 described species and a cumulative geographical range which actually defines that of the tribe. The ranges of the other zabrine genus, *Zabrus* Clairville (1806), and of *Pseudamara* Lindroth (1968), which has been transferred from the Zabrini to the Sphodrini recently by Hieke (2010, 2013), are fully within the range of *Amara*.

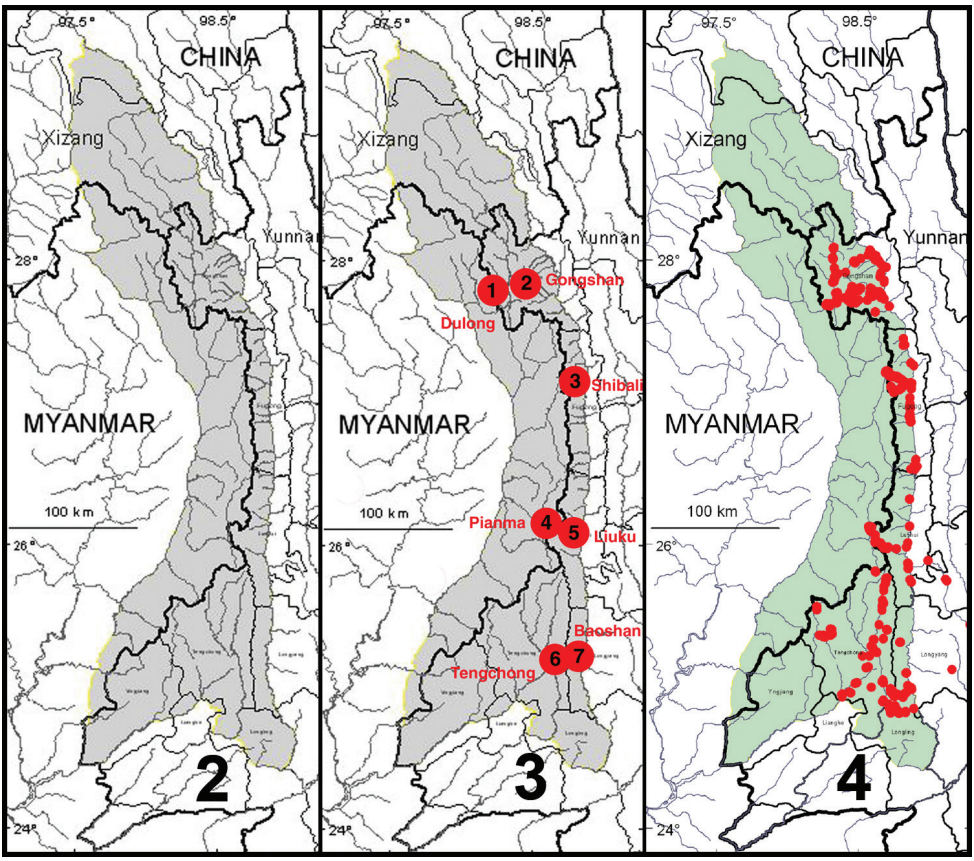
Amara is most diverse in temperate parts of the Holarctic Region. Along with members of the tribe Harpalini, zabrines are unusual among Carabidae in feeding

mainly on seeds (Johnson and Cameron 1969), particularly those of the grass (Graminaceae) and mustard (Cruciferae) families, but also on fruits, flowers and other plant parts. Apparently, both adults and larvae use seeds as a main food source. Probably because of their feeding preferences, *Amara* species occur mainly in open areas, such as grasslands, meadows, forest edges, and disturbed habitats of all types, including both those associated with natural environmental processes (e.g., landslides, eroded or scoured stream banks, floodplains and areas burned by lightning strikes) and those created by humans (e.g., forest clearings, roadcuts and ruderal (waste) sites around human settlements or other constructs and agricultural sites).

As is the case with most other terrestrial anthropod groups, the *Amara* fauna of the study area has not been well documented previously. Most of our current knowledge of the Southeast Asian regional fauna is from the works of Baliani (1932, 1934a, 1934b, 1937, 1943), Hieke (see References section) and Jedlička (1934a, 1934b, 1956, 1957), with significant additional contributions from Andrewes (1930), Bates (1876, 1883, 1891), Morawitz (1863a, 1863b), Motschulsky (1844), Putzeys (1875) and Tschitschérine (1894, 1897, 1899). Based on our study of the material collected for the project and additional specimens from the region housed in other collections, we recognize a total of 13 *Amara* species found to occur in the study area, all of which have been described previously. We present here a key for identification of adults of these species, as well as nomenclatural data, diagnoses, illustrations of dorsal habitus and male genitalia, and information about geographical and habitat distributions within the study area and overall geographical distribution for each species. We also discuss geographical distributions of the species with respect to seven core areas and to each other, as well as broader geographical range patterns and the altitudinal ranges of the species.

Materials and methods

The natural physiographic limits of the study area for the project are as shown in Fig. 2 and include areas in eastern Myanmar and southern Xizhang (Tibet); but we had permission to survey only those parts in Yunnan Province. Specialists for all taxonomic groups concentrated their efforts on seven core areas within the project region (Fig. 3), selected to facilitate comparisons of possible north to south and east to west spatial differences within the regional biota, as well as recognition of areas of local endemism. Other areas were sampled as time and opportunity permitted. The entomological team made a total of 13 expeditions to the Gaoligong region. Our sampling sites within the region are shown in Fig. 4. Habitats included in the study area range from subtropical lowland rainforest to the margin of glaciers and snowfields. In all, more than 35,000 carabid specimens were collected during the project by using a variety of collecting methods, including hand collecting both day and night, beating vegetation, sifting litter with subsequent extraction by hand or by mini-Winkler units, and Malaise flight traps and pitfall traps. All specimens were



Figures 2–4. 2 Map showing natural extent of study area, colored in gray (however, sampling was permitted only in those portions in Yunnan Province **3** Map showing location of core sampling areas **4** Map showing locations of all entomological sampling sites.

sorted to morphospecies (i.e., presumptive species units based on features of external structure and male and female genitalic traits) and detailed systematic studies of taxonomic groups are ongoing.

A total of 1,327 specimens representing zabrine species were collected during the project. All of these specimens have been divided among and are deposited in collections of our home institutions. Codens used throughout this report for collections in which specimens, including primary types, are deposited are as follows:

BMNH	British Museum (Natural History), London, United Kingdom
CAS	California Academy of Sciences, San Francisco, U.S.A.
CMEY	Collection of P. Meyer, Darmstadt, Germany
CWRA	Collection of D. Wrase, Berlin, Germany
DEI	Deutsches Entomologisches Institut, Eberswalde, Germany
FRSDD	Forest Research Institute, Dehra Dun, India

IOZ	National Zoological Museum of China, Institute of Zoology, Beijing, China
IRSNB	Institut Royal des Sciences Naturelles de Belgique, Brussels, Belgium
MCSNG	Museo Civico di Storia Naturale, Genoa, Italy
MNHN	Muséum National d'Histoire Naturelle, Paris, France
NHRS	Naturhistoriska Riksmuseet, Stockholm, Sweden
NMPC	National Museum (Natural History), Prague, Czech Republic
NZSI	National Zoological Collection, Zoological Survey of India, Calcutta, India
ZIN	Zoological Institute Academy of Sciences, St.Petersburg, Russia
ZFMK	Zoologisches Forschungsmuseum "Alexander Koenig", Bonn, Germany
ZMHB	Museum für Naturkunde an der Humboldt-Universität, Berlin, Germany
ZMMU	Zoological Museum, Moscow University, Moscow, Russia

The only measurements taken were of body length, measured from the anterior margin of the clypeus to the apex of the longer elytron. Digital images of dorsal habitus of a typical representative member of each morphospecies were taken using an Automontage imaging system from Synchroscopy with a JVC KY-F-75U digital camera and a Leica M420 dissecting microscope. The "CASENT" number associated with each image, as noted in figure captions, is a unique identifier that refers to the particular specimen photographed and its CAS database record. Distribution maps for each species were generated from geographical coordinate data maintained in a Biota Version 3.0 database (Colwell 2012) using the ArcMap program in ArcGIS for Desktop Version 10.2 software from Esri.

Taxonomy

Adult specimens of species represented in the Gaoligong Shan region can be distinguished using the following key.

Key for Identification of Adults of *Amara* species of the Gaoligong Shan region

1 Medial protibial spurs trifid (Fig. 5a); dorsal surface dark metallic green, nonmetallic black in a very few specimens; body length 7.0–8.5 mm; elytron with parascutellar pore-puncture present...***A.* (*Zezea*) *davidi* Tschitschérine, 1897**

– Medial protibial spurs simple (Fig. 5b) 2

2 Last abdominal sternite of male with two pairs of setiferous punctures (Fig. 5d) near hind margin (second seta absent from one side in a few males for total of three setae); dorsal surface dark piceous; body length 7–8 mm; pronotum with both inner and outer basal impressions deep and broadly foveate (Fig. 14a) .....***A.* (*Xenocelia*) *sikkimensis* Andrewes, 1930**

– Last abdominal sternite of male with one pair of setiferous punctures (Fig. 5c) near hind margin (Fig. 5d)..... 3

3 Body length more than 11 mm; tarsomere 5 of hind tarsi with five or six setal pairs ventrally (Fig. 6a); dorsal surface dark piceous; body length 11–13 mm, body form stout; pronotum (Fig. 20a) with lateral margins markedly rounded, basal area punctate, in most specimens also punctate laterally in basal half and near anterior margin.....***A.* (*Bradytus*) *pingshiangi* Jedlička, 1957**

– Body length less; tarsomere 5 of hind tarsi with two (in a few specimens three) setal pairs ventrally (Fig. 6b) 4

4 Elytron with parascutellar pore-puncture present; dorsal surface with metallic luster.....5

– Elytra without parascutellar pore-puncture 7

5 Base of pronotum evenly convex from one side to the other, outer basal impressions absent or only very faintly suggested; body length 9–10 mm; sclerites of internal sac of median lobe of male aedeagus as in Fig. 7e–f..... .....***A.* (*Amara*) *congrua* Morawitz, 1863**

– Base of pronotum slightly flattened at the sides, only the middle part evenly convex, outer basal impressions evident, either shallow and obliquely linear (Fig. 11a) or deep and broadly foveate (Fig. 12a); sclerites of internal sac of median lobe of male aedeagus with different form (Fig. 7a–d) **6**

6 Base of pronotum coarsely punctate; outer basal impressions shallow and obliquely linear (Fig. 11a); male aedeagus with median lobe distinctly broader in apical one-third than more basally, apical lamella shorter, broadly rounded apically and with sides only slightly convergent subapically (Fig. 11c); sclerites of internal sac of median lobe of male aedeagus as in Fig. 7a–b; body length 9–10 mm.....***A.* (*Amara*) *silvestrii* Baliani, 1937**

– Base of pronotum finely punctate; outer basal impressions deep and broadly foveate (Fig. 12a); male aedeagus with median lobe not or only slightly broader in apical one-third than more basally, apical lamella longer, narrowly rounded apically and with sides more distinctly convergent apically (Fig. 12c); sclerites of internal sac of median lobe of male aedeagus as in Fig. 7c–d; body length 8.5–10.0 mm .....***A.* (*Amara*) *shaanxiensis* Hieke, 2002**

7 Dorsal surface light-brown to brownish black, without metallic reflection, entire legs and antennae pale; body length 6.5–8.0 mm; male aedeagus with apical third of median lobe broader than middle third (Fig. 21c), apical hook of right paramere large and slightly subapical (Fig. 8a)..... .....***A.* (*Reductocelia*) *lucidissima* Baliani, 1932**

– Dorsal surface darker, with or without distinct metallic reflection, at least femora dark (piceous to black) **8**

8 Pronotum with lateral margins straight or faintly to distinctly sinuate just anterior to basal angles, rounded near middle, less rounded or nearly straight also in anterior one-third in most specimens, anterior angles distinctly and narrowly projected anteriorly beyond anterior margin; dorsal surface dark with distinct metallic blue-green reflection in most specimens, non-metallic black in a few specimens **9**

– Pronotum with lateral margins more or less evenly rounded from apical to basal angle, anterior angles not or only faintly and broadly projected anteriorly beyond anterior margin; dorsal surface with or without metallic reflection..... **10**

9 Pronotum (Fig. 18a) with lateral explanation narrow throughout, outer basal impressions foveate and distinct from lateral groove, punctation of base not extended anteriorly along sides beyond basal one-third; elytral microsculpture effaced or nearly so in both males and females; body length 7.0–7.5 mm..... ***A.* (*Bradytus*) *elegantula* Tschitschérine, 1899**

– Pronotum (Fig. 16a) with lateral explanation distinctly broader basally, outer basal impressions indistinct from lateral groove in most specimens, punctation of base extended anteriorly along sides to pronotal mid-length; elytral microsculpture comprised of isodiametric meshes, faintly impressed or nearly effaced in males, deeply impressed and distinct in females; body length 7.5–9.0 mm ..... ***A.* (*Bradytus*) *chalciope* (Bates, 1891)**

10 Elytral microscuplture comprised of distinctly transverse meshes in both males and females (more transverse and less deeply impressed in males than in females); pronotum (Fig.19a) only slightly narrower anteriorly than basally, anterior margin almost as wide as posterior margin, pronotal base very coarsely punctate, outer basal impressions sharply delimited laterally by narrow, slightly oblique raised (but not carinate) areas..... ..... ***A.* (*Bradytus*) *simplicidens* Morawitz, 1863**

– Elytral microscuplture comprised of distinctly isodiametric meshes in both males and females (more deeply impressed in females than in males); pronotum (Figs13a, 15a, 17a) more distinctly narrowed anteriorly than basally, anterior margin clearly narrower than posterior margin, pronotal base moderately coarsely punctate, outer basal impressions either not sharply delimited laterally by raised areas or, if so, then the raised area broader **11**

11 Pronotum (Fig. 15a) with posterior angles distinctly rounded (narrowly so in some individuals), slightly to moderately obtuse; elytra with slight sub-basal depressions centered on striae 6 (visible on right elytron in Fig. 15a), also on striae 4 and/or 5 in some individuals; dorsal surface black, with very faint metallic blue or green metallic reflection in most individuals, more vivid (as in Fig. 15a) in or lacking from a few specimens; body length 8.5–9.0 mm ... . ***A.* (*Harpaloamara*) *latithorax* Baliani, 1934**

– Pronotum (Figs 13a, 17a) with posterior angles either obtusely angulate and slightly denticulate or narrowly rounded (if the latter, then body length 7.5 mm or less); elytra without evident sub-basal depressions; dorsal surface with or without metallic reflection..... **12**

12 Dorsal surface with distinct metallic copper or bronze reflection, non-metallic black in very few specimens; pronotum (Fig. 13a) with posterior angles narrowly rounded, basal impressions deeply foveate but small in diameter, outer basal impressions not distinctly delimited laterally by a broad convexity;

elytral striae distinct throughout but only shallowly impressed in most individuals; metatibiae of males without a brush-like patch of setae medially in the apical half; body length 6.5–7.5 mm.....
.....***A.* (*Pseudoamara*) *birmana* Baliani, 1934**

– Dorsal surface black or piceous, without or with only very faint metallic green reflection; pronotum with posterior angles obtusely angulate and slightly denticulate, basal impressions broadly and deeply foveate, outer basal impression distinctly delimited laterally by a broad convexity; elytral striae distinct throughout and deeply impressed; metatibiae of males with a brush-like patch of setae medially in the apical half; body length 7.7–8.7 mm .....
.....***A.* (*Bradytus*) *dissimilis* Tschitschérine, 1894**

1. *Amara* (*Zezea*) *davidi* Tschitschérine, 1897
http://species-id.net/wiki/Amara_davidi
Figs 5a, c, e, 6b, 9, 22a, 27–30

Amara (*Triaena*) *davidi* Tschitschérine, 1897: 67. Type material: Holotype male ("type") and 1 paratype female in ZIN (Hieke 1970: 143), 4 paratypes in MNHN. Type locality: China, Sichuan, "Mou-Pin (leg. David)".

Diagnosis. Adults of this species (Fig. 9) can be distinguished from those of all other species in the region by their trifid medial protibial spurs (Fig. 5a). *Amara davidi* is the only member of subgenus *Zezea*, members of which share this feature, known from the region.

Habitat distribution. Specimens of this species were collected from under stones in open roadside and waste areas (Fig. 22a) with scattered grasses and shrubs at elevations ranging from 2020 to 2440 m, syntopic (together in the same habitat) with adults of *A. birmana*, *A. shaanxiensis*, *A. sikkimensis* and *A. silvestrii* at one or more sites.

Geographical distribution within the Gaoligong Shan. Fig. 9d. We examined a total of 3 specimens (all females) from the following localities: ***Gongshan County:*** Heiwadi (16.8 km W of Cikai on Dulong Valley Road, 27.79584°/98.58443°, 2020 m, 20 April 2002, H.B. Liang, W.D. Ba, G.D. Yang & X.Q. Li collectors [2 females; CAS, IOZ]). ***Longyang County:*** Bawan-Tengchong Road Km 41 (near yakou, 24.93972°/98.75333°, 2440 m, 15 October 2003, H.B. Liang & J.J. Yang (1 female; CAS).

Members of this species were collected in both the northern and southern parts of the study area (Core Areas 2, 6 and 7) but not in the central part. This gap in distribution is most likely an artifact of inadequate sampling and not a real disjunction.

Overall geographical distribution. Fig. 27. This species has been recorded from Beijing, Gansu, Hubei, Qinghai, Shaanxi, Sichuan and Yunnan Provinces in China. Its occurrence in the study area represents the southwestern limit of its known geographical range.

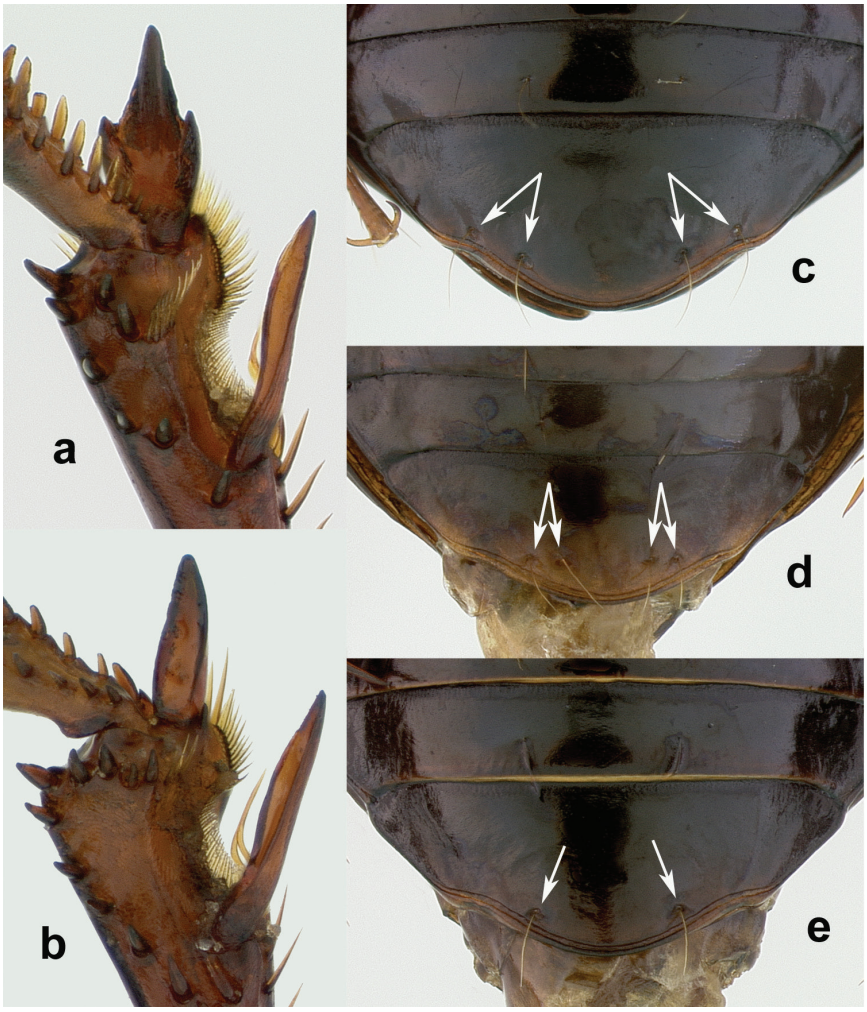


Figure 5. Tibial and abdominal apices. **a–b** right tibial apices, lateroventral aspect; a. *Amara davidi* Tschitshérine **b** *Amara sikkimensis* Andrewes, typical of all other *Amara* species of the area **c–e** abdominal apices, ventral aspect, with white arrows indicating insertion points for setae **c** *A. sikkimensis*, typical of all *Amara* females **d** *Amara sikkimensis* Andrewes male **e** *Amara latithorax* Baliani, typical of males of all other *Amara* species of the area.

Figure 6. Tarsomere 5 of left hind tarsus, medial aspect. **a** *Amara pingshiangi* Jedlička **b** *Amara sikkimensis* Andrewes, typical of all other *Amara* species of the area.

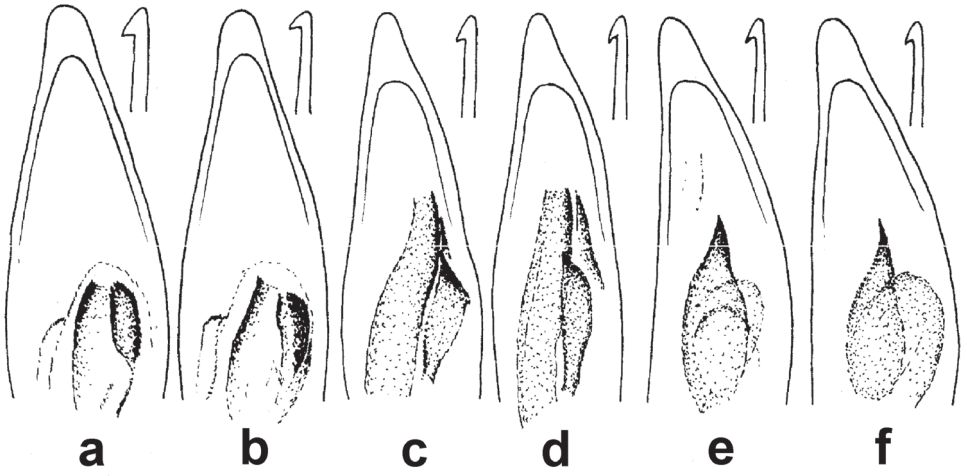


Figure 7. Apical and subapical region of median lobe (dorsal aspect) and apex of right paramere (medial aspect) of aedeagus of males. **a–b** *Amara silvestrii* Baliani **c–d** *Amara shaanxiensis* Hieke **e–f** *Amara congrua* Morawitz.

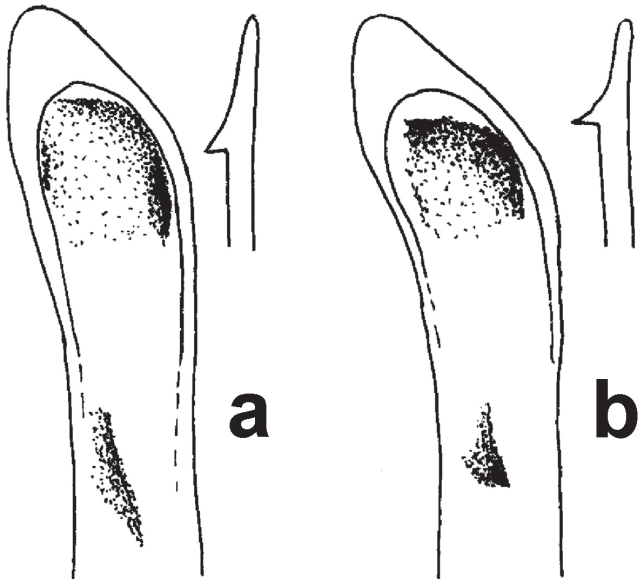


Figure 8. Apical region of median lobe (dorsal aspect) and apex of right paramere (medial aspect) of aedeagus of males. **a** *Amara lucidissima* Baliani **b** all other species of subgenus *Reductocelia* (for comparative purposes only, no other species of this subgenus in the area).

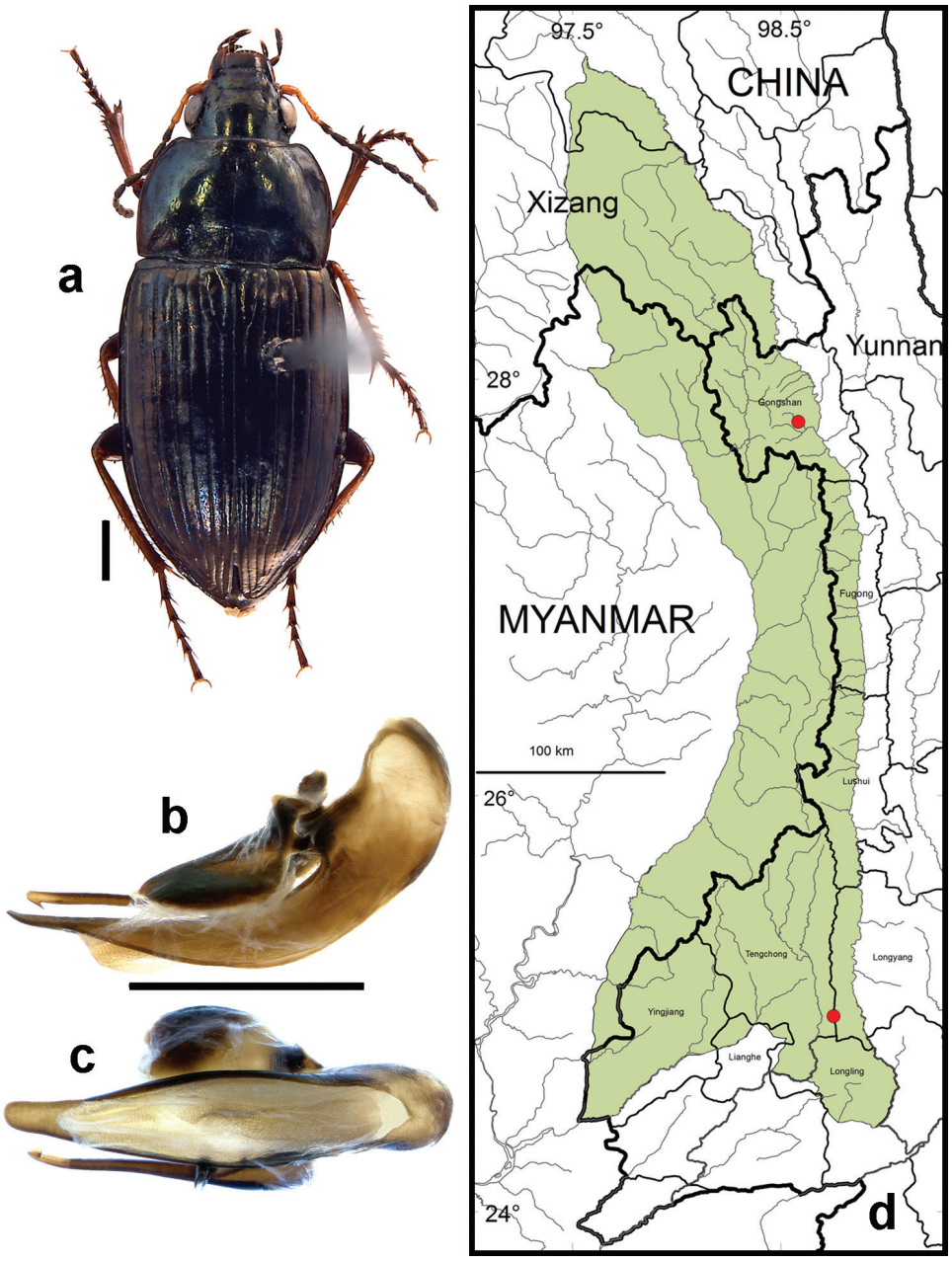


Figure 9. *Amara* (*Zezea*) *davidi* Tschitschérine. **a** dorsal habitus (CASENT1010925) **b–c** median lobe of aedeagus of male (CASENT8125447) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A. davidi* in the Gaoligong Shan region, scale line = 100 km.

2. *Amara* (*Amara*) *congrua* Morawitz, 1863
http://species-id.net/wiki/Amara_congrua
Figs 5b–c, e, 6b, 7e–f, 10, 22b, 27–30

Amara mongolica Motschulsky, 1844: 185, nomen oblitum. Type material: Number of syntypes not specified and unknown, a fragmentary male specimen in ZMMU (Keleinikova 1976: 206) identified as holotype in that collection by Hieke. Type locality: "sur la frontière de la Mongolie", probably northeastern China, Outer Manchuria (now Primorsky Krai of Russia). Synonymy suggested by Morawitz 1863b: 63, synonymized by Hieke (1973: 116).

Amara (*Amara*) *congrua* Morawitz, 1863b: 62. Type material: Number of syntypes not specified, but at least several, with 5 syntypes in ZIN; lectotype male and 1 paralectotype designated by Hieke (1973: 25), the 3 other syntypes (paralectotypes) are adults of *A. chalcites* Dejean. Type locality: Japan: Hakodate.

