# A new species of Agelas from the Zanzibar Archipelago, western Indian Ocean (Porifera, Demospongiae) 

Renata Manconi', Roberto Pronzato ${ }^{2}$, Erica Perino ${ }^{2}$<br>I Dipartimento di Scienze della Natura e del Territorio (Dip.Ne.T.), Università di Sassari, Via Muroni 25, I-07100, Sassari, Italy 2 Dipartimento di Scienze della Terra dell'Ambiente e della Vita (Di.S. T.A.V.), Corso Europa 26, I-16132 Genova, Italy<br>Corresponding author: Renata Manconi (r.manconi@uniss.it)

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#### Abstract

A new sponge species (Demospongiae: Agelasida: Agelasidae) is described from the eastern coast of Unguja Island in the Zanzibar Archipelago. Agelas sansibarica sp. n. is compared to all other Agelas species described so far. The new species differs from its congeners mainly in its three categories of verticillate spicules (acanthostyles, acanthostrongyles, and acanthoxeas) and their sizes. Acanthostrongyles, well represented in the spicular complement, are an exclusive trait of the new species widening the morphological range of the genus. Summarizing on spicular complement and spicular morphotraits of 36 species belonging to the genus Agelas: i) 32 species show only acanthostyles from Indo-Pacific ( $n=14$ ), Atlantic ( $\mathrm{n}=17$ ), and Mediterranean ( $\mathrm{n}=1$ ); ii) three Indo-Pacific species show acanthostyles and acanthoxeas; iii) one species $A$. sansibarica sp. $\mathbf{n}$. from the western Indian Ocean is characterised by the unique trait of three categories of verticillate spicules (acanthostyles, acanthostrongyles and acanthoxeas). A key for the IndoPacific species is supplied together with short descriptions, illustrations, and geographic range; literature on chemical bioprospecting of the genus Agelas is also provided.


## Keywords

Biodiversity, sponges, morpho-taxonomy, diagnostic key, geographic range, Unguja Island

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## Introduction

The sponge fauna of the Zanzibar Archipelago is poorly studied and data are reported almost exclusively in very old papers (Lendenfeld 1897, Baer 1906, Jenkin 1908, Sollas 1908, Thomas 1976). In none of these papers species belonging to the genus Agelas Duchassaing \& Michelotti, 1864 (Porifera: Demospongiae: Agelasida: Agelasidae) are reported. The presence of Agelas mauritiana (Carter, 1883) along the Zanzibar coasts was recently recorded (Said et al. 2010) as producer of bioactive compounds.

The widespread genus Agelas, including until now 35 valid species, was established by Duchassaing and Michelotti (1864: 76) describing the type species Agelas dispar from the Caribbean Sea. Agelas oroides is the only Mediterranean species, and is endemic. The western Atlantic (Gulf of Mexico, Caribbean, and Brazil) hosts 17 species. The majority of the latter (13) were recently revised while the remaining four species were considered dubious or suggested as synonyms (Van Soest 2002, Muricy et al. 2011, Parra-Velandia et al. 2014).

The Indo-Pacific species of Agelas number 18, including the new species here described. The most widespread species is Agelas mauritiana (including its oxeata variety) recorded in the Australian western Pacific, and the Indian Ocean from the Mascarenes Archipelago (type locality), Seychelles Archipelago, Madagascar, and Mozambique Channel to the southern Red Sea and east to Sri Lanka.

Several species (14) are reported only once from the type locality i.e. Agelas axifera Hentschel, 1911; A. bispiculata Vacelet, Vasseur \& Lévi, 1976; A. braekmani Thomas, 1998 (1997); A. carpenteri (Gray, 1867); A. cavernosa Thiele, 1903; A. citrina Gotera \& Alcolado, 1987; A. dendromorpha Lévi, 1993; A. inaequalis Pulitzer-Finali, 1986; $A$. linnaei de Voogd, Parra-Velandia \& Van Soest, 2008; A. nakamurai Hoshino, 1985; A. nemoechinata Hoshino, 1985; A. novaecaledoniae Lévi \& Lévi, 1983; A. robusta, Pulitzer-Finali 1982; A. semiglaber Pulitzer-Finali, 1996.

In the framework of sponges, applied research on bioactive compounds at a global level (e.g. Murray et al. 2013) focuses on Agelas species as producers of interesting molecules e.g. A. clathrodes, A. linnaei, A. mauritiana, A. nakamurai, A. oroides, and A. sceptrum (Walker et al. 1981, Fathi-Afshar et al. 1989, Keifer et al. 1991, Braekman et al. 1992, Bernan et al. 1993, König and Wright 1993, Chanas et al. 1996, König et al. 1998, Eder et al. 1999, Assmann et al. 2000, 2001, 2004, Fattorusso and Taglialatela-Scafati 2000, Assmann and Köck 2002, Fujita et al. 2003, Bickmeyer et al. 2004, 2005, 2008, Bickmeyer 2005, Costantino et al. 2006, Meketa and Weinreb 2006, Ferretti 2006, Vik et al. 2006, Ding et al. 2007, Ferretti et al. 2007, 2009, Vergne et al. 2008, Hertiani et al. 2010, Said et al. 2010, Regalado et al. 2011, Mordhorst et al. 2015). In this scenario of intensive bioprospecting, research knowledge of systematics and taxonomy in depth is a key tool to identify and define the status of specimens/biomaterial to be processed.

The present paper aims to report the discovery of a new species of Agelas from the Zanzibar Archipelago comparing it to all species belonging to the genus. To support global sharing of information on faunistics and taxonomy of Porifera from not widely accessible data sources an updated overview on the morphology and geographic distribution of

Agelas species from the Indo-Pacific area is also provided together with a brief description and exhaustive iconography, as well as a dichotomous key to Indo-Pacific species.

## Materials and methods

Representative fragments of six sponge specimens from the Unguja Island were studied. Growth form, surface traits, skeletal architecture, shape and size of the spicules are considered diagnostic morphotraits. Spicule dimensions are given as maximum, minimum, and medium lengths and widths of $c a .400$ spicules.

The skeletal architecture was investigated by hand-cut sections of the ectosome and choanosome. To study the three-dimensional arrangements of fibres and spicules in the skeleton, fragments $c a .10 \times 10 \times 2 \mathrm{~mm}$ were cut, cleaned with $5 \%$ sodium hypochlorite $(\mathrm{NaClO})$ for 24 h in a warm temperature $\left(35-40^{\circ} \mathrm{C}\right)$, then washed and stirred five times in abundant double distilled water, washed and stirred twice in ethanol $95 \%$, and finally allowed to air dry and gold-sputtered or mounted in Eukitt. The skeletal samples were than studied by light microscope (LM) and scanning electron microscope (SEM). Spicule preparations were made by dissolving a small fragment of the specimen in $65 \%$ boiling nitric acid $\left(\mathrm{HNO}_{3}\right)$ and cleaned spicules were rinsed four times with water, once with $95 \%$ ethanol. The spicules were air-dried on slides, mounted in Eukitt, and observed by a Leitz Dialux $20 \mathrm{~EB}(\mathrm{LM})$, as well as on aluminium stubs and coated with gold for the observation with a Vega3 TESCAN type LMU (SEM).

Specimens were deposited at the Museo civico di Storia Naturale "Giacomo Doria" of Genoa, Italy (acronym MSNG). For the taxonomy of genus and species level the Systema Porifera (Hooper and Van Soest 2002) and the World Porifera Database (Van Soest et al. 2015) are considered as reference.

## Systematic account

Phylum Porifera Grant, 1835
Class Demospongiae Sollas, 1885
Order Agelasida Hartman, 1980
Family Agelasidae Verrill, 1907
Genus Agelas Duchassaing \& Michelotti, 1864
Chalinopsis Schmidt, 1870 (junior synonym)
Ectyon Gray, 1867 (junior synonym)
Oroidea Gray, 1867 (junior synonym)
Pachychalinopsis Schmidt, 1880 (nomen nudum)
Siphonochalinopsis Schmidt, 1880 (nomen nudum)
Diagnosis (emended from Van Soest 2002, p. 820). Massive-lobate, encrusting, tubular, branching or flabellate sponges, often of considerable size, with smooth to finely
conulose surfaces provided with small rounded and/or key-hole shaped apertures. Colour usually orange or brownish-orange. Consistency toughly compressible, firm. No ectosomal specialization. Choanosomal skeleton isotropic or anisotropic, occasionally irregular, network of primary ascending spongin fibres and secondaries. Main fibres mostly cored by megascleres. Main and interconnecting fibres echinated by megascleres in most cases. Spicules as verticillate styles, or styles and oxeas, or styles, oxeas and strongyles. Biogeographic pattern of 36 nominal species mostly matches tropical waters, a single species occurs in the Mediterranean. The genus has not been recorded from the eastern Pacific, West Africa, and the northern Atlantic European coasts.

## Agelas sansibarica Perino \& Pronzato, sp. n.

http://zoobank.org/7F8E3929-DD8D-4991-A8E0-C391C89AC1D0
Figs 1-5

Material examined. Holotype: MSNG 57991 (A30), 70\% ethanol, Jambiani ( $06^{\circ} 18^{\prime} 44.8^{\prime \prime} \mathrm{S}, 39^{\circ} 33^{\prime} 32^{\prime \prime} \mathrm{E}$ ), eastern coast of Unguja Island, Zanzibar Archipelago, United Republic of Tanzania, SCUBA diving, 4.vii.2010, leg. Mr. Okala. Paratypes: MSNG 57992, MSNG 57993, MSNG 57994, MSNG 57995, MSNG 57996 (A12, A26, A27, A28, A29, respectively) ibid.

Diagnosis. Agelas with unique spicular complement composed of three spicular categories, oxeas, styles and strongyles with spines arranged in a variable number of verticilles.

Etymology. The speciphic epithet refers to the Zanzibar Archipelago.
Habitat. Coral reef, quite common at $7-12 \mathrm{~m}$ of depth. Water temperature 28$31^{\circ} \mathrm{C}$. Salinity 20-36\% (Fryday 2011). As reported by the Swiss Marine NGO manager of the local sponge farming facility (Jambiani Lagoon) the new species is massively farmed (Christian Vaterlaus, pers. comm., 2010).

Geographic distribution. Western Indian Ocean, but only recorded from the type locality to date.

Description. Growth form massive, thick, rounded, 6-10 cm in diameter. Colour in life purple to orange and light brown. Consistency firm and elastic. Surface rough to the touch, finely hispid, finely conulose for tips of ascending fibres supporting the dermal membrane, with regularly scattered circular and convoluted depressions ( 0.5 cm in diameter) very similar to those of $A$. cerebrum. Oscules few, small, irregularly scattered. Choanosomal skeleton as an irregularly reticulate network of spongin fibres. Primary fibres $50-110(71.67 \pm 17.63) \mu \mathrm{m}$ in diameter, strongly echinate by single, scattered spicules to groups of diverging spicules; ascending primary fibres cored by spicules also present. Secondary fibres $20-50(35 \pm 9) \mu \mathrm{m}$ in diameter notably echinate and cored by spicules. Tertiary network not observed.

Megascleres as three categories of monaxons mostly with acute spines. Acanthostyles $90-250(180.72 \pm 28.66) \times 7.5-20(13.46 \pm 2.59) \mu \mathrm{m}$ ornate by verticillate spines arranged as $11-27(17.8 \pm 2.86)$ whorls. Acanthoxeas $130-295(195 \pm 43.09)$


Figure I. Genus Agelas. Biogeographic pattern (grey areas). The red dot indicates the type locality of the new species Agelas sansibarica sp. n. at Jambiani ( $06^{\circ} 18^{\prime} 44.8^{\prime \prime} \mathrm{S}, 39^{\circ} 33^{\prime} 32^{\prime \prime} \mathrm{E}$ ), eastern coast of Unguja Island, Zanzibar Archipelago, United Republic of Tanzania.


Figure 2. Agelas sansibarica sp. n. Type specimen (alcohol preserved, colour different from in vivo) from the Zanzibar Archipelago.


Figure 3. Agelas sansibarica sp. n. Spicular complement of verticillate acanthostyles, acanthoxeas and acanthostrongyles (SEM).
$\times 7.5-15(12.17 \pm 1.89) \mu \mathrm{m}$ ornate by verticillate spines arranged as $14-26(19.24 \pm$ 3.47) whorls. Acanthostrongyles $80-245(148.18 \pm 36.82) \times 4-17(11.09 \pm 4.24) \mu \mathrm{m}$ ornate by verticillate spines arranged as $9-26(15.76 \pm 3.85)$ whorls. Annulate spicules apparently young.

Remarks. The new species is characterized by the co-presence of three categories of spicules never recorded in other Agelas species. Acanthostrongyles are abundant, ca. $20-30 \%$ of the total number of spicules.

## Discussion

## Geographic range of Indo-Pacific Agelas species

Madagascar, Mozambique Channel, Seychelles and Mascarene archipelagos (Western Indian Ocean province) harbour four species, whereas Japan (Ryukyu Archipelago) and New Caledonia enumerates two species each. Only one species each is recorded


Figure 4. Agelas sansibarica sp. n. Spicular complement of verticillate acanthostyles, acanthoxeas and acanthostrongyles (LM).
from Philippines, Papua New Guinea, and Funafuti. Only one species each is harboured in the Red Sea/Gulf of Aden, Sri Lanka, Moluccas, Sunda Shelf/Java Sea (Indonesia), Hong Kong, Funafuti, and Australia (Fig. 1).

## Diagnostic morphotraits comparative analysis of Agelas Indo-Pacific species

To discriminate between all 36 Agelas species by diverging diagnostic morphotraits is notably difficult, as highlighted in the previous section. Morphotraits of the genus are extremely conservative and different species appear very similar. Focusing on the IndoPacific species our attempt was not as completely successful as is also the case for the Atlantic species by Parra-Velandia et al. (2014).

Atlanto-Mediterranean Agelas species (18) seems to possess only acanthostrongyles, including the uncertain A. fascicularis, A. flabelliformis, A. inaequalis, and $A$. rudis not redescribed by Parra-Velandia et al. (2014).


Figure 5. Agelas sansibarica sp. n. a skeletal network of spongin fibres echinated by spicules (SEM) b detail of fibres surface echinated by verticillate spicules (SEM) $\mathbf{c}$ section of a primary fibre cored by a verticillate acanthostrongyle d-e skeletal network (LM).

Among the 17 previously known Indo-Pacific Agelas species, the spicular complement of 14 species is composed of acanthostyles in a single or two-dimensional classes (see Appendix 1, Figs 6-21 for details).

The most common and studied Indo-Pacific species, i.e. A. mauritiana, are characterized by a single spicular type acanthostyles, which are extremely variable in morphology, abundance of spines, and dimensional range (sometime more than three times in length) (see Table 1). The Atlantic $A$. dispar and the Mediterranean $A$. oroides show a similar size variability of acanthostyles. Only the Indo-Pacific $A$. axifera, $A$. mauritiana var. oxeata, and $A$. novaecaledoniae show two different categories of spicules, i.e. acanthostyles and acanthoxeas.

The new species $A$. sansibarica is characterized by the unique morphotrait of three categories of megascleres, i.e. acanthostyles, acanthoxeas, and acanthostrongyles with spines arranged in verticilles regularly scattered along the entire spicule. No other Agelas species exhibit this spicular combination. Acanthostrongyles, well identifiable and abundant, represent an exclusive diagnostic trait of the new species. The functional

Table I. Agelas mauritiana. Morphometries and morphotraits by different authors.

| References | Acanthostyles $\mu \mathbf{m m}$ | Whorls <br> $\mathbf{n}^{\mathbf{o}}$ | Colour | Habitus size <br> $(\mathbf{c m})$ | Consistency |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Carter 1883 | 132 | $15-18$ | - | - | - |
| Thiele 1903 | $200 \times 14-15$ | 16 | - | - | - |
| Dendy 1905 | $176 \times 16$ | - | dark <br> brown | tubular <br> $3.1 \times 1.6$ length <br> $\times$ diameter | firm <br> resilient |
| Laubenfels 1954 | $170-180 \times 10-14$ | $12-18$ | - | - | - |
| Lévi 1961 | $150-160 \times 8-12$ | $16-20$ | brown | massive <br> $6-10 \times 4$ | firm <br> resilient <br> soft |
| Lévi 1964 | $275 \times 12-13$ | $15-17$ | - | - | - |
| Lévi 1967 | $140-230 \times 8-10$ | $10-15$ | - | - | - |
| Vacelet and Vasseur 1965 | $135-250$ | $13-20$ | - | - | - |
| Vacelet and Vasseur 1971 | $80-180 \times 7.5-12.5$ | $18-23$ | brown | encrusting <br> $1.6-1.5$ <br> thickness | firm <br> resilient <br> coriaceus |
| Thomas 1979 | $112-212 \times 6-8$ | $6-8$ | pale <br> yellow | encrusting <br> cavernous | firm <br> resilient <br> compressible |

role of acanthostrongyles is doubled since echinanting spicules arm both the fibres surface and the core of the axial part of fibres.

Summarizing spicular complements and spicular morphotraits of 36 Agelas species: i) 32 species show only acanthostyles from Atlantic (17), Mediterranean (1), and the majority (14) of the Indo-Pacific areas; ii) three Indo-Pacific species show acanthostyles and acanthoxeas; iii) only one species $A$. sansibarica sp . n. from the western Indian Ocean show a spicular component composed of acanthostyles, acanthoxeas, and acanthostrongyles.

## Key to the Indo-Pacific Agelas species

The present key is an attempt to discriminate between the Indo-Pacific species, but the scenario appears very intricate mainly because morphotraits from many descriptions and illustrations are overlapping (see Table 1). A similar attempt, on the Atlantic species, was performed by Parra-Velandia et al. (2014) emphasizing that: "Caribbean Agelas taxonomy rests heavily on the external morphology"; as a consequence their key is essentially based on growth form and colour. Since this is the situation, our key is not simply dichotomous and allows the disctintion of only 13 of the 17 Indo-Pacific species (see Appendix 1). The remaining four species have acanthostyles with length ranges which are widely overlapping (from less than 150 to more than $250 \mu \mathrm{~m}$ ). Three
of these ( $A$. carpenteri, $A$. marmarica, and $A$. robusta) are known only from the original descriptions; on the contrary, $A$. mauritiana is reported by several authors but with discordant descriptions (Table 1).

1 Spicular complement composed by 1 or 2 spicular types (acanthoxeas, acanthostyles) 2

- Spicular complement composed by 3 spicular types (acanthoxeas, acanthostyles, acanthostrongyles)
A. sansibarica sp. n.

2 Spicular complement composed by 2 spicular types (acanthoxeas and acanthostyles) 3

- Spicular complement composed by 1 spicular type (acanthostyles) ............. 4

3 Sponge body cup-shaped ..............................................................A. axifera

- Sponge body blade-shaped............................................A. novaecaledoniae
- Sponge body lobed ....................................................A. mauritiana oxeata
- Sponge body digitate ...................................................... A. dendromorpha
- $\quad$ Sponge body as slim cylindrical erected axis (branched or unbranched) A. gracilis

4 Acanthostyles of 2-dimensional categories................................................... 5

- Acanthostyles of 1-dimensional category...................................................... 7

5 Long acanthostyles spiny only at the tips ................................A. semiglabra

- Long and short acanthostyles almost entirely spiny.................A. bispiculata

7 Primary and secondary fibres uncored......................................................... 8

- Primary and/or secondary fibres cored ......................................................... 9


9 Primary and secondary fibres cored...................................A. nemoechinata
- Primary fibres cored and secondary uncored .............................................. 10

10 Acanthostyles (185-265 $\times 8-15 \mu \mathrm{~m}$ ) with 15-23 whorls.......A. nakamurai

- Acanthostyles (130-220 $\times 4-21 \mu \mathrm{~m}$ ) with 8-18 whorls..........A. braekmani
- Acanthostyles (80-370×5-24 $\mu \mathrm{m}$ ) with 11-33 whorls................A. linnaei


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## References

Assmann M, Köck M (2002) Bromosceptrin, an alkaloid from the marine sponge Agelas conifera. Zeitschrift fur Naturforschung 57c: 157-160. doi: 10.1515/znc-2002-1-226
Assmann M, Lichte E, Pawlik JR, Köck M (2000) Chemical defenses of the Caribbean sponges Agelas wiedenmayeri and Agelas conifera. Marine Ecology Progress Series 207: 255-262. doi: 10.3354/meps207255
Assmann M, Zea S, Köck M (2001) Sventrin, a new bromopyrrole alkaloid from the Caribbean sponge Agelas sventres. Journal of Natural Products 64: 1593-1595. doi: 10.1021/ np010350e
Assmann M, Lichte E, Köck M (2004) Multiple defensive roles for bromopyrrole alkaloids from Caribbean Agelas sponges. In: Pansini M, Pronzato R, Bavestrello G, Manconi R (Eds) Sponge Sciences in the New Millennium, Bollettino dei Musei e degli Istituti Biologici dell'Università di Genova 68: 187-193.
Baer L (1906) Silicospongien von Sansibar, Kapstadt und Papeete. Archiv fur Naturgeschichte 72: 1-32, pl. i-v.
Bernan VS, Roll DM, Ireland CM, Greenstein M, Maiese WM, Steinberg DA (1993) A study on the mechanism of action of sceptrin, an antimicrobial agent isolated from the South Pacific sponge Agelas mauritiana. Journal of Antimicrobial Chemotherapy 32: 539-550. doi: $10.1093 / \mathrm{jac} / 32.4 .539$
Bickmeyer U (2005) Bromoageliferin and dibromoageliferin, secondary metabolites from the marine sponge Agelas conifera, inhibit voltage-operated, but not store-operated calcium entry in PC12 cells. Toxicon 45: 627-632. doi: 10.1016/j.toxicon.2005.01.006
Bickmeyer U, Assmann M, Köck M, Schütt C (2005) A secondary metabolite, 4,5-dibromopyr-role-2-carboxylic acid, from marine sponges of the genus Agelas alters cellular calcium signals. Environmental Toxicology and Pharmacology 19(3): 423-427. doi: 10.1016/j. etap.2004.12.003
Bickmeyer U, Drechsler C, Köck M, Assmann M (2004) Brominated pyrrole alkaloids from marine Agelas sponges reduce depolarization-induced cellular calcium elevation. Toxicon 44(1): 45-51. doi: 10.1016/j.toxicon.2004.04.001
Bickmeyer U, Grube A, Klings KW, Köck M (2008) Ageladine A, a pyrrole-imidazole alkaloid from marine sponges, is a pH sensitive membrane permeable dye. Biochemical and Biophysical Research Communications 373(3): 419-422. doi: 10.1016/j.bbrc.2008.06.056
Braekman JC, Daloze D, Stoller C, van Soest RWM (1992) Chemotaxonomy of Agelas (Porifera, Demospongiae). Biochemical Systematics and Ecology 20: 417-431. doi: 10.1016/0305-1978(92)90082-O

Carpenter WB (1856) The microscope and its revelations. Blanchard and Lea, Philadephia, 724 pp.
Carter HJ (1883) Contributions to our Knowledge of the Spongida. Annals and Magazine of Natural History (5) 12(71): 308-329, pls XI-XIV.
Chanas B, Pawlik JR, Lindel D, Fenical W (1996) Chemical defense of the Caribbean sponge Agelas clathrodes. Journal of Experimental Marine Biology and Ecology 208: 185-196. doi: 10.1016/S0022-0981(96)02653-6

Costantino V, Fattorusso E, Imperatore C, Mangoni A (2006) Glycolipids from Sponges. Part 17. 1 Clathrosides and Isoclathrosides, Unique Glycolipids from the Caribbean Sponge Agelas clathrodes. Journal of natural products 69(1): 73-8. doi: 10.1021/np050331v
de Voogd NJ, Parra-Velandia FJ, Van Soest RWM (2008) A new Agelas (Demospongiae: Agelasida: Agelasidae) from the Thousand Islands, West-Java, Indonesia. Zoölogische Mededelingen Leiden 82(22): 235-243.
Dendy A (1905) Report on the sponges collected by Professor Herdman, at Ceylon, in 1902. In: Herdman WA (Ed.) Report to the Government of Ceylon on the Pearl Oyster Fisheries of the Gulf of Manaar. 3 (Supplement 18). Royal Society, London, 57-246, pls I-XVI.
Dendy A (1921) Report on the Sigmatotetraxonida collected by H.M.S. "Sealark" in the Indian Ocean. Transactions of the Linnean Society of London (ser. Zoology) 18(1): 1-164.
Ding N, Li C, Liu Y, Zhang Z, Li Y (2007) Concise synthesis of clarhamnoside, a novel glycosphingolipid isolated from the marine sponge Agelas clathrodes. Carbohydrate Research 342(14): 2003-2013. doi: 10.1016/j.carres.2007.05.018
Duchassaing De Fonbressin P, Michelotti G (1864) Spongiaires de la mer Carä̈be. Natuurkundige verhandelingen van de Hollandsche maatschappij der wetenschappen te Haarlem 21(2): $1-124$, pls I-XXV.
Eder C, Proksch P, Wray V, van Soest RWM, Ferdinandus E, Pattisina LA, Sudarsono (1999) New bromopyrrole alkaloids from the Indopacific sponge Agelas nakamurai. Journal of Natural Products 62(9): 1295-1297. doi: 10.1021/np990071f
Fathi-Afshar R, Allen TM, Krueger CA (1989) Some pharmacological activities of novel adeninerelated compounds isolated from a marine sponge Agelas mauritiana. Canadian journal of physiology and Pharmacology 67(4): 276-281. doi: 10.1139/y89-045
Fattorusso E, Taglialatela-Scafati O (2000) Two novel pyrroleimidazole alkaloids from the Mediterranean sponge Agelas oroides. Tetrahedron Letter 41: 9917-9922. doi: 10.1016/ S0040-4039(00)01764-0
Ferretti C (2006) Aquaculture of two Mediterranean sponge species for bioactive molecules production. PhD thesis, Genoa University, 211 pp.
Ferretti C, Marengo B, De Ciucis C, Nitti M, Pronzato MA, Marinari UM, Pronzato R, Manconi R, Domenicotti C (2007) Effects of Agelas oroides and Petrosia ficiformis crude extracts on human neuroblastoma cell survival. International Journal of Oncology 30: 161-169. doi: 10.3892/ijo.30.1.161

Ferretti C, Vacca S, De Ciucis C, Marengo B, Duckworth AR, Manconi R, Pronzato R, Domenicotti C (2009) Growth dynamics and bioactivity variation of the Mediterranean demosponges Agelas oroides (Agelasida, Agelasidae) and Petrosia ficiformis (Haplosclerida, Petrosiidae). Marine Ecology 30(3): 1-10. doi: 10.1111/j.1439-0485.2008.00278.x
Fryday S (2011) A Study of Sponge Aquaculture in Jambiani: Is Shallow Farming Feasible? ISP Collection. Paper 1194. http://digitalcollections.sit.edu/isp_collection/1194
Fujita M, Nakao Y, Matsunaga S, Seiki M, Itoj Y, Yamashita J, van Soest RWM, Fusetani N (2003) Ageladine A An anti angiogenetic matrix metalloproteinase inhibitor from the marine sponge Agelas nakamurai. Journal of the American Chemical Society 125: 15700-15701. doi: 10.1021/ja038025w

Gray JE (1867) Notes on the Arrangement of Sponges, with the Descriptions of some New Genera. Proceedings of the Zoological Society of London 1867(2): 492-558, pls XXVII-XXVIII.
Hentschel E (1911) Tetraxonida. 2. Teil. In: Michaelsen W, Hartmeyer R (Eds) Die Fauna Südwest-Australiens. Ergebnisse der Hamburger südwest-australischen Forschungsreise 1905 3(10): 279-393.
Hertiani T, Edrada-Ebel R, Ortlepp S, van Soest RWM, de Voogd NJ, Wray V, Hentschel U, Kozytska S, Müller WEG, Proksch P (2010) From anti-fouling to biofilm inhibition: New cytoitoxic secondary metabolites from two Indonesian Agelas sponges. Bioorganic \& medicinal chemistry 18(3): 1297-1311. doi: 10.1016/j.bmc.2009.12.028
Hooper J, Van Soest RWM (2002) Systema Porifera. A Guide to the Classification of Sponges. vol. 1. Kluwer Academic/Plenum Publisher, New York, 1101 pp. doi: 10.1007/978-1-4615-0747-5_1
Hoshino T (1985) Description of two new species in the genus Agelas (Demospongiae) from Zamami Island, the Ryukyus, Japan. Proceedings of the Japanese Society of Systematic Zoology 30: 1-10, pls I-II.
Jenkin CF (1908) The calcareous sponges. The marine fauna of Zanzibar and British East Africa, from collection made by Cyril Crosland, M.A., in the years 1901 and 1902. Proceedings of the Zoological Society of London 1908: 434-456.
Keifer PA, Schwartz RE, Koker MES, Hughes RG Jr., Rittschof D, Rinehart KL (1991) Bioactive bromopyrrole metabolites from the Caribbean sponge Agelas conifera. The Journal of Organic Chemistry 56(9): 2965-2975. doi: 10.1021/jo00009a008
König GM, Wright AD (1993) Agelorins A and B, and 11-epifistularin-3, three new antibacterial fistularin-3 derivatives from the tropical marine sponge Agelas oroides. Heterocycles 36: 1351-1358. doi: 10.3987/COM-92-6317
König GM, Wright AD, Linden A (1998) Antiplasmodial and cytotoxic metabolites from the Maltese sponge Agelas oroides. Planta Medica 64: 443-447. doi: 10.1055/s-2006-957477
Laubenfels MW De (1954) The Sponges of the West-Central Pacific. Oregon State Monographs. Studies in Zoology 7: i-x, 1-306, pls I-XII.
Lendenfeld R Von (1897) Spongien von Sansibar. Abhandlungen herausgegeben von der Senckenbergischen naturforschenden Gesellschaft 21: 93-133, pls 9-10.
Lévi C (1958) Résultats scientifiques des Campagnes de la ‘Calypso’. Campagne 1951-1952 en Mer Rouge (suite). 11. Spongiaires de Mer Rouge recueillis par la 'Calypso' (1951-1952). Annales de l'Institut océanographique 34(3): 3-46.
Lévi C (1961) Résultats scientifiques des Campagnes de la 'Calypso'. Campagne 1954 dans l'Océan Indien (suite). 2. Les spongiaires de l'Ile Aldabra. Annales de l'Institut océanographique 39(1): $1-32$, pls $1-2$.
Lévi C (1964) Spongiaires du canal de Mozambique. Bulletin du Muséum national d'Histoire naturelle, Ser. 2, 36(3): 384-395.
Lévi C (1967) Démosponges Récoltées en Nouvelle-Calédonie par la Mission Singer-Polignac. Expédition Française sur les récifs coralliens de la Nouvelle-Calédonie, Paris 2: 13-28, pls I-III.
Lévi C (1993) Porifera Demospongiae: Spongiaires bathyaux de Nouvelle-Calédonie, récoltés par le 'Jean Charcot'. Campagne BIOCAL, 1985. In: Crosnier A (Ed.) Résultats des cam-
pagnes MUSORSTOM, Vol. 11. Mémoires du Muséum national d'Histoire naturelle (A, Zoologie) 158: 9-87.
Lévi C, Lévi P (1983) Démosponges bathyales récoltées par le N/O' Vauban' au sud de la Nou-velle-Calédonie. Bulletin du Muséum national d'Histoire naturelle (4, A) 5(4): 931-997.
Lévi C, Lévi P (1989) Spongiaires (MUSORSTOM $1 \& 2$ ). In: Forest J (Ed.) Résultats des Campagnes MUSORSTOM, Vol. 4. Mémoires du Muséum national d'Histoire naturelle (A, Zoologie) 143: 25-103.
Meketa ML, Weinreb SM (2006) Total synthesis of ageladine A, an angiogenesis inhibitor from the marine sponge Agelas nakamurai. Organic Letter 30: 1443-1446. doi: 10.1021/ol0602304
Mordhorst T, Awal S, Jordan S, Petters C, Sartoris L, Dringen R, Bickmeyer U (2015) The Chemically Synthesized Ageladine A-Derivative LysoGlow84 Stains Lysosomes in Viable Mammalian Brain Cells and Specific Structures in the Marine Flatworm Macrostomum lignano. Marine Drugs 13(2): 920-935. doi: 10.3390/md13020920
Muricy G, Lopes DA, Hajdu E, Carvalho MS, Moraes FC, Klautau M, Menegola C, Pinheiro US (2011) Catalogue of Brazilian Porifera. Museu Nacional, Rio de Janeiro, 300 pp .
Murray PM, Moane S, Collins C, Beletskaya T, Thomas OP, Duarte AW, Nobre FS, Owoyemi IO, Pagnocca FC, Sette LD, McHugh E, Causse E, Perez-Lopez P, Feijoo G, Moreira MT, Rubiolo J, Leiros M, Botana LM, Pinteus S, Alves C, Horta A, Pedrosa R, Jeffryes C, Agathos SN, Allewaert C, Verween A, Vyverman W, Laptev I, Sineoky S, Bisio A, Manconi R, Ledda F, Marchi M, Pronzato R, Walsh DJ (2013) Sustainable production of biologically active molecules of marine based origin. New Biotechnology 30: 839-850. doi: 10.1016/j.nbt.2013.03.006
Parra-Velandia FJ, Zea S, Van Soest RWM (2014) Reef sponges of the genus Agelas (Porifera: Demospongiae) from the Greater Caribbean. Zootaxa 3794(3): 301-343. doi: 10.11646/ zootaxa.3794.3.1
Pulitzer-Finali G (1982) Some shallow water sponges from Hong Kong. In: Morton BS, Tseng CK (Eds) Proceedings 1st International Marine Biology Workshop, The Marine Flora and Fauna of Hong Kong and Southern China. Hong Kong University Press, 97-100.
Pulitzer-Finali G (1993) A collection of marine sponges from East Africa. Annali del Museo civico di Storia Naturale "Giacomo Doria" 89: 247-350.
Pulitzer-Finali G (1996) Sponges from the Bismarck Sea. Bollettino dei Musei e degli Istituti Biologici dell'Università di Genova 60-61: 101-138.
Regalado EL, Laguna A, Mendiola J, Thomas OP, Nogueiras C (2011) Bromopyrrole alkaloids from the Caribbean sponge Agelas cerebrum. Química Nova 34(2): 289-291. doi: 10.1590/ S0100-40422011000200022
Said SA, Moshi MJ, Nondo RSO, Masimba PJ, Innocent E, Guantai AN (2010) Evaluation of the potential of the marine sponges of the Zanzibar Island to yield antimalarial and antimicrobial active compounds. Tanzanian Journal of Health Research 12 (3): 195-202.
Sollas IBJ (1908) The inclusion of foreign bodies by sponges, with a description of a new genus and species of monoaxonida. Annals and Magazine of natural History 1(8): 395-401. doi: 10.1080/00222930808692424

Thiele J (1903) Kieselschwämme von Ternate. II. Abhandlungen herausgegeben von der Senckenbergischen naturforschenden Gesellschaft 25: 933-968, pl. XVIII.

Thomas PA (1973) Marine Demospongiae of Mahe Island in the Seychelles Bank (Indian Ocean). Annales du Musée royal de l'Afrique centrale. Sciences zoologiques 203: 1-96, pls 1-8.
Thomas PA (1976) The history of spongology of the Indian Ocean. Journal of the Marine Biological Association of India 18(3): 610-625.
Thomas PA (1979) Studies on sponges of the Mozambique Channel. Annalen. Reeks in 8 Koninklijk Museum voor Midden-Afrika: zoologische wetenschappen, 227. Koninklijk Museum voor Midden-Afrika, Tervuren, Belgium, 73 pp., pl. 3.
Thomas PA (1981) A second collection of marine Demospongiae from Mahe Island in the Seychelles Bank (Indian Ocean). Annalen. Reeks in 8 - Koninklijk Museum voor Mid-den-Afrika: zoologische wetenschappen, 233. Koninklijk Museum voor Midden-Afrika, Tervuren, Belgium, 54 pp., pl. 4.
Thomas PA (1998) Sponges of Papua and New Guinea III Orders Poecilosclerida Topsent and Halichondrida Vosmaer. Journal of the Marine Biological Association of India 39(1-2): 148-154. doi: 10.1016/0077-7579(89)90016-1
Vacelet J, Vasseur P (1965) Spongiaires des grottes et surplombs des récifs de Tuléar (Madagascar). Recueil des Travaux de la Station marine d'Endoume 2-4: 71-123.
Vacelet J, Vasseur P (1971) Éponges des récifs coralliens de Tuléar (Madagascar). Téthys, Suppl. 1: 51-126.
Vacelet J, Vasseur P, Lévi C (1976) Spongiaires de la pente externe des récifs coralliens de Tuléar (Sud-Ouest de Madagascar). Mémoires du Muséum national d'Histoire naturelle (A, Zoologie) 49: 1-116, pls I-X.
Van Soest RWM (1989) The indonesian sponge fauna: a status report. Netherlands Journal of Sea Research 23(2): 223-230.
Van Soest RWM (2002) Family Agelasidae Verrill, 1907. In: Hooper J, Van Soest RWM (Eds) Systema Porifera. A Guide to the Classification of Sponges. vol. 1. Kluwer Academic/Plenum Publisher, New York, 819-820. doi: 10.1007/978-1-4615-0747-5_86
Van Soest RWM, Boury-Esnault N, Hooper JNA, Rützler K, de Voogd NJ, Alvarez de Glasby B, Hajdu E, Pisera AB, Manconi R, Schoenberg C, Janussen D, Tabachnick KR, Klautau M, Picton B, Kelly M, Vacelet J, Dohrmann M, Díaz MC, Cárdenas P (2015) World Porifera database. http://www.marinespecies.org/porifera
Vergne C, Appenzeller J, Ratinaud C, Martin M, Debitus C, Zaparucha A, Al-Mourabit A (2008) Debromodispacamides B and D: Isolation from the marine sponge Agelas mauritiana and stereoselective synthesis using a biomimetic proline route. Organic Letters 10(3): 493-496. doi: $10.1021 / \mathrm{ol} 702866 \mathrm{~m}$
Vik A, Hedner EE, Charnock C, Samuelsen O, Larsson R, Gundersen LL, Bohlin L (2006) (+)-agelasine D: Improved synthesis and evaluation of antibacterial and cytotoxic activities. Journal of Natural Products 69: 381-386. doi: 10.1021/np050424c
Walker RP, Faulkner DJ, Van Engen D, Clardy J (1981) Sceptrin, an antimicrobial agent from the sponge Agelas sceptrum. Journal of the American Chemical Society 103: 6772-6773. doi: 10.1021/ja00412a052
Whitelegge T (1897) The Sponges of Funafuti. Memoirs of the Australian Museum 3: 323332, pl. XVIII. doi: 10.3853/j.0067-1967.3.1897.499

## Appendix I

Indo-Pacific species belonging to the genus Agelas reported from the literature.

## Agelas axifera Hentschel, 1911

Fig. 6
Description (modified from Hentschel 1911). Growth form club-shaped ( $12 \times 6 \mathrm{~cm}$ ), walls 0.5 cm in thickness. Surface irregular. Colour orange. Ectosomal skeleton not reported. Choanosomal skeleton irregularly reticulate network (meshes $320 \mu \mathrm{~m}$ in diameter) of fibres echinated by few spicules. Primary fibres ( $80 \mu \mathrm{~m}$ in diameter) cored by spicules. Secondary fibres ( $40 \mu \mathrm{~m}$ in diameter) not cored. Megascleres verticillate of two categories. Acanthostyles and acanthoxeas of similar size (112-152 $\times 5-7 \mu \mathrm{~m}$ ) ornate by 7-15 regular whorls with 5-6 acuminate thorns each one. Habitat. Not reported. Geographic distribution. Pacific Ocean, Australia. Remarks. Type specimen stranded on beach at Champion Bay, Geraldton, Western Australia.


Figure 6. Agelas axifera. a living specimen $\mathbf{b}$ skeleton fragment with two spicular types, axially embedded in a fibre and arming the surface $\mathbf{c}$ acanthostyles $\mathbf{d}$ acanthoxea (a modified from an original underwater shot by J. Hooper b-d modified from Hentschel 1911).

## Agelas bispiculata Vacelet, Vasseur \& Lévi, 1976

Fig. 7
Description (modified from Vacelet et al. 1976). Growth form massive; hemispherical fragments ( $5-6 \mathrm{~cm}$ in diameter). Surface hispid. Oscules and pores not evident.


Figure 7. Agelas bispiculata. Spicular complement of acanthostyles of two size categories (modified from Vacelet et al. 1976).

Consistency elastic. Colour yellowish in spirit. Ectosomal skeleton not reported. Choanosomal skeleton as reticulate network of thick, armed spongin fibres. Primary fibres ( $70 \mu \mathrm{~m}$ in diameter) axially cored by large acanthostyles type I and echinated by small acanthostyles type II. Secondary fibres ( $40-50 \mu \mathrm{~m}$ in diameter) less abundant, without spicules. Megascleres of one category, acanthostyles of two dimensional classes. Acanthostyles type I $(320-400 \times 14-17 \mu \mathrm{~m})$ ornate by 20 not accentuate whorls. Acanthostyles type II $(55-120 \times 6-10 \mu \mathrm{~m})$ ornate by $11-15$ accentuate whorls. Habitat. Coral reefs, shade zone (caves, cavities). Geographic distribution. Western Indian Ocean. Recorded only from Mozambique Channel (eastern Madagascar). Remarks. de Voogd et al. (2008) focused on larger acanthostyles localized in the axial skeleton, and the smaller ones echinanting the fibres. Known only from the type locality, Grand Recife, Entsetreky (Tulear), Madagascar.

