ZooKeys 534: 1–16 (2015)
doi: 10.3897/zookeys.534.5961
http://zookeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

# Eriophyoid mites (Acari, Eriophyoidea) associated with tea plants, with descriptions of a new genus and two new species

Xiao Han[1], Yun Zuo[1], Xiao-Feng Xue[1], Xiao-Yue Hong[1]

1 *Department of Entomology, Nanjing Agricultural University, Nanjing, Jiangsu 210095, China*

Corresponding author: *Xiao-Yue Hong* (xyhong@njau.edu.cn)

Academic editor: *E. de Lillo* | Received 28 December 2014 | Accepted 28 September 2015 | Published 11 November 2015

*http://zoobank.org/8B32CB6A-4622-4696-AE19-95E0DB69E5C7*

**Citation:** Han X, Zuo Y, Xue X-F, Hong X-Y (2015) Eriophyoid mites (Acari, Eriophyoidea) associated with tea plants, with descriptions of a new genus and two new species. ZooKeys 534: 1–16. doi: 10.3897/zookeys.534.5961

## Abstract

A new genus and two new species of mites in the family Eriophyidae, *Theaphyes rapaneae* **gen. n.** and **sp. n.** which is found on the type host *Rapanea neriifolia* (Sieb. et Zucc.) Mez (Myrsinaceae) and *Paracaphyllisa theacea* **sp. n.**, are described and illustrated. They are vagrants on the tea plant *Camellia sinensis* (L.) Kuntze and no apparent symptoms were detected. A key to the eriophyoid mites including thirteen species associated with tea plants all over the world is provided.

## Keywords

Prostigmata, *Camellia* spp., Theaceae, taxonomy, Yunnan Province, China

## Introduction

Tea plants (*Camellia*) are perennial evergreen plants in the family Theaceae. They constitute a highly diverse taxon, presently composed of approximately 625 species (The Plant List on-line database 2013), distributed especially in tropical and subtropical areas. Some of these plant species are of extreme socio-economic importance.

Eriophyoid mites (Acari: Prostigmata) have a worldwide distribution. Eriophyoidea is a large mite superfamily with more than 4,000 described species (Zhang et al. 2011). They are strictly phytophagous, many of them can have the pest status in agricultural systems and are considered the second most economically important group of mite plant pests (Lindquist et al. 1996a). Nearly 80% have been reported on a single host species, 95% on one host genus and 99% on one host family (Skoracka et al. 2010).

Between 2009 and 2013, field investigations were conducted in southern part of China in order to look for eriophyoids on tea plants, leading to the discovery of a new genus and two new species. It is worth noting that the new genus and the new species were also found on the type host *Rapanea neriifolia* (Sieb. et Zucc.) Mez (Myrsinaceae).

Along with the current new records, thirteen species have been reported from tea plants worldwide (Table 1). They infest leaves in most cases, occasionally buds, stems and flowers. Some species can cause great economic loss to tea plants. This is the case of *Acaphylla theae* (Watt), a major pest all over the world, inducing leaf russeting, and *Calacarus carinatus* (Green), which causes bronzing and white cast skin streaks on both leaf surfaces. This paper describes the new genus and species, summarizes the main information on the eriophyoid mites found until now on tea plants, and provides a key to these mite species.

## Material and methods

Plants were examined in field by the aid of hand-lens (30×) and eriophyoids, together with parts of their host plants, were placed in vials and stored in 75% ethanol. Each vial was marked with the collection data and herbaria were prepared for future identification of plant samples.

In the laboratory, the liquid contents were poured into a Petri dish from the vials, mite specimens were picked up using a fine pin and slide-mounted using Keifer's Booster and modified Berlese medium (Amrine and Manson 1996). Specimens were examined under a Zeiss A2 (Germany) research microscope equipped with phase contrast (A-plan phase objectives: ×10/0.25, ×20/0.45; EC plan-NEOFLUAR phase objectives: ×40/0.75; ×100/1.3 oil immersion) and drawings were made by camera Lucida. Images were taken with the same microscope (under 100× oil immersion with 10× eyepieces) using an Axio Cam MRc (Carl Zeiss) system, connected to a computer and using Axiovision image analysis software. The morphological terminology follows Lindquist (1996b) and Amrine et al. (2003), and the generic classification was made according to Amrine et al. (2003). The genera elevated after 2003 were arranged in the list by us. Specimens were measured according to de Lillo et al. (2010). For each species, the holotype female measurements precede the corresponding range for paratypes (given in parentheses). All measurements are in micrometers (μm) and are lengths when not otherwise specified. All type specimens are deposited as slide mounted specimens in the Arthropod/Mite Collection of the Department of Entomology, Nanjing Agricultural University (NJAU), Jiangsu Province, China.

**Table 1.** Eriophyoid mites associated with tea trees around the world.

| Family | Subfamily | Tribe | Species |
|---|---|---|---|
| Eriophyidae | Cecidophyinae | Colomerini | *Cosetacus camelliae* (Keifer, 1945) |
| | | | *Theaphyes rapaneae* **gen. *et* sp. n.** |
| | Nothopodinae | Colopodacini | *Paracolopodacus camelliae* Kuang & Huang, 1994 |
| | Phyllocoptinae | Acaricalini | *Acaphyllisa indiae* (Keifer, 1954) |
| | | | *Acaphyllisa parindiae* Keifer, 1978 |
| | | | *Acaphylla theae* (Watt, 1898) |
| | | | *Acaphylla theavagrans* Kadono, 1992 |
| | | | *Paracaphyllisa theacea* sp. n. |
| | | Calacarini | *Calacarus carinatus* (Green, 1890) |
| | | Tegonotini | *Phyllocoptacus camelliae* Kuang & Lin, 2005 |
| | | | *Shevtchenkella camelliae* Song, Xue & Hong, 2008 |
| | | Phyllocoptini | *Tergilatus camelliae* Wei, Feng & Huang, 1999 |
| Diptilomiopidae | Diptilomiopinae | | *Diptilomiopus camelliae* Wang & Chen, 2013 |

Host plant names and their synonymies are in accordance with The Plant List (http://www.theplantlist.org/). Data on eriophyoid mites were extracted from the catalogue by Davis et al. (1982), Amrine and Stasny (1994) and from the computerized catalog of the Eriophyoidea (Amrine and de Lillo, pers. comm.); a further record was added based on the searching made on the most common abstract indexes. When available, the following information was summarized for each listed eriophyoid species based on literature: a) previous genus name assignment and possible synonymies; b) information about the host plant species; c) documenting relationships between eriophyoid species and host plants based on literature; d) distribution within geographic realms according to Udvardy (1975); e) the most relevant remarks.

## Results

Thirteen eriophyoid mite species in eleven genera of two eriophyoid families have been reported from tea plants around the world (Table 1) and a key to eriophyoid mites on tea plants is provided below.

### *Theaphyes* gen. n.

http://zoobank.org/7929EC1E-07C5-47E5-AA24-D67734AC5E6D

**Type species.** *Theaphyes rapaneae* sp. n.

**Diagnosis.** Body fusiform; scapular tubercles placed ahead of rear shield margin and scapular setae projecting upwards; frontal shield lobe absent. All coxal setae present; antaxial genual seta absent from leg II; tarsal solenidion slightly knobbed, located below empodium; empodium entire. Opisthosoma with a wide dorsal furrow; all usual opisthosoma setae present with the exception of setae *e* and *h1*; female genital cover flap appressed to coxal plates.

**Etymology.** The genus designation is the combination of *Thea*- and -*phyes*; *Thea*- is derived from the family name of the host plant, -*phyes* is derived from the type genus *Eriophyes* in the family Eriophyidae. The gender is feminine.

**Remarks.** The new genus is assigned to the Family Eriophyidae, Subfamily Cecidophyinae, Tribe Colomerini. It is similar to *Epicecidophyes clerodendris* Mondal & Chakrabarti, 1981, but can be differentiated from the latter by the absence of opisthosomal setae *e* (setae *e* are present in *Epicecidophyes*) and by a wide furrow on the dorsal opisthosoma (a broad middorsal ridge is on the dorsal opisthosoma of *Epicecidophyes*). The tarsal solenidion is located below the empodium similarly to *Catachela machaerii* Keifer, 1969, *Dechela epelis* Keifer, 1965 and *Dechela phoebe* Wang, Han, Xue & Hong, 2014.

### ***Theaphyes rapaneae*** **sp. n.**

http://zoobank.org/B7A8BE17-72C9-4524-BFB9-2E2C7CFBCE86
Fig. 1

**Description.** FEMALE: (n = 9, ventral-dorsal position on slides). Body fusiform, white, 152 (152–153), 80 (80–85) wide. **Gnathosoma** 19 (19–20), projecting obliquely downwards, pedipalp coxal setae (*ep*) 2 (2–3), dorsal pedipalp genual setae (*d*) 8 (7–8), cheliceral stylets 20 (19–20). **Prodorsal shield** 58 (57–58), 80 (80–82) wide, admedian lines complete curving mesally at their posterior ends; frontal shield lobe absent. Scapular tubercles ahead of rear shield margin, 25 (24–25) apart, scapular setae (*sc*) 2 (2–3), projecting upward. **Coxigenital region** with 5 (5–6) semiannuli between coxae and genitalia. Coxal plates with a few short lines, anterolateral setae on coxisternum I (*1b*) 7 (6–7), 15 (15–16) apart, proximal setae on coxisternum I (*1a*) 11 (10–11), 14 (14–15) apart, proximal setae on coxisternum II (*2a*) 12 (12–15), 33 (32–33) apart. Prosternal apodeme absent. **Leg I** 27 (26–27), femur 11 (10–11), basiventral femoral setae (*bv*) 5 (5–6); genu 3 (2–3), antaxial genual setae (*l"*) 21 (20–21); tibia 3 (2–3), paraxial tibial setae (*l'*) 4 (4–5), located at 2/3 from the dorsal base; tarsus 7 (6–7), paraxial, fastigial, tarsal setae (*ft'*) 15 (15–16), antaxial, fastigial, tarsal setae (*ft"*) 18 (18–20), paraxial, unguinal, tarsal setae (*u'*) 4 (4–5); tarsal empodium (*em*) 5 (4–5), simple, 5-rayed, tarsal solenidion (*ω*) 5 (5–6), slightly knobbed, located below empodium. **Leg II** 20 (20–21), femur 10 (10–11), basiventral femoral setae (*bv*) 6 (6–7); genu 3 (2–3), antaxial genual setae (*l"*) absent; tibia 2 (2–3); tarsus 7 (6–7), paraxial, fastigial, tarsal setae (*ft'*) 3 (3–4), antaxial, fastigial, tarsal setae (*ft"*) 18 (17–18), paraxial, unguinal, tarsal setae (*u'*) 4 (3–4); tarsal empodium (*em*) 5 (4–5), simple, 5-rayed, tarsal solenidion (*ω*) 7 (7–8), little knobbed, located below empodium. **Opisthosoma** dorsally with 26 (26–29) semiannuli, smooth, with a wide furrow, ventrally

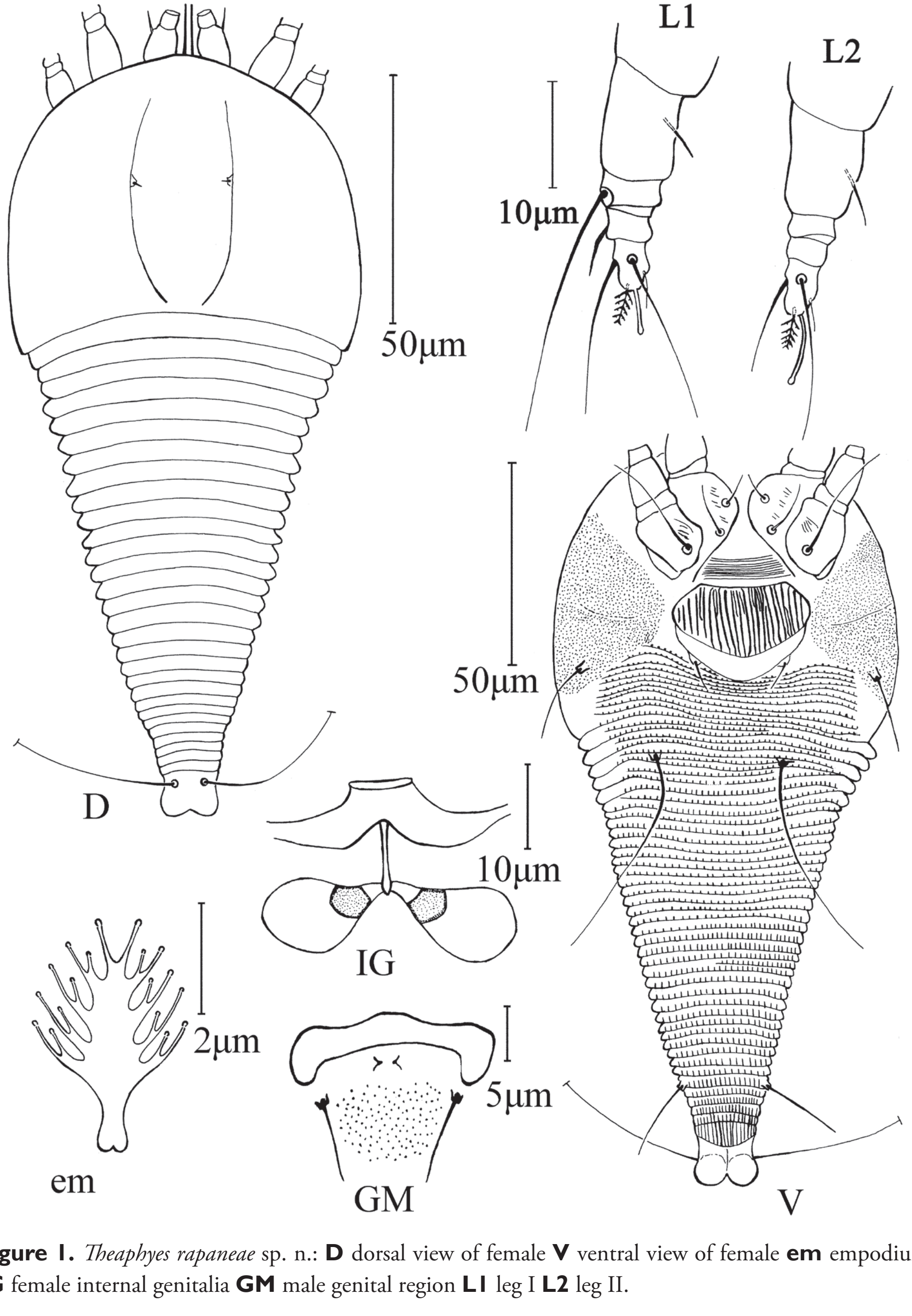


**Figure 1.** *Theaphyes rapaneae* sp. n.: **D** dorsal view of female **V** ventral view of female **em** empodium **IG** female internal genitalia **GM** male genital region **L1** leg I **L2** leg II.

with 54 (52–54) semiannuli, with linear microtubercles. Setae *c2* 19 (18–19) on ventral semiannulus 6 (6–7), 85 (80–85) apart; setae *d* 35 (34–35) on ventral semiannulus 21 (20–21), 32 (30–32) apart; setae *e* absent, setae *f* 15 (15–16) on

5th–6th ventral semiannulus from rear, 20 (20–21) apart. Setae *h1* absent, *h2* 50 (50–60). **Genital coverflap** 20 (18–20), 38 (38–39) wide, coverflap with 22–23 longitudinal ridges in one rank, some ridges not complete, setae *3a* 6 (5–6), 24 (18–24) apart.

MALE: (n = 4, ventral-dorsal position on slides). 142 (142–145), 69 (69–70) wide; white. **Gnathosoma** 19 (18–19), projecting obliquely downwards, pedipalp coxal setae (*ep*) 2 (1–2), dorsal pedipalp genual setae (*d*) 6 (5–6), cheliceral stylets 17 (16–17). **Prodorsal shield** 53 (53–54), 65 (65–70) wide, admedian lines complete curving mesally at their posterior ends; frontal shield lobe absent. Scapular tubercles ahead of rear shield margin, 22 (22–24) apart, scapular setae (*sc*) 3 (2–3), projecting upward. **Coxigenital region** with 5 (5–6) semiannuli between coxae and genitalia. Coxal plates with a few short lines, anterolateral setae on coxisternum I (*1b*) 5 (5–6), 10 (10–12) apart, proximal setae on coxisternum I (*1a*) 7 (7–8), 14 (12–14) apart, proximal setae on coxisternum II (*2a*) 10 (10–11), 27 (27–28) apart. Prosternal apodeme absent. **Leg I** 20 (20–21), femur 12 (11–12), basiventral femoral setae (*bv*) 5 (5–6); genu 3 (2–3), antaxial genual setae (*l''*) 17 (17–18); tibia 3 (2–3), paraxial tibial setae (*l'*) 4 (4–5), located at 2/3 from the dorsal base; tarsus 5 (4–5), paraxial, fastigial, tarsal setae (*ft'*) 13 (13–14), antaxial, fastigial, tarsal setae (*ft''*) 17 (15–17), paraxial, unguinal, tarsal setae (*u'*) 4 (4–5); tarsal empodium (*em*) 5 (4–5), simple, 5-rayed, tarsal solenidion (*ω*) 5 (5–6), slightly knobbed, located below empodium. **Leg II** 18 (17–18), femur 9 (8–9), basiventral femoral setae (*bv*) 4 (4–6); genu 2 (2–3), antaxial genual setae (*l''*) absent; tibia 3 (3–4); tarsus 5 (4–5), paraxial, fastigial, tarsal setae (*ft'*) 4 (4–5), antaxial, fastigial, tarsal setae (*ft''*) 15 (14–15), paraxial, unguinal, tarsal setae (*u'*) 3 (3–4); tarsal empodium (*em*) 5 (4–5), simple, 5-rayed, tarsal solenidion (*ω*) 7 (7–8), slightly knobbed, located below empodium. **Opisthosoma** dorsally with 28 (26–28) semiannuli, smooth, with a wide furrow; ventrally with 51 (48–51) semiannuli, with linear microtubercles. Setae *c2* 12 (12–13) on ventral semiannulus 6 (5–6), 65 (64–69) apart; setae *d* 20 (18–22) on ventral semiannulus 16 (15–17), 27 (25–27) apart; setae *e* absent, setae *f* 14 (14–15) on 5th–6th ventral semiannulus from rear, 20 (18–20) apart. Setae *h1* absent, *h2* 52 (51–52). Genitalia 20 (20–21) wide, setae *3a* 5 (5–6), 15 (13–15) apart.

**Type host plant.** *Rapanea neriifolia* (Sieb. et Zucc.) Mez (Myrsinaceae)

**Other host plant.** *Camellia sinensis* (L.) Kuntze

**Relation to the host plant.** Vagrant. No damage to the host plant was observed.

**Type locality.** Nanling National Forest Park, Guangdong Province (24°53'50"N, 113°01'18"E), elevation 1,408 m, 31 July 2012, coll. Qiong Wang, Hao-Sen Li and Jing-Feng Guo.

**Type material.** Holotype, single female on a microscope slide (slide number NJAUAcariEriGD21.1; marked Holotype), from *R. neriifolia*. Paratypes, 4 females and 4 males mounted on separate microscope slides (slide number NJAUAcariEriGD21.2–NJAUAcariEriGD21.9), same collection data of the holotype.

**Other material.** 10 females mounted on separate microscope slides (slide numbers NJAUAcariEriYN304B.1–NJAUAcariEriYN304B.10), from *C. sinensis*.

**Etymology.** The specific designation *rapaneae* is the genitive case derived from the genus name of the type host plant, *Rapanea*.

**Remarks.** This species is found on the Myrsinaceae *R. neriifolia* and also on *C. sinensis*. Slight morphological differences were observed between the populations found on the two host species: the population on *C. sinensis* is longer, thinner and with more ventral annuli (62–66) than the population on *R. neriifolia* which is provided with fewer ventral annuli (52–54). The population found on *C. sinensis* occurred with other eriophyoid species and no males were collected. Current data do not allow understanding if the mite species colonizes regularly and successfully *C. sinensis* and it needs further biological studies.

### *Paracaphyllisa theacea* sp. n.

http://zoobank.org/AC45840F-0982-40F3-8897-CDD76B3FD531
Fig. 2

**Description.** FEMALE: (n = 8, ventral-dorsal position on slides). Body fusiform, 200 (190–200), 80 (75–80) wide; white. **Gnathosoma** 35 (32–35), projecting obliquely downwards, pedipalp coxal setae (*ep*) 3 (2–3), dorsal pedipalp genual setae (*d*) 9 (8–9), cheliceral stylets 40 (38–40). **Prodorsal shield** 50 (50–52), 75 (70–75) wide, median line absent, admedian and submedian lines sinuous; front shield lobe present 12 (11–12). Scapular tubercles ahead of rear shield margin, 37 (35–37) apart, scapular setae (*sc*) 4 (3–4), projecting anteriorly. **Coxigenital region** with 8 (8–9) semiannuli between coxae and genitalia, smooth. Coxal plates smooth, anterolateral setae on coxisternum I (*1b*) 10 (10–11), 14–15 apart, anterolateral setae on coxisternum I (*1a*) 15 (13–15), 12 (11–12) apart, proximal setae on coxisternum II (*2a*) 40 (35–40), 30 (30–31) apart. Prosternal apodeme absent. **Leg I** 37 (37–40), femur 15 (14–15), basiventral femoral setae (*bv*) 15 (15–16); genu 5 (4–5), antaxial genual setae (*l"*) 43 (42–43); tibia 8 (7–8), paraxial tibial setae (*l'*) 1, located at center; tarsus 8 (7–8), paraxial, fastigial, tarsal setae (*ft'*) 30 (29–30), antaxial, fastigial, tarsal setae (*ft"*) 33 (33–34), paraxial, unguinal, tarsal setae (*u'*) 6 (5–6); tarsal empodium (*em*) 5 (5–6), divided, 5-rayed, tarsal solenidion (*ω*) 12 (11–12), slightly knobbed. **Leg II** 34 (32–34), femur 12 (12–14), basiventral femoral setae (*bv*) 11 (10–11); genu 5 (4–5), antaxial genual setae (*l"*) absent; tibia 6 (5–6); tarsus 8 (7–8), paraxial, fastigial, tarsal setae (*ft'*) 9 (9–10), antaxial, fastigial, tarsal setae (*ft"*) 26 (26–27), paraxial, unguinal, tarsal setae (*u'*) 5 (4–5); tarsal empodium (*em*) 5 (5–6), divided, 5-rayed, tarsal solenidion (*ω*) 11 (11–12), slightly knobbed. **Opisthosoma** dorsally with 38 (37–38) semiannuli, smooth, with three ridges, ventrally with 62 (62–69) semiannuli, with rounded microtubercles. Setae *c2* 35 (33–35) on ventral semiannulus 15 (12–15), 60 (57–60) apart; setae *d* 70 (67–70) on ventral semiannulus 26 (25–27), 45 (43–45) apart; setae *e* 50 (50–52) on ventral semiannulus 41 (41–44), 20 (19–20) apart, setae *f* 23 (23–25) on 6th–7th ventral semiannulus from rear, 15 (15–16) apart. Setae *h1* absent, *h2* 55 (52–55). **Genital coverflap** 15 (15–16), 30 (29–30) wide, coverflap with 23 (18–23) longitudinal ridges and dense short lines at base, setae *3a* 14 (13–14), 20 (20–21) apart.