Amara zimmermanni Putzeys, 1875: LI (röm. 51) [nec Heer, 1837: 38]. Type material: Number of syntypes not specified, but at least several, with 3 syntypes in IRSNB and 2 in DEI (Döbler 1975: 148); two of those syntypes are adults of *A. chalcites* Dejean, and the specimen from Kyoto in IRSNB, which has been considered as "Type", is an adult of *A. congrua* Morawitz. Type locality: Japan, Kyoto. Synonymized by Hieke (1973: 23), previously synonymized incorrectly with *A. chalcites* Dejean by Bates (1876: 4).

Amara striatella Putzeys, 1875:LII (röm. 52). Type material: Number of syntypes not specified, but 4 of them in IRSNB; lectotype male designated by Hieke (1973: 27); one of those syntypes is an adult of *A. chalcites* Dejean. Type locality: Japan, Kyoto. Synonymized by Hieke (1973: 23), previously synonymized incorrectly with *A. chalcites* Dejean (as «var. *striatella*») by Bates (1883: 242).

Amara (*Amara*) *mandzhurica* Lutshnik, 1935: 257. Type material: Holotype female (not a male as stated by Lutshnik) in ZIN. Type locality: China: Manchuria: "Ertzendjantzy". Synonymized by Hieke (1973: 58).

Amara (*Amara*) *ovatoides* Baliani, 1943: 38. Type material: Holotype female (not a male as stated by Baliani, but as can be seen in his Fig. 1), in MCSNG. Type locality: China, Shanghai. Synonymized by Hieke (1978: 314).

Amara (*Amara*) *abnormalis* Jedlička, 1956:213. Type material: Holotype and 1 paratype in ZFMK, 2 paratypes in NMPC. Type locality: China, Fujian, Kuatun. Synonymized by Hieke (1973: 2).

Diagnosis. Adults of this species (Fig. 10) can be distinguished from those of all other species in the region by the following combination of character states: body length 9–10 mm; base of the pronotum evenly convex from one side to the other, outer basal impressions absent or only very faintly suggested; elytra with parascutellar pore puncture present; medial protibial spurs simple; tarsomere 5 of hind tarsi with two or (in a few specimens) three pairs of setae ventrally (Fig. 6b); last abdominal sternite of male with one pair (Fig.5e)

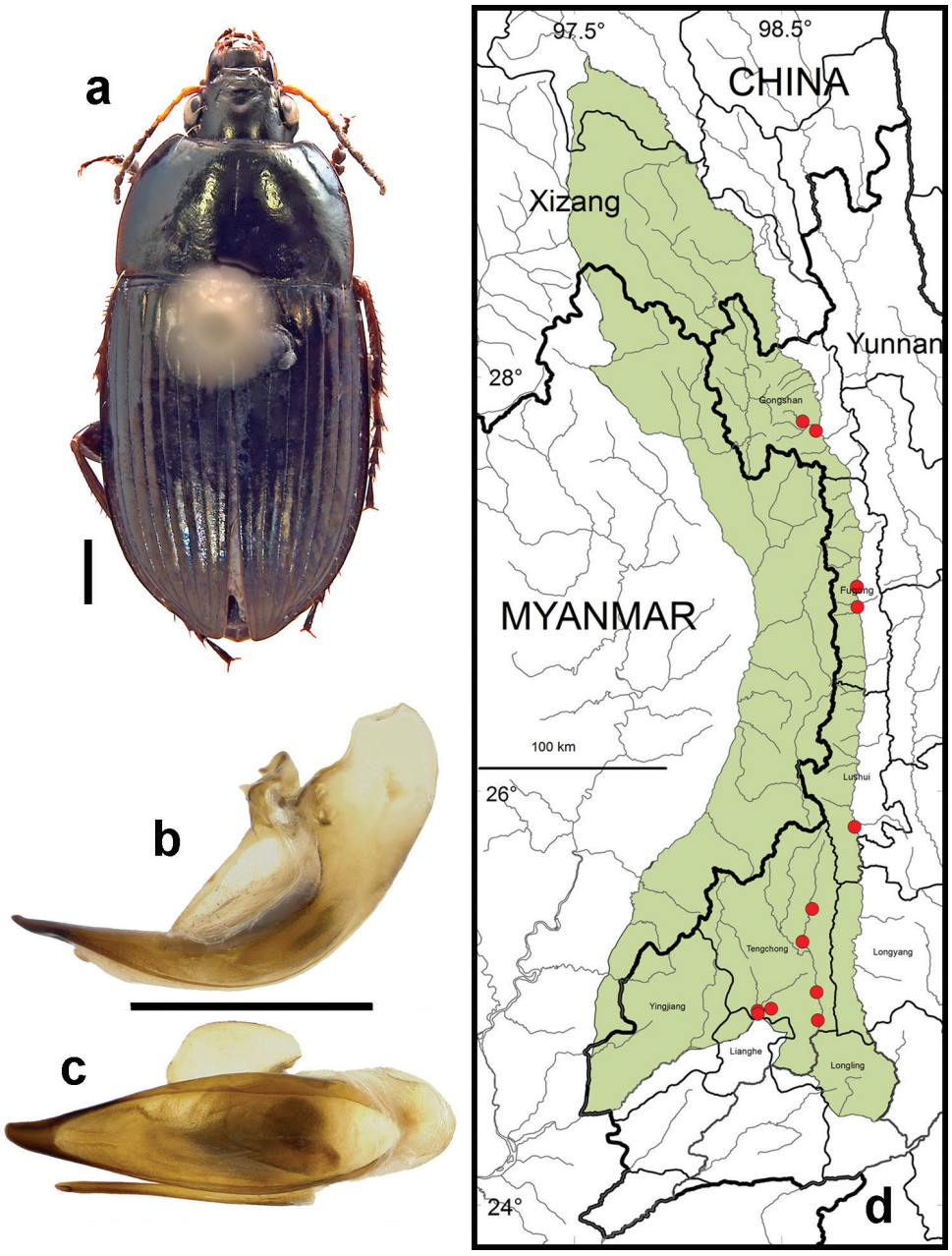


Figure 10. *Amara* (*Amara*) *congrua* Morawitz. **a** dorsal habitus (CASENT1039647) **b–c** median lobe of aedeagus of male (CASENT1039647) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A. congrua* in the Gaoligong Shan region, scale line = 100 km.

and female with two pairs (Fig.5c) of setiferous punctures near hind margin; sclerites of internal sac of median lobe of male aedeagus with form as in Fig. 7e–f.

Habitat distribution. Specimens of this species were collected in daytime from under stones and other cover in open roadside areas with scattered grasses and shrubs (Fig. 22b), at the edges of agricultural fields, including wet and dry rice paddies, and on open banks of streams, and in these same habitats at night, when beetles were found active on bare substrate. Specimens were found at elevations ranging from 892 to 2000 m. The only other *Amara* species members of which were found syntopic with those of *A. congrua* was *A. latithorax,* with adults of both species found together at only one site at an elevation of 1223 m.

Geographical distribution within the Gaoligong Shan. Fig. 10d. We examined a total of 33 specimens (17 males and 16 females) from the following localities: ***Fugong County:*** Lumadeng Township (Chihengdi village, 26.98749°/98.86310°, 1230 m, 29 April 2004, D.H. Kavanaugh & H.B. Liang collectors [3 males and 2 females; CAS, IOZ]); Shangpa Township (road on west side of Nu Jiang S of Shangpa, 26.88952°/98.86539°, 1223 m, 22 April 2004, D.H. Kavanaugh & C.E. Griswold collectors [1 male and 1 female; CAS]). ***Gongshan County***: Cikai Township (27.27064°/98.66557°, 1500 m, 28 June 2000, D.H. Kavanaugh & H.B. Liang collectors [1 male; CAS]); Heiwadi village (27.78594°/98.60117°, 1880-2000 m, 28 June 2000, D.H. Kavanaugh & H.B. Liang collectors [1 female; IOZ]). ***Lushui County:*** Liuku Township (Laimo village, 25.82767°/98.85120°, 892 m, 15 May 2004, H.B. Liang & X.Y. Li collectors [1 male and 1 female; CAS, IOZ]). ***Tengchong County:*** Hehua Township (3.8 km S of Hehua along Daying Jiang at Nangyan village, 24.93873°/98.38444°, 1140 m, 2 June 2006, D.H. Kavanaugh, R.L. Brett & D.Z. Dong collectors [1 female; CAS]), (5.4 km S of Hehua along Daying Jiang at Dengma village, 24.92346°/98.38612° , 1105 m, 2 June 2006, D.H. Kavanaugh, R.L. Brett & D.Z. Dong collectors [1 female; IOZ]; Jietou Township (stream 0.7 km N of Jietou, 25.43128°/98.64773°, 1564 m, 22 May 2006, D.H. Kavanaugh, R.L. Brett & H.B. Liang collectors [3 males and 2 females; CAS, IOZ]); Qingshui Township (Liangyang village in Rehai area, 24.94919°/98.44921°, 1450 m, 1 June 2006, D.H. Kavanaugh, R.L. Brett, H.D. Liang, D.Z. Dong & P. Hu collectors [1 female; IOZ]); Qushi Township (Longchuan Jiang at Qinqiao in Qinqiao village, 25.27250°/98.60083°, 1464 m, 6 June 2006, D.H. Kavanaugh, R.L. Brett & D.Z. Dong collectors [7 males and 5 females; CAS, IOZ, ZMHB]); Shangying Township (Bawan-Tengchong Road KM 63, 25.02917°/98.66917°, 1360 m, 19 October 2003, H.B. Liang & X.C. Shi collectors [1 female; IOZ]); Wuhe Township (west bank of Longchuan Jiang at Tongjiazhuang village, 24.89284°/98.67439°, 1210 m, H.B. Liang collector 24 May 2005 [1 male; IOZ]).

Members of this species were collected from the northern to the southern parts of the study area (Core Areas 2, 3, 5 and 6), but they were found only on the eastern side of the mountain range in northern and central areas (Core Areas 2,3 and 5) and only on the western versant in the southern part (Core Area 6). This distribution pattern is most likely an artifact of inadequate sampling on the western slope of the mountain range, much of which is in Myanmar.

Overall geographical distribution. Fig. 27. This species has been recorded from China (Beijing, Fujian, Gansu, Guizhou, Hebei, Heilongjiang, Hongkong, Hubei, Jiangsu, Jiangxi, Jilin, Liaoning, Nei Mongol, Shaanxi, Shanghai, Sichuan, Yunnan and Zhejian Provinces), Japan (southern half), Laos, North and South Korea, Myanmar (extreme north), Russia (Primorskij Krai), Taiwan and Vietnam (extreme north).

3. *Amara* (*Amara*) *silvestrii* Baliani, 1937

http://species-id.net/wiki/Amara_silvestrii
Figs 5b–c, 5e, 6b, 7a–b, 11, 23a, 27–30

Amara (*Amara*) *silvestrii* Baliani, 1937: 179. Type material: Holotype male in MCSNG. Type locality: China, Yunnan "Yunnan-fu".

Diagnosis. Adults of this species (Fig. 11) can be distinguished from those of all other species in the region by the following combination of character states: body length 9–10 mm; base of pronotum slightly flattened at the sides, only the middle part evenly convex, coarsely punctuate, outer basal impressions shallow and obliquely linear (Fig. 11a); elytra with parascutellar pore puncture present; medial protibial spurs simple; tarsomere 5 of hind tarsi with two or (in a few specimens) three pairs of setae ventrally (Fig. 6b); last abdominal sternite of male with one pair (Fig.5e) and female with two pairs (Fig.5c) of setiferous punctures near hind margin; male aedeagus with median lobe distinctly broader in apical one-third than more basally, apical lamella shorter, broadly rounded apically and with sides only slightly convergent subapically (Fig. 11c), sclerites of internal sac with form as in Fig. 7a–b.

Habitat distribution. Specimens of this species were collected in daytime from under stones and other cover in open roadside areas (Fig. 23a) and meadows with scattered grasses and shrubs, at the edges of agricultural fields, including wet and dry rice paddies, under clods of soil in recently tilled fields and on open banks of streams, and in these same habitats at night, when beetles were found active on bare substrate. They were also collected under debris and in leaf litter in deciduous forests and also in crevices between stones in a talus slope. Members of this species were found at elevations ranging from 1515 to 3000 m, syntopic with adults of *A. birmana*, *A. chalciope*, *A. davidi*, *A. lucidissima*, *A. shaanxiensis*, and *A. sikkimensis* at one or more sites.

Geographical distribution within the Gaoligong Shan. Fig. 11d. We examined a total of 34 specimens (18 males and 16 females) from the following localities: ***Fugong County:*** Lishadi Township (Shibali area, 27.16536°/98.78003° , 2535 m, D.H. Kavanaugh, P. Paquin & D.Z. Dong collectors [1 female; CAS]), (0.5 km W of Shibali, 27.16665°/98.77936°, 2537 m, 18 August 2005, P. Paquin collector [1 male and 1 female; CAS]), (below Shibali on Yaping Road, 27.16520° /98.77980° , 2530 m, 24 April 2004m, H.B. Liang & X.Y. Li collectors [1 male; IOZ]), (7.5 km below Shibali on Yaping Road, 27.14627°/98.81559°, 2030 m, 3 May 2004, H.B. Liang & M. Xi collectors [1 female; IOZ]); Lumadeng Township (0.5 km W of Lao Shibali on Lao Shibali Road,

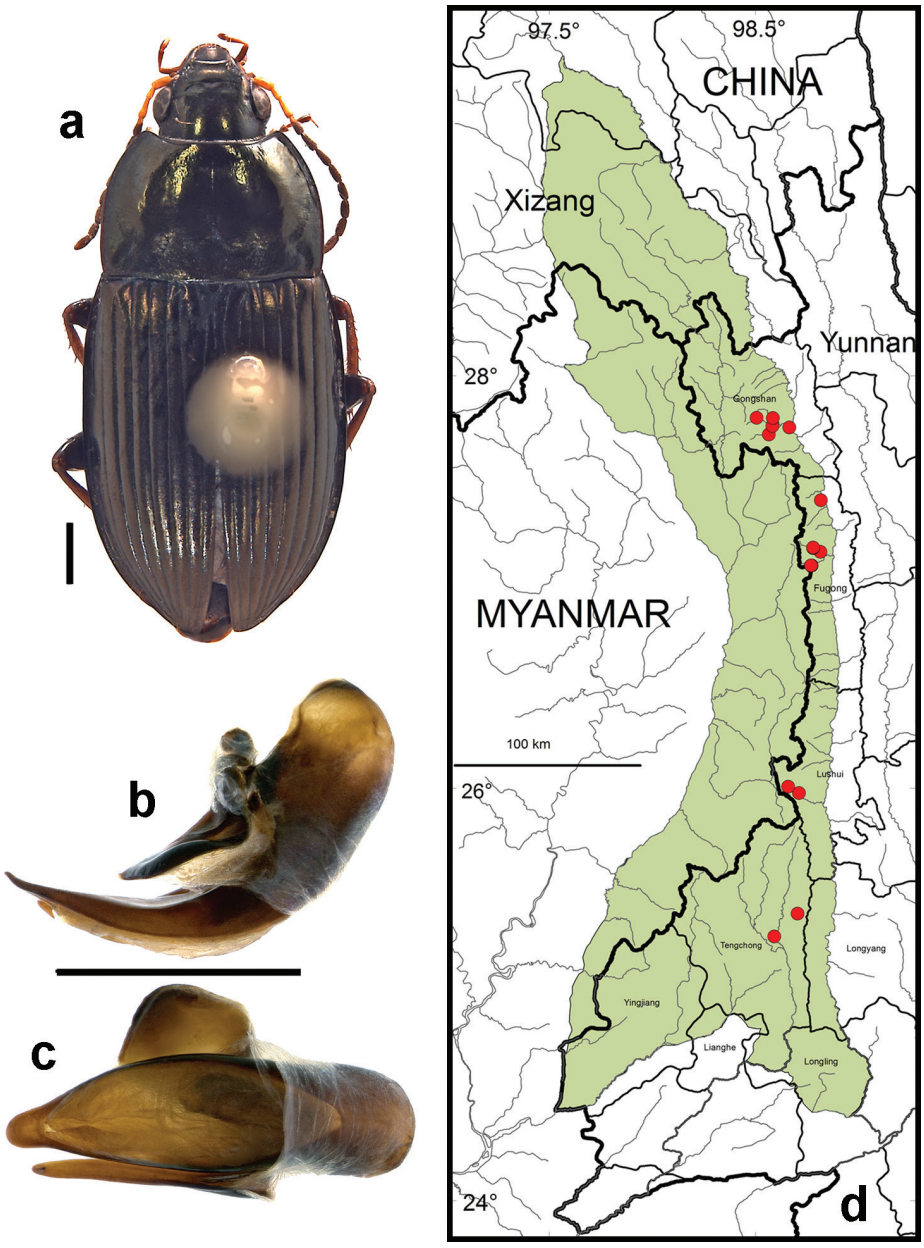


Figure 11. *Amara* (*Amara*) *silvestrii* Baliani. **a** dorsal habitus (CASENT1035225) **b–c** median lobe of aedeagus of male (CASENT1035225) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A. silvestrii* in the Gaoligong Shan region, scale line = 100 km.

27.08072°/98.76920°, 2305 m, 22 August 2008, P. Paquin collector [1 male; CAS]), (South Fork of Yamu He at Yejiadi, 27.08994°/98.77325°, 2307 m, 10 May 2004, H.B. Liang collector [2 males and 1 female; CAS, IOZ); Maji Township (Majimi village near

power station on Gaxie He, 27.39630°/98.81701°, 1567 m, 28 April, 2004, H.B. Liang collector [1 male; IOZ]). ***Gongshan County:*** Cikai (27.74972°/98.66444°, 1515 m, 5 October 2002, H.B. Liang & W.D. Ba [1 female; IOZ]); Dabadi (41 km W of Cikai on Dulong Valley Road, 27.79655°/98.50562°, 3000 m, 27 September to 6 October 2002, D.H. Kavanaugh, P.E. Marek, H.B. Liang & D.Z. Dong collectors [5 males and 6 females; CAS, IOZ, ZMHB]); Heiwadi (16.8 km W of Cikai on Dulong Valley Road, 27.79584°/98.58443°, 2020 m, 15 and 20 April 2002, H.B. Liang, W.D. Ba & C.G. Jin collectors [2 males and 1 female; IOZ, ZMHB]); Qiqi area (27.71542°/98.56529°, 2000-2020 m, 9-14 July 2000, D.H. Kavanaugh & H.B. Liang collectors [1 female; CAS]); Cikai Township (8.3 to 13.1 km NW of Cikai on Dulong Valley Road, 27.75653°/98.58214°, 2620-3000 m, 23 September 2002, D.H. Kavanaugh, P.E. Marek & D.Z. Dong collectors [1 female; CAS]). ***Lushui County:*** Luzhang Township (Yaojiaping He at Pianma Road, 25.97722°/98.71091°, 2527 m, 20 May 2005, D.H. Kavanaugh, C.E. Griwold, H.B. Liang, D.Z. Dong & G. Tang collectors [1 male; CAS]); Pianma Township (6 km ESE of Pianma, 26.00808°/98.65921°, 2210 m, 15 May 2005, H.B. Liang & D.Z. Dong collectors [2 males and 2 females; CAS, IOZ]). ***Tengchong County:*** Jietou Township (Cha He at Shaba village, 25.39256°/98.70488°, 1840 m, 25 May 2006, D.H. Kavanaugh, R.L. Brett & D.Z. Dong collectors [1 male; CAS]); Qushi Township (Longchuan Jiang at Longkou village, 25.28167°/98.59167°, 1500 m, D.H. Kavanaugh & C.E. Griswold collectors [1 male; CAS]).

Members of this species were collected from the northern to the southern parts of the study area (Core Areas 2, 3, 5 and 6), but they were found only on the eastern side of the mountain range in northern half of the study area (Core Areas 2 and 3), on both side in the central part (Core Areas 3 and 4) and only on the western versant in the southern part (Core Area 6). This distribution pattern is most likely an artifact of inadequate sampling on the western slope of the mountain range in the north, some of which is in Myanmar.

Overall geographical distribution. Fig. 27. This species has been recorded from China (Gansu, Hubei, Shaanxi, Sichuan and Yunnan Provinces), Myanmar (extreme north) and Taiwan. Its occurrence in the study area represents the southwestern limit of its known geographical range.

4. *Amara* (*Amara*) *shaanxiensis* Hieke, 2002

http://species-id.net/wiki/Amara_shaanxiensis
Figs 5b–c, 5e, 6b, 7c–d, 12, 22a, 25b, 27–30

Amara (*Amara*) *shaanxiensis* Hieke, 2002: 663. Type material: Holotype male and 1 paratype in CWRA, 2 male and 2 female paratypes in ZMHB. Type locality: China, Shaanxi, Zhouzi Xian, Pass between Banfangzi and Xingian, 2000 m.

Diagnosis. Adults of this species (Fig. 12) can be distinguished from those of all other species in the region by the following combination of character states: body length

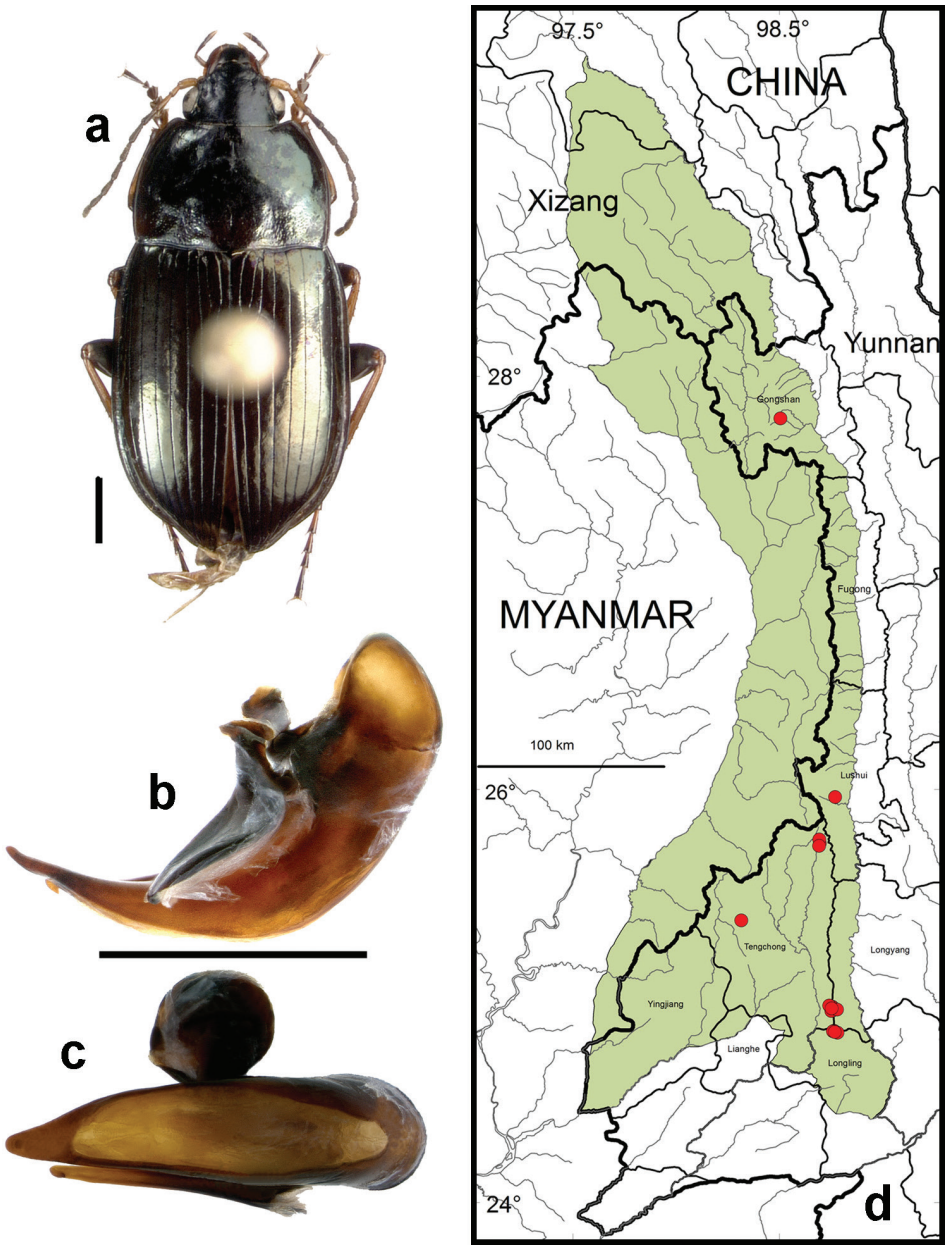


Figure 12. *Amara* (*Amara*) *shaanxiensis* Hieke. **a** dorsal habitus (CASENT1013215) **b–c** median lobe of aedeagus of male (CASENT1024088) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A. shaanxiensis* in the Gaoligong Shan region, scale line = 100 km.

8.5–10 mm; base of pronotum slightly flattened at the sides, only the middle part evenly convex, finely punctate; outer basal impressions deep and broadly foveate (Fig. 12a); elytra with parascutellar pore puncture present; medial protibial spurs simple;

tarsomere 5 of hind tarsi with two or (in a few specimens) three pairs of setae ventrally (Fig. 6b); last abdominal sternite of male with one pair (Fig.5e) and female with two pairs (Fig.5c) of setiferous punctures near hind margin; male aedeagus with median lobe not or only slightly broader in apical one-third than more basally, apical lamella longer, narrowly rounded apically and with sides more distinctly convergent apically (Fig. 12c), sclerites of internal sac with form as in Fig. 7c-d.

Habitat distribution. Specimens of this species were collected in daytime from under stones and other cover in open roadside areas (Figs 22a, 25b), meadows and marshy areas with scattered grasses and shrubs, at the edges of agricultural fields, including wet and dry rice paddies and on open banks of streams, and in these same habitats at night, when beetles were found active on bare substrate. They were also collected under debris in daytime and on the surface of leaf litter at night in deciduous forests. Members of this species were found at elevations ranging from 1837 to 3000 m, syntopic with adults of *A. birmana*, *A. chalciope*, *A. davidi*, *A. lucidissima*, *A. pingxiangi*, *A. sikkimensis* and *A. silvestrii* at one or more sites.

Geographical distribution within the Gaoligong Shan. Fig. 12d. We examined a total of 88 specimens (36 males and 52 females) from the following localities: ***Gongshan County:*** Dabadi (41 km W of Cikai on Dulong Valley Road, 27.79655°/98.50562°, 3000 m, D.H. Kavanaugh, P.E. Marek, H.B. Liang, D.Z. Dong & X.C. Liang collector [1 male and 4 females; CAS, IOZ]). ***Longling County:*** Xiaheishan Forest Reserve (Guchengshan at 1.2 km SSE of Km 23.5 on Route 23.5, 24.82888°/98.76001°, 2020 m, 25-26 May 2005, D.H. Kavanaugh, C.E. Griswold, H.B.Liang and D.Z. Dong collectors [4 males and 4 female; CAS]). ***Longyang County:*** Bawan-Tengchong Road (Km 29-35, 24.92916°/98.75861°, 2000-2350 m, 12 October 2003, D.Z. Dong collector [1 female; IOZ]), (Km 36-37, 24.93417°/98.77944°, 2150 m, H.B. Liang & X.C. Shi collectors [2 males and 1 female; IOZ, ZMHB]), (Km 40–41, 24.92694°/98.75278°, 2404 m, 12 October 2003, H.B. Liang & X.C. Shi collectors [1 female; IOZ]), (Km 41 near yakou, 24.93972° /98.75333°, 2440 m, 15 October 2003, H.B. Liang & J.J. Yang collectors [1; female; IOZ]), (Km 42 at Sanchawa, 24.94750°/98.75556°, 2300 m, 13 October 2003, H.B. Liang & X.C. Shi collectors [1 male; CAS]; Luoshuidong area (at Sancha He, 24.94833°/98.75667°, 2300 m, 30 May 2005, D.H. Kavanaugh & H.M. Yan collectors [1 female; CAS]; 3 June 2005, D.H. Kavanaugh, C.E. Griswold, H.B. Liang, D.Z. Dong & H.M Yan collectors [1 male; CAS]); Nankang Forestry Station (at Km 19.8 on Route S317, 24.82284°/98.78207°, 2060 m, 23 May 2005, D.H. Kavanaugh, C.E. Griswold, H.B. Liang, D.Z. Dong, H.M. Yang & G. Tang collectors [3 males and 7 females; CAS, IOZ, ZMHB]; Nakang Yakou (24.82587° /98.76832° , 2148 m, 22 May 2005, H.B. Liang collector [(just N of yakou, 24.83178°/98.76472°, 2180 m, 22 May 2005, D.H. Kavanaugh, C.E. Griswold & D.Z. Dong collectors [2 males and 2 females; CAS, IOZ]; 25 May 2005, D.H. Kavanaugh & C.E. Griswold [1 female; CAS]). ***Lushui County:*** Luzhang Township (Lusai He, 25.96378°/98.77032°, 1873 m, 20 May 2005, H.B. Liang & D.Z. Dong collectors [5 males; CAS, IOZ]). ***Tengchong County:*** Houqiao Township (5.9 airkm NE of Houqiao below Guyong Forestry Station, 25.36562°/98.31610°, 2030 m, 27

May 2006, D.H. Kavanaugh, R.L. Brett, H.B. Long, D.Z. Dong & Z.C. Liu collectors [1 male and 3 females; CAS, IOZ]); Jietou Township (2.0 km N of Dahetou Ligganjiao on Longtang He, 25.75743°/98.69457°, 2080 m, 16 May 2006, D.Z. Dong collector [1 male; CAS]), (1.4 km S of Dahetou Ligganjiao along Longchuan Jiang, 25.72717°/98.69322°, 1960 m, 16 May 2006, H.B. Liang collector [2 males and 3 females; CAS, IOZ]), (Longtang He at Dahetou Lingganjiao, 25.73947°/98.69630°, 2010 m, 14-20 May 2006, D.H. Kavanaugh, R.L. Brett, H.B. Liang & P. Hu collectors [8 males and 15 female; CAS, IOZ]); Shangying Township (Bawan-Tenchong Road Km 42-46, 24.95361°/98.74222°, 2290 m, 14 and 17 October 2003, H.B. Liang & X.C. Shi collectors [4 males and 2 females; CAS, IOZ]).