## Agelas braekmani Thomas, 1998

## Fig. 8

Description (modified from Thomas 1998). Growth form tubular and irregularly branched 10 mm in diameter, branches tips blind or with apical oscule $2-4 \mathrm{~mm}$ in diameter, or sometime bearing a funnel-shaped opening with an orifice 30 mm in diameter. Consistency stiff, cork-like. Foreign particles as shell pieces embedded on the wall at place. Surface hispid. Ectosomal skeleton as erected spicules supporting the dermal membrane. Choanosomal skeleton as reticulate network of spiculous spongin fibres, mesh size 180-560 $\mu \mathrm{m}$. Primary fibres echinate and thick (up to $132 \mu \mathrm{~m}$ in diameter) feeble cored by acanthostyles. Secondaries not cored, fairly common echinated by spicules $(42-76 \mu \mathrm{~m})$. Megascleres verticillate of a single category. Acanthostyles 130-220


Figure 8. Agelas braekmani. a schematic drawings of two specimens $\mathbf{b}$ spicular complement of verticillate acanthostyles $\mathbf{c}$ skeleton architecture with echinate fibres, sponge surface on the right (modified from Thomas 1998).
(159) $\times 4-21 \mu \mathrm{~m}$ ( $15 \mu \mathrm{~m}$ excluding spines; up to $25 \mu \mathrm{~m}$ with spines) ornamented by verticillate spines arranged as $8-18$ whorls. Younger spicules partly annulated, each spine tubercled at the base. Habitat. Shallow water. Geographic distribution. Pacific Ocean. Recorded from Hansa Bay (type locality), Madang Province, Bismarck Sea. Remarks. This species was not considered in the revision by de Voogd et al. (2008).

## Agelas carpenteri (Gray, 1867)

Fig. 9
Halichondria (?) Carpenter, 1856 in Gray (1867)
Ectyon carpenteri Gray, 1867

Description (modified from Gray 1867). Growth form massive. Ectosomal skeleton not reported. Choanosomal skeleton as a reticulate network of cylindrical spongin fibres echinated by single scattered spicules or groups of diverging spicules. Spicules fusiform, verticillate with $c a .10$ whorls. Habitat. Not reported. Geographic distribution. Western Indian Ocean. Recorded only once from Madagascar. Remarks. This species is poorly described and illustrated. The spicule typology (oxeas or styles) are not reported by the author. Gray erected this species on the basis of what is shown by Carpenter (1856) in his book on microscopy.


Figure 9. Agelas carpenteri. Drawing of the reticulate network with spongin fibres echinated by verticillate spicules perpendicularly arranged (modified from Carpenter 1856).

## Agelas cavernosa Thiele, 1903

Fig. 10

Description (modified from Thiele 1903). Growth form irregularly massive with basal portion bearing digitiform outgrowths with a single, large oscule at the tips. Surface grainy with small stones or other foreign particulate. Colour blackish. Cavernous structure. Ectosomal skeleton not reported. Choanosomal skeleton as a dense network of brownish fibres. Fibres uncored, echinated by spicules. Megascleres of a single category. Acanthostyles $(200 \times 15 \mu \mathrm{~m})$ verticillate, ornamented by 16 whorls of 15 spines each. Habitat. Tropical; not reported in detail. Geographic distribution. Ternate (type locality), Halmahera, Maluku Islands (Moluccas), eastern Indonesia. Remarks. The original description and particularly the illustration (only one spicule) are not exhaustive.


Figure 10. Agelas cavernosa. The original illustration of verticillate acanthostyles ornate by spiny whorls by Thiele (1903).

e

Figure II. Agelas ceylonica. a very low quality image of the specimen studied by Dendy $1921 \mathbf{b}$ schematic drawing of a branched specimen by Van Soest 1989 c skeleton architecture with echinate fibres d-e spicular complement of verticillate acanthostyles (c modified from Thomas $1981 \mathbf{d}$ modified from Dendy 1921 e modified from Lévi 1961).

## Agelas ceylonica Dendy, 1905

Fig. 11
Description (modified from Dendy 1905, 1921, Lévi 1961, Thomas 1981). Growth form notably variable from ramose with slender subcylindrical digitiform branches with blunt tips ( $2-5 \mathrm{~mm}$ in diameter; 27 mm total height) to bushy, very irregular $60 \times 41 \times$

40 mm (Lévi 1961) or encrusting ( $20 \times 15 \mathrm{~mm}, 1-3 \mathrm{~mm}$ in thickness) with oscules and pores not evident (Thomas 1981). Surface minutely hispid by spicules, irregular, conulose due to sharp, blunt, minute conules resulting from the protruding tips of ascending fibres. Consistency compressible, quite soft, elastic, resilient, fibrous and fairly tough in spirit. Colour brown, dark brown in spirit (Dendy 1905, 1921), orange (Lévi 1961), pale gray (Thomas 1981). Ectosomal skeleton as erect spicules (Thomas 1981). Choanosomal skeleton irregular network of pale-coloured spongin fibres ( $30 \mu \mathrm{~m}$ in diameter) cored by spicules and abundantly echinated by acanthostyles. Ascending primary and secondary fibres not well defined (20-60 $\mu \mathrm{m}$ in diameter), never cored by spicules (Thomas 1981). Megascleres asbelonging to two categories of styles: spiny, very variably verticillate and smooth. Acanthostyles $240 \times 20 \mu \mathrm{~m}$ (Dendy 1905, 1921), $80-275 \times 5-15 \mu \mathrm{~m}$ with 16-21 verticilles and $100-300 \times 6-15 \mu \mathrm{~m}$ with 13-23 verticilles (Lévi 1961), acanthostyles $(240 \times 2 \mu \mathrm{~m})$ straight to slightly curved, with small, conic spines (Thomas 1981). Smooth styles $(320 \times 24 \mu \mathrm{~m})$ less frequently present (Dendy 1921). Habitat. Not reported. Geographic distribution. Indian Ocean. Recorded from south India, Sri Lanka, Indonesia, and Seychelles. Remarks. Recently recorded from Indonesia (de Voogd et al. 2008). The latter authors report that acanthostyles in the Manaar Gulf (type locality) specimens have a maximum dimension of $240 \times 20 \mu \mathrm{~m}$.

## Agelas dendromorpha Lévi, 1993

Fig. 12
Description (modified from Lévi 1993). Growth form bush-like (30-35 $\times 15-40 \mathrm{~mm}$ ) branched, with main stem $9-10 \mathrm{~mm}$ in height, 3 mm in diameter. Branches with terminal buds ( $2-3 \mathrm{~mm}$ in diameter). Dermal membrane hispidate. Ectosomal skeleton as small acanthostyles in the dermal membrane. Choanosomal skeleton dense with spongin fibres echinated by spicules at the end of the main column or branches. Megascleres of a single category with two dimensional classes. Acanthostyles I (130-260 $\times 10-12$ $\mu \mathrm{m})$ abundant, slightly curved, verticillate by 12-18 irregular whorls. Acanthostyles II $(60-100 \times 3-4 \mu \mathrm{~m})$ from the ectosome less abundant, with 8-9 less organized whorls. Habitat. Deep water, 245-275 m of depth. Geographic distribution. Western Pacific Ocean. Recorded only from the type locality in New Caledonia. Remarks. Also small oxea-like spiny spicules reported in original illustrations but not in descriptions. de Voogd et al. (2008) reported that verticillation is absent in smaller acanthostyles.

## Agelas gracilis Whitelegge, 1897

Fig. 13
Description (modified from Whitelegge 1897, Lévi and Lévi 1989). Growth form subcylindrical, thin (2-3 mm in diameter; 25-75 mm in length) unbranched, settled



b

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\begin{aligned}
& \text { inivnin } \\
& \text { Rrivirs } \\
& \text { cincigno }
\end{aligned}
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Figure 12. Agelas dendromorpha. a the sponge specimens of the type series $\mathbf{b}$ spicular complement of two spicular types, acanthostyles and acanthoxeas; small oxea-like spicules (bottom, right) are not reported in the original description (modified from Lévi 1993).


Figure 13. Agelas gracilis. a ramose slim dry specimen b-c spicular complement of verticillate acanthostyles of different dimensional categories (a-b modified from Lévi and Lévi $1983 \mathbf{c}$ modified from Whitelegge 1897).
on shells fragments. Surface uneven, hispid, with numerous minute conules (0.2-0.5 mm in height, $2-5 \mathrm{~mm}$ apart). A few minute pores between the conules. Consistency soft, spongy but also a bit tough. Colour greyish-yellow in spirit. Ectosomal skeleton not reported. Choanosomal skeleton network irregularly reticulate of spongin fibres, with oval or oblong mesh, rarely angular. Primary fibres ( $70 \mu \mathrm{~m}$ in diameter) with an axial plexus from which secondary ( $45 \mu \mathrm{~m}$ in diameter) and tertiary fibres ( $25 \mu \mathrm{~m}$ in diameter) are given off. Megascleres of single category. Acanthostyles (100-220 $\times$ $7-13 \mu \mathrm{~m}$ ) verticillate by 16 to 24 whorls of small spines (Whitelegge 1897). Habitat. Coral reef, 72-125 m of depth. Geographic distribution. Western Pacific Ocean. Recorded from Funafuti and Philippines. Remarks. Lévi and Lévi (1989) reported branched growth form, fibres (20-30 $\mu \mathrm{m}$ in diameter), acanthostyles of two dimensional classes, type I $90-120 \times 7-8 \mu \mathrm{~m}$ with $9-12$ verticilles, and type II 190-290 $\times$ $8-13 \mu \mathrm{~m}$ with $17-21$ verticilles. de Voogd et al. (2008) report that the specimen from the deeper subtidal ( $85-90 \mathrm{~m}$ ) in the Philippines (Lévi and Lévi 1989) was ascribed to this species despite the divergence in spicular size.

## Agelas linnaei de Voogd, Parra-Velandia \& Van Soest, 2008

Fig. 14

Description (modified from de Voogd et al. 2008). Growth form roundly lobate to thickly flabellate ( 8 cm in height, 2.5 cm in diameter). Consistency very soft, spongy. Colour bright orange at the surface to cream-orange internally. Surface with dense conules ( $1-3 \mathrm{~mm}$ in height) supported by tips of ascending fibres covered by a bright easily distinguishable membrane. Small apertures ( $<2 \mathrm{~mm}$ ) scattered on the surface, bigger pores $(2-3 \mathrm{~mm})$ connected to internal axial canals sometime present between some lobes. Choanosome dense with narrow canals (primary canals $200 \mu \mathrm{~m}-2.00 \mathrm{~mm}$ in diameter; secondary canals $100 \mu \mathrm{~m}-1.00 \mathrm{~mm}$ in diameter). Ectosomal skeleton not reported. Choanosomal skeletal network irregularly and densely reticulate; primary fibres (35-80 $\mu \mathrm{m}$ in diameter) aggregated in packs, more or less undulated, heavily cored ( $1-7$ spicules in cross section) and echinate; secondary fibres $(25-40 \mu \mathrm{~m}$ in diameter) not cored and less echinate. Megascleres of a single category. Acanthostyles (78.7-(187)-372.3 $\times 5.2-(12.1)-24 \mu \mathrm{~m})$ straight, a few slightly curved, ornate by $11-$ (19.3)-33 whorls with 5-12 spines each; whorls conspicuous in the spicule centre but sometimes faint and irregular at the spicule tip and head. Habitat. Coral reef, overgrowing other reef invertebrates. Geographic distribution. Recorded from the Thousands Islands Reef complex, off Jakarta, West Java, Indonesia. Type locality: Peniki Island and Payang Island. Remarks. de Voogd et al. (2008) focused on the whorl measurements performed in the middle third of the spicule because spine abundance is dependent upon the width. This is a useful rule to perform uniform measurements of whorls in verticillate spicules.


Figure 14. Agelas linnaei. a type series specimens (liquid preserved) $\mathbf{b}$ a living shallow water specimen $\mathbf{c}$ spongin skeleton with spicules $\mathbf{d}$ verticillate acanthostyles (modified from de Voogd et al. 2008).

## Agelas marmarica Lévi, 1958

Fig. 15

Description (modified from Lévi 1958, Vacelet and Vasseur 1965, Vacelet and Vasseur 1971). Growth form not recorded. Colour orange to/or bright red. Ectosomal skeleton not reported. Choanosomal skeleton as a reticulate network of fibres $<30 \mu \mathrm{~m}$ in diameter. Megascleres of a single category. Acanthostyles $(230 \times 10 \mu \mathrm{~m})$ verticillate by 19-21 whorls of spines (Lévi 1958). Acanthostyles type I 100-270×7-14 $\mu \mathrm{m}$ with 21-25 whorls; acanthostyles type II $160-215 \times 7-20 \mu \mathrm{~m}$ with $16-24$ whorls (Vacelet and Vasseur 1965). Habitat. Coral reef, 20-30 m of depth. Geographic distribution. Indian Ocean. Recorded from Mozambique Channel (Madagascar) and Red Sea. Type locality: Saudi Arabian Red Sea. Remarks. Spicules morph and their sizes are very variable in descriptions and illustrations of different authors.

## Agelas mauritiana (Carter, 1883)

Fig. 16, Table 1
Ectyon mauritiana Carter, 1883
Description (modified from Carter 1883, Thiele 1903, Dendy 1905, Laubenfels 1954, Lévi 1961, 1964, 1967, Vacelet and Vasseur 1965, 1971, Thomas 1979, 1998). Growth form highly variable: encrusting, tubular, massive, sometimes cavernous (Table 1) also ramose or massively branched 4.5 cm in height bearing five blunt branches 2 cm in di-

a


Figure 15. Agelas marmarica. a-b spicular complement (a modified from Vacelet and Vasseur 1965 b modified from Lévi 1958).


Figure 16. Agelas mauritiana. a drawing of a massive specimen $\mathbf{b}$ skeleton fragment $\mathbf{c}-\mathbf{g}$ spicular complement b-d A. mauritiana var. oxeata a modified from Van Soest 1989; b-d modified from Thomas 1979 c modified from Carter 1883 e modified from Vacelet and Vasseur 1965 f modified from Lévi 1964 g modified from Lévi 1961).
ameter with a circular oscule at the tip. Surface with raised oscules $2-3 \mathrm{~mm}$ in diameter (Lévi 1961, Vacelet and Vasseur 1971). Consistency firm, resilient coriaceus, but also soft, compressible. Colour notably variable (Table 1). Surface distinctly conulose at growing portions, older ones smooth and glabrous (Thomas 1979). Ectosomal skeleton not reported. Choanosomal skeleton as a dense, irregularly reticulate network of stout fibres very abundantly echinated (Dendy 1905, Lévi 1961, Thomas 1979). Primaries and secondary fibres amber -coloured and not differentiated from each other (Thomas 1979). Megascleres as verticillate acanthostyles of two size classes. Acanthostyles $130-275 \times 8-20 \mu \mathrm{~m}$ with 10-20 whorls (Table 1). Smaller acanthostyles also reported (Table 1). Habitat. Not reported. Geographic distribution. Indian Ocean and West Pacific. Mascarene Archipelago (Mauritius is the type locality) and Seychelles Archipelago (Aldabra), Madagascar, Mozambique, Gulf of Aden, southern Red Sea, Gulf of Aqaba, Sri Lanka, and Australia. Remarks. Variable morphometries are reported by different authors (Table 1).

## Agelas mauritiana var. oxeata Lévi, 1961

Fig. 16

Description (modified from Lévi 1961). Growth form lobed, each of the two lobes measures 20 mm in length and 8 mm in diameter. Colour brownish-red. Surface velvety. Choanosomal skeleton of primaries fibres cored by oxeas. Megascleres (100-220 $\times 4-18 \mu \mathrm{~m})$ of two categories. Acanthostyles verticillate with $14-16$ whorls. Acanthoxeas verticillate with 20-24 whorls. Habitat. Shallow water, 12 m of depth. Geographic distribution. Indian Ocean. Recorded only from Aldabra Island (type locality) in the Seychelles Archipelago. Remarks. This variety was not considered in the revision by de Voogd et al. (2008).

## Agelas nakamurai Hoshino, 1985

Fig. 17
Description (modified from Hoshino 1985). Growth form massive, rounded or thickly encrusting. Colour orange rufous to brick red at the surface in dry specimens. Surface smooth, uneven, with irregularly meandering surface grooves. Consistency firmly spongy, resilient when wet; very hard, hardly compressible when dry. Ectosomal skeleton armed by tangential acanthostyles irregularly distributed. Choanosomal skeleton as a reticulate network with elliptical meshes (40-200 $\mu \mathrm{m}$ in diameter) of primary ascending spongin fibres and secondaries. Primary fibres (70-100 $\mu \mathrm{m}$ in diameter) cored by $4-8$ acanthostyles, and echinated by the same acanthostyles. Secondary fibres (20-70 $\mu \mathrm{m}$ in diameter) not cored, in places echinated by acanthostyles. Megascleres of a single category. Acanthostyles $185-(226)-267 \times 8-(12)-15 \mu \mathrm{~m}$, straight to slight-


Figure I7. Agelas nakamurai. a skeleton architecture $\mathbf{b}$ close up of spicules insertion in the spongin fibres c acanthostyles (modified from Hoshino 1985).
ly curved, ornate by 15-23 whorls with eight spines each. Habitat. Shallow water, 20 m depth. Geographic distribution. Pacific Ocean. South Kuroshio, east Japan. Zamami Island (type locality), Ryukyu Archipelago, Japan. Remarks. Also recorded from Indonesia (de Voogd et al. 2008).

## Agelas nemoechinata Hoshino, 1985

Fig. 18

Description (modified from Hoshino 1985). Growth form massive or thickly encrusting.

Consistency spongy, resilient when wet, hard and difficult to compress when dry. Colour madder brown at the surface to rufous-orange in the interior when dry. Oscules from 1-3 to $5-8 \mathrm{~mm}$ in diameter. Ectosomal skeleton not reported. Choanosomal skeleton reticulate network with elliptical meshes (50-250 $\mu \mathrm{m}$ in diameter) of spongin fibres. Primary and secondary fibres almost indistinguishable (20-50 $\mu \mathrm{m}$ in diameter) and cored by 1-3 acanthostyles, occasionally not cored, only slightly echinated. Megascleres verticillate of a single category. Acanthostyles 170-(189)-210 $\times 9-(11)-13 \mu \mathrm{~m}$, straight to gently curved, ornate by $16-23$ regular whorls, each with eight spines. Habitat. Shallow water, 20 m depth. Geographic distribution. North Pacific Ocean. Recorded from south Kuroshio (east Japan). Type locality: Zamami Island, Ryukyu Archipelago. Remarks. Also recorded from Indonesia (de Voogd et al. 2008). These authors report acanthostyles occasionally sharply pointed at both ends (oxeas), as previously reported also in the original figures.


Figure 18. Agelas nemoechinata. a skeleton architecture b spicular complement (modified from Hoshino 1985).

## Agelas novaecaledoniae Lévi \& Lévi, 1983

Fig. 19
Description (modified from Lévi and Lévi 1983). Growth form as a thick blade (18 cm in height, 12.5 cm in diameter, $1-4 \mathrm{~cm}$ in thickness). Consistency elastic. Colour ochre brown. Surface irregularly cavernous and strongly hispid. Oscules ( $2-3 \mathrm{~mm}$ in diameter) numerous, $3-8 \mathrm{~mm}$ apart. Ectosomal skeleton armed by spicules. Choanosomal skeleton as a reticulate network of fibres ( $100 \times 20 \mu \mathrm{~m}$ in diameter) laminar and fibrillar, rarely echinate at the sponge basal portion. Megascleres of two categores. Acanthostyles $100-190 \times 5-8 \mu \mathrm{~m}$ ( $7-10$ with spines) straight or slightly curved, verticillate by $12-17$ whorls of spines. Acanthoxeas slightly curved ( $120-250 \times 5 \mu \mathrm{~m}$ ) verticillate by $12-18$ whorls of spines. Habitat. Deep water, $390-395 \mathrm{~m}$ of depth. Geographic distribution. Pacific Ocean. Recorded from New Caledonia. Remarks. Known only from the type locality.

## Agelas robusta Pulitzer-Finali, 1982

Fig. 20
Description (modified from Pulitzer-Finali 1982). Growth form encrusting ( 5 mm in thickness) to massive, roundish ( $6 \times 3 \mathrm{~cm}$ in diameter). Cavernous (clathrous) structure,


Figure 19. Agelas novaecaledoniae. a type specimen b spicular complement with two spicular types (modified from Lévi and Lévi 1983).
with narrow channels through the entire sponge. Consistency tough and resilient. Colour dull orange, dull yellowish-brown. Ectosomal skeleton not reported. Choanosomal skeleton reticulate with irregular meshes of pale spongin fibres ( $38-80 \mu \mathrm{~m}$ in diameter) abundantly echinate by acanthostyles. Megascleres of a single category. Acanthostyles very stout, verticillate ( $170-250 \times 14-30 \mu \mathrm{~m}$ spine included) with $11-12$ whorls of short, blunt spines. Habitat. Not reported. Geographic distribution. Pacific Ocean. Recorded from Hong Kong, Southern China. Remarks. Known only from the type locality. At present for this species only three slides are available after damaging of type materials during the recent Genova flood in 2014 (October).

## Agelas semiglabra Pulitzer-Finali, 1996

Fig. 21


Figure 20. Agelas robusta. a type specimen (dry) b spicular complement of acanthostyles very stout, verticillate by blunt spines (modified from Pulitzer-Finali 1982).

Description (modified from Pulitzer-Finali 1996). Growth form encrusting, very small. Skeleton architecture not reported. Megascleres of single category and two size classes. Acanthostyles type I verticillate ( $230-375 \times 11-16 \mu \mathrm{~m}$ ), spiny only towards the tips. Acanthostyles type II $(75-100 \times 3.5 \mu \mathrm{~m})$ verticillate, entirely spiny. Habitat. Shallow water. Geographic distribution. Pacific Ocean. Recorded from Bismarck Sea, known only from Papua New Guinea (type locality). Remarks. The specific epithet ending with $-e r$ is masculine despite the gender Agelas is feminine, as a consequence the ending must be changed into -ra. Because of the overlap in spicule dimension de Voogd et al. (2008) report that is not possible to distinguish different size categories.


Figure 21. Agelas semiglabra. Spicular complement with two dimensional categories of acanthostyles; long acanthostyles spiny only at the tips (modified from Pulitzer-Finali 1996).

## Agelas spp.

Several findings from the Seychelles Archipelago (Thomas 1973) and Kenya (PulitzerFinali 1993). The revisitation of the 11 Agelas specimens slides of the Pulitzer-Finali collection from East Africa highlighted the presence of only styles in the spicular complement with notable variability of thickness, length, and spinosity. This confirms his opinion: 'It would be inappropriate at the moment to try to identify some of them with established species and to propose new species.' Also in this case the original material is not available after damaging of types during the recent Genova flood in 2014 (October).

# A new quadrannulate species of Orobdella (Hirudinida,Arhynchobdellida, Orobdellidae) from western Honshu, Japan 

Takafumi Nakano ${ }^{1,2}$<br>I Department of Science Education, Graduate School of Education, Hiroshima University, Higashihiroshima 739-8524, Japan 2 Department of Zoology, Graduate School of Science, Kyoto University, Kyoto 606-8502, Japan<br>Corresponding author: Takafumi Nakano (tnakano@hiroshima-u.ac.jp)

[^1]
#### Abstract

A new quadrannulate species of Orobdella Oka, 1895, Orobdella naraharaetmagarum sp. n., from the mountainous region of western Honshu, Japan is described. Orobdella naraharaetmagarum is a small species with a body length of less than 5 cm . Phylogenetic analyses using nuclear $18 S$ rRNA and histone H 3 , as well as mitochondrial cytochrome $c$ oxidase subunit $\mathrm{I}, \mathrm{tRNA}^{\mathrm{Crs}}, \mathrm{tRNA}^{\text {Mer }}, 12 \mathrm{~S}$ rRNA, $\mathrm{RRNA}{ }^{\mathrm{Val}}$, $16 S$ rRNA, $\mathrm{tRNA}{ }^{\text {teu }}$ and NADH dehydrogenase subunit 1 markers indicated that the present new species is the sister species of the quadrannulate Orobdella esulcata Nakano, 2010. Furthermore, mitochondrial DNA genealogy within $O$. naraharaetmagarum demonstrated that this new species is divided into eastern and western lineages.


## Keywords

Hirudinea, Orobdella, new species, gastroporous, molecular phylogeny, Japan

## Introduction

The terrestrial macrophagous leech genus Orobdella Oka, 1895 contains 12 species that are distributed throughout the Japanese Archipelago, Korean Peninsula, and Taiwan (Nakano 2014, Nakano and Lai 2012, Nakano and Seo 2014). These 12 species are split into three groups based on their mid-body somite annulation: seven species in the quadrannulate (four annuli) group, four in the sexannulate (six annuli) group, and one octannulate (eight annuli) species.

Orobdella leeches had been considered large species, with body lengths reaching to 10 cm or greater (Sawyer 1986). In recent years, however, small mature leeches belonging to this genus have been discovered in Japan and described as new species: Orobdella koikei Nakano, 2012b from Hokkaido, and Orobdella masaakikuroiwai Nakano, 2014 from central Honshu. The bodies of mature individuals of these two species are shorter than 4 cm . Both species possess mid-body somites that are quadrannulate. Nakano (2014) suggested that differences in the body lengths of mature leeches might enable more than one species of Orobdella to coexist in the same region.

Additional small Orobdella leeches were collected from Chugoku District, western Honshu, Japan. The body lengths of the specimens were less than 5 cm . Nevertheless, a few individuals were regarded as mature leeches because they possessed an obvious clitellum. These specimens are described here as a new species. In addition, the phylogenetic position of this new species was estimated using nuclear 18S rRNA and histone H3, as well as mitochondrial cytochrome $c$ oxidase subunit $\mathrm{I}, \mathrm{tRNA}{ }^{\mathrm{Cys}}$, $\mathrm{tRNA}^{\mathrm{Met}}, 12 \mathrm{~S}$ rRNA, tRNA ${ }^{\text {Val }}, 16 \mathrm{~S}$ rRNA, tRNA ${ }^{\text {Leu }}$, and NADH dehydrogenase subunit 1 sequence data.

## Materials and methods

## Sampling and morphological examination

Leeches were collected from five localities in Chugoku district, western Honshu, Japan (Fig. 1). When possible, elevation and geographical coordinates for localities were obtained using a Garmin eTrex GPS unit.

Almost all of the specimens were relaxed by the gradual addition of absolute ethanol (EtOH) to freshwater. For DNA extraction, botryoidal tissue was removed from the posterior part of the body around the caudal sucker of every specimen, and then preserved in absolute EtOH. The remainder of the body was fixed in $10 \%$ formalin and preserved in $70 \% \mathrm{EtOH}$. Four measurements were taken: body length (BL) from the anterior margin of the oral sucker to the posterior margin of the caudal sucker, maximum body width (BW), caudal sucker length (CL) from the anterior to the posterior margin of the sucker and caudal sucker width (CW) from the right to the left margin of the sucker. Examination, dissection, and drawing of the specimens were conducted using a stereoscopic microscope with a drawing tube (Leica M125). Specimens used in this study have been deposited in the Zoological Collection of Kyoto University (KUZ).


Figure I. Map showing the collection localities of the specimens examined in this study. Open circle (5) indicates the type locality of the new species, Orobdella naraharaetmagarum sp. n., and closed circles (I-4) indicate additional localities.

The numbering convention is based on Moore (1927): body somites are denoted by Roman numerals, and the annuli in each somite are given alphanumeric designations.

## PCR and DNA sequencing

The extraction of genomic DNA from botryoidal tissues preserved in absolute EtOH followed Nakano (2012b). Primer sets for the PCR and cycle sequencing (CS) reactions used in this study were as follows: for 18 S rRNA, A and L (PCR and CS), C and Y (PCR and CS), as well as O and B (PCR and CS) (Apakupakul et al. 1999); for histone H3 (H3), H3aF and H3bR (PCR and CS) (Colgan et al. 1998); for cytochrome $c$ oxidase subunit I (COI), LCO 1490 and HCO 2198 (PCR and CS) (Folmer et al. 1994), and LCO-in (Nakano 2012b) and HCO-outout (Nakano 2012a) (PCR and CS), or LCOinerpo2 (5'-GCTATTACAATATTACTTACAGATCG-3'; this study) and HCO-out (Nakano 2012b) (PCR and CS); for $\mathrm{tRNA}^{\mathrm{Cys}}$, $\mathrm{tRNA}^{\mathrm{Met}}, 12 \mathrm{~S}$ rRNA, $\mathrm{tRNA}^{\mathrm{Val}}$ and 16 S rRNA (tRNA ${ }^{\text {Cys }}-16 \mathrm{~S}$ ), 12 SA-out and $12 \mathrm{SB}-\mathrm{in}$ (PCR and CS), and 12SA-in and 12SBout (Nakano 2012b) or 12SB-outin (5'-AAAGGTACGAATATATTTAC-3'; this study) (PCR and CS); for $\mathrm{tRNA}{ }^{\text {Leu }}$ and NADH dehydrogenase subunit 1 (ND1) ( $\mathrm{tRNA}{ }^{\text {Leu }}-$

ND1), LDN3000 and HND1932 (PCR and CS) (Light and Siddall 1999). The PCR reactions and DNA sequencing were performed using the modified method mentioned in Nakano (2012a). The PCR reactions were performed using a GeneAmp PCR System 2700 and a GeneAmp PCR System 9700 (Applied Biosystems) as well as a T100 Thermal Cycler (Bio-Rad). The PCR mixtures were heated to $94^{\circ} \mathrm{C}$ for 5 min , followed by 35 cycles at $94^{\circ} \mathrm{C}(10$ s each $), 52^{\circ} \mathrm{C}$ for 18 S and $\mathrm{H} 3,60^{\circ} \mathrm{C}$, and $44^{\circ} \mathrm{C}$, respectively, for the anterior, and posterior parts of $\mathrm{tRNA}^{\mathrm{Cys}}-16 \mathrm{~S}$ or $42^{\circ} \mathrm{C}$ for COI and $t R N A^{\text {Leu }}-\mathrm{ND} 1$ (20 s), and $72^{\circ} \mathrm{C}(42 \mathrm{~s} \mathrm{each})$, and a final extension at $72^{\circ} \mathrm{C}$ for 6 min . The sequencing mixtures were heated $96^{\circ} \mathrm{C}$ for 2 min , followed by 40 cycles at $96^{\circ} \mathrm{C}(10 \mathrm{~s}$ each $), 50^{\circ} \mathrm{C}$ ( 5 s each) and $60{ }^{\circ} \mathrm{C}$ ( 48 s each). The obtained sequences were edited using DNA BASER (Heracle Biosoft S.R.L.). The DNA sequences listed in Table 1 were newly obtained in this study and were deposited with the International Nucleotide Sequence Database Collaboration (INSDC) through the DNA Data Bank of Japan (DDBJ).

## Molecular phylogenetic and genetic distance analyses

Eighty published sequences were obtained from the INSDC for use in molecular phylogenetic analyses (Table 1). In addition to 12 known Orobdella species, the following four erpobdelliform species were used as outgroup taxa: Erpobdella japonica Pawłowski, 1962 (Erpobdellidae), Gastrostomobdella monticola Moore, 1929 (Gastrostomobdellidae), Mimobdella japonica Blanchard, 1897, and Odontobdella blanchardi (Oka, 1910) (both Salifidae).

The phylogenetic position of the newly identified Orobdella species within the genus was estimated based on $18 \mathrm{~S}, \mathrm{H} 3$, COI, $\mathrm{tRNA}^{\mathrm{Cys}}-16 \mathrm{~S}$, and $\mathrm{tRNA}{ }^{\text {Leu }}-\mathrm{ND} 1$ sequences. The alignments of H 3 and COI were trivial, as no indels were observed. 18 S , $\mathrm{tRNA}{ }^{\mathrm{Cys}}-16 \mathrm{~S}$, and $\mathrm{tRNA}{ }^{\text {Leu }}-\mathrm{ND} 1$ were aligned using MAFFT v. 7.245 L-INS-i (Katoh and Standley 2013). The lengths of the 18S, H3, COI, tRNA ${ }^{\text {Cys }}-16 S$, and tRNA ${ }^{\text {Leu }}-N D 1$ sequences were $1,844,328,1,267,1,120$, and 633 bp , respectively. The concatenated sequences yielded $5,192 \mathrm{bp}$ of aligned positions.

Phylogenetic trees were constructed using maximum likelihood (ML) and Bayesian inference (BI). ML phylogenies were constructed using RAxML v. 8.1.5 (Stamatakis 2014) with the substitution model set as GTRCAT, immediately after nonparametric bootstrapping (Felsenstein 1985) conducted with 1,000 replicates. The best-fit partitioning scheme for the ML analyses was identified with the Akaike information criterion (Akaike 1974) using PartitionFinder v. 1.1.1 (Lanfear et al. 2012) with the "greedy" algorithm: 18S/the $1^{\text {st }}$ and $2^{\text {nd }}$ positions of $\mathrm{H} 3 /$ the $3^{\text {rd }}$ position of $\mathrm{H} 3 /$ the $1^{\text {st }}$ position of $\mathrm{COI} /$ the $2^{\text {nd }}$ position of $\mathrm{COI} /$ the $3^{\text {rd }}$ positions of COI and $\mathrm{ND} 1 /$ the $1^{\text {st }}$ position of ND1/the $2^{\text {nd }}$ position of ND2/12S/16S/tRNA ${ }^{\text {Cys }}, \mathrm{tRNA}^{\mathrm{Met}}, \mathrm{tRNA}^{\mathrm{Val}}$ and $\mathrm{tRNA}{ }^{\text {Leu }}$.

BI and Bayesian posterior probabilities (BPPs) were estimated using MrBayes v . 3.2.5 (Ronquist et al. 2012). The best-fit partition scheme and models for each partition were selected based on the Bayesian information criterion (Schwarz 1978) using PartitionFinder with the "greedy" algorithm: for 18 S and the $1^{\text {st }}$ position of H3, $\mathrm{K} 80+\mathrm{I}$; for the $2^{\text {nd }}$ position of H 3 , JC69; for the $3^{\text {rd }}$ position of H 3 , HKY85; for the
Table I. Samples used for the phylogenetic analyses. The information on the vouchers is accompanied by the collection locality numbers for Orobdella naraharaetmagarum sp. n. (see Fig. 1) and the INSDC accession numbers. Sequences marked with an asterisk were obtained for the first time in the present study. Acronyms: KUZ, the Zoological Collection of Kyoto University; UNIMAS, the Universiti Malaysia Sarawak.

| Species | Voucher (locality number) | 18S | Histone H3 | COI | tRNA ${ }^{\text {Cys }}$-16S | tRNA ${ }^{\text {Len }}$-ND1 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Orobdella naraharaetmagarum sp. n. | KUZ Z1360 (4) |  |  | LC087131* | LC087130* | LC087132* |
| Orobdella naraharaetmagarum sp. n. | KUZ Z1380 (2) |  |  | LC087134* | LC087133* | LC087135* |
| Orobdella naraharaetmagarum sp. n. | KUZ Z1535 (1) |  |  | LC087137* | LC087136* | LC087138* |
| Orobdella naraharaetmagarum sp. n. | KUZ Z1582 Paratype (5) |  |  | LC087140* | LC087139* | LC087141* |
| Orobdella naraharaetmagarum sp. n . | KUZ Z1652 Holotype (5) | LC087143* | LC087145* | LC087144* | LC087142* | LC087146* |
| Orobdella naraharaetmagarum sp. n. | KUZ Z1654 Paratype (5) |  |  | LC087148* | LC087147* | LC087149* |
| Orobdella naraharaetmagarum sp. n. | KUZ Z1655 (3) |  |  | LC087151* | LC087150* | LC087152* |
| Orobdella dolichopharynx Nakano, 2011b | KUZ Z120 Holotype | AB663665 | AB698876 | AB679680 | AB679681 | AB828558 |
| Orobdella esulcata Nakano, 2010 | KUZ Z29 Holotype | AB663655 | AB698873 | AB679664 | AB679665 | AB828555 |
| Orobdella ijimai Oka, 1895 | KUZ Z110 Topotype | AB663659 | AB698877 | AB679672 | AB679673 | AB828559 |
| Orobdella kawakatsuorum Richardson, 1975 | KUZ Z167 Topotype | AB663661 | AB698878 | AB679704 | AB679705 | AB828561 |
| Orobdella ketagalan Nakano \& Lai, 2012 | KUZ Z208 Holotype | AB704785 | AB704786 | AB704787 | AB828582 | AB828563 |
| Orobdella koikei Nakano, 2012b | KUZ Z156 Holotype | AB698883 | AB698882 | AB679688 | AB679689 | AB828560 |
| Orobdella masaakikuroiwai Nakano, 2014 | KUZ Z694 Holotype | AB938003 | AB938013 | AB938006 | AB937997 | AB938016 |
| Orobdella mononoke Nakano, 2012a | KUZ Z224 Holotype | AB698868 | AB698869 | AB698866 | AB698867 | AB828564 |
| Orobdella octonaria Oka, 1895 | KUZ Z181 Topotype | AB698870 | AB698871 | AB679708 | AB679709 | AB828562 |
| Orobdella shimadae Nakano, 2011b | KUZ Z128 Holotype | AB663663 | AB698875 | AB679676 | AB679677 | AB828557 |
| Orobdella tsushimensis Nakano, 2011a | KUZ Z134 Holotype | AB663653 | AB698872 | AB679662 | AB679663 | AB828554 |
| Orobdella whitmani Oka, 1895 | KUZ Z45 Topotype | AB663657 | AB698874 | AB679668 | AB679669 | AB828556 |
| Erpobdella japonica Pawłowski, 1962 | KUZ Z178 | AB663648 | AB698879 | AB679654 | AB679655 | AB828542 |
| Gastrostomobdella monticola Moore, 1929 | UNIMAS/A3/BH01/10 | AB663649 | AB698880 | AB679656 | AB679657 | AB828543 |
| Mimobdella japonica Blanchard, 1897 | KUZ Z179 | AB663650 | AB698881 | AB679658 | AB679659 | AB828544 |
| Odontobdella blanchardi (Oka, 1910) | KUZ Z180 | AB663651 | AB938012 | AB938004 | AB937995 | AB938014 |

$1^{\text {st }}$ position of COI, GTR+G; for the $2^{\text {nd }}$ positions of COI and ND1, HKY85+I; for the $3^{\text {rd }}$ positions of COI and ND1 plus 16 S , HKY85 $+\mathrm{I}+\mathrm{G}$; and for the $1^{\text {st }}$ position of ND1, and $12 S, \mathrm{tRNA}^{\mathrm{Cys}}$, $\mathrm{tRNA} A^{\mathrm{Met}}$, $\mathrm{tRNA}{ }^{\mathrm{Val}}$ and $\mathrm{tRNA}^{\text {Leu }}$, GTR $+\mathrm{I}+\mathrm{G}$. Two independent runs of four Markov chains were conducted for 12 million generations, and the tree was sampled every 100 generations. The parameter estimates and convergence were checked using Tracer v. 1.6.0 (Rambaut and Drummond 2009) and the first 30,001 trees were discarded based on these results.

The phylogenetic relationships within the available Orobdella materials were estimated based on sequences of COI, $t \mathrm{RNA}^{\mathrm{Cys}}-16 \mathrm{~S}$ and $t \mathrm{RNA}^{\text {Leu }}-\mathrm{ND} 1 . \mathrm{tRNA}^{\mathrm{Cys}}-16 \mathrm{~S}$ and tRNA ${ }^{\text {Leu }}-$ ND1 were aligned using MAFFT L-INS-i. The lengths of the COI, $\mathrm{tRNA}^{\text {Cys }}{ }^{-}$ $16 S$, and $t R N A{ }^{\text {Leu }}-N D 1$ sequences were $1,267,634$, and $1,107 \mathrm{bp}$, respectively. The concatenated sequences yielded $3,008 \mathrm{bp}$ of aligned positions. ML phylogenies were constructed in RAxML with the substitution model set as GTRCAT, immediately after nonparametric bootstrapping conducted with 1,000 replicates. The best-fit partitioning scheme was identified with the Akaike information criterion using PartitionFinder with the "greedy" algorithm: the $1^{\text {st }}$ position of $\mathrm{COI} /$ the $2^{\text {nd }}$ positions of COI and $\mathrm{ND} 1 /$ the $3^{\text {rd }}$ positions of COI and ND1/the $2^{\text {nd }}$ position of ND $1 /$ the $1^{\text {st }}$ position of ND1/tRNA${ }^{\text {Cys }}, \mathrm{tRNA}^{\text {Met }}, \mathrm{tRNA}^{\mathrm{Val}}$, $\mathrm{tRNA}^{\text {Leu }} / 12 \mathrm{~S} / 16 \mathrm{~S}$. BI and BPPs were estimated using MrBayes. The best-fit partition scheme and models for each partition were selected based on the Bayesian information criterion using PartitionFinder with the "greedy" algorithm: for the $1^{\text {st }}$ positions of COI and ND1, GTR $+\mathrm{I}+\mathrm{G}$; for the $2^{\text {nd }}$ positions of COI and ND1, F81+I; for the $3^{\text {rd }}$ positions of COI and ND1 plus $16 \mathrm{~S}, \mathrm{HKY}+\mathrm{G}$; tRNA ${ }^{\mathrm{Cys}}$, $\mathrm{tRNA}^{\text {Met }}$, 12 S , $\mathrm{tRNA}{ }^{\text {Val }}$ and $\mathrm{RRNA}^{\text {Leu }}$, GTR $+\mathrm{I}+\mathrm{G}$. Two independent runs of four Markov chains were conducted for 10 million generations and the tree was sampled every 100 generations. The parameter estimates and convergence were checked using Traced, and the first 25,001 trees were discarded based on these results.

Nodes with bootstrap support (BS) values higher than $70 \%$ were considered sufficiently resolved (Hillis and Bull 1993). Nodes with BPPs higher than $95 \%$ were considered statistically significant (Leaché and Reeder 2002).

Pairwise comparisons of uncorrected $p$-distances for seven COI sequences (1,266 bp) obtained from specimens of the studied species and Orobdella esulcata Nakano, 2010 were calculated using MEGA6.06 (Tamura et al. 2013).

## Taxonomy

Family Orobdellidae Nakano et al., 2012
http://zoobank.org/5F5BABE8-BD26-4FC7-9593-F73E62E26122

Genus Orobdella Oka, 1895
http://zoobank.org/FA8333ED-8C17-41FD-AFC1-62A4F98D4AC1

## Orobdella narabaraetmagarum sp. n.

http://zoobank.org/5A831984-50F6-433A-A058-ED2ECFF2DFDC
Figs 2-5
Diagnosis. Body length of mature individual less than 5 cm . Somite IV uniannulate, somites VIII-XXV quadrannulate. Male gonopore in middle of XI b6, female gonopore in middle of XIII a1, behind gastropore, gonopores separated by $1 / 2+4+1 / 2$ annuli. Clitellum in XI b5 to XIII a2. Pharynx reaching to XIII b5/b6-XIII/XIV. Gastropore conspicuous, in middle of XIII a1. Gastroporal duct bulbous, slightly winding at junction with gastropore. Paired epididymides in XIV b6-XV b5 to XVIII b6-XX a2/b5, occupying 16-20 annuli (four to five somites). Atrial cornua developed, ellipsoid or ovate.