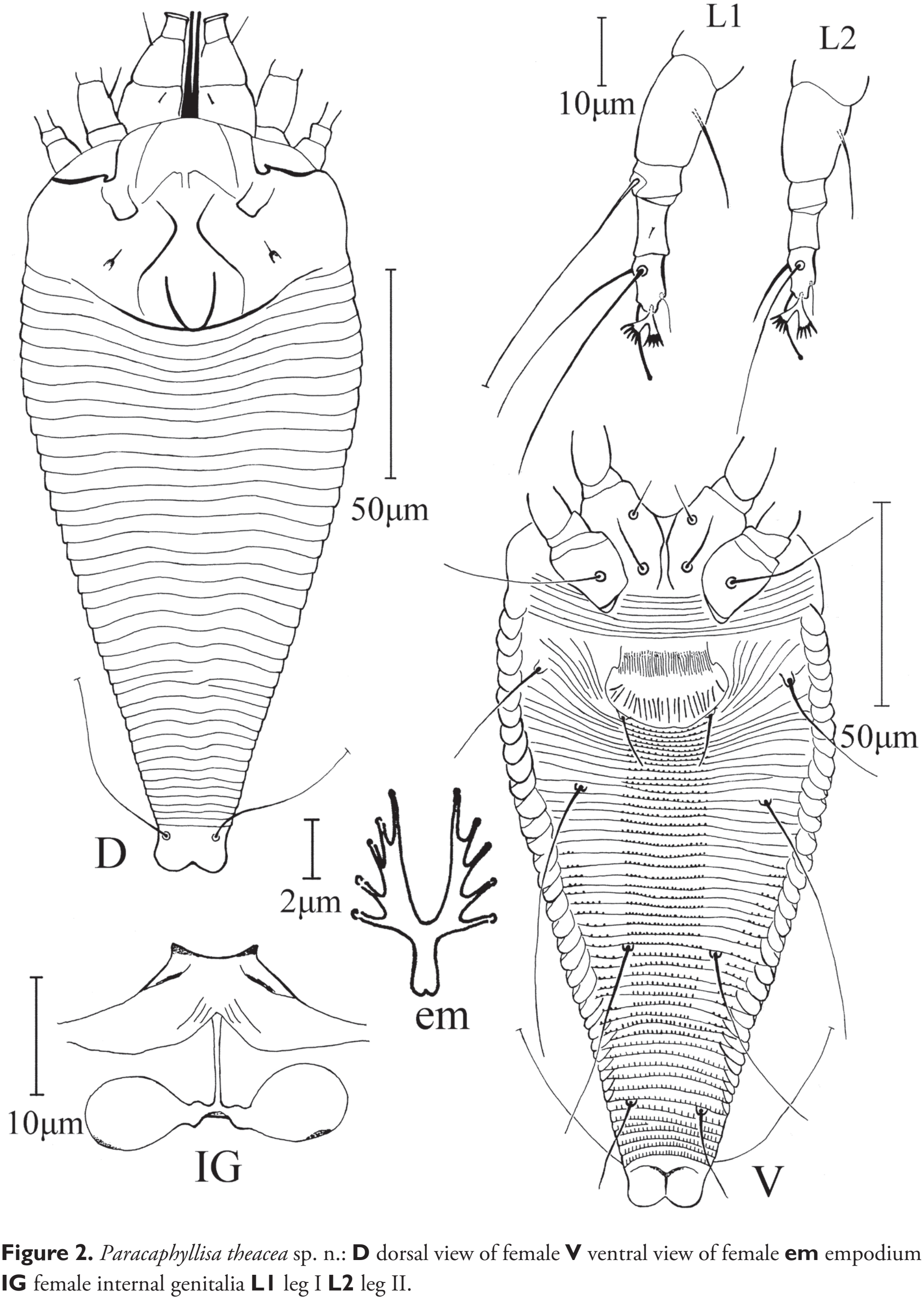


**Figure 2.** *Paracaphyllisa theacea* sp. n.: **D** dorsal view of female **V** ventral view of female **em** empodium **IG** female internal genitalia **L1** leg I **L2** leg II.

MALE: Unknown.

**Type host plant.** *Camellia sinensis* (L.) Kuntze

**Relation to the host plant.** Vagrant. No damage to the host plant was observed.

**Type locality.** Pihe Village, Fugong County, Nujiang Lisu autonomous prefecture, Yunnan Province (26°33'05"N, 98°55'08"E), elevation 2,122 m, 26 June 2013, coll. Xiao Han, Qiong Wang and Jing-Feng Guo.

**Type material.** Holotype, single female on a microscope slide (slide number NJAUAcariEriYN304C.1; marked Holotype). **Paratypes** 7 females mounted on separate microscope slides (slide number NJAUAcariEriYN304C.2–NJAUAcariEriYN304C.8).

**Etymology.** The specific designation *theacea* is derived from the family name of the host plant; feminine in gender.

**Differential diagnosis.** This new species is similar to *Paracaphyllisa adinandrae* Kuang & Luo, 2005, but can be differentiated from the latter by the design of prodorsal shield which is provided with admedian and submedian lines (prodorsal shield design of *P. adinandrae* has median, admedian and submedian lines), smooth coxal plates (coxal plates have short lines in *P. adinandrae*) and coverflap with 23 (18–23) longitudinal ridges and dense short lines at its base (coverflap is smooth in *P. adinandrae*).

**Remarks.** The new species is surrounded with white hairs around the body.

## Accounts of further species on *Camellia*

### *Acaphyllisa indiae* (Keifer, 1954)

*Acaphylla indiae*; Keifer 1954: 126.
*Acaphyllisa indiae*; Amrine and Stasny 1994: 14.

**Host.** *Camellia sinensis* (L.) Kuntze.

**Relation to the host plant.** Vagrant, causing leaf rusting.

**Distribution.** Indomalayan region.

### *Acaphyllisa parindiae* Keifer, 1978

*Acaphyllisa parindiae*; Keifer 1978: 15.

**Host.** *Camellia sinensis* (L.) Kuntze.

**Relation to the host plant.** Vagrant, causing leaf rusting.

**Distribution.** Indomalayan region.

### *Acaphylla theae* (Watt, 1898)

*Phytoptus theae* Watt, 1898
*Eriophyes theae* (Watt, 1903); Nalepa 1923: 46.
*Acaphylla theae*; Das and Sengupta 1958: 40 (synonym of *Acaphylla steinwedeni* Keifer, 1943).
*Acaphylla steinwedeni*; Keifer 1943: 215.
*Acaphylla steinwedeni*; Keifer 1954: 126.
*Acaphylla steinwedeni*; Keifer 1975: 545.
*Acaphylla steinwedeni*; Amrine and Stasny 1994: 13.
*Acaphylla steinwedeni*; Baker et al. 1996: 86.

**Host.** *Camellia japonica* L., *C. oleifera* Abel, *C. reticulata* Lindl., *C. sasanqua* Thunb., *C. sinensis* (L.) Kuntze, *C. sinensis* var. *assamica* (J.W. Mast.) Kitam.

**Relation to the host plant.** Vagrant. This species occurs on the undersurface of the leaves and is often associated with *Calacarus carinatus* (Green) (reported as *C. adornatus* (Keifer, 1940)). *Acaphylla steinwedeni* does not leave as much debris on the leaves as *C. carinatus*, but it may actually be more important as a rust mite. Both mite species overwinter on the leaves and show no deuterogyny.

**Distribution.** Australian, Nearctic, Indomalayan and Palaearctic regions.

**Remarks.** *Phytoptus theae* was reported infesting *C. sinensis* by Watt (1898) who provided a drawing and a short description of the mite, and described the injury on the tea plant. Many authors have wrongfully listed the mite as *Phytoptus theae* Watt & Mann, 1903, based on the more available publication. Improperly, Nalepa (1929) listed *P. theae* as a nude name. Keifer (1954) identified *A. steinwedeni* from specimens provided by Dr. Das and which were referred to have been the object of the name *P. theae*. Das and Sengupta (1958) made *A. steinwedeni* as junior synonym of *A. theae*, making this last one as the genotype of the genus *Acaphylla*. Finally, Amrine and Stasny (1994) listed *A. theae* as possible synonym (they marked the synonymy with a question mark) of *A. steinwedeni* without any further indication about it and the use of the names.

### *Acaphylla theavagrans* Kadono, 1992

*Acaphylla theavagrans*; Kadono 1992: 149–151.

**Host**. *Camellia sinensis* (L.) Kuntze.

**Relation to the host plant.** Vagrant, causing rust.

**Distribution.** Indomalayan region.

### *Calacarus carinatus* (Green, 1890)

*Typhlodromus carinatus* Green, 1890: 35.

*Eriophyes carinatus*; Nalepa 1923: 31.
*Epitrimerus adornatus*; Keifer 1940: 32.
*Calacarus carinatus*; Baker et al. 1996: 86.

**Host.** *Camellia caudata* Wallich, *C. sinensis* (L.) Kuntze, *C. kissi* Wallich, *C. japonica* L., *C. sasanqua* Thunb., *Capsicum annuum* L. (Solanaceae), *Viburnum opulus* L. (Adoxaceae).

**Relation to the host plant.** Vagrant, causing bronzing and leaving white cast skin streaks. Wax is produced on the five ridges and prodorsal shield.

**Distribution.** Africotropical, Australian, Indomalayan, Nearctic, Palaearctic regions.

**Remarks.** This free-living species leaves much debris on the host leaves and occurs on the leaves associated with *A. steinwedeni*. They both overwinter on the leaves and show no deuterogyny.

### *Cosetacus camelliae* (Keifer, 1945)

*Aceria camelliae*; Keifer 1945: 137–138.
*Cosetacus camelliae*; Amrine and Stasny 1994: 168.
*Cosetacus camelliae*; Baker et al. 1996: 86.

**Host.** *Camellia japonica* L., *Camellia* sp.

**Relation to the host plant.** Vagrant. The mite lives under leaf and flower buds, probably causing premature flower drop.

**Distribution.** Australian, Nearctic, Neotropic, Palaearctic regions.

### *Diptilomiopus camelliae* Wang & Chen, 2013

*Diptilomiopus camelliae*; Tan et al. 2013: 802–804.

**Host.** *Camellia caudata* Wallich.

**Relation to the host plant.** Vagrant. No damage to the host was observed.

**Distribution.** On the border between Palaearctic and Indomalayan regions.

### *Paracolopodacus camelliae* Kuang & Huang, 1994

*Paracolopodacus camelliae*; Kuang and Huang 1994: 229–230.

**Host.** *Camellia oleifera* Abel.

**Relation to the host plant.** Vagrant.

**Distribution.** On the border between Palaearctic and Indomalayan regions.

### ***Phyllocoptacus camelliae*** **Kuang & Lin, 2002**

*Phyllocoptacus camelliae*; Kuang and Lin 2002: 84–85.
*Phyllocoptacus camelliae*; Kuang et al. 2005: 51–52.

**Host.** *Camellia sinensis* (L.) Kuntze.

**Relation to the host plant.** Vagrant.

**Distribution.** On the border between Palaearctic and Indomalayan regions.

### ***Shevtchenkella camelliae*** **Song, Xue & Hong, 2008**

*Shevtchenkella camelliae*; Song et al. 2008: 48–49.

**Host.** *Camellia sinensis* (L.) Kuntze.

**Relation to the host plant.** Vagrant, causing no apparent damage to the host plant.

**Distribution.** On the border between Palaearctic and Indomalayan regions.

### ***Tergilatus camelliae*** **Wei, Feng & Huang, 1999**

*Tergilatus camelliae*; Wei et al. 1999: 144–146.

**Host.** *Camellia sinensis* (L.) Kuntze.

**Relation to the host plant.** Not stated.

**Distribution.** On the border between Palaearctic and Indomalayan regions.

### Key to eriophyoid mite species associated with tea plant

1 Gnathosoma small in comparison to the body, chelicerae straight or slightly curved........ **2**
– Gnathosoma large in comparison to the body, chelicerae abruptly curved and bent down near their base..... ***Diptilomiopus camelliae*** **Wang & Chen, 2013**
2 Tibiae reduced or completely fused with tarsi........ ***Paracolopodacus camelliae*** **Kuang & Huang, 1994**
– Tibiae distinct from tarsi........ **3**
3 Setae *e* absent........ **4**
– Setae *e* present........ **5**
4 Median line absent, admedian lines complete curving mesally at their posterior ends; frontal lobe absent. Scapular setae *sc* projecting upward. Empodium 5-rayed........ ***Theaphyes rapaneae*** **gen. et sp. n.**

– Median, admedian and submedian lines incomplete; frontal lobe present. Scapular setae *sc* projecting upward. Empodium 6-rayed .............................. ........................................ ***Tergilatus camelliae*** **Wei, Feng & Huang, 1999**

5 Female genital apodeme bent up and shortened, usually appearing as a heavy transverse line in ventral view, ridges on female coverflap in 2 uneven ranks... ................................................................. ***Cosetacus camelliae*** **(Keifer, 1945)**

– Female genital apodeme extending moderate distance forward, does not appear as a heavy transverse bar in ventral view, female coverflap smooth or variably sculptured.......................................................................................... **6**

6 Empodium entire ..................................................................................... 7

– Empodium divided..................................................................................... **9**

7 Scapular tubercles and setae *sc* absent...... ***Calacarus carinatus*** **Green, 1890**

– Scapular tubercles and setae *sc* present......................................................... **8**

8 Dorsal opisthosoma with anterior annuli fused forming a broad plate joined to prodorsal shield. Prodorsal shield with admedian and submedian lines, scapular tubercles ahead of rear shield margin, scapular setae *sc* projecting upward. Leg II without genual setae (*l”*), tarsal empodium 6-rayed. Coverflap smooth ................................ ***Phyllocoptacus camelliae*** **Kuang & Lin, 2005**

– Dorsal opisthosoma without fused annuli forming a plate. Prodorsal shield smooth, scapular tubercles on rear shield margin, scapular setae *sc* projecting posteriorly. Leg II with usual setae, tarsal empodium 7-rayed. Coverflap with 14 longitudinal ridges.......................................................................... .................................. ***Shevtchenkella camelliae*** **Song, Xue & Hong, 2008**

9 Coxal setae *1b* absent.................................................................................. **10**

– Coxal setae *1b* present.................................................................................. **11**

10 Coxal area with short lines, prodorsal shield with median line present on the posterior 2\5 and 4\5, frontal lobe bilobed, coxae smooth ............................ ................................................................................. ***Acaphylla theae*** **(Watt, 1898)**

– Coxal area smooth, prodorsal shield with median line absent, frontal lobe not as above, coxae with granules ........... ***Acaphylla theavagrans*** **Kadono, 1992**

11 Genual II setae (*l”*) absent.......................................................................... **12**

– Genual II setae (*l”*) present; prodorsal shield without median line, admedian lines with short recurving sections, meeting cross lines at 1/4 and 2/3, tarsal empodium 3-rayed .............................. ***Acaphyllisa parindiae*** **Keifer, 1978**

12 Prodorsal shield with median line complete, submedian lines curving from the median and forming a double loop between the dorsal tubercles, prodorsal shield laterally with a broad lobe over the coxae. Leg II with femoral seta *(bv)* absent, tarsal empodium 8-rayed ........ ***Acaphyllisa indiae*** **Keifer, 1954**

– Prodorsal shield without median line, submedian lines not as above, prodorsal shield laterally without a broad lobe over the coxae. Leg II with femoral seta *(bv)* present, tarsal empodium 5-rayed .... ***Paracaphyllisa theacea*** **sp. n.**

## Acknowledgements

This research was funded by the National Natural Science Foundation of China (No. 31172132). We thank Jing-Feng Guo of NJAU for reviewing an earlier draft of this manuscript. We are very grateful to JW Amrine Jr for valuable comments on the manuscript.

## References

Amrine JW Jr, Manson DCM (1996) Preparation, mounting and descriptive study of eriophyoid mites. In: Lindquist EE, Sabelis MW, Bruin J (Eds) Eriophyoid Mites: Their Biology, Natural Enemies and Control. Elsevier, World Crop Pests 6, Elsevier Science Publishers, Amsterdam Netherlands, 383–396. doi: 10.1016/S1572-4379(96)80023-6

Amrine JW Jr, Stasny TA (1994) Catalog of the Eriophyoidea (Acarina: Prostigmata) of the world. Indira Publishing House, West Bloomfield, Michigan, USA, 804 pp.

Amrine JW Jr, Stasny TA, Flechtmann CHW (2003) Revised keys to world genera of Eriophyoidea (Acari: Prostigmata). Indira Publishing House, West Bloomfield, Michigan, USA, 244 pp.

Baker EW, Kono T, Amrine JW Jr, Delfinado-Baker M, Stasny TA (1996) Eriophyoid mites of the United States. Indira Publishing House, West Bloomfield, Michigan, USA, 394 pp.

Das GM, Sengupta N (1958) Observations on the pink mite, *Acaphylla theae* (Watt) Keifer, of tea in north-east India. Journal of Zoological Society, India 10: 39–48.

Davis R, Flechtmann CHW, Boczek JH, Barke HE (1982) Catalogue of Eriophyid Mites (Acari, Eriophyoidea). Warsaw Agricultural University Press, Warsaw, Poland, 254 pp.

de Lillo E, Craemer C, Amrine JW Jr, Nuzzaci EG (2010) Recommended procedures and techniques for morphological studies of Eriophyoidea (Acari: Prostigmata). Experimental and Applied Acarology 51(1–3): 283–307. doi: 10.1007/s10493-009-9311-x

Green EE (1890) Insect Pests of the tea plant. Colombo, Ceylon, 85 pp.

Kadono F (1992) A new species of eriophyid mite injurious to tea plant in Japan (Acari: Eriophyidae). Acta Arachnologica 41(2): 149–152. doi: 10.2476/asjaa.41.149

Keifer HH (1940) Eriophyid Studies VIII. Bulletin of the California Department of Agriculture 29: 21–46.

Keifer HH (1943) Eriophyid Studies XIII. Bulletin of the California Department of Agriculture 32: 212–222.

Keifer HH (1945) Eriophyid Studies XV. Bulletin of the California Department of Agriculture 34: 137–140.

Keifer HH (1954) Eriophyid Studies XXII. Bulletin of the California Department of Agriculture 43: 121–131.

Keifer HH (1965) Eriophyid Studies B-13. Bulletin of the California Department of Agriculture, 1–20.

Keifer HH (1969) Eriophyid Studies C-2. Agriculture Research Service-United State Department of Agriculture, 1–20.

Keifer HH (1975) Injurious eriophyoid mites. In: Jeppson LR, Keifer HH, Baker EW. Mites injurious to economic plants. University California Press, Berkeley, California, USA, 327–561.

Keifer HH (1978) Eriophyid Studies C-15. Agriculture Research Service-United State Department of Agriculture, 1–24.

Kuang HY, Huang LW (1994) A new genus and two new species of Eriophyidae from China (Acari: Eriophyoidea). Acta Entomologica Sinica 37(2): 229–232.

Kuang HY, Luo GH, Wang AW (2005) Fauna of eriophyid mites from China (II) (Acari: Eriophyoidea). China Forestry Publishing House, Beijing, China, 176 pp.

Kuang HY, Lin JZ (2002) A new species of pest mite on tea in China *Phyllocoptacus camelliae* Kuang & Lin sp. n. (Acari: Eriophyoidea). Journal of Tea 28(2): 84–85. [In Chinese, with English abstract]

Lindquist EE (1996a) Evolution of Eriophyoid mites in relation to their host plants. In: Lindquist EE, Sabelis MW, Bruin J (Eds) Eriophyoid mites: their biology, natural enemies and control. Elsevier, World Crop Pests, 6, Elsevier Science Publishers, Amsterdam, Netherlands, 277–300. doi: 10.1016/S1572-4379(96)80018-2

Lindquist EE (1996b) External anatomy and notation of structures. In: Lindquist EE, Sabelis MW, Bruin J (Eds) Eriophyoid mites: their biology, natural enemies and control. World Crop Pests, 6, Elsevier Science Publishers, Amsterdam, Netherlands, 3–31. doi: 10.1016/S1572-4379(96)80003-0

Mondal S, Chakrabarti S (1981) Studies on eriophyid mites (Acarina: Eriophyoidea) of India. X. New genus and new species from West Bengal. Oriental Insects 15(3): 313–319. doi: 10.1080/00305316.1981.10434400

Nalepa A (1923) Index nominum quae ab a. 1886 eriophyidarum generibus, speciebus et subspecibus imposita sunt. Conscriptus ab. Marcellia 20: 25–66.

Nalepa A (1929) Neuer Katalog der bisher Beschriebenen Gallmilben, ihrer Gallen und Wirtspflanzen. Marcellia 25: 67–183.

Skoracka A, Smith L, Oldfield G, Cristofaro M, Amrine JW Jr (2010) Host-plant specificity and specialization in eriophyoid mites and their importance for the use of eriophyoid mites as biocontrol agents of weeds. Experimental and Applied Acarology 51(1–3): 93–113. doi: 10.1007/s10493-009-9323-6

Song ZW, Xue XF, Hong XY (2008) One new genus and four new species of Phyllocoptinae (Acari: Eriophyoidea) from Fujian Province, southeastern China. Zootaxa 1894: 42–52.

Tan Z, Lu XQ, Tao LF, Chen ZJ, Wang GQ (2013) Four new species of the genus *Diptilomiopus* Nalepa from China (Acari, Eriophyoidea). Acta Zootaxonomica Sinica 38(4): 801–806.

The Plant List (2013) Version 1.1. Published on the Internet. http://www.theplantlist.org/

Udvardy MDF (1975) A Classification of the Biogeographical Provinces of the World. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland, 50 pp.