Members of this species were collected in both the northern and southern parts of the study area (Core Areas 2, 5, 6 and 7), but not in the central part (Core Area 3). This gap in distribution is most likely an artifact of inadequate sampling and not a real disjunction.

Overall geographical distribution. Fig. 27. This species has been recorded from Shaanxi and Yunnan Provinces in China, and its occurrence in the study area represents the southwestern limit of its known geographical range.

5. *Amara* (*Pseudoamara*) *birmana* Baliani, 1934

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

Figs 5b–c, 5e, 6b, 13, 22a, 23a, 25a, 25b, 27–30

Amara (*Amara*) *birmana* Baliani, 1934a: 189. Type material: Holotype female in BMNH, 1 paratype female in MCSNG. Type locality: Burma [without specific locality, but probably from the mountains of northern Myanmar near the border with Yunnan Province, China]. Transferred to subgenus *Pseudoamara* Baliani by Hieke (2002: 624).

Amara (*Celia*) *yunnana* Baliani, 1934a: 193. Type material: Holotype male and 6 paratypes in BMNH. Type locality: China, Yunnan, Yunnan-fou. Synonymized by Hieke (1975: 333).

Amara (*Pseudoamara*) *beesoni* Baliani, 1934a: 190. Type material: Holotype male and allotype in BMNH, 4 paratypes in BMNH and MCSNG. Type locality: India, Assam, Shillong. Synonymized by Hieke (1975: 285).

Diagnosis. Adults of this species (Fig. 13) can be distinguished from those of all other species in the region by the following combination of character states: body length 6.5-7.5 mm; dorsal surface with distinct metallic copper or bronze reflection, non-metallic black in very few specimens, at least femora and outer antennomeres dark (piceous to black); elytral microsculpture comprised of distinctly isodiametric meshes in both males and females (more deeply impressed in females than in males); pronotum (Fig. 13a) more distinctly narrowed anteriorly than basally, anterior margin clearly narrower than posterior margin, lateral margins more or less evenly rounded from apical to basal

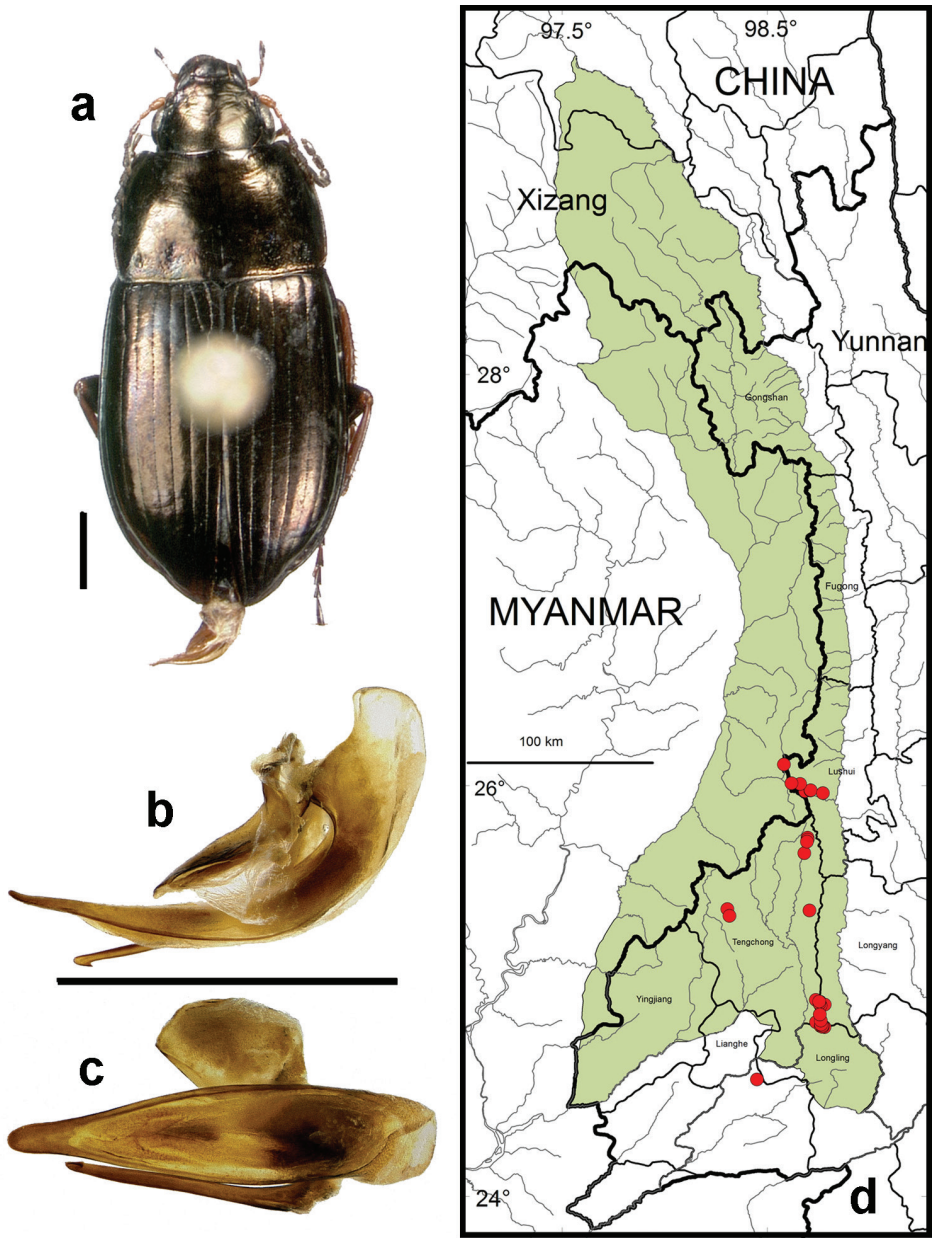


Figure 13. *Amara* (*Pseudoamara*) *birmana* Baliani. **a** dorsal habitus (CASENT1011859) **b–c** median lobe of aedeagus of male (CASENT1039066) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A. birmana* in the Gaoligong Shan region, scale line = 100 km.

angle, anterior angles not or only faintly and broadly projected anteriorly beyond anterior margin, posterior angles narrowly rounded, basal impressions deeply foveate but small in diameter, outer basal impressions not distinctly delimited laterally by a broad

convexity; elytra without evident sub-basal depressions, parascutellar pore puncture absent, elytral striae distinct throughout but only shallowly impressed in most individuals; medial protibial spurs simple; metatibiae of males without a brush-like patch of setae medially in the apical half; tarsomere 5 of hind tarsi with two or (in a few specimens) three pairs of setae ventrally (Fig. 6b); last abdominal sternite of male with one pair (Fig.5e) and female with two pairs (Fig.5c) of setiferous punctures near hind margin; male aedeagus with apical third of median lobe about as broad as middle third, apical hook of right paramere smaller and closer to apex (Fig. 8a).

Habitat distribution. Specimens of this species were collected, often in great abundance, in daytime from under stones and other cover in open roadside areas (Figs 22a, 25a) and waste areas around human settlements (Figs 23a, 25b) with scattered grasses and shrubs, at the edges of agricultural fields and on open banks of streams, and in these same habitats at night, when beetles were found active on bare substrate. They were also collected under rotting logs on a deciduous forest floor. Members of this species were found at elevations ranging from 1590 to 3150 m, syntopic with adults of *A. chalciope*, *A. davidi*, *A. dissimilis*, *A. lucidissima*, *A. pingxiangi*, *A. shaanxiensis*, *A. sikkimensis* and *A. silvestrii* at one or more sites.

Geographical distribution within the Gaoligong Shan. Fig. 13d. We examined a total of 244 specimens (126 males and 118 females) from the following localities: ***Longling County:*** Longjiang Township (small stream along road at 1.2 km SSE of Km 23.5 on Route 23.5, 24.82888°/98.76001°, 2020 m, 25–27 May 2005, D.H. Kavanaugh, C.E. Griswold, H.B. Liang & D.Z. Dong collectors [4 males and 5 females; CAS, IOZ]), (Xiaoheishan Forest Station, 24.83671°/98.76185°, 2067 m, 28 May 2005, H.B. Liang, K.J. Guo & H.M. Yan collectors [2 females; CAS, IOZ]). ***Longyang County:*** Bawan Township (mountain near Nankang Yakou, 24.83250°/98.76944°, 2245 m, 27 October 2003, H.B. Liang & X.C. Shi collectors [3 males and 5 females; CAS, IOZ]), (Km 24 on Baoshan-Tengchong Highway near Nankang Yakou, 24.82583°/98.77222°, 2130 m, 26 October 2003, H.B. Liang & X.C. Shi collectors [6 males and 5 females; CAS, IOZ]), (Km 36–37 on Bawan-Tenchong Road, 24.93417°/98.77944°, 2150 m, 12 October 2003, H.B. Liang & X.C. Shi collectors [1 female; IOZ]), (Km 40 on Bawan-Tenchong Road at Dasheyao Plant Protection Station, 24.92944°/98.75861°, 2320 m, 16 October 2003, H.B. Liang & J.J Yang collectors [1 female; IOZ], 3 June 2005, D.H. Kavanaugh, D.Z. Dong & J.J. Yang collectors [1 male and 1 female; CAS, IOZ]), 90 km W of Baoshan, 26–28 May 1995, S. Bečvar collector [1 female; ZMHB]), (Luoshuidong area at Sancha He, 24.94833°/98.75667°, 2300 m, 26–31 October 1998, D.H. Kavanaugh & C.E. Griswold collectors [6 males and 4 females; CAS, IOZ, ZMHB], 3 June 2005, D.H. Kavanaugh, C.E. Griswold, H.B. Liang, D.Z. Dong & H.M. Yan collectors [1 female; CAS], 24.94865 0176/98.75193°, 2350 m, 30 May 2005, H.B. Liang & J.J. Yang collectors [3 males and 1 female; CAS, IOZ]), (Nankang Forest Station (24.82444°/98.77889°, 2085 m, 27 October 2003, H.B. Liang & X.C. Shi collectors [9 males and 12 females; CAS, IOZ]), (Nankang Yakou (24.83167°/98.76667°, 2130 m, 4–7 November1998, D. H. Kavanaugh collector [25

males and 20 females; CAS, IOZ, ZMHB], 24.82587°/98.76832°, 2148 m, 22 May 2005, H.B. Liang collector [1 male and 1 female; CAS, IOZ], 24.83124°/98.76843°, 2210 m, 23 May 2005, H.B. Liang collector [2 females; CAS, IOZ]), (just N of Nankang Yakou, 24.83178°/98.76472°, 2180 m, 22 and 26 May 2005, H.B. Liang & D.Z. Dong collectors [5 males and 4 females; CAS, IOZ]). ***Lushui County:*** Luzhang Township (Km 44.7 on Pianma Road at Yaojiaping, 25.97538°/98.71006°, 2516 m, 11 May 2005, D.H. Kavanaugh, H.B. Liang, D.Z. Dong & G. Tang collectors [1 female; CAS]), (Fengxue Yakou at Pianma Road, 25.97228°/98.68336°, 3150 m, D.H. Kavanaugh, P.E. Marek & H.B. Liang collectors [1 female; CAS]), (Lusai He, 25.96378°/98.77032°, 1873 m, 20 May 2005, H.B. Liang & D.Z. Dong collectors [3 amles and 1 female; CAS, IOZ]), (Yaojiaping He at Pianma Road, 25.97722°/98.71091°, 2527 m, 20 May 2005, D.H. Kavanaugh, C.E. Griswold, H.B. Liang, D.Z. Dong & G. Tang collectors [1 female; IOZ]); Pianma Township (6 km ESE of Pianma, 26.00808°/98.65921°, 2310 m, 15 May 2005, H.B. Liang & D.Z. Dong collectors [5 males and 6 females; CAS, IOZ]), (20 km N of Pianma along Gangfang He at Gulang Village, 26.10321°/98.58094°, 1590 m, 14 May 2005, H.B. Liang collector [1 female; IOZ]), (Xia Pianma Village, 26.01137°/98.61788°, 1850 m, 13 May 2005, H.B. Liang collector [1 male; IOZ]). ***Tengchong County:*** Houqiao Township (5.9 airkm NE of Houqiao below Guyong Forestry Station, 25.3562°/98.31610°, 2030 m, 27 May 2006, D.H. Kavanaugh, R.L. Brett & D.Z. Dong collectors [1 female; IOZ]), (8.5 airkm NNE of Houqiao at Gaoshidong, 25.39858°/98.30533°, 2580 m, 27 May 2006, D.H. Kavanaugh, R.L. Brett & D.Z. Dong collectors [1 male and 1 female; CAS, IOZ]); Jietou Township (Dahetou Lingganjiao, Longtang He, 25.73947°/98.69630°, 2010 m, 14–16 and 18 May 2006, D.H. Kavanaugh, R.L. Brett & H.B. Liang collectors [16 males and 11 female; CAS, IOZ], 0.3 km S in Longchuan Jiang valley, 25.73678°/98.69639°, 2005 m, 18 May 2006, D.Z. Dong collector [4 males and 5 females; CAS, IOZ], 1.4 km S along Longchuan Jiang, 25.72717°/98.69322°, 1960 m, 19 May 2006, D.H. Kavanaugh, R.L. Brett & D.Z. Dong collectors [2 females; CAS, IOZ], 0.75 km N on Longtang He, 25.74622°/98.69612°, 2030 m, 18 May 2006, D.H. Kavanaugh & R.L. Brett collectors [1 female; CAS]), (Longchuan Jiang from Dahetou Village to Dahetou Lingganjiao, 25.67125°/98.68016°, 1838–2010 m, 14 May 2006, H.B. Liang collector [2 males and 1 female; CAS, IOZ]), (Shaba Village, Cha He, 25.39256°/98.70488°, 1840 m, 25 May 2006, D.H. Kavanaugh, R.L. Brett & D.Z. Dong collectors [1 male and 1 female; CAS]); Shangying Township (Km 41 on Bawan-Tenchong Road near Yakou, 24.93972°/98.75333°, 2440 m, 15 October 2003, H.B. Liang, X.C. Shi & D.Z. Dong collectors [2 males and 1 female; CAS, IOZ]), (Km 42–46 on Bawan-Tenchong Road, 24.95361°/98.74222°, 2290 m, 14 and 17 October 2003, H.B. Liang & X.C. Shi collectors [7 males and 2 female; CAS, IOZ]), (Km 46–51 on Bawan-Tenchong Road, 24.95722°/98.73667°, 2220 m, 17 October 2003, H.B. Liang & X.C. Shi collectors [1 male; IOZ]); Wuhe Township (Km 24 on Baoshan-Tengchong Highway, 24.82889°/98.76028°, 2008 m, 29 October 2003, N.D. Penny, T. Briggs & X.Y. Li collectors [6 males; CAS, IOZ]), (Km 28.8 on Route S317 at Zheng-

ding Forestry Station, 24.84855°/98.73761°, 1834 m, 23 May 2005, D.Z. Dong & H.M. Yan collectors [1 male and 2 females; CAS, IOZ]), (31 km SE of Tengchong, 24.88639°/98.75611°, 26 August 2009, D.W. Wrase collector [1 male and 2 females; ZMBH]), (33 km SE of Tengchong, 24.85611°/98.76000°, 2100–2200 m, 31 May and 4 June 2007, A. Pütz collector [2 males and 1 female; ZMHB], 31 May 2007, D.W. Wrase collector [1 male; ZMHB]), (100 km W of Baoshan, 14–21 June 1993, E. Jendek & O. Sausa collectors [1 male; ZMHB]), (Xiaodifang Village, 24.85722°/98.75917°, 2150 m, 29 October 2003, D.Z. Dong collector [3 males and 1 female; CAS, IOZ]), (Xiaoheishan Forest Station, 24.82889°/98.76000°, 2025 m, 29 October 2003, H.B. Liang collector [6 males and 7 females; CAS, IOZ]).

Members of this species were collected only in the southern half of the study area (Core Areas 4, 5, 6 and 7), on both eastern and western slopes of the mountain range.

Overall geographical distribution. Fig. 27. This species has been recorded from China (Sichuan and Yunnan Provinces), India (Assam, Arunashal Pradesh and Sikkim) and Myanmar. Its occurrence in the study area represents the southern limit of its known geographical range.

6. *Amara* (*Xenocelia*) *sikkimensis* Andrewes, 1930

http://species-id.net/wiki/Amara_sikkimensis
Figs 5b–d, 6b, 14, 23a, 23b, 27–30

Amara (*Leiocnemis*) *sikkimensis* Andrewes, 1930: 24. Type material: Holotype male and 7 paratypes in BMNH. Type locality: China, Xizang Autonomous Region (southern Tibet), Rongshar Valley. Transferred to subgenus *Xenocelia* by Hieke (2001: 106).

Amara (*Bradytus*) *coelestis* Baliani, 1932: 16. Type material: 26 syntypes in BMNH, MCSNG and ZMHB, lectotype not yet designated. Type locality: China, Sichuan, Kangding ("Tatsienlu-Chiulung"). Transferred to subgenus *Celia* by Baliani (1937: 176); synonymized by Hieke (1975: 292).

Amara (*Celia*) *expolita* Baliani, 1934a:191. Type material: Holotype male in BMNH, allotype in ZSIC, and 8 paratypes in BMNH, MCSNG and ZMHB, 18 more "syntypes" not yet accounted for. Type locality: India, "Punyab: Simla Hills, Baghi". Synonymized by Hieke (1975: 299).

Diagnosis. Adults of this species (Fig. 14) can be distinguished from those of all other species in the region by the following combination of character states: body length 7-8 mm; dorsal surface dark piceous; pronotum with both inner and outer basal impressions deeply impressed; elytra with parascutellar pore puncture absent; medial protibial spurs simple; tarsomere 5 of hind tarsi with two or (in a few specimens) three pairs of setae ventrally (Fig. 6b); last abdominal sternite of both male (Fig.5d) and female (Fig.5c) with two pairs of setiferous punctures near hind margin (second seta absent from one side in a few males for total of three setae).

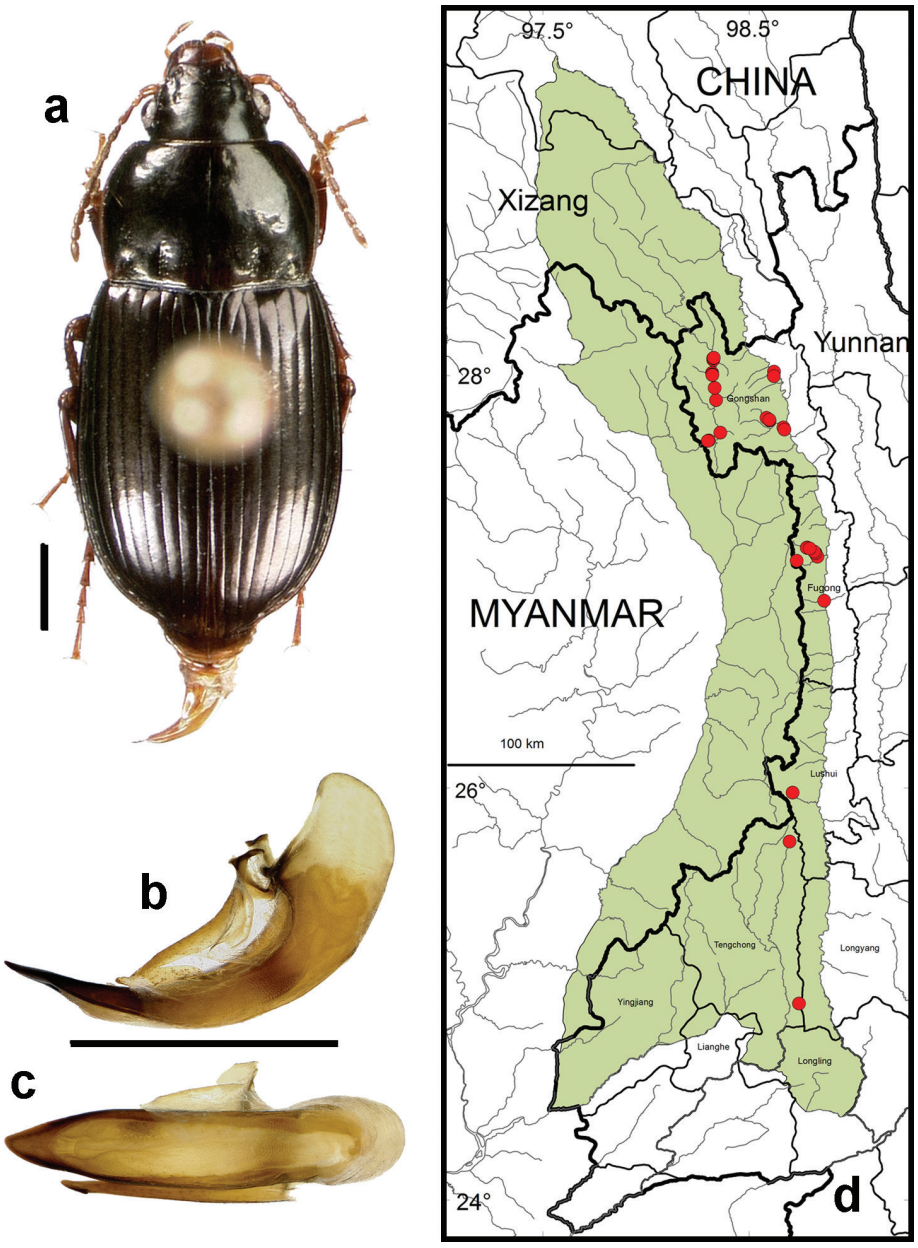


Figure 14. *Amara* (*Xenocelia*) *sikkimensis* Andrewes. **a** dorsal habitus (CASENT1015288) **b–c** median lobe of aedeagus of male (CASENT1025342) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A. sikkimensis* in the Gaoligong Shan region, scale line = 100 km.

Habitat distribution. Specimens of this species were collected in daytime from under stones and other cover in open roadside areas (Fig. 23b) and other waste areas around human settlements (Fig. 23a) with scattered grasses and shrubs, at the edges

of agricultural fields, and on open rocky, graveled and sandy banks of streams, and in these same habitats at night, when beetles were found active on bare substrate. They were especially conspicuous on open sandy beaches at night. Members of this species were found at elevations ranging from 1175 to 2800 m, syntopic with adults of *A. birmana*, *A. chalciope*, *A. davidi*, *A. dissimilis*, *A. latithorax*, *A. lucidissima*, *A. shaanxiensis* and *A. silvestrii* at one or more sites.

Geographical distribution within the Gaoligong Shan. Fig. 14d. We examined a total of 164 specimens (92 males and 72 females) from the following localities: ***Fugong County:*** Lishadi Township (Shibali area, 27.16536°/98.78003°, 2535 m, 6 October 2007, H.L. Shi collector [1 female; IOZ]), (0 to 2 km E of Shibali on Shibali Road, 27.16100°/98.79370°, 2300–2350 m, 18 August 2005, D.Z. Dong collector [1 male and 1 female; IOZ]), (0.1 km below Shibali on Shibali Road, 27.16577°/98.78091°, 2545 m, 5 May 2004, D.H. Kavanaugh & C.E. Griswold collectors [1 male; CAS]), (0.3 km SE of Shibali on North Fork Yamu He, 27.16337°/98.78208°, 2475 m, 7 May 2004, D.H. Kavanaugh & C.E. Griswold collectors [1 male and 1 female; CAS]), (1.5 km below Shibali on Yaping Road, 27.16284°/98.78989°, 2420 m, 2 May 2004, H.B. Liang & G.X. Peng collectors [1 male and 1 female; CAS, IOZ]), (Shilajia Village at Shibali Road, 27.13947°/98.82184°, 1800–1900 m, 24–25 April 2004, D.H. Kavanaugh & C.E. Griswold collectors [2 females; CAS, IOZ]), (11 km above Nu Jiang on Yaping Road at Shimowa Village, 27.13839°/98.82147°, 1850–1928 m, 25 April 2004, H.B. Liang collector [4 males and 5 females; CAS, IOZ]); Lumadeng Township (7.0 km SW of Lao Shibali on Lao Shibali Road at tributary of South Fork Yamu He, 27.10220°/98.73107°, 2800 m, 13 August 2005, D.H. Kavanaugh & P. Paquin collectors [1 male; CAS]), (7.5 km below Shibali on Yaping Road, 27.14627°/98.81559°, 2030 m, 3 May 2004, H.B. Liang & M. Xie collectors [2 males and 2 female; CAS, IOZ]), (South Fork Yamu He above Shilajia Village, 27.12101°/98.83173°, 1630–1790 m, 26 April 2004, D.H. Kavanaugh collector [1 female; CAS]), (Yaping Road below Shibali, 27.16520°/98.77980°, 2530 m, 24 April 2004, H.B. Liang & X.Y. Li collectors [1 male; IOZ]); Shangpa Township (Nu Jiang at west end of footbridge in Shangpa, 26.90743°/98.86391°, 1175–1180 m, 20 April 2004, H.B. Liang collector [1 female; IOZ]). ***Gongshan County:*** Bingzhongluo Township (Bingzhongluo Village, 28.01940°/98.62106°, 1760 m, 21 April 2002, H.B. Liang & W.D. Ba collectors [2 males and 1 female; IOZ, ZMHB]), (Gongdangshenshan, 27.99725°/98.62003°, 2489 m, 12 November 2004, H.B. Liang collector [1 male; CAS]); Cikai Township (Heiwadi, 16.8 km W of Cikai on Dulong Valley Road, 27.79584°/98.58443°, 2020 m, 20 April 2002, H.B. Liang & W.D. Ba collectors [2 males; IOZ]), (Heiwadi Village, 27.79584°/98.58443°, 1965 m, 14 November 2004, H.B. Liang, D.Z. Dong & G. Tang collectors [26 males and 14 females; CAS, IOZ]), (North Fork Pula He above Heiwaidi Village, 27.78644°/98.59831°, 1890 m, 15 November 2004, D.H. Kavanaugh & V.F. Lee collectors [3 males; CAS, IOZ]), (Nu Jiang in Cikai at Dashaba, 27.73845°/98.67092°, 1430 m, 11 November 2003, D.H. Kavanaugh,

H.B. Liang, D.Z. Dong & G. Tang collectors [1 female; CAS]), (Pula He just above Nu Jiang Road, 27.74861°/98.66675°, 1440 m, 11 November 2004, D.H. Kavanaugh, H.B. Liang, D.Z. Dong & G. Tang collectors [1 female; CAS]); Dulongjiang Township (Bapo, Miliwang, 27.72383°/98.36117°, 1956 m, 31 October 2004, H.B. Liang collector [21 males and 8 females; CAS, IOZ, ZMHB]), (0.6 km N of Dizhengdang Village on Dulong Jiang, 28.08442°/98.32652°, 1880 m, 29–30 October 2004, D.H. Kavanaugh, D.Z. Dong & G. Tang collectors [4 males and 5 females; CAS, IOZ]), (S of Dizhengdang Village at Silalong He, 28.07654°/98.32603°, 1890 m, 30 October 2004, D.H. Kavanaugh, D.Z. Dong & G. Tang collectors [2 males and 3 females; CAS, IOZ]), (Dizheng Wang, 28.08686°/98.32840°, 1900–1970 m, 30 October 2004, D.H. Kavanaugh & D.Z. Dong collectors [1 female; CAS]), (Dulong Jiang at Elideng Village, 28.00287°/98.32145°, 1640 m, 3 November 2004, D.H. Kavanaugh, H.B. Liang, D.Z. Dong & G. Tang collectors [1 male and 2 females; CAS, IOZ]), (Dulong Jiang at Xiajiudang Village, 27.94092°/98.33340°, 1580 m, 4 November 2004, D.H. Kavanaugh, D.Z. Dong & G. Tang collectors [2 females; CAS, IOZ]), (0.5 km N of Kongdang, 27.88111°/98.34063°, 1500 m, 25 October 2004, D.H. Kavanaugh, H.B. Liang, D.Z. Dong & G. Tang collectors [1 female; CAS], 5 November 2004, H.B. Liang collector [1 female; IOZ]), (2.3–3.3 airkm S of Longyuan Village on Dulong Jiang, 28.00532°/98.32145°, 1685–1720 m, 2 November 2004, D.H. Kavanaugh, D.Z. Dong & G. Tang collectors [2 males and 1 female; CAS, IOZ]), (Maku, 27.68553°/98.30425°, 1823 m, 2 November 2004, H.B. Liang collector [14 males and 13 females; CAS, IOZ]), (Siran Wang, 0.2 km above confluence with Dulong Jiang, 28.01347°/98.32117°, 1720 m, 2 November 2004, D.H. Kavanaugh & D.Z. Dong collectors [1 female; CAS]). ***Lushui County:*** Luzhang Township (Yaojiaping He at Pianma Road, 25.97722°/98.71091°, 2527 m, 20 May 2005, D.H. Kavanaugh, C.E. Griswold, H.B. liang, D.Z. Dong & G. Tang collectors [1 male; CAS]). ***Tengchong County:*** Jietou Township (Longtang He at Dahetou Lingganjiao, 25.73947°/98.69630°, 2010 m, 20 May 2005, H.B. Liang & P. Hu collectors [1 female; IOZ]); Shangying Township (Km 42–46 on Bawan-Tengchong Road, 24.95361°/98.74222°, 2290 m, 14 October 2003, H.B. Liang & X.C. Shi collectors [1 male; IOZ]).