Type materials. Holotype. KUZ Z1652, dissected, collected from under a rock along a mountain trail at Mt. Kanmuriyama, Hatsukaichi, Hiroshima Pref., Japan ( $34.47325^{\circ}, 132.10362^{\circ}$; Elev. 757 m ; locality number 5), by TN on 25 April 2015. Paratypes. Two specimens from near the type locality, along a forest road, "Japan National Route 488", Hatsukaichi, both dissected: KUZ Z1582, under a rock ( $34.50118^{\circ}$, $132.08933^{\circ}$; Elev. 790 m ; locality number 5), by Yoshiko Yamane on 10 August 2014, and KUZ Z1654, under a rotten tree ( $34.50182^{\circ}, 132.08961^{\circ}$; Elev. 791 m ; locality number 5), by TN on 16 June 2015. For locality numbers, see Fig. 1.

Additional materials. In total four specimens were examined, all dissected. Three specimens collected from Hiroshima Pref., Japan: KUZ Z1360, from Hosomi, Kitahiroshima ( $34.685^{\circ}, 132.292^{\circ}$; Elev. 470 m ; locality number 4), by Yukiko Narahara on 9 July 2011; KUZ Z1380, from Mt. Azumayama, Hiwacho, Shobara ( $35.0639^{\circ}$, $133.0268^{\circ}$; Elev. 1010 m ; locality number 2), by Ayane Maga on 3 October 2011; and KUZ Z1655, from under a rock along a mountain trail at Mt. Izaiyama, Hiwacho-Mitsugaichi, Shobara ( $35.00143^{\circ}, 133.04640^{\circ}$; Elev. 906 m ; locality number 3), by TN on 17 June 2015. KUZ Z1535, collected from under a rock along a mountain trail at Mt. Iimoriyama, Noigura, Kotoura, Tottori Pref., Japan ( $35.37603^{\circ}, 133.59953^{\circ}$; Elev. 619 m; locality number 1), by TN on 11 December 2013. For locality numbers, see Fig. 1.


Figure 2. Orobdella naraharaetmagarum sp. n., holotype, KUZ Z1652. A Dorsal and B ventral views. Scale bar: 5 mm .


Figure 3. Orobdella naraharaetmagarum sp. n., holotype, KUZ Z1652. A Dorsal and B ventral views of somites I-VIII. C Dorsal and $\mathbf{D}$ ventral views of somites XXIV-XXVII and caudal sucker E Ventral view of somites XI-XIII F Ventral view of gastropore and female gonopore $\mathbf{G}$ Ventral view of gastroporal duct. Scale bars: $1 \mathrm{~mm}(\mathbf{C}-\mathbf{E}, \mathbf{G}), 0.5 \mathrm{~mm}(\mathbf{A}, \mathbf{B})$ and $0.25 \mathrm{~mm}(\mathbf{F})$. Abbreviations: af, annular furrow; an, anus; cp, crop; fg, female gonopore; gd, gastroporal duct; gp, gastropore; mg, male gonopore; np, nephridiopore; and ph, pharynx.

Etymology. The specific name is a noun in the genitive case formed directly from the names of Ms Yukiko Narahara and Ms Ayane Maga, who collected specimens of this new species. Its stem is determined as "naraharaetmag" herein.

Description of holotype. Body firm and muscular, elongate, with constant width in caudal direction, dorsoventrally compressed, BL 40.0 mm , BW 5.3 mm (Fig. 2). Caudal sucker ventral, elliptic, CL 2.4 mm , CW 3.0 mm (Figs 2B, 3D).

Somite I completely merged with prostomium (Fig. 3A). Somites II-IV uniannulate, II not separate from I (Fig. 3A). Somite V biannulate, $(a 1+a 2)>a 3$; a3 forming posterior margin of oral sucker (Fig. 3A, B). Somites VI and VII triannulate,
$a 1=a 2=a 3$ (Fig. 3A, B). Somites VIII - XXV quadrannulate, $a 1=a 2=b 5=b 6$ (Fig. 3A-E). Somite XXVI dorsally triannulate, $a 1>a 2<a 3$, $a 3$ with slight furrow; ventrally biannulate, $(a 1+a 2)>a 3$, $(a 1+a 2)$ with slight furrow; $(a 1+a 2)$ being ventrally last complete annulus (Fig. 3C, D). Somite XXVII uniannulate with slight dorsal furrow; anus behind it with no post-anal annulus (Fig. 3C).

Male gonopore in middle of XI b6 (Fig. 3E). Female gonopore slightly anterior to middle of XIII a1, inconspicuous, located posterior to gastropore (Fig. 3E, F). Gonopores separated by $1 / 2+4+1 / 2$ annuli (Fig. 3E).

Anterior ganglionic mass in VI a2 and a3. Ganglion VII in a2. Ganglia VIII-X, of each somite, in a2. Ganglia XI and XII, of each somite, in a2 (Fig. 4A). Ganglion XIII in a2 and b5 (Fig. 4A). Ganglion XIV in a2 (Fig. 4A). Ganglia XV-XX, of each somite, in a1 and a2 (Fig. 4A). Ganglia XXI-XXIII, of each somite, in a2. Ganglion XXIV in a1. Ganglion XXV in b6 of XXIV and al of XXV. Ganglion XXVI in b5 and b 6 of XXV. Posterior ganglionic mass in $(\mathrm{a} 1+\mathrm{a} 2)$ of XXVI.

Eyes in three pairs, first pair dorsally on posterior margin of II, second and third pairs dorsolaterally on posterior margin of $\mathrm{V}(\mathrm{a} 1+\mathrm{a} 2)$ (Fig. 3A). Papillae numerous, minute, hardly visible, one row on every annulus.

Nephridiopores in 17 pairs, one each situated ventrally at posterior margin of al of each somite in VIII-XXIV (Fig. 3B, D, E).

Pharynx agnathous, euthylaematous, reaching to XIII b5/b6 (Fig. 3G). Crop tubular, acecate, reaching to XIX b5/b6. Gastropore conspicuous, ventral, slightly anterior to middle of XIII a1 (Fig. 3E, F). Gastroporal duct bulbous, slightly winding at junction with gastropore, joining with crop in XIV al (Fig. 3G). Intestine tubular, acecate, reaching to XXIV a1. Rectum tubular, thin-walled, straight.

Testisacs multiple (Fig. 4A); on right side, in XVIII b6 to XXIV a2, in total app. 28 testisacs, 1 in XVIII, 3 in XIX, 5 in XX, 4 in XXI, 6 in XXII, 7 in XXIII, 2 in XXIV; on left side, in XIX a1 to XXV a2, in total app. 27 testisacs, 5 in XIX, 6 in XX, 4 in XXI, 4 in XXII, 4 in XXIII, 3 in XXIV, 1 in XXV. Paired epididymides; right epididymis in XIV b6 to XVIII b6, occupying 17 annuli; left epididymis in XIV/XV to XVIII b6, occupying 16 annuli (Fig. 4A). Ejaculatory bulbs absent. Paired ejaculatory ducts; right duct in XI a2/b5 to XIV b6; left duct in XI a2/b5 to XIV/XV; coiled in position posterior to ovisacs; each duct crossing ventrally beneath each ovisac, then curved in position anterior to ovisacs; each widening from respective junction with epididymis, narrowing at junction with atrial cornua, then turning sharply inward toward atrial cornua without pre-atrial loop (Fig. 4A). Pair of muscular atrial cornua ellipsoid, in XI b5 and b6 (Fig. 4A-D). Atrium short, muscular, globular in XI b5 and b6 (Fig. 4B-D). Penis sheath and penis absent.

Paired ovisacs globular; right ovisac in XIII a2 and b5; left ovisac in XIII a1 and a2 (Fig. 4A, E). Oviducts, thin-walled, left oviduct crossing ventrally beneath nerve cord; both oviducts converging into common oviduct in XIII a2 (Fig. 4A, E). Common oviduct thin-walled, short, directly descending to female gonopore (Fig. 4E).

Variations. BL 48.2 (KUZ Z1654)-33.0 (KUZ Z1360) mm, BW 4.4 (KUZ Z1535)-2.7 (KUZ Z1380) mm, CL 2.5 (KUZ Z1654)-1.2 (KUZ Z1380) mm, CW


Figure 4. Orobdella naraharaetmagarum sp. n., holotype, KUZ Z1652. A Dorsal view of reproductive system including ventral nervous system. B Dorsal (including positions of ganglia XI and XII), C lateral, and $\mathbf{D}$ ventral views of male atrium. E Dorsal view of female reproductive system including position of ganglion XIII. Scale bars: $2 \mathrm{~mm}(\mathbf{A}), 0.5 \mathrm{~mm}(\mathbf{B}-\mathbf{D})$ and $0.25 \mathrm{~mm}(\mathbf{E})$. Abbreviations: ac, atrial cornua; at, atrium; cod, common oviduct; ed, ejaculatory duct; ep, epididymis; gp, gastropore; od, oviduct; ov, ovisac; and ts, testisac.
3.0 (KUZ Z1654)-1.8 (KUZ Z1360, Z1380) mm. Somite XXVI triannulate, a1 = a2 < a3 (KUZ Z1380, Z1582); KUZ Z1360, Z1535, Z1654, Z1655, a3 with slight dorsal furrow. Somite XXVII uniannulate or biannulate (KUZ Z1360). Male gonopore generally in middle of XI b6, rarely slightly anterior or posterior to middle of XI b6. Female gonopore in middle of XIII a1, slightly anterior or posterior to middle of XIII a1. X b5 and XIII a2, respectively, being first and last annuli of clitellum. Eyes generally three pairs; KUZ Z1654, Z1655, first pair dorsally on anterior margin of III; KUZ Z1582, multiple eyes detected, one eye on left dorsal of II/III, one small eyespot on right dorsal of III, one small eyespot on left dorsal of III/IV, one small eyespot on right dorsal of IV, and two pairs of eyes dorsolaterally on posterior margin of V (al + a2). Pharynx reaching to XIII b5/b6-XIII/XIV. Crop reaching to XIX b5/b6-XX a1. Gastropore in middle of XIII a1, slightly anterior or posterior to middle of XIII a1. Gastroporal duct generally bulbous; KUZ Z1360, Z1582, tubular. Intestine reaching to XXIII/XXIV-XXIV/XXV. Testisacs multiple; right side app. 11-24 sacs in XIX b6XX b5 to XXIV b5-b6; left side app. 11-23 sacs in XIX b6-XX a2 to XXIII b6-XXV a1. Paired epididymides; right epididymis in XV a1-XV b5 to XIX a2-XX a2/b5, occupying 17-20 annuli; left epididymis in XV a1-XV b5 to XIX b5-XX a2, occupying 17-20 annuli. Paired ejaculatory ducts, curved, loosely curved, or straight in position posterior to ovisacs. Atrial cornua ovate, fusiform, or ellipsoid in XI b5 and b6; KUZ Z1535 in XI b5-XII a. Atrium generally in XI b5 and b6; KUZ Z1535, Z1582 in XI b6. Paired ovisacs generally in XIII a2 and b5; KUZ Z1535, undeveloped, in XIII a2. Right or left oviduct crossing ventrally beneath nerve cord; KUZ Z1380 both oviducts converging into common oviduct in XIII a1/a2.

Coloration. In life, dorsal surface bluish gray (Fig. 5A, B), or gray; ventral surface reddish white or ash gray; clitellum, when obvious, whitish gray (Fig. 5B). Color faded in preservative; KUZ Z1535 with one dorsal black line from VIII b5 to XXVI a2.

Distribution. This species was primarily collected in Hiroshima Prefecture in Chugoku District, Honshu, Japan, and in Tottori Prefecture. The lowest elevation among the localities was 470 m , and the highest was 1010 m . The locality data for this species suggested that it is distributed in mountainous regions in Chugoku District, Honshu, Japan.

Natural history. This species was generally found curled up under rocks or rotten trees in moist mountainous habitats (Fig. 5C, D). Oligochaete worms were sometimes observed in the digestive tract during specimen dissection. Therefore, this species is an earthworm-eater, as are the other known Orobdella leeches.

A mature leech with an obvious clitellum was collected on 16 June. Moreover, the holotype, which appeared to have a clitellum (Fig. 5A), was collected on 25 April. These findings suggest that the reproductive season of the new species begins in May and then continues at least to mid-to-late June.

Remarks. The new species unambiguously belongs to Orobdella as it has all the generic diagnostic characteristics defined in Nakano et al. (2012): post-anal annulus absent; pharynx agnathous, euthylaematous; gastropore in XIII; gastroporal duct lying on female organ; gonopores separated by more than one full somite; testisacs multiple;


Figure 5. Orobdella naraharaetmagarum sp. n., holotype, KUZ Z1652 (A, D) and paratype, KUZ Z1654 (B). Habitat of holotype (C). A and B Dorsal views of live animals. D Live animal found curled up under a stone at the type locality. Scale bars: 5 mm .
male atrium in XI without penis sheath and penis; ovisacs globular in XIII; female median reproductive system essentially lacking.

The specimens were small (up to 48 mm ). However, one leech (KUZ Z1654) was determined to be mature because it possessed an obvious clitellum. The holotype, which had a body length of 40 mm , also possessed a slightly developed clitellum and developed testisacs. Two specimens (KUZ Z1360, Z1582) possessed a tubular gastroporal duct. This tubular gastroporal duct was thought to be observed in immature individuals because these two specimens had undeveloped, undetectable testisacs.

Taxonomic studies (Nakano 2010, 2012b, 2014, Nakano and Gongalsky 2014, Nakano and Lai 2012, Nakano and Seo 2014) indicate that the new species differs from the seven other quadrannulate species (i.e., O. esulcata, O. kawakatsuorum Richardson, 1975, O. ketagalan Nakano \& Lai, 2012, O. koikei, O. masaakikuroiwai, O. tsushimensis Nakano, 2011a, and O. whitmani Oka, 1895) by the following combination of characteristics (Table 2): body length less than 5 cm , IV uniannulate, gonopores separated by $1 / 2+4+1 / 2$ annuli, XXV quadrannulate, gastroporal duct bulbous, epididymides in XIV to XX, atrial cornua developed, ellipsoid or ovate. Among the above seven quadrannulate species, two species, $O$. koikei and $O$. masaakikuroiwai, are known to have body lengths shorter than 5 cm . Orobdella naraharaetmagarum can be distinguished from these two species by the annulation of XXV and the length of the epididymides.

The new species is distinguishable from the four sexannulate species $O$. dolichopharynx Nakano, 2011b, O. ijimai Oka, 1895, O. mononoke Nakano, 2012a, and O. shimadae Nakano, 2011b and the octannulate species O. octonaria Oka, 1895, since $O$. naraharaetmagarum possesses mid-body somites that are quadrannulate.
Table 2. Comparisons of morphological characters between Orobdella naraharaetmagarum $\mathrm{sp} . \mathrm{n}$. and seven quadrannulate congeneric species.

| Character | O. naraharaetmagarum <br> sp. n. | O. esulcata <br> Nakano, 2010 | O. kawakatsuorum <br> Richardson, $\mathbf{1 9 7 5}$ | O. ketagalan <br>  <br> Lai, 2012 | O. koikei <br> Nakano, 2012b | O. masaakikuroivai <br> Nakano, 2014 | O. tsushimensis <br> Nakano, 2011a | O. whitmani <br> Oka, 1895 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Body length of <br> matureleech | less than 5 cm | up to approx. 10 cm | up to approx. 10 cm | up to approx. <br> 10 cm | less than 4 cm | less than 4 cm | up to approx. <br> 10 cm | up to approx. <br> 10 cm |
| Annulation <br> of IV | uniannulate | uniannulate | biannulate | uniannulate | uniannulate | uniannulate | uniannulate | uni- or <br> biannulate |
| Number of <br> annuli between <br> gonopores | $1 / 2+4+1 / 2$ | $2 / 3+4+1 / 3$ | 6 | $1 / 2+4+1 / 2$ | $1 / 2+4+1 / 2$ | $1 / 2+4+1 / 2$ | $1 / 2+5$ | $1 / 2+4+1 / 2$ |
| Annulation of <br> XXV | quadrannulate | quadrannulate | quadrannulate | quadrannulate | triannulate | quadrannulate | quadrannulate | quadrannulate |
| Gastroporal <br> duct | bulbous | tubular, but bulbous <br> at junction with <br> gastropore | simple tubular | simple tubular | bulbous | bulbous | bulbous | bulbous |
| Epididymides | XV (posterior of XIV) <br> to XX | XVI to XX | XVI to XVII | absent | XV to XX | XVI to XVIII | XVII to XIX | XVI to XVIII |
| Atrial cornua | developed, ellipsoid or <br> ovate | developed, ovate | undeveloped | undeveloped | developed, ovate | developed, ovate | developed, ovate | developed, |
| ovate |  |  |  |  |  |  |  |  |

## Molecular phylogenies and genetic distances

The BI tree (Fig. 6) for estimating the phylogenetic position of the new species had an identical topology to that of the ML tree ( $\ln L=-24617.61$; not shown). The monophyly of Orobdella naraharaetmagarum and $O$. esulcata was strongly supported ( $\mathrm{BS}=$ $100 \%$, BPP = 1.0).

The ML tree (ln $L=-15057.02$ ) (Fig. 7) used to construct the phylogenetic relationships of the new species had an almost identical topology to that of the BI tree (not shown). The monophyly of the specimens identified as $O$. naraharaetmagarum was recovered $(\mathrm{BS}=100 \%, \mathrm{BPP}=1.0)$. This clade was divided into two subclades (hereafter lineages 1 and 2). The monophyly of lineage 1 was strongly supported ( $\mathrm{BS}=$ $99 \%$, BPP $=1.0$ ). Lineage 1 comprised three specimens: KUZ Z1380 (locality number 2 in Fig. 1), Z1535 (locality number 1), and Z1655 (locality number 3). KUZ Z1380 and Z1655 formed a monophyletic group $(\mathrm{BS}=99 \%, \mathrm{BPP}=0.99)$. The monophyletic lineage $2(\mathrm{BS}=100, \mathrm{BPP}=1.0)$ contained four individuals: KUZ Z1380 (locality number 4), Z1582, Z1650, and Z1652 (locality number 5). In the ML phylogeny, the three specimens KUZ Z1582, Z1650, and Z1652 formed a monophyletic lineage, although this relationship was not supported ( $\mathrm{BS}=33 \%$ ). The monophyly of KUZ Z1582 and Z1652 was also not fully supported $(B S=63 \%, B P P=0.76)$.

The pairwise COI uncorrected $p$-distance within $O$. naraharaetmagarum was $0.6-4.7 \%($ mean $=3.3 \%)($ Table 3). The genetic distance between lineages 1 and 2


Figure 6. Bayesian inference tree for $5,192 \mathrm{bp}$ of nuclear 18 S rRNA and histone H 3 and mitochondrial COI, tRNA ${ }^{\text {Cys }}$, tRNA ${ }^{\text {Met }}, 12 \mathrm{~S}$ rRNA, $\mathrm{tRNA}^{\mathrm{Val}}, 16 \mathrm{~S}$ rRNA, $\mathrm{tRNA}{ }^{\text {Leu }}$ and ND1 markers. Numbers on nodes represent bootstrap values for maximum likelihood and Bayesian posterior probabilities. A species name of Orobdella in red indicates a quadrannulate species; in green, sexannulate; and in blue, octannulate.


Figure 7. Maximum likelihood tree ( $\ln L=-15057.02$ ) for $3,008 \mathrm{bp}$ of mitochondrial COI, tRNA ${ }^{\mathrm{Cys}}$, tRNA ${ }^{\text {Met }}, 12 \mathrm{~S}$ rRNA, tRNA ${ }^{\text {Val }}, 16 \mathrm{~S}$ rRNA, tRNA ${ }^{\text {Leu }}$ and ND1 markers. Numbers on nodes represent bootstrap values for maximum likelihood and Bayesian posterior probabilities.

Table 3. Uncorrected $p$-distances for the 1266 bp for the COI sequences of Orobdella naraharaetmagar$u m \mathrm{sp} . \mathrm{n}$. specimens, with associated collection locality numbers (see Fig. 1).

| Specimen (locality number) | $\mathbf{1}$ | $\mathbf{2}$ | $\mathbf{3}$ | $\mathbf{4}$ | $\mathbf{5}$ | $\mathbf{6}$ | $\mathbf{7}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1: KUZ Z1535 (1) |  |  |  |  |  |  |  |
| 2: KUZ Z1380 (2) | 0.042 |  |  |  |  |  |  |
| 3: KUZ Z1655 (3) | 0.041 | 0.031 |  |  |  |  |  |
| 4: KUZ Z1360 (4) | 0.045 | 0.043 | 0.041 |  |  |  |  |
| 5: KUZ Z1654 (5) | 0.042 | 0.042 | 0.042 | 0.011 |  |  |  |
| 6: KUZ Z1582 (5) | 0.047 | 0.043 | 0.042 | 0.014 | 0.009 |  |  |
| 7: KUZ Z1652 (5) | 0.047 | 0.046 | 0.044 | 0.013 | 0.010 | 0.006 |  |

was $4.1-4.7 \%$ (mean $=4.4 \%$ ). The genetic divergences within lineages 1 and 2 were $3.1-4.2 \%$ (mean $=3.8 \%$ ) and $0.6-1.4 \%$ (mean $=1.1 \%$ ), respectively. In addition, that between $O$. naraharaetmagarum and $O$. esulcata was $8.4-9.1 \%$ (mean $=8.9 \%$ )

## Discussion

The obtained molecular phylogenies showed that the present specimens formed a wellsupported clade. In addition, the mean value of the COI uncorrected $p$-distance among the individuals was $4.4 \%$. This value indicated a clear gap between the present speci-
mens and the closest congener, Orobdella esulcata. Therefore, all of the specimens examined can be considered to belong to the same species, Orobdella naraharaetmagarum.

Although the precise phylogenetic position of $O$. tsushimensis from the Korean Peninsula and the adjacent islets could not be determined in the obtained phylogenies (see Fig. 6), they showed that the genus Orobdella comprises three clades: a Hokkaido lineage including $O$. kawakatsuorum and $O$. koikei; an eastern lineage consisting of four species, $O$. ijimai, $O$. masaakikuroiwai, $O$. octonaria, and $O$. whitmani, distributed in eastern Honshu; and a western lineage containing five previously described species, $O$. mononoke, $O$. dolichopharynx and $O$. shimadae from the Nansei Islands, O. ketagalan from Taiwan, and O. esulcata recorded in Kyushu, Japan. The present phylogenies demonstrated that $O$. naraharaetmagarum was a member of the last clade, and formed a monophyly with $O$. esulcata with strong support. Therefore, the range of the western lineage group covers the area from Chugoku District, at the western tip of Honshu, to Taiwan.

As indicated in Figure 7, Orobdella naraharaetmagarum was divided into eastern (lineage 1 ; locality numbers $1-3$ ) and western (lineage 2 ; locality numbers 4,5 ) phylogroups. The COI uncorrected $p$-distances within lineage 1 were higher than those within lineage 2. The calculated genetic divergences between the three specimens collected from Mt. Kanmuriyama (locality number 5; KUZ Z1582, Z1652, and Z1654) and one individual, KUZ Z1360, from Kitahiroshima (locality number 4) was $1.1-1.4 \%$. The geographic distance between these two collection localities is ca. 28 km . In comparison, the genetic distance between KUZ Z1380 collected on Mt. Azumayama (locality number 2) and KUZ Z1655 from Mt. Izaiyama (locality number 3) was greater than this value (3.1\%), although these two localities are separated only by ca. 7 km . These phylogenetic relationships and genetic divergences implied that leeches belonging to lineage 2 dispersed more recently and rapidly than those of lineage 1. Such discordance between the COI genetic divergences and geographical distances was also seen in the small species $O$. masaakikuroiwai (Nakano 2014). Further molecular phylogenetic studies will help to reveal the biogeographical history of the Orobdella leeches.

The phylogenetic position of $O$. naraharaetmagarum also indicated that the small size of the mature leeches evolved in parallel within Orobdella, as mentioned in Nakano (2014). According to the obtained molecular phylogenies and the phylogenetic trees from studies (Nakano 2012b, 2014), each of the three small species, O. koikei, O. masaakikuroiwai, and $O$. naraharaetmagarum may have diverged from a single large quadrannulate species. As with the other two small species (Nakano 2012b, 2014), O. naraharaetmagarum is also distributed sympatrically with undescribed large quadrannulate species in Chugoku District (Nakano, unpublished data). Therefore, further systematic studies should be carried out to reveal the species diversity and evolutionary history of the genus Orobdella.

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## References

Akaike H (1974) A new look at the statistical model identification. IEEE Transactions on Automatic Control 19: 716-723. doi: 10.1109/TAC.1974.1100705
Apakupakul K, Siddall ME, Burreson EM (1999) Higher level relationships of leeches (Annelida: Clitellata: Euhirudinea) based on morphology and gene sequences. Molecular Phylogenetics and Evolution 12: 350-359. doi: 10.1006/mpev.1999.0639
Blanchard R (1897) Hirudinées du Musée de Leyde. Notes from the Leyden Museum 19: 73-113.
Colgan DJ, McLauchlan A, Wilson GDF, Livingston SP, Edgecombe GD, Macaranas J, Cassis G, Gray MR (1998) Histone H3 and U2 snRNA DNA sequences and arthropod molecular evolution. Australian Journal of Zoology 46: 419-437. doi: 10.1071/ZO98048
Felsenstein J (1985) Confidence limits on phylogenies: an approach using the bootstrap. Evolution 39: 783-791. doi: 10.2307/2408678
Folmer O, Black M, Hoeh W, Lutz R, Vrijenhoek R (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3: 294-299.
Hillis DM, Bull JJ (1993) An empirical test of bootstrapping as a method for assessing confidence in phylogenetic analysis. Systematic Biology 42: 182-192. doi: 10.1093/sysbio/42.2.182
Katoh K, Standley DM (2013) MAFFT multiple sequence alignment software version 7: improvements in performance and usability. Molecular Biology and Evolution 30: 772-780. doi: $10.1093 / \mathrm{molbev} / \mathrm{mst} 010$
Lanfear R, Calcott B, Ho SYW, Guindon S (2012) PartitionFinder: Combined selection of partitioning schemes and substitution models for phylogenetic analyses. Molecular Biology and Evolution 29: 1695-1701. doi: 10.1093/molbev/mss020
Leaché AD, Reeder TW (2002) Molecular systematics of the eastern fence lizard (Sceloporus undulatus): a comparison of parsimony, likelihood, and Bayesian approaches. Systematic Biology 51: 44-68. doi: 10.1080/106351502753475871

Light JE, Siddall ME (1999) Phylogeny of the leech family Glossiphoniidae based on mitochondrial gene sequences and morphological data. The Journal of Parasitology 85: 815-823. doi: 10.2307/3285816

Moore JP (1927) The segmentation (metamerism and annulation) of the Hirudinea. In: Harding WA, Moore JP. The Fauna of British India, including Ceylon and Burma. Hirudinea. Taylor \& Francis, London, 1-12.
Moore JP (1929) Leeches from Borneo with descriptions of new species. Proceedings of the Academy of Natural Sciences of Philadelphia 81: 267-295.
Nakano T (2010) A new species of the genus Orobdella (Hirudinida: Arhynchobdellida: Gastrostomobdellidae) from Kumamoto, Japan, and a redescription of $O$. whitmani with the designation of the lectotype. Zoological Science 27: 880-887. doi: 10.2108/zsj.27.880
Nakano T (2011a) A new species of Orobdella (Hirudinida: Arhynchobdellida: Gastrostomobdellidae) from Tsushima Island, Japan. Species Diversity 16: 39-47.
Nakano T (2011b) Redescription of Orobdella ijimai (Hirudinida: Arhynchobdellida: Gastrostomobdellidae), and two new species of Orobdella from the Ryukyu Archipelago, Japan. Zootaxa 2998: 1-15.
Nakano T (2012a) A new sexannulate species of Orobdella (Hirudinida, Arhynchobdellida, Orobdellidae) from Yakushima Island, Japan. ZooKeys 181: 79-93. doi: 10.3897/zookeys.181.2932
Nakano T (2012b) A new species of Orobdella (Hirudinida, Arhynchobdellida, Gastrostomobdellidae) and redescription of $O$. kawakatsuorum from Hokkaido, Japan with the phylogenetic position of the new species. ZooKeys 169: 9-30. doi: 10.3897/zookeys.169.2425
Nakano T (2014) A new quadrannulate species of Orobdella (Hirudinida, Arhynchobdellida, Orobdellidae) from central Honshu, Japan. ZooKeys 445: 57-76. doi: 10.3897/zookeys.445.7999
Nakano T, Gongalsky KB (2014) First record of Orobdella kawakatsuorum (Hirudinida: Arhynchobdellida: Erpobdelliformes) from Kunashir Island, Kuril Islands. Biodiversity Data Journal 2: e1058. doi: 10.3897/BDJ.2.e1058
Nakano T, Lai Y-T (2012) A new species of Orobdella (Hirudinida, Arhynchobdellida, Orobdellidae) from Taipei, Taiwan. ZooKeys 207: 49-63. doi: 10.3897/zookeys.207.3334
Nakano T, Ramlah Z, Hikida T (2012) Phylogenetic position of gastrostomobdellid leeches (Hirudinida, Arhynchobdellida, Erpobdelliformes) and a new family for the genus Orobdella. Zoologica Scripta 41: 177-185. doi: 10.1111/j.1463-6409.2011.00506.x
Nakano T, Seo H-Y (2014) First record of Orobdella tsushimensis (Hirudinida: Arhynchobdellida: Gastrostomobdellidae) from the Korean Peninsula and molecular phylogenetic relationships of the specimens. Animal Systematics, Evolution and Diversity 30: 87-94. doi: 10.5635/ASED.2014.30.2.087

Oka A (1895) On some new Japanese land leeches. (Orobdella nov. gen.). The Journal of the College of Science, Imperial University, Japan 8: 275-306.
Oka A (1910) Key to Japanese leeches. Dobutsugaku Zasshi 22: 56-64.
Pawłowski LK (1962) O występowaniu pijawki Erpobdella octoculata (L.) w Japonii. Zeszyty Naukowe Uniwersytetu Łódzkiego Seria II Nauki Matematyczno-przyrodnicze 12: 127-136.
Rambaut A, Drummond AJ (2009) Tracer v. 1.6. http://tree.bio.ed.ac.uk/software/tracer/

Richardson LR (1975) A new species of terricolous leeches in Japan (Gastrostomobdellidae, Orobdella). Bulletin of the National Science Museum Series A (Zoology) 1: 39-56.
Ronquist F, Teslenko M, van der Mark P, Ayres DL, Darling A, Höhna S, Larget B, Liu L, Suchard MA, Huelsenbeck JP (2012) MrBayes 3.2: Efficient Bayesian phylogenetic inference and model choice across a large model space. Systematic Biology 61: 539-542. doi: 10.1093/sysbio/sys029

Sawyer RT (1986) Leech Biology and Behaviour. Clarendon Press, Oxford, 1065 pp.
Schwarz G (1978) Estimating the dimension of a model. The Annals of Statistics 6: 461-464. doi: 10.1214/aos/1176344136
Stamatakis A (2014) RAxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. Bioinformatics 30: 1312-1313. doi: 10.1093/bioinformatics/btu033
Tamura K, Stecher G, Peterson D, Filipski A, Kumar S (2013) MEGA6: Molecular Evolutionary Genetics Analysis version 6.0. Molecular Biology and Evolution 30: 2725-2729. doi: 10.1093/ molbev/mst197

# Endonura Cassagnau in Iran, with a key to species of the genus (Collembola, Neanuridae, Neanurinae) 

Adrian Smolis ${ }^{1}$, Morteza Kahrarian², Agata Piwnik', Dariusz Skarżyński'<br>I Institute of Environmental Biology, University of Wroctaw, Przybyszewskiego 63-77, 51-148 Wroctaw, Poland<br>2 Department of Plant breeding and Agronomy, College of Agriculture, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran<br>Corresponding author: Dariusz Skarżyński (dariusz.skarzynski@uni.wroc.pl)

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#### Abstract

Three new species of Endonura are described from Iran. Endonura dichaeta sp. n. can be recognized by an ogival labrum, head without chaetae O and E , chaeta D connected with tubercle Cl , tubercle Dl with five chaetae on head, absence of tubercles Di on thorax I and tubercle ( $\mathrm{Di}+\mathrm{Di}$ ) of thorax V with $2+2$ chaetae. Endonura ceratolabralis sp. $\mathbf{n}$. is characterized by large body size, reduction of labral chaetotaxy, ogival labrum, head without chaeta O and fusion of tubercles Di and De on first thoracic segment. Endonura persica sp. n . is distinguished from its congeners by a nonogival labrum, absence of chaeta O , tubercles Dl and ( $\mathrm{L}+\mathrm{So}$ ) with five and eight chaetae respectively and claw with inner tooth. The key to all species of the genus is given.


## Keywords

Springtails, taxonomy, new species

## Introduction

Endonura was established by Cassagnau (1979) as one of four subgenera within the genus Neanura MacGilliwray, 1893. Later, Deharveng (1982) raised it to the generic level. At present, Endonura is one of the largest ( 37 valid species) and most accurately studied genera within the subfamily Neanurinae (Dallai 1983, Deharveng 1979, 1982, Fanciulli and Dallai 2008, Pomorski and Skarżyński 2000, Pozo and Simón 1982, Smolis and Kaprus' 2003, 2009, Smolis 2006, Smolis et al. 2007, 2011). It is mostly a Palaearctic genus and only one species, E. reticulata (Axelson, 1905), is known from the Nearctic (Alaska, Smolis et al. 2011). According to a recent definition (Smolis 2008), Endonura is characterized by the following characters: 0-2 ocelli, reduced mouth parts with a thin mandible and a styliform maxilla, separate tubercles Di and De on the head, the non-cross-type of chaetotaxy on the head and three or two tubercles on abdomen V. The highest species diversity is observed in Europe ( 32 from among the 37 known species). However, this may be a false picture because many areas of the Palaearctic have been poorly studied by collembologists. Undoubtedly, one of such regions is Central Asia, but in this case the situation is rapidly and positively changing (Arbea and Kahrarian 2015, Kahrarian 2014, Kahrarian et al. 2013, Mayvan et al. 2015, Shayanmehr et al. 2013, Smolis et al. 2012). In the present paper, three new non-European Endonura from the western part of Iran are described. An updated key to all species of the genus is included.

## Terminology

Terminology for the description follows that given in Deharveng (1983), Deharveng and Weiner (1984), Smolis and Deharveng (2006) and Smolis (2008).

## Abbreviations used:

General morphology: abd. - abdomen, ant. - antenna, AOIII - sensory organ of antennal segment III, Cx - coxa, Fe - femur, Scx2 - subcoxa 2, T - tibiotarsus, th. - thorax, Tr - trochanter, VT - ventral tube.

Groups of chaetae: Ag - antegenital, An - chaetae of anal lobes, ap - apical, ca centroapical, cm - centromedial, cp - centroposterior, d - dorsal, Fu - furcal, vc - ventrocentral, Ve or ve - ventroexternal, Vea - ventroexternoanterior, Vem - ventroexternomedial, Vep - ventroexternoposterior, Vel - ventroexternolateral, Vec - ventroexternocentral, Vei - ventroexternointernal, Vi or vi - ventrointernal, Vl - ventrolateral.

Tubercles: Af - antenno-frontal, Cl - clypeal, De - dorsoexternal, Di - dorsointernal, Dl - dorsolateral, L - lateral, Oc - ocular, So - subocular.

Types of chaetae: Ml - long macrochaeta, Mc - short macrochaeta, Mcc - very short macrochaeta, me - mesochaeta, mi - microchaeta, ms - $s$-microchaeta or microsensillum, S or $s$ - chaeta $s$, bs - border $s$-chaeta on ant. IV, miA - microchaetae on
ant. IV, iv - ordinary chaetae on ventral ant. IV, or - organite of ant. IV, brs - border $s$-chaeta on ant. IV, i - ordinary chaeta on ant. IV, mou - cylindrical s-chaetae on ant. IV („soies mousses"), x - labial papilla $x$, L' - ordinary lateral chaeta on abd. V, B4, B5 - ordinary chaetae on tibiotarsi.

## Materials and methods

The specimens were cleared in Nesbitt's fluid, subsequently mounted on slides in Swan's medium and observed using a phase contrast microscope Nikon E600. Photographs were made using a camera Nikon D5100 mounted on a microscope mentioned above. Photographs were stacked using Helicon Focus 6.2.2. and prepared for publication using Adobe Photoshop CS3. Material is deposited in the Department of Invertebrate Biology, Evolution and Conservation, Institute of Environmental Biology, University of Wrocław, Poland.

## Taxonomy

## Endonura dichaeta sp. n.

http://zoobank.org/4CBE64B2-069B-4254-AF20-43D26E6CFE10
Figs 1-4, Table 1

Type material. Holotype: adult female on slide, Iran, Osmanevand area, near Golestan village (N3355', E4706', 1241 m a.s.l.), litter in oak forest, 13.XII.2013, leg. M. Kahrarian. Paratypes: female, two males and two juveniles on slides, same data as holotype.

Other material. Two females and male on slide, Iran, Osmanevand area, near Chelkooshk village ( $\mathrm{N} 34^{\circ} 03^{\prime}, \mathrm{E} 47^{\circ} 12^{\prime}, 1516 \mathrm{~m}$ a.s.l.), litter in oak forest, 31.I.2014, leg. M. Kahrarian; three juveniles on slide, Iran, Paveh county, near Shabankereh village (N3452.978', E46우0.760', 1632 m a.s.l.), litter in oak forest, 20.I.2014, leg. M. Kahrarian; two females and juvenile, Iran, Kermanshah county, near Chahar zebra-e-oliya village (N34ํ $13^{\prime}, \mathrm{E} 46^{\circ} 40^{\prime}, 1592 \mathrm{~m}$ a.s.l.), litter in oak forest, 24.I.2014, leg. M. Kahrarian.

Etymology. The species name refers to rare feature within the genus - only two chaetae Di on each side of tubercle ( $\mathrm{Di}+\mathrm{Di}$ ) of abdomen V .

Diagnosis. Habitus typical of the genus Endonura. Dorsal tubercles present and well developed, except tubercles Di on th. I. $2+2$ unpigmented eyes. Buccal cone long, labrum ogival. Head with chaetae A, B, C, D, F and G. Chaetae O and E absent. Tubercles Cl and Af separate. Tubercle Cl with chaetae D . Tubercles Dl and ( $\mathrm{L}+\mathrm{So}$ ) on head with five and eight chaetae respectively. Tubercles De on th. II and III with three and four chaetae respectively. Tubercles L on abd. III and IV with three and six chaetae respectively. Abd. IV and V with eight and three tubercles respectively. Claw without inner tooth. Tibiotarsi with chaetae B4 and B5 short.


Figures I-4. Endonura dichaeta sp. n.: I head (holotype), dorsal and lateral chaetotaxy $\mathbf{2}$ ventral sclerification of labrum $\mathbf{3}$ dorsal chaetotaxy of thorax $\mathbf{4}$ dorsal chaetotaxy of abdomen III-VI. Arrows indicate the position of eyes.

Description. Habitus typical of the genus. Body length (without antennae): 0.751.55 mm (holotype 1.30 mm ). Colour of the body white. $2+2$ medium unpigmented eyes (Fig. 1).

Types of dorsal ordinary chaetae. Macrochaetae Ml relatively long, strongly thickened, almost cylindrical, arc-like or straight, narrowly sheathed, feebly serrated, apical-
ly pointed (Figs 1, 3-4); macrochaetae Mc and Mcc thickened, straight and pointed; mesochaetae and microchaetae short, thin, feebly serrated and pointed.

Head. Labrum ogival, with ventral sclerifications as in Fig. 2. Labrum chaetotaxy $2 / 2,4$. Labium with four basal, three distal and four lateral chaetae, papillae x absent. Maxilla styliform, mandible thin tridentate. Chaetotaxy of antennae as in Table 1c. Apical vesicle distinct, trilobed. S-chaetae of ant.IV long and moderately thickened. Chaetotaxy of head as in Table 1a, b, and Fig. 1. Chaeta D connected with tubercle Cl. Tubercle Af on head longer than tubercles Oc. Tubercle Dl with five chaetae, chaeta Dl 3 absent, chaeta Dl6 as minute microchaeta and hard to detect (Fig. 1). Tubercle (L+So) with eight chaetae, chaetae So2 and L3 absent, chaeta So6 as Mc (Fig. 1). Elementary tubercles BE and CD present. Chaeta A shorter than B .