Wang Q, Han X, Xue XF, Hong XY (2014) Three new species of eriophyoid mites (Acari, Eriophyoidea) associated with Lauraceae in China. ZooKeys 406: 81–100. doi: 10.3897/zookeys.406.6897

Watt G (1898) The pests and blights of tea plant. Government Press, Calcutta, India, 400–408.

Watt G, Mann HH (1903) The pests and blights of the tea plant. 2nd ed. Office Supplement Government Printing, Calcutta, India, 368–371.

Wei SG, Feng YB, Huang NX (1999) Three new species of Phyllocoptinae (Acari: Eriophyidae) from China. Systematic and Applied Acarology 4: 143–147. doi: 10.11158/saa.4.1.21

Zhang ZQ, Fan QH, Pesic V, Smit H, Bochkov AV, Khaustov AA, Baker A, Wohltmann A, Wen T, Amrine JW Jr, Beron P, Lin J, Gabrys G, Husband R (2011) Order Trombidiformes Reuter, 1909. In: Zhang ZQ (Ed.) Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness. Zootaxa 3148: 129–138.

ZooKeys 534: 17–34 (2015)
doi: 10.3897/zookeys.534.6019
http://zookeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

# A new genus and species of cyclopoid (Crustacea, Copepoda, Cyclopinidae) from a coastal system in the Gulf of Mexico

Eduardo Suárez-Morales[1], Roberto Javier Almeyda-Artigas[2]

[1] *El Colegio de la Frontera Sur (ECOSUR), Unidad Chetumal, A.P. 424, Chetumal 77014, Quintana Roo,Mexico* [2] *Universidad Autónoma Metropolitana- Xochimilco, Departamento El Hombre y su Ambiente, Mexico, D.F., Mexico*

Corresponding author: *Eduardo Suárez-Morales* (esuarez@ecosur.mx)

Academic editor: *D. Defaye* | Received 15 April 2015 | Accepted 8 October 2015 | Published 11 November 2015

*http://zoobank.org/A8F196E3-4C82-4B0D-8264-95069311CE9A*

**Citation:** Suárez-Morales E, Almeyda-Artigas RJ (2015) A new genus and species of cyclopoid (Crustacea, Copepoda, Cyclopinidae) from a coastal system in the Gulf of Mexico. ZooKeys 534: 17–34. doi: 10.3897/zookeys.534.6019

## Abstract

A new, monotypic genus of the interstitial marine cyclopoid copepod family Cyclopinidae G.O. Sars, 1913 is described from male and female specimens collected at Laguna de Términos, a large coastal lagoon system in the southern Gulf of Mexico. *Mexiclopina campechana* **gen. et sp. n.** cannot be adequately placed in any extant genus within the family. It differs from other cyclopinid genera in having a unique combination of characters including: 1) absence of modified brush-like seta on the mandibular exopod; 2) maxillule exopod with stout setal elements and brush-like setae absent; 3) basis of mandible with one seta; 4) presence of a modified seta on endopod of fourth leg; 5) fifth leg exopod unsegmented, armed with three elements in the female and five in the male; 6) intercoxal sclerite of first swimming leg with two medial spiniform processes on distal margin. The new genus is monotypic and appears to be most closely related to *Cyclopina* Claus, 1863 and *Heptnerina* Ivanenko & Defaye, 2004; the new species was compared with species of *Cyclopina* and it resembles *C. americana* Herbst, 1982 and *C. caissara* Lotufo, 1994. This is the second record of a species of Cyclopinidae in Mexico and the first in the Gulf of Mexico; the number of cyclopinid species recorded from the Americas is now 13.

## Keywords

Free-living copepods, coastal zooplankton, taxonomy, interstitial copepods

## Introduction

The cyclopoid copepod family Cyclopinidae G.O. Sars, 1913 is one of the most diverse and successful among the benthic marine poecilostomatoid/cyclopoid copepods. It contains 12 valid genera (Boxshall and Halsey 2004; Boxshall 2015). Members of this family occupy a wide range of habitats, having been reported from shallow coastal environments (Reid 1990; Lotufo 1994; Karanovic 2008), anchialine caves (Jaume and Boxshall 1996a), and deep-sea hydrothermal vents (Ivanenko and Defaye 2004). Its knowledge in the Americas is still developing, but it is clear that its diversity has been more studied in South America than in the other subcontinents (Nicholls 1939; Lotufo and Rocha 1991; Lotufo 1994; Rocha and Botelho1998). Only one species of the diverse and widespread genus *Cyclopina*, *C. caissara* Lotufo, 1994 has been recorded in Mexico and Central America (Reid 1990; Gómez and Martínez-Arbizu 2004) and nine in South America, mainly in Brazil (Lotufo and Rocha 1991; Lotufo 1994; Rocha and Botelho 1998). Overall, the knowledge of the cyclopinid copepod diversity in this kind of habitats is still lagging and certainly deserves further taxonomic research, particularly in the Northwestern Atlantic region.

Laguna de Términos, in the Mexican state of Campeche, in the southern Gulf of Mexico (between 18°26’ and 18°44’N; 91°13’ and 91°54’W) is one of the largest lagoon estuarine ecosystems of the gulf; it has a significant ecological and economic importance in southeastern Mexico because of its permanent connection to the sea and high productivity and diverse fish fauna (Yáñez-Arancibia and Day 1982; Ramos-Miranda et al. 2006). Copepods have been investigated but only those of the plankton community (Salas-Marmolejo 1981). As part of a study to know the helminth fauna of this coastal system and the role played by invertebrates and vertebrates as intermediate, “transport”, “carrier”, paratenic or definitive hosts, night samples were obtained at shallow areas of the lagoon where a mixture of plankton and epibenthic or interstitial copepods was likely to be collected. Our samples contained a new genus and species of the family Cyclopinidae which is herein fully described and illustrated based on male and female specimens.

## Methods

Night zooplankton samples were obtained on February 13, 2015 with three hand nets (two of 100 and one of 200 µm) in shallow areas (depth: 60–120 cm) of the lagoonal system, particularly at Isla Tortuga (18°44'29.3"N; 91°29'44.6"W). Water temperature was 25 °C, salinity 28psu, and pH slightly alkaline (7.5). Trawls followed a parallel course with respect to the coastline. Samples were placed in a bucket with 5 liters of water; copepods were isolated alive 5 hours after collection, they were later on fixed in 4% formaldehyde buffered with borax (30 g/l of formaldehyde at 40%) and kept in a 5% glycerin/ 70% ethanol solution. More than 35 male and female specimens were taxonomically examined in the laboratory; specimens were processed, dissected and examined following Reid (2003). Dissected specimens/appendages were mounted in semi-permanent slides with glycerine sealed with Entellan®, a commercial, fast drying mounting medium and sealant. Drawings were prepared at 1000× magnification with the aid of a camera lucida mounted on a standard Olympus CX31 compound microscope. Some specimens were prepared for SEM examination with a TOPCON SM-510 microscope at facilities of ECOSUR in Tapachula, Mexico. The process included dehydration of specimens in progressively higher ethanol solutions (60, 70, 80, 96, 100%), critical point drying, and gold-palladium coating (20 nm) following usual methods. This hitherto unknown genus and species was described and illustrated following the current standards for the taxonomic study of the group (Gómez and Martínez Arbizu 2004; Karanovic 2008). The type specimens were deposited in the collection of zooplankton held at El Colegio de la Frontera Sur (ECO-CH-Z), in Chetumal, Mexico and in the National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM). Original zooplankton samples containing more non-type specimens remain in the helminth collection of the Universidad Autónoma Metropolitana-Xochimilco, Mexico (CHUX), maintained by the co-author (RJAA).

## Results

### Order Cyclopoida Rafinesque, 1815
### Family Cyclopinidae G.O. Sars, 1913

### Genus *Mexiclopina* gen. n.

http://zoobank.org/CE58F654-7286-4B69-9671-9282D5DD69DF

**Type species.** *Mexiclopina campechana* sp. n.

**Etymology.** The genus name is composed by the prefix 'Mexi' in reference to Mexico, the country from which it was collected and the suffix 'clopina' to show its affinity with the genus *Cyclopina*.

**Diagnosis.** First pedigerous somite free, posterolateral margins of second and third pedigerous somites slightly produced. Caudal ramus with six setae, seta I absent. Female antennule 10-segmented, 6th segment longest; male antennule 15-segmented. Antenna with single exopodal seta. Mandibular palp with one basal seta, 2-segmented endopod and 4-segmented exopod; fourth exopodal segment with two ordinary setae. Maxillule endopod with seven setae, exopod with four short, stout elements. Maxilliped 6-segmented. Legs 1–4 with 3-segmented rami; spine and seta formula as for type species. Endopod segment 3 of leg 4 with modified outer seta. Female fifth leg exopod unsegmented, bearing three elements (setae/spines); male fifth leg exopod unsegmented, armed with five elements, three setae, two spines. Sixth leg with two setae in female, and with two setae plus short spiniform process in male.

### *Mexiclopina campechana* sp. n.

http://zoobank.org/D569F55D-9C92-41E5-842C-C711103C014D
Figs 1–6

**Material examined.** Holotype. Adult female, dissected, mounted in glycerin sealed with Entellan (ECO-CHZ-09298), Laguna de Términos, Campeche, Mexico (18°44'29.3"N;91°29'44.6"W), collected February 13, 2015 by R. J. Almeyda-Artigas, C. Lara-Bautista, and C. Chamorro-García. Allotype male, dissected, same site, date, and collectors (ECO-CHZ-09299). Paratypes. Two adult females, dissected, slides (ECO-CHZ-09300), 6 adult females, undissected, ethanol-preserved, vial (ECO-CHZ-09301); 3 adult males, undissected, ethanol-preserved, vial (ECO-CHZ-09302). One female, one male, specimens undissected, ethanol-preserved, same locality and collectors (USNM-1283307). One female and 2 males, all used for SEM analysis. Other material examined included +25 undissected adult and juvenile specimens, deposited at CHUX (G1106, G1107).

**Description of adult female.** Length range (including caudal rami) of type specimens (*n*=11) 350–400 µm, average: 372 µm. Body cyclopiform (Fig.1A), robust in dorsal view. Lateral margins of pedigers 3–5 produced posteriorly, with rounded margins. Posterior margins of pedigers 3 and 4 smooth in all specimens examined. Urosome 5-segmented. Posterior margin of urosomites with crenulated hyaline frill (Fig. 3A). Genital double-somite symmetrical (Figs 1A; 3A), broadest at anterior rounded half, slightly tapering posteriorly into straight margins, with pair of dorsal sensilla on posterior margin.

Anal somite with ventral and dorsal surfaces smooth, posterior margin ornamented with row of minute spinules along ventral margin at point of insertion of caudal rami. Anal operculum smooth. Caudal ramus (Fig. 1D) length/width ratio range: 1.17–1.20. Dorsal and ventral surface of caudal rami smooth except for row of spinules along posterior margin at insertion of caudal setae (Fig. 1D). Inner margin of caudal rami smooth. Rami with six setae; seta I absent; seta II inserted midway of outer margin; seta III shorter than seta VI, both lightly plumose; seta IV about 3.2 times as long as seta III, with heteronomous ornamentation, with spinules on proximal outer margin and with plumose distal half; proximal inner margin with few spinules, distal third plumose; seta V longest, about 1.5 times as long as seta IV, naked proximally, with few rigid spinules proximally and lightly plumose distally along both margins; dorsal seta VII as long as seta II, about twice as long as ramus (Fig. 1D). Rostrum wide, tapering distally into pointed tip.

*Antennule* (Fig.1B): 10-segmented. Surface of segments smooth except for short curved comb of 7-8 spinules placed proximally on first segment. Armature of antennule segments indicating ancestral segmentation (in Roman numerals), with number of setae (Arabic numerals), and aesthetascs (aes) in parentheses: 1(I-II)(3), 2(III-V)(5), 3(VI-IX)(8), 4(X-XI)(4), 5(XII-XIV)(6), 6(XV-XX)(6+ae), 7(XXI-XXII)(2+ae), 8(XXIII-XXV)(3), 9(XXVI)(2), 10(XXVI-XXVIII)(7+ae).

*Antenna* (Fig.1C): 4-segmented, fused coxa and basis cylindrical, with long lightly setulose basal seta on outer margin and slender, short inner exopodal seta (exp in Fig. 1C). Endopod 3-segmented. First endopodal segment cylindrical, about twice as long as succeeding second segment, with long medial seta reaching distal margin of second endopodal segment; segment ornamented with patch of spinules around insertion of seta. Second endopodal segment with patch of spinules on proximal position. Setation formula of endopodal segments 1-3 as: 1, 5, 6.

*Mandible* (Fig. 2A): with robust gnathobase armed with long setulose seta. Gnathal blade with 7 teeth plus short, uniserially pinnate dorsal seta; row of spinules at base of medial teeth. Basis with long seta plus row of spinules on inner margin. Exopod 4-segmented, armed as 1,1,1,2, surface of segments smooth; apical seta being longest of exopodal setae; distal brush not observed. Fourth segment slightly longer than preceding two exopodal segments. Endopod 2-segmented, setal formula 3, 5; inner margin of proximal segment with row of setules.

*Maxillule* (Figs 2B; 5B): with well-developed precoxal arthrite armed with 9 setae/spines. Coxal epipodite represented by two unequal setae; coxal endite knob-like, armed with long seta. Appendage with two basal endites, proximal with three, distal with two setae. Endopod rounded, unsegmented, armed with 7 setae; exopod subrectangular, unsegmented, with 4 apical, relatively short stout setae (asterisks in Fig. 2B).

*Maxilla* (Fig. 2C): 5-segmented, syncoxal endites with setal formula as 3,1,3,3. Basis with robust claw and two pinnate setae; endopod 3-segmented, first and second segments with three and two setae, respectively, third with 4.

*Maxilliped* (Figs 2D; 5B): slender, 6-segmented, precoxa and coxa fused forming syncoxal segment with three endites; proximal endite with single seta, second with 3 unequal setae, third endite ornamented with cluster of cuticular scales, armed with two long, subequal stout setae. Basis expanded distally, medial margin ornamented with row of long, stiff setules, and with two subdistal setae. Endopod 4-segmented; first and second segments naked, third segment with one lightly plumose seta, fourth segment with four elements including two short plumose and two long, stout simple setae.

*Legs 1–4* (Fig. 3B-H): biramous, each with distinct coxa and basis and 3-segmented endopodal and exopodal rami. Outer margin of all segments finely serrate in both sexes (Fig. 5E). Spines on exopodal segments flanged with serrate hyaline frill.

*Leg 1*(Fig. 3B, C): intercoxal sclerite subrectangular, with two medial spiniform processes on distal margin (Fig. 3F), otherwise smooth. Coxa with two submarginal short rows of minute spinules on outer margin and with pinnate inner seta. Basipod with long flexible outer seta almost reaching distal margin of exopodal ramus, plus stout, robust flanged inner spine (asterisk in Fig. 3B).

*Legs 2–3*: each with exopodal ramus longer than endopod, intercoxal sclerites with distal margin smooth (Fig. 3G). Coxa with two rows of spinules on outer margin; insertion point of inner seta naked. Basipod with outer seta shorter than leg 1 counterpart (Fig. 3D).

*Leg 4* (Fig. 3E): posterior surface of coxa furnished with two rows of minute spinules on proximal and lateral margins. Intercoxal sclerite posterior margin smooth (Fig. 3H). Basipod with outer seta shorter than leg 1 counterpart (Fig. 3E). Third endopodal segment with outermost subdistal setal element modified, proximal half stouter, wider than flexible, whip-like distal half (asterisk in Fig. 3E).

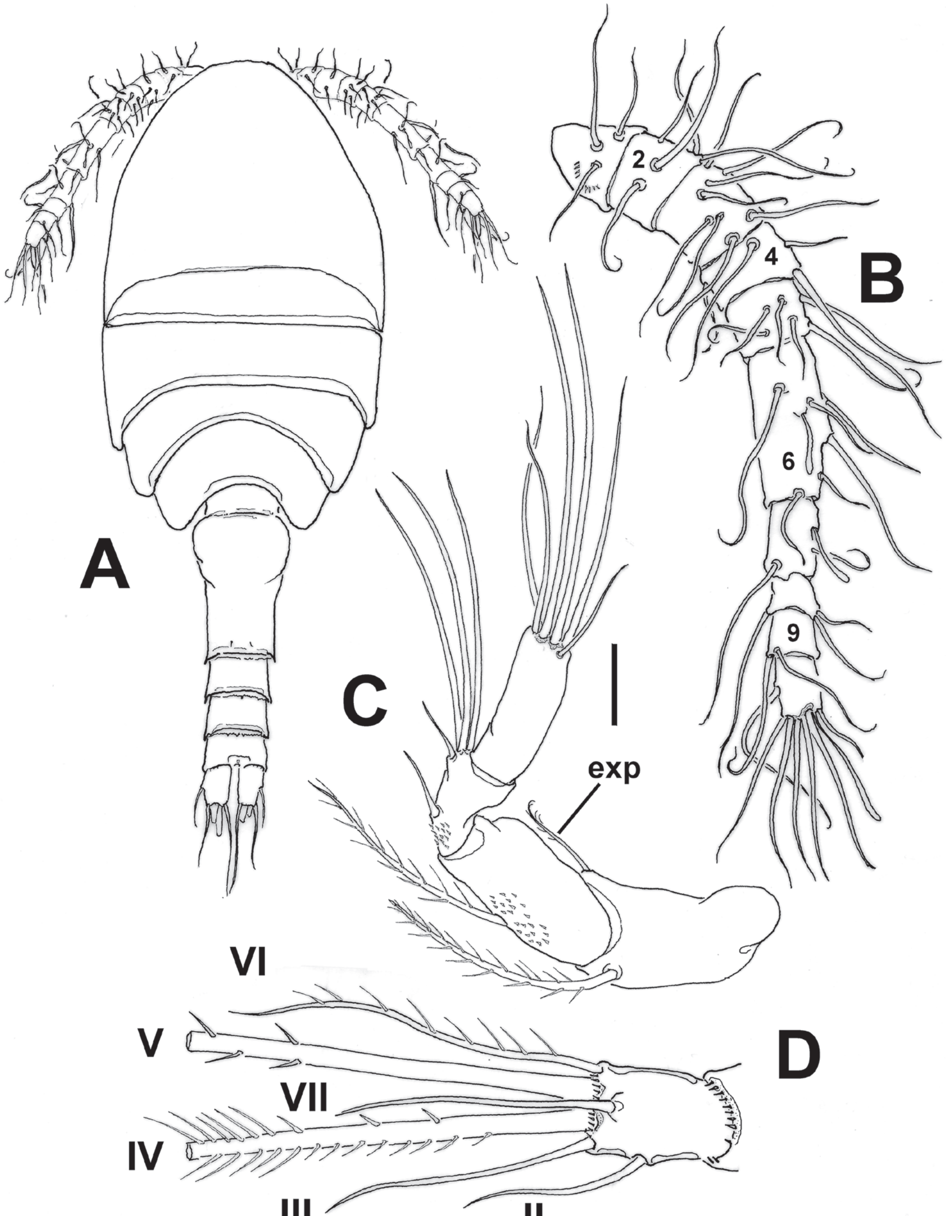


**Figure 1.** *Mexiclopina campechana* gen. et sp. n., female holotype. **A** habitus in dorsal view **B** antennule **C** antenna **D** left caudal ramus, dorsal view, showing position of caudal setae I-VII (plumosity of setae III and VI not illustrated). Scale bars: 50 µm (**A**); 10 µm (**B–D**).

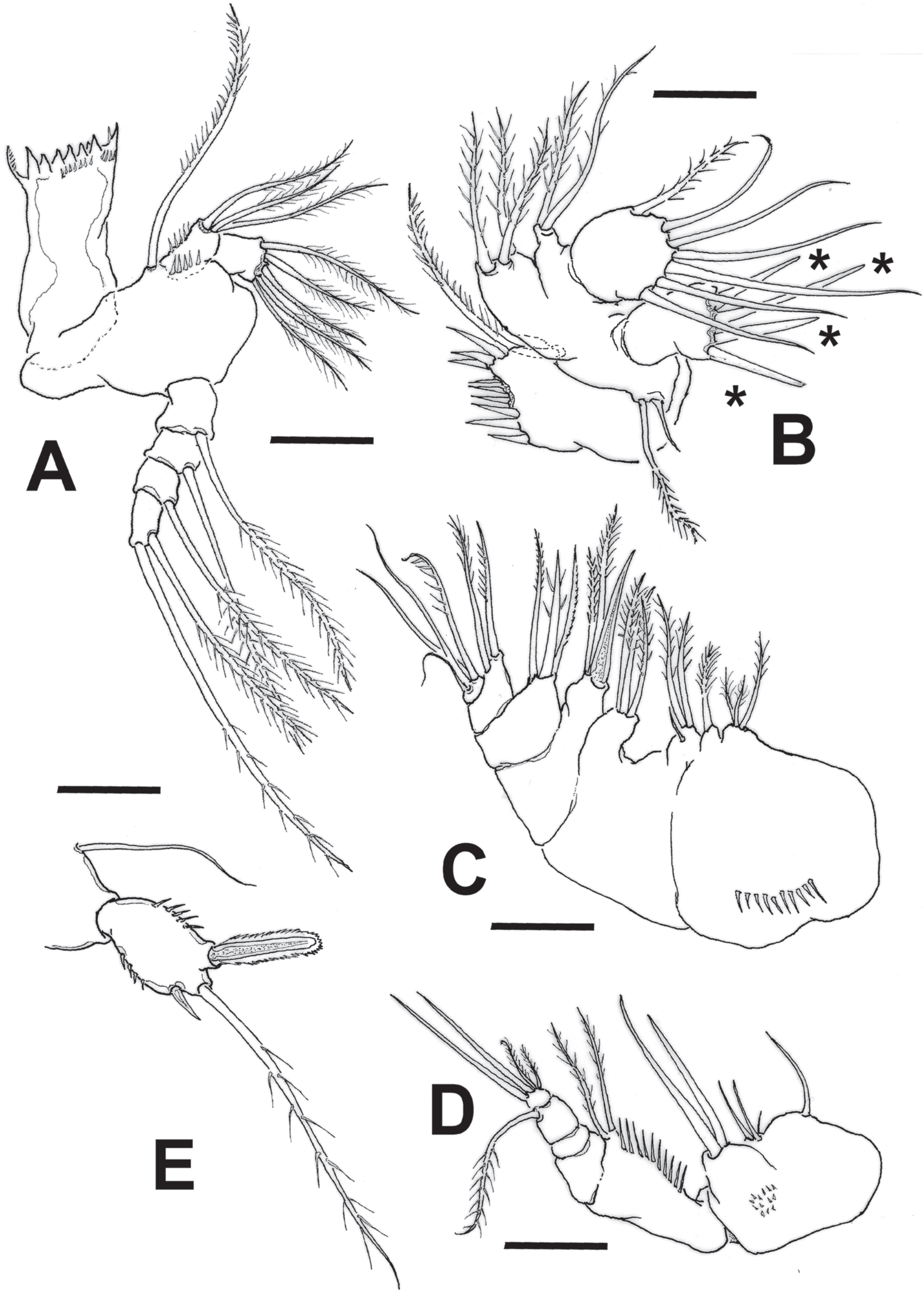


**Figure 2.** *Mexiclopina campechana* gen. et sp. n., female holotype. **A** mandible **B** maxillule, asterisks indicate stout exopodal setae **C** maxilla **D** maxilliped **E** fifth leg. Scale bars: 10 µm (**A–E**).