Members of this species were collected from the northern to the southern parts of the study area (Core Areas 1, 2, 3, 5 and 6), but they were found only on the western side of the mountain range in the southern part (Core Area 6). This distribution pattern may be an artifact of inadequate sampling on the eastern slope of the mountain range in the south.

Overall geographical distribution. Fig. 27. This species has been recorded from Bhutan, China (Gansu, Sichuan and Yunnan Provinces and Xizang Autonomous Region), India (Assam, Himachal Pradesh, Kashmir and Jammu, Sikkim and Uttar Pradesh), Nepal and Pakistan (northern). Its occurrence in the study area represents the southern limit of its known geographical range.

7. *Amara* (*Harpaloamara*) *latithorax* Baliani, 1934
http://species-id.net/wiki/Amara_latithorax
Figs 5b–c, 5e, 6b, 15, 22b, 23b, 27–30

Amara (*Harpaloamara*) *latithorax* Baliani, 1934a: 198. Type material: Holotype male, allotype, and 1 additional paratype in BMNH, 1 paratype in MCSNG, and 3 paratypes in FRSDD. Type locality: India, United Provinces, Kumaon, West Almora and Chakrata, Mundali.

Amara (*Bradytus*) *interrupta* Landin, 1955: 417. Type material: Holotype female in NHRS. Type locality: Myanmar (Burma), Kambaiti, 7000 ft. Synonymized by Hieke (1997: 227).

Amara (*Bradytus*) *neglecta* Landin, 1955: 416. Type material: Holotype male in NHRS. Type locality: Myanmar (Burma), Kambaiti, 2000 m. Synonymized by Hieke (1997:227).

Diagnosis. Adults of this species can be distinguished from those of all other species in the region by the following combination of character states: body length 8.5-9.0 mm; dorsal surface black, with very faint metallic blue or green metallic reflection in most individuals, more vivid (as in Fig. 15a) in or lacking from a few specimens, at least femora and outer antennomeres dark (piceous to black); pronotum (Fig. 15a) only slightly narrowed anteriorly with anterior margin nearly straight and clearly narrower than posterior margin, without or with only very slightly projected anterior angles, posterior angles distinctly rounded (narrowly so in some individuals), slightly to moderately obtuse, pronotal base moderately coarsely punctate, outer basal impressions either not sharply delimited laterally by raised areas or, if so, then the raised area broader; elytra elytra with slight sub-basal depressions centered on striae 6 (visible on right elytron in Fig. 15a), also on striae 4 and/or 5 in some individuals, parascutellar pore puncture absent; medial protibial spurs simple; tarsomere 5 of hind tarsi with two or (in a few specimens) three pairs of setae ventrally (Fig. 6b); last abdominal sternite of male with one pair (Fig.5e) and female with two pairs (Fig.5c) of setiferous punctures near hind margin.

Habitat distribution. Specimens of this species were collected in daytime from under stones and other cover in open roadside areas (Figs 22b, 23b) and meadows with scattered grasses and shrubs, at the edges of agricultural fields, including wet and dry rice paddies and on open sandy banks of streams, and in these same habitats at night, when beetles were found active on bare substrate. Members of this species were found at elevations ranging from 1195 to 2022 m, syntopic with adults of *A. chalciope*, *A. congrua*, *A. dissimilis*, *A. lucidissima* and *A. sikkimensis* at one or more sites.

Geographical distribution within the Gaoligong Shan. Fig. 15d. We examined a total of 37 specimens (12 males and 25females) from the following localities: ***Fugong County:*** Aludi Village (Nu Jiang, 27.10834°/98.87218°, 1195-1250 m, 22 April 2004, D.H. Kavanaugh collector [1 female; CAS]); Lishadi Township (Shilajia Village at Shibali Road on North Fork Yamu He, 27.13947°/98.82184°, 1800–1900 m,

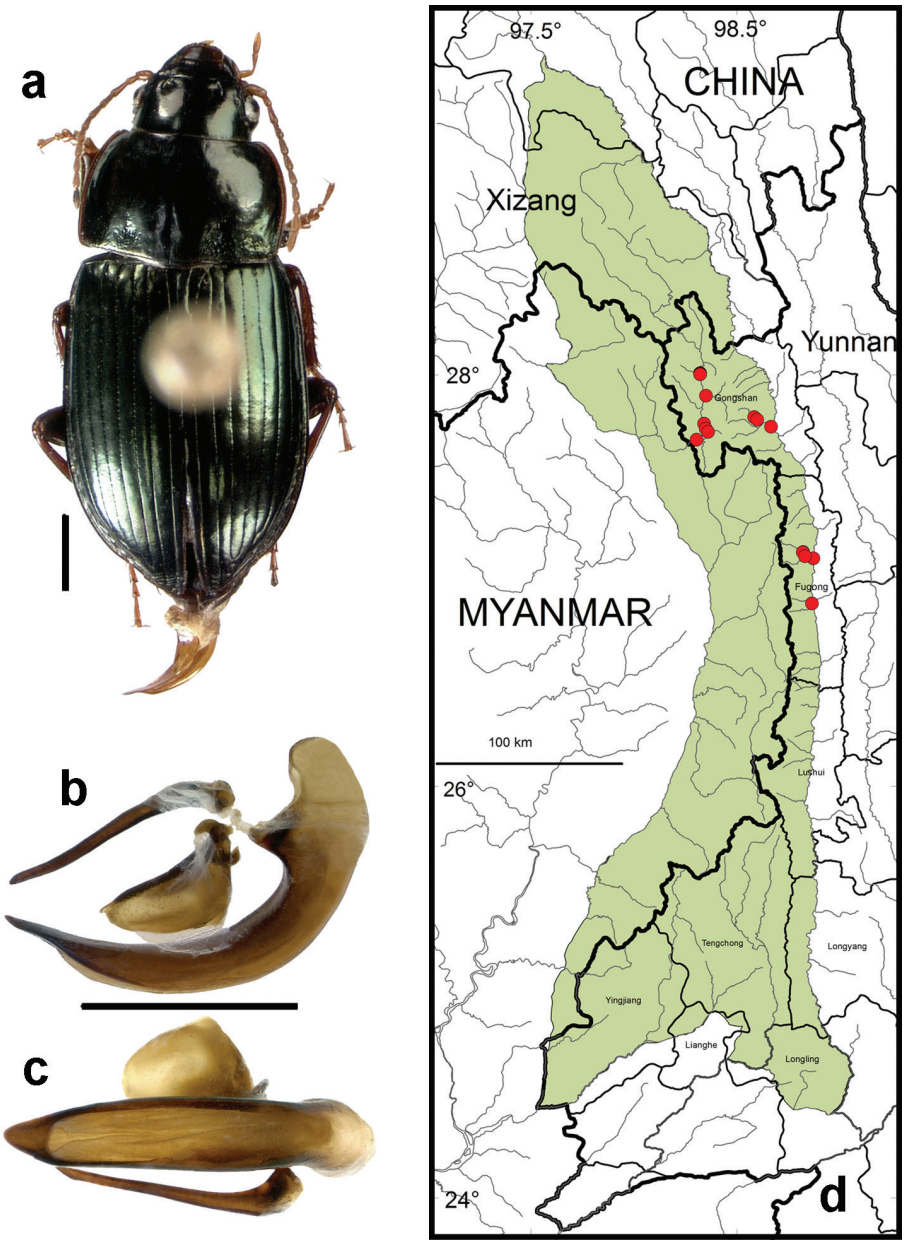


Figure 15. *Amara* (*Harpaloamara*) *latithorax* Baliani. **a** dorsal habitus (CASENT1015304); b-c. median lobe of aedeagus of male (CASENT10115091) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A.* in the Gaoligong Shan region, scale line = 100 km.

24-25 April 2004, D.H. Kavanaugh & C.E. Griswold collectors [1 female; CAS]), (11 km above Nu Jiang on Yaping Road at Shimowa Village, 27.13839°/98.82147°, 1850-1928 m, 25 April 2004, H.B. Liang collector [1 male and 2 females; CAS,

IOZ, ZMHB]); Shangpa Township (road on west side of Nu Jiang S of Shangpa, 26.88952°/98.86539°, 1223 m, 22 and 27 April 2004, D.H. Kavanaugh & C.E. Griswold collectors [1 male and 1 female; CAS, IOZ]). ***Gongshan County:*** Cikai Township (15 km W of Cikai on Dulong Valley Road, 27.79584°/98.58443°, 2022 m, 10 October 2002, D.H. Kavanaugh, P.E. Marek & H.B. Liang collectors [1 female; CAS]), (Heiwadi Village, 27.72250°/98.59902°, 1965 m, 14 November 2004, H.B. Liang, D.Z. Dong & G. Tang collectors [2 males; IOZ, ZMHB]), (Pula He just above Nu Jiang Road, 27.74861°/98.66675°, 1440 m, 23 October 2004, D.H. Kavanaugh & H.B. Liang collectors [1 female; IOZ], 11 November 2004, D.H. Kavanaugh, H.B. Liang, D.Z. Dong & G. Tang collectors [1 male and 2 females; CAS, IOZ]); Dulongjiang Township (Bapo, 27.73902°/98.34975°, 1412 m, 20 October 2004, H.B. Liang collector [1 female; IOZ], 3 November 2004, H.B. Liang collector [2 males and 1 female; CAS, IOZ], at Miliwang, 27.72383°/98.36117°, 1956 m, 31 October 2004, H.B. Liang collector [6 females; CAS, IOZ]), (Dulong Jiang at Elideng Village, 28.00287°/98.32145°, 1640 m, 3 November 2004, D.H. Kavanaugh, D.Z. Dong & G. Tang collectors [1 female; CAS]), (2.3-3.3 airkm S of Longyuan Village on Dulong Jiang, 28.00532°/98.32145°, 1685-1720 m, 2 November 2004, D.H. Kavanaugh, D.Z. Dong & G. Tang collectors [1 female; IOZ], 2.8 km S of Longyuan Village on Dulong Jiang, 28.00905°/98.32204°, 1660 m, 2 November 2004, D.H. Kavanaugh & D.Z. Dong collector [1 male; CAS]), (main road between Mabidang and Kongdang, 27.76361°/98.34111°, 1329 m, 5 November 2004, V.F. Lee & D.G. Long collectors [1 female; CAS]), (Maku, 27.68553°/98.30425°, 1823 m, 2 November 2004, H.B. Liang collector [2 males and 3 females; CAS, IOZ]), (Moqie Wang at KM 91 on Gongshan-Dulong Road, 27.89934°/98.34999°, 1550 m, 6 November 2004, D.H. Kavanaugh & H.B. Liang collectors [1 male and 1 female; CAS, IOZ]).

Members of this species were collected only in the northern half of the study area (Core Areas 1, 2 and 3), on both sides of the mountain range (Core Areas 1 and 2).

Overall geographical distribution. Fig. 27. This species has been recorded from Bhutan, China (Yunnan Province), India (Sikkim, Uttar Pradesh and West Bengal), Myanmar and Nepal. Its occurrence in the study area represents the southern and eastern limits of its known geographical range.

8. *Amara* (*Bradytus*) *chalciope* (Bates, 1891)

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

Figs 5b–c, 5e, 6b, 16, 24a, 24b, 25a, 26a, 27–30

Leiocnemis chalciope Bates, 1891: 71. Type material: Holotype male in BMNH. Type locality: China, Sichuan, snowy mountain near Kangding ("Snowy Range, near Tatsienlu"), 13000 ft.

Amara (*Niphobles*) *szetschuana* Jedlička, 1934a: 17. Type material: Holotype female in NMPC. Type locality: China, Sichuan, Kangding ("Tatsienlu"). Transferred to subgenus *Bradytus* by Baliani (1937: 176), synonymized by Hieke (1983: 361).

Diagnosis. Adults of this species (Fig. 16) can be distinguished from those of all other species in the region by the following combination of character states: body length 7.5–9.0 mm; dorsal surface dark with distinct metallic blue-green reflection in most specimens, non-metallic black in a few specimens, at least femora and outer antennomeres dark (piceous to black); elytral microsculpture comprised of isodiametric meshes, faintly impressed or nearly effaced in males, deeply impressed and distinct in females; pronotum (Fig. 16a) with lateral margins straight or faintly to distinctly sinuate just anterior to basal angles, rounded near middle, less rounded or nearly straight also in anterior one-third in most specimens, anterior angles distinctly and narrowly projected anteriorly beyond anterior margin, lateral explanation distinctly broader basally, outer basal impressions indistinct from lateral groove in most specimens, punctation of base extended anteriorly along sides to pronotal mid-length; elytra with parascutellar pore puncture absent; medial protibial spurs simple; metatibia of male without brush-like setae medially in the apical half; tarsomere 5 of hind tarsi with two or (in a few specimens) three pairs of setae ventrally (Fig. 6b); last abdominal sternite of male with one pair (Fig.5e) and female with two pairs (Fig.5c) of setiferous punctures near hind margin.

Habitat distribution. Specimens of this species were collected in daytime from under stones and other cover in open roadside areas (Figs 24b, 25a, 26a), particularly on bare granitic sand substrates on roadcuts, landslides, stream banks, flood outwash flats and open slopes above treeline (Fig. 24a), and in these same habitats at night, when beetles were found active on bare substrate. Members of this species were found at elevations ranging from 1500 to 3611 m (most abundantly between 2500 and 3200 m), and syntopic with adults of *A. birmana*, *A. dissimilis*, *A. elegantula*, *A. latithorax*, *A. lucidissima*, *A. shaanxiensis*, *A. sikkimensis*, *A. silvestrii* at one or more sites.

Geographical distribution within the Gaoligong Shan. Fig. 16d. We examined a total of 634 specimens (296 males and 338 females) from the following localities: ***Fugong County:*** Lishadi Township (Shibali area, 27.16553°/98.77854°, 2550 m, 5 and7 May 2004, D.H. Kavanaugh, H.B. Liang, X.Y. Li, X.Q. Li and H.M. Yan collectors [12 females; IOZ]), 27.16536° /98.78003° , 2535 m, 4–17 August 2005, D.H. Kavanaugh, H.B. Liang, P. Paquin & D.Z. Dong collectors [9 males and 7 females; CAS, IOZ], 4–5 October 2007, D.H. Kavanaugh, H.B. Liang & H.L. Shi collectors [1 male and 5 females]), (0.3 km SE of Shibali at North Fork Yamu River, 27.16337°/98.78208°, 2475 m, 7 May 2004, D.H. Kavanaugh & C.E. Griswold collectors [2 males; CAS]),(1.5 km below Shibali on Yaping Road, 27.16284° /98.78989°, 2420 m, 2 May 2004, H.B. Liang & G.X. Peng collectors [2 males and 6 females; CAS, IOZ]), (2.0 km E of Shibali on Shibali Road, 27.16276° /98.78927° , 2430 m, 6 August 2005, H.B. Liang collector [5 males and 2 females; CAS, IOZ], 27.16100° /98.79370° , 2300–2350 m, 18 August 2005, D.Z. Dong collector [3 males and 7 females; CAS, IOZ]), (2.7 km above of Shibali on Shibali Road, 27.17368° /98.76684° , 2735 m, 10 August 2005, D.H. Kavanaugh collector [2 females; CAS, IOZ]), (2.8 km above of Shibali on Shibali Road, 27.17405° /98.76722° , 2750 m, 9 August 2005, D.Z. Dong collector [1 male and 1 female; CAS, IOZ]), (4 km E of Shibali on Shibali Road, 27.15727° /98.79784° , 2280 m, 11 August 2005, D.Z. Dong collector [1

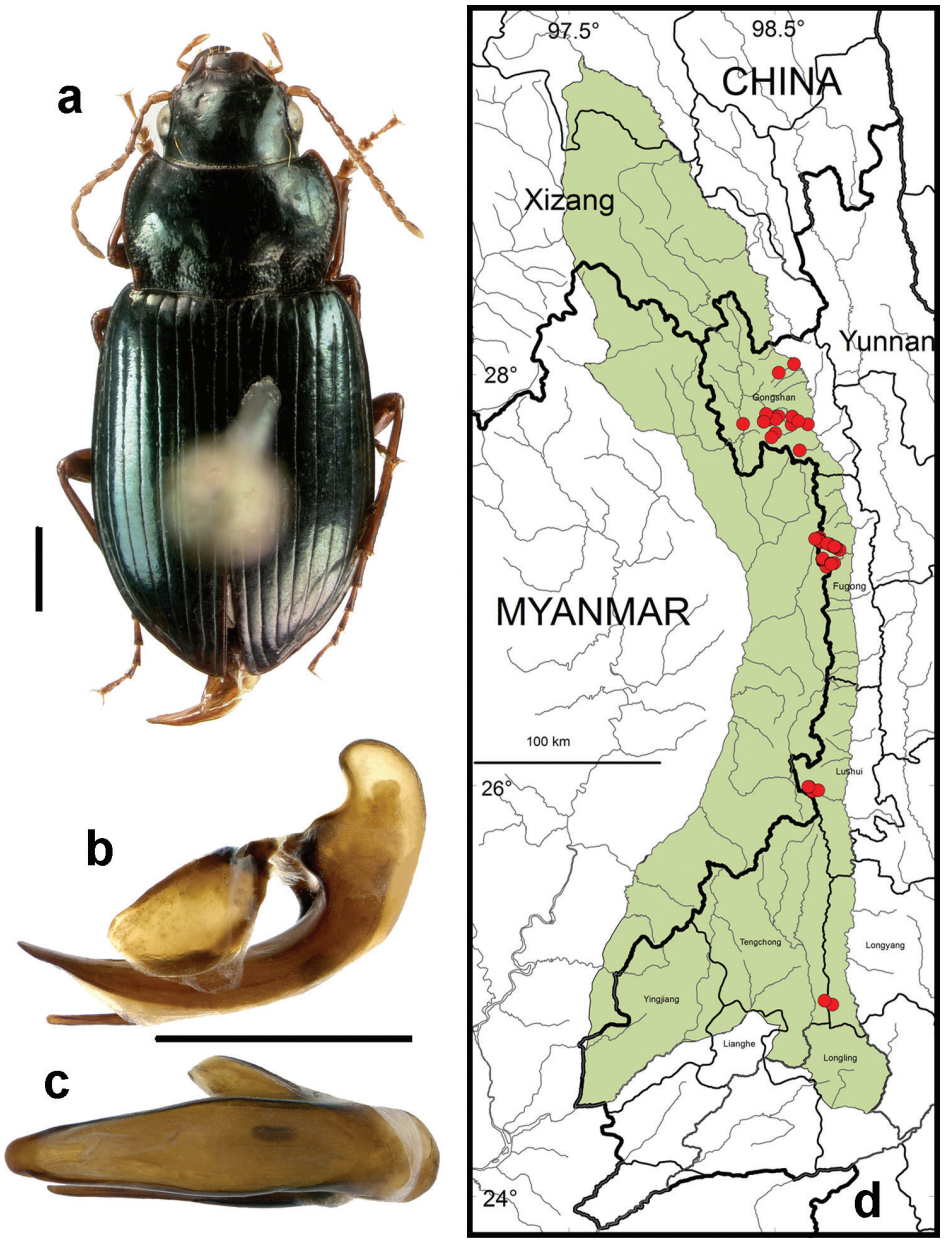


Figure 16. *Amara* (*Bradytus*) *chalciope* Bates. **a** dorsal habitus (CASENT1028265) **b–c** median lobe of aedeagus of male (CASENT1028375) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A. chalciope* in the Gaoligong Shan region, scale line = 100 km.

male and 1 female; CAS IOZ]), (4 km W of Shibali on Shibali Road, 27.17740° /98.75490° , 2800 m, 16 August 2005, D.Z. Dong collector [2 males and 1 female; CAS IOZ]), (8.4 to 9.5 km W of Shibali on Shibali Road, 27.18740° /98.71936°,

3160–3195 m, 13 August 2005, D.H. Kavanaugh, H.B. Liang & D.Z. Dong collectors [1 male and 1 female; CAS, IOZ]), (8.5 km above Shibali on Shibali Road at North Fork Yamu River, 27.18416° /98.72026°, 3100 m, 7 May 2004, D.H. Kavanaugh & B.X. Zhu collectors [1 male; CAS]), (9.5 to10.0 km W of Shibali on Shibali Road, 27.19438° /98.71486° , 3195–3200m, 12 August 2005, D.H. Kavanaugh, H.B. Liang & D.Z. Dong collectors [15 males and 12 females; CAS, IOZ, ZMHB]), (10 km above Shibali on Shibali Road, 27.20055° /98.71399° , 3121 m, 5–6 August 2005, D.H. Kavanaugh, P. Paquin & D.Z. Dong collectors [6 males and7 females; CAS, IOZ]), (10 km above Shibali on Shibali Road, 27.19980° /98.71375° , 3200 m, 16 August 2005, J.F. Zhang collector [10 males and 9 females; CAS, IOZ]), (10 to 11 km above Shibali on Shibali Road, 27.19980° /98.71375° , 3200–3280 m, 8 August 2005, D.H. Kavanaugh, H.B. Liang, P. Paquin & D.Z. Dong collectors [2 males and 3 females; CAS, IOZ]), (10.1 km above Shibali on Shibali Road, 27.20049° /98.71354° , 3225 m, 6 May 2004, D.H. Kavanaugh, C.E. Griswold, H.B. Liang & B.X Zhu collectors [3 males and 1 female; CAS, IOZ]), (10.1 to11.5 km above Shibali on Shibali Road, 27.20676° /98.71763° , 3225–3290 m, 8 May 2004, D.H. Kavanaugh, C.E. Griswold, H.B. Liang, X.Y. Li & Z.B. Xi collectors [1 male; IOZ]); Lumadeng Township (8.5 km above Shibali on Shibali Road at North Fork Yamu He, 27.18416°/98.72026°, 3100 m, 8 August 2005, D.H. Kavanaugh, P. Paquin, D.Z. Dong & J.F. Zhang collectors [1 female; CAS], (7.5 km below Shibali on Yaping Road, 27.14627°/98.81559°, 2030 m, 3 May 2004, H.B. Liang & M. Xie collectors [2 males; CAS, IOZ]), (Lao Shibali wood inspection station, 27.07831°/98.77416°, 2305 m, 21 August 2005, H.B. Liang & J.F. Zhang collectors [2 males; CAS, IOZ]), (1 km E of Lao Shibali on Lao Shibali Road at South Fork Yamu He, 27.08141°/98.78273°, 2275 m, 15 August 2005, D.H. Kavanaugh collector [1 males; CAS]), (1.3 km E of Lao Shibali on Lao Shibali Road at South Fork Yamu He, 27.08180°/98.78670°, 2250 m, 15 August 2005, D.H. Kavanaugh, H.B. Liang & J.F. Zhang collectors [2 males and 6 females; CAS, IOZ]), (1.6 km E of Lao Shibali on Lao Shibali Road at South Fork Yamu He, 27.08260°/98.78877°, 2240 m, 21 August 2005, D.H. Kavanaugh collector [5 males and 9 females; CAS, IOZ]), (6.7 km E of Lao Shibali on Lao Shibali Road at tributary of South Fork Yamu He, 27.10437°/98.73253°, 2805 m, 13 August 2005, D.H. Kavanaugh, H.B. Liang, D.Z. Dong & J.F. Zhang collectors [1 male and 3 females; CAS, IOZ]), (7.0 km E of Lao Shibali on Lao Shibali Road at tributary of South Fork Yamu He, 27.10220°/98.73107°, 2800 m, 13 August 2005, D.H. Kavanaugh & P. Paquin collectors [5 males; CAS, IOZ]); Lao Shibali Yakou (27.06429°/98.75123°, 3270 m, 13 August 2005, D.H. Kavanaugh & D.Z. Dong collectors [1 male and 2 females; CAS, IOZ]); ridge and cirques S of Shibali Yakou (27.20035°/98.69604°, 3599–3611 m, 5 October 2007, H.L. Shi, H.B. Liang & X.J. Peng collectors [1 female; IOZ]); South Fork Yamu He (at Lao Shibali, 27.07978°/98.77328°, 2305 m, 15 August 2005, D.H. Kavanaugh & D.Z. Dong collectors [2 females; IOZ]), (at Yejiadi, 27.08004°/98.77325°, 2307 m, 10 May 2004, H.B. Liang, X.Y. Li and B.X. Zhu collectors [3 males and 2 females; CAS, IOZ]). ***Gongshan County:*** Bapo (2 km N along Dulong Jiang,

27.76000°/98.34611°, 1510 m, 16–17 July 2000, P. Thomas collector [2 males; CAS, IOZ]), Bingzhongluo Township (Guocai He at Fucai, 28.00855°/98.51886°, 2800 m, 16 August 2006, D.Z. Dong collector [1 male; IOZ]), (Niwaluo He just above Nu Jiang Road, 28.05140°/98.59319°, 1630 m, 8 October 2002, D.H. Kavanaugh, P.E. Marek & D.Z. Dong collectors [1 female; CAS]); Cikai Township (8.3 to 13.1 km NW of Cikai on Dulong Valley Road, 27.75653°/98.58214°, 2630–3000 m, 23 September 2002, D.H. Kavanaugh, P.E. Marek & D.Z. Dong collectors [6 males and 10 females; CAS, IOZ]), (Km 49 on Gongshan-Dulong Road, 27.78075°/98.47000°, 3330m, 1 October 2002, D.H. Kavanaugh collector [5 males and 6 females; CAS, IOZ]), (53 km W of Cikai on Dulong Valley Road, 27.77422°/98.44716°, 3380 m, 1 October 2002, D.H. Kavanaugh & H.B. Liang collectors [2 females; CAS, IOZ]), (57 km W of Cikai on Dulong Valley Road, 27.80789°/98.45736°, 3162 m, 2 October 2002, H.B. Liang collector [2 males and 1 female; CAS, IOZ]); Heipu Yakou ((southeast slope, 27.77032°/98.44674°, 3365 m, 11and 13 August 2006, D.H. Kavanaugh, J.A. Miller, D.Z. Dong & Y. Liu collectors [6 males and 4 females; CAS, IOZ]); Dabadi (40 km W of Cikai on Dulong Valley Road, 27.79619°/98.51867°, 3900 m, 29 September 2002, H.B. Liang collector [38 males and 28 females; CAS, IOZ, ZMHB]), (41 km W of Cikai on Dulong Valley Road, 27.79655°/98.50562°, 3000 m, 27 September – 6 October 2002, D.H. Kavanaugh, P.E. Marek, H.B. Liang, D.Z. Dong & X.C. Li collectors [67 males and 70 females; CAS, IOZ, ZMHB]), (45 km W of Cikai on Dulong Valley Road, , 27.78253°/98.50444°, 3133 m, 2 October 2002, H.B. Liang collector [2 males and 2 females; CAS, IOZ]); Danzhu He drainage (27.63063°/98.62074°, 2700 m, 30 June-5 July 2000, D.H. Kavanaugh, C.E. Griswold & H.B. Liang collectors [20 males and 34 females; CAS, IOZ, ZMHB]); Heiwadi (15 km W of Cikai on Dulong Valley Road, 27.79584°/98.58443°, 2022 m, 4 October 2002, H.B. Liang, W.D. Ba and C.G. Jin collectors [1 male and 1 female; CAS, IOZ], 10 October 2002, D.H. Kavanaugh, P.E. Marek & H.B. Liang collectors [11 males and 4 females; CAS, IOZ]), (27.77415°/98.61382°, 1767 m, 5 November 2004, H.B. Liang collector [1 male; IOZ]); Qiqi He (27.75748°/98.66073°, 1500 m, 30 September-1 October 2007, D.H. Kavanaugh, H.B. Liang & H.L. Shi collectors [1 female; CAS]); Qiqi Trail (at No. 12 Bridge Camp, 27.71502°/98.50244°, 2775 m, 15–19 July 2000, D.H. Kavanaugh & H.B. Liang collectors [2 males and 1 female; CAS, IOZ]), (at Dongshaofang area, 27.69504°/98.48433°, 3230–3680 m, 16–17 July 2000, D.H. Kavanaugh & H.B. Liang collectors [8 male and 10 females; CAS, IOZ]). ***Longyang County:*** Bawan-Tengchong Road Km 36–37 (24.93417°/98.77944°, 2150 m, 12 October 2003, H.B.Liang & X.C. Shi collectors [1 female; IOZ]). ***Lushui County:*** Luzhang Township (Fengxue Yakou at Pianma Road, 25.97228°/98.68336°, 3150 m, 15 October 2002, D.H. Kavanaugh P.E. Marek & H.B. Liang collectors [8 males and 10 females], 11 May 2005, D.H. Kavanaugh, H.B. Liang, C.E. Griswold, D.Z. Dong & G. Tang collectors [1 female; CAS]), (Yaojiaping He at Pianma Road, 25.97722°/98.71091°, 2527 m, 19–20 May 2005, D.H. Kavanaugh, C.E. Griswold, H.B. Liang, D.Z. Dong & G. Tang collectors [23 males and 33 females; CAS, IOZ]); Pianma (9 km ESE on Pianma Road at Changya He,

25.99414°/98.66336°, 2450 m, 14 May 2005, H.B. Liang collector [2 females; CAS, IOZ]), (9.3 km ESE on Pianma Road, 25.99363°/98.66651°, 2460–2470m, 15–18 October 1998, D.H. Kavanaugh collector [6 males and 6 females; CAS, IOZ]), (Changya He, 25.99363°/98.66651°, 2460–2470m, 13 October 1998, D.H. Kavanaugh collector [3 males and 6 females; CAS, IOZ]). ***Tengchong County:*** Bawan-Tengchong Road Km 42–46 (24.95361°/ 98.74222°, 2290 m, 14 October 2003, H.B. Liang & X.C. Shi collectors [2 males and 1 female; CAS, IOZ].