Thorax, abdomen, legs. Body s-chaeta thin and smooth, shorter than nearby macrochaetae (Figs 3, 4). Chaetotaxy of th. and abd. as in Table 1d and in Figs 3, 4. Tubercles Di on th.I not differentiated. Chaetae De3 on th. III and abd. I-III as Mcc. Chaetae De2 on th. II-III and De3 on th. III connected with tubercle De. Chaetae De3 on abd. I-III connected with tubercle De (Fig. 4). The line of chaetae De1-chaeta

Table Ia. Chaetotaxy of Endonura dichaeta sp. n.: Cephalic chaetotaxy-dorsal side.

| Tubercle | Number of chaetae | Types of chaetae | Names of chaetae |
| :---: | :---: | :---: | :---: |
| Cl | 6 | $\begin{aligned} & \mathrm{Ml} \\ & \mathrm{Mc} \end{aligned}$ | $\begin{gathered} \mathrm{F} \\ \mathrm{D}, \mathrm{G} \end{gathered}$ |
| Af | 6 | $\begin{aligned} & \mathrm{Ml} \\ & \mathrm{Mc} \end{aligned}$ | $\begin{gathered} \mathrm{A} \\ \mathrm{~B}, \mathrm{C} \end{gathered}$ |
| Oc | 3 | $\begin{aligned} & \mathrm{Ml} \\ & \mathrm{Mc} \end{aligned}$ | $\begin{gathered} \text { Ocm, Ocp } \\ \text { Oca } \end{gathered}$ |
| Di | 2 | $\begin{aligned} & \mathrm{Ml} \\ & \mathrm{Mc} \end{aligned}$ | $\begin{aligned} & \text { Di1 } \\ & \text { Di2 } \end{aligned}$ |
| De | 2 | $\begin{aligned} & \mathrm{Ml} \\ & \mathrm{Mc} \end{aligned}$ | $\begin{aligned} & \mathrm{De} 1 \\ & \mathrm{De} 2 \end{aligned}$ |
| Dl | 5 | Ml <br> Mc <br> Mcc <br> mi | $\begin{gathered} \text { Dl1, D15 } \\ \text { D14 } \\ \text { D12 } \\ \text { D16 } \end{gathered}$ |
| (L+So) | 8 | Ml <br> Mc <br> me | $\begin{gathered} \text { L1, L4, So1 } \\ \text { L2, So6 } \\ \text { So3-5 } \\ \hline \end{gathered}$ |

Table Ib. Chaetotaxy of Endonura dichaeta sp. n.: Cephalic chaetotaxy-ventral side.

| Group | Number of chaetae |
| :---: | :---: |
| $V i$ | 6 |
| Vea | 3 |
| Vem | 3 |
| Vep | 4 |
| labium | $11,0 \times$ |

Table Ic. Chaetotaxy of Endonura dichaeta sp. n.: Chaetotaxy of antennae.

| Segment, Group | Number of chaetae | Segment, Group | Number of chaetae adult |
| :---: | :---: | :---: | :---: |
| I | 7 | IV | or, $8 \mathrm{~S}, \mathrm{i}, 12 \mathrm{mou}, 6 \mathrm{brs}$, <br> 2 iv |
| II | 11 |  |  |
| III | 5 sensilla AO III |  | $8 \mathrm{bs}, 5 \mathrm{miA}$ |
| ve | 5 |  | $2 \mathrm{bs}, 3 \mathrm{miA}$ |
| vc | 4 | ca | $3 \mathrm{bs}, 1 \mathrm{miA}$ |
| vi | 4 | cm | $8 \mathrm{miA}, 1 \mathrm{brs}$ |
| d | 5 | cp |  |

Table Id. Chaetotaxy of Endonura dichaeta sp. n.: Postcephalic chaetotaxy.

|  | Di | Terga <br> De | Dl | L | Scx2 | $\mathbf{C x}$ | Legs <br> $\mathbf{T r}$ | Fe | T |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| th. I | 1 | 2 | 1 | - | 0 | 3 | 6 | 13 | 19 |
| th. II | 3 | $2+s$ | $3+s+\mathrm{ms}$ | 3 | 2 | 7 | 6 | 12 | 19 |
| th. III | 3 | $3+s$ | $3+s$ | 3 | 2 | 8 | 6 | 11 | 18 |
|  |  |  |  |  |  |  | Sterna |  |  |
| abd. I | 2 | $3+s$ | 2 | 3 | VT: 4 |  |  |  |  |
| abd. II | 2 | $3+s$ | 2 | 3 | Ve: $4-5$ | Ve1 - | present |  |  |
| abd. III | 2 | $3+s$ | 2 | 3 | Vel:4-5 |  |  | Fu:5-6me | $2-4 \mathrm{mi}$ |
| abd. IV | 2 | $2+s$ | 3 | 6 | Vel: 4 | Vec: 2 | Vei: 2 | Vl: 4 |  |
| abd. V | $(2+2)$ | 7 | $5+s$ |  | Ag: 2 |  |  | Vl: 1 | L': 1 |
| abd. VI |  |  |  |  |  |  |  |  |  |

$s$ not perpendicular to the dorsomedian line on abd I-III. Furca rudimentary with 2-4 microchaetae. Tubercles Di on abd. V fused, with chaetae Di2 as Mc or Mcc, chaetae Di3 absent (Fig. 4). Chaetae L' and Vl on abd. V present. IV abd. with $2+2$ chaetae Ag. No cryptopygy. Chaetotaxy of legs as in Table 1d.

Remarks. In general appearance (shape of dorsal chaetae, chaetotaxy of central area of head and dorsal side of thorax and abdomen, complete absence of pigmentation and absence of cryptopygy), E. dichaeta sp. n. strongly resembles E. tartaginenis Deharveng, 1980 described from Corsica. Nevertheless, both taxa differ in some essential characters, important from taxonomic point of view: presence/absence of chaetae E on head (dichaeta sp. n. absent, tartaginenis present), number of chaetae Dl on head (dichaeta sp. n. five, tartaginenis six), number of chaetae (L+So) ( dichaeta sp. n. eight, tartaginenis nine), presence/absence of elementary tubercle EE on head (dichaeta sp. n. absent, tartaginenis present), presence/absence of tubercles Di on the first thoracic segment (dichaeta sp. n. absent, tartaginenis present), number of chaetae Di on abd. V (dichaeta sp. n. $2+2$, tartaginenis $3+3$ ) and presence/absence of tooth on claw (dichaeta sp. n. absent, tartaginenis present). In addition, the new species is characterized by only $2+2$ antegenital chaetae (tartaginenis $3+3$ ) and ogival labrum (unknown in tartaginenis), characters rarely observed within the genus.

## Endonura ceratolabralis sp. n.

http://zoobank.org/FC09DDF3-EB60-416D-B31C-A290A4E812D5
Figs 5-9, Table 2
Type material. Holotype: adult female on slide, Iran, Osmanevand area, near Markhor village (N3353', $547^{\circ} 05^{\prime}$, 1389 m a.s.l.), litter in oak forest, 13.XII.2013, leg. M. Kahrarian. Paratypes: 3 females on slide, same data as holotype.

Other material. Three females on slide, Iran, Osmanevand area, near Ghader marz village ( $\mathrm{N} 34^{\circ} 01.030^{\prime}, \mathrm{E} 47^{\circ} 12.415^{\prime}, 1682 \mathrm{~m}$ a.s.l.), litter in oak forest, 31.I.2014, leg. M. Kahrarian.

Etymology. The species name refers to sharp labral apex which looks like a horn ("cera" in latin).

Diagnosis. Habitus typical of the genus Endonura. Dorsal tubercles present and well developed. 2+2 eyes darkly pigmented. Buccal cone long. Head with chaetae A, B, C, D, E, F and G. Chaeta O absent. Tubercles Cl and Af separate. Tubercles Dl and ( $\mathrm{L}+\mathrm{So}$ ) on head with six and nine chaetae respectively. Tuberles Di and De on th. I fused. Tubercles De on th. II and III with three and four chaetae respectively. Tubercles L on abd. III and IV with three and 6-7 chaetae respectively. Abd. IV and V with eight and three tubercles respectively. Claw without inner tooth. Tibiotarsi with chaetae B4 and B5 short.

Description. Habitus typical of the genus. Body length (without antennae): 2.252.55 mm (holotype: 2.55 mm ). Colour of the body bluish grey. $2+2$ medium darkpigmented eyes (Fig. 5).

Types of dorsal ordinary chaetae. Macrochaetae Ml thickened, relatively long, arclike or straight, narrowly sheathed, feebly serrated, apically pointed or rarely rounded (Figs 5, 7-9); macrochaetae Mc and Mcc thickened, straight, pointed or apically rounded; mesochaetae and microchaetae short, thin and pointed.

Head. Buccal cone very long. Labrum ogival, with ventral sclerifications as in Fig. 6. Labrum chaetotaxy $0 / 2$, 2. Labium with four basal, three distal and four lateral chaetae, papillae x absent. Maxilla styliform, mandible thin with two basal and two apical teeth. Chaetotaxy of antennae as in Table 2c. Apical vesicle distinct, trilobed. S-chaetae of ant.IV of medium length and moderately thickened. Chaetotaxy of head as in Table 2a, b, and Fig. 5. Tubercles Cl and Af separate. Tubercle Af on head longer than tubercles Oc. Chaeta O absent. Chaeta D free. Tubercle Dl with six chaetae, chaeta Dl 3 present. Tubercle ( $\mathrm{L}+\mathrm{So}$ ) with nine chaetae, chaeta So2 absent and chaeta So3 as Mc (Fig. 5). Elementary tubercles BE and CD present. Chaeta A shorter than B.

Thorax, abdomen, legs. Body s-chaetae thin and smooth, shorter than nearby macrochaetae (Figs 7-9). Chaetotaxy of th. and abd. as in Table 2d and in Figs 7-9. Tubercles Di on th.I differentiated and fused with De (Fig. 7). Dorsal side of th. and abd. without free chaetae De. The line of chaetae De1-chaeta s perpendicular to the dorsomedian line on abd I-III. Furca rudimentary with two or without microchaetae. Tubercles Di on abd. V fused, with chaetae Di2 and Di3 as Mc (Fig. 9). Chaetae L’ and Vl on abd. V present. No cryptopygy. Chaetotaxy of legs as in Table 2d.


Figures 5-9. Endonura ceratolabralis sp. n.: $\mathbf{5}$ head (holotype), dorsal and lateral chaetotaxy $\mathbf{6}$ ventral sclerification of labrum $\mathbf{7}$ dorsal chaetotaxy of thorax $\mathbf{8}$ dorsal chaetotaxy of abd. II $\mathbf{9}$ dorsal chaetotaxy of abdomen IV-VI. Arrows indicate the position of eyes.

Remarks. Because of the very characteristic long and pointed labrum, E. ceratolabralis sp. n. seems to be most similar to E. cretensis (Ellis, 1976) (Crete) and E. gracilirostris Smolis et al. 2007 (Crimea). Nevertheless, the new species can be easily distinguished from these two taxa by the following combination of characters: maximum length of the body without antennae (ceratolabralis sp. n. 2.55 mm ; gracilirostris

Table 2a. Chaetotaxy of Endonura ceratolabralis sp. n.: Cephalic chaetotaxy-dorsal side.

| Tubercle | Number of chaetae | Types of chaetae | Names of chaetae |
| :---: | :---: | :---: | :---: |
| Cl | 4 | Ml | F |
|  |  | Mc | G |
| Af | 10 | Ml | A |
|  |  | Mc | B, C, D, E |
| Oc | 3 | Ml | Ocm, Ocp |
|  |  | me | Oca |
| Di | 2 | Ml | Di1 |
|  |  | Mc | Di2 |
| De | 2 | Ml | De1 |
|  |  | Mc | De2 |
| Dl | 6 | Ml | Dl1, Dl5 |
|  |  | Mc | Dl2, Dl3, Dl4 |
|  |  | mi | Dl6 |
| (L+So) | 9 | Ml | L1, L4, Sol |
|  |  | Mc | L2, L3, So3 |
|  |  | me | So4-6 |

Table 2b. Chaetotaxy of Endonura ceratolabralis sp. n.: Cephalic chaetotaxy-ventral side.

| Group | Number of chaetae |
| :---: | :---: |
| Vi | 6 |
| Vea | $3-4$ |
| Vem | 3 |
| Vep | 4 |
| Labium | $11,0 \mathrm{x}$ |

Table 2c. Chaetotaxy of Endonura ceratolabralis sp. n.: Chaetotaxy of antennae.

| Segment, Group | Number of chaetae | Segment, Group | Number of chaetae adult |
| :---: | :---: | :---: | :---: |
| I | 7 |  |  |
| II | $12-14$ |  |  |
| III | 5 ap | or, $8 \mathrm{~S}, \mathrm{i}, 12 \mathrm{mou}, 6 \mathrm{brs}, 2 \mathrm{iv}$ |  |
| ve | 5 |  | $8 \mathrm{bs}, 5 \mathrm{miA}$ |
| vc | 4 | ca | $2 \mathrm{bs}, 3 \mathrm{miA}$ |
| vi | 4 | cm | $3 \mathrm{bs}, 1 \mathrm{miA}$ |
| d | 5 | cp | $8 \mathrm{miA}, 1 \mathrm{brs}$ |

1.45 mm ; cretensis 0.8 mm ), labral formula (ceratolabralis sp. n. 0/2, 2; gracilirostris $0 / 2,4$; cretensis $2 / 2,4$ ), presence/absence of chaeta O on head (ceratolabralis sp. n. absent, in others present), number of chaetae Dl on head (cretensis three, in others six), number of chaetae ( $\mathrm{L}+\mathrm{So}$ ) on head (cretensis seven, in others nine), fusion/separation of tubercles Di and de on th. I (gracilirostris separate, in others fused), number of ordinary chaetae De on th. III (cretensis two, others three), presence/absence of free chaetae on thorax (ceratolabralis sp. n. absent, in others present) and number of chaetae Di on abd. V (cretensis 1-2, others three).

Table 2d. Chaetotaxy of Endonura ceratolabralis sp. n.: Postcephalic chaetotaxwy.

|  | Di | Terga | D1 | L | Scx2 | Cx | $\begin{gathered} \text { Legs } \\ \mathrm{Tr} \end{gathered}$ | Fe | T |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| th. I | 1 | 2 | 1 | - | 0 | 3 | 6 | 13 | 19 |
| th. II | 3 | 2+s | $3+s+m s$ | 3 | 2 | 7 | 6 | 12 | 19 |
| th. III | 3 | 3+s | 3+s | 3 | 2 | 8 | 6 | 11 | 18 |
|  |  |  |  |  |  |  | Sterna |  |  |
| abd. I | 2 | 3+s | 2 | 3 | VT: 4 |  |  |  |  |
| abd. II | 2 | 3+s | 2 | 3 | Ve: 5-6 | Ve1- | Present |  |  |
| abd. III | 2 | 3+s | 2 | 3 | Vel:4-5 |  |  | Fu:3-6me | 0-2mi |
| abd. IV | 2 | 2+s | 3 | 6-7 | Vel: 4 | Vec: 2 | Vei: 2 | Vl: 4 |  |
| abd. V | (3+3) | 5+s |  |  | Ag: 3 |  |  | V1: 1 | L': 1 |
| abd. VI |  | 7 |  |  | Ve: 13-14 |  |  | An: 2mi |  |

## Endonura persica sp. n.

http://zoobank.org/9CFE5947-62CC-4A3E-ABF7-5B84EA69A21A
Figs 10-13, Table 3
Type material. Holotype: adult female on slide, Iran, Kermanshah area, near Ghaleh shahin village ( $\mathrm{N} 34^{\circ} 25.590^{\prime}$, $\mathrm{E} 05^{\circ} 12.415^{\prime}$, 566 m a.s.l.), litter in willow shrubs, 7.IV.2014, leg. M. Kahrarian. Paratypes: two females, four males and four juveniles on slides, same data as holotype.

Other material. Female on slide, Iran, Kermanshah Province, Halashi County, near Sarfiroozabad village ( $\mathrm{N} 34^{\circ} 02^{\prime}, \mathrm{E} 47^{\circ} 10^{\prime}, 1624 \mathrm{~m}$ a.s.l.), litter in oak forest, 15.II.2014, leg. M. Kahrarian; female and male on slide, Iran, Osmanevand area, near Sarjoob village (N33 ${ }^{\circ} 56^{\prime}, E 47^{\circ} 08^{\prime}, 1240 \mathrm{~m}$ a.s.l.), litter in oak forest, 13.XII.2013, leg. M. Kahrarian.

Etymology. The species name refers to the historic name of Iran, Persia.
Diagnosis. Habitus typical of the genus Endonura. Dorsal tubercles present and generally well developed, only tubercles Di on th. I weakly differentiated. $2+2$ large dark-pigmented eyes. Buccal cone rather short. Head with chaetae A, B, C, D, E , F and G. Chaeta O absent. Tubercles Cl and Af separate. Tubercles Dl and ( $\mathrm{L}+\mathrm{So}$ ) on head with five and eight chaetae respectively. Tubercles De on th. II and III with three and four chaetae respectively. Tubercles L on abd. III and IV with four and 6-7 chaetae respectively. Abd. IV and $V$ with eight and three tubercles respectively. Claw with inner tooth. Tibiotarsi with chaetae B4 and B5 long.

Description. Habitus typical of the genus. Body length (without antennae): $0.75-1.90 \mathrm{~mm}$ (holotype: 1.10 mm ). Colour of the body bluish grey. $2+2$ large dark pigmented eyes (Fig. 10).

Types of dorsal ordinary chaetae. Macrochaetae Ml thickened, relatively long, arclike or straight, narrowly sheathed, feebly serrated, apically rounded or rarely pointed (Figs 10, 12); macrochaetae Mc and Mcc thickened, straight and not pointed; mesochaetae and microchaetae short, thin and pointed.


Figures 10-13. Endonura persica sp. n.: $\mathbf{1 0}$ head and th. I, dorsal and lateral chaetotaxy II ventral sclerification of labrum $\mathbf{1 2}$ dorsal chaetotaxy of abdomen III-VI (holotype) $\mathbf{1 3}$ tibiotarsi and claw of leg III. Arrows indicate the position of eyes.

Head. Buccal cone short. Labrum rounded, with ventral sclerifications as in Fig. 11. Labrum chaetotaxy $4 / 2,4$. Labium with four basal, three distal and four lateral chaetae, papillae x absent. Maxilla styliform, mandible thin with two basal and two apical teeth. Chaetotaxy of antennae as in Table 3c. Apical vesicle distinct trilobed. S-chaetae of ant.IV of medium length and moderately thickened. Chaetotaxy of head as in Table 3a, b, and Fig. 10. Chaetae D and E free. Tubercles Cl and Af separate.

Table 3a. Chaetotaxy of Endonura persica sp. n.: Cephalic chaetotaxy-dorsal side.

| Tubercle | Number of chaetae | Types of chaetae | Names of chaetae |
| :---: | :---: | :---: | :---: |
| Cl | 4 | $\mathrm{Ml}$ | F |
| Af | 10 | M1 Mc <br> Mc or Mcc | $\begin{gathered} \text { B } \\ \text { A, C, E } \\ \text { D } \end{gathered}$ |
| Oc | 3 | $\begin{aligned} & \mathrm{Ml} \\ & \mathrm{Mc} \\ & \mathrm{mi} \end{aligned}$ | $\begin{aligned} & \text { Ocm } \\ & \text { Ocp } \\ & \text { Oca } \\ & \hline \end{aligned}$ |
| Di | 2 | $\begin{gathered} \hline \mathrm{Ml} \\ \mathrm{Mcc} \end{gathered}$ | $\begin{aligned} & \hline \text { Di1 } \\ & \text { Di2 } \end{aligned}$ |
| De | 2 | Ml Mcc | $\begin{aligned} & \text { De1 } \\ & \text { De2 } \\ & \hline \end{aligned}$ |
| Dl | 5 | Ml <br> Mc or Mcc | $\begin{gathered} \text { Dl1, D15 } \\ \text { Dl2, D14, Dl6 } \end{gathered}$ |
| (L+So) | 8 | Ml Mc me or mi | $\begin{gathered} \text { L1, L4, So1 } \\ \text { L2 } \\ \text { So3-6 } \end{gathered}$ |

Table 3b. Chaetotaxy of Endonura persica sp. n.: Cephalic chaetotaxy-ventral side.

| Group | Number of chaetae |
| :---: | :---: |
| Vi | 6 |
| Vea | $3-4$ |
| Vem | 3 |
| Vep | 4 |
| labium | $11,0 \mathrm{x}$ |

Table 3c. Chaetotaxy of Endonura persica sp. n.: Chaetotaxy of antennae.

| Segment, Group | Number of chaetae | Segment, Group | Number of chaetaev adult |
| :---: | :---: | :---: | :---: |
| I | 7 | $\begin{aligned} & \text { IV } \\ & \text { ap } \end{aligned}$ | or, $8 \mathrm{~S}, \mathrm{i}, 12 \mathrm{mou}, 6 \mathrm{brs}, 2 \mathrm{iv}$ |
| II | 12-14 |  |  |
| III | 5 sensilla AO III |  |  |
| ve | 5 |  | $8 \mathrm{bs}, 5 \mathrm{miA}$ |
| vc | 4 | ca | $2 \mathrm{bs}, 3 \mathrm{miA}$ |
| vi | 4 | cm | $3 \mathrm{bs}, 1 \mathrm{miA}$ |
| d | 5 | cp | $8 \mathrm{miA}, 1 \mathrm{brs}$ |

Tubercle Af on head longer than tubercles Oc. Tubercle Dl with five chaetae, chaeta Dl3 absent. Tubercle (L+So) with eight chaetae, chaetae So2 and L3 absent (Fig. 10). Elementary tubercle BE absent. Chaeta A shorter than B.

Thorax, abdomen, legs. Body s-chaetae fine and smooth, distinctly shorter than nearby macrochaetae (Fig. 12). Chaetotaxy of th. and abd. as in Table 3d and in Figs

Table 3d. Chaetotaxy of Endonura persica sp. n.: Postcephalic chaetotaxy.

|  | Di | Terga De | Dl | L | Scx2 | Cx | $\begin{gathered} \text { Legs } \\ \mathrm{Tr} \end{gathered}$ | Fe | T |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| th. I | 1 | 2 | 1 | - | 0 | 3 | 6 | 13 | 19 |
| th. II | 3 | $2+s$ | $3+s+m s$ | 3 | 2 | 7 | 6 | 12 | 19 |
| th. III | 3 | 3+s | 3+s | 3 | 2 | 8 | 6 | 11 | 18 |
|  |  |  |  |  |  |  | Sterna |  |  |
| abd. I | 2 | 3+s | 2 | 3 | VT: 4 |  |  |  |  |
| abd. II | 2 | 3+s | 2 | 3 | Ve: 5-6 | Ve1- | present |  |  |
| abd. III | 2 | 3+s | 2 | 4 | Vel: 5 |  |  | Fu:5-10me | 0 mi |
| abd. IV | 2 | $2+s$ | 3 | 6-7 | Vel: 4 | Vec: 2 | Vei: 2 | V1: 4 |  |
| abd. V | (3+3) | 8+s |  |  | Ag: 3 |  |  | V1: 1 | L': 1 |
| abd. VI |  | 7 |  |  | Ve: 13-14 |  |  | An: 2mi |  |

10, 12. Tubercles Di on th.I differentiated or not. Chaetae De2 on th. II-III and De3 on th. III free. Chaetae De3 on abd. I-III free (Fig. 12). The line of chaetae De1chaeta s parallel to the dorsomedian line on abd. I-III. Furca rudimentary without microchaetae. Tubercles Di on abd. V fused, with chaetae Di2 as Mcc and Di3 as mi (Fig. 12). Chaetae Vl on abd. V present. Cryptopygy slightly developed. Chaetotaxy of legs as in Table 3d. Tibiotarsi with rather long chaetae B4 and B5. Claw with inner tooth (Fig. 13).

Remarks. In general appearance and presence of inner tooth on claw, characters rarely observed within the genus, E. persica sp. n. strongly resembles to E. dentifera Smolis et al. 2007 (described from Crimea). However, the new species can be reliably separated from Crimean species with the following characters: number of chaetae Dl on head (persica sp. n. five, dentifera six), number of chaetae (L+So) on head (persica sp. n. eight, dentifera ten), presence/absence of tubercles Di on the first thoracic segment (persica sp. n. present, dentifera absent) and number of chaetae L of abd. IV (persica sp. n. 6-7 chaetae, dentifera 8-9).

## Key to the genus Endonura

In 1982, Deharveng, in his PhD thesis, elevated Endonura to the generic level and prepared a key to the genus that comprised 23 species. Nowadays, including the taxa described herein, the genus contains 40 members and is the second largest of the tribe Neanurini, after Deutonura Cassagnau, 1979. Moreover, after the publication of Deharveng's paper (date), a few species were redescribed and one taxon was synonymised
(Smolis and Kaprus' 2003, Smolis 2008, Smolis et al. 2007, 2011). Considering these facts, the preparation of an updated key to all species of the genus seemed to be highly recommended.
1
Head with fusion of tubercles Af and Cl ..... 2

- Head with separation of tubercles Af and Cl ..... 7

2. Chaeta O on head present ..... 3
Chaeta O on head absent. ..... 4
3 Tubercles Di on th. I present and fused with De , tubercle ( $\mathrm{Di}+\mathrm{Dl}+\mathrm{L}$ ) on abd.V with nine chaetae ..........E. poinsotae Deharveng, 1980 (France, Corsica)- Tubercles Di on th. I absent, tubercle $(\mathrm{Di}+\mathrm{Dl}+\mathrm{L})$ on abd. V with seven chae-tae............................................... E. ichnusae Dallai, 1983 (Italy, Sardinia)
Tubercles De on abd. I-III with four chaetae ..... 5 ..... 4Tubercles De on abd. I-III with three chaetae

$\qquad$E. granulata (Cassagnau \& Delamare Deboutteville, 1955) (Lebanon)
Tubercles Di and De on th. I fused, cryptopygy strongly developedE. gladiirostra Smolis \& Kaprus', 2003 (Israel)
Tubercles Di and De on th. I separate, cryptopygy absent or weakly devel- oped ..... 6Chaeta E on head present, Tubercle Dl on head with four chaetaeE. tyrrbenica Dallai, 1983 (Italy, Sardinia)Chaeta E on head absent, Tubercle Dl on head with six chaetae.E. pejai Deharveng, 1980 (France, Corsica)
7 Tubercle Af on head equal or shorter than tubercles Oc ..... 8
Tubercle Af on head longer than tubercles Oc. ..... 9
-Labrum with ventral sclerifications ogival and without prelabral chaetae.E. gracilirostris Smolis et al., 2007 (Crimea, Moldova)
Labrum with ventral sclerifications nonogival and with prelabral chaetae.
E. taurica (Stach, 1951) (Crimea)
9 Chaeta O on head present ..... 10
Chaeta O on head absent. ..... 26
10 Eyes completely absent ..... 11
Eyes present ..... 12
11 Tubercles Di on th. I present...E. arbasensis Deharveng, 1979 (France, Spain)

- Tubercles Di on th. I absent ...E. caeca (Gisin, 1963) (Bosnia and Herzegovina)
12 Anterior eye present and located outside tubercle OcE. asiatica Smolis et al., 2011 (Kyrgyzstan)
- Anterior eye present or absent, if present located within tubercle Oc ..... 13
13 Anterior eye present ..... 14
- anterior eye absent. E. immaculata Deharveng, 1980 (France, Corsica)
14 Claw with inner tooth, tibiotarsi with long chaetae B4 and B5 ..... 15
Claw without tooth, tibiotarsi with short chaetae B4 and B5 ..... 16
15
Tubercle Dl on head with three chaetae, tubercles Di on th. II-III with two chaetae....................................... E. tetrophtalma (Stach, 1929) (Hungary)16- Chaeta E on head presentTubercle Dl on head with five chaetae, tubercles Di on th. II-III with threechaetae..................E. lusatica (Dunger, 1966) (Germany, Poland, Ukraine)
17
Chaeta E on head absent18
17 Tubercle Cl on head with chaetae D, elementary tubercle DF presentE. colorata (Gama, 1964) (Portugal)
Tubercle Dl on head with six chaetae
Tubercle Cl on head without chaetae D, elementary tubercle DF absent E. cantabrica (Deharveng, 1979) (Spain)
Tubercle Dl on head with less number of chaetae ..... 25
19 Tubercles Di on head present ..... 20
Tubercles Di on head absent
E. dalensi Deharveng, 1979 (Andorra, France, Spain, Italy)
Body white ..... 21 ..... 20
Body blue or bluish-grey ..... 22

21. Tubercle (L+So) on head with nine chaetae, macrochaetae thin and pointed ..E. deharvengi Cassagnau \& Péja, 1979 (Greece)
Tubercle (L+So) on head with eight chaetae, macrochaetae thickened and blunt. E. levantica Smolis et al., 2011 (Israel)
Tubercle De on th. III with two ordinary chaetae
E. gladiolifer (Cassagnau, 1954) (Algeria, Spain)
Tubercle De on th. III with three ordinary chaetae ..... 23
23 Tubercle Cl on head with chaetae D , furca rudimentary with microchaetae.E. alavensis Pozo \& Simon, 1982 (Spain)
Tubercle Cl on head without chaetae D , furca rudimentary without micro- chaetae. ..... 24
24Cryptopygy strong and complete, tubercles of abd. VI invisible in dorsalviewE. ludovicae (Denis, 1948) (France, Corsica)
Cryptopygy absent or weak, tubercles of abd. VI well or partially visible in dorsal view ..... 27
27 Body bluish-grey ..... 28
Body white ..... 30

Claw with inner tooth, labrum chaetotaxy 4/2, 4

Claw without inner tooth, labrum chaetotaxy $0 / 2,2$

E. ceratolabralis sp. n. (Iran)

29 Tubercle Dl on head with five chaetae, tubercles Di on th. I present E. persica sp. n. (Iran)

- Tubercle Dl on head with six chaetae, tubercles Di on th. I absent E. dentifera Smolis et al., 2007 (Crimea)

Chaeta C on head absent
31

- Chaeta C on head present ..... 33
Macrochaetae Dil on abd. V distinctly thickened and club-likeE. baculifer Deharveng, 1979 (Portugal)- Macrochaetae Dil on abd. V slightly thickened and cylindrical................. 3232

32 Eyes present, tubercles Di on th. I present. E. transcaucasica (Stach, 1951) (Georgia)

- Eyes absent, tubercles Di on th. I absent....E. carpatica Smolis, 2006 (Poland)

33 Tubercle Cl on head with chaetae D, elementary tubercle DF present ...... 34

- Tubercle Cl on head without chaetae D, elementary tubercle DF absent... 35

34 Chaeta E on head present, tubercle Dl on head with six chaetae
E. tartaginenis Deharveng, 1980 (France, Corsica)

Chaeta E on head absent, tubercle Dl on head with five chaetae
E. dichaeta sp. n. (Iran)

Chaeta E on head present
.....................E. urotuberculata Pomorski \& Skarżyński, 2000 (Bulgaria)

- Chaeta E on head absent........................................................................... 36

36 Chaeta L4 on head free, eyes absent or present unpigmented.................... 37

- Chaeta L4 within tubercle (L+So), eyes present and pigmented ................ 39

37 Abd. V with two tubercles
E. incolorata (Stach, 1951) (Poland, Ukraine, Romania)

- Abd. V with three tubercles.

38 Abd. IV with eight tubercles, macrochaetae Ml relatively short E. tatricola (Stach, 1951) (Poland, Slovakia)

Abd. IV with five tubercles, macrochaetae Ml long
E. dudichi (Loksa, 1967) (Hungary, Poland, Slovakia)

39
Tubercle Dl on head with six chaetae, tubercle L on abd. III with three chaetae. E. centaurea Cassagnau \& Péja, 1979 (Greece)

- Tubercle Dl on head with five chaetae, tubercle L on abd. III with four chaetae. E. saleri Fanciulli \& Dallai, 2008 (Italy)


## Discussion

Considering the data presented here and those obtained from the literature (Mayvan et al. 2015, Shayanmehr et al. 2013, Smolis et al. 2012), Neanurinae fauna of Iran
comprises ten species and seven genera: Bilobella aurantiaca (Caroli, 1912), Cryptonura persica Smolis et al., 2012, C. maxima Smolis et al., 2012, Deutonura decolorata (Gama \& Gisin, 1964) (Gisin 1964), Endonura ceratolabralis sp. n., E. dichaeta sp. n., E. persica, sp. n., Neanura muscorum (Templeton, 1835), Persanura hyrcanica Mayvan et al. 2015, Thaumanura echinata (Kos, 1940). It should be noted, however, that until now only the western part of Iran has been roughly studied. Although future research may change the present picture of the subfamily diversity in the studied country and region, some preliminary conclusions can be drawn. The first is related to the higher systematic pattern and composition of Neanurinae of Iran. This fauna consists almost exclusively of members of the tribe Neanurini, the most diverse and dominant among Neanurinae in the western Palaearctic. To date, none of the Lobellini and Paranurini genera have been found in Iran, although they are numerous and widely distributed in south, south-east and east Asia. The second conclusion seems to be more expected, Endonura species from Iran resemble those known from south-east Europe. It suggests their close affinity and the historical connection between these faunas. The third conclusion sheds light on the distribution and the history of this genus. Most Endonura species were recorded from Mediterranean and temperate zones of Europe, where they live predominantly in forests. It is worth saying that the greatest diversity of the genus through the continent is more or less correlated to the areas of land that have never been subjected to glaciations. Till now, the occurrence of only a few species is documented outside Europe, especially in the Middle East (Smolis and Kaprus 2003, 2009; Smolis et al. 2011). The recent and present discoveries of Endonura species in Kyrgyzstan (Smolis et al. 2011) and Iran significantly expand the list of species and also our knowledge on the genus. Undoubtedly, diverse forest habitats of the coastal and montane regions of Iran and adjacent countries hide a rich fauna of Neanurinae. We therefore hope that a more comprehensive study in the future will allow us to present a better picture of the distribution of Endonura in Iran and the near East.

## References

Arbea JI, Kahrarian M (2015) The genus Folsomides Stach (Collembola, Isotomidae) in Kermanshah Province (W Iran) with the description of two new species. Zootaxa 3925: 281-290. doi: 10.11646/zootaxa.3925.2.9
Axelson WM (1905) Einige neue Collembolen aus Finland. Zoologisher Anzeiger 28: 788-794.
Caroli E (1912) Contribuzioni alla conoscenza dei Collemboli italiani. I. La tribu degli Achorutini CB (1906). Archivio zoologico italiano 6: 349-374.
Cassagnau P (1954) Sur un rudiment de furca chez les Neanurinae et sur quelques espèces de ce groupe. Extrait Du Bulletin de la Société D’Histoire Naturelle de Toulouse 89: 27-34.
Cassagnau P (1979) Les Collemboles Neanuridae des Pays Dinaro-Balkaniques: leur interêt phylogénétique et biogéographique. Biologia Gallo-Hellenica 8: 185-203.
Cassagnau P (1989) Les Collemboles Neanurinae; elements pour une synthèse phylogénétique et biogéographique. In: Dallai R (Ed.) $3^{\text {rd }}$ International Seminar on Apterygota, Siena, 171-182.

Cassagnau P, Delamare Deboutteville C (1955) Mission Henri Coiffait (1951). 3. Collemboles. Archivesde Zoologie Expérimentale et Génerale 91: 365-395.
Cassagnau P, Péja N (1979) Diagnoses préliminaries de quelques Neanuridae de Grèce et d'Albanie. Biologia Gallo-Hellenica 8: 205-222.
Dallai $R(1983)$ Interesse biogeografico dei Neanuridi (Collembola) della Sardegna e delle isole dell'Arcipelago Toscano. Lavori della Societa Italiana di Biogeografia (N.S.) 8: 417-465.
Deharveng L (1979) Contribution à la connaissance des Collemboles Neanurinae de France et de la Peninsule Iberique. Travaux du Laboratoire d'Écobiologie des Arthropodes Edaphiques, Toulouse 1:1-61.
Deharveng L (1980) Contribution à la connaissance systématique, écologique et biogéographique des collemboles Neanurinae de Corse. Revue d'écologie et de biologie du sol 17(3): 419-435.
Deharveng L (1982) Contribution a l'etude des Collemboles Neanurinae: évolution, spéciation, polymorphisme somatique et chromosomique des formes européennes. PhD thesis, University of Paul Sabatier, Toulouse, France.
Deharveng L (1983) Morphologie évolutive des Collemboles Neanurinae en particulier de la lignée Neanurinae. Travaux de Laboratoire d'Écobiologie des Arthropodes Édaphiques, Toulouse 4: 1-63.
Deharveng L, Weiner W (1984) Collemboles de Corée du Nord III-Morulinae et Neanurinae. Travaux de Laboratoire d'Écobiologie des Arthropodes Édaphiques, Toulouse 4: 1-61.
Denis JR (1948) Sur la faune Française des Aptérygotes (XXIVe note). Étude du matériel récolté en Corse par P. et L. Rémy en 1942. Annales des Sciences Naturelles Zoologie $11^{e}$ série, 9: 1-12.
Dunger W (1966) Zur Kenntnis von Neanura tetrophtalma (Stach) (Collembola: Apterygota). Abhandlungen und Berichte des Naturkundemuseums Görlitz 41(4): 1-11.
Ellis WN (1976) Autumn fauna of Collembola from Central Crete. Tijdschrift voor Entomologie 119: 221-236.
Fanciulli PP, Dallai R (2008) Three new species of Collembola from north-east Italy. Zootaxa 1701: 15-28.
Gama MM (1964) Colêmbolos de Portugal Continental. Mémorias e Estudos do Museu Zoológico da Universidade de Coimbra 292: 1-252.
Gisin H (1963) Sieben neue Arten von Collembolen aus Bosnien und Wiederbeschreibung von Onychiurus serratuberculatus Stach. Extrait du Godišnjak Biološkog Instituta Univerziteta u Sarajevu 14: 3-13.
Gisin H (1964) Collemboles d'Europe. VI. Revue suisse de Zoologie 74(20): 383-400. doi: 10.5962/bhl.part. 75615

Kahrarian M (2014) New records of Poduromorpha for the Iranian springtail fauna (Collembola). Natura Somogyiensis 25: 21-26.
Kahrarian M, Vafei-Shooshtari R, Skarżyński D, Konikiewicz M, Soleymannezhadyan E, Shayan Mehr M, Shams B (2013) A new species and new records of the genus Hypogastrura Bourlet, 1839 (Collembola, Hypogastruridae) from Iran. Zootaxa 3709: 89-94. doi: 10.11646/zootаха.3709.1.4
Kos F (1940) Terricole Collembolen aus Slovenien. Glasnik, Bulletin de la Société Scientifique de Skoplje 22: 136-168.

Loksa I (1967) Vier neue Höhlencollembolen aus Ungarn (Biospeologica Hungarica, XIII). Opuscula Zoologica Budapest VI (2): 289-296.
Mayvan MM, Shayanmehr M, Smolis A, Skarżyński D (2015) Persanura hyrcanica, a new genus and species of Neanurinae (Collembola: Neanuridae) from Iran, with a key to genera of the tribe Neanurini. Zootaxa 3918: 552-558. doi: 10.11646/zootaxa.3918.4.4
Pomorski RJ, Skarżyński D (2000) A new species of Endonura Cassagnau, 1979 from Bulgaria with remarks on Endonura centaurea (Cassagnau \& Peja, 1979) (Collembola, Neanuridae). Zoosystema 22: 117-120.
Pozo J, Simón JC (1982) Colémbolos del Pais Vasco I. Neanura (Endonura) occidentalis alawensis nov. ssp. y Neanura (Deutonura) plena ssp. plena Stach, 1951. Eos 57: 221-229.
Shayanmehr M, Yahyapour E, Kahrarian M, Lafooraki E (2013) An introduction to Iranian Collembola (Hexapoda): an update to the species list. Zookeys 335: 69-83. doi: 10.3897/ zookeys. 335.5491
Smolis A (2006) Endonura carpatica, a new species from Poland (Collembola, Neanuridae, Neanurinae). Genus 17: 471-476.
Smolis A (2008) Redescription of four Polish Endonura Cassagnau, 1979 (Collembola, Neanuridae, Neanurinae), with a nomenclature of the ventral chaetae of antennae. Zootaxa 1858: 9-36.
Smolis A, Deharveng L (2006) Vitronura mascula, a new species of Neanurinae (Collembola: Neanuridae) from northern Vietnam, with a key to the species of the genus. Revue suisse de Zoologie 113: 263-268. doi: 10.5962/bhl.part. 80349
Smolis A, Deharveng L, Kaprus' IJ (2011) Studies on the non-European Endonura Cassagnau, 1979 (Collembola, Neanuridae, Neanurinae). Zootaxa 3004: 45-56.
Smolis A, Falahati A, Skarżyński D (2012) The genus Cryptonura Cassagnau, 1979 (Collembola, Neanuridae, Neanurinae) in Iran. Zootaxa 3530: 51-58.
Smolis A, Kaprus' IJ (2003) A new species of the genus Endonura Cassagnau, 1979 from Israel (Collembola: Neanuridae). Genus 14: 325-329.
Smolis A, Kaprus' IJ (2009) Redescription of Endonura cretensis (Ellis, 1976) (Collembola: Neanuridae: Neanurinae) with a new record from Israel. Annales Zoologici 59: 1-6. doi: 10.3161/000345409X432538

Smolis A, Skarżyński D, Pomorski RJ, Kaprus' IJ (2007) Redescription of Endonura taurica (Stach, 1951) and E. quadriseta Cassagnau \& Péja, 1979, and description of two new species of the genus Endonura Cassagnau, 1979 (Collembola: Neanuridae: Neanurinae) from the Crimea (Ukraine). Zootaxa 1442: 19-35.
Stach J (1929) Verzeichnis der Apterygogenea Ungarns. Annales Musei Nationalis Hungarici, Budapest, 26: 282-283.
Stach J (1951) The Apterygotan fauna of Poland in relation to the world-fauna of this group of insects. Family: Bilobidae. Polska Akademia Umiejętności, Acta monographica Musei Historiae Naturalis, Kraków, 97 pp.
Templeton R (1835) Thysanura Hiberbnicae, or descriptions of such species of spring-tailed insects (Podura and Lepisma, Lin.) as have been observed in Ireland. Transactions of the Entomological Society of London 1(2): 89-98. doi: 10.1111/j.1365-2311.1838. tb00147.x

# A new Chinese Pseudoogeton species and key to the species of the genus (Coleoptera, Tenebrionidae, Amarygmini) 

Sai-Hong Dong', Guo-Dong Ren ${ }^{\prime}$<br>I The Key Laboratory of Zoological Systematics and Application, College of Life Sciences, Hebei University, Baoding 071002, P. R. China<br>Corresponding author: Guo-Dong Ren (gdren@hbu.edu.cn)

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#### Abstract

Pseudoogeton maoxianum sp. $\mathbf{n}$. is described from Sichuan, China. A key to the males of the species of Pseudoogeton Masumoto, 1989 is presented.


## Keywords

Tenebrionidae, Pseudoogeton, new species, China, key to species

## Introduction

Pseudoogeton (Tenebrionidae: Amarygmini) was established by Masumoto (1989) with P. amplipennis (Fairmaire, 1897) as the type species. The genus is similar to Plesiophthalmus Motschulsky, 1858, but it can be distinguished from the latter by the absence of hind wings or shortened hind wings.

Although Bremer and Lillig (2014) are of the opinion that the absence of hind wings is not a satisfactory character state to separate the genus from Plesiophthalmus; still, Pseudoogeton is retained as a separate genus until other characters are found to justify its status or to merge it with Plesiophthalmus.

[^2]At present the genus contains six valid species described by Fairmaire $(1891,1897)$ and Masumoto (1981, 1989, 1996, 2010). They are distributed in the mountains of China (P. amplipenne (Fairmaire, 1897), P. gebieni Masumoto, 1989, P. ovipenne (Fairmaire, 1891) and P. uenoi (Masumoto, 1981)), the Ryukyu Island (P. kimurai Masumoto, 1996) and Laos (P. endoi Masumoto, 2010).