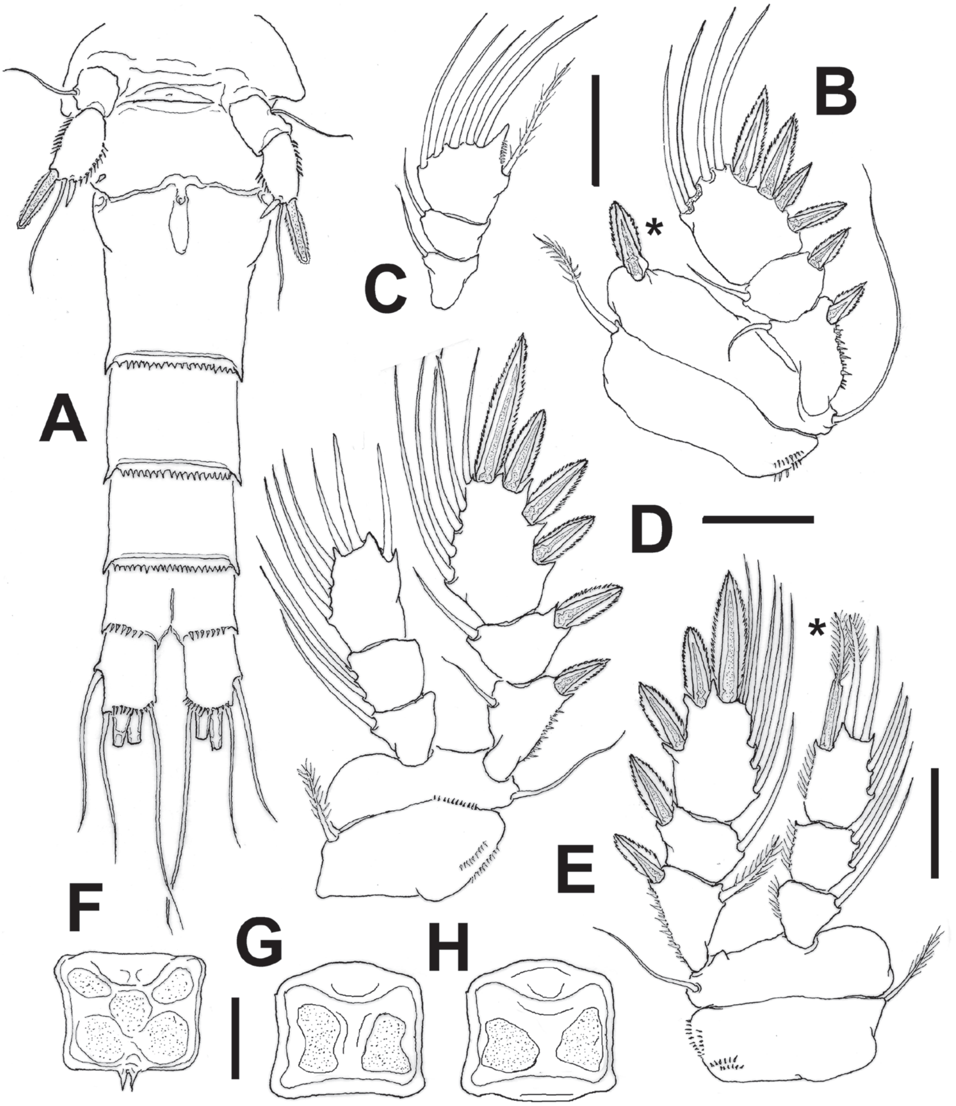


**Figure 3.** *Mexiclopina campechana* gen. et sp. n., female holotype. **A** urosome showing fifth legs, ventral view **B** first swimming leg with exopod **C** endopod of first leg **D** third leg **E** fourth leg, asterisk indicates modified seta on endopod **F** intercoxal sclerite of first leg showing spiniform processes **G** same, third leg **H** same, fourth leg. Scale bars: 50 µm (**A**); 10 µm (**B–H**).

Armature formula of swimming legs as:

| | coxa | basis | exopod | endopod |
|---|---|---|---|---|
| leg 1 | 0-1 | 1-I | I-1;I-1;III,I,4 | 0-1;0-1;1,2,3 |
| leg 2 | 0-1 | 1-0 | I-1;I-1;III,I1;4 | 0-1;0-2;1,2,3 |
| leg 3 | 0-1 | 1-0 | I-1;I-1;III,I1,4 | 0-1;0-2;1,2,3 |
| leg 4 | 0-1 | 1-0 | I-1;I-1;II,I1,4 | 0-1;0-2;1,2,2 |

*Leg 5* (Figs 2E; 3A): with coxobasis subrectangular, armed with single seta on outer margin, inner margin smooth. Exopod unsegmented, subrectangular, ornamented with longitudinal row of few spinules along inner margin and group of minute spinules on outer margin (Figs 2E; 5A). Exopod armature consisting of one short inner spine, one medial setulose seta and one outer blunt spine flanged with serrate hyaline frill, latter about 2.4 times as long as inner spine.

*Leg 6* (Fig. 5A): inserted laterally, represented by short plate armed with inner slender unipinnate spine and outer setulose seta (asterisks in Fig. 5A).

**Description of adult male.** Length of allotype 325 µm, of rest of male paratypes (*n*=7): 313–328 µm, average 321 µm. Body cyclopiform, smaller than female and slightly narrower (Figs 4A; 5D). Rostrum as in female (Fig. 6F). Length/width ratio of caudal ramus 1.20–1.22, setation pattern as in female (Figs. 4B; 5C). Antennules, symmetrical, digeniculate, 15-segmented (Figs 4C; 6A, B). Segment 9 concave, partially covering proximal half of succeeding segment 10. Armature of segments as follows: 1(I-II)(2), 2(III-V)(6), 3(VI-VIII)(3), 4(IX)(1+ae), 5(X-XI)(1), 6(XII)(naked), 7(XIII)(2), 8(XIV)(2), 9(XV)(1+sp), 10(XVI)(2+sp), 11(XVII)(sp), 12(XVIII)(1+sp), 13(XIX-XX)(1+sp), 14(XXI-XXII)(1+sp), 15(XXIII-XXVIII)(11+2ae). Geniculations between ancestral segments XV and XVI (9–10) and XX-XXI (13–14).Spines on segments 9–12 pectinate (asterisks in Fig. 6B). Terminal segment with modified, hypertrophied flattened aesthetasc on apical position (mfs in Fig. 6A). Segmentation and setation pattern of mouthparts (Figs 6A, C, F; 5B) and swimming legs 1-4 (Fig. 5D, E) as in female.

*Leg 5* (Figs 4D; 6D, E) with coxobasis subrectangular, armed with outer seta. Exopod unsegmented, ornamented with few spinules on inner margin and group of minute spinules on outer margin (Figs 4D, 6E). Exopod armed with five elements, two long, inner setae, one small medial spine, one medial seta and outer flanged spine with serrate hyaline frill; as in female, latter element (arrowed in Fig. 6E) blunt, about 2.5 times as long as inner spine.

*Leg 6* represented by flat, rounded plate bearing two slender setae and an inner spiniform process (Figs 4D; 6D).

**Type locality.** Laguna de Términos (18°44'29.3"N; 91°29'44.6"W), state of Campeche, Mexico, southern Gulf of Mexico.

**Etymology.** The species is named after the state of Campeche in southeast Mexico. Gender is feminine.

**Habitat.** The lagoon has a length of 70 km and 30 km at its widest sector. It has extense coverage of seagrass beds (mainly *Thalassia testudinum*), mangrove areas and zones with no vegetation. It is a shallow system, (average depth = 2.5 m). The lagoon receives freshwater input from several rivers. Most of its bottom is covered by sediments of sand, silt and clay with a high content of calcium carbonate mainly in the vicinity of Boca de Puerto Real (between 50 and 70%).

**Remarks.** Based on the first examination of these specimens, they were tentatively identified as a species of *Cyclopina* Claus, 1863 by the combined display of the following features: 10-segmented female antennule with sixth antennulary segment being longest, antenna with single exopodal seta; female fifth leg exopod with three armature elements, the apical seta flanked by two spines; leg 1 with 3-segmented endopod; and

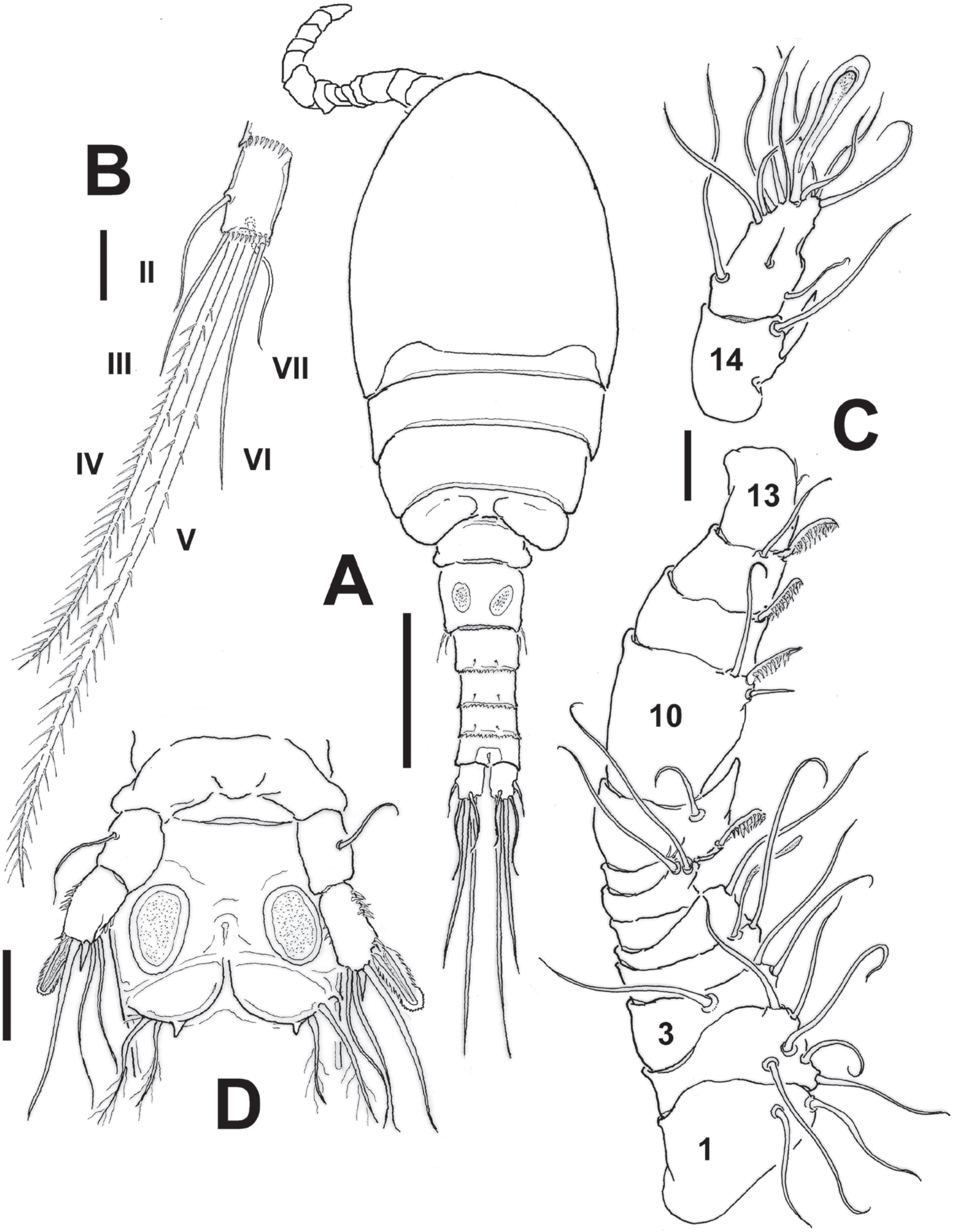


**Figure 4.** *Mexiclopina campechana* gen. et sp. n., male allotype. **A** habitus, dorsal view **B** right caudal ramus, ventral view showing position of caudal setae I-VII **C** geniculate antennule, segments 14–15 shown separately **D** fifth and sixth legs, ventral view. Scale bars: 50 µm (**A**); 10 µm (**B–D**).

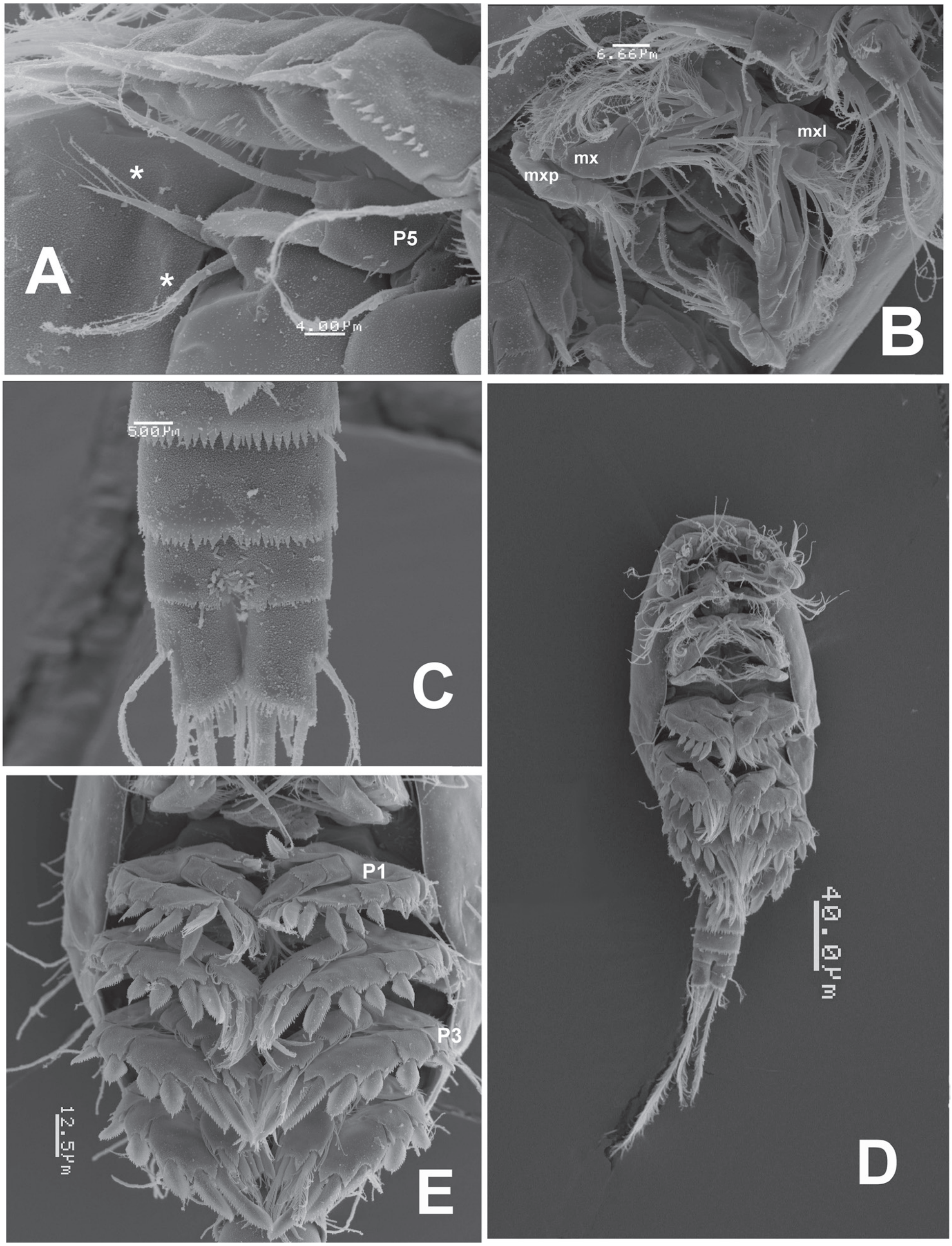


**Figure 5.** *Mexiclopina campechana* gen. et sp. n., from the Gulf of Mexico, SEM-prepared female. **A** fifth leg and sixth leg armature (indicated by asterisks); male specimen: **B** ventral view of mouthparts including maxillule (mxl), maxilla (mx), and maxilliped (mxp) **C** preanal and anal somites and caudal rami **D** habitus, ventral view **E** legs 1–4 showing ornamentation and part of armature, ventral view; leg 1 (P1) and leg 3 (P3) indicated.

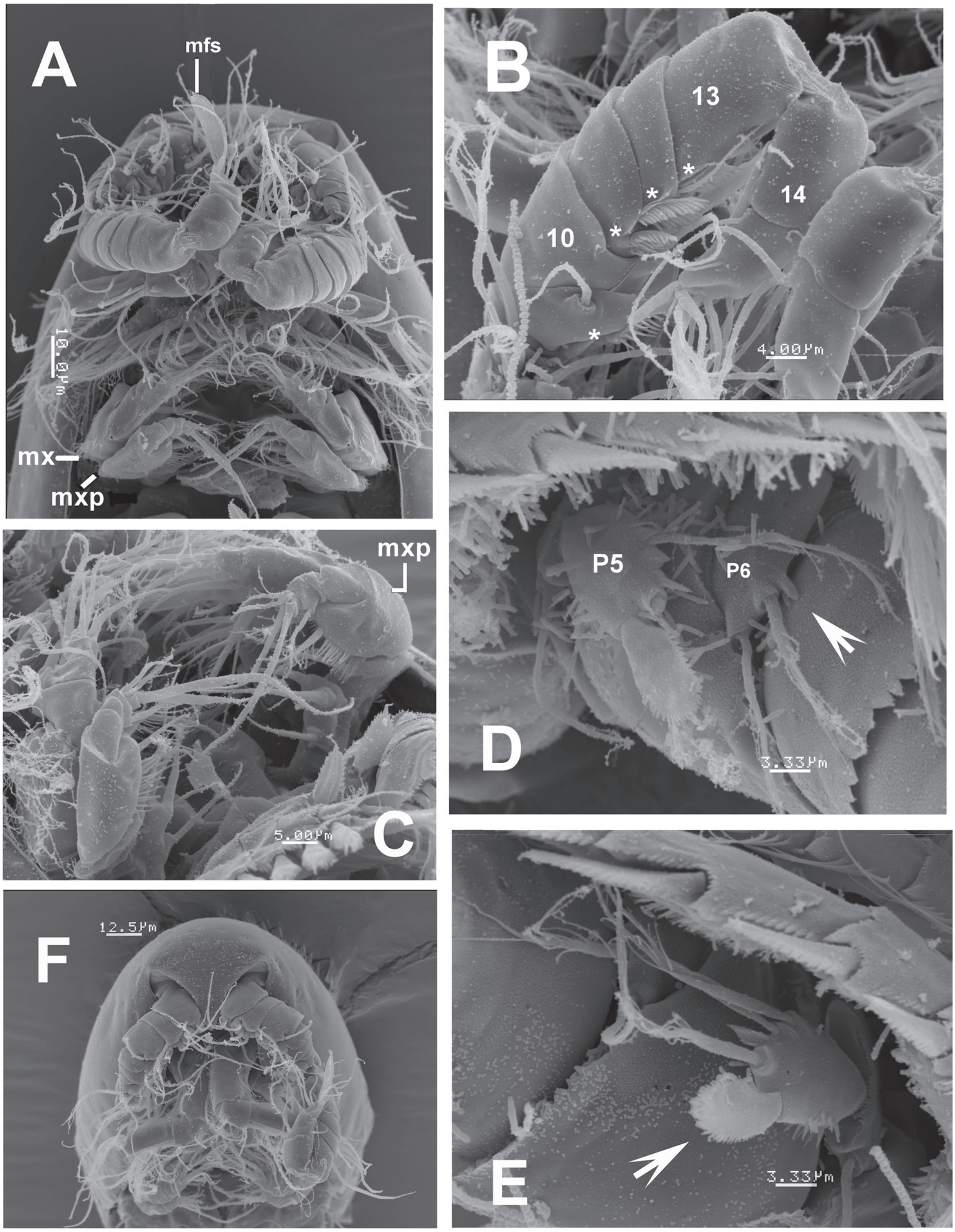


**Figure 6.** *Mexiclopina campechana* gen. et sp. n., from the Gulf of Mexico, SEM-prepared males. **A** cephalic area showing digeniculate antennules (note flattened aesthetasc-mfs) and mouthparts including maxilla (mx) and maxilliped (mxp) **B** distal segments (9-15) of antennule showing position of pectinate setae (asterisks) **C** detail of maxillipedal (mxp) ornamentation of basis and endopodal segmentation and armature, ventral view **D** fifth leg(P5) partly damaged but with distinctive serrate spine and sixth leg (P6) with inner spiniform process (arrowed) **E** fifth leg **F** rostrum, geniculate antennules and antennae, ventral view; another male specimen.

caudal seta I absent (cf. Vervoort 1964; Jaume and Boxshall 1997; Boxshall and Halsey 2004). However, when Jaume and Boxshall's (1996b) key to the cyclopinid genera was run, our specimens could not be adequately placed in a genus and it did not fit in the generic diagnoses of other related cyclopinids (Jaume and Boxshall 1996a, b, 1997; Martínez Arbizu 1997a, b; Humes 1999; Ivanenko and Defaye 2004). Also, based on our morphological comparison with *Cyclopina esilis* Brian, 1938, the best described species of *Cyclopina* (Jaume and Boxshall 1996a), it was clear that despite their affinities, the new genus and *Cyclopina* diverge in several important characters. In addition, the monotypic genus *Heptnerina* (Ivanenko and Defaye 2004) shares some characters with the new genus (i.e., swimming legs segmentation, number of female antennulary segments, armature of male and female fifth legs, segmentation of mandible palp) but differ in some others, as explained below. Overall, the genus *Mexiclopina* gen. n. differs from the other cyclopinid genera in having a unique combination of characters including: 1) absence of modified brush-like seta on the 4th mandibular exopodal segment; 2) maxillule exopod with stout setal elements and no brush-like setae; 3) presence of modified seta on the fourth leg endopod; 4) fifth leg exopod armed with three elements in the female and five in the male; 5) outer exopodal spine of leg 5 blunt in both sexes; 6) male sixth leg with two outer slender setae and inner spiniform process; 7) intercoxal sclerite of first swimming leg with two medial spiniform processes on distal margin. The new genus diverges from *Heptnerina* in the lack of an endopodal lobe in leg 5, in the presence of a single antennary exopodal seta *vs.* two setae present in *H. confusa* (Ivanenko and Defaye 2004, fig. 3A), and the lack of a modified seta on the maxillule exopodal lobe and also in the mandible exopod (Ivanenko and Defaye 2004, figs. 3A, C). The new genus differs from *Cyclopina* in the lack of a brush-like seta on the mandible exopod (Jaume and Boxshall 1996a; Lotufo 1994); this character is distinctive of the genus and it is present in the type species, *C. gracilis* Claus, 1863. Remarkably, in the new genus the intercoxal sclerite of leg 1 has a distinctive feature not previously observed in *Cyclopina*; it has two medial spiniform processes on the posterior margin (Fig. 3F), similar acute processes in leg 1 are present in *Troglocyclopina balearica* Jaume & Boxshall, 1996 (Jaume and Boxshall 1996b), but are absent in *Heptnerina* (Ivanenko and Defaye 2004). The new genus clearly diverges from *Troglocyclopina* Jaume & Boxshall, 1996 in having six setae instead of five on the distal segment of endopod of leg 1 (Jaume and Boxshall 1996b, figs. 4A) but also in the presence of two exopodal setae on the antenna (Jaume and Boxshall 1996b, fig. 3A) *vs.* a single exopodal seta in *Mexiclopina*.