This is the only species recorded from all seven Core Areas in the Gaoligong Shan region; but in the southern half of the study area, it is restricted to only the highest elevations, where members are found mainly on the passes over the crest of the mountain range and on the slopes just below the passes on both sides.

Overall geographical distribution. Fig. 27. This species has been recorded from Bhutan and China (Fujian, Sichuan and Yunnan Provinces and Xizang Autonomous Region).

9. *Amara* (*Bradytus*) *dissimilis* Tschitschérine, 1894

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

Figs 5b–c, 5e, 6b, 17, 22a, 24b, 27–30

Amara (*Bradytus*) *dissimilis* Tschitschérine, 1894: 404. Type material: Holotype male in ZIN. Type locality: China, Gansu, Ponggartang ("Thibet sept., Amdo, village Ndàmi"). [Note: The holotype was erroneously labeled "*Brad. dissors* Tschit. 1894 typ!" by Hieke (1999a: 165).

Amara (*Bradytus*) *emmerichi* Baliani, 1932: 14. Type material: Holotype male ("type") and one paratype in CBAL, additional paratypes in DEI (Döbler 1975: 112), NMPC and ZMHB. Type locality: China, Sichuan, Kangding ("Tatsienlu-Chiulung"). Synonymized by Hieke (1999a: 165).

Amara (*Bradytus*) *lama* Baliani, 1934b:110. Type material: Holotype female and 1 paratype in BMNH, 2 paratypes in MCSNG. Type locality: Tibet, Rong Tö Valley, 4000-7000 ft. Synonymized by Hieke (1997: 225).

Amara (*Bradytus*) *komala* Jedlička, 1934b: 116. Type material: Holotype female in NMPC, 1 paratype female in CMEY. Type locality: China, Yunnan, Longchuan Jiang ("Soling-ho" Valley). Synonymized by Hieke 1995: 297.

Amara (*Bradytus*) *mera* Jedlička, 1934b: 116. Type material: Holotype female and 1 paratype female in NMPC. Type locality: China, Yunnan, "Yunnan-fou". Synonymized by Hieke (1995: 297).

Diagnosis. Adults of this species (Fig. 17) can be distinguished from those of all other species in the region by the following combination of character states: body length 7.7–8.7 mm; dorsal surface dark brown to black, without or with only very faint metallic green reflection, at least femora and outer antennomeres dark (piceous to black); elytral microsculpture comprised of distinctly isodiametric meshes in both males and females (more deeply impressed in females than in males); pronotum (Fig. 17a) dis-

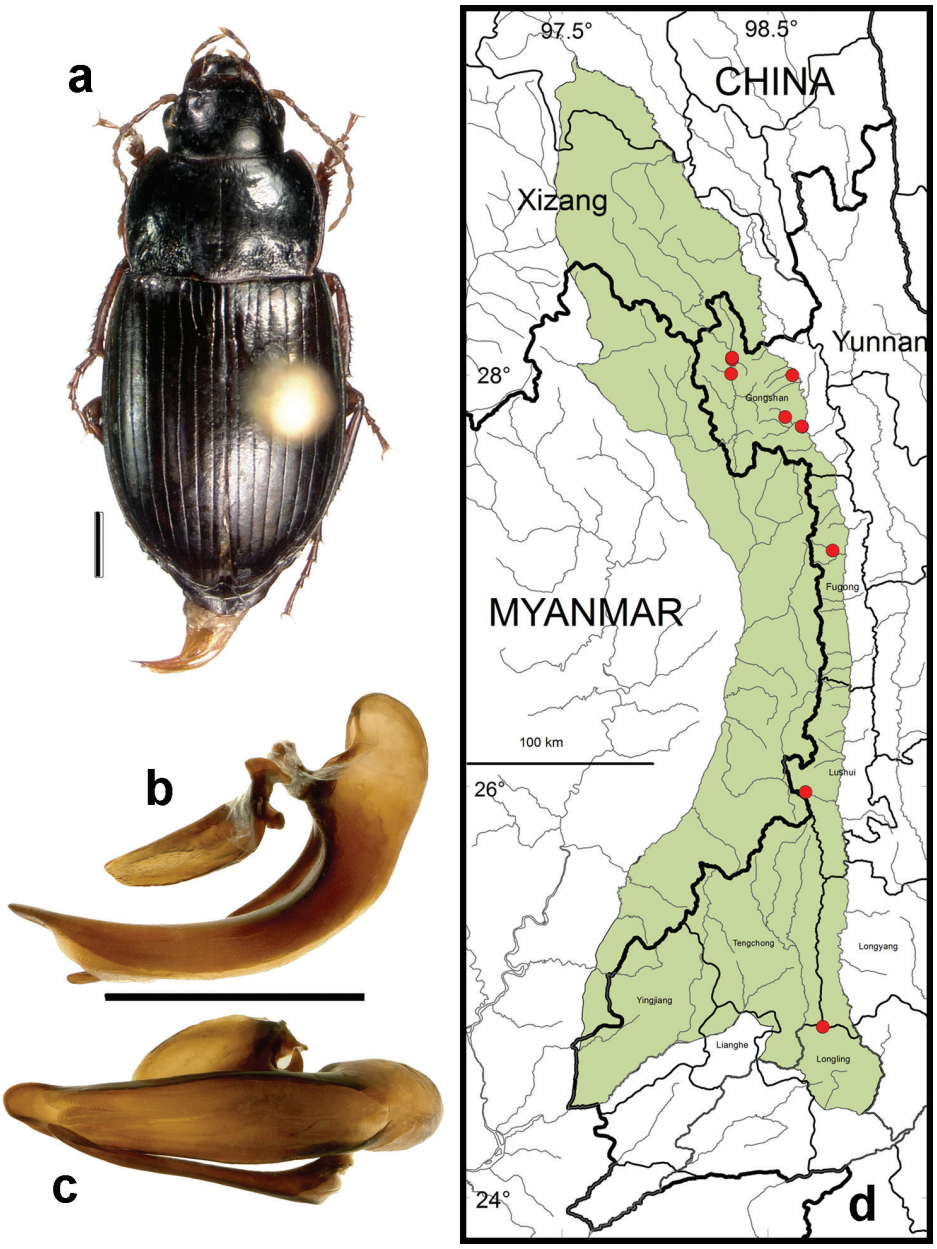


Figure 17. *Amara* (*Bradytus*) *dissimilis* Tschitschérine. **a** dorsal habitus (CASENT1033318) **b–c** median lobe of aedeagus of male (CASENT1002115) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A. dissimilis* in the Gaoligong Shan region, scale line = 100 km.

tinctly narrowed anteriorly, with anterior margin clearly narrower than the hind margin, lateral margins more or less evenly rounded from apical to basal angle, anterior angles slightly projected anteriorly beyond anterior margin, posterior angles obtusely

angulate and slightly denticulate, basal impressions broadly and deeply foveate, outer basal impression distinctly delimited laterally by a broad convexity; elytra without evident sub-basal depressions, pore puncture absent, elytral striae distinct throughout and deeply impressed; medial protibial spurs simple; metatibiae of males with a brush-like patch of setae medially in the apical half; tarsomere 5 of hind tarsi with two or (in a few specimens) three pairs of setae ventrally (Fig. 6b); last abdominal sternite of male with one pair (Fig.5e) and female with two pairs (Fig.5c) of setiferous punctures near hind margin.

Habitat distribution. Specimens of this species were collected in daytime from under stones and other cover in open roadside areas (Fig. 24b) and other waste areas (Fig. 22a) around human settlements with scattered grasses and shrubs, at the edges of meadows and agricultural fields, and on open rocky banks of streams, and in these same habitats at night, when beetles were found active on bare substrate. Members of this species were found at elevations ranging from 1500 to 3611 m (most abundantly between 1500 and 3150 m), and syntopic with adults of *A. birmana*, *A. chalciope*, *A. latithorax*, *A. lucidissima*, *A. pingshiangi*, *A. sikkimensis* and *A. silvestrii* at one or more sites.

Geographical distribution within the Gaoligong Shan. Fig. 17d. We examined a total of 14 specimens (7 males and 7 females) from the following localities: ***Fugong County:*** Lumadeng Township (7.5 km below Shibali on Yaping Road, 27.14627°/98.81559°, 2030 m, 3 May 2004, H.B. Liang & M. Xie collectors [1 female; IOZ]). ***Gongshan County:*** Bingzhongluo Township (Gongdong, 27.99858°/98.61933°, 2506 m, P.E. Marek collector [1 female; CAS]); Cikai Township (27.74939°/98.66453°, 1515 m, 25 September 2002, H.B. Liang & W.D. Ba collectors [1 male and 1 female; IOZ]), (Pula He just above Nu Jiang Road, 27.74861°/98.66675°, 1440m, 23 October 2004, D.H. Kavanaugh & H.B. Liang collectors [1 female; IOZ]); Dulongjiang Township (0.6 km N of Dizhengdang village on Dulong Jiang, 28.08442°/98.32652°, 1880m, 29 October 2004, D.H. Kavanaugh, D.Z. Dong & G. Tang collectors [2 males; CAS, IOZ]), Dulongjiang Township (S of Dizhengdang village at Sialong He, 28.07654°/98.32603°, 1890 m, 30 October 2004, D.H. Kavanaugh, D.Z. Dong & G. Tang collectors [1 female; CAS]), (2.3 to 3.3 airkm S of Longyuan village on Dulong Jiang, 28.00532°/98.32145°, 1685–1720 m, 2 November 2004, D.H. Kavanaugh, D.Z. Dong & G. Tang collectors [2 females; CAS, IOZ]); Heiwadi (16.8 km W of Cikai on Dulong Valley Road, 27.79584°/98.58443°, 2150 m, 4 October 2002, H.B. Liang, W.D. Ba & C.G. Jin collectors[1 male; IOZ]; 10 October 2004, D.H. Kavanaugh, P.E. Marek & H.B. Liang collectors [1 male; CAS]). ***Longyang County****:* Nankang Yakou (24.83167°/98.76667°, 2130 m, 4 November 1998, D.H. Kavanaugh collector [1 males; CAS]). ***Lushui County:*** Luzhang Township (Fengxue Yakou at Pianma Road, 25.97228°/98.68336°, 3150 m, 11 October 1998, D.H. Kavanaugh collector [1 male; CAS]).

This species was recorded from all but one Core Area (Core Area 5) in the Gaoligong Shan region. In the southern half of the study area, it is restricted to only the highest elevations, where members are found mainly on the passes over the crest of the mountain range.

Overall geographical distribution. Fig. 27. This species has been recorded from Gansu, Qinghai, Shaanxi, Sichuan and Yunnan Provinces and Xizang Autonomous Region in China. Its occurrence in the study area represents the southern limit of its known geographical range.

10. *Amara* (*Bradytus*) *elegantula* Tschitschérine, 1899

http://species-id.net/wiki/Amara_elegantula
Figs 5b–c, 5e, 6b, 18, 26a, 26b, 27–30

Amara (*Leiocnemis*) *elegantula* Tschitschérine, 1899: 659. Type material: a male (one of three syntypes) labeled "type" in ZIN acknowledged as holotype (Hieke 1981: 221). Type locality: Sikkim, Darjeeling, 12000 ft.

Diagnosis. Adults of this species (Fig. 18) can be distinguished from those of all other species in the region by the following combination of character states: body length 7.0–7.5 mm; dorsal surface dark with distinct metallic blue-green reflection in most specimens, non-metallic black in a few specimens, at least femora and outer antennomeres dark (piceous to black); elytral microsculpture effaced or nearly so in both males and females; pronotum (Fig. 18a) with lateral margins straight or faintly to distinctly sinuate just anterior to basal angles, rounded near middle, less rounded or nearly straight also in anterior one-third in most specimens, anterior angles distinctly and narrowly projected anteriorly beyond anterior margin, lateral explanation narrow throughout, outer basal impressions foveate and distinct from lateral groove, punctation of base not extended anteriorly along sides beyond basal one-third; elytra with parascutellar pore puncture absent; medial protibial spurs simple; tarsomere 5 of hind tarsi with two or (in a few specimens) three pairs of setae ventrally (Fig. 6b); last abdominal sternite of male with one pair (Fig.5e) and female with two pairs (Fig.5c) of setiferous punctures near hind margin; male aedeagus with apical third of median lobe about as broad as middle third, apical hook of right paramere smaller and closer to apex (Fig. 8a).

Habitat distribution. Specimens of this species were collected in daytime from under stones and other cover in open roadside areas near the crest of the mountain range (Fig. 26a), on the rocky heath tundra in areas with scattered vegetation, and on stabilized scree slopes between persistent snow patches in glacial cirques (Fig. 26b). At night, specimens were found in these same areas active on the bare substrate. Specimens were found at elevations ranging from 3350 to 4000 m, the highest sites sampled. The only other *Amara* species members of which were found syntopic with those of *A. elegantula* was *A. chalciope,* with adults of both species found together at only one site at an elevation of 3365 m (Fig. 26a), near the lower altitudinal limit of the former and the upper altitudinal limit of the latter.

Geographical distribution within the Gaoligong Shan. Fig. 18d. We examined a total of 60 specimens (30 males and 30 females) from the following locali-

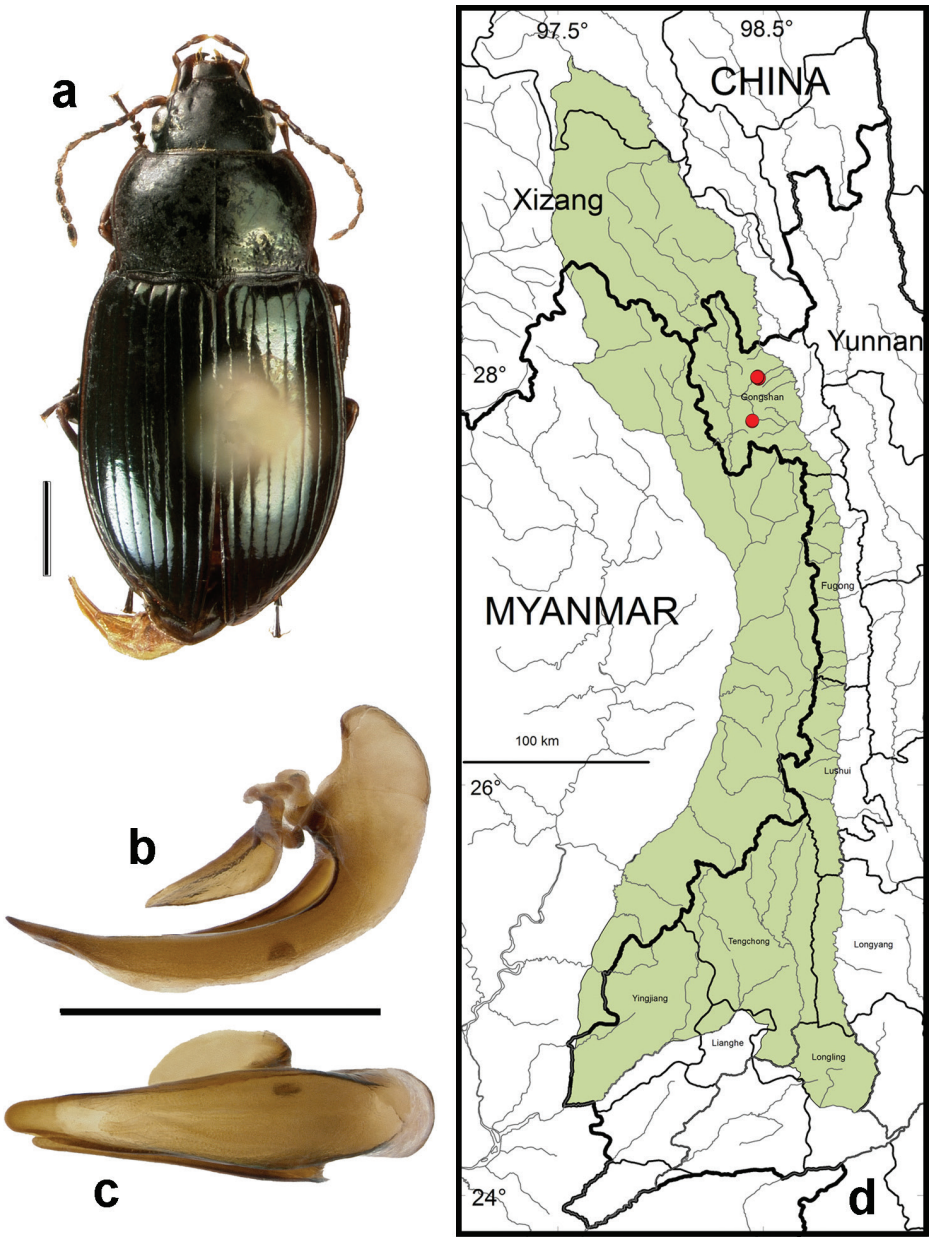


Figure 18. *Amara* (*Bradytus*) *elegantula* Tschitschérine. **a** dorsal habitus (CASENT1026671) **b–c** median lobe of aedeagus of male (CASENT1026255) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A. elegantula* in the Gaoligong Shan region, scale line = 100 km.

ties: ***Gongshan County:*** Heipu Yakou (northwest slope along road W of tunnel, 27.77447°/98.44793°, 3350 m, 13 August 2006, D.H. Kavanaugh & J.A. Miller collectors [2 females; CAS, IOZ]), (southeast slope, 27.77032°/98.44674°, 3365 m,

11–13 August 2006, D.H. Kavanaugh, J.A. Miller, D.Z. Dong & Y. Liu collectors [15 males and 9 females; CAS, IOZ]); southwest slope of Kawakarpu Shan (on slope NE of Chukuai Lake, 27.98206°/98.48027°, 3950 m, 20 August 2006, Y. Liu, P. Hu, D.Z. Dong & J. Wang collectors [4 males and 3 females; CAS, IOZ]), (0.9 km N of Chukuai Lake, 27.98981°/98.47392°, 4000 m, 21 August 2006, D.H. Kavanaugh, J. Xiong & C.H. Li collectors [2 females; CAS, IOZ]), (0.3 km NNE of Chukuai Lake, 27.98393°/98.47491°, 3745 m, 19 August 2006, D.H. Kavanaugh, J.A. Miller, D.Z. Dong, J. Xiong & C.H. Li collectors [7 males and 8 females; CAS, IOZ, ZMHB]), (0.4 km NW of Chukuai Lake, 27.98231°/98.47069°, 3808 m, 21 October 2006. D.Z. Dong collector [2 males; CAS, IOZ]), (0.75 km NW of Chukuai Lake, 27.98631°/98.47069°, 3820 m, 21 August 2006, Y. Liu, P. Hu & J. Wang collectors [1 male and 2 females; CAS, IOZ]), (0.3 km SW of Chukuai Lake, 27.97686°/98.47799°, 3750 m, 19 August 2006, Y. Liu collector [2 males and 3 females; CAS, IOZ]).

This species was recorded only from the northern part of the study area (Core Areas 1 and 2), where it is restricted to the highest elevations sampled, along the crest of the mountain range and both east and west slopes just below the crest.

Overall geographical distribution. Fig. 27. This species has been recorded from Bhutan, China (Yunnan Province and Xizang Autonomous Region), India (Sikkim and West Bengal) and eastern Nepal. Its occurrence in the study area represents the southern and eastern limits of its known geographical range.

11. *Amara* (*Bradytus*) *simplicidens* Morawitz, 1863

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

Figs 5b–c, 5e, 6b, 19, 27–30

Amara (*Bradytus*) *simplicidens* Morawitz, 1863b: 60. Type material: 3 syntypes (2 males and 1 female) in ZIN (lectotype not yet designated). Type locality: Japan, Hokkaido, Hakodate.

Amara (*Bradytus*) *punctatissima* Baliani, 1932: 13. Type material: Holotype male, allotype and at least 1 other paratype in MCSNG, 1 paratype in DEI. Type locality: China, Sichuan, Kangding ("Tatsienlu, Grenze O.Tibet"). Synonymized by Hieke (1995: 301).

Amara (*Leiocnemis*) *marginicollis*, Lutshnik, 1915: 130. Type material: Holotype female, originally in Lutshnik collection, but now missing (Hieke 1999a: 171). Type locality: Japan, Harima. Synonymized by Hieke (1999a: 171).

Amara (*Leiocnemis*) *matsumurae* Csiki, 1929: 450, new name for *A. marginicollis* Lutshnik, 1915, [nec Morawitz 1863a:259]. Synonymized by Hieke (1999a: 171).

Diagnosis. Adults of this species (Fig. 19) can be distinguished from those of all other species in the region by the following combination of character states: body length 8.3–8.4 mm; dorsal surface dark brown to black, without metallic reflection, at least femora and outer antennomeres dark (piceous to black); elytral microsculpture com-

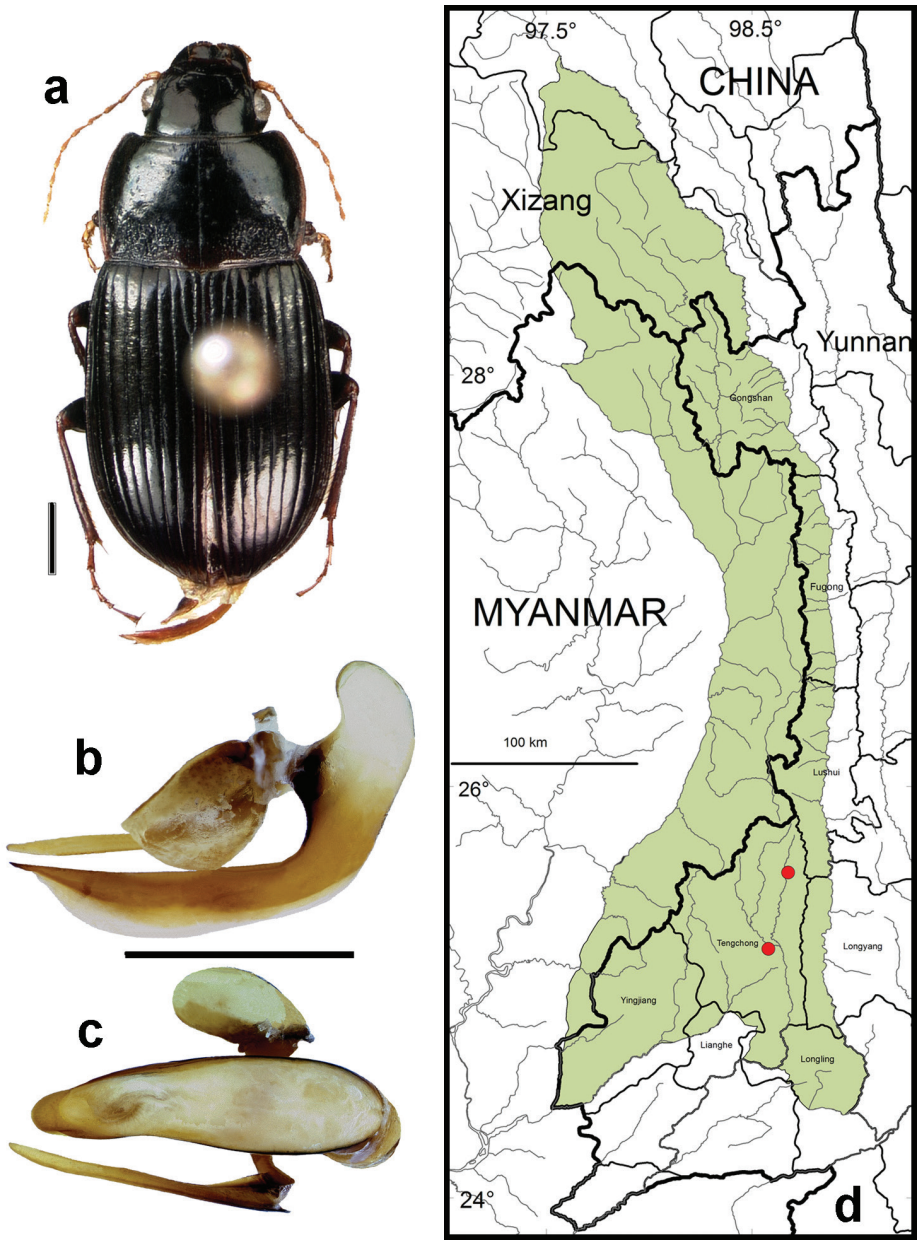


Figure 19. *Amara* (*Bradytus*) *simplicidens* Morawitz **a** dorsal habitus (CASENT1013861) **b–c** median lobe of aedeagus of male (CASENT1013861) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A. simplicidens* in the Gaoligong Shan region, scale line = 100 km.

prised of distinctly transverse meshes in both males and females (more transverse and less deeply impressed in males than in females); pronotum (Fig.19a) only slightly narrower anteriorly than basally, anterior margin almost as wide as posterior margin,

lateral margins more or less evenly rounded from apical to basal angle, anterior angles slightly projected anteriorly beyond anterior margin, posterior angles sharp, not rounded, outer basal impressions sharply delimited laterally by narrow, slightly oblique raised (but not carinate) areas, pronotal base very coarsely punctate; elytra with parascutellar pore puncture absent; medial protibial spurs simple; metatibia of male with brush-like setae medially in the apical half; tarsomere 5 of hind tarsi with two or (in a few specimens) three pairs of setae ventrally (Fig. 6b); last abdominal sternite of male with one pair (Fig. 5e) and female with two pairs (Fig. 5c) of setiferous punctures near hind margin.

Habitat distribution. Specimens of this species were collected in daytime from under stones on the open bank of a small stream at an elevation of 1740 m and at night on wet stones along a roadside at 1515 m elevation. The only other *Amara* species members of which were found syntopic with those of *A. simplicidens* was *A. lucidissima,* with adults of both species found together at the 1740 m site.

Geographical distribution within the Gaoligong Shan. Fig. 19d. We examined a total of 2 specimens (1 male and 1 female) from the following localities: ***Tengchong County:*** Datang Village (Maluchong, 25.58194°/ 98.67583°, 1740 m, 24 October 2003, H.B. Liang collector [1 male; CAS]); Longchuan Jiang (at Xiangyang Bridge, 25.21056°/98.58028°, 1515 m, 23 October 2003, H.B. Liang & X.C. Shi collectors [1 female; IOZ]).

This species was recorded only from the western slope of the southern part of the study area (Core Area 6).

Overall geographical distribution. Fig. 27. This species has been recorded from China (Fujian, Heilongjiang, Henan, Hubei, Jiangsu, Jiangxi, Sichuan,Yunnan, and Zhejian Provinces), Japan, North Korea, and Russia (Khabarovsk and Primorsky Kraya, Sakhalinskaya Oblast, and the Kuril Islands). Its occurrence in the study area represents the western limit of its known geographical range.

12. *Amara* (*Bradytus*) *pingshiangi* Jedlička, 1957

http://species-id.net/wiki/Amara_pingshiangi
Figs 5b–c, 5e, 6a, 20, 25b, 27–30

Amara (*Curtonotus*) *pingshiangi* Jedlička, 1957: 24. Type material: Lectotype female in NMPC (Hieke 1990: 238). Type locality: China, "Süd China: Pingshiang", probably Jiangsu Province. Transferred to subgenus *Bradytus* by Hieke (1990: 238).