Working on Chinese specimens of the genus deposited in the Museum of Hebei University (MHBU), Baoding, a new species was found, which was collected by the authors in Sichuan Province of China in 1999. In this paper the new species is described and a key to males of the species of Pseudoogeton is presented.

## Material and methods

The photos were taken with a Leica DFC 450 digital microscope camera attached to Leica M205A stereomicroscope. The aedeagus was dissected, cleared in $5 \% \mathrm{NaOH}$ solution, and placed in glycerin for observation and imaging. Images were edited using Adobe Photoshop CS6. The terminology follows Masumoto (2010). All measurements given are in millimeters. The type specimens are deposited in MHBU, Baoding, China.

## Results

## Key to the species of Pseudoogeton (males)

P. ovipenne from Hubei whose holotype is female is not in the key.

1 Hind wings shortened........................................................................................ 2

- Hind wings absent...................................................................................... 3

2 Pronotum approx. as wide as long; apicale of aedeagus arrowheaded (Figs 25-26, in Masumoto 1989). China (Taiwan) .................................. P. uenoi

- $\quad$ Pronotum approx. 1.4 times as wide as long; apicale of aedeagus simply short fusiform. Japan P. kimurai

3 Body blackish brown, with ferruginous tinge, dorsal surface strongly shining; apicale of aedeagus elongated equilateral triangular, lateral sides gradually narrowed forward. Laos P. endoi

- Black, or with violet and sericeous tinge; lateral sides of apicale of aedeagus abruptly narrowed forward 4
4 Pronotum widest in middle (Fig. 3); aedeagus stouter, apicale length/width < 1.5 (Figs 5-7). China (Sichuan)
P. maoxianum sp. n.
- Pronotum widest behind middle; aedeagus slender, apicale length/width > 1.5 5
5 Dorsal surface of body with violet tinge; pronotum hemispherical; striae on elytra fine and shallow, intervals almost not punctate. China (Sichuan) ........ P. gebieni
- Dorsal surface of body black, pronotum moderately convex and transverse; striae on elytra strong and deep, intervals with clear punctures. China (Sichuan) $\qquad$ .I. amplipenne


## Pseudoogeton maoxianum sp. n .

http://zoobank.org/C3E7E346-28DE-4EBC-A8A6-62CBED3F2AAB
Type specimens. Holotype $\begin{gathered} \\ \text { (MHBU) : CHINA, Sichuan, Maoxian County, Mt. Xi- }\end{gathered}$ aomiaoshan, 1600m, 22.viii.1999, leg. Guo-Dong Ren \& Sai-Hong Dong. Paratype: $1 q$ (MHBU): same data as holotype [Transliterated from Chinese labels].

Distribution. China (Sichuan).
Diagnosis. The new species is characterized by the following: pronotum nearly hemispherical, widest in middle; elytra strongly convex, with fine strial puncture; apicale of aedeagus stouter, ratio of length/width $=1.4$; basale 1.9 times longer than apicale.

Description. Male. Wingless; body oblong oval (Fig. 1), dorsum strongly convex, black; elytra with sericeous tinge, pronotum and legs more lustrous than elytra.

Clypeus transverse, with dense punctures. Frontoclypeal suture fine and straight. Genae relatively small, roundly protruded laterad. Eyes small, reniform, distance between them approximately 2.3 times their own diameter. Mentum trapezoidal. Gula widely triangular. Terminal maxillary palpomeres securiform. Antennae filiform (Fig. 9), reaching over half of elytra; length ratio of antennomeres 1 to 11 as $0.33: 0.20$ : 1.24: 0.59: 0.78: 0.69: 0.69: 0.64: 0.57: 0.61: 0.85 .

Pronotum (Fig. 3) convex, almost hemispherical, 1.3 times as wide as long, widest in middle, roundly narrowed anteriorly and posteriorly, anterior margin slightly arcuate, finely beaded, posterior margin noticeably produced, lateral margins finely beaded, visible in dorsal view throughout their whole length, anterior and posterior corners obtuse in lateral view; disc with tiny and sparse punctures.

Scutellum widely triangular, with a few punctures.
Elytra ovate, approximately 1.5 times as long as wide, approximately 2.6 times longer and 1.3 times wider than pronotum. Dorsum convex, maximum height at basal third, widest at basal $2 / 5$, lateral sides roundly narrowed anteriorly and posteriorly. Disc with rows of tiny and sparse punctures, their distance equal to $3-4$ times of puncture diameter; intervals flat and wide, transversely micro-aciculate, with extremely tiny punctures; lateral margins finely beaded.

Prosternum with a deep median groove between coxae. Prosternal process (Fig. 4) strongly bent upwards, with apophysis near apex.

Legs slender and rather long. Anterior edge of profemora (Fig. 8) with acute spine in apical third. Protibiae moderately curved, slightly widened and haired in apical half. Ratio of length of pro-, meso- and metatarsomeres 1 to 5 (or 4, metatarsomeres) as $0.60: 0.42: 0.42: 0.29: 1.13 ; 1.13: 0.63: 0.45: 0.28: 1.14 ; 1.93: 0.71: 0.46: 1.18$. Claws sharp, falciform.


Figures I-9. Pseudoogeton maoxianum sp. n. I Habitus, male 2 Habitus, female $\mathbf{3}$ Pronotum 4 Prosternal process 5 Aedeagus in dorsal view $\mathbf{6}$ Aedeagus in lateral view $\mathbf{7}$ Aedeagus in ventral view 8 Foreleg 9 Antenna. Scale bars: 1 mm .

Abdominal ventrites with microscopic punctures and setae, ventrite V slightly emarginate at apex.

Aedeagus fusiform (Figs 5-7), 3.5 mm long. Apicale elongate, lateral sides serrate, ratio of length/width $=1.4$. Basale 1.9 times longer than apicale.

Female: Body stouter than male (Fig. 2), pronotum 1.5 times as wide as long, elytra ovate, about 1.4 times as long as wide, about 3.0 times longer and 1.4 times wider than pronotum; prosternum groove between the coxae shallow.

Body length: $\delta^{\lambda}: 12.9 \mathrm{~mm} ; ~ Q: 15.2 \mathrm{~mm}$. Body width: ${ }^{\lambda}: 5.7 \mathrm{~mm} ; ~ q: 7.8 \mathrm{~mm}$.
Etymology. This specific epithet is derived from the type locality, Maoxian County, Sichuan Province, China.

## Acknowledgments

We thank Dr. Ottó Merkl, Mrs. Aranka Grabant and Mr. Tamás Németh (Hungarian Natural History Museum, Budapest) for providing the photographs of the holotype of P. gebieni, and Mrs. Cai-Xia Yuan and Mrs. Shan-Shan Liu (College of Life Sciences, Hebei University) for taking photographs of the holotype of P. uenoi from National Science Museum (Nat. Hist.), Tokyo, Japan, and P. amplipenne and P. ovipenne from Muséum National d`Histoire Naturelle, Paris, France. The research was supported by the National Natural Science Foundation of China (No. 31572309, No. 31402003), the Foundation of the Key Laboratory of Zoological Systematics and Application in Hebei Province (No. 14967611D).

## References

Bremer HJ, Lillig M (2014) World Catalogue of Amarygmini, Rhysopaussini and Falsocossyphini (Coleoptera; Tenebrionidae). Mitteilungen der Münchner Entomologischen Gesellschaft 104 (Suppl.): 3-176.
Fairmaire L (1891) Descriptions de Coléoptères de l'intérieur de Chine (6 partie). Comptes Rendus de la Société Entomologique de Belgique 35: 6-24.
Fairmaire L (1897) Coléoptères du Szé-tchouen et de Koui-tchéou (Chine). Notes from the Leyden Museum 19: 241-255.
Löbl I, Merkl O, Ando K, Bouchard P, Lillig M, Masumoto K, Schawaller W (2008) Tenebrionidae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera. Vol. 5. Apollo Books, Stenstrup, 105-352.
Masumoto K (1981) Tenebrionidae of Formosa (2). Elytra (Tokyo) 9: 15-52.
Masumoto K (1989) Plesiophthalmus and its Allied Genera (Coleoptera Tenebrionidae: Amarigmini) (Part 4). Japanese Journal of Entomology 57(2): 295-317.
Masumoto K (1996) Two New Tenebrionid species (Coleoptera) from the Ryukyu Islands. Japanese Journal of Entomology 64(1): 211-214.
Masumoto K (2010) Additions to Plesiophthalmus and its Allied Genera (Coleoptera: Tenebrionidae: Amarygmini) from Asia, Part 5. Entomological Review of Japan 65(2): 255-279.

# Revision of the wingless Sikkimia Duvivier (Coleoptera, Chrysomelidae, Galerucinae) from Taiwan, including a new generic synonymy and four new species descriptions 

Chi-Feng Lee', Jan Bezděk ${ }^{2}$<br>I Applied Zoology Division, Taiwan Agricultural Research Institute, 189 Chung-Cheng Road, Wufeng, Taichung 413, Taiwan 2 Department of Zoology, Mendel University, Zemédělská 1, 61300 Brno, Czech Republic<br>Corresponding author: Chi-Feng Lee (chifeng@tari.gov.tw)

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#### Abstract

The genus Taiwanolepta Kimoto, 1989 (type species T. babai Kimoto, 1989) is proposed as a junior synonym of Sikkimia Duvivier, 1891. Sikkimia species from Taiwan form a group characterized by the reduction of their hind wings. Most of them cannot be distinguished using external morphology, except by the structure of last two antennomeres in males. Diagnoses are made by using distribution, aedeagal, and gonocoxal morphology. The group includes one previously described species, Sikkimia babai (Kimoto, 1989), comb. n., and four new species, S. meihuai sp. n., S. sufangae sp. n., S. tsoui sp. n., and S. yuae sp. n. Speciation models, supporting the high diversity of Sikkimia species in Taiwan, are discussed. Sikkimia metallica Jacoby, 1903 and S. tamra Maulik, 1936, both from southern India, are transferred to the genus Cerophysa Chevrolat, 1836.


## Keywords

Leaf beetles, Polygonum chinense, nocturnal behavior, taxonomic revision

## Introduction

Subsequent to the original description of the genus, several new genera have been proposed for Sikkimia species. Based on the study of type specimens, the genera Yunomela Chen, 1964 and Vietocerus Lopatin, 2003 were synonymized with Sikkimia by Bezděk and Zhang (2006). Another genus, Taiwanolepta Kimoto, 1989, is here synonymized. While continental Sikkimia species have well developed wings and are capable of flying, the Taiwanese species have, until now, been classified in Taiwanolepta and are wingless and nocturnal. In Taiwan, Sikkimia species appeared to be rare as no recent records had been reported.

The basic bionomics of Taiwanese Sikkimia populations can be summarized as follows: adults are nocturnal and closely associated with these host plants: Polygonum chinense L., P. posumbu Buch.-Ham. ex Don, and P. thunbergii Sieb. \& Zucc. (Polygonaceae); Rubus swinhoei Hance and R. corchorifolius L. f. (Rosaceae); and Dumasia miaoliensis Y. C. Liu \& F. Y. Lu subsp. bicolor (Hayata) Ohashi \& Tateishi (Fabaceae); mainly feed on the host plant $P$. chinense. This plant is widely distributed and grows on the edges of forests, roads, walking trails, and rivers. As these environments are easily accessible, adults can be collected by searching for adults on host plants at night. Approximately 350 specimens have been collected throughout Taiwan by members of the Taiwan Chrysomelid Research Team (TCRT) led by author Lee.

## Materials and methods

Larvae were put into small glass containers (diameter $142 \mathrm{~mm} \times$ height 50 mm ) with cuttings from their host plants at average $20.8^{\circ} \mathrm{C}, 74 \% \mathrm{RH}$, with a photoperiod of 12:12 (L:D) for laboratory rearing. When mature larvae began searching for pupation sites, they were transferred to smaller plastic containers (diameter $90 \mathrm{~mm} \times$ height 57 mm ) filled with moist soil (about $80 \%$ of container volume).

The abdomen was separated from the body and boiled in a $10 \% \mathrm{KOH}$ solution, followed by washing in distilled water to prepare genitalia for drawing purposes. The genitalia were then dissected from the abdomen, mounted on slides in glycerin, and studied and drawn using a Leica M165 stereomicroscope. For detailed examination a Nikon ECLIPSE 50i microscope was used.

At least three pairs from each species were examined to delimit the variability of diagnostic characters.. When a species was collected from more than one locality, at least one pair from each locality was examined. Females are associated with a distinct species based on localities where they were collected. Length is measured from the anterior margin of the eye to the elytral apex, and width at the greatest width of the elytra.

Specimens studied herein are deposited at the following institutes: The Natural History Museum (BMNH), London, UK; Jan Bezděk collection (JBCB), Brno, Czech Republic; Ehime University (EUMJ), Matsuyama, Japan; Kitakyushu Museum of

Natural History and Human History (KMNH), Kitakyushu, Japan; TARI: Taiwan Agricultural Research Institute, Taichung, Taiwan. Depositions are indicated with their recognized abbreviations except for those deposited at TARI.

## Taxonomy

## Genus Sikkimia Duvivier, 1891

Sikkimia Duvivier, 1891: 154 (type species: Sikkimia antennana Duvivier, 1891, by monotypy); Maulik 1936: 520 (redescription).
Yunomela Chen, 1964: 201 (type species: Yunomela rufa Chen, 1964, by original designation); Bezděk and Zhang 2006 (as synonym of Sikkimia).
Taiwanolepta Kimoto, 1989: 73 (type species: Taiwanolepta babai Kimoto, 1989, by original designation). New Synonym
Vietocerus Lopatin, 2003: 103 (type species: Vietocerus kabakovi Lopatin, 2003, by original designation); Bezděk and Zhang 2006 (as synonym of Sikkimia).

Remarks. The diagnostic characters for the genus Sikkimia, as indicated by Bezděk and Zhang (2006), are modified and extended as follows: body large ( $6.1-12.0 \mathrm{~mm}$ ), robust, orange, red or brown; last two segments of antennae strongly enlarged in most males (Figs 1-2); frontal tubercles large, sub-quadratic; pronotum with antebasal transverse impression, limited on sides by short longitudinal furrows, and an additional longitudinal groove half way between short longitudinal furrows and lateral margin, running parallel to the lateral margin (Fig. 1); all pronotal margins bordered; procoxal cavities closed; apical ventrite trilobed in male, with internal anterior margin extended (Figs 7, $48 \& 49$ ); and claws appendiculate.

As all the main diagnostic characters are shared by both the continental and Taiwanese species, Taiwanolepta is here synonymized with Sikkimia. Taiwanese species differ from the continental species in having a shorter body ( $6.1-9.0 \mathrm{~mm}$ ) reduced hind wings and consequently reduced humeral calli. The apical antennomere in the male is spear-shaped and more or less symmetrical in continental species (Fig. 2, see also the drawings in Bezděk and Zhang (2006)), while strongly asymmetrical in Taiwanese species (Figs 24-47). Outer longitudinal grooves on pronotum are deeper in Taiwanese species while more feeble in continental species. Aedeagus sclerotized ventrally in Taiwanese species, but membranous in continental species. Internal sclerite divergent apically in almost all Taiwanese species (Figs 19, 53, 66, 86), while the continental $S$. rufa has the sclerite divergent basally (Fig. 3). On the other hand, the structure of the spermatheca, gonocoxae, ventrite VIII and extended internal part of male abdominal ventrite V in the male are very similar (these structures of $S$. rufa as in Figs 5-8, and for the other Taiwanese species as in Figs 21-23, 48, 49, 55-57, 68-70, 81-83).

Biology. Taiwanese species of Sikkimia appear to be univoltine, based on field observations. Larvae are nocturnal and found on the underside of the host plant's leaves


Figures I-2. Sikkimia rufa (Chen). I Male, dorsal view 2 Three apical antennomeres of right antenna, ventral view.
between February and April. Larval development takes about 20-22 days, based on laboratory rearing. Mature larvae leave the host plant and burrow into the soil where they build underground chambers for pupation. The pupal stage lasts for 22 days, and adults begin to emerge after April. The adults are also nocturnal and live for more than


Figures 3-8. Sikkimia rufa (Chen). 3 Aedeagus, dorsal view 4 Aedeagus, lateral view 5 Apices of gonocoxae 6 Eigth abdominal ventrite $\mathbf{7}$ Male abdominal ventrites III-V 8 Spermatheca.
three months, a lengthy longevity for chrysomelids. Females deposited single eggs on leaves under laboratory conditions, but these failed to hatch. Presumably Sikkimia species overwinter as adults, as some females were collected during winter.


Figures 9-16. Field photography. 9 Larva of Sikkimia sufangae sp. n. feeding on Polygonum chinense 10 Larva of $S$. tsoui sp. n. feeding on Rubus corchorifolius II Larva of $S$. tsoui sp. n. feeding on Dumasia miaoliensis subsp. bicolor $\mathbf{1 2}$ Larva of Gallerucida singularis feeding on P. chinense $\mathbf{1 3}$ Female of $S$. tsoui sp. n. feeding on stem of $R$. corchorifolius $\mathbf{1 4}$ Female of $S$. sufangae sp. n. 15 Male of $S$. tsoui sp. n. feeding on leaves of $R$. swinhoei 16 Female of $S$. sufangae sp. n. feeding on flowers of $P$. posumbu.

All known Sikkimia species feed on the leaves of $P$ ．chinense L．（Polygonaceae）（Fig． 9）．However，some populations of S．tsoui sp．n．also feed on other plants in different areas．For example，populations from Yangminshan National Park（including Hsiaoy－ uken，Erhtzuping，Lengshuiken，Tatunshan）have been observed feeding on R．swinhoei （Fig．15）and R．corchorifolius（Fig．10）（Rosaceae），and members of populations from Tahunshan feed on Dumasia miaoliensis subsp．bicolor（Fig．11）（Fabaceae）．Specimens from these populations will feed on $P$ ．chinense if switched from their original host plant．

In Taiwan，leaf beetles from three genera are known to feed on $P$ ．chinense．These include Altica birmanensis（Jacoby，1896）（Lee and Cheng 2007），Gallerucida singu－ laris Harold， 1880 （Lee and Bezděk 2013），and Sikkimia species．Altica birmanensis inhabits lowlands，at elevations below 1200 m ．Gallerucida singularis occurs at slightly higher elevations，ranging between 1000 m and 1500 m ．Sikkimia species occupy the higher elevations，and are found from 1000 m to 2500 m in central and southern Taiwan．Thus $G$ ．singularis is sympatric with Sikkimia species in some areas．Although members of both taxa are nocturnal，their larvae prefer different sites on the host plant． Larvae of $G$ ．singularis always appear on the upper surface of leaves，their body seg－ ments lack lateral expansions，and the apical posterior tergites are narrower（Fig．12）． Sikkimia larvae occur on the underside of leaves，each body segment has lateral expan－ sions，and the apical posterior tergites are wider（Figs 9－11）．

Distribution．China，India（Sikkim），Laos，Myanmar，Taiwan，and Vietnam．

## Revision of Taiwanese Sikkimia

## Sikkimia babai（Kimoto，1989），comb．n．

Taiwanolepta babai Kimoto，1989： 74.

Type locality．Taiwan：Kaoshiung county，Shinanshan（溪南山）， $23^{\circ} 05^{\prime} 36^{\prime \prime N}$ ， $120^{\circ} 48^{\prime} 18^{\prime \prime} \mathrm{E}, 2600 \mathrm{~m}$.

Type material．Deposition of type specimens（holotype and one paratype）was not indicated by the original paper．The paratype ${ }^{\top}$ was found at the KMNH，labeled： ＂Thu Yun Shan［出雲山］，near Liu Kui［六龜］，S－Taiwan 23．VII． 1986 Col．K Baba／ Taiwanolepta babai n．sp．Det．S．Kimoto， 1989 ／PARATYPE（printed on blue paper） ／PHOTO（printed on red paper）＂．

Other material examined（ $\mathrm{n}=18$ ）．Kaoshiung： $7 \delta^{\lambda}, 7 q$ ，Tengchi（藤枝）， $23^{\circ} 04^{\prime} 02^{\prime \prime} \mathrm{N}, 120^{\circ} 45^{\prime} 21^{\prime \prime} \mathrm{E}, 2 . V I .2008$ ，leg．C．－F．Lee（2 spec．in JBCB）； $10^{\top}$ ，same locality，26．V．2009，leg．C．－F．Lee；1 ，Shihshan logging trail（石山林道，＝Tengchi）， 1．X．2008，leg．M．－H．Tsao； $1 \delta^{\lambda}, 3 q+$ ，same locality，2．X．2008，leg．M．－H．Tsou．

Description．Male．Length $7.1-7.5 \mathrm{~mm}$ ；width $3.9-4.1 \mathrm{~mm}$ ．Coloration reddish－ brown，head dark brown，legs and antennae black．Antenna（Fig．17）elongate，about as long as body；antennomeres I to VIII filiform；IX widening slightly towards apex；$\times$ and XI extremely swollen（Figs 24－26，36－38），$\times$ with a deep groove，from middle to apex，


Figures 17-23. Sikkimia babai (Kimoto). 17 Antenna, male 18 Antenna, female 19 Aedeagus, dorsal view $\mathbf{2 0}$ Aedeagus, lateral view 21 Gonocoxae 22 Eighth abdominal ventrite $\mathbf{2 3}$ Spermatheca.
of mesal surface; apex of XI pointed, weakly concave in apical $1 / 3$ of mesal surface and in basal $1 / 4$ of outer surface; dorsal surface with two longitudinal ridges, one centrally located, curved, from middle to basal $1 / 5$; other longitudinal ridge along mesal surface from middle to basal $1 / 4$; one deep groove between the two longitudinal ridges; one transverse groove near base; small process at apical $1 / 3$ near outer margin; length ratios


Figures 24-35. Photographs of male antennomeres X-XI. 24 S. babai (Kimoto), outer view 25 Ventral view 26 Inner view $27 S$. meihuai sp. n., outer view 28 Ventral view 29 Inner view $\mathbf{3 0} S$. sufangae sp. n., outer view 3 I Ventral view 32 Inner view 33 S. yuae sp. n., outer view $\mathbf{3 4}$ Ventral view 35 Ditto, inner view.
of antennomeres II to XI about $1.0: 1.2: 2.0: 1.9: 1.9: 1.9: 1.7: 1.9: 3.2: 3.5$, and length to width ratios of antennomeres II to XI about $1.4: 1.5: 2.4: 2.1: 2.1: 2.3: 2.2$ : $1.8: 2.4: 2.0$. Pronotum transverse, $1.7 \times$ wider than long; anterior and posterior mar-
gins almost straight；lateral margins weakly rounded or straight；disc finely punctured． Elytra narrow，about $1.3 \times$ longer than wide；densely and randomly punctuate，humeri reduced．Abdominal ventrite V（Fig．48）trilobed，internal anterior margin extended， reaching ventrite III；median longitudinal，internal ridge running from base to apex of extension．Abdominal tergite I with only spiracles sclerotized；tergites II－V with scle－ rotized spiracles and transverse weakly sclerotized areas；most of tergite VI and spiracles strongly sclerotized；tergite VII entirely and strongly sclerotized．Aedeagus（Figs 19－20） narrow in dorsal view，about $6.2 \times$ longer than wide，parallel－sided in basal $1 / 3$ ，becom－ ing slightly narrower towards apex；apex subtriangular and pointed；ventral surface well sclerotized and smooth；narrow and moderately curved in lateral view；endophallic scle－ rite longitudinal and slender，bifurcate apically，about $0.3 \times$ as long as aedeagus．

Female．Length $8.1-8.4 \mathrm{~mm}$ ；width $5.3-5.8 \mathrm{~mm}$ ．Similar to males，but dark brown ventrally；antennae（Fig．18）filiform，antennomeres $\times$ and XI not swollen； length ratio of II to XI about $1.0: 1.7: 2.2: 2.2: 2.2: 2.0: 1.8: 1.9: 2.2: 2.8$ ，and length to width ratios of II to XI about $1.9: 2.4: 3.4: 3.6: 3.8: 3.6: 3.2: 3.3: 3.7$ ： 4．4．Elytra wider than in male，length equal to width．Gonocoxae（Fig．21）slender，to－ gether about $4.0 \times$ longer than wide，joined from base almost to middle，base strongly narrowed in basal $1 / 3$ with a long medial groove，apices tubular and sub－parallel，inner margins slightly indented medially，apex with nine setae．Ventrite VIII（Fig．22）with extremely long spiculum；apical margin widely rounded，weakly sclerotized basally， disc with long scattered setae along apical margin．Abdominal tergites I－III mem－ branous，only spiracles sclerotized，tergites IV－VII entirely and strongly sclerotized． Receptacle of spermatheca（Fig．23）strongly swollen and transverse，pump elongate and moderately curved，proximal spermathecal duct long and wide．

Diagnosis．Sikkimia babai is similar to S．sufangae sp．n．They share a slender ae－ deagus（more than $5.9 \times$ longer than wide），but in $S . b a b a i$ it is parallel－sided（aedeagus wider basally in S．sufangae sp．n．（Fig．66，67））．Antennomere XI in male S．babai has one process on the inner antero－lateral surface and the outer antero－lateral surface is flat（process absent on inner antero－lateral surface and outer antero－lateral surface depressed in S．sufangae sp．n．）．The gonoxae are sub－parallel in S．babai（diverging in S．sufangae sp．n．）．

Host plant．Polygonum chinense L．（Polygonaceae）．
Distribution．Tengchi（Kaoshiung county）（Fig．50）and its surrounding areas．

## Sikkimia meihuai sp．n．

http：／／zoobank．org／DD3EE7B6－4DD2－4CD7－AAF7－F2FCD115C6CC
Figs 27－29，39－41，50－57

Type locality．Taiwan：Taitung county，Liyuan（栗園）， $23^{\circ} 13^{\prime} 17^{\prime \prime} \mathrm{N}, 121^{\circ} 00^{\prime} 40$＂ E ， 1800 m．

Type material（ $\mathrm{n}=19$ ）．Holotype $\delta^{\lambda}$ ：Taitung：Liyuan（栗園），23．VI．2010，leg． M．－H．Tsou．Paratypes： $3 \delta^{\lambda}, 2 q q$ ，same data as holotype； $2 q q$ ，same locality，


Figures 36－47．Illustrations of male antennomeres X－XI． 36 S．babai（Kimoto），outer view $\mathbf{3 7}$ Ventral view 38 Inner view $\mathbf{3 9} S$ ．meihuai sp．n．，outer view 40 Ventral view 41 Inner view 42 S．sufangae sp．n．， outer view 43 Ventral view 44 Inner view $45 S$ ．yuae sp．n．，outer view 46 Ventral view 47 Inner view．

19．VI．2013，leg．C．－F．Lee； 7 q $q$ ，same locality，24．VII．2013，leg．C．－F．Lee； 1 § 3 ， 9 q， Motien（摩天）， $23^{\circ} 11^{\prime} 41^{\prime \prime N}, 121^{\circ} 01^{\prime} 18^{\prime \prime} \mathrm{E}, 20 . \mathrm{VI} .2011$ ，leg．C．－F．Lee（ $1 \delta^{\top}, 2 q$ 早 in JBCB）．


Figures 48-49. Male abdominal ventrites III-V, dorsal view. 48 Sikkimia babai 49 S. tsoui sp. n.

Description. Male. Length $7.3-7.5 \mathrm{~mm}$; width $4.0-4.2 \mathrm{~mm}$. Coloration brown, head dark brown, legs and antennae black. Antenna (Fig. 51) long, about as long as body; antennomeres I-VII filiform; VIII-IX widening slightly;x and XI extremely swollen (Figs 27-29, 39-41), $\times$ with a shallow groove from middle to apex of mesal surface, XI moderately concave in basal $1 / 4$ of outer surface, weakly concave in apical $1 / 3$ of mesal surface and pointed apically; dorsal surface with two longitudinal ridges, one close to mesal margin, extending from middle and abbreviated near base, other longitudinal ridge along mesal margin extending from apical $1 / 3$, projecting in middle, and ending in basal $1 / 4$, with a deep groove between the longitudinal ridges, and a transverse groove near the base; length ratio of II to XI about $1.0: 1.3: 1.8: 1.6$ : $1.8: 1.6: 1.4: 1.3: 1.8: 2.8$, and length to width ratios of II to XI about $2.0: 2.0$ $: 2.7: 2.4: 2.7: 2.2: 2.3: 1.9: 2.8: 2.8$. Pronotum transverse, $1.5 \times$ as wider than long; anterior and posterior margins almost straight, slightly concave medially; lateral margin weakly rounded; disc with finely punctured. Elytra narrow, about $1.2 \times$ longer than wide; densely and randomly punctuate, humeri reduced. Abdominal ventrite V trilobed, internal anterior margin extended, reaching ventrite III; median longitudinal internal ridge running from base to apex of extension. Abdominal tergite I with only spiracles sclerotized; tergites II-V with sclerotized spiracles and transverse weakly sclerotized areas; most of tergite VI and spiracles strongly sclerotized; tergite VII entirely and strongly sclerotized. Aedeagus (Figs 53-54) wide in dorsal view, about $4.8 \times$ longer than wide, base strongly incised medially, wide in basal $1 / 3$, becoming slightly narrower towards the subtriangular apex; ventral surface well sclerotized and smooth; broad and moderately curved in lateral view; endophallic sclerite longitudinal and slender, bifurcate apically, about $0.3 \times$ as long as aedeagus.

Female. Length $7.5-8.2 \mathrm{~mm}$; width $4.5-4.8 \mathrm{~mm}$. Similar to male, but antennae (Fig. 52) filiform, antennomeresx and XI not swollen; length ratio of II to XI about $1.0: 1.6: 2.1: 2.0: 2.1: 2.0: 1.8: 1.9: 2.1: 2.6$, and length to width ratios of II to XI about $1.9: 2.6: 3.3: 3.1: 3.3: 3.2: 2.9: 3.0: 3.3: 4.2$. Elytra relatively wide, about $1.1 \times$ longer than wide. Gonocoxae (Fig. 55) wide, together about $2.7 \times$ longer than wide and joined from base almost to middle, basal margin deeply indented medially narrowing strongly in basal $1 / 3$ with a short medial groove, apices tubular and parallel, narrowing slightly in apical $1 / 3$ and curving inward, with nine setae. Ventrite VIII (Fig. 56) weakly sclerotized; with extremely long speculum; apex transverse, api-


Figure 50. Distribution map of Sikkimia species of Taiwan, solid line: 1000 m , broken line: 2000 m . Brown dots: S. sufangae sp. n., green dots: S. babai, pink dots: S. yuae sp. n., red dots: S. tsoui sp. n., blue dots: S. meibuai sp. n.


Figures 5I-57. Sikkimia meihuai sp. n. 5I Antenna, male 52 Antenna, female 53 Aedeagus, dorsal view 54 Aedeagus, lateral view $\mathbf{5 5}$ Gonocoxae $\mathbf{5 6}$ Eighth abdominal ventrite $\mathbf{5 7}$ Spermatheca.
cal margin widely rounded, with scattered long setae along apical margin. Abdominal tergites I-III membranous with only spiracles sclerotized, tergites IV-VII entirely and strongly sclerotized. Receptacle of spermatheca (Fig. 57) strongly swollen and transverse; pump elongate and strongly curved; spermathecal duct short but extremely wide.

Diagnosis．Sikkimia meihuai sp．n．is similar to S．yuae sp．n．in greatest width of the aedeagus（ $4.8 \times$ longer than wide），but differs in having the aedeagus narrowing very slightly towards the apex（distinctly narrower in apical $1 / 3$ in $S$ ．yuae sp．n．）；short median ridge on antennomere IX in males（long median ridge in S．yuae sp．n．）；and wider gonocoxae， $2.7 \times$ longer than wide（slender gonocoxae in $S$ ．yuae sp．n．， $4.4 \times$ longer than wide）．

Host plant．Polygonum chinense L．（Polygonaceae）．
Etymology．This new species is named after Mr．Mei－Hua Tsou，who is a member of TCRT and the first to collect this new species．

Distribution．East half of South Cross－Island Highway（南横公路）（Fig．50）．

## Sikkimia sufangae sp．n．

http：／／zoobank．org／9AD84610－CAB7－4517－934E－689E4A8F3393
Figs 9，14，16，30－32，42－44，50，58－70

Type locality．Taiwan：Pingtung county，Tahanshan（大漢山），22 ${ }^{\circ} 24^{\prime} 27^{\prime \prime} \mathrm{N}$ ， $120^{\circ} 45^{\prime} 23^{\prime \prime} \mathrm{E}, 1400 \mathrm{~m}$.

Type material（ $\mathrm{n}=75$ ）．Holotype ${ }^{\top}$ ：Pingtung：Tahanshan（大漢山），6．VI．2012， leg．C．－F．Lee．Paratypes： 5 ふた, $9 q$ ，same data as holotype（ 2 ふす， $2 q$ 早 in JBCB）； $1 \widehat{\sigma}^{\lambda}$ ，same locality，18．VII．2007，leg．C．－F．Lee； $1 \widehat{\sigma}^{\widehat{ }}, 1$ ，same locality，22．I．2009； leg．S．－F．Yu； $1 \delta^{\lambda}$ ，same locality，25．V．2009，leg．M．－L．Jeng；1q，same locality， 21．I．2012，leg．S．－F．Yu；1q，same locality，19．VII．2012，leg．C．－F．Lee； $2 \widehat{刃}^{\top} \widehat{J}^{\text {d }}$ ，same locality，29．IV．2013，leg．Y．－T．Chung； $1{ }^{\text {§，}}$ ，same locality，2．VI．2013，leg．J．Yama－ sako（EUMJ）；1q，same locality，29．VI．2013，leg．B．－X．Guo； $3 q$ ，same locality， 8．VII．2013，leg．B．－X．Guo； $3 q$ ，${ }^{2}$ ，same locality，11．VII．2013，leg．B．－X．Guo； 1 q， same locality，12．VII．2013，leg．Y．－T．Chung；1q，same locality，19．VII．2013，leg． M．－H．Tsou；1q，28．VIII．2014，leg．Y．－T．Chung； $3 q$ ，+ ，4．X．2014，leg．Y．－T．Chung； $8 \widehat{\jmath}^{\lambda}, 1$ ，same locality，1．V．2015，leg．Guo \＆Chung； $1 \jmath^{\lambda}$ ，same locality，19．V．2015， leg．Y．－T．Chung； $3 \delta^{\top} 0^{\lambda}$ ，same locality，27．V．2015，leg．Y．－T．Chung； $1 \delta^{\lambda}$ ，same local－ ity，29．V．2015，leg．Y．－T．Chung； $4 \delta^{\top} \widehat{J}, 3 q$ ， ，same locality，6．VI．2015，leg．Y．－T． Chung； $3 \circlearrowleft^{\top} 0^{\lambda}$ ，Peitawushan（北大武山）， $22^{\circ} 37^{\prime} 47^{\prime \prime} \mathrm{N}, 120^{\circ} 45^{\prime} 41^{\prime \prime} \mathrm{E}, 22$ IV．2015，leg． J．－C．Chen； $7 \circlearrowleft^{\top} \delta^{\lambda}, 7$ O $Q$ ，same locality，24．IV．2015，leg．J．－C．Chen．

Description．Male．Length $7.8-9.0 \mathrm{~mm}$ ；width $4.0-4.3 \mathrm{~mm}$ ．Coloration（Figs 58－ 60）brown，head dark brown，legs and antennae black．Antenna（Fig．64）long，about as long as body；antennomeres I to VII filiform；VIII and IX widening slightly；$\times$ and XI （Figs 30－32，42－44）extremely swollen，$\times$ with shallow groove from middle to apex of mesal surface；apex of XI pointed，moderately concave in basal $1 / 4$ of outer surface and in apical $1 / 3$ of mesal surface，dorsal surface with two longitudinal ridges，one close to mesal margin，from base to near middle，strongly curved；other longitudinal ridge along mesal margin extending from basal $1 / 4$ to apical $1 / 3$ ，projecting medially，with a deep groove between the longitudinal ridges，and a transverse groove near the base，shallowly depressed on outer antero－lateral surface；length ratio of II to XI about $1.0: 1.4: 1.8: 2.2$


Figures 58-63. Habitus of Sikkimia sufangae sp. n. $\mathbf{5 8}$ Male, dorsal view $\mathbf{5 9}$ Male, ventral view $\mathbf{6 0}$ Male, lateral view 61 Female, dorsal view $\mathbf{6 2}$ Female, ventral view $\mathbf{6 3}$ Female, lateral view.
$: 2.0: 1.9: 2.1: 1.9: 1.8: 2.8$, and length to width ratios of II to XI about $1.6: 1.9: 2.9$ $: 2.7: 2.6: 2.8: 2.8: 2.5: 1.9: 2.2$. Pronotum transverse, $1.5 \times$ wider than long; anterior and posterior margins almost straight; lateral margin weakly rounded; disc with small punctures. Elytra narrow, about $1.4 \times$ longer than wide; densely and randomly punctuate, humeri reduced. Abdominal ventrite V trilobed, internal anterior margin extended, reaching ventrite III; median longitudinal, internal ridge running from base to apex of extension. Abdominal tergite I with only spiracles sclerotized; tergites II-V with sclerotized spiracles and transverse weakly sclerotized areas; most of tergite VI and spiracles strongly sclerotized; tergite VII entirely and strongly sclerotized. Aedeagus (Figs 66-67)


Figures 64-70. Sikkimia sufangae sp. n. 64 Antenna, male 65 Antenna, female 66 Aedeagus, dorsal view 67 Aedeagus, lateral view 68 Gonocoxae 69 Eighth abdominal ventrite $\mathbf{7 0}$ Spermatheca.
slender, about $5.9 \times$ longer than wide, base moderately incised medially, basal $1 / 3$ wide, narrowing considerably towards the rounded apex, ventral surface well sclerotized and smooth; moderately curved in lateral view; endophallic sclerite longitudinal and extremely slender, bifurcate apically, about $0.3 \times$ as long as aedeagus.

Female．Length 7．8－8．1 mm；width 5．2－5．3 mm．Similar to males（Figs 61－63）， but antennae filiform（Fig．65），antennomeres $\times$ and XI not swollen；length ratio of II to XI about $1.0: 1.5: 2.0: 1.9: 2.0: 1.9: 1.8: 1.9: 2.0: 2.6$ ，and length to width ratios of II to XI about $1.9: 2.3: 3.3: 3.2: 3.4: 3.1: 3.0: 3.1: 3.4: 4.0$ ．Elytra as wide as long．Gonocoxae（Fig．68）slender，about $3.6 \times$ longer than wide，joined from base to middle，base rounded，strongly narrowed in basal $1 / 3$ ，apices tubular curved slightly inwards，diverging，apex with seven or eight setae．Ventrite VIII（Fig．69） weakly sclerotized；apex extremely transverse，apical margin widely rounded，disc with long scattered long setae towards apex．Abdominal tergites I－III membranous with only the spiracles sclerotized，IV－VII entirely and strongly sclerotized．Receptacle of spermatheca（Fig．70）strongly swollen and transverse，pump long and strongly curved； proximal spermathecal duct short and swollen distally．

Diagnosis．Sikkimia sufangae is similar to S．babai．See diagnosis of S．babai for a summary of the differentiating characteristics of these two species．

Host plant．Polygonum chinense L．；P．posumbu Buch．－Ham．ex Don（Polygonaceae） （Fig．16）．

Etymology．This new species is named after Mrs．Su－Fang Yu，who is a member of TCRT and the first to collect this new species．

Distribution．Southern Taiwan（Fig．50）．

## Sikkimia tsoui sp．n．

http：／／zoobank．org／385E17EE－64F8－4B24－AF8B－E7D2C948731C
Figs 10，11，13，15，49，50，71－83
Type locality．Taiwan：Taipei city，Hsiaoyuken（小油坑）， $25^{\circ} 10^{\prime} 38^{\prime \prime} \mathrm{N}, 121^{\circ} 32^{\prime} 50^{\prime \prime} \mathrm{E}$ ， 800 m．

Type material（n＝229）．Holotype ơ：Taipei：Hsiaoyuken（小油坑），22．VI．2008， leg．M．－H．Tsou．Paratypes： 1 ，same as holotype； $1 \delta^{\top}$ ，same locality，21．IV．2008，leg． M．－H．Tsou； $2 \widehat{\delta}^{\lambda}$ ，same locality，24．IV．2008，leg．M．－H．Tsou； $6 q$ ， ，same locality， 22．VI．2008，leg．S．－F．Yu； $1 \delta^{\lambda}$ ，same locality，24．V．2008，leg．M．－H．Tsou； $1 \delta^{\lambda}, 3 q$ ， same locality，5．IV．2009，leg．M．－H．Tsou； $8 \delta^{\top} \sigma^{\lambda}, 13 q$ ， ，same locality，8．V．2010，leg． M．－H．Tsou； $2 \widehat{o}^{\text {ond }}, 8 q$ ，same locality，15．V．2011，leg．M．－H．Tsou； $1 q$ ，Erhtzuping （二子坪）， $25^{\circ} 11^{\prime} 01^{\prime \prime} \mathrm{N}, 121^{\circ} 31^{\prime} 07^{\prime \prime} \mathrm{E}, 14 . V I I I .2011$ ，leg．M．－H．Tsou； $7 \widehat{o}^{\top}, 4+9$ ， same locality，3．VI．2011，leg．M．－H．Tsou；2 $~$ 早，Lengshuiken（冷水坑）， $25^{\circ} 10^{\prime} 03^{\prime \prime N}$ ， $121^{\circ} 33^{\prime} 46 " E, 07 . I V .2009$ ，leg．H．Lee； $1 \delta^{\top}$ ，same locality，08．IV．2009，leg．H．Lee； 1 ，Tatunshan（大屯山）， $25^{\circ} 11^{\prime} 12^{\prime \prime} \mathrm{N}, 121^{\circ} 31^{\prime} 22^{\prime \prime} \mathrm{E}, 22 . V .2010$ ，leg．M．－H．Tsou； Hsinchu：1 ，Lupi（魯壁）， $24^{\circ} 39^{\prime} 56^{\prime \prime} \mathrm{N}, 121^{\circ} 16^{\prime} 47^{\prime \prime} \mathrm{E}, 19 . \mathrm{VII} .2008$ ，leg．M．－H． Tsou； $1 \delta^{\lambda}, 2 q$ 早，Mamei（馬美）， $24^{\circ} 40^{\prime} 13^{\prime \prime N}, 121^{\circ} 19^{\prime} 13^{\prime \prime} \mathrm{E}, 10 . V I I .2010$ ，leg．M．－H． Tsou； $1 \delta^{\lambda}$ ，Tahunshan（大混山）， $24^{\circ} 41^{\prime} 20^{\prime \prime} \mathrm{N}, 121^{\circ} 16^{\prime} 29^{\prime \prime} \mathrm{E}, 08 . I V .2009$ ，leg．M．－H． Tsou； $1^{\lambda}$ ，same locality，11．IV．2009，leg．M．－H．Tsou；1q，same locality，13．IV．2009， leg．M．－H．Tsou； $1 \delta^{\text {º，}}$ ，Talu logging trail（大鹿林道）， $24^{\circ} 32^{\prime} 06^{\prime \prime} \mathrm{N}, 121^{\circ} 07^{\prime} 01^{\prime \prime} \mathrm{E}$ ， 1．VIII．2015，leg．Y．－L．Lin；Ilan： 1 中，Mingchi（明池）， $24^{\circ} 39^{\prime} 01^{\prime \prime} \mathrm{N}, 121^{\circ} 28^{\prime} 22^{\prime \prime} \mathrm{E}$ ，


Figures $\mathbf{7 I - 7 6}$ ．Habitus of Sikkimia tsoui sp．n． 71 Male，dorsal view $\mathbf{7 2}$ Male，ventral view $\mathbf{7 3}$ Male， lateral view $\mathbf{7 4}$ Female，dorsal view $\mathbf{7 5}$ Female，ventral view $\mathbf{7 6}$ Female，lateral view．

2．VII．2008，leg．H．－J．Chen； $1 \delta^{\top}$ ，Taipingshan（太平山）， $24^{\circ} 29^{\prime} 53^{\prime \prime} \mathrm{N}, 121^{\circ} 32^{\prime} 06^{\prime \prime} \mathrm{E}$ ， 5．VIII．2015，leg．Y．－T．Chung；16q ，Yuanyanghu（鴛鴦湖）， $24^{\circ} 34^{\prime} 36^{\prime \prime} \mathrm{N}$ ，

 leg．H．Lee； 3 ふた $\begin{gathered}\text { ，Tatung（大同，}=\text { Yuanyanghu），19．VIII．2010，leg．H．－H．Lee；Mi－}\end{gathered}$ aoli： $1 \delta^{\widehat{ }}$ ，Luchang（鹿場）， $24^{\circ} 32^{\prime} 26^{\prime \prime} \mathrm{N}, 121^{\circ} 01^{\prime} 38^{\prime \prime} \mathrm{E}, 1 . \mathrm{VI} .2014$ ，leg．Y．－M．Weng；




Figures 77-83. Sikkimia tsoui sp. n. 77 Antenna, male 78 Antenna, female 79 Aedeagus, dorsal view 80 Aedeagus, lateral view 81 Eighth abdominal ventrite 82 Gonocoxae 83 Spermatheca.