Other remarkable features of the new genus include: 1) the short, stout distal setae of the exopodal segment of the maxillule (asterisks in Fig. 2B); these setae are long, flexible in *Cyclopina* (Lotufo 1994; Jaume and Boxshall 1996a; Karanovic 2008) and *Heptnerina* (Ivanenko and Defaye 2004); 2) the female P6, represented by short plate armed with two slender setae; it is similar to that known in species of *Cyclopina* but differs from *Heptnerina* (Ivanenko and Defaye 2004, fig. 1E), with three unequal setae; and 3) the modified, short spiniform outer seta of the third endopodal segment of leg 4 (asterisk in Fig. 3E), not described in any other cyclopinid.

Because of the close morphological resemblance of the new species with *Cyclopina*, we performed a comparison with the most closely related species of this genus. Only a few species of *Cyclopina* have a female leg5 with the inner spine of the exopodal segment less than half the length of the outer spine, the latter being longer than the segment itself (Jaume and Boxshall 1996a). This group of species include *C. kieferi* Schäfer, 1936, from Europe, *C. esilis* Brian, 1938 from Mediterranean anchialine caves, *C. americana* Herbst, 1982, from North Carolina, USA, *C. caissara* Lotufo, 1994 from Brazil (Lotufo 1994) and from the Mexican Pacific (Gómez and Martínez Arbizu 2004), and *C. amita* from Australia (Karanovic 2008). The new species shares this feature with this group of species but it can be easily distinguished from *C. caissara* by the segmentation of the antennules, the new species having 10 segments, like most other known species of *Cyclopina*, whereas *C. caissara* has a 12-segmented antennule both in specimens from Brazil (Lotufo 1994, fig. 37) and from Mexico (Gómez and Martínez Arbizu 2004, fig. 3A). Also, the length/width ratio of the caudal rami differs between these two species, being slightly longer in *C. caissara* (ratio=1.3–1.5; Lotufo 1994; Gómez and Martínez Arbizu 2004) *vs.* 1.17–1.2 in the new species. The shape and size of the outermost terminal flanged spine of the male fifth leg differ in these species, being broad and blunt in the new species *vs.* slender and pointed in *C. caissara* (Lotufo 1994, fig. 52). Also, the female fifth leg differs in the size and proportions of these spines; the outer spine is more than 4 times as long as the inner one in *C. caissara* (Lotufo 1994, fig. 49), whereas in the new species this element is only about twice longer than the inner spine. In *C. caissara* the armature of the female sixth leg consists only of two elements, the inner one corresponding to a thick stout serrate seta (Lotufo 1994, fig. 50; Gómez and Martínez Arbizu 2004, fig. 1C), thus differing from the slender seta present in homologous position in the new species (Fig. 5A).

The new species differs from *C. esilis* in the display of a long terminal seta on the exopod of mandibular palp; it is the longest and is slightly broader than the rest of exopodal setae; contrastingly, this seta is remarkably short and modified, umbrella-like, in *C. esilis* (Jaume and Boxshall 1996a, fig. 2B). In addition, both species can be readily distinguished by the proportions of the caudal rami, being 2.6–3.3 times longer than wide, relatively elongate in *C. esilis* (Jaume and Boxshall 1996a, fig. 1F,G), *vs.* short and subquadrate (length/width ratio 1.2) in the new species.

*Mexiclopina campechana* sp. n. differs from *C. americana* in body shape, with the third and fourth pedigerous somites strongly produced posteriorly, the process of the fourth somite reaching well beyond the posterior margin of the fifth pedigerous somite (Fig. 1A); in *C. americana* the posterolateral corners of the fourth pedigerous somite do not reach the posterior margin of the succeeding somite (Herbst 1982, fig. 1). Also, in *C. americana* the female anal somite is 1.16 times as long as the caudal ramus (Herbst 1982, fig.1), whereas in the new species the anal somite is shorter (0.8 times) than the caudal ramus. The length/width ratio of the caudal rami is also slightly different in both species, 1.2 in *M. campechana* sp. n., *vs.* 1.3 in *C. americana* (Herbst 1982, fig. 2). They differ also in the relative length of the antennulary segments, particularly in the shorter segment 6 in *C. americana*, which is 26% of the antennule length (Herbst

1982, fig. 3), *vs*. 21% in the new species from Campeche. In *C. americana* the antenna lacks the exopodal seta (Herbst 1982, fig. 4), which is present in the new species (Fig. 1C), but in some species like *C. amita* this seta is also absent (Karanovic 2008). In ventral view the male anal somite of *C. americana* is long, 1.45 times as long as the caudal rami (Herbst 1982, fig. 10), whereas in the new species it is relatively shorter, 0.7 times as long as the caudal ramus (Figs4A; 5C). In addition, both sexes have a crenulate hyaline frill on the posterior margin of urosomites(Figs. 3A, 5C), whereas these margins are smooth in both sexes in *C. americana* (Herbst 1982, figs 1;10; 11). In *C. americana* the male fifth leg has four elements on the exopodal segment (Herbst 1982, fig. 13), *vs*. five in the new species. In addition, the sixth leg of the new species has, like the majority of the species of *Cyclopina* for which males are known (Karanovic 2008), an inner spine aside the two usual setae; this spine is absent in both *C. americana* (Herbst 1982, figs 10;11) and *C. amita* (Karanovic 2008, fig. 36C). The new species differs from *C. amita* in the antennule segmentation; this appendage having 11 segments in the Australian species (Karanovic 2008, fig. 34A) *vs*. 10 segments in *M. campechana*.

The new species of *Mexiclopina* shows also some resemblance with *C. kieferi*, but in this species the external spine of the female fifth leg is 1.2–1.5 times as long as the internal spine (*vs*. 2.5 in the new species), the caudal rami are clearly longer than the anal somite and have a length/width ratio of 2.6 (Vervoort 1964; Lotufo 1994),thus differing from *M. campechana*, with an anal somite as long as the caudal rami, which in turn have a 1.2 length/width ratio.

Males are known for only about half the known nominal species of *Cyclopina* (Karanovic 2008) and the available keys are based on females (Vervoort 1964), thus, characters of this gender have not been fully explored but some of them appear to be potentially important to define species. For instance, the male of *C. esilis* shares several features with the new species, but the antennulary armature differs. The male antennule of *C. esilis* has pectinate spines on each of segments 10-13 (Jaume and Boxshall 1996, fig. 4D), whereas these spines are distributed on segments 9-12 in the new species (Fig. 6B). In addition, the male antennule of *C. americana* has 13 segments (Herbst 1982, fig. 12) *vs*. 15 in the new species; the last antennular segment is distinctly acute in *C. americana* (Herbst 1982, fig. 12) and blunt in the new species. Details of the male antennulary armature were not shown in the description of *C. americana* (Herbst 1982), but this appendage is likely to provide additional differences at the species level.

The male fifth leg of the new species has 5 elements on the exopodal segment, thus diverging from most species of *Cyclopina* for which males have been described thus far. This feature is shared only with *C. esilis*, *C. caissara*, *C. kieferi*, *C. amita*, and *C. confusa*, but the latter has an ornamented anterior surface of the female fifth leg, thus diverging from the smooth condition of the same surface in *M. campechana*.

The copepod fauna of the Laguna de Términos has been known mainly from plankton surveys (Suárez-Caabro and Gómez-Aguirre 1965; Salas-Marmolejo 1981); relatively little is known from other copepod habitats. The local copepod diversity of interstitial environments may equal or exceed that of their planktonic relatives. The sampling of shallow coastal systems frequently results in the capture of epibenthic or interstitial fauna that is integrated into the water column. This appears to be the case in the new species, belonging to a genus of interstitial forms (Karanovic 2008).

This work increases the number of species of cyclopinids known from the Americas (Wilson 1932; Nicholls 1939; Herbst 1982; Reid 1990; Lotufo and Rocha 1991; Lotufo 1994; Rocha and Botelho 1998; Gómez and Martínez Arbizu 2004). Records of this family now comprise thirteen species of *Cyclopina*: *C. agilis* Wilson, 1932, *C. laurentica* Nicholls, 1939, *C. vachoni* Nicholls, 1939, *C. americana* Herbst, 1982, *C. caiala* Lotufo & Rocha, 1991, *C. janaina* (Lotufo & Rocha, 1991), *C. arenosa* Lotufo, 1994, *C. caissara* Lotufo, 1994, *C. caroli* Lotufo, 1994, *C. mediterranea* Steuer, 1940, *C. dorae* Lotufo, 1994, *C. yutimaete* Lotufo, 1994, and a species of the new genus, *Mexiclopina campechana*. The new species is the first cyclopinid described from Mexico, and represents the first record of the family in the Gulf of Mexico (see Suárez-Morales et al. 2009). After the finding of *C. caissara* in the Mexican Pacific coast (Gómez and Martínez Arbizu 2004), it is the second record of cyclopinids in the country.

## Acknowledgements

We gratefully acknowledge the support by Guadalupe Nieto, Laboratorio de Microscopía Electrónica de Barrido, El Colegio de la Frontera Sur (ECOSUR) at Tapachula, for her help and advice in the SEM processing and examination of specimens of the new species. Rosa María Hernández (ECOSUR-Chetumal) provided catalogue numbers of type specimens deposited in the Collection of Zooplankton. Our gratitude to Dr. Luis Amado Ayala Pérez, Lab. de Ecología Aplicada, DEHA, UAM-Xochimilco for logistic support. Pas. Biol. Cynthia Lara-Bautista and Pas. Biol. Citlali Chamorro-García helped during the zooplankton sampling. We thank the field assistance from Mr. Santiago Felipe Puch Salazar (guide) and Mr. Gabriel Naal Hernández (boatman), both environmental watchmen at CONANP-Campeche. The comments from Damià Jaume and V. N. Ivanenko were very useful to improve this contribution and are deeply appreciated.

## References

Boxshall GA (2015) *Cyclopina* Claus, 1863. In: Walter TC, Boxshall G (2015) World of Copepods database. World Register of Marine Species. http://www.marinespecies.org/aphia.php?p=taxdetails&id=106437 [accessed on 2015-03-27]

Boxshall GA, Halsey SH (2004) An Introduction to Copepod Diversity. The Ray Society, London, 966 pp.

Brian A (1938) Description d'une nouvelle espèce de Copépode Cyclopoide du genre *Cyclopina* (*C. esilis* n. sp.). Bulletin de la Société Zoologique de France 63: 13–18.

Claus C (1863) Die freilebenden Copepoden mit besonderer Berücksichtigung der Fauna Deutschlands, der Nordsee, und des Mittelmeeres. Verlag von Wilhelm Engelmann, Leipzig, 230 pp. doi: 10.5962/bhl.title.58676

Gómez S, Martínez Arbizu P (2004) First record of the genus *Cyclopina* (Copepoda: Cyclopoida), and fully illustrated redescription of *Cyclopina caissara* from northwestern Mexico. Anales del Instituto de Biología, Universidad Nacional Autónoma de México, Serie Zoología 75: 121–134.

Herbst HV (1982) Drei neue marine Cyclopoida Gnathostoma (Crustacea: Copepoda) aus dem nordamerikanischen Kiistenbereich. Gewässer und Abwasser 68/69: 107–124.

Humes AG (1999) Copepoda (Cyclopinidae and Misophriidae) from a deep-sea hydrothermal site in the northeastern Pacific. Journal of Natural History 33: 961–978. doi: 10.1080/002229399300038

Ivanenko VN, Defaye D (2004) A new genus and species of deep-sea cyclopoids (Copepoda, Cyclopinidae) from the Mid-Atlantic Ridge (Azores Triple Junction, Lucky Strike). Zoosystema 26(1): 49–64.

Jaume D, Boxshall GA (1996a) Rare cyclopoid copepods (Crustacea) from Mediterranean littoral caves. Bulletin of the Natural History Museum Zoology Series 62: 83–99.

Jaume D, Boxshall GA (1996b) Two new genera of cyclopinid copepods (Crustacea) from anchialine caves on western Mediterranean and eastern Atlantic islands. Zoological Journal of the Linnean Society 117: 283–304. doi: 10.1111/j.1096-3642.1996.tb02191.x

Jaume D, Boxshall GA (1997) Two new genera of cyclopinid copepods (Cyclopoida: Cyclopinidae) from anchialine caves of the Canary and Balearic Islands, with a key to genera of the family. Zoological Journal of the Linnean Society 120: 79–110. doi: 10.1111/j.1096-3642.1997.tb01273.x

Karanovic T (2008) Marine interstitial Poecilostomatoida and Cyclopoida (Copepoda) of Australia. Crustaceana Monographs 9.Koninklijke Brill, Leiden, 336 pp. doi: 10.1163/ej.9789004164598.i-332

Lotufo GR (1994) *Cyclopina* (Copepoda, Cyclopoida) from Brazilian sandy beaches. Zoologica Scripta 23: 147–159. doi: 10.1111/j.1463-6409.1994.tb00381.x

Lotufo GR, Rocha CEF (1991) Copepods from intertidal interstitial water of Salvador, Brazil. I. *Cuipora janaina* gen. n., sp. n. and *Cyclopina caiala* sp. n.(Cyclopoida: Cyclopinidae). Bijdragen tot de Dierkunde 61: 107–118.

Martínez Arbizu P (1997a) *Cyclopicina sirenkoi* sp. n. (Copepoda: Cyclopinidae) from deep waters in the Laptev Sea (Arctic Ocean), with comments on the phylogenetic relationships of copepod orders. Senckenbergiana Biologica 77: 89–99.

Martínez Arbizu P (1997b) A new genus of cyclopinid copepods (Crustacea), with a redescription of *Smirnovipina barentsiana* comb. nov. (Smirnov,1931). Sarsia 82: 313–323.

Nicholls AG (1939) Marine harpacticoids and cyclopoids from the shores of the St. Laurence. Station Biologique de Saint-Laurent. Fauna et Flora Laurentianae. 2. Naturaliste Canadien 66: 241–316.

Ramos-Miranda J, Flores-Hernández D, Ayala-Pérez LA, Rendón-Von Osten J, Villalobos G, Sosa-López A (2006) Atlas hidrológico e ictiológico de la Laguna de Términos. EPOMEX Universidad de Campeche/CONANP, 173 pp.

Reid JW (1990) Continental and coastal free-living Copepoda (Crustacea) of Mexico, Central America and the Caribbean region. In: Navarro D, Robinson JG (Eds) Diversidad Biológica en la Reserva de la Biosfera de Sian Ka'an, Quintana Roo, México. CIQRO/Univ. of Florida, Mexico City, 175–213.

Reid JW (2003) A technique for observing copepods. In: Ueda H, Reid JW (Eds) Copepoda Cyclopoida. Genera *Mesocyclops* and *Thermocyclops*. Guides to the Identification of the Microinvertebrates of the Continental Waters of the World. 20. Backhuys Publishers, Amsterdam, 8.

Rocha CEF, Botelho MJC (1998) Maxillopoda-Copepoda. Cyclopoida. In: Young PS (Ed.) Catalogue of Crustacea of Brazil (Série Livros N. 6). Museu Nacional, Rio de Janeiro, 129–166.

Salas-Marmolejo J (1981) Distribución y abundancia de los copépodos (Copepoda) en la Laguna de Términos, México, durante un ciclo anual (1978). B.Sc. Thesis, Fac. Ciencias, Universidad Nacional Autónoma de México.

Suárez-Caabro JA, Gómez-Aguirre S (1965) Observaciones sobre el plancton de la Laguna de Términos, Campeche, México. Bulletin of Marine Science 15: 1072–1120.

Suárez-Morales E, Fleeger JM, Montagna PA (2009) Free-living Copepoda of the Gulf of Mexico. In: Felder DL, Camp DK (Eds) Gulf of Mexico – Its Origins, Waters, and Biota, Biodiversity. Texas A&M University Press, 841–870.

Steuer A (1940) Über einige CopepodaCyclopoida der Mediterranen Amphioxussande. Note dell'Istituto Italo Germanico di Biologia Marina di Rovigno d'Istria 2(17): 1–27.

Vervoort W (1964) Free-living Copepoda from Ifaluk Atoll in the Caroline Islands. United States National Museum Bulletin 236: 1–431. doi: 10.5479/si.03629236.236.1

Walter TC, Boxshall GA (2015) Cyclopinidae Sars G.O., 1913. In: Walter TC, Boxshall GA (2015) World of Copepods database. World Register of Marine Species. http://www.marinespecies.org/aphia.php?p=taxdetails&id=106414 [accessed on 2015-09-02]

Wilson CB (1932) The copepods of the Woods Hole region, Massachusetts. Bulletin of the United States National Museum 158: 1–635. doi: 10.5479/si.00963801.80-2915.1

Yáñez-Arancibia A, Day Jr JW (1982) Coastal Lagoons. Ecological characterization of Terminos Lagoon, a tropical lagoon-estuarine system in the Southern Gulf of Mexico. Oceanologica Acta Special 5: 431–440.

ZooKeys 534: 35–54 (2015)
doi: 10.3897/zookeys.534.6456
http://zookeys.pensoft.net

CATALOGUE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

# Catalog of the adelgids of the world (Hemiptera, Adelgidae)

Colin Favret[1], Nathan P. Havill[2], Gary L. Miller[3], Masakazu Sano[4], Benjamin Victor[5]

**1** *University of Montreal, Biodiversity Centre, 4101 rue Sherbrooke est, Montreal, Quebec, H1X 2B2 Canada* **2** *USDA Forest Service, Northern Research Station, 51 Mill Pond Road, Hamden, CT 06514, USA* **3** *USDA-ARS, Systematic Entomology Laboratory, 10300 Baltimore Ave, Bldg. 005, BARC-West, Beltsville, MD 20705, USA* **4** *Hokkaido University, Graduate School of Agriculture, Systematic Entomology, Kita 9 Nishi 9, Kita-ku, Sapporo 060-8589, Hokkaido, Japan* **5** *University of Montreal, Classical Studies Centre, 3774 rue Jean-Brillant, Montreal, Quebec, H3T 1P1 Canada*

Corresponding author: *Colin Favret* (ColinFavret@AphidNet.org)

Academic editor: *B. Price* | Received 2 September 2015 | Accepted 13 October 2015 | Published 11 November 2015

*http://zoobank.org/CA4C9C2D-9573-45B2-B72F-0A156601DC31*

**Citation:** Favret C, Havill NP, Miller GL, Sano M, Victor B (2015) Catalog of the adelgids of the world (Hemiptera, Adelgidae). ZooKeys 534: 35–54. doi: 10.3897/zookeys.534.6456

## Abstract

A taxonomic and nomenclatural Catalogue of the adelgids (Hemiptera: Adelgidae) is presented. Six family-group names are listed, five being synonyms of Adelgidae. Twenty-two genus-group names, of which nine are subjectively valid and in use, are presented with their type species, etymology, and grammatical gender. One hundred and six species-group names are listed, of which 70 are considered subjectively valid.

## Keywords

Aphidomorpha, nomenclature, Sternorrhyncha, taxonomy, woolly adelgid

## Introduction

Adelgidae is a small family of Hemiptera with 65 species, closely related to Aphididae. They exhibit a two-year life cycle, with some species alternating hosts between spruce (*Picea*) one year and species of another conifer genus (*Abies*, *Larix*, *Pinus*, *Pseudotsuga*,

*Tsuga*) the next. Other species or populations do not alternate hosts, feeding only on *Picea* or one of the other conifer genera. Like other Aphidomorpha, Adelgidae exhibit cyclical parthenogenesis, although they are oviparous unlike the viviparous Aphididae. Some adelgid species are important forestry pests, most notably the hemlock woolly adelgid, *Adelges tsugae* (Annand) and the balsam woolly adelgid, *Adelges piceae* (Ratzeburg). Havill and Foottit (2007) present a thorough overview of the biology and evolution of the family.

The closest relatives of the Adelgidae are two extinct families, Elektraphididae and Mesozoicaphididae, the three families comprising the superfamily Adelgoidea (Heie and Wegierek 2009). The oldest fossils of the extinct families date to the Cretaceous, whereas the only fossil adelgid, *Adelges balticus* Wegierek, 2003, is Eocene in age. Heie and Wegierek (2011) present a list of the fossil Aphidomorpha, including the one adelgid and the 20 other Adelgoidea species.