Diagnosis. Adults of this species (Fig. 20) can be distinguished from those of all other species in the region by the following combination of character states: body length 11–13 mm, body form stout; dorsal surface dark piceous, at least femora and outer antennomeres dark (piceous to black); pronotum with lateral margin markedly rounded,pronotal base punctate, lateral areas in basal half and near anterior margin also punctuate in most specimens; elytra with parascutellar pore puncture absent; me-

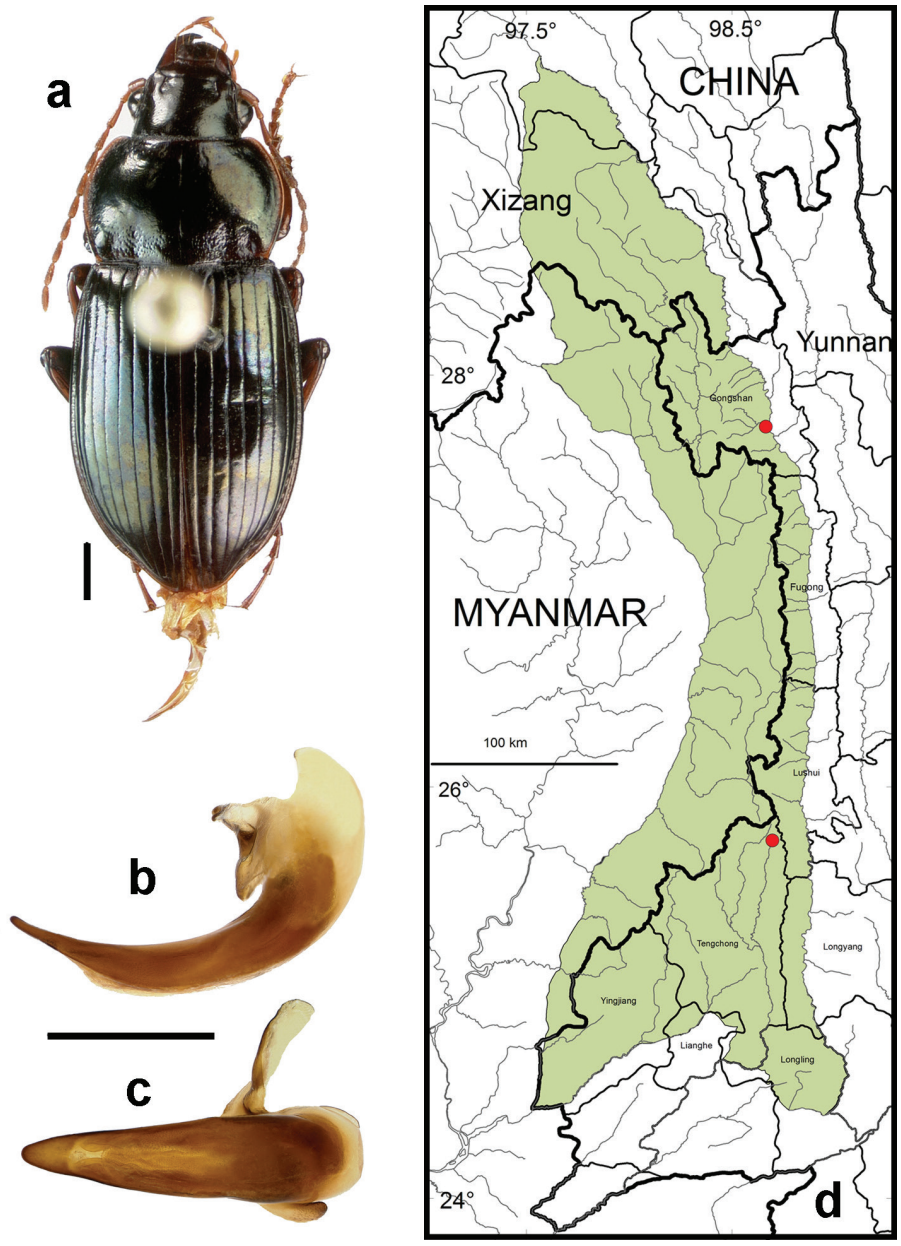


Figure 20. *Amara* (*Bradytus*) *pingshiangi* Jedlička. **a** dorsal habitus (CASENT1038324) **b–c** median lobe of aedeagus of male (CASENT1038324) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A. pingshiangi* in the Gaoligong Shan region, scale line = 100 km.

dial protibial spurs simple; tarsomere 5 of hind tarsi with five or six pairs of setae ventrally (Fig. 6a); last abdominal sternite of male with one pair (Fig.5e) and female with two pairs (Fig.5c) of setiferous punctures near hind margin.

Habitat distribution. Specimens of this species were collected only at night, active on the ground in marshy meadow margin areas (Fig. 25b) near forest edges, at elevations ranging from 1515 to 2010 m, and syntopic with adults of *A. birmana*, *A. dissimilis* and *A. shaanxiensis* at one or more sites.

Geographical distribution within the Gaoligong Shan. Fig. 20d. We examined a total of 3 specimens (2 males and 1 female) from the following localities: ***Gongshan County:*** Cikai Township (27.74939°/98.66453°, 1515 m, 25 Sep. 2002, H.B. Liang & W.D. Ba collectors [1 female; IOZ]). ***Tengchong County:*** Longtang He (at Dahetou Lingganjiao, 25.73947°/ 98.6963°, 2010 m, 16 May 2006, D.H. Kavanaugh collector [1 male; CAS], 18 May 2006, D.H. Kavanaugh & R.L. Brett collectors [1 male; CAS]).

Members of this species were collected at only two sites, one in the northeastern part (Core Area 2) and other in the southwestern part (Core Area 6) of the study area, but not in intervening areas. This gap in distribution is most likely an artifact of inadequate sampling and not a real disjunction.

Overall geographical distribution. Fig. 27. This species has been recorded from Fujian, Jiangxi, Sichuan, Yunnan and Zhejiang Provinces in China. Its occurrence in the study area represents the western limit of its known geographical range.

13. *Amara* (*Reductocelia*) *lucidissima* Baliani, 1932

http://species-id.net/wiki/Amara_lucidissima
Figs 5b–c, 5e, 6b, 8a, 21, 22a, 27–30

Amara (*Celia*) *lucidissima* Baliani, 1932: 10. Type material: Holotype male and allotype in MCSNG, 2 female paratypes in NMPC, and 1 female paratype in ZMHB. Type locality: China, Sichuan, Kangding ("Tatsienlu-Chiulung"). Synonymized with *Amara alacris* Tschitschérine by Hieke (1975: 316), again treated as a distinct species by Hieke (1994: 320), and transferred to subgenus *Reductocelia* by Hieke (1999b:350).

Amara (*Leiocnemis*) *kuatensis* Jedlička, 1956: 209. Type material: Holotype male in ZFMK, about 200 paratypes in NMPC and ZFMK. Type locality: China, Fujian, Kuatun. Synonymized with *A. alacris* Tschitschérine by Hieke (1975: 312), later synonymized with *A. lucidissima* by Hieke (1994: 320).

Diagnosis. Adults of this species (Fig. 21) can be distinguished from those of all other species in the region by the following combination of character states: body length 6.5–8.0 mm; dorsal surface light-brown to brownish black, without metallic reflection, entire legs and antennae pale; elytra with parascutellar pore puncture absent; medial protibial spurs simple; tarsomere 5 of hind tarsi with two or (in a few specimens) three pairs of setae ventrally (Fig. 6b); last abdominal sternite of male with one pair (Fig.5e) and female with two pairs (Fig.5c) of setiferous punctures near hind margin; male aedeagus with apical third of median lobe broader than middle third, apical hook of right paramere large and slightly subapical (Fig. 8a).

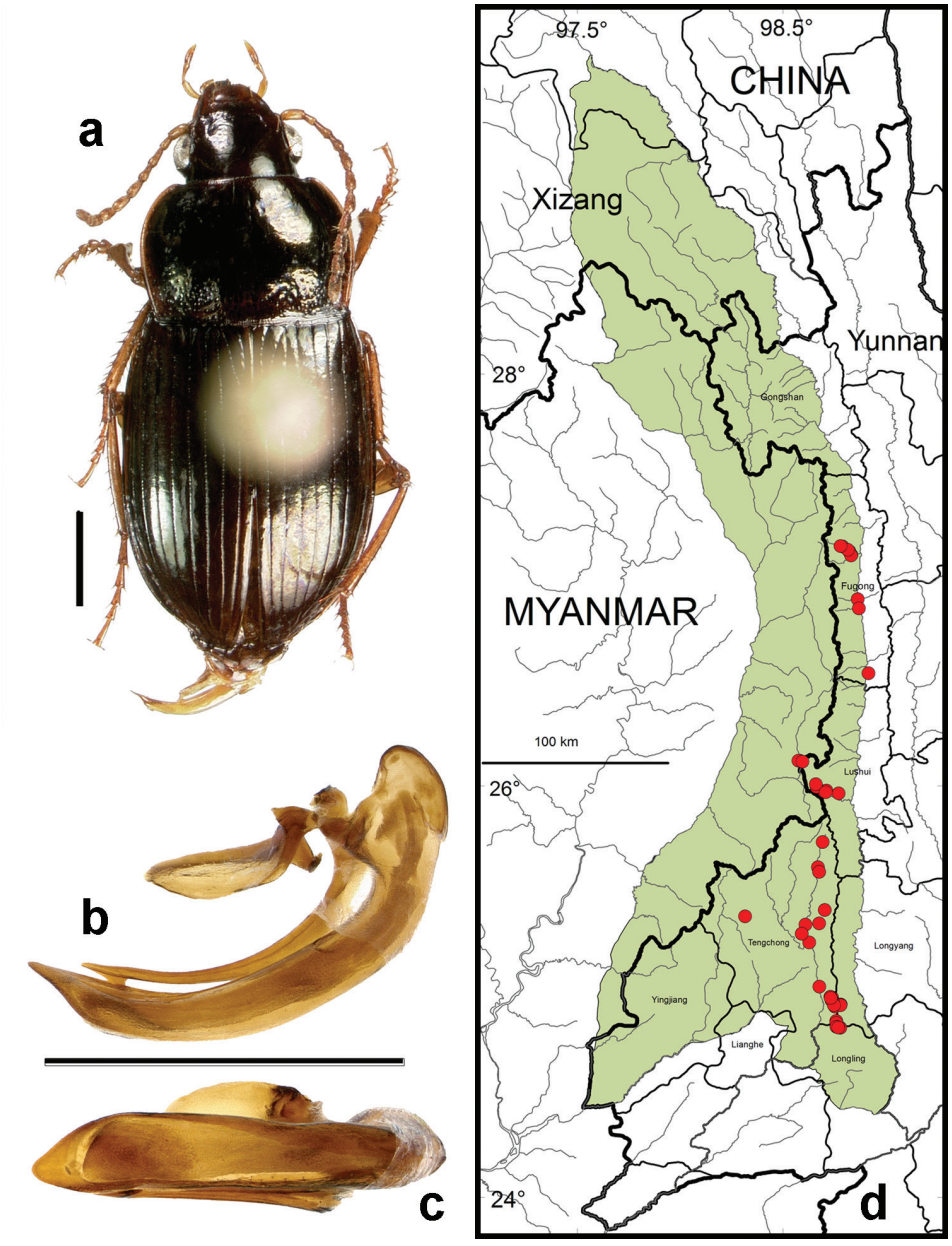


Figure 21. *Amara* (*Reductocelia*) *lucidissima* Baliani. **a** dorsal habitus (CASENT1011863) **b–c** median lobe of aedeagus of male (CASENT1002221) **b** left lateral aspect **c** dorsal aspect; scale lines = 1.0 mm **d** Map of localities records (red circles) for *A. lucidissima* in the Gaoligong Shan region, scale line = 100 km.

Habitat distribution. Specimens of this species were collected, often in great abundance, in daytime from under stones and other cover in open roadside areas and waste areas (Fig. 22a) around human settlements with scattered grasses and shrubs, at

the edges of agricultural fields and on open banks of streams, and in these same habitats at night, when beetles were found active on bare substrate. Members of this species were found at elevations ranging from 1185 to 3140 m and syntopic with adults of *A. birmana*, *A. chalciope*, *A. dissimilis*, *A. latithorax*, *A. shaanxiensis*, *A. sikkimensis*, *A. simplicidens* and *A. silvestrii* at one or more sites.

Geographical distribution within the Gaoligong Shan. Fig. 21d. We examined a total of 581 specimens (276 males and 305 females) from the following localities: ***Fugong County:*** Mugujia Village (Guquan He, 26.86177°/ 98.86900°, 1175 m, 21 April 2004, D.H. Kavanaugh collector [1 female; CAS]); Shibali Road (above Shilajia village, 27.13947°/ 98.82184°, 1900 m, 24 April 2004, D.H. Kavanaugh collector [2 females; CAS]), (above Shilajia Village at North Fork Yamu He, 27.13947°/ 98.82184°, 1800–1900 m, 25 April 2004, D.H. Kavanaugh & C.E. Griswold collectors [18 males and 8 females; CAS, IOZ]); South Fork Yamu He (above Shilajia Village, 27.12101°/98.83173°, 1630–1790 m, D.H. Kavanaugh collector [1 male; CAS]). ***Longyang County:*** Bawan-Tengchong Road Km 36 (24.9375°/ 98.78028°, 2075 m, 11 October 2003, H.B.Liang collector [2 males and 2 females; CAS, IOZ]); Bawan-Tengchong Road Km 48–51 near Dahaoping Forest Station (24.97556°/ 98.73000°, 2014 m, 18 October 2003, H.B. Liang collector [1 male, 3 females; CAS, IOZ]); Bawan-Tengchong Road Km 40–41 (24.92694°/ 98.75278°, 2404 m, 12 October 2003, H.B.Liang collector [7 males and 3 females; CAS, IOZ]); Bawan-Tengchong Road Km 51 near Dahaoping Forest Station (24.9725°/ 98.73889°, 2170 m, 18 October 2003, H.B. Liang & X.C. Shi collectors [1 female; IOZ]); Nankang Forest Station (24.82444°/ 98.77889°, 2085 m, 27 October 2003, H.B. Liang & X.C. Shi collectors [12 males, 6 females; CAS, IOZ]); Nankang Yakou (24.83167°/ 98.76667°, 2130 m, 4–7 November 1998, D.H. Kavanaugh collector [23 males and 44 females; CAS, IOZ]), (at Baoshan-Tengchong Road Km 24, 24.82583°/ 98.77222°, 2130 m, 26 October 2003m, H.B. Liang & X.C. Shi collectors [11 males and 10 females; CAS, IOZ]), (mountain NW of Nankang Yakou, 24.83250°/ 98.76944°, 2245 m, 27 October 2003, H.B. Liang & X.C. Shi collectors [1 male and 1 female; CAS, IOZ]). ***Lushui County:*** Gangfang Sancha Lukou (26.12167°/ 98.575°, 1550 m, 14–15 October 1998, D.H. Kavanaugh collector [3 males and 5 females; CAS, IOZ]). ***Tengchong County:*** Bawan-Tengchong Road Km 42–46 (24.95361°/ 98.74222°, 2290 m, 14 October 2003, H.B. Liang & X.C. Shi collectors [2 males and 1 female; IOZ], 17 October 2003, H.B. Liang collector [1 male and 2 females; IOZ]); Bawan-Tengchong Road Km 46–51 (24.95722°/ 98.73667°, 2220 m, 17 October 2003, D.Z. Dong, H.B. Liang & X.C. Shi collectors [16 males and 25 females; CAS, IOZ]); Bawan-Tengchong Road Km 65 at Longwenqiao (25.02396°/ 98.67675°, 1285 m, 19 October 2003, D.Z. Dong collector [4 males and 1 female; CAS, IOZ]); Baoshan-Tengchong Road Km 24 (24.82889°/ 98.76028°, 2008 m, 29 October 2003, N.D. Penny & T.S. Briggs collectors [5 males and 6 females; CAS, IOZ]); 5–8 km E of Dahaoping (24.93417°/ 98.7475°, 2358 m, 18 October 2003, N.D. Penny, T.S. Briggs, & D.Z. Dong collectors [1 male; CAS]); Datang Village (Maluchong, 25.58194°/ 98.67583°, 1740 m, 24 October 2003, H.B. Liang collector [1 male; IOZ]), (Danlonghe Bridge,

Figure 22. Photographs of habitats for *Amara* species in the Gaoligong Shan region. a. Baoshan-Tengchong Road at Nankang Yakou, elevation 2130 m; habitat in which specimens of *A. birmana*, *A. davidi, A. dissimilis*, *A. lucidissima* and *A. shaanxiensis* were collected. b. Gongshan County, Cikai Township, Heiwadi Village area, elevation 1800 m; habitat in which specimens of *A. congrua* and *A. latithorax* were collected.

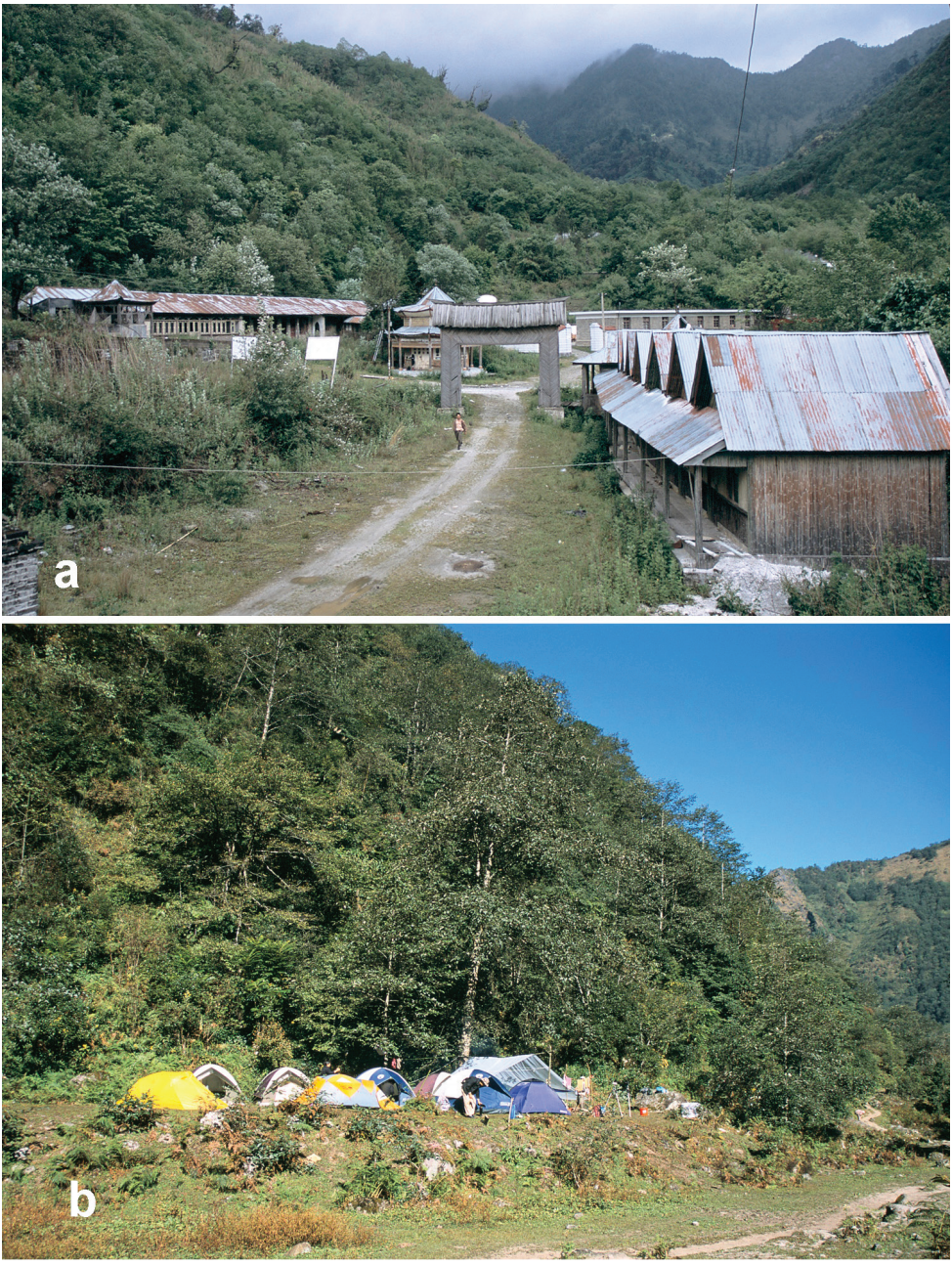


Figure 23. Photographs of habitats for *Amara* species in the Gaoligong Shan region. **a** Lushui County, Yaojiaping just off Pianma Road, elevation 2600 m; habitat in which specimens of *A. birmana*, *A. sikkimensis* and *A. silvestrii* were collected **b** Gongshan County, Dulong Valley, 2.8 km S of Longyuan Village, elevation 1660 m; habitat in which specimens of *A. latithorax* and *A. sikkimensis* were collected.

Figure 24. Photographs of habitats for *Amara* species in the Gaoligong Shan region. **a** Gongshan County, Dongshaofang area just below pass into Dulong Valley, elevation 3500 m; habitat in which specimens of *A. chalciope* were collected **b** Lushui County, Pianma Road just W of Fengxue Yakou, elevation 3150 m; habitat in which specimens of *A. dissimilis* and *A. chalciope* were collected.

Figure 25. Photographs of habitats for *Amara* species in the Gaoligong Shan region. **a** Lushui County, Pianma Road just E of Fengxue Yakou, elevation 3150m; habitat in which specimens of *A. birmana* and *A. chalciope* were collected **b** Tengchong County, Longtang He at Dahetou Lingganjiao, elevation 2010 m; habitat in which specimens of *Amara birmana*, *A. pingshiangi* and *A. shaanxiensis* were collected.

Figure 26. Photographs of habitats for *Amara* species in the Gaoligong Shan region. **a** Gongshan County, Heipu Yakou just E of Tunnel, elevation 3365 m; habitat in which specimens of *A. chalciope* and *A. elegantula* were collected **b** Gongshan County, southwest slope of Kawakarpu Shan on slope abiove and NE of Chukuai Lake, elevation 3950 m; habitat in which specimens of *A. elegantula* were collected.

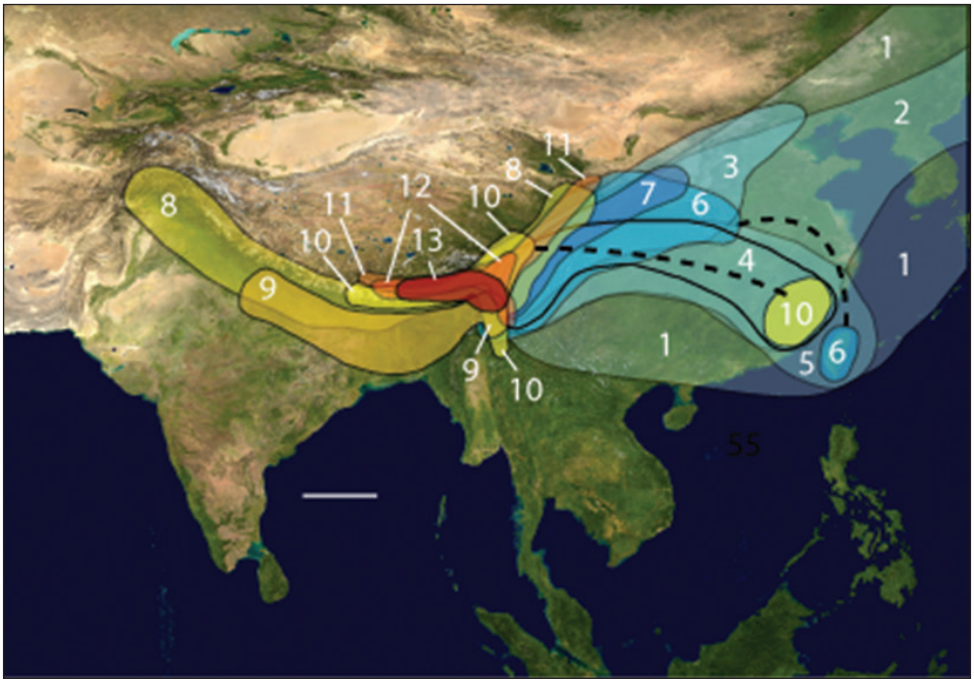


Figure 27. Map showing approximate overall geographical distributions of species occurring in the Gaoligong Shan region (ranges that extend to the upper right corner of the map are truncated there but continue northeast to Japan and the Russian Far East); dashed lines connect apparently significant disjunct areas of the range of a species; scale line = 500 km. **1** *Amara* (*Amara*) *congrua* Morawitz **2** *Amara* (*Bradytus*) *simplicidens* Morawitz **3** *Amara* (*Zezea*) *davidi* Tschitschérine **4** *Amara* (*Bradytus*) *pingshiangi* Jedlička **5** *Amara* (*Reductocelia*) *lucidissima* Baliani **6** *Amara* (*Amara*) *silvestrii* Baliani **7** *Amara* (*Amara*) *shaanxiensis* Hieke; **8** *Amara* (*Xenocelia*) *sikkimensis* Andrewes **9** *Amara* (*Harpaloamara*) *latithorax* Baliani **10** *Amara* (*Bradytus*) *chalciope* (Bates) **11** *Amara* (*Bradytus*) *dissimilis* Tschitschérine **12** *Amara* (*Pseudoamara*) *birmana* Baliani; **13** *Amara* (*Bradytus*) *elegantula* Tschitschérine.

25.60500°/ 98.67028°, 1768 m, 24October 2003, H.B. Liang & X.C. Shi collectors [3 males and 3 females; CAS, IOZ]); Longchuan Jiang (at Longkou Village, 25.28167°/ 98.59167°, 1500 m, 2 November 1998, D.H. Kavanaugh & C.E. Griswold collectors [4 males and 11 females; CAS, IOZ]), (at Xiaojiangqiao (25.23944°/ 98.62722°, 1445 m, 21 October 2003, H.B. Liang & X.C. Shi collectors [1 male and 2 females; CAS, IOZ]), (at Yonganqiao (25.32556°/ 98.60944°, 1500 m, 22 October 2003, H.B. Liang & X.C. Shi collectors [10 male and 10 females; CAS, IOZ]), (at Yonganqiao (25.60500°/ 98.67583°, 1500 m, 22 October 2003, H.B. Liang & X.C. Shi collectors [2 females; IOZ]); Longkou Village, 25.28167°/ 98.59167°, 1500 m, 22 October 2003, H.B. Liang & X.C. Shi collectors [15 males and 26 females; CAS, IOZ]); Shaba Village (25.39639°/ 98.70306°, 1850 m, 23 October 2003, H.B. Liang & X.C. Shi collectors [6 males and 7 female; CAS, IOZ]); Xiaodifang Village (24.85722°/ 98.75917°, 2150 m, 29 October 2003, D.Z. Dong collector [2 males and 1 female;

CAS, IOZ]); Xiaoheishan Forest Station (24.82889°/ 98.76000°, 2025 m, 29 October 2003, H.B. Liang collector [32 males and 41 females; CAS, IOZ]); Zhoujia-po Village, 25.33222°/98.67611°, 1740 m, 24 October 2003, D.Z. Dong collector [2 males; CAS]); near Zhoujia-po village (25.58194°/ 98.67611°, 1725 m, 24 October 2003, N.D. Penny & T.S. Briggs collectors [2 females; CAS, IOZ].

This species was recorded from the southern two-thirds of the study area (Core Areas 2,4, 5, 6 and 7), on both eastern and western slopes of the mountain range.

Overall geographical distribution. Fig. 27. This species has been recorded from China (Fujian, Hubei, Sichuan, Yunnan, and Zhejiang Provinces) and Taiwan. Its occurrence in the study area represents the western limit of its known geographical range.

Discussion

Although the Gaoligong Shan region is at the heart of one of the world's biodiversity hotspots (Myers et al. 2000), this area is near the southern limit of the geographical range of genus *Amara* in Asia; and so it is not surprising that species diversity there is less than in comparable areas farther north. Of the 13 species we recorded from the area based on material from our ten years of sampling plus additional records from collections (see list in Materials and Methods section above), none of these species are new to science or endemic to the area. Nonetheless, the composition of the *Amara* fauna of the area is of interest on several levels.

Broad geographical distribution patterns. The overall geographical ranges of the 13 species, superimposed on one another, are graphically approximated in Fig. 27. Among the geographical ranges of these species, three general range patterns are apparent. The first pattern includes seven species (*A. congrua*, *A. davidi*, *A. lucidissima*, *A. pingshiangi*, *A. shaanxiensis*, *A. sikkimensis* and *A. simplicidens*), more or less broadly distributed in China and eastern Asia, but all of which have their western range limits at or near the Gaoligong Shan region. Two of these, *A. congrua* and *A. simplicidens*, have ranges that extend east and north to Japan and the Russian Far East, as well as across most of China east of the study area. Strangely, members of these two species were among the least frequently encountered *Amara* in the area during our study. The ranges of four species with eastern distributional ranges, *A. congrua*, *A. simplicidens*, *A. pingshiangi* and *A. lucidissima*, include Fujian Province in China. There are gaps in the known distributions of all of these species between the study area and Fujian, and inadequate sampling is likely the cause of these apparent gaps. For three species, *A. congrua*, *A. lucidissima* and *A. silvestrii*, known geographical ranges also include Taiwan. Both *A. congrua* and *A. lucidissima* are also known from Fujian, right across the South China Sea from Taiwan, a disjunction of only about 250 to 400 km, depending on localities compared. The nearest Taiwanese localities for *A. silvestrii* are more than 1400 km distant from the nearest mainland sites, in Shaanxi Province, and this may represent a real and significant range disjunction. The remaining species included among the class of eastern patterns, *A. shaanxiensis*, has the most restricted known

geographical distribution, recorded only from Yunnan and from Shaanxi Province, but it likely also occurs in intervening areas in along the southern edge of the Qinghai-Xizang Plateau in Sichuan and Gansu Provinces.