 $24^{\circ} 14^{\prime} 41^{\prime \prime} \mathrm{N}, 120^{\circ} 58^{\prime} 30^{\prime \prime} \mathrm{E}, 19 . X .2011$ ，leg．C．－F．Lee；2才す，Tahsuehshan（大雪山， ＝Anmashan），7．VI．2010，leg．C．－F．Lee； 2 q $q$ ，same locality，4．VI．2012，leg．J．－C． Chen；Taoyuan： $10^{\top}$ ，Hsuanyuan（萱源）， $24^{\circ} 39^{\prime} 11^{\prime \prime N}, 121^{\circ} 24^{\prime} 177^{\prime \prime} \mathrm{E}, 13 . V .2010$ ，leg． S．－F．Yu；4q + ，same locality，1．VI．2010，leg．W．－T．Liu；1 ${ }^{\text {Th }}$ ，Lalashan（拉拉山）， $24^{\circ} 40^{\prime} 47^{\prime \prime} \mathrm{N}, 121^{\circ} 23^{\prime} 02^{\prime \prime} \mathrm{E}, 20 . \mathrm{IV} .2008$ ，leg．C．－F．Lee．

Description．Male．Length $6.1-6.5 \mathrm{~mm}$ ；width 3．7－3．8 mm．Coloration brown （Figs 71－73），legs and antennae black．Antenna（Fig．77）long，about long as body； filiform；length ratio of antennomeres II to XI about $1.0: 1.3: 1.8: 1.8: 1.7: 1.7$ ： $1.7: 1.7: 1.7: 2.1$ and length to width ratios of II to XI about $2.1: 2.6: 3.6: 3.6$ ： $4.0: 4.0: 4.0: 4.0: 4.0: 4.9$ ．Pronotum transverse， $1.6 \times$ wider than long；anterior and posterior margins almost straight；lateral margin weakly rounded；disc with reduced punctures．Elytra wide，about $1.2 \times$ longer than wide；densely and randomly punctu－ ate，humeri reduced．Abdominal tergite I membranous with sclerotized spiracles；II－ VI with medial transverse patch sclerotized as well as area surrounding spiracles；VII mostly sclerotized，with spiracle inside sclerotized area．Abdominal ventrite V（Fig．49） trilobed，internal anterior margin extended，reaching ventrite III；median longitudinal， internal ridge extending from base to mid－length of extension．Aedeagus（Figs 79－80） wide in dorsal view，about $4.5 \times$ longer than wide，base shallowly incised medially； greatest width in basal $1 / 3$ ，becoming very slightly narrower towards the subtriangular apex；ventral surface well sclerotized，concave medially；narrow and moderately curved in lateral view；endophallic sclerite longitudinal，slender，joined from base to near apex，about $0.4 \times$ as long as aedeagus（Fig．79）．

Female．Length 8．0－8．3 mm；width 4．9－5．7 mm．Similar to male（Figs 74－76）． Antenna（Fig．78）about long as body；filiform；length ratio of antennomeres II to XI about $1.0: 1.3: 1.8: 1.8: 1.7: 1.7: 1.7: 1.8: 1.8: 2.1$ and length to width ratios of II to XI about $2.2: 3.0: 3.9: 3.8: 4.0: 4.0: 4.0: 4.2: 4.3: 6.0$ ．Elytra as long as wide， wider than in male．Gonocoxae（Fig．82）extremely wide，about $2.9 \times$ longer than wide， joined from basal $1 / 5$ to middle，with several long and many short dense setae on tubu－ lar apices；greatest width at base incised medially，narrowing slightly in basal $1 / 3$ before widening slightly again．Abdominal tergites I and II membranous，only area surround－ ing of spiracles sclerotized；III with one pair of transverse sclerotized areas near middle； IV with one transverse sclerotized area at middle； V and VI with sclerotized areas larger than on IV；VII mostly sclerotized with spiracles lying inside sclerotized area．Ventrite VIII（Fig．81）strongly sclerotized；apex transverse，apical margin weakly emarginate， with long dense setae along apical margin．Receptacle of spermatheca（Fig．83）swol－ len，pump long and strongly curved，spermathecal duct long and slender．

Variation．Specimens collected from Hsiaoyuken have more robust antennae （length ratio of antennomeres II to XI about $1.0: 1.5: 2.2: 2.1: 2.2: 2.1: 2.1: 2.2$ ： $2.3: 2.7$ and length to width ratios of II to XI about $1.6: 2.4: 3.2: 3.4: 3.5: 3.3$ ： $3.3: 3.7: 3.7: 4.3$ ）．

Diagnosis．This species is easily distinguished from other Taiwanese species of Sikkimia using a combination of the following characters：filiform antennae in males （swollen antennomeres $\times$ and XI in other species），reduced median ridge on internal anterior margin extension of abdominal ventrite V （well developed internal median ridge in other species），and the endophallic sclerite of aedeagus that is joined from the base almost to the apex（endophallic sclerite of aedeagus bifurcate apically in other spe－ cies）；abdominal tergites IV－VI largely membranous in female，and gonocoxae much wider with numerous setae on their apices（other species with entirely sclerotized ab－ dominal tergites，slender gonocoxae with few setae on their apices in other species）．

Host plant．Polygonum chinense L．；P．thunbergii Sieb．\＆Zucc．（Polygonaceae）； Rubus swinhoei Hance；R．corchorifolius L．f．（Rosaceae）；Dumasia miaoliensis Y．C．Liu \＆F．Y．Lu subsp．bicolor（Hayata）Ohashi \＆Tateishi（Fabaceae）．

Etymology．This new species is named after Mr．Mei－Hua Tsou，who is a member of TCRT and the first to collect this new species．

Distribution．North and Central Taiwan（Fig．50）．The distribution extend northwards to Yamingshan National Park（陽明山國家公園）and southwards to Hsitou（溪頭）．

## Sikkimia yuae sp．n．

http：／／zoobank．org／288CCEA4－D157－43B8－A523－ED8B454EEDFF
Figs 33－35，50，84－90

Type locality．Taiwan：Kaoshiung county，Chungchihkung（中之關）， $23^{\circ} 17^{\prime} 10^{\prime \prime N}$ ， $120^{\circ} 53^{\prime} 51^{\prime \prime} \mathrm{E}, 2300 \mathrm{~m}$.

Type material（ $\mathrm{n}=16$ ）．Holotype $\delta^{\top}$ ：Kaoshiung：Chungchihkung（中之關），
 in JBCB）；1才， 2 q q，Taoyuan（桃源＝Chungchihkung），1．VII．2009，leg．S．－F．Yu．

Description．Male．Length $7.1-7.5 \mathrm{~mm}$ ；width $3.9-4.1 \mathrm{~mm}$ ．Coloration reddish－ brown，head dark brown，legs and antennae black．Antenna（Fig．84）long，about long as body；antennomeres I to VII filiform；VIII and IX slightly widened；$\times$ and XI ex－ tremely swollen（Figs 33－35，45－47），$\times$ with deep groove from middle to apex of mesal surface，apex of XI pointed，moderately concave in apical $1 / 3$ of mesal surface and in basal $1 / 4$ of outer surface，dorsal surface with two longitudinal ridges，one close to me－ sal margin extending from basal $1 / 4$ to apical $1 / 3$ ，other longitudinal ridge along mesal margin from basal $1 / 4$ to the middle，deep groove between longitudinal ridges，trans－ verse groove near base；length ratio of antennomeres II to XI about 1.0 ： 1.3 ： 1.5 ： 1.5 ： $1.6: 1.6: 1.5: 1.6: 2.5: 3.1$ ，length to width ratios of antennomeres II to XI about 1.8 $: 1.8: 2.4: 2.2: 2.3: 2.3: 2.1: 2.0: 2.7: 2.7$ ．Pronotum transverse， $1.6 \times$ wider than long；anterior and posterior margins sinuate，weakly concave medially；lateral border－ margin weakly rounded；disc with fine scattered punctures．Elytra narrow，about $1.2 \times$ longer than wide；punctuate densely，reduced humeri，lateral margin rounded，widest just posterior of the middle．Abdominal ventrite V trilobed，internal anterior margin extended，reaching ventrite III；median longitudinal，internal ridge running from base


Figures 84-90. Sikkimia yuae sp. n. 84 Antenna, male $\mathbf{8 5}$ Antenna, female $\mathbf{8 6}$ Aedeagus, dorsal view 87 Aedeagus, lateral view 88 Gonocoxae 89 Eighth abdominal ventrite $\mathbf{9 0}$ Spermatheca.
to apex of extension. Abdominal tergite I with only spiracles sclerotized; II-V with spiracles sclerotized and transverse weakly sclerotized areas; most of VI and spiracles strongly sclerotized; whole of VII strongly sclerotized. Aedeagus (Figs 86-87) wide
in dorsal view，about $4.8 \times$ longer than wide，base shallowly incised medially；greatest width in basal $1 / 3$ ，narrowing slightly towards apical $1 / 3$ ，widening slightly subapi－ cally before the subtriangular apex with a pointed tip；ventral disc well sclerotized and smooth；aedeagus wide and moderately curved in lateral view；endophallic sclerite lon－ gitudinal and slender，bifurcate apically，about $0.4 \times$ as long as aedeagus．

Female．Length $7.8-8.2 \mathrm{~mm}$ ；width $5.3-5.6 \mathrm{~mm}$ ．Similar to male，but underside dark brown；antenna（Fig．85）filiform，antennomeres $\times$ and XI not swollen；length ratio of antennomeres II to XI about $1.0: 1.2: 1.9: 1.8: 1.9: 1.9: 1.7: 1.9: 2.1: 2.6$ ， and length to width ratios of II to XI about $2.0: 2.0: 3.2: 3.4: 3.5: 3.4: 3.3: 3.5$ ： $4.8: 4.3$ ．Elytra wider than in male，length and width the same．Gonocoxae（Fig．88） slender，about $4.4 \times$ longer than wide，joined from base to just before middle，apices tubular，straight and subparallel，with 9－10 apical setae，base rounded and slightly narrower than greatest width at middle，narrowing slightly at basal $1 / 3$ ．Ventrite VIII （Fig．89）with extremely long spiculum；apex very small and oval in shape，weakly scle－ rotized basally，disc with long scattered setae．Abdominal tergites I－III membranous with only the spiracles sclerotized，IV－VII entirely and strongly sclerotized．Receptacle of spermatheca（Fig．90）slightly swollen，pump short and moderately curved，sper－ mathecal duct wide and long．

Diagnosis．This new species can be distinguished from others by the following combination of characters：apical $1 / 3$ of aedeagus narrowing slightly before widen－ ing slightly again subapically（aedeagus parallel in S．babai and widening basally in S．sufangae sp．n．and S．meihuai sp．n．），and straight subparallel apices of gonocoxae （curved apices of gonocoxae in S．meihuai sp．n．，S．babai，and S．sufangae sp．n．）．

Host plant．Polygonum chinense L．（Polygonaceae）．
Etymology．This new species is named after Mrs．Su－Fang Yu，who is a member of TCRT and the first person to collect this new species．

Distribution．West half of South Cross－Island Highway（南横公路）（Fig．50）．

## Key to species of Sikkimia in Taiwan

Antenna filiform in male（Fig．77）；median longitudinal internal ridge on ab－ dominal ventrite V reduced，extending from base to mid－length of extension （Fig．49）；endophallic sclerite of aedeagus joined from base to near apex（Fig． 79）；abdominal tergites IV－VI of females membranous（Fig．13）；gonocoxae extremely wide，base much wider than medially，apex with numerous setae （Fig．82）
－Antennomeres $\times$ and XI of males swollen（Figs 17，51，64，84），median lon－ gitudinal internal ridge on abdominal ventrite $V$ well developed，extending from base to apex of extension（Fig．48），endophallic sclerite of aedeagus bifurcate apically（Figs 19，53，66，86）；abdominal tergite IV－VI of females entirely sclerotized（Fig．14）；gonocoxae slender，base subequal or narrower than in middle，apex with few setae（Figs 21，55，68，88）

2 Aedeagus narrowing slightly towards apical $1 / 3$, widening slightly subapically (Fig. 86); median anterior ridge on antennomere XI extending into apical $1 / 3$ in males (Figs 33-35, 45-47); apices of gonocoxae straight and subparallel (Fig. 88)
S. yuae sp. n.

- Aedeagus parallel-sided or widened basally (Figs 19, 53, 66); median ridge of antennomere XI abbreviated or curved outwards at middle in males (Figs 24-32, 36-44); apex of gonocoxa curved (Figs 21, 55, 68) 3
3 Aedeagus slender, more than $5.9 \times$ longer than wide (Figs 19, 66); median ridge of antennomere XI curved medially in males (Figs 24-26, 30-32); gonocoxae slender, more than $3.6 \times$ longer than wide (Figs 21, 68)............. 4
- Aedeagus wide, $4.8 \times$ longer than wide (Fig. 53); median ridge of antennomere XI abbreviated medially in males (Figs 27-29, 39-41); gonocoxae wide, about $2.7 \times$ longer than wide (Fig. 55)
S. meihuai sp. n.

4 Aedeagus parallel-sided (Fig. 19); antennomere XI in males with a small process on inner antero-lateral surface and flat on outer antero-lateral surface (Figs 24-26, 36-38); gonocoxae sub-parallel (Fig. 21).... S. babai (Kimoto)

- Aedeagus wide basally (Fig. 66); antennomere XI in males without processes on inner antero-lateral area and depressed on outer antero-lateral area (Figs 30-32, 42-44); gonocoxae diverging (Fig. 68)
S. sufangae sp. n.


## Species excluded from Sikkimia

As mentioned by Maulik (1936) and subsequently also by Bezděk and Zhang (2006), the descriptions of S. metallica Jacoby, 1903 and S. tamra Maulik, 1936 are very different to other Sikkimia and their position in Sikkimia was regarded as doubtful. In 2007, one of us (JB) examined the type specimens of both species. They are here moved from Sikkimia and to Cerophysa Chevrolat, 1836.

The reason why Jacoby (1903) classified his new species in Sikkimia is unknown to us. Probably he misinterpreted or overlooked some important characters like colour of uthe venter, impressions on the pronotum, or structure of the antennae. Duvivier (1891: 154) described the pronotal impressions as "présentant de chaque côté une profonde impression oblique" what probably allows some misinterpretations. The pronotum of $S$. metallica has transverse impression in the middle more or less interrupted medially. The differences in the structure of antennae Jacoby (1903) attributed to the sexual dimorphism as the specimens of $S$. metallica are females.

Maulik (1936) also did not examined true S. antennata as he published only the English translation of Duvivier's description of Sikkimia. It is evident that he compared S. tamra with Jacoby's S. metallica and thus mistakenly classified his species also in Sikkimia.

The main differencies between true Sikkimia species and S. tamra with S. metallica can be described as follows: true Sikkimia are large ( $6.1-12.0 \mathrm{~mm}$ ), robust and convex species of orange, red or brown upperside, last two antennomeres in males are strongly
modified (except $S$. tsoui sp. n.), pronotum with antebasal transverse impression limited on sides by short longitudinal furrows and additional longitudinal groove parallel to lateral margin and procoxal cavities closed behind. The same characters of S. tamra and $S$. metallica (which simultaneously allow us to transfer both species to Cerophysa) are: body $5.5-6.0 \mathrm{~mm}$ long, narrow, subparallel, flat, with upperside metallic green, antennae without modifications; pronotum with transverse impression in the middle of pronotum and procoxal cavities open behind. The structure of antennae is variable throughout Cerophysa. In some species one, two or three antennomeres can be modified, but never last two antennomeres.

## Cerophysa metallica (Jacoby, 1903), comb. n.

Sikkimia metallica Jacoby, 1903: 122.

Type locality. Nilgiri hills.
Type material. Syntype ( $\mathrm{Q}, \mathrm{BMNH}$ ), labeled: "Nilgiri Hills (printed on white label) / 482 (handwritten on white label) / Type (printed on red label) / Sikkimia metallica Jac. (handwritten on blue label) / Andrewes Bequest B. M. 1922-221. (printed on white label)".

## Cerophysa tamra (Maulik, 1936), comb. n.

Sikkimia tamra Maulik, 1936: 523.

Type locality. Nilgiri hills.
Type material. Syntype (unsexed, BMNH), labeled: "Type (printed on white round label with red collar) / Nilgiri Hills. G. F. Hampson 94-89. (printed on white label) / Sikkimia tamra M. S. Maulik TYPE 1935 (handwritten and printed on white label)".

## Catalogue of Sikkimia

Sikkimia antennata Duvivier, 1891
Sikkimia babai (Kimoto, 1989), comb. n.
Sikkimia kabakovi (Lopatin, 2003)
Sikkimia meihuai sp. n.
Sikkimia miranda (Lopatin, 2003)
Sikkimia rufa (Chen, 1964)
Sikkimia sufangae sp. n.
Sikkimia tsoui sp. n.
Sikkimia yuae sp. n.

Sikkim
Taiwan
Vietnam
Taiwan
Vietnam
China (Yunnan), Laos, Myanmar
Taiwan
Taiwan
Taiwan

## Discussion

Lee（2015）proposed a possible cause of brachelytry of leaf beetles for tropical forest habitats．Reduction of hind wings may result from the production of physogastric fe－ males．Nocturnal behavior increases survival since natural enemies are less of a threat． Males actively search for mates．As like survival at adverse environments such as islands， deserts and alpine regions，flight is not essential at night and energy can be diverted to egg production（Beenen and Jolivet 2008）．Thus，brachelytry is a predictable evolu－ tionary trend．Although no related reports for this hypothesis，wingless chrysomelids at tropical forest habitats can be used to test．Like Taiwanese populations of Paraplotes， those of Sikkimia are nocturnal with brachelytrous females．Moreover，the elytral calli of both sexes，and hind wings of males，are reduced．Thus Taiwanese populations of Sikkimia support this hypothesis of brachelytry in leaf beetles．

Species richness of Sikkimia in Taiwan（five species）is lower than that of Para－ plotes（ten species）（Lee 2015），possibly due to several causes．All Sikkimia species are allopatric on the same mountain ranges and not separated by elevation．Only one Sikkimia species，S．tsoui sp．n．，occupies northern and central Taiwan，whereas five species of Paraplotes are recorded from the same area．In addition to its wider distribu－ tion，S．tsoui sp．n．is abundant in some areas．For example，there were so many adults at Hsitou（溪頭）and Yuanyanghu（鴛蔦湖）that during one night 50 adults were collected at Hsitou and 51 at Yuanyanghu．Both features may be the result of some autamorphic characters in S．tsoui sp．n．Males of S．tsoui sp．n．have no enlarged api－ cal antennomeres，a character that may be involved in courtship behavior．Lack of this secondary sexual character may result in low speciation．The ability to feed on a wide range of host plants，weak sclerotization of abdominal tergites，and the unique shape of gonocoxae may increase the fitness of this species．

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## References

Beenen R, Jolivet P (2008) Classification and habitat of brachelytrous Chrysomelidae (Coleoptera). In: Jolivet P, Santiago-Blay J, Schmitt M (Eds) Research on Chrysomelidae, Volume 1. Brill, Leiden/Boston, 161-173.
Bezděk J, Zhang L (2006) Yunomela Chen, 1964 and Vietocerus Lopatin, 2003, new synonyms of Sikkimia Duvivier, 1891 (Coleoptera: Chrysomelidae: Galerucinae). Genus 17: 351-358.
Chevrolat LAA (1836) [new taxa]. In: Dejean PFAM (Ed.) Catalogue des coléoptères de la collection de M. le Comte Dejean. Deuxième edition. Livraison 5. Méqugnon-Marvis Pères et Fils, Paris, 361-442.
Chen SH (1964) New genera and species of Galerucinae from China. Acta Entomologica Sinica 13: 201-211.
Duvivier A (1891) Mélanges entomologiques. Bulletin ou Comptes-Rendus des Séanges de la Société Entomologique de Belgique 35: 145-156.
Jacoby M (1903) Decriptions of the new genera and species of phytophagous Coleoptera obtained by Mr H.-L. Andrewes and Mr T.-R.-D. Bell at the Nilgiri Hills and Kanara. Annales de la Société Entomologique de Belgique 47: 80-128.
Kimoto S (1989) Description of a new genus and three new species of Taiwanese Chrysomelidae (Coleoptera) collected by Dr. Kintaro Baba, on the occasion of his entomological survey in 1986. Entomological Review of Japan 44: 73-78.
Lee C-F (2015) The genus Paraplotes Laboissière, 1933 in Taiwan, a speciose group with brachelytrous females (Coleoptera: Chrysomelidae: Galerucinae). Zootaxa 3904: 223-248. doi: 10.11646/zootaxa.3904.2.3

Lee C-F, Bezděk J (2013) Revision of Gallerucida singularis species group (Coleoptera: Chrysomelidae: Galerucinae). Zootaxa 3647: 358-370. doi: 10.11646/zootaxa.3647.2.7
Lee C-F, Cheng H-T (2007) The Chrysomelidae of Taiwan I. Sishou-Hills Insect Observation Network Press, Taipei, 200 pp. [In Chinese]
Lopatin I (2003) A new genus and its two new species of leaf-beetles from Vietnam (Coleoptera: Chrysomelidae: Galerucinae). Genus 14: 103-107.
Maulik S (1936) The fauna of British India including Ceylon and Burma. Coleoptera, Chrysomelidae (Galerucinae). Taylor and Francis, London, 648 pp .

# Denopelopia amicitia, a new Tanypodinae from Brazil (Diptera, Chironomidae) 

Galileu P. S. Dantas', Neusa Hamada', Humberto F. Mendes ${ }^{2}$<br>I Instituto Nacional de Pesquisas da Amazônia, Caixa Postal 478, 69011-970, Manaus, AM, Brazil 2 Universidade Federal de Alfenas, Instituto de Ciências da Natureza, Rua Gabriel da Silva Monteiro, 700, Centro, 32130-000, Alfenas - MG, Brazil<br>Corresponding author: Galileu Dantas (galileu.psd@gmail.com)

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#### Abstract

A new species of Denopelopia from Brazil is described based on adult male and pupa. The male of the new species can be distinguished from all other species of the genus by the genitalia and fore-tibial spur morphology. The pupa is very similar to those of $D$. atria, but it can be distinguished by the absence of distinct constrictions in the respiratory atrium of the thoracic horn. Generic diagnosis to male and pupa of Denopelopia is emended and keys to male and pupae of known species are provided.


## Keywords

Tanypodinae, Pentaneurini, Amazonian, Neotropical Region, taxonomy, aquatic Insects

## Introduction

The tanypod genus Denopelopia was erected by Roback and Rutter (1988) based on a single species ( $D$. atria) from the Nearctic region. According to these authors, Denopelopia is closely related to Telmatopelopia Fittkau and Zavrelimyia Fittkau, these suppositions were recently corroborated by Silva and Ekrem (2015).

[^3]After the genus description, one undescribed species was reported from Panama based on adult male (Spies and Reiss 1996). So far, Denopelopia is composed of five described species, three of them with Asian distribution; Cheng and Wang (2005) described D. diaoluonica, D. bractea and D. viridula, from China, Kobayashi and Endo (2008) transferred Yaequintus irioquereus Sasa \& Suzuki to the genus Denopelopia as senior synonym of $D$. bractea. The last species described on the genus, $D$. moema, was collected in Midwestern Brazil (Silva et al. 2014). Only one species, D. atria, has immature stages described, the remaining are known only as adult males.

In the present study, a new species from the Brazilian Amazon rainforest is described based on adult male and pupa, the generic diagnosis to male and pupa of Denopelopia (Roback and Rutter 1988, Murray and Fittkau 1989) is emended and keys to males and pupae are provided.

## Materials and methods

A pupa was collected in a small pond using a hand net. It was reared in laboratory isolated in a vial to obtain the associated adult; for further details on rearing techniques see Mendes (2002). The material examined was slide-mounted in Euparal, following the procedures outlined by Pinder $(1986,1989)$. The colour is described as observed in specimen conserved in alcohol. The general terminology follows Sæther (1980). The holotype of the named species was deposited in the Invertebrates collections of the Instituto Nacional de Pesquisas da Amazônia (INPA), Amazonas, Manaus, Brazil.

## Taxonomy

## Denopelopia Roback \& Rutter, 1988

Denopelopia Roback \& Rutter, 1988: 117.

Type species. Denopelopia atria Roback \& Rutter, 1988.
Emended diagnosis. Based on the additional characters found in D. amicitia sp. n., the generic diagnosis for the pupa and male of Denopelopia given by Roback and Rutter (1988) and Murray and Fittkau (1989) must be emended. Male: scutal tubercle absent; wing densely covered with macrotrichia, costa not produced beyond $\mathrm{R}_{4+5}$, ending clearly before $\mathrm{M}_{1+2}$; tibial spurs with elongate apical tooth, more than half the length of the entire spur; tergite IX straight or rounded, with a transverse row of setae; gonocoxite with or without internal lobe. Pupa: wholly brown; thoracic horn elongated, with an apical nipple, a small plastron plate and respiratory atrium with or without constrictions; thoracic comb present; TVII with 3 lateral filaments; anal lobe with spines on the outer margin only; genital sac not surpassing apex of anal lobe.

## Denopelopia amicitia sp. n.

http://zoobank.org/09A94352-BDD3-423A-A61B-1740C1452F0C

Type material. Holotype male with pupal exuviae, Brazil, Amazonas State, Presidente Figueiredo, pisciculture pond, BR $174-\mathrm{Km} 121,01^{\circ} 55^{\prime} 50.2^{\prime \prime} \mathrm{S}, 60^{\circ} 03^{\prime} 02.0^{\prime \prime} \mathrm{W}, 10 /$ xii/2012, G.P.S. Dantas, (INPA).

Diagnosis. Male: AR 1.92; wing with well-developed anal lobe; spur of the fore tibia with the most basal tooth longer and slender than the other lateral teeth and strongly curved backwards; tergite IX rounded; gonocoxite with a well-developed setose lobe at the base. Pupa: with a distinct apical nipple, $38 \mu \mathrm{~m}$ long and $42 \mu \mathrm{~m}$ wide, L/W 0.9 ; absence of distinct constrictions in the respiratory atrium of the thoracic horn.

Etymology. From Latin, amicitia, meaning friends, referring to friends who helped during fieldwork.

Male ( $\mathrm{n}=1$ ). Total length 2.90 mm . Wing length 1.7 mm . Total length $/$ wing length 1.67. Wing length/length of profemur 2.34.

General coloration brown. Head yellow, occipital area brown; maxillary palp yellow; pedicel yellow, brown near the insertion of the flagellum; flagellomere I-XII light brown, VIII-VIV yellow. Thorax dark brown, pleura light brown. Legs yellow. Wings with membrane transparent, veins yellow. Abdomen: T I yellow, with light brown pigmentation on the anterolateral margin, T II-III yellow with clear brown band close to anterior margin; TIV with $1 / 3$ anterior brown; TV-VIII brown, genitalia yellow.

Head (Fig. 1A). AR 1.92. Antenna with 14 flagellomere; thirteenth flagellomere $585 \mu \mathrm{~m}$ long. Apical flagellomere $92 \mu \mathrm{~m}$ long; $23 \mu \mathrm{~m}$ wide at base; with a subapical setae $65 \mu \mathrm{~m}$ long. Temporal setae 14 . Clypeus $99 \mu \mathrm{~m}$ long, $82 \mu \mathrm{~m}$ wide, with 19 setae. Cibarial pump with anterior margin concave, $215 \mu \mathrm{~m}$ long and with orifice 95 from apex. Tentorium $165 \mu \mathrm{~m}$ long. First palpomere reduced. Palpomere lengths ( $1-5$ in $\mu \mathrm{m}): 30 ; 65 ; 156 ; 168 ; 265$.

Thorax (Fig. 1B). Scutal tubercle absent. Acrostichals 30, biserial, starting close to antepronotum and reaching half of scutum; dorsocentrals 14 , biserial anteriorly and uniserial posteriorly; prealars 6, in a single irregular row; supraalar 1. Antepronotum with 3 setae. Scutellum with 22 setae, in three rows. Postnotum without setae.

Wing (Figs. 1D, 2A). 1.7 mm long, 0.4 mm wide. VR $0.91(\mathrm{Cu}=510 \mu \mathrm{~m}, \mathrm{M}=$ $560 \mu \mathrm{~m})$. Membrane with covering of macrotrichia, denser at the $1 / 3$ distal; costa 1.6 mm long, not produced beyond apex of $\mathrm{R}_{4+5} . \mathrm{R}_{2+3}$ present. MCu proximal to the RM . Brachiolum with 3 setae. Squama with 12 setae. Anal lobe well-developed.

Legs. Fore leg: tibia with an apical, pectinate spur, $47 \mu \mathrm{~m}$ long, with three lateral teeth and one elongate apical tooth, the most basal tooth is longer and slender than the other lateral teeth and strongly curved backwards (Fig. 2B); two preapical setae $138 \mu \mathrm{~m}$ long; width at apex of tibia $40 \mu \mathrm{~m}$; $\mathrm{ta}_{1}$ with one preapical stout setae, $86 \mu \mathrm{~m}$ long; $\mathrm{ta}_{2}$ with one preapical stout setae, $75 \mu \mathrm{~m}$ long; $\mathrm{ta}_{3}$ with two preapical stout setae, $72 \mu \mathrm{~m}$ long. Mid leg: tibia with two apical, pectinate spurs, 33 and $59 \mu \mathrm{~m}$ long, longest spur with three lateral teeth and one elongate apical tooth, shortest spur with three lateral teeth and one apical tooth (Fig. 2C); two preapical setae $119 \mu \mathrm{~m}$ long; width at apex of tibia $38 \mu \mathrm{~m}$; ta ${ }_{1}$ with a preapical stout setae, $71 \mu \mathrm{~m}$ long; $\mathrm{ta}_{2}$ with two preapical stout


Figure I. Denopelopia amicitia sp. n. Adult male: $\mathbf{A}$ head $\mathbf{B}$ thorax $\mathbf{C}$ wing.
setae, $65 \mu \mathrm{~m}$ long; ta ${ }_{3}$ with two preapical stout setae, $48 \mu \mathrm{~m}$ long. Hind leg: tibia with two apical, pectinate spurs, 39 and $78 \mu \mathrm{~m}$ long, longest spur with three lateral teeth and one elongate apical tooth, shortest spur with three lateral teeth and one apical tooth (Fig. 2D); one preapical setae $182 \mu \mathrm{~m}$ long; width at apex of tibia $44 \mu \mathrm{~m}$; ta ${ }_{1}$ with one preapical stout setae, $90 \mu \mathrm{~m}$ long; ta ${ }_{2}$ with two preapical stout setae, $61 \mu \mathrm{~m}$ long. Tibial comb on hind leg with 7 bristles, the lateral longer than the medial ones (Fig. 2E). Claws of all legs normal, curved, sharply pointed; pulvilli absent. Lengths (in $\mu \mathrm{m})$ and proportions of leg segments as in Table 1.

Hypopygium (Figs. 2F-G). Tergite IX rounded, with 7 posterior setae. Anal point conical. Phallapodeme indistinct. Sternapodeme with triangular anterior process. Gonocoxite subcylindrical, $130 \mu \mathrm{~m}$ long, $40,55,65 \mu \mathrm{~m}$ wide at apex, at mid and at base respectively; with an internal setose lobe at the base, as in figure 2G. Gonostylus simple and slightly curved, $70 \mu \mathrm{~m}$ long; megaseta $10 \mu \mathrm{~m}$ long. HR 1.83; HV 4.10.

Table I. Lengths (in $\mu \mathrm{m}$ ) and proportions of leg segments in Denopelopia amicitia sp. n., male ( $\mathrm{n}=1$ ).

|  | $\mathbf{F e}$ | $\mathbf{t i}$ | $\mathbf{t a}_{\mathbf{1}}$ | $\mathbf{t a}_{\mathbf{2}}$ | $\mathbf{t a}_{\mathbf{3}}$ | $\mathbf{t a}_{\mathbf{4}}$ | $\mathbf{t a}_{5}$ | $\mathbf{L R}$ | BV | $\mathbf{S V}$ |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| $\mathbf{p}_{1}$ | 729 | 850 | 743 | 422 | 341 | 204 | 109 | 0.87 | 2.16 | 2.12 |
| $\mathbf{p}_{2}$ | 717 | 1016 | 758 | 412 | 294 | 184 | 109 | 0.75 | 2.49 | 2.29 |
| $\mathbf{p}_{3}$ | 782 | 797 | 550 | 315 | 220 | 132 | 93 | 0.80 | 2.80 | 2.87 |



Figure 2. Denopelopia amicitia sp. n. Adult male: A wing B fore tibial spur $\mathbf{C}$ mid tibial spur $\mathbf{D}$ hind tibial spur $\mathbf{E}$ hypopygium in dorsal view $\mathbf{F}$ hypopygium with tergite IX removed.

Pupa ( $\mathrm{n}=1$ ). Dimensions. Male abdomen 2.63 mm long.
Coloration. Cephalothorax brownish; thoracic horn dark brown, apical nipple transparent, plastron plate yellowish. Tergite I light brown, scar brown, T II-AL brown (Fig. 3C).

Cephalothorax. Frontal apotome somewhat triangular (Fig. 4A). Wing sheath smooth, 1.1 mm long and 0.4 mm wide. Thoracic horn elongate and narrow (Fig. 3AB, 4B-C), $390 \mu \mathrm{~m}$ long and $48 \mu \mathrm{~m}$ wide; with a distinct apical nipple, $38 \mu \mathrm{~m}$ long and $42 \mu \mathrm{~m}$ wide; plastron plate rounded, $28 \mu \mathrm{~m}$ long; aeropyle tube bended at the base, 53 $\mu \mathrm{m}$ long. Horn sac tubular, filling the respiratory atrium, except at the base; respiratory atrium without distinct constriction (Fig. 3A-B, 4B). Thoracic horn with small surface spines at the base (Fig. 4C). Basal lobe well developed, as in figure 4C. Thoracic comb with 12 conical teeth.

Abdomen (Fig. 3C). Tergite I without shagreen, T II-TVIII with shagreen composed by scattered fine spinules. Sternite II with a large field of shagreen composed by spinules arranged in combs (Fig. 4D). T I with a distinct and elongate scar, $170 \mu \mathrm{~m}$ long. T VII with 3 lateral filaments, $252 \mu \mathrm{~m}$ long; filaments placed at 132, 210 and $275 \mu \mathrm{~m}$ from base to apex of segment. T VIII with 5 lateral filaments, $372 \mu \mathrm{~m}$ long. Anal lobe as in figures 3D and 4E, $350 \mu \mathrm{~m}$ long, $213 \mu \mathrm{~m}$ wide at base and with two lateral macrosetae with sticky sheaths; outer margins with 12 spinules; inner margins without spinules. Genital sac smaller than anal lobe, $233 \mu \mathrm{~m}$ long, $162 \mu \mathrm{~m}$ wide at base. GS/AL 0.67.

## Systematic remarks

To date, Labrundinia is the only genus in the Tanypodinae which features a rounded male tergite IX, considered a synapomorphy for the group (Silva et al. 2015). The presence of this trait in D. amicitia n. sp. might suggest that a new genus should be erected to accommodate this species. However, considering that many tanypod genera are not properly studied, with only few described species, in many of these descriptions, this trait might have been overlooked by peers. Moreover, the pupa of $D$. amicitia sp. $n$. is very similar to that of $D$. atria, which leaves no doubt that the two species are congeneric. The adults of Denopelopia can be easily distinguished from those of Labrundinia by morphology of tibial spurs. In Denopelopia the spurs are well-developed with an elongated apical tooth and two spurs are present in the posterior tibia, while in Labrundinia the spurs are small, with subequal teeth and are absent in the posterior tibia. According to Roback and Rutter (1988), Denopelopia is closely related to Telmatopelopia and Zavrelimyia based on the overall morphology of adults and immature stages. However, adults of Denopelopia possess costa (C) not produced beyond $\mathrm{R}_{4+5}$ and ending clearly before $\mathrm{M}_{1+2}$, while in Telmatopelopia and Zavrelimyia costa is slightly produced and ends above or slightly beyond $\mathrm{M}_{1+2}$. The pupae of Denopelopia has anal macrosetae with adhesive sheath and spines only at the outer margin of the


Figure 3. Denopelopia amicitia sp. n. Pupa: A thoracic horn, in frontal view B thoracic horn, in lateral view $\mathbf{C}$ abdomen, in dorsal view $\mathbf{D}$ T VII-VIII and Anal lobe.


Figure 4. Denopelopia amicitia sp. n. Pupa: A frontal apotome B thoracic horn $\mathbf{C}$ base of thoracic horn, basal lobe and thoracic comb D shagreen of sternite II E T VII-VIII and Anal lobe.
anal lobe, which contrast to Telmatopelopia with no adhesive sheath and Zavrelimyia that possesses spines both in the outer and inner margins of the anal lobe. In addition, Denopelopia has spines restricted to the base of the external membrane of the thoracic horn and possesses three lateral filaments in tergite VII, in contrast to Telmatopelopia and Zavrelimyia, which have the external membranes of the thoracic horn covered with spines and possess four lateral filaments in tergite VII. The larva of Denopelopia can be recognized by the presence of a trifid paraligula and elongated labial vesicles, in contrast to Telmatopelopia and Zavrelimyia where the paraligula is bifid and the labial vesicles are more or less rounded.

The male of $D$. amicitia sp. n. can be distinguished from all other species of the genus by the hypopygium morphology. It has a well-developed setose lobe at the base of the gonocoxite, which is absent or reduced in other species of the genus. In addition, the male of $D$. amicitia sp. n. has the anal lobe of the wing well-developed, which sets it apart from $D$. viridula and $D$. diaoluonica, that have it reduced and absent, respectively; the absence of two scale-shaped bristles at the apex of the anterior tibia, the well-developed anal lobe of the wing and the sternapodeme with a pointed anterior process, distinguishes $D$. amicitia sp. n. from $D$. irioquerea; the morphology of the anterior tibial spur and the rounded tergite IX distinguishes $D$. amicitia sp . n. from $D$. moema and $D$. atria. The pupal stage is similar to that of $D$. atria due to the morphology of the thoracic horn and the number of lateral filaments on tergite VII, but can be distinguished by the absence of distinct constrictions in the respiratory atrium and by the low length/width ratio of the apical nipple.

## Ecological notes

There is little information on the biology of Denopelopia, since only D. atria has its immature stages described. This species was described based on material collected and reared from a shallow drainage ditch amongst Typha sp., with low dissolved oxygen and relatively high iron concentrations (Roback and Rutter 1988) in Florida (USA). This species has also been collected in lentic environments in Costa Rica (Epler 2001) and an unreared larva of the genus was recorded from Southeastern Brazil by TrivinhoStrixino and Strixino (1995).

The pupa of $D$. amicitia sp. n. was collected in a small disabled pisciculture pond, associated with marginal vegetation, in a eutrophic environment where a carcass of a large animal, in advanced stages of decomposition, was observed.

Several attempts to collect additional material were made; however, the pond where it was collected was drained and sampling in the adjacent areas, such as streams and wetlands, was not successful.