Adelgid classification has long been unstable. It was first hampered by the adoption of the genus name *Chermes* Linnaeus, 1758, which had also been used for psyllids and scale insects (Favret et al. 2014). The name was eventually suppressed by the International Commission on Zoological Nomenclature (Evans and China 1965), but not before 137 nominal species had been described in combination with *Chermes*, including 43 Adelgidae (Favret et al. 2014). Towards the end of the 19th Century and in the first half of the 20th Century, several workers described many new species and erected new genera. Most notably, there was little agreement about adelgid taxonomy between the two most prolific adelgid workers, the Russian N.A. Cholodkovsky and the German C. Börner. With the application of molecular data and explicit systematic analyses (Havill et al. 2007, Havill and Foottit 2007), adelgid classification has become more stable. Many researchers have adopted a system with two genera (*Adelges* Annand and *Pineus* Shimer) and several subgenera, although some have preferred to treat the latter as full genera (Binazzi 1984, Zurovcová et al. 2010).

While several world catalogs and species lists of the more diverse Aphididae have been published (Wilson and Vickery 1918, Patch 1938, Hille Ris Lambers and Eastop 1976, Remaudière and Remaudière 1997), a comprehensive catalog of the Adelgidae has never been produced. Perhaps the small size of the family contributed to its neglect, but the relative inaccessibility of the taxonomic literature, written in multiple languages and in often hard-to-find sources, possibly made the task too daunting. We here present a taxonomic and nomenclatural list of the extant adelgid nominal taxa, including six family-group, 22 genus-group, and 106 species-group names. Of these, we list one valid family (Adelgidae), two and seven valid genera and subgenera (not counting nominotypical subgenera), and 65 and five valid species and subspecies (not counting nominotypical subspecies). We include one genus-group nomen dubium, four suppressed genus-group names, three species-group nomina dubia, and two unavailable species-group names; the many such names still in combination with *Chermes* are not listed here (Favret et al. 2014).

Despite having nomenclatural priority, *Coccus laricis* Bouché, 1834 has long been treated as a synonym of *A. laricis* Vallot, 1836 (Börner 1952, Steffan 1972, Eastop and

Hille Ris Lambers 1976). *Coccus laricis* Bouché has not been used as a valid name after 1899, meeting the requirements of nomen oblitum per ICZN Article 23.9.1.1 (International Commission on Zoological Nomenclature 1999). Meanwhile, *Adelges laricis* Vallot has been used frequently. To address ICZN Article 23.9.1.2 and thus consider *A. laricis* Vallot a nomen protectum, we here list 25 works that used the name as valid, published by at least ten authors in the immediately preceding 50 years and encompassing a span of not less than ten years (Carter 1971, Podeur 1971, Steffan 1972, Li and Tsai 1973, Parry 1973, Eichhorn and Carter 1978, Zhang et al. 1980, Fang 1982, Binazzi 1984, Luo 1988, Rohfritsch 1988, Eichhorn 1994, Battisti et al. 1997, Fang and Yan 1997, Szklarzewicz et al. 2000, Wegierek 2002, Rożkowski 2004, Skrzypczyńska 2004, Havill and Foottit 2007, Havill et al. 2007, Zurovcová et al. 2010, Michalik et al. 2012, Sano and Ozaki 2012, Toenshoff et al. 2012, Gavrilov-Zimin et al. 2015).

In order to facilitate future species descriptions, we followed the model of recent aphid genus-group catalogs by including information on etymology and grammatical gender (Favret et al. 2008, 2009, Cortés Gabaudan et al. 2011, Nieto Nafría et al. 2011). In cases where two page numbers are provided for original descriptions, the first number refers to a nomenclaturally valid diagnosis, such as in a dichotomous key, the second references the formal description. Valid names are in bold font, synonyms are preceded by '='. Synonyms of family-group names are presented with their rank-specific endings replaced by '__'. Nominal species are listed under their current generic placement with the original genus in parentheses. The taxonomic catalog is followed by an alphabetical index to help find the current placement of each name. It is our hope that this catalog will serve as an initial point of convergence in our understanding of adelgid systematics and a point of departure on which future research will be built. Future updates will be published on Aphid Species File (Aphid.SpeciesFile.org).

## Catalogue

**ADELGIDAE** Annand 1928:31
    Original spelling. Adelginae
    Type genus. *Adelges* Vallot 1836
  =CHERMES__ Herrich-Schaeffer 1854:VIII
    Original spelling. Chermiden
    Type genus. *Chermes* Linnaeus 1758
    Note. Suppressed (Evans and China 1965)
  =CHERMAPH__ Hunter 1901:70
    Original spelling. Chermaphinae
    Type genus. *Chermaphis* Maskell 1884
  =DREYFUSI__ Börner 1930:155
    Original spelling. Dreyfusiini
    Type genus. *Dreyfusia* Börner 1908a
  =PINE__ Nüsslin in Börner 1909c:51

Original spelling. Pineini
Type genus. *Pineus* Shimer 1869
=SACCHIPHANT__ Steffan 1968:128
Original spelling. Sacchiphantini
Type genus. *Sacchiphantes* Curtis 1844

***ADELGES*** Vallot 1836
Subgenus ***ADELGES*** Vallot 1836:72
Type species. *Adelges laricis* Vallot 1836, by original monotypy
Etymology. Greek adelos 'unclear', 'secret' + Greek ge 'earth' + -s [concealed in the earth]
Gender. Masculine
=*ANISOPHLEBA* Koch 1857:320
Type species. *Anisophleba hamadryas* Koch 1857, by subsequent monotypy
Etymology. Greek anisos 'unequal' + Greek phleps 'vein' + -a
Gender. Feminine
=*LARICETHUS* Amyot 1847:485
Type species. *Adelges laricis* Hartig 1839, by original monotypy
Etymology. Greek larix 'larch' + Greek eth- 'custom', 'habit' + -us
Gender. Masculine
Note. Suppressed (China 1963)
***aenigmaticus*** Annand 1928:34,73 (*Adelges*)
***geniculatus*** (Ratzeburg 1844:202) (*Chermes*)
***isedakii*** Eichhorn in Eichhorn and Carter 1978:280 (*Adelges*)
***japonicus*** (Monzen 1929:71) (*Chermes*)
***karamatsu*** Inouye 1945:54,86 (variety of *Adelges laricis* Vallot)
***lapponicus*** (Cholodkovsky 1889b:390) (*Chermes*)
=*praecox* (Cholodkovsky 1898:28) (variety of *Chermes lapponicus* Cholodkovsky)
***lariciatus*** (Patch 1909:137) (*Chermes*)
***laricis*** Vallot 1836:72 (*Adelges*) (nomen protectum with respect to *Coccus laricis* Bouché)
subspecies ***laricis*** Vallot 1836
=*atratus* (Buckton 1883:39) (*Chermes*)
=*coccineus* (Ratzeburg 1843:202) (*Chermes*)
=*consolidatus* (Patch 1909:137) (*Chermes*)
=*hamadryas* (Koch 1857:320) (*Anisophleba*)
=*lariceti* (Altum 1889:279) (*Chermes*)
=*laricis* (Bouché 1834:22) (*Coccus*) (nomen oblitum with respect to *Adelges laricis* Vallot)
=*laricis* (Hartig 1839:644) (*Chermes*)
=*obtectus* (Ratzeburg 1844:200) (*Chermes*)
=*strobilobius* (Kaltenbach 1843:203) (*Chermes*)

subspecies ***potaninilaricis*** Zhang in Zhang et al. 1980:383 (subspecies of *Adelges laricis* Vallot)

***tardoides*** (Cholodkovsky 1911:175) (variety of *Chermes strobilobius* Kaltenbach)

***tardus*** (Dreyfus 1888:3) (*Chermes*)

=*affinis* (Börner 1908b:167) (*Cnaphalodes*) (Börner 1908a:417 nomen nudum)

=*niger* (Solowiow 1924:41) (*Chermes*)

Subgenus ***ANNANDINA*** Favret et al. 2015:176

Type species *Adelges tsugae* Annand 1924b, by original designation

Etymology. (Percy Nicol) Annand [American entomologist] + -ina

Gender. Feminine

***tsugae*** Annand 1924b:79 (*Adelges*)

Subgenus ***APHRASTASIA*** Börner 1909a:1

Type species. *Chermes pectinatae* Cholodkovsky 1888, by original monotypy

Etymology. Greek aphrastos 'unnoticed' + -ia

Gender. Feminine

***pectinatae*** (Cholodkovsky 1888:47) (*Chermes*)

subspecies ***ishiharai*** (Inouye 1936:75) (*Chermes*)

subspecies ***pectinatae*** (Cholodkovsky 1888)

Subgenus ***CHOLODKOVSKYA*** Börner 1909b:1

Type species. *Chermes viridanus* Cholodkovsky 1896, by original monotypy

Etymology. (Nikolai Alexandrovitsch) Cholodkovsky [Russian entomologist] + -a

Gender. Feminine

***oregonensis*** Annand 1928:34,67 (*Adelges*)

***viridanus*** (Cholodkovsky 1896:39) (*Chermes*)

=*laricicola* (Shinji 1930:151) (*Chermes*)

***viridulus*** (Cholodkovsky 1911:175) (*Chermes*)

Subgenus ***DREYFUSIA*** Börner 1908a:416

Type species. *Chermes piceae* Ratzeburg 1844, by subsequent designation (Börner 1908b:138)

Etymology. (Ludwig Theodor) Dreyfus [German entomologist] + -ia

Gender. Feminine

*abietispiceae* (Stebbing 1903:57) (*Chermes*) nomen dubium (Choldkovsky (1906:49, 1915:60) indicates that the species is probably real but that the description is insufficient to confirm its identity; Schneider-Orelli and Schneider (1954:414) agree that Stebbing's description provides insufficient morphological information to compare with their description of *Dreyfusia knucheli* Schneider-Orelli and Schneider. Ghosh (1983:11) considered it a synonym of *Dreyfusia knucheli*, but qualified it with a question mark)

=*himalayensis* (Stebbing 1910:100) (*Chermes*) (unavailable, described in synonymy with *Chermes abietispiceae* Stebbing 1903)

*funitectus* (Dreyfus 1888:6) (*Chermes*) nomen dubium (Favret et al. 2015)

***joshii*** (Schneider-Orelli and Schneider 1959:260) (*Dreyfusia*)

***knucheli*** (Schneider-Orelli and Schneider 1954:416) (*Dreyfusia*)

***merkeri*** (Eichhorn 1957:312) (*Dreyfusia*)

***nebrodensis*** (Binazzi and Covassi 1991:246) (*Dreyfusia*)

***nordmannianae*** (Eckstein 1890:90) (*Chermes*)

=*nuesslini* (Börner 1908c:739) (*Dreyfusia*)

***piceae*** (Ratzeburg 1844:204) (*Chermes*)

subspecies ***canadensis*** (Merker and Eichhorn 1956:454) (form of *Dreyfusia piceae* (Ratzeburg))

subspecies ***occidentalis*** Foottit and Mackauer 1983:302 (subspecies of *Adelges piceae* (Ratzeburg))

subspecies ***piceae*** (Ratzeburg 1844)

=*bouvieri* (Cholodkovsky 1902:10) (variety of *Chermes piceae* Ratzeburg)

***pindrowi*** Yaseen and Ghani 1971:191,193 (*Adelges*)

***prelli*** (Grosmann 1935:822) (*Dreyfusia*)

***schneideri*** (Börner 1931:684) (*Dreyfusia*)

***todomatsui*** (Inouye 1945:73,92) (*Dreyfusia*)

Subgenus ***GILLETTEELLA*** Börner 1930:157

Type species. *Chermes cooleyi* Gillette 1907, inherited from replaced name

Etymology. (Clarence Preston) Gillette [American entomologist] + -ella [diminutive suffix]

Gender. Feminine

Note. Replacement name for *Gillettea* Börner 1909d

=*GILLETTEA* Börner 1909d:504

Type species. *Chermes cooleyi* Gillette 1907, by original monotypy

Etymology. (Clarence Preston) Gillette [American entomologist] + -a

Gender. Feminine

Note. Junior homonym of *Gillettea* Ashmead 1897:69 (Hymenoptera, Cynipidae)

***cooleyi*** (Gillette 1907:3) (*Chermes*)

***coweni*** (Gillette 1907:10) (variety of *Chermes cooleyi* Gillette)

*cummingae* (Steffan 1968:10,22,42) (*Gilletteella*) nomen nudum

***glandulae*** (Zhang in Zhang et al. 1980:382) (*Gilletteella*)

Subgenus ***SACCHIPHANTES*** Curtis 1844:831

Type species. *Chermes abietis* Linnaeus 1758, by original monotypy

Etymology. Greek sakkos ‘coarse cloth’, ‘sail’ + Greek hyphantēs ‘weaver’

Gender. Masculine

=*ELATIPTUS* Amyot 1847:484

Type species. *Chermes abietis* Linnaeus 1758, by original monotypy

Etymology. Greek elatē ‘fir’ + Greek ipt- ‘harm’ + -us

Gender. Masculine

Note. Suppressed (China 1963) and junior objective synonym of *Sacchiphantes* Curtis 1844

=*PHLOEOPHTHIRIDIUM* van der Hoeven 1849:509

Type species. *Chermes abietis* Linnaeus 1758, by original monotypy

Etymology. Greek phloios ‘bark’ + Greek phtheir- ‘destroy’ + Greek -idium [diminutive suffix]

Gender. Neuter

Note. Junior objective synonym of *Sacchiphantes* Curtis 1844

***abietis*** (Linnaeus 1758:454) (*Chermes*)

=*abietislaricis* (Eckstein 1890:88) (*Chermes*) based on Dreyfus’s (1889:82) description of a *Larix*-associated form of *Chermes abietis*

=*alaeviridis* (Solowiow 1924:39) (*Chermes*)

=*gallarumabietis* (De Geer 1773:99) (*Aphis*) nomen dubium

=*laricifoliae* (Fitch 1858:752) (*Chermes*)

***diversis*** Annand 1928:34,69 (*Adelges*)

***karafutonis*** Kono and Inouye 1938:169,170 (*Adelges*)

***kitamiensis*** (Inouye 1963:341) (*Sacchiphantes*)

***roseigallis*** (Li and Tsai 1973:135,141,148) (*Sacchiphantes*)

***segregis*** (Steffan 1961:67) (*Sacchiphantes*)

***torii*** (Eichhorn in Eichhorn and Carter 1978:284) (*Sacchiphantes*)

***viridis*** (Ratzeburg 1843:202) (*Chermes*)

=*occidentalis* (Cholodkovsky 1910:281) (*Chermes*)

*CHERMES* Linnaeus 1758:453

Type species. None (see Favret et al. 2014)

Etymology. Arabic kirmiz ‘crimson’

Gender. Masculine

Note. Suppressed (Evans and China 1965), see Favret et al. (2014) for list of species-group names described under *Chermes*

*GISTELIELLA* Strand 1928:46

Type species. *Chermes lapidarius* Fabricius 1803, inherited from replaced name

Etymology. (Johannes) Gistel [German entomologist] + -i + ella [diminutive suffix]

Gender. Feminine
Note. Replacement name for *Aphanus* Gistel 1837, nomen dubium
=*APHANUS* Gistel 1837:111
Type species. *Chermes lapidarius* Fabricius 1803, by original monotypy
Etymology. Greek aphanēs ‘invisible’
Gender. Masculine
Note. Junior homonym of *Aphanus* Laporte 1833:35 (Hemiptera, Lygaeidae)
*lapidaria* (Fabricius 1803:306) (*Chermes*) nomen dubium (placement unknown)

***PINEUS*** Shimer 1869:383
Subgenus ***PINEODES*** Börner 1926:240
Type species. *Chermes pinifoliae* Fitch 1858, by original monotypy
Etymology. *Pine(us)* [Hemiptera: Adelgidae]+ Greek -ōdēs ‘resembling’
Gender. Masculine
***pinifoliae*** (Fitch 1858:741) (*Chermes*)
=*abieticolens* (Thomas 1879:156) (*Chermes*)
=*armiger* (Annand 1924a:5) (*Chermes*)
=*montanus* (Gillette 1907:14) (*Chermes*)

Subgenus ***PINEUS*** Shimer 1869:383
Type species. *Coccus pinicorticis* Fitch 1855, by original monotypy
Etymology. Latin pineus ‘of or pertaining to pine’
Gender. Masculine
=*CHERMAPHIS* Maskell 1884:292
Type species. *Kermaphis pini* var. *laevis* Maskell 1885, by subsequent designation (Eastop and Hille Ris Lambers 1976:144)
Etymology. *Cherm(es)* [Hemiptera] + *Aphis* [Hemiptera: Aphididae]
Gender. Feminine
=*CNAPHALODES* Amyot and Audinet Serville 1843:595
Type species. *Chermes pini* Goeze 1778, by original monotypy
Etymology. Greek knaphallon ‘pillow’ + Greek -ōdēs ‘resembling’
Gender. Masculine
=*EOPINEUS* Steffan 1968:11
Type species. *Chermes strobi* Ratzeburg 1844, by subsequent designation (Eastop and Hille Ris Lambers 1976:188)
Etymology. Greek ēōs ‘dawn’, ‘early’ + *Pineus* [Hemiptera: Adelgidae]
Gender. Masculine
=*KERMAPHIS* Maskell 1885:19
Type species. *Anisophleba pini* Koch 1857, by subsequent designation (Eastop and Hille Ris Lambers 1976:232)
Etymology. *Kerm(es)* [Hemiptera: Coccoidea] + *Aphis* [Hemiptera: Aphididae]
Gender. Feminine

=*PITYOPSYLLA* Amyot 1847:461
Type species. *Chermes pini* Goeze 1778, by original monotypy
Etymology. Greek pitys 'pine' + *Psylla* [Hemiptera: Psyllidae]
Gender. Feminine
Note. Suppressed (China 1963) and junior objective synonym of *Cnaphalodes* Amyot and Audinet Serville 1843

***abietinus*** Underwood and Balch 1964:523 (*Pineus*)
***armandicola*** Zhang et al. 1992:360,394 (*Pineus*)
***boerneri*** Annand 1928:34,112 (*Pineus*) (Takahashi (1937:11), Inouye (1945:36), and Ghosh (1983:8) list this species as a synonym of *Pineus laevis* (Maskell), but Maskell's (1885:16) description is insufficient to validate synonymy)
***boycei*** Annand 1928:35,102 (*Pineus*)
***cembrae*** (Cholodkovsky 1888:47) (*Chermes*)
subspecies ***cembrae*** (Cholodkovsky 1888)
=*sibiricus* (Cholodkovsky 1889b:388) (*Chermes*)
subspecies ***pinikoreanus*** Zhang and Fang 1981:15 (subspecies of *Pineus cembrae* (Cholokovsky))
***cladogenous*** Fang and Sun 1985:3 (*Pineus*)
***coloradensis*** (Gillette 1907:16) (*Chermes*)
***cortecicolus*** Fang and Sun 1985:2 (*Pineus*)
***engelmannii*** Annand 1928:36,130 (*Pineus*)
***floccus*** (Patch 1909:137) (*Chermes*)
***ghanii*** Yaseen and Ghani 1971:191,199 (*Pineus*)
***harukawai*** Inouye 1945:13,21,31,80 (*Pineus*)
***havrylenkoi*** Blanchard 1944:52 (*Pineus*)
***hosoyai*** Inouye 1945:22,32,81 (*Pineus*)
***konowashiyai*** Inouye 1945:13,21,34,81 (*Pineus*)
***laevis*** (Maskell 1885:16) (variety of *Kermaphis pini* (Koch))
***matsumurai*** Inouye 1945:13,22,37,82 (*Pineus*)
***orientalis*** (Dreyfus 1888:3,6) (*Chermes*)
***patchae*** Börner 1926:239 (*Pineus*)
***pineoides*** (Cholodkovsky 1903:263) (variety of *Chermes pini* (Koch))
***pini*** (Goeze 1778:328) (*Chermes*)
=*coniferarum* (Cholodkovsky 1889a:222) (*Chermes*)
=*pini* (Koch 1857:322) (*Anisophleba*)
=*pinicola* (Cholodkovsky 1915:57) (variety of *Chermes pini* (Koch))
***piniyunnanensis*** Zhang et al. 1992:361,394 (*Pineus*)
***sichunanus*** Zhang in Zhang et al. 1980:381 (*Pineus*)
***similis*** (Gillette 1907:15) (*Chermes*)
***simmondsi*** Yaseen and Ghani 1971:191,195 (*Pineus*)
***strobi*** (Hartig 1839:643) (*Coccus*)
=*corticalis* (Kaltenbach 1843:197) (*Chermes*)
=*pinicorticis* (Fitch 1855:871) (*Coccus*)

=*strobi* (Baerensprung 1849:174) (*Coccus*)
=*strobi* (Ratzeburg 1844:203) (*Chermes*)
***sylvestris*** Annand 1928:34,115 (*Pineus*)
***wallichianae*** Yaseen and Ghani 1971:191,202 (*Pineus*)

## Index of genus-group and species-group names

***ADELGES*** Vallot 1836
*abieticolens* Thomas 1879 – synonym of *Pineus* (*Pineodes*) *pinifoliae*
***abietinus*** Underwood and Balch 1964 – *Pineus* (*Pineus*)
***abietis*** Linnaeus 1758 – *Adelges* (*Sacchiphantes*)
*abietislaricis* Eckstein 1890 – synonym of *Adelges* (*Sacchiphantes*) *abietis*
*abietispiceae* Stebbing 1903 – *Adelges* (*Dreyfusia*)
***aenigmaticus*** Annand 1928 – *Adelges* (*Adelges*)
*affinis* Börner 1908b – synonym of *Adelges* (*Adelges*) *tardus*
*alaeviridis* Solowiow 1924 – synonym of *Adelges* (*Sacchiphantes*) *abietis*
*ANISOPHLEBA* Koch 1857 – synonym of *Adelges* (*Adelges*)
***ANNANDINA*** Favret et al. 2015 – subgenus of *Adelges*
*APHANUS* Gistel 1837 – synonym of *Gisteliella*
***APHRASTASIA*** Börner 1909a – subgenus of *Adelges*
***armandicola*** Zhang et al. in Chen 1992 – *Pineus* (*Pineus*)
*armiger* Annand 1924a – synonym of *Pineus* (*Pineodes*) *pinifoliae*
*atratus* Buckton 1883 – synonym of *Adelges* (*Adelges*) *laricis larici*
***boerneri*** Annand 1928 – *Pineus* (*Pineus*)
*bouvieri* Cholodkovsky 1902 – synonym of *Adelges* (*Dreyfusia*) *piceae piceae*
***boycei*** Annand 1928 – *Pineus* (*Pineus*)
***canadensis*** Merker and Eichhorn 1956 – subspecies of *Adelges* (*Dreyfusia*) *piceae*
***cembrae*** Cholodkovsky 1888 – *Pineus* (*Pineus*)
*CHERMAPHIS* Maskell 1884 – synonym of *Pineus* (*Pineus*)
*CHERMES* Linnaeus 1758
***CHOLODKOVSKYA*** Börner 1909b – subgenus of *Adelges*
***cladogenous*** Fang and Sun 1985 – *Pineus* (*Pineus*)
*CNAPHALODES* Amyot and Audinet Serville 1843 – synonym of *Pineus* (*Pineus*)
*coccineus* Ratzeburg 1843 – synonym of *Adelges* (*Adelges*) *laricis laricis*
***coloradensis*** Gillette 1907 – *Pineus* (*Pineus*)
*coniferarum* Cholodkovsky 1889a – synonym of *Pineus* (*Pineus*) *pini*
*consolidatus* Patch 1909 – synonym of *Adelges* (*Adelges*) *laricis laricis*
***cooleyi*** Gillette 1907 – *Adelges* (*Gilletteella*)
***cortecicolus*** Fang and Sun 1985 – *Pineus* (*Pineus*)
*corticalis* Kaltenbach 1843 – synonym of *Pineus* (*Pineus*) *strobi*
***coweni*** Gillette 1907 – *Adelges* (*Gilletteella*)
*cummingae* Steffan 1968 – *Adelges* (*Gilletteella*)