The second general geographical range pattern includes two species, *A. elegantula* and *A. latithorax*, with geographical ranges that include only the Himalayan region immediately to the west and the Gaoligong Shan region, where they reach their eastern distributional limit. *Amara elegantula* ranges as far west as eastern Nepal and adjacent parts of Xizang Autonomous Region (Tibet), and the range of *A. latithorax* also extends west to Nepal, but apparently only on the southern slope of the Himalaya (i.e., it has not been recorded from the northern side of that range). The third general range pattern includes the remaining four species, *A. birmana*, *A. chalciope*, *A. dissimilis* and *A. sikkimensis*. The geographical distributions of each of these species include the Gaoligong Shan region and areas of varied distance to both the northwest and the northeast along the Himalayan range and the southern edge of the Qinghai-Xizang Plateau, respectively. Of these, *A. sikkimensis* has the broadest distribution, extended from northen Pakistan in the west to Gansu Province in the east. The known range of *A. chalciope* extends from Bhutan and Xizang Autonomous Region in the west to Sichuan in the east, with a significantly disjunct occurrence also in Fujian Province in southeastern China. Populations currently included under this name actually may represent a complex of species, a solid understanding of which will require additional study. The known range of *A. dissimilis* extends from Xizhang in the northwest to Shaanxi in the northeast and actually includes parts of the Qinghai-Xizang Plateau itself in southern Qinghai Province. Finally, *A. birmana* has the most restricted range of the species with this pattern, known only from northeastern India and northern Myanmar in the west to Sichuan in the east.

On first glance, the observed diversity of *Amara* species in the study area appears to be due simply to an overlap of faunal elements from both the east and the west. Certainly several of the species with broad distributions in large parts of eastern Asia (e.g., *A. congrua* and *A. simplicidens*) likely have their origins in regions to the northeast and so their occurrence in the study area is likely the results of range expansion into the region. However, even a casual look at the majority of range patterns illustrated in Fig. 27 tempts us to suggest that the Gaoligong Shan region, as a core part of the Hengduan Mountains System, may have served as an area of origin for at least part of the *Amara* fauna which now also occupies the Himalayan Ranges and southern edge of the Qinghai-Xizang Plateau to the west and east, respectively. The Hengduan Mountains date their origins to the late Mesozoic, whereas the uplift of the Himalayan Ranges and Qinghai-Xizang Plateau began later, in the early Cenozoic (Chaplin 2006). So this region may have been an area of differentiation, speciation and origin of montane elements from which, rather than to which, at least some of the species now ranging more broadly in the region subsequently spread. However, an understanding of phylogenetic relationships among the Eurasian and Oriental *Amara* species is required in order to test this hypothesis, and such an analysis has not yet been undertaken. Comparative DNA sequence data in particular should be highly informative for

resolving these relationships. Schmidt et al. (2012) provided distributional and molecular phylogenetic evidence that together support a "Tibetan origin" for the Himalayan endemic *Ethira* clade of Pterostichini, rather than an origin by dispersal either from western Asia or from mountainous areas to the east of the Himalaya, as we suggest here for *Amara*. However, because they could not determine the sister group of the *Ethira* clade from their analysis, it remains unclear whether more inclusive (i.e., older, more basal) relationships are with some element of the pterostichine fauna of the temperate north (as they suggest) or not. Pterostichine material from the Gaoligong Shan inventory project is currently under study, and it will be interesting to see if this material provides any new insights into the origins of that element of the present faunas of the Himalayan Ranges and southern edge of the Qinghai-Xizang Plateau.

Regional geographical and altitudinal distribution patterns. Within the Gaoligong Shan study area, most of the species represented are broadly distributed, both geographically and altitudinally. This is not surprising given the shared preferences of their members for open and disturbed habitats. Such areas are abundant in the lowlands, most often associated with agriculture and human habitation. They are also abundant at all elevations within in the Gaoligong Shan itself, whether in naturally open alpine areas above tree line or in open areas along streams, on flood outwash flats or stabilized landslides, or in open sites created by humans, such as along road cuts, in forest clearcuts and previously burned areas and around all forms of human settlement and activity. What is perhaps unexpected is that a few of the species are quite restricted in their geographical and altitudinal ranges within the study area.

The chart in Fig. 28 summarizes the recorded regional distributions of the species with respect to our project-designated Core Areas; and the recorded altitudinal ranges for each species are shown in Fig. 29. Only *A. chalciope* is recorded from all seven Core Areas, and this species also shows the broadest altitudinal range (from 1500 to just over 3600 m). *Amara dissimilis* is recorded from six of the Core Areas (not yet recorded from Core Area 5) and also has a broad altitudinal range (from 1515 to 3150 m). Two species, *A. silvestrii* and *A. sikkimensis,* are recorded from five of the Core Areas, including both the northernmost and southernmost, so they are likely to be found in the other Core Areas with additional sampling. Both species also occupy broad altitudinal ranges (from 1515 to 3000 m and from 1175 to 2800 m, respectively). Four species have been recorded from fewer Core Areas but nonetheless are likely to be found more widely in the region with additional sampling in gap areas in their ranges. *Amara davidi* has been recorded from three Core Areas (1, 6 and 7), *A. shaanxiensis* from four (2, 5, 6 and 7), *A. pingshiangi* from two (2 and 6) and *A. congrua* from four (2, 3, 5 and 6). Among these, *A. shaanxiensis* has the broadest recorded altitudinal range (from just over 1800 to 3000 m) and *A. davidi* and *A. pingshiangi* the narrowest (from 2020 to 2440 m and from 1515 to 2010 m, respectively). *Amara congrua* has a moderately broad recorded altitudinal range (from 892 to 2000 m), including the lowest elevation at which any *Amara* species has been recorded in the study area. The five species not yet mentioned all have geographical and, in some cases, also altitudinal ranges that are restricted to at least some extent. Among these, *A. lucidissima* is the most widespread,

	Core Area						
	1	2	3	4	5	6	7
A. elegantula	X	X					
A. davidi	X					X	X
A. shaanxiensis		X			X	X	X
A. birmana				X	X	X	X
A. dissimilis	X	X	X	X		X	X
A. silvestrii		X	X	X	X	X	
A. pingxiangi		X				X	
A. simplicidens						X	
A. chalciope	X	X	X	X	X	X	X
A. latithorax	X	X	X				
A. lucidissima			X	X	X	X	X
A. sikkimensis	X	X	X		X	X	
A. congrua		X	X		X	X	

Figure 28. Chart showing the representation of *Amara* species in project-designated Core Areas (see Fig. 3) in the Gaoligong Shan region.

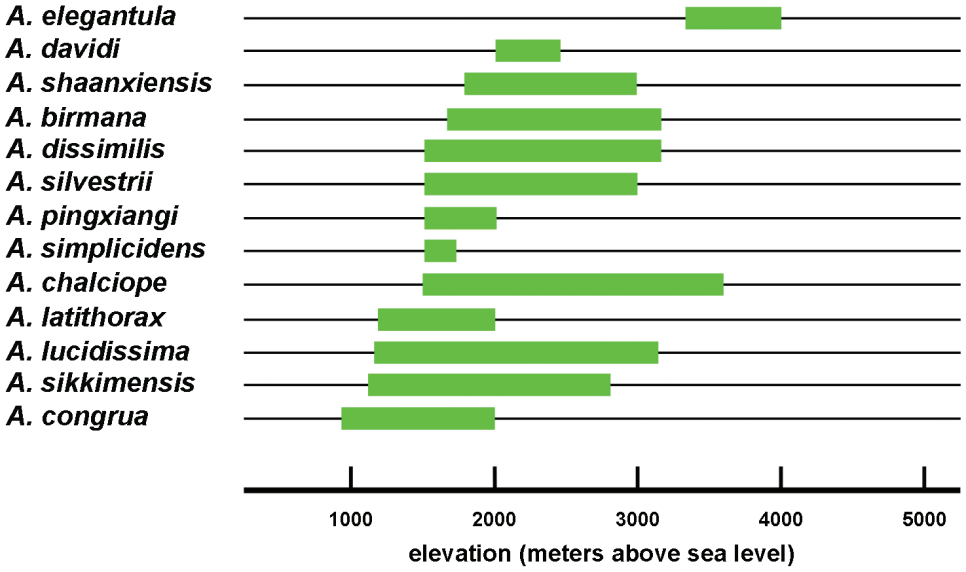


Figure 29. Chart illustrating the altitudinal ranges of *Amara* species represented in the Gaoligong Shan region.

both geographically (Core Areas 3–7) and altitudinally (from 1185 to 3140 m); and because it has been locally abundant wherever it has been found, the absence of records from the northern Core Areas (1 and 2) is significant. Similarly, *Amara birmana*

has been recorded only from the southern half of the study area (Core Areas 4-7), at elevations ranging from 1590 to 3150 m, and this is likely a true measure of its actual distribution in the region. Two species, *A. elegantula* and *A. latithorax*, have been recorded only from the northern part of the study area (in Core Areas 1 and 2 and 1-3, respectively). However, these two differ markedly in their altitudinal ranges, with *A. latithorax* recorded at elevations ranging from about 1200 to 2000 m and *A. elegantula* found only at elevations ranging from 3350 to at least 4000 m. For *A. elegantula*, a geographical range restricted to the north is expected, given its restricted high-elevation altitudinal range and the physiography of the study area, with virtually all contiguous areas above 3300 m found in the north. However, we find the restricted northern distribution of *A. latithorax* surpising, given that its altitudinal range requirements seemingly could be met virtually anywhere along the length of the Gaoligong Shan. The remaining species, *A. simplicidens*, has been recorded only from Core Area 6 in the southwestern part of the study area and only at relatively low elevations (from 1515 to 1740 m). This is somewhat surprising given that the overall geographical range of this species is so large, extended eastward all the way to Japan and the Russian Far East.

A comparison of recorded diversity for *Amara* species among the seven Core Areas (Fig. 28) shows that all areas are occupied by at least five species, with highest diversity in Core Area 6 (with 11 of the 13 species), second highest in Core Area 2 (with 9 species) and lowest recorded diversity in Core Area 4 (which is also by far the smallest Core Area). Core Areas 1 and 2 uniquely share one species, *A. elegantula*, and Core Areas 1-3 together are uniquely occupied two species (*A. elegantula* and *A. latithorax*). Core areas 3-7 together are uniquely occupied by three species, *A. birmana*, *A. lucidissima* and *A. simplicidens*; and Core Areas 4-7 together uniquely include two of these, *A. birmana* and *A. simplicidens*. Only Core Area 6 has a species, namely *A. simplicidens*, not shared with any other Core Area. Consequently, but perhaps not surprisingly, the northern and southern extremes of the study area (Core Areas 1 and 2 in the north and 4-7 in the south) have the most distinctive *Amara* faunas, with Core Area 3 apparently representing a region of faunal transition.

With respect to the altitudinal distribution of the *Amara* fauna of the study area (Fig. 29), several points can be made. Highest species diversity is concentrated at about 2000 m in elevation, with 11 of the 13 species recorded from that elevation. Only *A. elegantula* and *A. simplicidens* do not occur at that elevation, the former only far above that level, the latter only below it. Three species, *A. congrua*, *A. latithorax* and *A. pingshiangi* reach their upper altitudinal limit at about this level, and one, *A. davidi*, reaches its lower limit. The altitudinal ranges of only four species (*A. congrua*, *A. latithorax*, *A. lucidissima* and *A. sikkimensis*) extend below about 1200 m, and those of only two species (*A. chalciope* and *A. elegantula*) include areas above 3200 m. It could be quite informative to monitor future changes in the altitudinal ranges of these species with respect to the baseline data recorded here as one measure of climate change.

Syntopy of species in the regional fauna. Because virtually all *Amara* species prefer habitats that are open and more or less disturbed, either by natural processes or through human activities, and because there is so much overlap in both the geo-

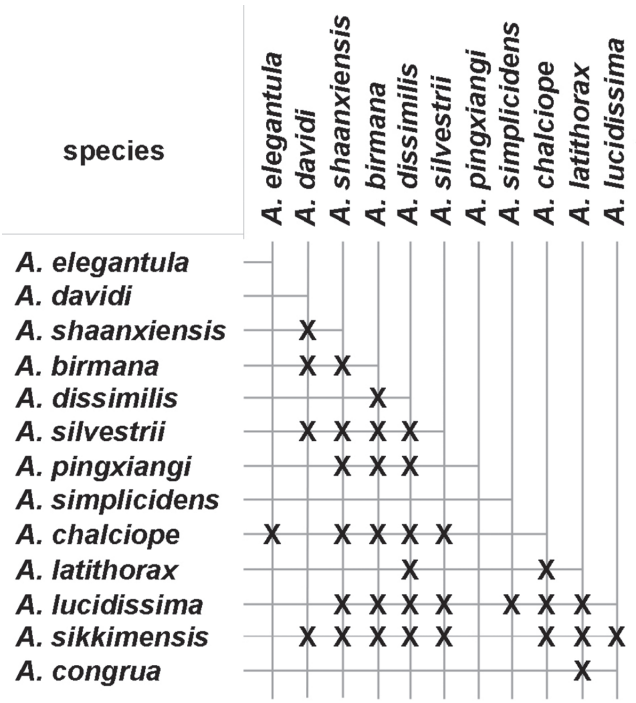


Figure 30. Chart illustrating the co-occurence (syntopy) of *Amara* species in samples from the same habitats and at the same sites in the Gaoligong Shan region.

graphical and altitudinal ranges of species represented in the study area, it is not at all surprising to find that specimens of several different species can be found together at the same site in the same habitat (i.e., syntopic). This co-occurrence of species at sites in the region is summarized in Fig. 30. During fieldwork for this project, it was not uncommon to find several species, up to seven in at least one instance, together at the same time at the site. Four species, *A. birmana*, *A. chalciope*, *A. lucidissima* and *A. sikkimensis*, have been recorded syntopic with eight other species in one or more sites; three species, *A. dissimilis, A. shaanxiensis* and *A. silvestrii*, have been found syntopic with seven other species; and *A. davidi*, *A. latithorax* and *A. pingshiangi* have been recorded syntopic with four, five and three other species each, respectively. Members of these ten species are often found together, in various combinations, at different sites in the study area, although not one of them co-occurs with all the others. By contrast, three species have been found syntopic with just one other species. *Amara congrua* adults have been found together with those of *A. latithorax* one time (in Shanga, Fugong County). Members of *A. simplicidens* have been found just once with those of *A. lucidissima* (near Datang Village, Tengchong County). Finally, adults of *A. elegantula* have been found twice with those of *A. chalciope* twice, both at sites around Heipu Yakou (Pass) on the Gongshan-Dulong Road at an elevation of 3365 m, where the altitudinal ranges of these species overlap narrowly. It is possible that *A. congrua* and

A. simplicidens will be found co-occurring more broadly with the same species or with other species in the future because the geographical and/or altitudinal ranges of each are within the ranges of other species, whereas the restricted geographical and altitudinal ranges of *A. elegantula* should preclude any but the already observed co-occurrence with *A. chalciope*.

In the future, it will be interesting to compare and contrast both the broad and regional geographical distributions and the altitudinal and ecological range patterns seen in other carabid groups represented in the area with those found among the *Amara* species and reported here.

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Phylogenetic relationships of Malaysia's long-tailed macaques, *Macaca fascicularis*, based on cytochrome *b* sequences

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Abstract

Phylogenetic relationships among Malaysia's long-tailed macaques have yet to be established, despite abundant genetic studies of the species worldwide. The aims of this study are to examine the phylogenetic relationships of *Macaca fascicularis* in Malaysia and to test its classification as a morphological subspecies. A total of 25 genetic samples of *M. fascicularis* yielding 383 bp of Cytochrome *b* (Cyt *b)* sequences were used in phylogenetic analysis along with one sample each of *M. nemestrina* and *M. arctoides* used as outgroups. Sequence character analysis reveals that Cyt *b* locus is a highly conserved region with only 23% parsimony informative character detected among ingroups. Further analysis indicates a clear separation between populations originating from different regions; the Malay Peninsula versus Borneo Insular, the East Coast versus West Coast of the Malay Peninsula, and the island versus mainland Malay Peninsula populations. Phylogenetic trees (NJ, MP and Bayesian) portray a consistent clustering paradigm as Borneo's population was distinguished from Peninsula's population (99% and 100% bootstrap value in NJ and MP respectively and 1.00 posterior probability in Bayesian trees). The East coast population was separated from other Peninsula populations (64% in NJ, 66% in MP and 0.53 posterior probability in Bayesian). West coast populations were divided into 2 clades: the North-South (47%/54% in NJ, 26/26%

in MP and 1.00/0.80 posterior probability in Bayesian) and Island-Mainland (93% in NJ, 90% in MP and 1.00 posterior probability in Bayesian). The results confirm the previous morphological assignment of 2 subspecies, *M. f. fascicularis* and *M. f. argentimembris*, in the Malay Peninsula. These populations should be treated as separate genetic entities in order to conserve the genetic diversity of Malaysia's *M. fascicularis*. These findings are crucial in aiding the conservation management and translocation process of *M. fascicularis* populations in Malaysia.

Keywords
Long-tailed macaque, *Macaca fascicularis*, Cytochrome *b*, phylogenetic relationships

Introduction

Macaca fascicularis (Raffles, 1821) is also known as long-tailed, crab-eating or cynomolgus macaque. This species is well distributed in the countries of Malaysia, Brunei, Bangladesh, Cambodia, Nicobar Islands, Indonesia, Lao PDR, Myanmar, Philippines, Singapore, Thailand, Timor-Leste and Vietnam (Figure 1) (Gumert et al. 2011). There appears to be a hybrid zone between *M. fascicularis* and *M. mulatta* (Zimmermann, 1780) in the northern range above mainland Southeast Asia, which makes it difficult to determine the northern distribution limit of *M. fascicularis* (Fooden, 1996). The distribution of long-tailed macaques was extended to the Pacific Ocean (Palau) (Crombie and Pregill 1999), Indian Ocean (Mauritius) (Trask et al. 2013) and New Guinea (Kemp and Burnett 2003) due to human-mediated introduction of the species to these respective regions in the recent past.

At least 10 subspecies of *M. fascicularis* are presently recognized; *M. f. atriceps* (Kloss, 1919), *M. f. aurea* (Geoffroy, 1831), *M. f. condorensis* (Kloss, 1926), *M. f. fascicularis* (Raffles, 1821), *M. f. fusca* (Miller, 1903), *M. f. karimondjawae* (Sody, 1949), *M. f. lasiae* (Lyon, 1916), *M. f. philippinensis* (Geoffroy, 1843), *M. f. tua* (Kellog, 1944) and *M. f. umbrosa* (Miller, 1902) (Groves 2001; Brandon-Jones et al. 2004) based on their morphological characteristics. These subspecies classifications were distinguished based on three critical aspects: tail length, pelage coloration and form of the cheek whiskers (Groves 2001). Both Groves (2001) and Brandon-Jones et al. (2004) agreed that only one subspecies, *M. f. fascicularis*, is distributed in Peninsula Malaysia and Borneo. Medway (1969), on the other hand, has acknowledged 3 subspecies of *M. fascicularis* distributed in Malaysia, specifically, *M. f. fascicularis* (Raffles, 1821) (Peninsula Malaysia); *M. f. argentimembris* (Kloss, 1911) (Redang Island) and *M. f. laeta* (Elliot, 1909) (Tioman Island and Tinggi Island). Raven (1935) acknowledged *M. f. argentimembris* by Kloss, 1911 observed in Redang Island as subspecies distributed in East Coast of Peninsula Malaysia. Weitzel et al. (1988) also acknowledged the distribution of *M. f. laeta* by Elliot (1909) observed in Tioman Island and Tinggi Island as subspecies distributed in the East Coast of Peninsula Malaysia.

Zhang et al. (1993) conducted one of the earliest thorough studies on the phylogeny of *M. fascicularis* that exploited mitochondrial DNA (mtDNA) using restriction endonuclease analysis. Smith et al. (2007) studied mtDNA variation within and among

Figure 1. Distribution of the long-tailed macaque (*M. fascicularis*) in Southeast Asia (Gumert et al. 2011).

regional populations of *M. fascicularis* by applying an astonishing 1053 samples comprising 5 regional populations (Malaysia, Indonesia, Indochina, the Philippines and Mauritius). Deinard and Smith (2001) screened the nuclear DNA sequences (natural resistance-associated macrophage protein 1, *NRAMP1*) of 59 individuals representing 11 species of macaques, and their results suggest that *M. fascicularis* may not be as primitive as the mtDNA data suggests. Numerous other genetic studies on *M. fascicularis* have been conducted. Tosi et al. (2002) determined the introgression between *M. fascicularis* and *M. mulatta* using Y-chromosome and mitochondrial markers. Otting et al. (2009) studied the haplotypes in pedigreed cynomolgus macaques. Street et al. (2007) analyzed the nucleotide polymorphisms in *M. mulatta* and *M. fascicularis*. Blancher et al. (2008) described the phylogeny of 4 populations of *M. f. fascicularis* (Indonesia, Indochina, Philippines and Mauritius). Stevison and Kohn (2009) conducted genetic analysis to determine hybridization between rhesus and long-tailed macaques. Finally, Md-Zain et al. (2010a) determined the phylogenetic relationships of Cercopithecidae using *M. fascicularis* as a representative.

Despite the abundance of genetic studies on or including *M. fascicularis*, the phylogenetic relationships among Malaysia's long-tailed macaques remain uncertain.

However, these phylogenetic data are crucial for conservation management of *M. fascicularis* as this species is reported as a pest in human settlement areas (Md-Zain et al. 2010b; 2011). For example, *M. fascicularis* engages frequently in crop-raiding activities, and these behaviors are often reinforced by humans that feed these macaques either directly or indirectly, which leads to unintentional habituation of the species. The annual report by the Department of Wildlife and National Parks (PERHILITAN) (2010) indicated that *M. fascicularis* is at the top of the human-wildlife conflict species case list. From a recorded 9,286 complaints of wildlife disturbance from various species, complaints on *M. fascicularis* disturbance were the highest, with 5,930 complaints (63.86%). The phylogenetic relationships of Malaysia's *M. fascicularis* data are crucial in planning and executing the translocation process of this species in the future, which is one of the major actions in the conservation management and human-wildlife conflict management of the species. By understanding the phylogenetic relationships of Malaysia's crab-eating macaque, the plan for translocation the species can finally be carried out without a risk of losing important genetic diversity or even unique genetic lineages of the species.

Phylogenetic studies at the subspecies level are very scarce (Rosli et al. 2014), as many primatologists are making the species group classifications the focal point in their studies. Both Vun et al. (2011) and Blancher et al. (2008) have successfully explained the phylogenetic relationships of *Presbytis* and *M. fascicularis*, respectively, at population level using Cyt *b* sequences, proving that Cyt *b* is a suitable locus for population level studies of Cercopithecidae. Thus, the objectives of this research are to determine the phylogenetic relationships of Malaysia's *M. fascicularis* using mitochondrial Cyt *b* sequences and to test genetically the subspecies classifications as made by Medway (1969), Groves (2001) and Brandon-Jones et al. (2004) based on morphological characteristics.

Methods

DNA extraction, polymerase chain reaction (PCR) and sequencing

Altogether, 27 genetic samples (Table 1 and Figure 2) were used in this research. These samples were provided by the Department of Wildlife and National Parks (PERHILITAN) and Sabah Parks. The samples derive mainly from feces collected in the original habitats of *M. fascicularis*. In addition, blood and tissue samples collected from a roadkill specimen of *M. fascicularis* were also used in this study. Mitochondrial DNA (mtDNA) was extracted from each genetic sample using QIAGEN DNeasy Blood and Tissue Kit, following the manufacturer's protocol. A mtDNA genome from FTA (fast technology for analysis of nucleic acids) sample was extracted using the WHATMAN® GenSolve Recovery Kit, also following the manufacturer's protocol. DNA was extracted from 0.5 g – 1.0 g of fecal sample using innuPREP Stool DNA kit (Analytik Jena) following the manufacturer's protocol.

Table 1. Details on the samples used in this study

No.	Sample name	Taxon	Locality
1	MF135	*Macaca fascicularis fascicularis*	Port Dickson, Negeri Sembilan
2	MF136	*Macaca fascicularis fascicularis*	Port Dickson, Negeri Sembilan
3	MF137	*Macaca fascicularis fascicularis*	Port Dickson, Negeri Sembilan
4	MF138	*Macaca fascicularis fascicularis*	Port Dickson, Negeri Sembilan
5	M1	*Macaca fascicularis fascicularis*	Bangi, Selangor
6	BM95	*Macaca fascicularis fascicularis*	Kluang, Johor
7	MF488	*Macaca fascicularis fascicularis*	Tanjung Tokong. Pulau Pinang
8	MF489	*Macaca fascicularis fascicularis*	Tanjung Tokong. Pulau Pinang
9	MF490	*Macaca fascicularis fascicularis*	Tanjung Tokong. Pulau Pinang
10	MF491	*Macaca fascicularis fascicularis*	Tanjung Tokong. Pulau Pinang
11	MF719	*Macaca fascicularis fascicularis*	Pantai Remis, Perak
12	MF720	*Macaca fascicularis fascicularis*	Pantai Remis, Perak
13	MF721	*Macaca fascicularis fascicularis*	Pantai Remis, Perak
14	MF722	*Macaca fascicularis fascicularis*	Pantai Remis, Perak
15	ALMFD16	*Macaca fascicularis fascicularis*	Pasir Mas, Kelantan
16	ALMFD17	*Macaca fascicularis fascicularis*	Pasir Mas, Kelantan
17	ALMFD28	*Macaca fascicularis fascicularis*	Pasir Mas, Kelantan
18	ALMFD29	*Macaca fascicularis fascicularis*	Pasir Mas, Kelantan
19	ALMFA62	*Macaca fascicularis fascicularis*	Kuala Gula, Perak
20	ALMFA63	*Macaca fascicularis fascicularis*	Kuala Gula, Perak
21	ALMFA64	*Macaca fascicularis fascicularis*	Kuala Gula, Perak
22	ALMFA65	*Macaca fascicularis fascicularis*	Kuala Gula, Perak
23	MF03	*Macaca fascicularis fascicularis*	Pulau Sapi, Sabah
24	MF04	*Macaca fascicularis fascicularis*	Pulau Sapi, Sabah
25	MF05	*Macaca fascicularis fascicularis*	Pulau Sapi, Sabah
26	BM97	*Macaca nemestrina*	Zoo Taiping, Perak
27	BM104	*Macaca arctoides*	Malacca Zoo

Figure 2. Sampling location of *M. fascicularis* throughout Peninsula Malaysia and Borneo.

Polymerase Chain Reaction (PCR) was employed in order to amplify the targeted locus in the mtDNA genome, which is a partial fragment of the Cyt *b* gene, by using Mastercycler® nexus (Eppendorf North America, Inc.). PCR was performed by using

Phusion™ Flash High-Fidelity PCR Master Mix (Finnzymes, OY), which has extreme speed (extension times of 15 s/kb or less), high accuracy (proofreads DNA polymerase with a fidelity of 25 X *Taq polymerase*) and a very high yield in reduced times. Primers used in this study were (L14724) 5'- CGAAGCTTGATATGAAAAACCATCGTTG -3' (Pääbo and Wilson 1988) and (H15149) 5'- AAACTGCAGCCCCTCAGAAT-GATATTTGTCCTCA - 3' (Kocher et al. 1989). PCR reactions were carried out under the following parameters: 98°C initial denaturation for 30 seconds, followed by 30 cycles of 98°C denaturation for 10 seconds, 55°C of annealing for 30 seconds, 72°C extension for 30 seconds and the final extension stage at 72°C for 10 minutes. The PCR product was purified using the Vivantis G-F1 PCR Clean-up Kit, and the purified PCR products were sent to the 1st Base Laboratories Sdn Bhd (Malaysia) for sequencing.

Sequence and phylogenetic analysis

Sequence results obtained from the 1st Base Laboratories Sdn Bhd were proofread and edited using Bioedit Sequence Alignment Editor, and the Sequence Similarity searches were performed using GenBank BLASTn application to validate the DNA sequences obtained. DNA sequences were submitted to GenBank under accession number KJ592589-KJ592594. Bioedit's ClustalW multiple alignment algorithm was then used to align the sequence results, and sequence analysis and phylogenetic analysis were performed. DNASP 4.0 (Rozas et al. 2003), PAUP 4.0b10 (Swofford 2002) and MEGA version 4.0 (Tamura et al. 2007) software were used for sequence analysis to determine nucleotide diversity (π) and net nucleotide divergence (Da); genetic distance and single nucleotide polymorphisms (SNPs) of the sequences/datasets respectively.