## Key to adult males of Denopelopia (adapted from Cheng and Wang (2005) to include the Brazilian species)

1 Apex of fore tibia with two large scale-like setae
D. irioquerea (Sasa \& Suzuki, 2000)

- Fore tibiae without scale-like setae ............................................................... 2

2 Gonocoxite with a well-developed setose lobe at the base.. D. amicitia sp. $\mathbf{n}$

- Gonocoxite without a well-developed setose lobe at the base ....................... 3

3 Wing with well-developed anal lobe............................................................ 4

- Wing with reduced or absent anal lobe ........................................................ 5

4 Anterior margin of abdominal segment I and IV with distinctive brown spots .............................. D. moema Silva, Wiedenbrug \& Oliveira, 2014

- Anterior margin of abdominal segment I and IV without brown spots ........
D. atria Roback \& Rutter, 1988
$5 \quad \mathrm{AR}>0.9$; wing with anal lobe reduced .. D. viridula Cheng \& Wang, 2005
- $\quad$ AR $<0.6$; wing with anal lobe absent
D. diaoluonica Cheng \& Wang, 2005


## Key to pupae of Denopelopia

1 Respiratory atrium without distinct constriction (Fig. 3A-B, 4C); proportion L/W of apical nipple of thoracic horn 0.9
D. amicitia sp. n

- Respiratory atrium with distinct constriction; proportion L/W of apical nipple of thoracic horn about 2.0
D. atria Roback \& Rutter, 1988


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## References

Cheng M, Wang X (2005) Denopelopia Roback \& Rutter from China with emendation of the generic diagnosis (Diptera: Chironomidae: Tanypodinae). Zootaxa 1042: 55-63.
Epler JH (2001) Identification manual for the larval Chironomidae (Diptera) of North and South Carolina. A guide to the taxonomy of the midges of the southeastern United States,
including Florida. Department of Environmental and Natural Resources, Division of Water quality, Raleigh and St. Johns River Water Management District, Palatka, 526 pp.
Mendes HF (2002) Rearing Tanypodinae, Telmatogetoninae and Orthocladiinae in Brazil - an empirical approach. Chironomus Newsletter 15: 29-32.
Murray DA, Fittkau EJ (1989) The adult males of Tanypodinae (Diptera: Chironomidae) of the Holarctic region Keys and diagnoses. In: Wiederholm T (Ed.) Chironomidae of the Holarctic region. Keys and diagnoses. Part 3 Adult males. Entomologica Scandinavica Supplement 34: 37-123.
Kobayashi T, Endo K (2008) Synonymic notes on some species of Chironomidae (Diptera) described by Dr. M. Sasa ( $\dagger$ ). Zootaxa 1712: 49-64.
Pinder LCV (1986) The pupae of Chironomidae (Diptera) of the Holarctic region - Introduction. In: Wiederholm T (Ed.) Chironomidae of the Holarctic region. Keys and diagnoses. Part 2. Pupae. Entomologia scandinavica Supplement 28: 5-7.
Pinder LCV (1989) The adult of Chironomidae (Diptera) of the Holarctic region - Introduction. In: Wiederholm T (Ed.) Chironomidae of the Holarctic region. Keys and diagnoses. Part 3. Adult males. Entomologia scandinavica Supplement 34: 5-9.
Roback SS, Rutter PR (1988) Denopelopia atria, a new genus and species of Pentaneurini (Diptera: Chironomidae: Tanypodinae) from Florida. Spixiana Supplement 14: 117-27.
Sæther OA (1980) Glossary of chironomid morphology terminology (Diptera: Chironomidae). Entomologica Scandinavica Supplement 14: 1-51.
Silva FL, Wiedenbrug S, Oliveira CSN (2014) Denopelopia moema, a new Tanypodinae (Diptera: Chironomidae) from the Neotropical Region. Zootaxa 3753(3): 297-99. doi: 10.11646/zootaxa.3753.3.9

Silva FL, Ekrem T (2015) Phylogenetic relationships of non-biting midges in the subfamily Tanypodinae (Diptera: Chironomidae) inferred from morphology. Systematic Entomology. doi: 10.1111/syen. 12141
Silva FL, Ekrem T, Fonseca-Gessner AA (2015) Out of South America: phylogeny of non-biting midges in the genus Labrundinia (Diptera: Chironomidae) suggests multiple dispersal events to Central and North America. Zoologica Scripta 44: 59-71. doi: 10.1111/zsc. 12089
Spies M, Reiss F (1996) Catalog and bibliography of Neotropical and Mexican Chironomidae (Insecta, Diptera). Spixiana Supplement 22: 61-119.
Trivinho-Strixino S, Strixino G (1995) Larvas de Chironomidae (Diptera) do Estado de São Paulo: guia de identificação e diagnose dos gêneros. PPG-ERN/UFSCar, São Carlos, 229 pp.

# A review of Cyclidiinae from China (Lepidoptera, Drepanidae) 

Nan Jiang ${ }^{1}$, Shuxian Liu ${ }^{1,2}$, Dayong Xue', Hongxiang Han ${ }^{1}$<br>I Key Laboratory of Zoological Systematics and Evolution, Institute of Zoology, Chinese Academy of Sciences, Beijing 100101, China 2 University of the Chinese Academy of Sciences, Beijing 100049, Chin<br>Corresponding author: Hongxiang Han (hanhx@ioz.ac.cn)

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#### Abstract

The subfamily Cyclidiinae from China is reviewed: two genera and seven species are reported from China One new subspecies, Cyclidia fractifasciata indistincta subsp. n., is described. Two new synonyms are established: Cyclidia substigmaria (Hübner, 1831) (= Cyclidia substigmaria brunna Chu \& Wang, 1987, syn. n. = Cyclidia tetraspota Chu \& Wang, 1987, syn. n.). One misidentification in Chu \& Wang (1987) is corrected. Identification keys and diagnoses for all discussed Chinese species are provided. External features and genitalia are depicted. In addition, results of DNA barcoding for five taxa of Cyclidia are briefly discussed.


## Keywords

DNA barcodes, morphology, new subspecies, new synonymy, taxonomy

## Introduction

The subfamily Cyclidiinae Warren, 1922, is the smallest subfamily within four subfamilies (besides Drepaninae, Oretinae, and Thyatirinae) of Drepanidae. This subfamily was first proposed as Eucherinae by Strand (1911) based on the genus Euchera Hübner, 1825. Later, it was treated as a separate family (Inoue 1962), followed by other authors (Fletcher 1979, Chu and Wang (1987, 1991) (Yan et al. 2009). However, Minet (1983) regarded Cyclidiinae as a subfamily of Drepanidae, based on the study of the tympanal organs. This treatment was later followed by many researchers, e.g. Holloway (1998) and Minet (2002), and was also supported by molecular data (Wu et al. 2010).

Recently, Chen (2011) performed a phylogenetic analysis of Cyclidiinae, based on morphological characters. In his study, the monophyly of respectively Cyclidiinae, Cyclidia and Mimozethes was supported, and most synapomorphies for Cyclidiinae proposed by previous studies were shown to be plesiomorphies. Three major synapomorphies of Cyclidiinae were given (Chen 2011): 1) the developed anterotergal syndeses (a paired of semi-translucent structure, see Yan et al. 2005) at the anterior margin of the $2^{\text {nd }}$ tergum; 2 ) a pair of androconial hair-pencils on the $2^{\text {nd }}$ pleuron of the male and 3) the short and robust gnathos in the male genitalia.

Species of Cyclidiinae are distributed in the Palearctic Asia and Oriental regions. Up to the present, two genera (Cyclidia Guenée, 1858 and Mimozethes Warren, 1901) have been recognized in Cyclidiinae. Ten species and eight subspecies are included in Cyclidia, with six species and four subspecies (C. substigmaria substigmaria (Hübner, 1831), C. substigmaria brunna Chu \& Wang, 1987, C. substigmaria intermedia Prout, 1918, C. tetraspota Chu \& Wang, 1987, C. rectificata rectificata (Walker, 1862a), C. fractifasciata (Leech, 1898), C. sericea Warren, 1922, C. orciferaria Walker, 1860) recorded in China (Moore 1886, Aurivillius 1894, Swinhoe 1899, Strand 1911, Warren 1914, Bryk 1943, Inoue 1962, Chu and Wang 1991, Chang 1989, Holloway 1998, Lutz and Kobes 2002). Three species are included in Mimozethes, with two species recorded in China, M. lilacinaria (Leech, 1897) and M. angula Chu \& Wang, 1987. However, the taxonomy of some Chinese taxa remained unclear ( e.g. the subspecies delimitation of C. substigmaria; the taxonomic status of C. tetraspota and the puzzling distribution of C. sericea) (Yan et al. 2009, Chen 2011). It is obviously that further research is needed and molecular markers could be used to clarify these problems.

The DNA barcoding method using a 658 bp base pair fragment of the cytochrome c oxidase subunit I gene (COI) as a tool for species discrimination was first put forward based on two hundred closely related species of Lepidoptera (Hebert et al. 2003). It has since been successfully used for species delimitation in lepidopteran species that are difficult to separate morphologically (see Hajibabaei et al. 2006, Yang et al. 2012). The barcoding gap between intra- and inter-specific variation was used for species
discrimination (Hebert et al. 2004a, Meier et al. 2006, Meier et al. 2008, Sihvonen et al. 2014, Jiang et al. 2014).

In the present study an overview of the Chinese Cyclidiinae is given with diagnostic characters for each genus and species, one new subspecies is described, two new synonyms are established, and one misidentification in Chu and Wang (1987) is revised. Also photos of external features and genitalia are provided of all Chinese species discussed. In addition, we discuss the application of the results of DNA barcoding for delimitation of five taxa of Cyclidia. As a result of this study five species and five subspecies of Cyclidia and two species of Mimozethes are regarded as valid for the fauna of China.

## Materials and methods

Morphology. Studied specimens mainly belong to the Institute of Zoology, Chinese Academy of Sciences, Beijing, China (IZCAS) and the Natural History Museum, London, United Kingdom BMNH. Terminology for wing venation follows the ComstockNeedham System (Comstock 1918), and that of the genitalia is based on Klots (1970), Nichols (1989) and Kristensen (2003). Photographs of the moths were taken with digital cameras. Composite sharp images were generated using Auto-Montage software version 5.03.0061 (Synoptics Ltd). The plates were compiled using Adobe Photoshop software.

DNA-Barcoding. Prior to DNA sequencing, one or two legs were removed from several specimens of each of five examined taxa (C. substigmaria substigmaria, C. rectificata rectificata, C. fractifasciata fractifasciata, C. fractifasciata indistincta, C. orciferaria). DNA extraction was done using Qiagen DNeasy Blood and Tissue Kit (Qiagen, Beijing, China). The primers for the amplification of the 658 bp fragment were LepF1 (5'-ATTCAACCAATCATAAAGATATTGG-3'), LepR1 (5'-TAAACTTCTGGAT-GTCCAAAAAATCA-3') (Hebert et al. 2004a). The PCR reactions were performed using the standard procedure described by Hebert et al. (2004a). The PCR products were detected by $1 \%$ agarose gel electrophoresis and directly sequenced with ABI PRISM 3730xl capillary sequencers. The amplification and sequencing for some dried material (Sequence ID begins with "DB") were carried out in BGI-Shenzhen, (China) using standard protocols described in Hebert et al. (2004a). Forward and reverse nucleotide sequences were assembled in SeqMan 5.01 (DNASTAR, Inc. 1996). The assembled sequences were aligned and manually edited in MEGA 5.0 (Tamura et al. 2011). The neighbor-joining (NJ) tree (Saitou and Nei 1987) was reconstructed based on Kimura 2-parameter (K2P) distances (Kimura 1980) using MEGA 5.0. All the sequences have been deposited in GenBank under accession numbers, and their full data including images and are in the Barcode of Life Database (http://www.boldsystems.org; see Ratnasingham and Hebert 2007) (Table 1).

Table I. Cyclidia species included in this study with GenBank accession numbers and BOLD process ID.

| Taxa | Sequence ID | Collecting locality | Collecting date | GenBank accession no. | $\begin{aligned} & \text { BOLD } \\ & \text { process ID } \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: |
| C. substigmaria substigmaria | DB00162 | West Tianmushan, Zhejiang | Jul. 2003 | KR872896 | CLDC001-15 |
|  | DB00173 | Wuzhishan, Hainan | May 2007 | KR872897 | CLDC002-15 |
|  | DB00174 | Lingshui, Hainan | May 2007 | KR872898 | CLDC003-15 |
|  | DB00181 | Baotianman, Henan | Aug. 2008 | KR872899 | CLDC004-15 |
|  | DB00182 | Luoyang, Henan | Aug. 2006 | KR872900 | CLDC005-15 |
|  | DB00184 | Baoshan, Yunnan | Aug. 2007 | KR872901 | CLDC006-15 |
|  | DB00189 | Yanling, Hunan | Jul. 2008 | KR872902 | CLDC007-15 |
|  | IOZ LEP M 01129 | Mengla, Yunnan | Jul. 2013 | KR872903 | CLDC008-15 |
|  | IOZ LEP M 01134 | Tengchong, Yunnan | Aug. 2013 | KR872904 | CLDC009-15 |
|  | IOZ LEP M 01304 | West Tianmushan, Zhejiang | Jul. 2011 | KR872905 | CLDC010-15 |
|  | IOZ LEP M 08961 | Mengla, Yunnan | Jul. 2013 | KR872906 | CLDC011-15 |
|  | IOZ LEP M 09195 | Qushi, Yunnan | Aug. 2013 | KR872907 | CLDC012-15 |
|  | IOZ LEP M 16605 | Kangxian, Gansu | Aug. 2014 | KR872908 | CLDC013-15 |
|  | IOZ LEP M 16606 | Kangxian, Gansu | Aug. 2014 | KR872909 | CLDC014-15 |
|  | IOZ LEP M 16607 | Kangxian, Gansu | Aug. 2014 | KR872910 | CLDC015-15 |
|  | IOZ LEP M 16608 | Kangxian, Gansu | Aug. 2014 | KR872911 | CLDC016-15 |
|  | IOZ LEP M 17993 | Liuku, Yunnan | Sep. 2014 | KR872912 | CLDC017-15 |
|  | IOZ LEP M 17994 | Liuku, Yunnan | Sep. 2014 | KR872913 | CLDC018-15 |
|  | IOZ LEP M 02790 | Guilin, Guangxi | Apr. 1952 | KR872914 | CLDC019-15 |
| C. rectificata rectificata | DB00226 | Bomi, Tibet | Aug. 2005 | KR872923 | CLDC020-15 |
|  | DB00228 | Mêdog, Tibet | Aug. 2006 | KR872924 | CLDC021-15 |
|  | DB00229 | Mainling, Tibet | Aug. 2006 | KR872925 | CLDC022-15 |
|  | IOZ LEP M 03475 | Zayü, Tibet | Aug. 2014 | KR872926 | CLDC023-15 |
|  | IOZ LEP M 03476 | Zayü, Tibet | Aug. 2014 | KR872927 | CLDC024-15 |
|  | IOZ LEP M 03477 | Zayü, Tibet | Aug. 2014 | KR872928 | CLDC025-15 |
|  | IOZ LEP M 16015 | Zayü, Tibet | Aug. 2014 | KR872929 | CLDC026-15 |
| C. fractifasciata fractifasciata | IOZ LEP M 00657 | Pianma, Yunnan | May 2011 | KR872930 | CLDC027-15 |
|  | IOZ LEP M 00683 | Pianma, Yunnan | May 2011 | KR872931 | CLDC028-15 |
|  | IOZ LEP M 07012 | Pianma, Yunnan | May 2011 | KR872932 | CLDC029-15 |
|  | IOZ LEP M 07013 | Pianma, Yunnan | May 2011 | KR872933 | CLDC030-15 |
| C. fractifasciata indistincta | IOZ LEP M 16601 | Kangxian, Gansu | Aug. 2014 | KR872934 | CLDC031-15 |
|  | IOZ LEP M 16602 | Kangxian, Gansu | Aug. 2014 | KR872935 | CLDC032-15 |
|  | IOZ LEP M 16603 | Kangxian, Gansu | Aug. 2014 | KR872936 | CLDC033-15 |
|  | IOZ LEP M 16604 | Kangxian, Gansu | Aug. 2014 | KR872937 | CLDC034-15 |
|  | IOZ LEP M 09387 | Wushan, Chongqing | Jul. 2013 | KT250118 | CLDC035-15 |
| C. orciferaria | DB00202 | Bawangling, Hainan | May 2007 | KR872915 | CLDC036-15 |
|  | DB00203 | Wuzhishan, Hainan | Apr. 2008 | KR872916 | CLDC037-15 |
|  | DB00210 | Yanling, Hunan | Jul. 2008 | KR872917 | CLDC038-15 |
|  | DB00211 | Yanling, Hunan | Jul. 2008 | KR872918 | CLDC039-15 |
|  | DB00213 | Shixing, Guangdong | Jun. 2008 | KR872919 | CLDC040-15 |
|  | DB00216 | Baoshan, Yunnan | Aug. 2007 | KR872920 | CLDC041-15 |
|  | IOZ LEP M 01208 | West Tianmushan, Zhejiang | Jul. 2011 | KR872921 | CLDC042-15 |
|  | IOZ LEP M 01324 | West Tianmushan, Zhejiang | Jul. 2011 | KR872922 | CLDC043-15 |

## Results

## Taxonomy

Cyclidiinae Warren, 1922
Cyclidiinae Warren, 1922: 444.

## Cyclidia Guenée, 1858

Cyclidia Guenée, 1858: 62. Type species: Cyclidia substigmaria (Hübner, 1831), by monotypy.
Nelcynda Walker, 1862a: 1142. Type species: Nelcynda rectificata Walker, 1862, by monotypy.
Ciclidia Chou \& Xiang, 1984: 159. [Incorrect spelling of Cyclidia Guenée.]

Generic characters. Head. Antennae lamellate, partly unipectinate, rami very short (Fig. 1a). Frons not protruding. Labial palpi with third segment distinct, up-curved. Thorax. Hind tibia with two pairs of spurs. Apex of forewing often rounded, sometimes pointed and protruding. Wing colour usually white or grey (except C. orciferaria); antemedial and postmedial lines of forewing double; medial line of forewing broad; terminal lines of both wings usually double, sometimes single (e.g. C. substigmaria, C. rectificata, and C. diehli Lutz \& Kobes, 2002). Venation (Fig. 3a). Forewing with $R_{1}$ separate, $\mathrm{R}_{2-4}$ and $\mathrm{R}_{5}$ stalked, $\mathrm{R}_{2}$ and $\mathrm{R}_{3+4}$ stalked, $\mathrm{R}_{5}$ and $\mathrm{M}_{1}$ separate, $\mathrm{M}_{2}$ arising from middle of discocellulars; Hind wing with $\mathrm{Sc}+\mathrm{R}_{1}$ close to Rs beyond distal cell, then far from $\mathrm{Rs}, \mathrm{M}_{2}$ arising from middle of discocellulars. Anterotergal syndeses developed at anterior margin of $2^{\text {nd }}$ tergum (Fig. 2). A pair of androconial hair-pencils present on $2^{\text {nd }}$ sternum of male (Fig. 2). Male genitalia. Uncus triangular; socii developed, often sclerotized (except C. orciferaria), sometimes with small setose process at base (e.g. C. pitimani (Moore, 1886), C. sericea and C. diehli); gnathos connected at middle and with median process narrow and triangular; valva simple and broad; juxta deeply concaved posteriorly; saccus short and broad, rounded terminally; phallus slightly curved; vesica without cornuti. Female genitalia. Papillae anales broad and rounded; lamella postvaginalis usually well developed; ductus bursae very long and narrow, with a colliculum; corpus bursae oval, with a paired band-like spinose signa.

Diagnosis. Cyclidia is quite different from Mimozethes externally and in the genitalia. For example, externally, the rami of the antennae are much shorter; the species of Cyclidia are much larger, and the postmedial lines of forewing are often double, while in Mimozethes, it is single and forms a ">" shaped protrusion near $\mathrm{R}_{5}$; in the male genitalia, the socii are well developed in Cyclidia, but absent in Mimozethes; the sacculus unmodified in Cyclidia but forming a process in Mimozethes; in the female genitalia, the signa are a paired band-like sclerotization in Cyclidia, but absent in Mimozethes.

Distribution. China, Japan, Korean Peninsula, south and southeast Asia.


Figures I-3. I Male antennae $\mathbf{a}$ Cyclidia substigmaria $\mathbf{b}$ Mimozethes angula $\mathbf{2}$ Anterotergal syndeses and androconial hair-pencils $\mathbf{3}$ Wing venation (from Chu and Wang, 1991) a C. substigmaria b M. angula.

## Key to Chinese Cyclidia species

1 Wings colour white or grey ..... 2

- Wings colour blackish brown C. orciferaria, Figs 18-19
2 Discal spots on hind wing distinct ..... 3
- Discal spots on hind wing indistinct ..... 4
3 Discal spots on hind wing dark grey..C. substigmaria substigmaria, Figs 4-8
Discal spots on hind wing black. C. substigmaria intermedia, Fig. 9
Terminal lines of both wings single C. rectificata rectificata, Figs 10-11
- Terminal lines of both wings double........................................................... 5

5 Outer margin of forewing medial line forming an right angle below $M_{3} \ldots . .6$

- Outer margin of forewing medial line not forming an right angle below $\mathrm{M}_{3}$. C. pitimani, Figs 12-13 Outer line of antemedial line and inner line of postmedial line of forewing distinct C. fractifasciata fractifasciata, Figs 14-15
- Outer line of antemedial line and inner line of postmedial line of forewing invisible $\qquad$ C. fractifasciata indistincta, Figs 16-17


## Cyclidia substigmaria (Hübner, 1831)

Euchera substigmaria Hübner 1831: 29. pl. 90, figs 519, 520. Syntypes, China.
Cyclidia substigmaria: Guenée 1858: 63.
Abraxas capitata Walker, 1862a: 1121. Holotype $q$, China: Hong Kong (BMNH).
Euchera capitata: Strand 1911: 196.
Cyclidia substigmaria brunna Chu \& Wang, 1987: 205. Holotype §, China: Sichuan: Emeishan, Qingyinge (IZCAS). Syn. n.
Cyclidia tetraspota Chu \& Wang, 1987: 206. Holotype ō, China: Yunnan: Xishuangbanna, Yunjinghong (IZCAS). Syn. n.

Diagnosis. In external appearance, this species is distinguishable from other congeners by the following characters: the discal spots of hind wing are very distinct on the upper side and the underside; the discal spot of the forewing is covered with white scales on the upper side; two greyish brown markings are present inside the anal angle of the forewing. The male genitalia of the species are close to those of $C$. rectificata, but the terminal part of the uncus and the socii are narrower; the vesica is much more scobinate. In the female genitalia, the two signa are close to each other posteriorly, while in C. rectificata, they are almost parallel.

Remarks. There are five subspecies of C. substigmaria:
C. s. substigmaria (Hübner, 1831), most parts of China and Vietnam;
C. s. intermedia Prout, 1918 in Tibet;
C. s. nigralbara Warren, 1914 in Japan and Korean Peninsula;
C. s. modesta Bryk, 1943 in Myanmar;
C. s. superstigmaria Prout, 1918 in India and Nepal.

Distribution. China, Japan, Korean Peninsula, India, Nepal, Myanmar, Vietnam.
Biological notes. Sugi (1987) and Holloway (1998) mentioned that larval Cyclidiinae may be uniquely associated with the plant family Alangiaceae (now incorporated in Cornaceae). However, Cyclidia substigmaria also has been recorded from Malvaceae (Hibiscus cannabinus L.) (Chu 1981, Chu and Wang 1987, 1991, Kadoorie Farm and Botanical Garden 2004). The morphology of the eggs, larva, pupa and life history of C. substigmaria were described in detail by Zhou and Wang (1985), Chu and Wang (1991) and Yan et al. (2009).

## Cyclidia substigmaria substigmaria（Hübner，1831）

Figs 4－8，24－28，37－39，48－50

Diagnosis．The subspecies is very similar to C．substigmaria intermedia，but differs externally by the paler discal spot of the hind wing and the two less distinct markings inside the anal angle of the forewing．

Type material examined．CHINA：Sichuan（IZCAS）： $1 \delta^{\lambda}$（Holotype of C． substigmaria brunna），Emeishan，Qingyinge，800－1000 m，17．V．1957，coll．Wang Zongyuan．Zhejiang（IZCAS）： 1 Q（Allotype of C．substigmaria brunna），Hang－ zhou，4．V．1975，coll．Zhang Baolin．Fujian（IZCAS）：3ठ（Paratypes of C．substig－ maria brunna），Wuyishan，6－21．V．1983，coll．Wang Linyao．Yunnan（IZCAS）： 19 （Paratypes of C．substigmaria brunna），Liuku， $2500 \mathrm{~m}, 23 . V .1981$ ，coll．Liao Subai； $1 \sigma^{\lambda}$（Holotype of C．tetraspota），Xishuangbanna，Yunjinghong， $650 \mathrm{~m}, 22 . \mathrm{VI} .1959$ ， coll．Meng Xuwu；1q（Allotype of C．tetraspota），Yiwubanna，Menglun， 650 m ， 23．VII．1959，coll．Zhang Facai； $1 \widehat{c}^{\text {® }}$（Paratype of C．tetraspota），ibidem，28．V．1958， coll．Wang Shuyong．Hainan（IZCAS）： $1 \widehat{c}^{\widehat{ }}$（Paratype of C．tetraspota），Wanning， 10 m，9．IV．1960，coll．Li Zhenfu．Guangxi（IZCAS）： $1 \delta^{\lambda}$（Paratype of C．tetraspota）， Guilin，Liangfeng，20．IV．1952．Hongkong（BMNH）： 1 q，collector and collecting date unknown（Holotype of C．substigmaria capitata）．

Additional material examined．CHINA：Henan（IZCAS）：1才，Luoyang， Huaguoshan，4．VIII．2006，coll．Song Hao； 1 q，Baiyunshan， 1400 m，27．VII．2003， coll．Lu Yanan； $1 \delta^{\lambda}$ ，Jigongshan，25．VI．1984．Shaanxi（IZCAS）： $2{ }^{\lambda} 1 q$ ，Ningshan， Guanghuojie， 1189 m，28．VII．2014，coll．Liu Shuxian and Ban Xiaoshuang；1才， Zhashui，Yingpanzhen， 980 m，31．VII．2014，Liu Shuxian and Ban Xiaoshuang； $1 \sigma^{\top}$ ，Xunyang，Bailiuzhen， 386 m，3．VIII．2014，coll．Liu Shuxian and Ban Xia－ oshuang．Gansu（IZCAS）：1才，Wenxian，Qiujiaba，2200－2350 m，29．VI．1998， coll．Yuan Decheng；1q，Kangxian，Baiyunshan，1250－1750 m，12．VII．1998，coll． Wang Shuyong； $1 \delta^{\top} 7$ q，Kangxian，Yangba，Meiyuangou， 1000 m，13．VIII．2014， coll．Xue Dayong \＆Ban Xiaoshuang；1q，Wenxian，Lukou，22．V．1987．Jiangsu （IZCAS）： $7 \delta^{\top} 4$ ，Chemo，22．IV－2．V．1935，coll．O．Piel．Anhui（IZCAS）： 1 q， Linzongchang，IX．1970，coll．Mai Weiqiang；2q，Yuexi，Linyeju，11．IX．1982，coll． Zhou Tiying．Zhejiang（IZCAS）： $5 \delta^{\top} 3$ ，Lin＇an，West Tianmushan， $400-1506 \mathrm{~m}$ ， 6．IX．1981，26－30．VII．2003，27．VII．2011，coll．Xue Dayong et al．； $15 \delta^{\top} 1$ ，Tian－ mushan，15－25．VI．1936，25－30．VIII．1947，22．VIII．1972，28－31．VII．1998，coll． O．Piel et al．； $1 \delta^{\top} 1$ ，Hangzhou，4．V．1975，1981，coll．Zhang Baolin；1ठ，Qingy－ uan，Fengyangshan，Datianping， 1290 m，6－10．VIII．2003，coll．Han Hongxiang． Hubei（IZCAS）： 10 ，Shennongjia，Muyu，22．VII．1998，coll．Zhou Hongzhang； 1 ，Shennongjia，Dalongtan， $2700 \mathrm{~m}, 27 . V I I .1998$ ，coll．Zhou Haisheng； $1{ }^{\text {® }}$ ， Xingshan，Longmenhe， 1300 m，12．IX．1994，coll．Song Shimei；4q，Xuan＇en， 650 m，25．V．1989，coll．Li Wei；1q，Hefeng，Fenshuiling Linchang，31．VII．1989，coll． Li Wei．Jiangxi（IZCAS）：1q，Yifeng，Yuanqian，8．IX．1959．Hunan（IZCAS）： 1 ，Yanling，Taoyuandong， $631 \mathrm{~m}, 4-8 . V I I .2008$ ，coll．Chen Fuqiang；1q，Fen－ ghuang，15．IX．1988，coll．Song Shimei；1q，Cili，3．IX．1988，coll．Song Shimei．


Figures 4-I I. Adults. 4-9 Cyclidia substigmaria substigmaria 4 male (with dot-like and wavy submarginal line of the forewing, Yunnan) $\mathbf{5}$ ditto, underside $\mathbf{6}$ male (with faint, broad and interrupted submarginal line of the forewing, Zhejiang) $\mathbf{7}$ male (holotype of C. substigmaria brunna, Sichuan) $\mathbf{8}$ male (holotype of C. tetraspota, Yunnan) 9 C. substigmaria intermedia, male (Tibet) IO-II C. rectificata $\mathbf{1 0}$ male (Tibet) I I ditto, underside. Scale bar: 1 cm .

Fujian (IZCAS): $11 \delta^{\top} 9$ Q , Wuyishan, 26.IV-14.VI.1983, coll. Wang Linyao and Zhang Baolin; $1 \delta^{\lambda}$, Xinkou, 15.VI.1981, coll. Lin Yibiao; $2 \delta^{\lambda} 1$ ㅇ, Jianyang, Huangkeng, 270-950 m, 23.IV-1.V.1960, coll. Jiang Shengqiao and Zuo Yong; 1우, Chong'an, Xingcun, Guadun, $840-1210 \mathrm{~m}$, 25.VIII.1960, coll. Ma Chenglin; 1q, Chong'an, Xingcun, Sangang, 740 m, 17.V.1960, coll. Zhang Yiran.
 Guangzhou，Sanyuanli，27．IV．1958，coll．Wang Linyao．Hainan（IZCAS）：Wan－ ning， 10 m，14．IV．1960，coll．Li Changqing； $3{ }^{\text {J }}$ ，Xinglong，24．III．1963，IV．1963， coll．Zhang Baolin； $3{ }^{\top}$ ，Lingshui，Diaoluoshan，4－5．V．2007，coll．Han Hongxi－ ang；1q，Wuzhishan，Shuiman， $600 \mathrm{~m}, 12 . V .2007$ ，coll．Han Hongxiang； 1 ， Baisha，Yinggeling， 434 m，3－4．XII．2007，coll．Li Jing； 1 q，Jianfengling，Tian－ chi，3．III．1982，coll．Long Yongcheng．Guangxi（IZCAS）： $1 \delta^{\top} 1$ ，Jinxiu，Luoxi－ ang，200－400 m，1－16．V．1999，coll．Huang Fusheng and Han Hongxiang；1q， Jinxiu，Yonghe， $500 \mathrm{~m}, 12 . \mathrm{IV} .1999$ ，coll．Han Hongxiang；1q，Jinxiu，Jinzhong Gonglu， 1100 m，12．V．1999，coll．Li Wenzhu；2才，Guilin，Yanshan，26．IX．1958， 19．XI．1959；1才5q，Fangcheng，Fulong，240－260 m，1．III．1998，19－20．IV．1998， coll．Li Wenzhu and Wu Chunsheng；1才，Napo，Nianjing， 900 m，11．IV．1998， coll．Wu Chunsheng；1q，Napo，Defu， 1350 m，19．VI．2000，coll．Yao Jian； 1 q， Napo，Nonghua， 990 m，13．IV．1998，coll．Li Wenzhu； 1 q，Napo，Baihe， 540 m，8．IV．1998，coll．Qiao Gexia；1 ${ }^{1}$ ，Pingxiang， $230 \mathrm{~m}, 8 . \mathrm{VI} .1976$ ，coll．Zhang Baolin；2 ，Longsheng，10－11．VI．1980，coll．Zhong Tiesen and Song Shimei； 2中，Daxin，Xialei， 680 m，31．III．1998，coll．Li Wenzhu；2す̉，Longzhou，Nong－ gang， 195 m，15－17．VII．2013，coll．Liu Shuxian and Li Xinxin．Sichuan（IZ－ CAS）：1q，Emeishan，Baoguosi，550－750 m，8．IV．1957，coll．Wang Zongyuan； 1ゐ，Emeishan，580－1100 m，22．VI．1955，coll．Zi Yunzhen；36才34q，Emeishan， Qingyinge，800－1000 m，17．IV－20．V．1957，19．IX－28．X．1957，coll．Zhu Fuxing et al．；1q，Yanyuan，Jinhe，2．VII．1984，coll．Chen Yixin．Guizhou（IZCAS）： 1 ， Sinan， 350 m，9．V．1983，coll．Liu Yanxian；1才，Koei－Yang，5．IX．1935．Yunnan （IZCAS）：2đ7q，Xishuangbanna，Mengna， $550 \mathrm{~m}, 22-30 . V I .1959$ ，coll．Zhang Yiran and Li Zhenfu； $1 \delta^{\lambda} 3$ ，Xiaomengyang， $850-1000 \mathrm{~m}, 6 . \mathrm{V} .1957$ ，12．VII－22． VIII．1957，10．X．1957，coll．Wang Shuyong et al．； $1 \delta^{\lambda} 1$ ，Xishuangbanna，Meng－ hun，160－750 m，4．VI．1958，coll．Meng Xuwu et al．；1q，Xishuangbanna，Yunjin－ ghong， $650 \mathrm{~m}, 3 . \mathrm{VII} .1957$ ，coll．Wang Shuyong； $2{ }^{\top} 6$ ，Xishuangbanna，Mengla， 620－650 m，2．V－6．VI．1959，coll．Zhang Yiran et al．；6 ${ }^{\top} 9$ ，Mengla，Menglun， 650－665 m，22－29．X．1958，3．IV－18．V．1964，29．VII．2013，coll．Wang Shuyong et al．； $1 \delta^{\top}$ ，Xishuangbanna，Menghai， $1200-1600 \mathrm{~m}, 18 . V I I .1958$ ，coll．Wang Shuyong；2q，Xishuangbanna，Ganlanba， 560 m，9－10．VII．1958，coll．Li Chuan－ long；1才，Xishuangbanna，Bubang， 700 m，14．IX．1993，coll．Yang Longlong； 1 ， Xishuangbanna，Yiwu，800－1300 m，13．VII．1959，coll．Pu Fuji；6ठ1 1 ，Baoshan， Baihualing， 1520 m, V．11－13．VIII．2007，coll．Wu Chunguang and Lang Song－ yun；2才1q，Baoshan，Bawan，1040－1100 m，19－23．1992，8－10．VIII．2007，8－10． VIII．2013，coll．Wu Chunguang et al．； $2 \delta^{\top} 3$ ，Baoshan，Xinujiang Hegu，800－ 1000 m，10－11．V．1955，coll．Xue Yufeng；1 §，Tengchong，Qushi，Dabacun， 1873 m，4．VIII．2013，coll．Liu Shuxian and Li Xinxin；7ふ1q，Tengchong，Zhengding， 1833 m，6－7．VIII．2013，coll．Liu Shuxian and Li Xinxin； 2 ，Tengchong，Heini－ tang， 1824 m，26－27．VI．2014，coll．Li Xinxin and Pan Xiaodan；1q，Cheli， 620 m，18．IV．1957，coll．Zang Lingchao；2才，Yuanyang，Nansha， 1100 m，26．V．1979，
coll. Luo Kezhong; $1 才 1$, Lushui, Liuku, $860-1220$ m, 18-19.IX.2014, coll. Liang Hongbin; $2 \widehat{4}$, Lushui, Pianma, 1750-1980 m, 7.V.1981, 8-12.V.2011, 3-4.VII.2014, coll. Zhang Xuezhong et al.; 1 q, Jinping, Mengla, 500 m, 2.V.1956, coll. Huang Keren; 1 , Jinping, Chang Potou, 1200 m, 23.V.1956, coll. Huang Keren. Vietnam (IZCAS): 19 , Tonkin, Hoa-Binh, leg. A. de Cooman.

Variation. The submarginal line of the forewing varies from dot-like and wavy to faint, broad and interrupted between veins. In the male genitalia, the terminal half of the costa vary from smooth (Fig. 27, IOZ LEP M 01129) to strongly protruding (Fig. 28, IOZ LEP M 08961) among the material on the same region.

Genetic data. The distance to the nearest neighbour C. rectificata is $8.92 \%$. The intrasubspecific divergence of the barcode region of $C$. substigmaria substigmaria ranges from $0 \%-2.6 \%$ (average distance $1 \%$ ) ( $\mathrm{n}=19$ ). Some specimens from Yunnan cluster together at some distance from all other specimens (Fig. 58). Despite the high divergence, no morphological characters were found which separate these populations.

Remarks. After examining the types of C. substigmaria brunna, C. tetraspota and a long series of material collected near their type localities, it was found that the external and genital features of C. substigmaria brunna and C. tetraspota are nearly identical to those of C. substigmaria substigmaria. Barcodes of one paratype of C. tetraspota (IOZ LEP M 02790) and two specimens from type locality of C. substigmaria brunna (IOZ LEP M 17993 and 17994) were clustered within C. substigmaria substigmaria in the Neighbour Joining (NJ) tree with the genetic distances from $0.015 \%-2.6 \%$ (see fig. 58). Thus, C. tetraspota and C. substigmaria brunna are considered as junior synonyms of $C$. substigmaria substigmaria.

Distribution. China (Henan, Shaanxi, Gansu, Jiangsu, Anhui, Zhejiang, Hubei, Jiangxi, Hunan, Fujian, Taiwan, Guangdong, Hainan, Hong Kong, Guangxi, Sichuan, Guizhou, Yunnan), Vietnam.

## Cyclidia substigmaria intermedia Prout, 1918

Figs 9, 29, 40, 51
Cyclidia substigmaria intermedia Prout, 1918:416. Holotype $\widehat{ }$, China: Tibet (BMNH).

Diagnosis. See under C. substigmaria substigmaria.
Type material examined. CHINA: Tibet (BMNH): $1 \circlearrowleft$ (Holotype), Tibet, collector and collecting date unknown, ex. Joicey Collection.

Additional material examined. CHINA: Tibet (IZCAS): $1 \delta$, Mêdog, Yarang, $1091 \mathrm{~m}, 20-23 . V I I I .2006$, coll. Lang Songyun; 1q, Mêdog, Beibung, 850 m , 24.VI.1983, coll. Han Yinheng; 2q, Mêdog, 2750 m, 22.VIII.1982, coll. Han Yinheng; 1q, Zayü, Dongyan, 1600 m, 17.VII. 1973.

Genetic data. No genetic data available.
Distribution. China (Tibet).

## Cyclidia rectificata（Walker，1862）

Nelcynda rectificata Walker，1862a：1142．Holotype 1才，India：Sikkim（BMNH）． Cyclidia muricolaria Walker，1862b：1483．Holotype 1 Q，India：Darjeeling（BMNH）． Cyclidia patulata Walker，1866：1537．Holotype $q$ ，India：Darjeeling（BMNH）．
Chorodna rectificata：Cotes and Swinhoe 1888： 475.
Enchera rectificata：Hampson 1893： 328.
Cyclidia rectificata：Warren 1922： 445.

Diagnosis．The species is very similar to C．diehli Lutz \＆Kobes， 2002 （Sumatra）ex－ ternally，but can be distinguished by the blackish brown and more distinct forewing submarginal line．The most distinct differences are in the male genitalia：the terminal part of the uncus is much narrower and longer；a rounded process with short setae is absent on the basal part of each socius，while C．diehli has this character；the terminal part of the valva is much broader than that of C．diehli．The male and female genitalia are also similar to those of $C$ ．substigmaria，the diagnosis can be seen under C．substig－ maria substigmaria．

Remarks．There are two subspecies of C．rectificata．C．rectificata rectificata（Walk－ er，1862）is distributed in China and India，and C．rectificata malaisei Bryk， 1943 is distributed in Myanmar．

Distribution．China，India，Myanmar．

## Cyclidia rectificata rectificata（Walker，1862）

Figs 10，11，30，41， 52
Diagnosis．See under C．rectificata．
Material examined．CHINA：Yunnan（IZCAS）： $1 才$ ，Tengchong，Heinitang， 1930 m，28－30．V．1992，coll．Xue Dayong．Tibet（IZCAS）：7q，Nyalam，Zham， $2250 \mathrm{~m}, 12-20 . V .1974$ ，coll．Zhang Xuezhong；1 ${ }^{\lambda}$ ，Cona， 2800 m, 8．VIII．1974， coll．Huang Fusheng； $1 \delta^{\lambda}$ ，Zham， $2200 \mathrm{~m}, 25 . V I .1975$ ，coll．Wang Ziqing； 1 q， Gyirong， $2800 \mathrm{~m}, 26 . V I I I .1975$ ，coll．Wang Ziqing；3q，Bomi，Yi’ong， 2300 m ， 23－29．VIII．1983，coll．Han Yinheng； 2 § 5 q，Nyingchi，Bomi，Tangmai， 2100 m， 29－31．VIII．2005，coll．Wang Xuejian； $3{ }^{\top} 1$ ，Nyingchi，Pêlung， $2115 \mathrm{~m}, 1-2$. IX．2005，coll．Wang Xuejian；4才3q，Zayü，Shang Zayü，1812－1960 m，21－23． VIII．2005，10－11．VIII．2014，coll．Wang Xuejian，Cheng Rui and Cui Le； $1 \delta^{\lambda} 1$ 中， Zayü，Rongcheng Binguan， 2178 m，8－12．VIII．2014，coll．Cheng Rui and Cui Le； 2 ，Mainling，Pai， $2883 \mathrm{~m}, 4-6 . V I I I .2006$ ，coll．Lang Songyun； 8011 ，Mêdog， Lage， $3213 \mathrm{~m}, 7-8 . V I I I .2006$ ，coll．Lang Songyun； 3 §2q，Mêdog，Dayandong， 2880 m，9．VIII．2006，coll．Lang Songyun；2才，Mêdog，Hanmi， 2095 m，10－11． VIII．2006，coll．Lang Songyun；2q，Mêdog，Pomo Gonglu 80K， 2118 m，24－25． VIII．2006，coll．Lang Songyun．

Genetic data. The intraspecific divergence of the barcode region of C. rectificata rectificata is $0 \%$ (average distance $0 \%)(\mathrm{n}=7)$. The distance to the nearest neighbour C. substigmaria is $8.92 \%$.