***diversis*** Annand 1928 – *Adelges* (*Sacchiphantes*)
***DREYFUSIA*** Börner 1908a – subgenus of *Adelges*
*ELATIPTUS* Amyot 1847 – synonym of *Adelges* (*Sacchiphantes*)
***engelmannii*** Annand 1928 – *Pineus* (*Pineus*)
*EOPINEUS* Steffan 1968 – synonym of *Pineus* (*Pineus*)
***floccus*** Patch 1909 – *Pineus* (*Pineus*)
*funitectus* Dreyfus 1888 – *Adelges* (*Dreyfusia*)
*gallarumabietis* De Geer 1773 – synonym of *Adelges* (*Sacchiphantes*) *abietis*
***geniculatus*** Ratzeburg 1844 – *Adelges* (*Adelges*)
***ghanii*** Yaseen and Ghani 1971 – *Pineus* (*Pineus*)
*GILLETTEA* Börner 1909d – synonym of *Adelges* (*Gilletteella*)
***GILLETTEELLA*** Börner 1930 – subgenus of *Adelges*
*GISTELIELLA* Strand 1928
***glandulae*** Zhang in Zhang et al. 1980 – *Adelges* (*Gilletteella*)
*hamadryas* Koch 1857 – synonym of *Adelges* (*Adelges*) *laricis laricis*
***harukawai*** Inouye 1945 – *Pineus* (*Pineus*)
***havrylenkoi*** Blanchard 1944 – *Pineus* (*Pineus*)
*himalayensis* Stebbing 1910 – synonym of *Adelges* (*Dreyfusia*) *abietispiceae*
***hosoyai*** Inouye 1945 – *Pineus* (*Pineus*)
***isedakii*** Eichhorn in Eichhorn and Carter 1978 – *Adelges* (*Adelges*)
***ishiharai*** Inouye 1936 – subspecies of *Adelges* (*Aphrastasia*) *pectinatae*
***japonicus*** Monzen 1929 – *Adelges* (*Adelges*)
***joshii*** Schneider-Orelli and Schneider 1959 – *Adelges* (*Dreyfusia*)
***karafutonis*** Kono and Inouye 1938 – *Adelges* (*Sacchiphantes*)
***karamatsu*** Inouye 1945 – *Adelges* (*Adelges*)
*KERMAPHIS* Maskell 1885 – synonym of *Pineus* (*Pineus*)
***kitamiensis*** Inouye 1963 – *Adelges* (*Sacchiphantes*)
***knucheli*** Schneider-Orelli and Schneider 1954 – *Adelges* (*Dreyfusia*)
***konowashiyai*** Inouye 1945 – *Pineus* (*Pineus*)
***laevis*** Maskell 1885 – *Pineus* (*Pineus*)
*lapidaria* Fabricius 1803 – *Gisteliella*
***lapponicus*** Cholodkovsky 1889b – *Adelges* (*Adelges*)
*LARICETHUS* Amyot 1847 – synonym of *Adelges* (*Adelges*)
*lariceti* Altum 1889 – synonym of *Adelges* (*Adelges*) *laricis laricis*
***lariciatus*** Patch 1909 – *Adelges* (*Adelges*)
*laricicola* Shinji 1930 – synonym of *Adelges* (*Cholodkovskya*) *viridanus*
*laricifoliae* Fitch 1858 – synonym of *Adelges* (*Sacchiphantes*) *abietis*
*laricis* Bouché 1834 – synonym of *Adelges* (*Adelges*) *laricis laricis*
*laricis* Hartig 1839 – synonym of *Adelges* (*Adelges*) *laricis laricis*
***laricis*** Vallot 1836 – *Adelges* (*Adelges*)
***matsumurai*** Inouye 1945 – *Pineus* (*Pineus*)
***merkeri*** Eichhorn 1957 – *Adelges* (*Dreyfusia*)
*montanus* Gillette 1907 – synonym of *Pineus* (*Pineodes*) *pinifoliae*

***nebrodensis*** Binazzi and Covassi 1991 – *Adelges* (*Dreyfusia*)
*niger* Solowiow 1924 – synonym of *Adelges* (*Adelges*) *tardus*
***nordmannianae*** Eckstein 1890 – *Adelges* (*Dreyfusia*)
*nuesslini* Börner 1908c – synonym of *Adelges* (*Dreyfusia*) *nordmannianae*
*obtectus* Ratzeburg 1844 – synonym of *Adelges* (*Adelges*) *laricis laricis*
*occidentalis* Cholodkovsky 1910 – synonym of *Adelges* (*Sacchiphantes*) *viridis*
***occidentalis*** Foottit and Mackauer 1983 – subspecies of *Adelges* (*Dreyfusia*) *piceae*
***oregonensis*** Annand 1928 – *Adelges* (*Cholodkovskya*)
***orientalis*** Dreyfus 1888 – *Pineus* (*Pineus*)
***patchae*** Börner 1926 – *Pineus* (*Pineus*)
***pectinatae*** Cholodkovsky 1888 – *Adelges* (*Aphrastasia*)
*PHLOEOPHTHIRIDIUM* van der Hoeven 1849 – synonym of *Adelges* (*Sacchiphantes*)
***piceae*** Ratzeburg 1944 – *Adelges* (*Dreyfusia*)
***pindrowi*** Yaseen and Ghani 1971 – *Adelges* (*Dreyfusia*)
***PINEODES*** Börner 1926 – subgenus of *Pineus*
***pineoides*** Cholodkovsky 1903 – *Pineus* (*Pineus*)
***PINEUS*** Shimer 1869
***pini*** Goeze 1778 – *Pineus* (*Pineus*)
*pini* Koch 1857 – synonym of *Pineus* (*Pineus*) *pini*
*pinicola* Cholodkovsky 1915 – synonym of *Pineus* (*Pineus*) *pini*
*pinicorticis* Fitch 1855 – synonym of *Pineus* (*Pineus*) *strobi*
***pinifoliae*** Fitch 1858 – *Pineus* (*Pineodes*)
***pinikoreanus*** Zhang and Fang 1981 – subspecies of *Pineus* (*Pineus*) *cembrae*
***piniyunnanensis*** Zhang et al. 1992 – *Pineus* (*Pineus*)
*PITYOPSYLLA* Amyot 1847 – synonym of *Pineus* (*Pineus*)
***potaninilaricis*** Zhang in Zhang et al. 1980 – subspecies of *Adelges* (*Adelges*) *laricis*
*praecox* Cholodkovsky 1898 – synonym of *Adelges* (*Adelges*) *lapponicus*
***prelli*** Grosmann 1935 – *Adelges* (*Dreyfusia*)
***roseigallis*** Li and Tsai 1973 – *Adelges* (*Sacchiphantes*)
***SACCHIPHANTES*** Curtis 1844 – subgenus of *Adelges*
***schneideri*** Börner 1931 – *Adelges* (*Dreyfusia*)
***segregis*** Steffan 1961 – *Adelges* (*Sacchiphantes*)
*sibiricus* Cholodkovsky 1889b – synonym of *Pineus* (*Pineus*) *cembrae cembrae*
***sichunanus*** Zhang in Zhang et al. 1980 – *Pineus* (*Pineus*)
***similis*** Gillette 1907 – *Pineus* (*Pineus*)
***simmondsi*** Yaseen and Ghani 1971 – *Pineus* (*Pineus*)
*strobi* Baerensprung 1849 – synonym of *Pineus* (*Pineus*) *strobi*
***strobi*** Hartig 1839 – *Pineus* (*Pineus*)
*strobi* Ratzeburg 1844 – synonym of *Pineus* (*Pineus*) *strobi*
*strobilobius* Kaltenbach 1843 – synonym of *Adelges* (*Adelges*) *laricis laricis*
***sylvestris*** Annand 1928 – *Pineus* (*Pineus*)
***tardoides*** Cholodkovsky 1911 – *Adelges* (*Adelges*)
***tardus*** Dreyfus 1888 – *Adelges* (*Adelges*)

***todomatsui*** Inouye 1945 – *Adelges* (*Dreyfusia*)
***torii*** Eichhorn in Eichhorn and Carter 1978 – *Adelges* (*Sacchiphantes*)
***tsugae*** Annand 1924b – *Adelges* (*Annandina*)
***viridanus*** Cholodkovsky 1896 – *Adelges* (*Cholodkovskya*)
***viridis*** Ratzeburg 1843 – *Adelges* (*Sacchiphantes*)
***viridulus*** Cholodkovsky 1911 – *Adelges* (*Cholodkovskya*)
***wallichianae*** Yaseen and Ghani 1971 – *Pineus* (*Pineus*)

## Acknowledgments

We thank Andrew Carmichael (USDA Systematic Entomology Laboratory) for literature research, Juan Manuel Nieto Nafría (University of León, Spain) for expert opinion and a meticulous cross-referencing of taxon names and bibliographic citations, Ed Jarzembowski (Nanjing Institute of Geology and Palaeontology, China) for help with etymologies, and Shalva Barjadze (Agricultural University of Georgia) for translating certain Russian texts. We also thank external reviewers Anders Albrecht and Rimantas Rakauskas and editor Benjamin Price for their time handling our manuscript. Nomenclature work has become much easier with the availability of digital historical literature. We would like especially to acknowledge the Biodiversity Heritage Library and Google Books for making available valuable literature resources. That which was not available online was available through interlibrary loan. Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA; USDA is an equal opportunity provider and employer.

## References

Altum B (1889) Waldbeschädigungen durch Thiere und Gegenmittel. Julius Springer, Berlin, 285 pp. doi: 10.1007/978-3-642-50828-8

Amyot CJB (1847) Entomologie française. Rhynchotes (Suite) (1). Annales de la Société Entomologique de France. Deuxième Série 5: 453–506.

Amyot CJB, Audinet Serville JG (1843) Histoire Naturelle des Insectes. Hémiptères. Librairie encyclopédique de Roret, Paris, 675 pp.

Annand PN (1924a) A new *Chermes* from pine (Hemiptera Aphidae). Canadian Entomologist 56(1): 5–6. doi: 10.4039/Ent565-1

Annand PN (1924b) A new species of *Adelges* (Hemiptera, Phylloxeridae). Pan-Pacific Entomologist 1(2): 79–82.

Annand PN (1928) A contribution toward a monograph of the Adelginae (Phylloxeridae) of North America. Stanford University Publication, University Series, Biological Sciences 6(1): 1–146.

Ashmead WH (1897) Description of some new genera in the family Cynipidae. Psyche 8(253): 67–69. doi: 10.1155/1897/60546

Baerensprung FV (1849) Beobachtungen über einige einheimische Arten aus der Familie der Coccinen. Zeitung für Zoologie, Zootomie und Palaeozoologie 1(22): 173–176.

Battisti A, Binazzi A, Gourov A, Khomentovsky P, Roques A (1997) A survey of conifer aphids from Siberia and Kamchatka (Homoptera Aphidoidea). Redia 80: 131–145.

Binazzi A (1984) Chiave per le specie afidiche più note delle conifere in Europa. Redia 67(appendix): 547–571.

Binazzi A, Covassi M (1991) Contributi alla conoscenze degli afidi delle conifere XII. Il gen. *Dreyfusia* Boerner in Italia con la descrizione di una specia nuova (Homoptera Adelgidae). Redia 74(1): 233–299.

Blanchard EE (1944) Descripciones y anotaciones de afidoideos argentinos. Acta Zoologica Lilloana 2: 15–62.

Börner C (1908a) [1907] Systematik und Biologie der Chermiden. Zoologischer Anzeiger 32(14): 413–428.

Börner C (1908b) Eine monographische Studie über die Chermiden. Arbeiten aus der Kaiserlichen Biologischen Anstalt für Land- und Forstwirtschaft 6(2): 81–320.

Börner C (1908c) Über Chermesiden IV. *Dreyfusia piceae* und *nüsslini* nov. spec. Zoologischer Anzeiger 33 (22/23): 737–750.

Börner C (1909a) *Aphrastasia pectinatae* (Chol.) CB. Self-published, Sankt Julian bei Metz, 1 pp.

Börner C (1909b) *Cholodkovskya viridana* (Chol.) CB. Self-published, Sankt Julian bei Metz, 2 pp.

Börner C (1909c) Untersuchungen über die Chermiden. Mitteilungen aus der Kaiserlichen Biologischen Anstalt für Land- und Forstwirtschaft 8: 50–60.

Börner C (1909d) Über Chermesiden VI. *Cholodkovskya*, *Aphrastasia* und *Gillettea*. Zoologischer Anzeiger 34(16/17): 498–511.

Börner C (1926) Zuchtung der Homopteren. In: Abderhalden E (Ed.) Handbuch der biologischen Arbeitsmethoden. 9 part 1(2). Urban & Schwarzenberg, Berlin & Wien, 215–270.

Börner C (1930) Beiträge zu einem neuen System der Blattläuse. Archiv für klassifikatorische und phylogenetische Entomologie 1(2): 115–180.

Börner C (1931) Aphidoidea, Blattläuse. Sorauer Handbuch der Pflanzenkrankheiten [offprint]. [See Nieto Nafría et al. 2007: 54]

Börner C (1952) Europae centralis Aphides. Die Blattläuse Mitteleuropas. Namen, Synonyme, Wirtspflanzen, Generationszyklen. Mitteilungen der Thüringischen Botanischen Gesellschaft, Supplement 3: 1–259.

Bouché PF (1834) Naturgeschichte der Insekten, besonders in Hinsicht ihrer ersten Zustände als Larven und Puppen. Nicolaischen Buchhandlung, Berlin, 216 pp.

Buckton GB (1883) Monograph of British Aphides. Volume 4. Ray Society, London, 228 pp.

Carter CI (1971) Conifer woolly aphids (Adelgidae) in Britain. Forestry Commission Bulletin 42: 1–51.

China WE (Ed.) (1963) Opinion 686. Amyot, Méthode mononymique: placed on the official index of rejected and invalid works in zoological nomenclature. Bulletin of Zoological Nomenclature 20(6): 423.

Cholodkovsky NA (1888) Über einige *Chermes*-Arten. Zoologischer Anzeiger 11(270): 45–48.

Cholodkovsky NA (1889a) Weiteres zur Kenntnis der *Chermes*-Arten. Zoologischer Anzeiger 12(305): 218–223.

Cholodkovsky NA (1889b) Neue Mittheilungen zur Lebensgeschichte der Gattung *Chermes* L. Zoologischer Anzeiger 12(312): 387–391.

Cholodkovsky NA (1896) Zur Biologie der Lärchen-*Chermes*-Arten. Zoologischer Anzeiger 19(494): 37–40.

Cholodkovsky NA (1898) Beiträge zu einer Monographie der Coniferen-Läuse. Trudy Vsesojuznogo Entomologiceskogo Obscestva 31: 1–61.

Cholodkovsky NA (1902) Second annotated catalogue of aphid (Aphidae) collections in Zoological Cabinet of St. Petersburg Institute of Forestry. Izvestiya S-Peterburgskogo Lesnogo Instituta 8(2): 1–11.

Cholodkovsky NA (1903) Aphidologische Mittheilungen. Zoologischer Anzeiger. 26(693): 258–263.

Cholodkovsky NA (1906) *Chermes* injurious to coniferous trees. Department of Agriculture, St. Petersburg, 60 pp.

Cholodkovsky NA (1910) Aphidologische Mitteilungen. Zoologischer Anzeiger 35(9/10): 279–284.

Cholodkovsky NA (1911) Aphidologische Mitteilungen. Zoologischer Anzeiger 37(8/9): 172–178.

Cholodkovsky NA (1915) *Chermes* injurious to coniferous trees (2). Department of Agriculture, Petrograd, 89 pp.

Cortés Gabaudan F, Nieto Nafría JM, Favret C, Barbagallo S, Sano M, Stekolshchikov AV (2011) Etymology and gender of genus-group names. In: Nieto Nafría JM, Favret C (Eds) Registers of Family-Group and Genus-Group Taxa of Aphidoidea (Hemiptera Sternorrhyncha). Universidad de León, León, 405–463.

Curtis J (1844) The spruce-cone Gall *Aphis* – (*Sacchiphantes Abietis*). The Gardeners' Chronicle and Agricultural Gazette 50: 831.

De Geer C (1773) Mémoires pour Servir à l'Histoire des Insectes. Volume 3. Pierre Hesselberg, Stockholm, 696 pp.

Dreyfus LT (1888) Über neue Beobachtungen bei den Gattungen *Chermes* und *Phylloxera*. Versammlung deutscher Naturforscher und Ärzte zu Köln 61: 1–10.

Dreyfus LT (1889) Ueber Phylloxerinen. J.F. Bergman, Wiesbaden, 88 pp. doi: 10.5962/bhl.title.8560

Eastop VF, Hille Ris Lambers D (1976) Survey of the World's Aphids. Dr. W. Junk, The Hague, 573 pp.

Eckstein K (1890) Zur Biologie der Gattung *Chermes* L. Zoologischer Anzeiger 13(328): 86–90.

Eichhorn O, Carter CI (1978) Investigation into conifer woolly aphids (Hemiptera: Adelgidae) in Japan, with the description of two new species. Zeitschrift für angewandte Entomologie 86: 273–289. doi: 10.1111/j.1439-0418.1978.tb01934.x

Eichhorn O (1957) Eine neue Tannenlaus der Gattung *Dreyfusia* (*Dreyfusia merkeri* nov. spec.). Zeitschrift für Angewandte Zoologie 44(3): 303–348.

Eichhorn O (1994) Numerical research upon the types and rates of offspring produced by the parthenogenetic generations of *Adelges laricis* Vall. (Hom., Adelgidae). Journal of Applied Entomology 117(1–5): 344–352. doi: 10.1111/j.1439-0418.1994.tb00745.x

Evans GO, China WE (Eds) (1965) Opinion 731. *Psylla* Geoffroy, 1762 (Insecta, Hemiptera): validated under the plenary powers with suppression of *Chermes* Linnaeus, 1758. Bulletin of Zoological Nomenclature 22(2): 86–87.

Fabricius JC (1803) Systema Rhyngotorum. Secundum Ordines, Genera, Species. Adiectis Synonymis, Locis, Observationibus, Descriptionibus. Carolum Reichard, Brunsvigae (Brunswick), 314 pp. doi: 10.5962/bhl.title.11644

Fang SY (1982) Biological statistical information on wing vein patterns of six aphids in the Xiaoxinanlin area. Journal of North-East Forestry University 6: 24–26.

Fang SY, Yan SC (1997) The conifer woolly aphids (Adelgidae) in China. Journal of Forestry Research 8(1): 30–32. doi: 10.1007/BF02864936

Fang SY, Sun JH (1985) Study of Korean pine adelgids in Northeast China, with descriptions of two new species. Journal of North-East Forestry University 13(3): 1–7.

Favret C, Miller GL, Nieto Nafría JM, Cortés Gabaudan F (2008) [2007] Catalog of the aphid genera described from the New World. Transactions of the American Entomological Society 133(3–4): 363–412.

Favret C, Miller GL, Nieto Nafría JM, Cortés Gabaudan F (2009) [2008]. Corrections and additions to the catalog of the aphid genera described from the New World. Transactions of the American Entomological Society 134(3–4): 275–282.

Favret C, Ouvrard D, Williams DJ (2014) Annotated list of the species-group taxa described in combination with *Chermes* Linnaeus 1758 (Hemiptera: Sternorrhyncha). Transactions of the American Entomological Society 140: 67–81. doi: 10.3157/061.140.0104

Favret C, Blackman RL, Stekolshchikov AV (2015) *Chermes funitectus* Dreyfus and the hemlock woolly adelgid (Hemiptera: Adelgidae). Entomological News 125(3): 174–178. doi: 10.3157/021.125.0304

Fitch A (1855) [1854]. Report on the noxious, beneficial, and other insects of the state of New York. Transactions of the New York State Agricultural Society 14: 691–880.

Fitch A (1858) [1857]. Fourth report on the noxious and other insects of the State of New York. Transactions of the New York State Agricultural Society 17: 687–814.

Foottit R, Mackauer M (1983) Subspecies of the balsam woolly aphid, *Adelges piceae* (Homoptera: Adelgidae), in North America. Annals of the Entomological Society of America 76(2): 299–304. doi: 10.1093/aesa/76.2.299

Gavrilov-Zimin IA, Stekolshchikov AV, Gautam DC (2015) General trends of chromosomal evolution in Aphidococca (Insecta, Homoptera, Aphidinea + Coccinea). Comparative Cytogenetics 9(3): 335–422. doi: 10.3897/CompCytogen.v9i3.4930

Ghosh AK (1983) A review of the family Adelgidae from the Indian subregion (Homoptera: Aphidoidea). Oriental Insects 17(1): 1–34. doi: 10.1080/00305316.1983.10433690

Gillette CP (1907) *Chermes* of Colorado conifers. Proceedings of the Academy of Natural Sciences of Philadelphia, 54(1): 3–22.

Gistel J (1837) Systematische Uebersicht der Wanzen und Cicaden der Umgebung von München. Faunus. Zeitschrift für Zoologie und vergleichende Anatomie 21: 98–111.

Goeze JAE (1778) Entomologische Beyträge zu des Ritter Linné Zwölften Ausgabe des Natursystems. Volume 2. Weidmann Erben und Reich, Leipzig, 352 pp.

Grosmann H (1935) Über eine neue Tannenlaus (*Dreyfusia Prelli* nov. spec.). Tharandter Forstliches Jahrbuch 86: 816–826.

Hartig T (1839) Jahresberichte Über die Fortschritte der Firstwissenschaft und forstlichen Naturkunde im Jahre 1836 und 1837 nebst Original-Abhandlungen aus dem Gebiete dieser Wissenschaften 1(4): 489–646.