Three methods of phylogenetic tree reconstructions were carried out; the distance-based method (*neighbor joining*, NJ) using MEGA version 4.0 (Tamura et al. 2007); the character-based method (*maximum parsimony*, MP) using Phylogenetic Analysis Using Parsimony (PAUP) version 4.0b10 (Swofford 2002) and Bayesian inference using MrBayes 3.1 (Huelsenbeck and Ronquist 2001). The Kimura-2-Parameter model was selected for NJ phylogenetic reconstructions. MP phylogenetic tree was carried out with heuristic search methods and 1000 random stepwise addition with the application of a 50% consensus-majority rule concept (Swofford 2002). In the MP analysis, each transition and transversion was calculated on average. The MP phylogenetic tree was constructed using a tree bisection and reconnection (TBR) algorithm, and all the trees constructed underwent 1000 bootstrap replications to obtain the bootstrap confidence level.

Modeltest version 3.7 software (Posada and Crandall 1998) was used to select the best substitution model for the partial Cyt *b* sequences using Akaike Information Criterion (AIC). The best substitution model was applied in the Bayesian analysis using MrBayes 3.1.2. software. The most suitable model that fit the data was the HKY+G model with a gamma shape parameter of 0.5455 and base frequencies of 0.2866 for A, 0.3171 for C, 0.1266 for G and 0.2696 for T. We ran Metropolis-coupled Markov Chain Monte Carlo (MCMC) with 300000 generations, with 0.008214 Split Fre-

quencies Probability (P) and tree was sampled every 10 generations. The first 25% of the trees obtained in the analysis was discarded as burn-in (7500 trees discarded from total 30000 trees), a majority-rule consensus of remaining trees was constructed and posterior probabilities (PP) were summarized for each branch.

Results

Comparison of the cytochrome *b* sequence of Malaysia's *M. fascicularis* with GenBank's sequence

Partial sequences of Cyt *b* locus in size of 383 bp were successfully sequenced for all 27 genetic samples (Table 1). The first analysis conducted on the sequences consisted of sequence similarity searches using the GenBank application to validate each sequence obtained was from the correct taxon of the acquired samples and to avoid encountering the data problem of nuclear insertion. All genetic samples matched the target species sequences in GenBank with samples FJ906803.1 (*M. fascicularis* complete genome) and corresponded to most of the ingroup samples with average query cover and maximum identities scores at 95% and 97%, respectively.

Sequence polymorphism, genetic distance and nucleotide diversity

A total of 27 genetic sequences in a size of 383 bp of Cyt *b* locus yielded 78 (20.37%) variable sites, of which 34 sites were parsimony informative characters (8.88%). Interestingly, when outgroup samples (*M. nemestrina* and *M. arctoides*) were excluded from the analysis, only 23 (6%) variable sites were detected, all of which were parsimony informative characters. From these 23 informative characters, 13 were generated by the inclusion of Borneo samples in the analysis; whereas, if the Borneo samples were excluded, only 10 (2.6%) parsimony informative characters were detected.

Pairwise genetic distances of Cyt *b* partial sequences were calculated with PAUP 4.0b10 (Swofford 2002) using the Kimura-2-Parameter model (Table 2). The genetic distance of samples originating from Borneo and Peninsula Malaysia showed a minimum genetic distance of 0.04068 (BM95) and a maximum value as high as 0.049 (ALMFA62, ALMFA63, ALMFA64 and ALMFA65), which is the highest value within the *M. fascicularis* genetic distance analysis. The genetic distance of samples originating from the East Coast of Peninsula Malaysia and West Coast of Peninsula Malaysia (excluding samples from Borneo) showed the minimum value of genetic distance was 0.008 (BM95), and the maximum value was 0.016 (ALMFA62, ALMFA63, ALMFA64 and ALMFA65). The separation of the island population of *M. fascicularis* and the mainland of Peninsula Malaysia populations (excluding samples from Borneo) showed a minimum value of genetic distance of 0.008 (MF719, MF720, MF721 and MF722) and a maximum value of genetic distance of 0.016 (MF135, MF136, MF137 and MF138 and M1).

Table 2. Pairwise distance of *Macaca fascicularis* samples based on Kimura-2-Parameter algorithm model.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	MF03 Mf Sabah	-													
2	MF04 Mf sabah	0.00000	-												
3	MF05 Mf Sabah	0.00000	0.00000	-											
4	BM95 Mf Johor	0.04068	0.04068	0.04068	-										
5	MF135 Mf NSembil	0.04636	0.04636	0.04636	0.00525	-									
6	MF136 Mf Nsembil	0.04636	0.04636	0.04636	0.00525	0.00000	-								
7	MF137 Mf Nsembil	0.04636	0.04636	0.04636	0.00525	0.00000	0.00000	-							
8	MF138 Mf Nsembi	0.04636	0.04636	0.04636	0.00525	0.00000	0.00000	0.00000	-						
9	M1 Mf Selangor	0.04636	0.04636	0.04636	0.00525	0.00000	0.00000	0.00000	0.00000	-					
10	MF719 Mf Perak	0.04351	0.04351	0.04351	0.00262	0.00789	0.00789	0.00789	0.00789	0.00789	-				
11	MF720 Mf Perak	0.04351	0.04351	0.04351	0.00262	0.00789	0.00789	0.00789	0.00789	0.00789	0.00000	-			
12	MF721 Mf Perak	0.04351	0.04351	0.04351	0.00262	0.00789	0.00789	0.00789	0.00789	0.00789	0.00000	0.00000	-		
13	MF722 Mf Perak	0.04351	0.04351	0.04351	0.00262	0.00789	0.00789	0.00789	0.00789	0.00789	0.00000	0.00000	0.00000	-	
14	ALMFA65 Mf Perak	0.04923	0.04923	0.04923	0.00789	0.01323	0.01323	0.01323	0.01323	0.01323	0.00525	0.00525	0.00525	0.00525	-
15	ALMFA64 Mf Perak	0.04923	0.04923	0.04923	0.00789	0.01323	0.01323	0.01323	0.01323	0.01323	0.00525	0.00525	0.00525	0.00525	0.00000
16	ALMFA63 Mf Perak	0.04923	0.04923	0.04923	0.00789	0.01323	0.01323	0.01323	0.01323	0.01323	0.00525	0.00525	0.00525	0.00525	0.00000
17	ALMFA62 Mf Perak	0.04923	0.04923	0.04923	0.00789	0.01323	0.01323	0.01323	0.01323	0.01323	0.00525	0.00525	0.00525	0.00525	0.00000
18	MF488 Mf P.Pinan	0.04636	0.04636	0.04636	0.01055	0.01592	0.01592	0.01592	0.01592	0.01592	0.00789	0.00789	0.00789	0.00789	0.01323
19	MF489 Mf P.Pinan	0.04636	0.04636	0.04636	0.01055	0.01592	0.01592	0.01592	0.01592	0.01592	0.00789	0.00789	0.00789	0.00789	0.01323
20	MF490 Mf P.Pinan	0.04636	0.04636	0.04636	0.01055	0.01592	0.01592	0.01592	0.01592	0.01592	0.00789	0.00789	0.00789	0.00789	0.01323
21	MF491 Mf P.Pinan	0.04636	0.04636	0.04636	0.01055	0.01592	0.01592	0.01592	0.01592	0.01592	0.00789	0.00789	0.00789	0.00789	0.01323
22	ALMFD16 Mf Kelan	0.03786	0.03786	0.03786	0.00789	0.01323	0.01323	0.01323	0.01323	0.01323	0.01055	0.01055	0.01055	0.01055	0.01592
23	ALMFD17 Mf Kelan	0.03786	0.03786	0.03786	0.00789	0.01323	0.01323	0.01323	0.01323	0.01323	0.01055	0.01055	0.01055	0.01055	0.01592
24	ALMFD28 Mf Kelan	0.03786	0.03786	0.03786	0.00789	0.01323	0.01323	0.01323	0.01323	0.01323	0.01055	0.01055	0.01055	0.01055	0.01592
25	ALMFD29 Mf Kelan	0.03786	0.03786	0.03786	0.00789	0.01323	0.01323	0.01323	0.01323	0.01323	0.01055	0.01055	0.01055	0.01055	0.01592
26	BM104 Ma Malacca	0.11558	0.11558	0.11558	0.11914	0.12574	0.12574	0.12574	0.12574	0.12574	0.12243	0.12243	0.12243	0.12243	0.12907
27	BM97 Mn ZooTaipi	0.11753	0.11753	0.11753	0.13751	0.14426	0.14426	0.14426	0.14426	0.14426	0.14087	0.14087	0.14087	0.14087	0.14087

Table 2. Continue.

		15	16	17	18	19	20	21	22	23	24	25	26	27
1	MF03 Mf Sabah													
2	MF04 Mf sabah													
3	MF05 Mf Sabah													
4	BM95 Mf Johor													
5	MF135 Mf NSembil													
6	MF136 Mf Nsembil													
7	MF137 Mf Nsembil													
8	MF138 Mf Nsembi													
9	M1 Mf Selangor													
10	MF719 Mf Perak													
11	MF720 Mf Perak													
12	MF721 Mf Perak													
13	MF722 Mf Perak													
14	ALMFA65 Mf Perak													
15	ALMFA64 Mf Perak	-												
16	ALMFA63 Mf Perak	0.00000	-											
17	ALMFA62 Mf Perak	0.00000	0.00000	-										
18	MF488 Mf P.Pinan	0.01323	0.01323	0.01323	-									
19	MF489 Mf P.Pinan	0.01323	0.01323	0.01323	0.00000	-								
20	MF490 Mf P.Pinan	0.01323	0.01323	0.01323	0.00000	0.00000	-							
21	MF491 Mf P.Pinan	0.01323	0.01323	0.01323	0.00000	0.00000	0.00000	-						
22	ALMFD16 Mf Kelan	0.01592	0.01592	0.01592	0.01323	0.01323	0.01323	0.01323	-					
23	ALMFD17 Mf Kelan	0.01592	0.01592	0.01592	0.01323	0.01323	0.01323	0.01323	0.00000	-				
24	ALMFD28 Mf Kelan	0.01592	0.01592	0.01592	0.01323	0.01323	0.01323	0.01323	0.00000	0.00000	-			
25	ALMFD29 Mf Kelan	0.01592	0.01592	0.01592	0.01323	0.01323	0.01323	0.01323	0.00000	0.00000	0.00000	-		
26	BM104 Ma Malacca	0.12907	0.12907	0.12907	0.12574	0.12574	0.12574	0.12574	0.10940	0.10940	0.10940	0.10940	-	
27	BM97 Mn ZooTaipi	0.14087	0.14087	0.14087	0.13751	0.13751	0.13751	0.13751	0.13416	0.13416	0.13416	0.13416	0.14702	-

Table 3. Measures of nucleotide diversity (π) and net nucleotide divergence among populations of *M. fascicularis* analyzed by locality.

Locality	Nucleotide Diversity (π)	Net nucleotide divergence (Da)
Sabah-Johor	0.01958	0.03916
Sabah-Negeri Sembilan	0.02536	0.04439
Sabah-Selangor	0.02219	0.04439
Sabah-Perak	0.02089	0.04289
Sabah-Pulau Pinang	0.02536	0.04439
Sabah-Kelantan	0.02089	0.03655
Johor-Negeri Sembilan	0.00209	0.00522
Johor-Selangor	0.00522	0.00522
Johor-Perak	0.00348	0.00373
Johor-Pulau Pinang	0.00418	0.01044
Johor-Kelantan	0.00313	0.00783
Negeri Sembilan-Selangor	0.00000	0.00000
Negeri Sembilan-Perak	0.00633	0.00895
Negeri Sembilan-Pulau Pinang	0.00895	0.01567
Negeri Sembilan-Kelantan	0.00746	0.01305
Selangor-Perak	0.00464	0.00895
Selangor-Pulau Pinang	0.00627	0.01567
Selangor-Kelantan	0.00522	0.01305
Perak-Pulau Pinang	0.00633	0.00895
Perak-Kelantan	0.00760	0.01156
Pulau Pinang-Kelantan	0.00746	0.01305

Table 4. Measures of nucleotide diversity (π) and net nucleotide divergence among populations of *M. fascicularis* analyzed by regions.

Regions	Nucleotide Diversity (π)	Net nucleotide divergence (Da)
Peninsula Malaysia-Borneo	0.01666	0.03801
East Coast-West Coast	0.00943	0.00865
Mainland-Island	0.00823	0.00918

Nucleotide diversity (π) and net nucleotide divergence (Da) were also calculated for the Cyt *b* sequence obtained using DnaSP v4.0. Two separate analyses for π and Da were conducted based on the origin of samples, by first sorting the sequences (excluding outgroup) according to their locality (states) (Table 3) and then according to regions (Table 4). The first analysis (Table 3) portrayed that π was the highest between Sabah and other states ranging from 0.019 to 0.025, and the results are consistent with Da, ranging from 0.037 to 0.044. π. The lowest values, 0 for π and Da, were found between Negeri Sembilan and Selangor. The second analysis (Table 4) revealed that the Peninsula Malaysia and Borneo populations have 0.017 π and 0.038 Da, which are the highest compared to other regions; the East Coast of Peninsula Malaysia and West Coast of Peninsula Malaysia populations have 0.09 π and 0.08 Da and mainland and island populations have 0.08 π and 0.09 Da, respectively.

Phylogenetic trees

Neighbor joining

The NJ phylogeny tree (Figure 3) was generated using Kimura-2-Parameter with 1000 bootstrap replication. The NJ phylogenetic tree showed that samples originating from Borneo remain monophyletic from samples originating from Peninsula Malaysia, supported with 99% bootstrap value. Samples from Peninsula Malaysia were divided into 2 clades; clade A and Clade B. Clade A portrays the separation of samples originating from the East Coast of Peninsula Malaysia from the remaining samples with 64% bootstrap value. Clade B on the other hand is the assemblage of populations of the West Coast of Peninsula Malaysia, supported by 90% bootstrap value. Within Clade B, two further clades were defined, namely island population (Pulau Pinang) and mainland populations (Perak, Negeri Sembilan, Johor, and Selangor) supported by 93% and

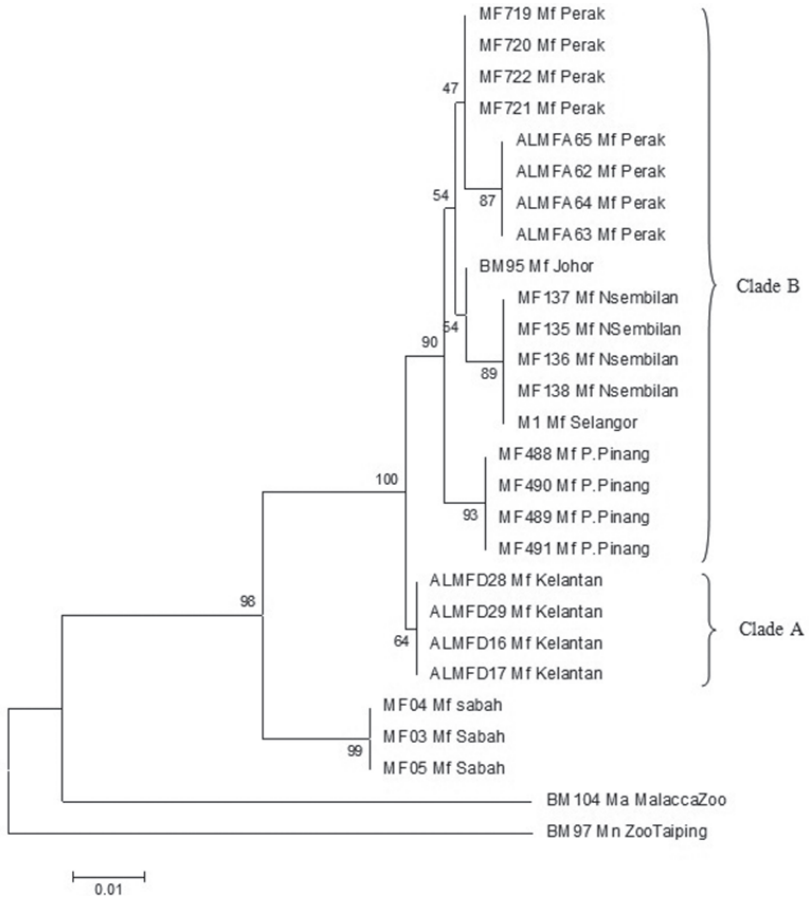

Figure 3. *Neighbor joining* phylogenetic tree using Kimura-2-Parameter algorithm with bootstrap values indicated on the branch.

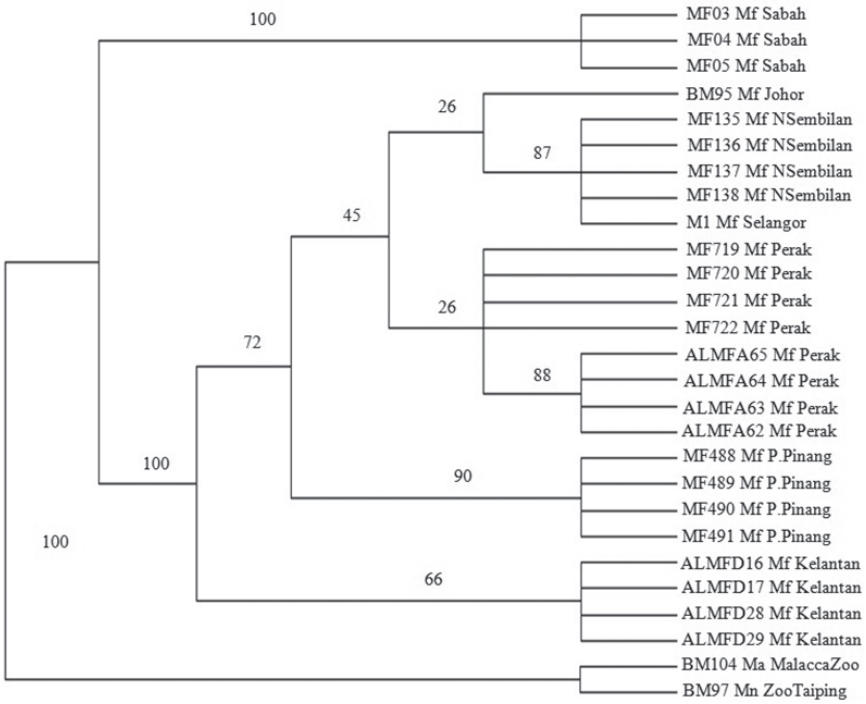

Figure 4. The Bootstrap 50% majority rule consensus maximum parsimony tree of *M. fascicularis* populations. Bootstrap values are indicated on the branch.

54% bootstrap value respectively. Populations from southern Peninsula (Negeri Sembilan, Johor and Selangor) and northern Peninsula (Perak) also were distinguished by 54% and 47% bootstrap value correspondingly.

Maximum parsimony

MP (Figure 4) analysis was conducted using PAUP 4.0 (CI = 0.929, HI = 0.071, RI = 0.944, RC = 0.878 and tree length = 85). *M. fascicularis* populations were separated into 2 main clades, a Borneo clade and a Peninsula Malaysia clade both supported by 100% bootstrap value in the MP tree. Peninsula Malaysia's population was further divided into 2 sub clades, the East Coast of Peninsula Malaysia and West Coast of Peninsula Malaysia populations supported by 66% and 72% bootstrap value respectively. The West Coast of Peninsula Malaysia populations were further divided into 2 clades, comprising the mainland and island populations (Pulau Pinang) supported by 45% and 90% bootstrap value. The Northern Peninsula (Perak) and Southern Peninsula (Selangor, Negeri Sembilan and Johor) clades were also separated, both supported by 26% bootstrap value.

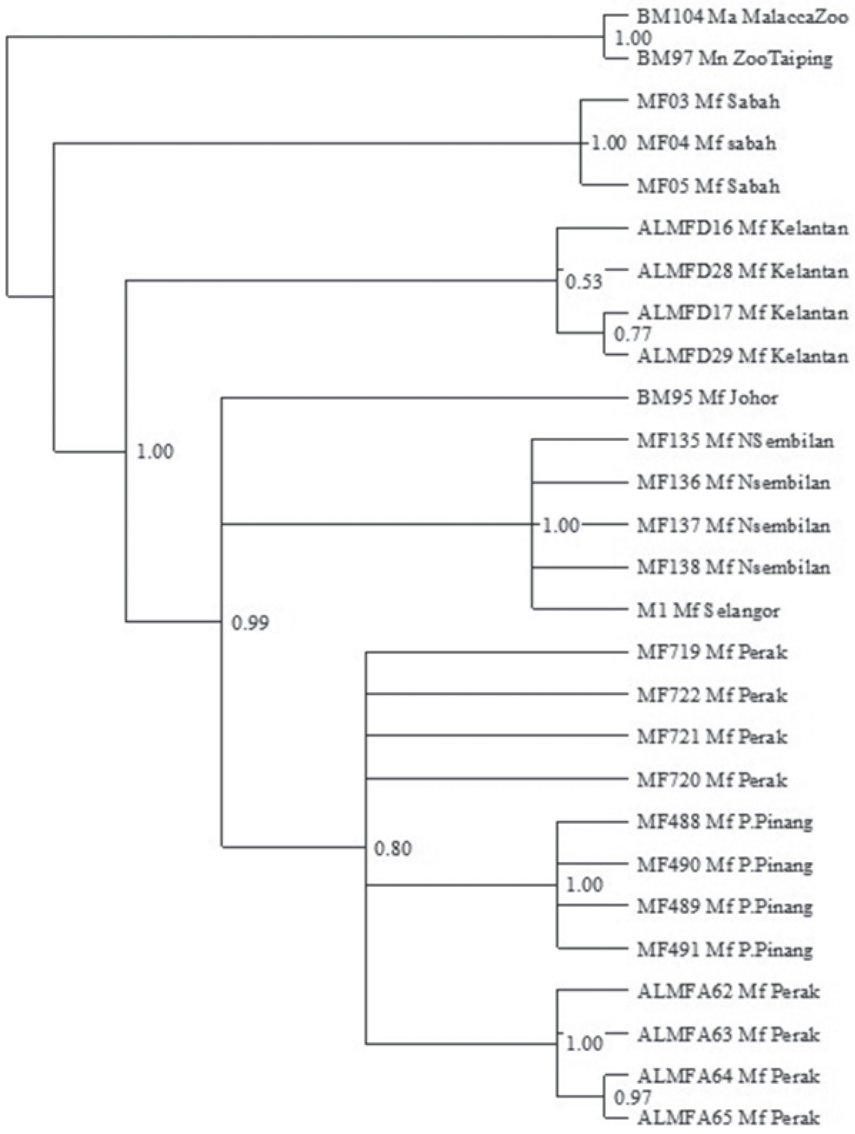

Figure 5. Bayesian inference of the 50% majority rule consensus tree of Cyt *b* sequence of *M. fascicularis* populations with Bayesian posterior probability (PP) are accordingly indicated on the branch.

Bayesian inference

Bayesian inference phylogenetic tree (Figure 5) results are generally consistent with neighbor joining and maximum parsimony phylogenetic trees. Separations of *M. fascicularis* populations originating from Borneo and Peninsula Malaysia correspond well with other phylogenetic trees. Within *M. fascicularis* populations from Peninsula Malaysia, the East

Coast of Peninsula Malaysia populations are yet again separated from the West Coast of Peninsula Malaysia populations with 0.53 and 0.99 posterior probabilities respectively. The island populations (Pulau Pinang), on the other hand, seem to group together with other mainland populations from the West Coast of Peninsula Malaysia. These are thoroughly inconsistent with both neighbor joining and maximum parsimony phylogenetic trees. The populations from Negeri Sembilan, Selangor and Johor are also distinguished from *M. fascicularis* populations from Perak and Pulau Pinang, supported by a 1.00 and 0.80 posterior probability.

Discussion

Sequence analysis of partial Cyt *b* sequences indicates that this locus is highly conserved which yielded only 78 (20.37%) variable sites among which only 34 (8.88%) of parsimony informative characters across *M. fascicularis*, *M. nemestrina* and *M. arctoides.* Vun et al. (2011) reported 156 (40.21%) variable sites and 124 (31.96%) parsimony informative sites in the partial Cyt *b* gene (388 bp) across *Presbytis* and *Trachypithecus* (Colobinae). These findings are much higher compared to findings in this research, although analysis in this research was done within one genus while Vun et al. (2011) analyzed across 2 genera. Haus et al. (2013) analyzed 28.86% variable sites and 19.82% parsimony informative sites from full Cyt *b* sequences in *Chlorocebus*, which are parallel with our findings, indicating Cyt *b* is a highly conserved gene. Mitochondria are well known to play a central role in a variety of cellular processes and are the main source of adenosine triphosphate (ATP) (Kujoth et al. 2005). Cyt *b* is a functional gene that contains both redox centers, Q_0 and Q_i, involved in electron transfer (Hatefi 1985; Howell and Gilbert 1988). Thus, even a single point mutation that occurs in this region will probably have a deleterious effect on the functional response of the locus.

Macaca fascicularis populations in Malaysia are evidently divided into 2 main clusters: the Borneo populations and Peninsula Malaysia populations. Thirteen parsimony informative characters were detected between these populations from a total of 23 parsimony informative characters. Pairwise genetic distance analysis indicated that the genetic distance between these 2 populations was the highest as compared to other populations in Malaysia with a value of 0.041-0.049, aside from monophyletic states of both populations in all phylogenetic trees. These findings are highly anticipated, considering the vicariance theory on population disjunction as the central thesis. In this scenario, the Borneo populations and Peninsula Malaysia populations are separated by the South China Sea. This separation more than likely caused the interruption of gene flow between both populations, causing them to accrue the major genetic differences observed in this study.

Populations of *M. fascicularis* in Peninsula Malaysia also form 2 further subgroups: east and west. The population from Kelantan forms a single clade in all phylogenetic trees and genetic analysis in comparison to the rest of the Peninsula Malaysia populations. Thus, the Kelantan population likely represents a unique lineage as compared

to other populations from Peninsula Malaysia. Results obtained by Vun et al. (2011) that used the same primers as in this research to study the phylogenetic relationships of genus *Presbytis* in Malaysia provide a suitable comparison. Vun et al. (2011) obtained a pairwise genetic distance (Kimura-2-Parameter) between *Presbytis melalophos robinsoni* and *Presbytis melalophos siamensis* as low as 0.058, and each of these subspecies has uniquely distinct morphological characteristics. In comparison, the pairwise genetic distance observed here between *M. fascicularis* populations of East and West coast of Peninsula Malaysia are 0.016; however, there are no documented morphological characteristics that differentiate these populations.

The observed genetic differences between populations of *M. fascicularis* are best viewed as subspecies separations. *M. f. laeta* (Elliot, 1909) was recorded by Medway (1969) as common on Tioman Island (the East Coast of Peninsula Malaysia), but a survey conducted by the Department of Wildlife and Nature Park, Malaysia, PERHILITAN (1995) proved otherwise. This particular subspecies was observed based on morphological characters on the mainland East Coast of Peninsula Malaysia by PERHILITAN (1995) as well as Weitzel et al. (1988), whose study also acknowledged the distribution of *M. f. laeta* in the East Coast of Peninsula Malaysia. Raven (1935), however, acknowledges *M. f. argentimembris* (Kloss, 1911) observed in Redang Island as the subspecies distributed in the East Coast of Peninsula Malaysia. Although these 2 classifications contradict each other on one dimension, both may be true. It may be possible that *M. f. argentimembris* are distributed in the North East Coast of Peninsula Malaysia and *M. f. laeta* are distributed in the South East Coast of Peninsula Malaysia. These are the most relevant classifications according to phylogenetic and genetic results of this study, which suggests that the Pasir Mas' population is *M. f. argentimembris*. In contrast, the populations of Kluang, Pantai Remis, Kuala Gula, Port Dickson, and Bangi distributed on the west coast should be *M. f. fascicularis*.

The results of this study are directly relevant to conservation management strategies of *M. fascicularis* in Malaysia, particularly in terms of the translocation process. The human-macaque conflict has intensified in Malaysia due to habitat degradation and habituation of the species. It is important to recognize the genetic diversity between populations of *M. fascicularis* so we are able to conserve the unique evolutionary lineages of the species. Thus, PERHILITAN can translocate the target populations of *M. fascicularis* within the same gene pool of the other populations (the Borneo-Peninsula; east-west; mainland-island and north-south populations). This translocation is important to avoid the loss of genetic diversity that cannot be recovered, or, in extreme cases, can result in hybridization of populations and potential outbreeding depression of the populations (DeSalle and Amato 2004).

Conclusion

The phylogenetic relationships of Malaysia's long-tailed macaques, *M. fascicularis,* are crucial, as they are at a center of the human-wildlife crisis in the field of primatology,

taxonomy and conservation biology. This research has shown that populations of *M. fascicularis* originating from Borneo and Peninsula Malaysia are distinguishable from each other based on genetic data. Within Peninsula Malaysia, further division occurs between the East Coast and West Coast of Peninsula Malaysia; mainland and island and Northern and Southern Peninsula populations. These data can aid the conservation management planning in terms of translocation of the target pest populations within similar gene pools. Further mtDNA and nuclear DNA studies of *M. fascicularis* at the population level are required to increase the number of individuals from each locality and increase the number of geographical locations to represent clades (east-west and Peninsula-Borneo), in which biogeographical factors can also be taken into account.

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