Distribution. China (Yunnan, Tibet), India.

## Cyclidia pitimani (Moore, 1886)

Figs 12, 13, 31, 42
Euchera pitimani Moore, 1886: 99. Syntypes including 1才, Burma: Tenasserim, Tavoy (BMNH).
Cyclidia pitimani: Warren, 1922: 445.
Cyclidia sericea Warren sensu Chu \& Wang, 1987: 206. (Misidentification)
Cyclidia sericea Warren sensu Chu \& Wang, 1991: 64, fig. 24, pl. 1: 4. (Misidentification)

Diagnosis. This species is very similar to C. sericea (Borneo, Sumatra), but can be distinguished by the following characters: smaller than C. sericea (the average forewing length of the male is 32 mm , against ca 40 mm in C. sericea); in C. pitimani, the doubled antemedial line form almost right angles anteriorly, especially the inner line, while in C. sericea, the protrusions of the antemedial lines are more rounded; the anterior part of the median band is much narrower in C. pitimani; the terminal spots are less distinct than those of $C$. sericea. In the male genitalia, the terminal part of the valva is broader and more rounded.

Material examined. CHINA: Yunnan (IZCAS): $2{ }^{\lambda}$, Xishuangbanna, Xiaomengyang, 850 m, 6-7.IX. 1957, coll. Zang Lingchao and Zhang Yiran (one male was originally incorrectly recorded as "Qinghai, Gonghe"); 2才, Xishuangbanna, Bubang, 700 m, 14.IX. 1993, coll. Yang Longlong.

Genetic data. No genetic data available.
Remarks. After examining the types of C. pitimani and C. sericea, and studying the descriptions and figures of the two species (Moore 1886, Warren 1922, Holloway 1998, Chen 2011), we found that the specimens from Yunnan which were identified as C. sericea by Chu and Wang $(1987,1991)$ well agree with C. pitimani. Thus, C. sericea in Chu and Wang $(1987,1991)$ is considered to be a misidentification of C. pitimani.

Chu and Wang $(1987,1991)$ recorded one male specimen from "Qinghai, Gonghe, 3150 m, 6.IX. 1957, coll. Zang Lingchao". After examination, it was noted that the locality on the label of this specimen was incorrect. According to the collecting records of IZCAS, the collector (Zang Lingchao) went to Xiaomengyang of Xishuangbanna in Yunnan on September 6th, 1957, and no collector went to Qinghai on that date. We also found another specimen of C. pitimani which was collected at the same locality on September 7th, 1957. So, the locality on label should be written as Yunnan, Xishuangbanna, Xiaomengyang, 850 m . Qinghai should be deleted from the range area of C. sericea and the species should be deleted from the fauna of China.

Distribution. China (Yunnan), Myanmar.


Figures I2-23. Adults. I2-I3 Cyclidia pitimani $1 \mathbf{2}$ male (Yunnan) $\mathbf{1 3}$ ditto, underside I4-I5 C. fractifasciata fractifasciata 14 male (Yunnan) I5 ditto, underside 16-I7 C. fractifasciata indistincta subsp. n. 16 male (holotype, Gansu) 17 ditto, underside 18-19 C. orciferaria 18 male (Hainan) 19 ditto, underside 20-21 Mimozethes angula 20 male (holotype, Sichuan) 21 ditto, underside 22-23 M. lilacinaria 22 male (holotype, Sichuan) 23 ditto, underside. Scale bar: 1 cm .


Figures 24-29. Male genitalia of Cyclidia. 24 C. substigmaria substigmaria (Baoshan, Yunnan, slide no. 41) $\mathbf{2 5}$ ditto (holotype of C. substigmaria brunna, Emeishan, Sichuan, slide no. 12) $\mathbf{2 6}$ ditto (holotype of C. tetraspota, Xishuangbanna, Yunnan, slide no. 10) 27 ditto (Xishuangbanna, Yunnan, slide no. 681) 28 ditto (Xishuangbanna, Yunnan, slide no. 683) 29 C. substigmaria intermedia (Tibet, slide no. 311). Scale bar: 1 mm .

## Cyclidia fractifasciata (Leech, 1898)

Euchera fractifasciata Leech, 1898: 360. Syntypes 1才, 1中, China: Western China (BMNH).
Cyclidia fractifasciata: Gaede 1931: 2.

Diagnosis. The species can be distinguished by the following characters: a black broad subbasal line is present on the forewing; the forewing medial line is broad at anterior half and very narrow and dot-like at posterior half; outer margin of the forewing medial line forms an almost right angle below $\mathrm{M}_{3}$; the phallus of the male genitalia forms a small protrusion posteriorly; the lamella postvaginalis of the female genitalia is rectangle.

Remarks. Chu and Wang (1991) did not record this species. The specimens from Yunnan should be identified as C. fractifasciata fractifasciata, and the specimens from Gansu and Chongqing should be identified as a new subspecies, C. fractifasciata indistincta subsp. n., based on adult morphology and DNA barcodes.

Distribution. China.

## Cyclidia fractifasciata fractifasciata (Leech, 1898)

Figs 14, 15, 32, 43, 53
Diagnosis. See under C. fractifasciata indistincta.
Material examined. CHINA: Yunnan (IZCAS): $1 \AA^{\AA}$, Dulongjiang, 1500 m , 29.V.2006, coll. Xiao Ningnian; 3 1 1 , Lushui, Pianma, 8-12.V.2011, coll. Yang Xiushuai and Wang Ke.

Distribution. China (Yunnan).
Genetic data. The intrasubspecific divergence of the barcode region in C. fractifasciata fractifasciata is $0 \%(\mathrm{n}=4)$.

## Cyclidia fractifasciata indistincta Jiang, Han \& Xue, subsp. n.

http://zoobank.org/8BC2D3BA-389A-43E9-991E-CA93B3DE1837
Figs 16, 17, 33, 44, 54

Description. Head. Antennae blackish brown dorsally, flat and unipectinate, basal half without rami, rami very short. Frons blackish grey, not protruding. Labial palpi black with third segment distinct, extending beyond frons. Vertex black scattered with grey scales.

Thorax. Patagia white at basal half and blackish grey at terminal half. Tegula blackish grey. Dorsal side of thorax white with two pairs of blackish grey patches medially.

Hind tibia with two pairs of spurs in both sexes. Forewing length: 37-40 mm. Apex of forewing rounded, not falcate; outer margin of both wings smooth. Wings white, transverse lines black. Forewing with a blackish brown patch basally; subbasal line broad; antemedial lines double, outer line indistinct and often invisible; medial line broad band-like at anterior half, very narrow and dot-like at posterior half; outer margin of medial line forming an almost right angle below $\mathrm{M}_{3}$; discal spot white, almost rhombic; postmedial lines double, wavy, inner line very obscure; submarginal line double, broad, and invisible between $\mathrm{M}_{3}$ and $\mathrm{CuA}_{1}$; terminal lines double and discontinuous on each vein, inner line composed of oval markings, outer line appearing as series of short strips, inner markings often fused with outer ones; fringes white mixed with blackish grey. Hind wing with indistinct submarginal line; terminal lines and fringes similar to those of forewing. Underside white, striations indistinct than those of upperside.

Abdomen. Abdominal segments diffused with white scales. Pairs of black quadrate markings on first to seventh abdominal segments. Anterotergal syndeses developed at anterior margin of $2^{\text {nd }}$ tergum. A pair of androconial hair-pencils present on $2^{\text {nd }}$ pleuron of male.

Male genitalia. Uncus triangular. Socii sclerotized, about four-fifths the length of uncus. Gnathos with median process small and triangular. Valva narrow terminally; costa sclerotized and almost straight. Juxta formed a pair of forcipiform processes posteriorly. Saccus semicircular, about two-fifths length of basal width. Phallus slightly curved, with a small triangular lateral process posteriorly; vesica without cornuti.

Female genitalia. Lamella postvaginalis rectangle. Ductus bursae with a colliculum, long and narrow, striate longitudinally. Corpus bursae oval, with a paired slender signa; signa separated and parallel.

Diagnosis. The subspecies is very similar to the nominate subspecies, but differs externally by the following characters: the outer line of the antemedial line and the inner line of the postmedial line on the forewing are invisible, while in the nominate subspecies, they are much more distinct; the forewing discal spot is larger; the inner terminal markings of the forewing are larger and fused with the outer ones partly, while in $C$. fractifasciata fractifasciata, they are often smaller and separated from the outer ones.

Type material examined. Holotype, ${ }^{\top}$, CHINA: Gansu (IZCAS): Kangxian, Yangba, Meiyuangou, 1000 m, 13.VIII.2014, coll. Xue Dayong and Ban Xiaoshuang. Paratypes: $3 \delta^{\top} 2 q$, same data as holotype. Chongqing (IZCAS): $1 q$, Wushan, Wulipo, Dangyang, Congping, 1773 m, 25.VII.2013, coll. Cheng Rui.

Genetic data. The intrasubspecific divergence of the barcode region in C. fractifasciata indistincta is $1 \%$. The intraspecific divergence of the barcode region between C. fractifasciata fractifasciata $(\mathrm{n}=4)$ and C. fractifasciata indistincta $(\mathrm{n}=5)$ is $2.3 \%$. The distance between C. fractifasciata with the nearest neighbour species C. substigmaria is $12.5 \%$.

Distribution. China (Gansu, Chongqing).
Etymology. The subspecies is named on the basis of the Latin adjective indistinctus, referring to the transverse lines of the forewing.


Figures 30-34. Male genitalia of Cyclidia. 30 C. rectificata (Tibet, slide no. 2) 3 I C. pitimani (Yunnan, slide no. 9) 32 C. fractifasciata fractifasciata (Yunnan, slide no. 724) 33 C. fractifasciata indistincta subsp. n. (paratype, Gansu, slide no. 721) 34 C. orciferaria (Hainan, slide no. 728). Scale bar: 1 mm .


Figures 35-47. 35-36 Male genitalia of Mimozethes. $\mathbf{3 5}$ M. angula (paratype, Sichuan, slide no. 34 ) $\mathbf{3 6}$ M. lilacinaria (Sichuan, BMNH, slide No. 304) 37-47 Phallus $\mathbf{3 7}$ Cyclidia substigmaria substigmaria (Tengchong, Yunnan, slide no. 682) $\mathbf{3 8}$ ditto (holotype of C. substigmaria brunna, Emeishan, Sichuan, slide no. 12) 39 ditto (holotype of C. tetraspota, Xishuangbanna, Yunnan, slide no. 10) 40 C. substigmaria intermedia (Tibet, slide no. 311) 4I C. rectificata (Tibet, slide no. 727) 42 C. pitimani (Yunnan, slide no. 9) 43 C. fractifasciata fractifasciata (Yunnan, slide no. 724) $\mathbf{4 4}$ C. fractifasciata indistincta subsp. n. (paratype, Gansu, slide no. 721) 45 C. orciferaria (Hainan, slide no. 728) $\mathbf{4 6}$ M. angula (holotype, Sichuan, slide no. 19) $\mathbf{4 7}$ M. lilacinaria (Sichuan, BMNH, slide No. 304). Scale bars: 1 mm .

## Cyclidia orciferaria Walker， 1860

Figs 18，19，34，45， 55
Cyclidia orciferaria Walker，1860：56．Syntypes，China：North China．
Cyclidia ociferaria Kirby，1892：725．［Incorrect spelling of Cyclidia orciferaria Walker．］

Diagnosis．This species is different from other congeners in the following external characters：the apex of the forewing is falcate；the wing colour is blackish brown；two bands covered with greyish blue scales are present on the forewing，and the inner band is narrower and less distinct than the outer band；the discal spot of the forewing is yel－ lowish brown，oblong，with a blackish brown narrow line medially；greyish blue scales are covered on the submarginal lines of both wings，and often absent on the middle part of the hind wing．There are also differences in the male genitalia：the socii are weakly sclerotized and much shorter than the uncus；the valva is short．In the female genitalia，the posterior margin of the lamella postvaginalis is slightly concaved；the two signa are tapered at posterior half and situated very close to each other．

Material examined．CHINA：Zhejiang（IZCAS）：2才，Tianmushan，20－23． VII．1973，coll．Zhang Baolin； 1 §1q，Lin’an，West Tianmushan， $400-1500 \mathrm{~m}$ ， 26．VII－29．VIII．2003，coll．Xue Dayong et al．；1才，West Tianmushan，Zhonglieci， 363 m，24．VII．2011，coll．Yan Keji；1 ${ }^{\lambda}$ ，West Tianmushan，Xianrending， 1506 m， 27．VII．2011，coll．Yan Keji； $2{ }^{\top} 2$ ，Taishun，Wuyanling，Shuangkengkou， 680 m， 28－29．VII．2005，coll．Lang Songyun；1q，Taishun，Siqianzhen， 250 m，4．VIII．2005， coll．Lang Songyun； $1 \delta^{\lambda}$ ，Ningbo，V．1981．Jiangxi（IZCAS）：1 ，Huzhi，28．VII． 1990. Hunan（IZCAS）： 2 §，Yanling，Taoyuandong， $631 \mathrm{~m}, 4-8$ ．VII．2008，coll．Chen Fu－ qiang；1才，Tianpingshan，25．VI．1981．Fujian（IZCAS）：1才，Jiangle，Longqishan， 800 m，15．IX．1990，coll．Yang Bin；8 ${ }^{\lambda}$ ，Wuyishan，24．IV－21．V．1983，coll．Wang Linyao；1q，Wuyishan，Sangang，24．VII．1980；1q，Nanping，Shangyang，9．VI．1963， coll．Zhang Youwei．Guangdong（IZCAS）： $1 \jmath^{\top}$ ，Ruyuan，Nanling，Baohuzhan， 1020 m，16－20．VII．2008，coll．Chen Fuqiang； 1 ，Shixing，Chebaling，365－401 m，22－26． VII．2008，coll．Chen Fuqiang．Hainan（IZCAS）： $4 \circlearrowleft^{\top} 2$ ，Nankai，Nanmaola， 1261 m，10－14．V．2009，coll．Chen Fuqiang and Yan Keji； $6 \delta^{\top} 1 q$ ，Jianfengling，Tianchi， 828 m，1－5．V．2007，18．V．2009，coll．Chen Fuqiang； $1 \delta^{\lambda} 2$ ，Bawangling，Dong＇er Linchang，1004－1015 m，8．V．2007，7．IV．2008，coll．Chen Fuqiang and Lang Song－ yun；11 ${ }^{\lambda}$ ，Wuzhishan，Shuiman，730－900 m，7－11．V．2007，1－3．IV．2008，coll． Lang Songyun and Han Hongxiang； $1 \delta^{\top} 3$ ，Lingshui，Diaoluoshan，190－920 m， $3-7 . V .2007$ ，coll．Han Hongxiang and Lang Songyun； 1 ，Qiongzhong，Limuling， 620 m，15．V．2007，coll．Han Hongxiang；1q，Xinglong，24．IV．1963，coll．Zhang Baolin．Guangxi（IZCAS）：3§2q，Fangcheng，Fulong，200－550 m，23－26．V．1999， coll．Yuan Decheng et al．； $1 \delta^{\top} 1$ ，Napo，Defu， 1350 m，19．VI．2000，coll．Zhu Chao－ dong； $1 \delta^{\AA}$ ，Jinxiu，Linhai Shanzhuang， $1100 \mathrm{~m}, 2 . V I I .2000$ ，coll．Li Wenzhu； $1{ }^{\text {§，}}$ Jinxiu，Jinzhong Gonglu， 1000 m，10．V．1999，coll．Han Hongxiang；1q，Daxin， Xialei， 680 m，31．III．1998，coll．Li Wenzhu．Yunnan（IZCAS）： $1 \jmath^{\top} 1 q$ ，Hekou，Xi－ aonanxi， 200 m，10－11．VI．1956，coll．Huang Keren et al．；1q，Pingbian，Daweis－


Figures 48-57. Female genitalia. 48 Cyclidia substigmaria substigmaria (Henan, sldie. no. 726 ) 49 ditto (Jiangsu, slide. no. 33) $\mathbf{5 0}$ ditto (paratype of $C$. tetraspota, Xishuangbanna, Yunnan, slide no. 36) 5 I C. substigmaria intermedia (Tibet, slide no. 685) $\mathbf{5 2}$ C. rectificata (Tibet, slide no. 3) $\mathbf{5 3}$ C. fractifasciata fractifasciata (Yunnan, slide no. 725) 54 C. fractifasciata indistincta subsp. n. (paratype, Gansu, slide no. 722) 55 C. orciferaria (Hainan, slide no. 729) $\mathbf{5 6}$ M. angula (Henan, slide no. 288) $\mathbf{5 7}$ M. Iilacinaria (Sichuan, slide no. 280). Scale bars: 1 mm .
han, 1500 m, 20.VI.1956, coll. Huang Keren et al.; $1{ }^{\widehat{ }}$, Xishuangbanna, Mengla, Menglun, 650 m, 1.VI. 1964 , coll. Zhang Baolin; $1 \delta^{\top} 1$ q, Mengla Linchang, 550 m , 20.IV.1982, coll. Wang Yongxian; 1 ${ }^{\text {², }}$, Mengla, 20.VI.1982, coll. Chen Yixin; 1 ㅇ, Mengla, Lengku, 623 m, 10.VI.1980, coll. Guo Zuyun; 1ठ², Xishuangbanna, Bubang, 700 m, 14.IX.1993, coll. Yang Longlong; 1 ${ }^{\text {§ }}$, Xishuangbanna, Damenglong, 650
m, 1.VIII.1958, coll. Zheng Leyi; $1 \delta^{\text {® }}$, Xishuangbanna, Dameng'a, 1050-1080m, 15.VIII.1958, coll. Wang Shuyong; 2才, Cangyuan, 790-1100 m, 19-22.V.1980, coll. Song Shimei and Shang Jinwen; 1才, Xiaomenglun, 21.IV.1982, coll. Wang Linyao; $1 \delta^{\lambda}$, Ruili, Dengga, 6-8.VI.1992, coll. Xue Dayong; $1 \delta^{\lambda}$, Baoshan, Baihualing, 1520 m, 11-13.VIII.2007, coll. Wu Chunguang.

Genetic data. The intraspecific divergence of the barcode region of C. orciferaria is ranges from $0 \%-1.7 \%$ (average distance $1.09 \%)(n=8)$. The distance to the nearest neighbour C. substigmaria is $11.5 \%$.

Distribution. China (Jiangsu, Zhejiang, Jiangxi, Hunan, Fujian, Guangdong, Hainan, Guangxi, Sichuan, Yunnan), Myanmar, Vietnam, Indonesia.

Biological notes. The morphology of the larva of C. orciferaria was illustrated in Chen (2011).

## Mimozethes Warren, 1901

Mimozethes Warren, 1901: 190. Type species: Euchera nana Warren, 1897, by original designation.

Generic characters. Head. Antennae lamellate and shortly unipectinate, basal part of antennae without rami (Fig. 1b). Frons not protruding. Labial palpi with second segment slightly curved, third segment oval. Thorax. Hind tibia with two pairs of spurs. Apex of forewing falcate; outer margin of forewing protruding. Wing. Wings colour dark brown. Forewing with silver grey antemedial line, sometimes indistinct; discal spot black and small; postmedial line silver grey, forming a ">" shaped protrusion near $\mathrm{R}_{5}$. Hind wing with medial line and postmedial line silver grey and almost straight. Black brown patches present near anal angle of both wings. Terminal lines of both wings composed of a series of blackish brown strips covering silver grey scales, very distinct towards apex. Underside with distinct discal spot, costa, apex and outer margin suffused with pale yellowish brown scales. Vein (Fig. 3b). Forewing with $\mathrm{R}_{1}$ separate, $\mathrm{R}_{2-4}$ and $\mathrm{R}_{5}$ stalked, $\mathrm{M}_{2}$ arising from middle of discocellulars; Hind wing with $\mathrm{Sc}+\mathrm{R}_{1}$ close to Rs beyond distal cell, then far from Rs, $\mathrm{M}_{2}$ arising from middle of discocellulars. Anterotergal syndeses developed at anterior margin of $2^{\text {nd }}$ tergum (Fig. 2). A pair of androconial hair-pencils present on $2^{\text {nd }}$ sternum of male (Fig. 2). Male genitalia. Uncus triangular, acute terminally; socii undeveloped; gnathos connected at middle and with median process small and acute apically; sacculus forming a long process; juxta short and broad, concaved posteriorly; saccus broad and rounded terminally; Phallus short; vesica without cornuti. Female genitalia. Papillae anales broad and rounded; lamella postvaginalis large and oval, with many tiny spines; ductus bursae long and narrow, with a colliculum; corpus bursae oval, without a signum.

Diagnosis. See under Cyclidia.

Remarks. According to Inoue (1962), M. argentilinearia (Leech, 1897) occurs in Japan and Taiwan. However, it has not been recorded from Taiwan in later studies (Inoue 1992, Yan et al. 2009, Chen 2011). Thus, following that, we do not include the species in this paper.

Distribution. China, Japan.

## Key to Chinese Mimozethes species

1 Outer margin of forewing weakly protruding; ventral margin of valva forming a small triangular protrusion apically in male genitalia ......M. angula, Figs 20-21

- Outer margin of forewing strongly protruding; ventral margin of valva not forming a small triangular protrusion apically in male genitalia
M. lilacinaria, Figs 22-23


## Mimozethes angula Chu \& Wang, 1987

Figs 20, 21, 35, 46, 56
Mimozethes angula Chu \& Wang, 1987: 207. Holotype §, China: Sichuan: Mt. Emei (IZCAS).

Diagnosis. This species is very similar to M. lilacinaria (Leech, 1897) and M. argentilinearia, but it can be distinguished by the following characters: the outer margin of the forewing is less strongly protruding than that of M. lilacinaria and M. argentilinearia; the black patch inside the anal angle of the forewing is less distinct than that of M. argentilinearia; the yellowish brown patch on the underside of the forewing is much smaller and less distinct than that of $M$. lilacinaria and $M$. argentilinearia. In the male genitalia, the uncus is shorter; the ventral margin of the valva forms a small triangular protrusion apically, but M. lilacinaria and M. argentilinearia lack this character; the sacculus process is much longer than that of $M$. lilacinaria.

Type material examined. CHINA: Sichuan (IZCAS): $1 \lesssim$ (Holotype), Emeishan, Qingyinge, 800-1000 m, 15.IX.1957, coll. Zhu Fuxing; $1 q$ (Allotype), same locality, 22.IX.1957, coll. Zhu Fuxing; 4才2? (Paratype), same locality, 22.VI.1957, 15-19. IX.1957, coll. Zhu Fuxing et al.

Additional material examined. CHINA: Henan (IZCAS): 1q, Baiyunshan, 13-15.VIII.2008, 1550 m, coll. Jiang Nan. Hubei (IZCAS): $1 \delta^{\lambda}$, Shennongjia, Dajiuhu, 1800 m, 1.VIII.1981, coll. Han Yingheng. Sichuan (IZCAS): $9{ }^{\top} 2$ q, Emeishan, Qingyinge, 800-1000 m, 20.VI.1957, 15-22.IX.1957, coll. Zhu Fuxing et al.; 1q, Qingchengshan, 1000 m, 4.VI.1979, coll. Shang Jinwen; 1才, Emeishan, 1288 m, 31.VII.2013, coll. Cheng Rui.

Genetic data. No genetic data available.
Distribution. China (Henan, Hubei, Sichuan).

## Mimozethes lilacinaria (Leech, 1897)

Figs 22, 23, 36, 47, 57
Decetia lilacinaria Leech, 1897: 184. Holotype 万, China: Sichuan: Emeishan (BMNH).
Heteromize lycoraearia Oberthür, 1912: 269. Holotype ${ }^{\lambda}$, China: Sichuan: Mou-pin (BMNH).
Mimozethes lilacinaria: Beccaloni et al. 2003 [accessed 26 November 2015].
Diagnosis. See under M. angula.
Type material examined. CHINA: Sichuan (BMNH): $1 \widehat{\widehat{ } \text { (Holotype), Omei- }}$ Shan, 3620 ft., Native coll. July \& Aug. 1890, Leech Coll. 1900-64, BMNH (E) 1377104.

Additional material examined. CHINA: Sichuan (BMNH): 1 $\widehat{\lambda}$, Chasseurs indigènes, de Tà-tsien-lou, Récolle de 1910, Ex Oberthür Coll. Brit. Mus. 1927-3, Drepanidae genitalia slide No. 304; 1 , Siao-Lou, 1900, Chasseurs indigènes, Ex Oberthür Coll. Brit. Mus. 1927-3. Yunnan (IZCAS): 19, Xishuangbanna, Menghai, 21.VII.1958, coll. Wang Shuyong.

Genetic data. No genetic data available.
Remarks. Chu and Wang (1991) did not record this species. The specimens from Yunnan should be identified as M. lilacinaria based on adult morphology.

Distribution. China (Sichuan, Yunnan).

## DNA barcoding results and discussion

Forty-three DNA barcode sequences of lengths 658bp were obtained for Cyclidia species. The nucleotide composition of Cyclidia species COI genes was $30.60 \%$ of A , 38.54 of T, $16.06 \%$ of C, $14.80 \%$ of G . The interspecific distance within the genus was range from $8.8 \%-13.9 \%$. The maximum intraspecific distances was $2.6 \%$ in $C$. substigmaria, $1.7 \%$ in C. orciferaria, $0.0 \%$ in C. rectificata, and $2.3 \%$ in C. fractifasciata. The maximum genetic distances observed within species ( $2.6 \%$ at COI) were less than the minimum distances observed between the species ( $8.8 \%$ ). There is a clear barcoding gap between intra and interspecific variation; furthermore, NJ tree also provided strong support for the separation of Cyclidia species (Fig. 58).

In recent revisionary work of Drepanidae, Song et al. $(2011,2012)$ and Park et al. (2011) found many new taxa, synonyms and misidentifications in earlier studies. However, when dealing with some morphologically similar taxa, it is difficult to discriminate only using the subtle diagnostic characters. The present study utilizing morphological and molecular characters revised some Chinese Cyclidia species. The morphological analysis indicated that some structures of the genitalia were found to be less diagnostic than the external characters between some species (i.e. C. substigmaria and $C$. rectificata). Sihvonen et al. (2014) also mentioned this trait in the Geometridae.


Figure 58. Neighbour joining tree (Kimura 2-parameter distance model for 658bp COI marker) for Chinese Cyclidia species. Terminals with sequence ID and collecting locality.

Additionally, some structures of the male genitalia (e.g. the shape of the valva) sometimes varied among individuals of C. substigmaria. Therefore, species have been delineated on the basis of a combination of data from morphology and DNA barcodes. In the molecular analysis, DNA barcodes proved to be very helpful. The interspecific divergence of Cyclidia species (minimum distance $8.8 \%$, maximum distance $13.9 \%$ ) was much larger than the $2 \%$ or $3 \%$ of the threshold for species diagnosis (Hebert et al.

2003, Hebert et al. 2004a, Hebert et al. 2004b). The remarkably high interspecific divergence and low intraspecific divergence on average $1 \%$ (minimum distance $0.0 \%$, maximum distance $2.6 \%$ ) fully supports the morphological species concept.

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## References

Aurivillius CHR (1894) Neue Spinner aus Asien. Entomologisk tidskrift 15: 169-177.
Beccaloni G, Scoble M, Kitching I, Simonsen T, Robinson G, Pitkin B, Hine A, Lyal C (Eds) (2003) The Global Lepidoptera Names Index (LepIndex). World Wide Web electronic publication. http://www.nhm.ac.uk/entomology/lepindex [accessed 26 Novermber 2015]
Bryk F (1943) Entomological results from the Swedish expedition 1934 to Burma and British India. Lepidoptera: Drepanidae. Arkiv för Zoologi Band 34A (13): 1-30.
Chang BS (1989) Illustrated moths of Taiwan 1. Taiwan Provincial Museum, Taipei, 242 pp. [In Chinese]
Chen YL (2011) Phylogenetic reconstruction of Cyclidiinae (Lepidoptera: Drepanidae). MS thesis, National Sun Yat-sen University, Kaohsiung, Taiwan. http://etd.lib.nsysu.edu.tw/ETD-db/ETD-search-c/getfile?URN=etd-0725111-051148\&filename=etd-0725111-051148. pdf [accessed 26 November 2015]
Chou I, Xiang H (1984) Studo de Drepanedoj el Yunnan Provinco (Lepidoptera: Drepanidae). Entomotaxonomia 6 (2-3): 159-169. [Abstract in Esperanto]
Chu HF, Wang LY (1987) Taxonomy and geographical distribution of Cyclidiidae. Acta Entomologica Sinica 30 (2): 203-211. [In Chinese]
Chu HF, Wang LY (1991) Fauna Sinica. Insecta. Vol. 3. Lepidoptera Cyclidiidae Drepanidae. Science Press, Beijing, vii+269 pp. [In Chinese]
Chu HF (Ed.) (1981) Iconocraphia Heterocerorum Sinicorum. Vol. I. Science Press, Beijing, iv+134 pp.+22 pp. (Index), 38 pls. [In Chinese]
Comstock JH (1918) The wings of insects. Comstock Publishing Company, Ithaca, New York, 430 pp.

Cotes EC, Swinhoe C (1888) Geometrites. In: Cotes E, Swinhoe CC (Eds) A catalogue of the moths of India. Part. IV. Trustees of the Indian Museum, Calcutta, 463-590.
Fletcher DS (1979) Geometroidea. In: Nye WB (Ed.) The Generic Names of Moths of the World. Vol. 3. Trustees of the British Museum (Natural History), London, 243 pp.
Gaede M (1931) Family: Drepanidae. In: Strand E (Ed.) Lepidopterorum Catalogus. Vol. 49. W. Junk, Berlin, 60 pp.

Guenée A (1858) Uranides and Phalénites. In: Boisduval JBAD, Guenée A (Eds) Histoire naturelle des insectes: Spécies général des Lépidoptères. IX. Roret, Paris, 1-551. [In French]
Hajibabaei M, Janzen DH, Burns JM, Hallwachs W, Hebert PDN (2006) DNA barcodes distinguish species of tropical Lepidoptera. Proceedings of the National Academy of Sciences of the United States of America 103: 968-971. doi: 10.1073/pnas. 0510466103
Hampson GF (1893) Illustrations of Typical Specimens of Lepidoptera Heterocera in the Collection of the British Museum. Part 9: The Macrolepidoptera Heterocera of Ceylon. Trustees of the British Museum (Natural History), London, v +182 pp.
Hebert PDN, Cywinska A, Ball SL, deWaard JR (2003) Biological identifications through DNA barcodes. Philosophical Transactions of the Royal Society B: Biological Sciences 270: 313-321. doi: $10.1098 / \mathrm{rspb} .2002 .2218$
Hebert PDN, Penton EH, Burns JM (2004a) Ten species in one: DNA barcoding reveals cryptic species in the neotropical skipper butterfly Astraptes fulgerator. Proceedings of the National Academy of Sciences of the United States of America 101: 14812-14817.
Hebert PDN, Stoeckle MY, Zemlak TS, Francis CM (2004b) Identification of birds through DNA barcodes. Plos Biology 2: 1657-1663.
Holloway JD (1998) The Moths of Borneo. Part 8: Family Castniidae. Callidulidae. Drepanidae and Uraniidae. Malayan Nature Journal 52: 7-76.
Hübner J (1824-1831) Zuträge zur Sammlung exotischer Schmetterlinge, bestehend in Bekundigung einzelner Fliegmuster neuer oder rarer nichteuropäischer Gattungen 3. Im Verlag der Hübner'schen Werke bei C. Geyer, Augsburg, 103 pp.
Inoue H (1962) Lepidoptera: Cyclidiidae, Drepanidae. In: Inoue H (Ed.) Insecta Japonica. Vol. 2. Hokuryukan Publishing, Tokyo, 1-54, 1-3 pls. [In Japanese]

Inoue H (1992) Geometridae, Thyatiridae, Cyclidiidae, Drepanidae. In: Heppner JB, Inoue H. Lepidoptera of Taiwan. Volume. 1, part 2: Checklist. Association for Tropical Lepidoptera, Florida, 111-129, 151-153.
Jiang N, Liu SX, Xue DY, Tang MJ, Xiao Q, Han HX (2014) External morphology and molecular identification of two tea Geometrid moth from southern China. Chinese Journal of Applied Entomology 51: 987-1002. [In Chinese]
Kadoorie Farm, Botanic Garden (2004) Report of Rapid Biodiversity Assessments at Dachouding and Sanyue Nature Reserves, Northwest Guangdong, China, April 2001. South China Forest Biodiversity Survey Report Series (Online Simplified Version): No. 37. KFBG, Hong Kong SAR, ii +33 pp .
Kimura M (1980) A simple method for estimating evolutionary rates of base substitutions through comparative studies of nucleotide sequences. Journal of molecular evolution 16: 111-120. doi: 10.1007/BF01731581

Kirby WF (1892) A Synonymic Catalogue of Lepidoptera Heterocera. R. Friedlander and Son., Berlin, 951 pp.
Klots AB (1970) Lepidoptera. In: Tuxen SL (Ed.) Taxonomist's Glossary of Genitalia in Insects. Munksgaard, Copenhagen, 115-130.
Kristensen NP (Ed.) (2003) Handbook of Zoology, Vol. IV. Arthropoda: Insecta. Part 36. Walter de Gruyter, Berlin, New York, 564 pp.
Leech JH (1897) On Lepidoptera Heterocera from China, Japan, and Corea. Annals and Magazine of Natural History (6) 19: 180-235. doi: 10.5962/bhl.title. 22195
Leech JH (1898) Lepidoptera Heterocera from Northern China, Japan and Corea. Transactions of the Royal Entomological Society of London 46(3): 261-379.
Lutz W, Kobes R (2002) Cyclidia diehli sp. n. (Lepidoptera: Cyclidiinae) a species new to science. Heterocera Sumatrana 12: 177-183.
Meier R, Kwong S, Vaidya G, Ng PKL (2006) DNA barcoding and taxonomy in Diptera: a tale of high intraspecific variability and low identification success. Systematic Biology 55: 715-728. doi: 10.1080/10635150600969864
Meier R, Zhang GY, Ali1 F (2008) The use of mean instead of smallest interspecific distances exaggerates the size of the "Barcoding Gap" and leads to misidentification. Systematic Biology 57: 809-813. doi: 10.1080/10635150802406343
Minet J, Scoble MJ (1999) The drepanoid/geometroid Assemblage. In: Kristensen NP (Ed.) Lepidoptera, Moths and Butterflies. Vol. I: Evolution, Systematics, and Biogeography. Handbook of Zoology. Vol. IV, Arthropoda: Insecta, Part 35. Walter de Gruyter, Berlin and New York, 301-320.
Minet J (1983) Étude morphologique et phylogénétique des organs tympaniques des Pyraloidea. I. généralités et homologies. (Lep. Glossata). Annales de la Société entomologique de France (N.S.) 19: 175-207. [In French]
Minet J (2002) The Epicopeiidae: Phylogeny and a redefinition, with the description of new taxa (Lepidoptera: Drepanoidea). Annales de la Societe Entomologique de France 38: 463-487. doi: 10.1080/00379271.2002.10697355
Moore F (1886) List of the Lepidopterous Insects collected in Tavoy and in Siam during 1884 and 1885 by the Indian Museum Collector. Part i. Heterocera. Journal of the Asiatic Society of Bengal 55: 97-101.
Nichols SW (Ed.) (1989) The Torre-Bueno Glossary of Entomology. New York Entomological Society in cooperation with the American Museum of Natural History, New York, 840 pp.
Oberthür C (1912) Revision des Phalénites décrites par Guenée dans le species général des Lépidoptéres (Tome IX.). Famille II. Ennomidae, Guenée. Études de Lépidoptérologie Comparée 6: 223-307, 346-355. [In French]
Park KT, Kim M, Kwon YD, Ji EM (2011) A review of the genus Oreta Walker in Korea, with description of a new species (Lepidoptera: Drepanidae). Journal of Asia-Pacific Entomology 14(3): 311-316. doi: 10.1016/j.aspen.2011.04.001
Prout LB (1918) New moth species in the Joicey collection. Annals and Magazine of Natural History 9(11): 412-416.
Ratnasingham S, Hebert PDN (2007) BOLD: The Barcode of Life Data System (http://www.barcodinglife.org). Molecular Ecology Notes 7:355-364. doi: 10.1111/j.1471-8286.2007.01678.x

Saitou N, Nei M (1987) The neighbor-joining method, A new method for reconstructing phylogenetic trees. Molecular Biology and Evolution 4: 406-425.
Scoble MJ (1992) The Lepidoptera, Form, Function and Diversity. Oxford University Press, Oxford, xi+404 pp.
Sihvonen P, Skou P, Flamigni C, Fiumi G, Hausmann A (2014) Revision of the Hylaea fasciaria (Linnaeus, 1758) species group in the western Palaearctic (Lepidoptera: Geometridae, Ennominae). Zootaxa 3768(4): 469-486.
Song WH, Xue DY, Han HX (2011) A taxonomic revision of Tridrepana Swinhoe, 1895 in China, with descriptions of three new species (Lepidoptera, Drepanidae). Zootaxa 3021: 39-62.
Song WH, Xue DY, Han HX (2012) Revision of Chinese Oretinae (Lepidoptera, Drepanidae). Zootaxa 3445: 1-36.
Strand E (1911) Family: Drepanidae. In: Seitz A (Ed.) The Macrolepidoptera of the World. Vol. 2: the Palearctic Bombyces and Sphinges. Alfred Kernen, Stuttgart, 195-206.
Sugi S (1987) Larvae of Large Moths in Japan. Kodansha, Tokyo, 453 pp, 120 pls. [In Japanese]
Swinhoe C (1899) New species of Oriental Lepidoptera. The Annals and Magazine of Natural History 7: 102-116. doi: 10.1080/00222939908678084
Tamura K, Peterson D, Peterson N, Stecher G, Nei M, Kumar S (2011) MEGA5: molecular evolutionary genetics analysis using likelihood, distance, and parsimony methods. Molecular Biology and Evolution 28: 2731-2739. doi: 10.1093/molbev/msr121
Walker F (1860) List of the specimens of Lepidopterous Insects in the collection of the British Museum. Part 20. Edward Newman, London, 1-276.
Walker F (1862a) List of the specimens of Lepidopterous Insects in the collection of the British Museum. Part 24. Edward Newman, London, 1021-1280.
Walker F (1862b) List of the specimens of Lepidopterous Insects in the collection of the British Museum. Part 25. Edward Newman, London, 1281-1477.
Walker F (1866) List of the specimens of Lepidopterous Insects in the collection of the British Museum. Part 35. Edward Newman, London, 1535-2040.
Warren W (1897) New genera and species of moths from the Old World regions in the Tring Museum. Novitates Zoologicae 4: 12-130.
Warren W (1901) Drepanulidae, Uraniidae, and Geometridae from the Palaearctic and IndoAustralian Regions. Novitates Zoologicae 8: 190-201.
Warren W (1901) Drepanulidae, Uraniidae, and Geometridae from the Palaearctic and IndoAustralian Regions. Novitates Zoologicae 8: 190-201.
Warren W (1914) New species of Drepanulidae, Noctuidae and Geometridae in the Tring Museum. Novitates Zoologicae 21: 401-425.
Warren W (1922-1928) Family: Drepanidae. In: Seitz A (Ed.) The Macrolepidoptera of the World. Vol. 10: Bombyces and Sphinges of the Indo-Australian Region. Alfred Kernen, Stuttgart, 443-490, pls. 48-50.
Wu CG, Han HX, Xue DY (2010) A pilot study on the molecular phylogeny of Drepanoidea (Insecta: Lepidoptera) inferred from the nuclear gene EF-1a and the mitochondrial gene COI. Bulletin of Entomological Research 100: 207-216. doi: 10.1017/S0007485309990162

Yan SH, Chen YL, Wu SW (2009) Biota Taiwanica. Hexapoda: Lepidoptera, Drepanoidea, Drepanidae (Cyclidiinae). National Sun Yat-Sen University, Kaohsiung, 10 pp.
Yen SH, Robinson GS, Quicke DLJ (2005) The phylogenetic relationships of Chalcosiinae (Lepidoptera, Zygaenoidea, Zygaenidae). Zoological Journal of the Linnean Society 143: 161-341. doi: 10.1111/j.1096-3642.2005.00139.x
Yang Z, Landry JF, Handfield L, Zhang Y, Alma Solis M, Handfield D, Scholtens BG, Mutanen M, Nuss M, Hebert PDN (2012) DNA barcoding and morphology reveal three cryptic species of Anania (Lepidoptera: Crambidae: Pyraustinae) in North America, all distinct from their European counterpart. Systematic Entomology 37: 686-705. doi: 10.1111/j.1365-3113.2012.00637.x

Zhou TY, Wang LY (1985) A preliminary study on Cycidia substigmaria. Chinese Bulletin of Entomology 22 (3): 113-116. [In Chinese]

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Odalisca Breedy ${ }^{1,2}$, Hector M. Guzman²<br>I Centro de Investigación en Estructuras Microscópicas, Centro de Investigación en Ciencias del Mar y Limnología, Universidad de Costa Rica. P.O. Box 11501-2060, Universidad de Costa Rica, San José, Costa Rica 2 Smithsonian Tropical Research Institute, P.O. Box 0843-03092, Panama, Republic of Panama<br>Corresponding author: Odalisca Breedy (odaliscab@gmail.com)

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Several errors came to our attention after our manuscript was published, which we address here. First, Figure 9 corresponds to the colour plate under Figure 10; Figure 10 corresponds to the SEM plate under Figure 9. Second, Figure 13 corresponds to the SEM plate under Figure 14. Third, Figure 14 is a new plate that was missing. Finally "Figure 12" that is written under Genus Swiftia Duchassaing \& Michelotti, 1864, in page 21 is a typo.

The correct, whole Figures and captions are reproduced here below.


Figure 9. Muricea tubigera Verrill, 1869a YPM 807. A Colony B Detail of branches C Sclerites, light micrograph.


Figure 10. Muricea tubigera Verrill, 1869a YPM 807. A, B Calycular and coenenchymal spindles C, D Axial sheath spindles.


Figure 13. Astrogorgia splendens (Thomson \& Simpson, 1909), BM 1933.05.03.094. SEM sclerites.


Figure 14. Leptogorgia ruberrima (W. Koch, 1886), BM 1933-03-13-024. A Fragment of the holotype B Sclerites, light micrograph C SEM sclerites.

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