Havill NP, Foottit RG (2007) Biology and evolution of Adelgidae. Annual Review of Entomology 52: 325–349. doi: 10.1146/annurev.ento.52.110405.091303

Havill NP, Foottit RG, von Dohlen CD (2007) Evolution of host specialization in the Adelgidae (Insecta: Hemiptera) inferred from molecular phylogenetics. Molecular Phylogenetics and Evolution 44: 357–370. doi: 10.1016/j.ympev.2006.11.008

Heie OE, Wegierek P (2009) A classification of the Aphidomorpha (Hemiptera Sternorrhyncha) under consideration of the fossil taxa. Redia 92: 69–77.

Heie OE, Wegierek P (2011) A list of fossil aphids (Hemiptera, Sternorrhyncha, Aphidomorpha). Monographs of the Upper Silesian Museum 6, 82 pp.

Herrich-Schaeffer D (1854) Vorwort des Herausgebers. In: Koch CL, Die Pflanzenläuse Aphiden getreu nach dem Leben abgebildet und beschrieben. J.L. Lotzbeck, Nürnberg. Volume 1: III-VIII.

Hunter WD (1901) The Aphididae of North America. Bulletin of the Iowa Agricultural Experiment Station 60: 63–138.

Inouye M (1936) Eine neue *Chermes*- Art (Adelgiden) auf Hokkaido. Insecta Matsumurana 11(1–2): 75–80.

Inouye M (1945) Monographische Studie über die Japanischen Koniferen-Gallenläuse (Adelgidae). Bulletin of the Hokkaido Forestry Experiment Station 15, 105 pp.

Inouye M (1963) Eine neue *Sacchiphantes*-Art von Adeligen, Schädlinge an Japanlärchen in Japan. Journal of the Japanese Forestry Society 45(10): 340–344.

International Commission on Zoological Nomenclature (ICZN) (1999) International Code of Zoological Nomenclature, Fourth Edition. International Trust for Zoological Nomenclature, London, 306 pp.

Kaltenbach JH (1843) Monographie der Familien der Pflanzenläuse (Phytophthires). P. Fagot, Aachen, 222 pp. doi: 10.5962/bhl.title.51483

Koch CL (1857) Die Pflanzenläuse Aphiden getreu nach dem Leben abgebildet und beschrieben. J.L. Lotzbeck, Nürnberg. Volume 9: 275–335.

Kono H, Inouye M (1938) Die Adelgiden, schädlich an Ezofichten und Akaezofichten in Japan. Insecta Matsumurana 12(4): 169–173.

Laporte FL (1833) [1832] Essai d'une classification systématique de l'ordre des Hémiptères (Hémiptères Héteroptères, Latr.). Magasin de Zoologie 2: 1–88.

Li CL, Tsai PH (1973) Studies on the larch adelgids in northeast China with description of a new species. Acta Entomologica Sinica 16(2): 133–153.

Linnaeus C (1758) Systema naturae per regna tri naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Editio Decima, Reformata. Volume 1. Laurentii Salvii, Holmiae (Stockholm), 824 pp.

Luo Y (1988) Life cycle and control of *Adelges laricis* Vall in the forestry areas of Liupan mountains. Ningxia Journal of Agro-forestry Science and Technology (China) 4: 23–24.

Maskell WM (1884) On an aphidian insect infesting pine trees. New Zealand Journal of Science 2(6): 291–292.

Maskell WM (1885) Note on an aphidian insect infesting pine trees, with observations on the name "*Chermes*" or "*Kermes*". Transactions of the New Zealand Institute 17: 13–19.

Merker E, Eichhorn O (1956) Die Formenkreise der gefährlichen Tannenläuse Gattung *Dreyfusia* (*Adelges*). Naturwissenschaften 19(43): 453–454. doi: 10.1007/BF00629526

Michalik A, Szklarzewicz T, Wegierek P, Wieczorek K (2013) The ovaries of aphids (Hemiptera, Sternorrhyncha, Aphidoidea): morphology and phylogenetic implications. Invertebrate Biology 132(3): 226–240. doi: /10.1111/ivb.12026

Monzen K (1929) Studies on some gall producing aphids and their galls. Saito Ho-on Kai (The Saito Gratitude Foundation) Monographs 1. The General Department of Scientific Research, Saito Ho-on Kai, Sendai, Japan, 80 pp.

Nieto Nafría JM, Favret C, Akimoto S, Barbagallo S, Chakrabarti S, Mier Durante MP, Miller GL, Qiao GX, Sano M, Pérez Hidalgo N, Stekolshchikov AV, Wegierek P (2011) Register of genus-group taxa of Aphidoidea. In: Nieto Nafría JM, Favret C (Eds) Registers of Family-Group and Genus-Group Taxa of Aphidoidea (Hemiptera Sternorrhyncha). Universidad de León, León, 81–404.

Nieto Nafría JM, Pérez Hidalgo N, Mier Durante MP (2007) New synonyms and several nomenclatural clarifications on family-group names in the Aphididae (Hemiptera Sternorrhyncha). Zootaxa 1629:51–55.

Parry WH (1973) Observations on the flight periods of aphids in a Sitka spruce plantation in north-eastern Scotland. Bulletin of Entomological Research 62(3): 391–399. doi: 10.1017/S0007485300003904

Patch EM (1909) *Chermes* of Maine spruces. Psyche 16: 136–137. doi: 10.1155/1909/942383

Patch EM (1938) Food-plant catalogue of the aphids of the world including the Phylloxeridae. Maine Agricultural Experiment Station Bulletin 393: 36–431.

Podeur G (1971) Contributions to the study of the diapause of certain Adelgidae (Homoptera: Aphidoidea) in the Lorraine region. Bulletin de l'École Nationale Superieure Agronomique de Nancy 13: 50–54.

Ratzeburg JTC (1843) Bericht über einige neue, den Waldbäumen schädliche Rhynchoten. Entomologische Zeitung 4(7): 201–204.

Ratzeburg JTC (1844) Die Forst-Insecten oder Abbildung und Beschreibung der in den wäldern Preussens und der Nachbarstaaten als schädlich oder nützlich bekannt gewordenen Insecten: Im systematischer Folge und mit besonderer Rücksicht auf die Vertilgung der Schädlichen. Volume 3. Nicolaische buchhandlung, Berlin, 314 pp.

Remaudière G, Remaudière M (1997) Catalogue of the World's Aphididae. INRA, Paris, 473 pp.

Rohfritsch O (1988) A resistance response of *Picea excelsa* to the aphid, (Homoptera: Aphidoidea) *Adelges abietis*. In: Mattson WJ, Levieux J, Bernard-Daga C (Eds) Mechanisms of Woody Plant Defenses Against Insects. Springer, New York, 253–266. doi: 10.1007/978-1-4612-3828-7_16

Rożkowski R (2004) Breeding value of Norway sprunce (*Picea abies* [L.] Karst.) from the Kłodzko Forest District (SW Poland). Journal of Forest Science 50(1): 17–23.

Sano M, Ozaki K (2012) Variation and evolution of the complex life cycle in Adelgidae (Hemiptera). Entomological Science 15: 13–22. doi: 10.1111/j.1479-8298.2011.00483.x

Schneider-Orelli O, Schneider F (1954) *Dreyfusia*-Befall an *Abies pindrow* im Nordwesthimalaya. Mitteilungen der Schweizerischen Entomologischen Gesellschaft 27(4): 413–422.

Schneider-Orelli O, Schneider F (1959) Weitere Untersuchungen über *Dreyfusia*-Befall im Nordwesthimalaya (Homopt. Adelgidae). Mitteilungen der Schweizerischen Entomologischen Gesellschaft 32(2–3): 258–270.

Shimer H (1869) [1868] Notes on *Chermes pinicorticis*. Transactions of the American Entomological Society 2(1): 383–385.

Shinji GO (1930) Some new Aphidids from North Eastern Japan. Lansania 2(20): 151–160.

Skrzypczyńska M (2004) Relationships between the number of dwarf shoots of *Larix decidua* Mill. damaged by different insect species in the Ojców National Park in southern Poland. Journal of Pest Science 77(3): 173–177. doi: 10.1007/s10340-004-0051-8

Solowiow P (1924) Beobachtungen über neue Arten der Gattung Chermes: *Chermes alaeviridis* n. sp. und *Chermes niger* n. sp. (Rhynchota, Phytophthires, Aphidae, Phylloxeridae). Zoologischer Anzeiger 60: 38–49.

Stebbing EP (1903) [1904] On the acquisition of alar appendages by the spruce form of *Chermes abeitis-piceae* MS. in the N.-W. Himalayas. Journal of the Asiatic Society of Bengal 72(2): 57–60.

Stebbing EP (1910) On the life-history of *Chermes himalayensis*, Steb., on the spruce (*Picea morinda*) and silver fir (*Abies webbiana*). Transactions of the Linnean Society of London. Second series 11(Part 6): 99–124.

Steffan AW (1961) Die Stammes- und Siedlungsgeschichte des Artenkreises *Sacchiphantes viridis* (Ratzeburg 1843) (Adelgidae, Aphidoidea). Zoologica: Original Abhandlungen aus dem Gesamtgebiete der Zoologie 109, 113 pp.

Steffan AW (1968) Evolution und Systematik der Adelgidae (Homoptera: Aphidina). Eine Verwandtschaftsanalyse auf vorwiegend ethologischer, zytologischer und kardiologischer Grundlage. Zoologica, Original-Abhandlungen aus dem Gesamtgebiete der Zoologie. 40(lieferung 5 heft 115), 139 pp.

Steffan AW (1972) Unterordnung Aphidina, Blattläuse. In: Schwenke W (Ed.) Die Forstschädlinge Europas. Volume 1. Paul Parey, Hamburg, 162–386.

Strand E (1928) [1926] Miscellanea nomenclatorica zoologica et palaeontologica. I-II. Archiv für Naturgeschichte 92(A-8): 30–75.

Szklarzewicz T, Wnęk A, Biliński SM (2000) Structure of ovarioles in *Adelges laricis*, a representative of the primitive aphid family Adelgidae. Acta Zoologica 81(4): 307–313. doi: 10.1046/j.1463-6395.2000.00061.x

Takahashi R (1937) Phylloxeridae of Formosa (Hemiptera). Transactions of the Natural History Society of Formosa 27(160): 11–14.

Thomas C (1879) Third annual report by Cyrus Thomas. Report of the State Entomologist on the Noxious and Beneficial Insects of the State of Illinois, 8th report, 212 pp.

Toenshoff ER, Daniela G, Horn M (2012) Co-evolution and symbiont replacement shaped the symbiosis between adelgids (Hemiptera: Adelgidae) and their bacterial symbionts. Environmental Microbiology 14(5): 1284–1295. doi: 10.1111/j.1462-2920.2012.02712.x

Underwood GR, Balch RE (1964) A new species of *Pineus* (Homoptera: Adelgidae) on *Abies*. Canadian Entomologist 96(3): 522–528. doi: 10.4039/Ent96522-3

Vallot JN (1836) Observations sur deux insectes hémiptères qui vivent, l'un sur le mélèze et l'autre sur le cafier. Comptes rendus hebdomadaires des Séances de l'Académie des Sciences 3: 72–73.

van der Hoeven J (1849) Handboek der Dierkunde. Volume 1. C.G. Sulpke, Amsterdam, 791 pp.

Wegierek P (2002) Relationships within Aphidomorpha on the basis of thorax morphology. University of Silesia, Katowice, Poland, 107 pp.

Wegierek P (2003) Apterous Phylloxeroidea (Hemiptera, Sternorrhyncha) from Baltic amber. Acta Zoologica Cracoviensia 46(fossil insects): 277–283.

Wilson HF, Vickery RA (1918) A species list of the Aphididae of the world and their recorded food plants. Transactions of the Wisconsin Academy of Sciences, Arts, and Letters 19: 22–352.

Yaseen M, Ghani MA (1971) Descriptions, and notes on the biology, of four new species of Adelgidae from West Pakistan. Bulletin of Entomological Research 61: 191–205. doi: 10.1017/S0007485300057722

Zhang GX, Fang SY (1981) A description of *Pineus cembrae pinikoreanus* Zhang et Fang, subsp. nov. (Homoptera: Adelgidae). Journal of North-East Forestry University 12(4): 15–18.

Zhang GX, Zhong TS, Tian ZJ (1980) Two new species and a new subspecies of Adelgidae from Sichuan China (Homoptera, Adelgidae). Zoological Research 1(3): 381–388.

Zhang GX, Zhong TS, Zhang WY (1992) Homoptera: Aphidoidea. In: Chen SX (Ed.) Insects of the Hengduan Mountains Region. Volume 1. Science Press, Beijing, 360–403.

Zurovcová M, Havelka J, Starý P, Věchtová P, Chundelová D, Jarošová A, Kučerová L (2010) “DNA barcoding” is of limited value for identifying adelgids (Hemiptera:Adelgidae) but supports traditional morphological taxonomy. European Journal of Entomology 107: 147–156. doi: 10.14411/eje.2010.020

ZooKeys 534: 55–60 (2015)
doi: 10.3897/zookeys.534.6036
http://zookeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

# *Paratullbergia* Womersley in China: the description of a new species and a key to the genus (Collembola, Tullbergiidae)

Yun Bu[1], Yan Gao[2]

[1] *Natural History Research Center, Shanghai Natural History Museum, Shanghai Science & Technology Museum, Shanghai, 200041, China* [2] *Shanghai Hengjie Chemical Co. Ltd., Shanghai, 201599, China*

Corresponding author: *Yun Bu* (buy@sstm.org.cn)

Academic editor: *L. Deharveng* | Received 30 April 2015 | Accepted 16 October 2015 | Published 11 November 2015

*http://zoobank.org/29325DB9-EF51-481B-B602-0B20B7810C0E*

**Citation:** Bu Y, Gao Y (2015) *Paratullbergia* Womersley in China: the description of a new species and a key to the genus (Collembola, Tullbergiidae). ZooKeys 534: 55–60. doi: 10.3897/zookeys.534.6036

## Abstract

The genus *Paratullbergia* Womersley, 1930 is recorded for the first time from China. *Paratullbergia changfengensis* **sp. n.** from Shanghai is described and illustrated. It is characterized by the presence of 1+1 pseudocelli on thoracic segment I, with two pairs of pseudocelli on each of thoracic segments II and III, presence of seta px on abdominal segment IV, seta a2 and p4 on abdominal segment V as microsetae, and less differentiated sensory seta p3 on abdominal segment V. Both sexes present. The new species can be easily distinguished from its congeners by the presence of pseudocelli on thoracic segment I. An updated key to the world species of the genus *Paratullbergia* is provided.

## Keywords

Identification key, taxonomy, pseudocelli, chaetotaxy

## Introduction

The family Tullbergiidae Bagnall, 1947 contains a group of tiny euedaphic collembolans with approximately 200 species reported in the world (Bellinger et al. 2015); however, the Chinese Tullbergiidae are poorly known, with only four species recorded to date (Rusek 1967; Tamura and Zhao 1996; Gao 2007; Bu et al. 2013). During the study of the collembolan collections from Changfeng Park of Shanghai, one new species belonging to the genus *Paratullbergia* Womersley, 1930 was identified and is described in the present paper.

The genus *Paratullbergia* contains eight species occurring in Holarctic, India, South Africa, and Australia (Prabhoo 1971; Rusek 1991; Dunger and Schlitt 2011; Bellinger et al. 2015). The habitus is similar to that of the genus *Mesaphorura* Rusek, 1973, with some species being robust, and having an integument with coarse granulation, antennal segment IV with 2 subapical sensory rods, antennal segment III with two large sensory clubs, bent towards one another and two small sensory rods, postantennal organ with 35-68 vesicles in 2-4 rows, and pseudocelli of type IV and type I. Asp stronger, longer than in *Mesaphorura*.

## Materials and methods

Specimens were collected by Berlese-Tullgren funnels and preserved in 80% ethanol. The material was mounted on slides in Hoyer's solution and dried in an oven at 45 °C for identification. Drawings were done with the aid of a phase contrast microscope. The type specimens are deposited in Shanghai Natural History Museum (SNHM), Shanghai, China.

Abbreviations used in the descriptions:

| | |
|---|---|
| **Th.** | thoracic segment; |
| **Abd.** | abdominal segment; |
| **Ant.** | antennal segment; |
| **s** | sensillum; |
| **PAO** | postantennal organ; |
| **a** | anterior setae; |
| **m** | medial setae; |
| **p** | posterior setae; |
| **pl** | pleural setae; |
| **pso** | pseudocelli. |

## Results

### Taxonomy

**_Paratullbergia changfengensis_ sp. n.**
http://zoobank.org/2E6BA83A-245D-4B94-89DA-99257167E83C
Figs 1–6, Table 1

**Material examined.** Holotype, male (No. Changfeng2-2) (SNHM), China, Shanghai, extracted from soil samples of broad-leaved forest of Changfeng Park, 31°13'N

121°23'E, 15-III-2015, coll. Y. Bu & Y. Gao. Paratypes, 2 females (Nos. Changfeng2-1, Changfeng3-Changfeng7) (SNHM), data same as holotype. Other materials: 2 juveniles and 1 male subadult (Nos. Changfeng1, Changfeng8, Changfeng9), data same as holotype.

**Description.** Adult body 0.85 mm long in average (0.7–1.0 mm, n = 7). Both females and males were present. Setae well differentiated into micro- and macrosetae (Fig. 1). Granulations coarse, formed by secondary granules, 2.5–4.0 μm in diameter. Pseudocellar formula: 11/122/11111, 5–8 μm in diameter; on antenna base composed by four ridges from one side only (type IV) (Fig. 2), others star-like (type I); on Th. I between seta m2 and m3, and close to hind margin; on Th. II and III between setae m4/m5 and p3/p4, and close to m5 and p3 respectively; on Abd. I–III posterior to seta p3; on Abd. IV parallel to seta p3; on Abd. V on the border of Abd. VI (Fig. 1).

Head seta a0 present (20–22 μm), c1 absent, oc2 as macroseta (25–30 μm), and sd5 as mesoseta (20–25 μm) (Fig. 1). Postantennal organ 25–30 μm long and 6–7 μm wide, composed of 32–47 elliptical vesicles arranged in two rows, and latero-externally widened with three rounded vesicles inserted (Fig. 2). Labrum with 4/5/4 setae. Labium with five papillae, six apical guard setae, six proximal setae, four basomedian setae, and five basolateral setae.

Antenna (100–135 μm) shorter than head (130–150 μm). Ant. segment IV (Fig. 3) with five slightly thickened sensilla a–e, without basal heel, sensilla a, c, e long and curved toward inside, b and d short. Small microsensillum, subapical organite and one large apical vesicles present. Antennal organ III (Fig. 3) consists of two small sensory rods concealed behind two papilla and two thick sensory clubs bent toward each other, with four guard setae.

Legs without clavate tibiotarsal hairs (Fig. 4). Coxa, trochanter, femur and tibiotarsus with 3/7/7; 6/6/5; 10/10/10; 15/15/14 setae on Leg I, II and III, respectively. Anal lobes with seta 12’ and l3’ (Fig. 5). Claw 25 μm long, with short empodial appendage. Anal spines 30–32 μm long.

Adult chaetotaxy given in Fig. 1, Fig. 5 and Table 1. Microsensilla present on Th. II-III, and lateral sensory setae s 37–39 μm long (Fig. 1). Thorax with 0, 2, 2 ventral setae. Abd. I–III each with 2+2 axial setae dorsally, setae m3 and m4 present. Abd. IV with seta px, setae m2 and m3 present. Abd. segment V with sensory seta p3 slightly

**Table 1.** Adult Chaetotaxy of *Paratullbergia changfengensis* sp. n.

| | | **Thorax** | | | **Abdomen** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Segments** | | **I** | **II** | **III** | **I** | **II** | **III** | **IV** | **V** |
| Dorsal | a | - | 10 | 10 | 10 | 10 | 10 | 10 | 10[4] |
| | m | 8 | 8 | 8 | 4[1] | 4[1] | 4[1] | 4[2] | - |
| | p | - | 8 | 8 | 10 | 10 | 10 | 11[3] | 8[5] |
| | pl | 2 | 3 | 3 | 2 | 3 | 3 | 6 | 2 |
| Ventral | | 0 | 2 | 2 | 12 | 17–20 | 19–23 | 22–26 | 10+(18–21)+4[6] |

[1] seta m3 and m4 present; [2] seta m2 and m3 present; [3] seta px present; [4] seta a2 as microseta; [5] sensory seta p3 slightly differentiated, seta p4 as microseta; [6] male genital plate with 18–21 setae.

**Figures 1–6.** *Paratullbergia changfengensis* sp. n. (holotype). **1** Habitus, dorsal view, s–sensillum, ms–microsensillum **2** Postantennal organ and pseudocelli **3** Ant. III and IV, a, b, c, d, e–large sensilla, ms–microsensillum, so–subapical organite, vs–apical vesicles, sc–sensory clubs, sr–sensory rods, vsc–ventral sensory club **4** Tibiotarsus III and claw **5** Abdomen, ventral view **6** Male genital plate.

differentiated, 22–29 µm long; seta a2 (15–16 µm) and p4 (19–21 µm) as microsetae (Fig. 1). Crescentic ridges on Abd. VI present.

Number of ventral setae on Abd. II, III and IV variable, with 17–20, 19–23, and 22–26 setae respectively (Fig. 5). Ventral tube with 4+4 apical setae and 2+2 basal setae (Fig. 5). Male genital plate with 18-21 setae (Fig. 6).

**Etymology.** The species is named after the Changfeng Park where the type specimens were collected.

**Distribution.** Known only from the type locality. Considering that all specimens were only found in Changfeng Park, and that no other *Paratullbergia* has ever been recorded from China, this species has been probably introduced from an other place together with plants and soil.

**Diagnosis.** *Paratullbergia changfengensis* sp. n. is characterized by the presence of pseudocelli on thoracic segment I, with two pairs of pseudocelli on each thoracic segment II and III, the presence of seta px on abdominal segment IV, setae a2 and p4 on abdominal segment V as microsetae, and less differentiated sensory seta p3 on abdominal segment V. Bisexual.

**Remarks.** The presence of pseudocelli on thoracic segment I easily distinguishes *Paratullbergia changfengensis* sp. n. from other congeners. It is similar to *P. trivandrana* Prabhoo, 1971 from India in the presence of two pairs of pseudocelli on each of thoracic segments II and III, but differs in the presence of pseudocelli on thoracic segment I (absent in *P. trivandrana*) and shape of sensory seta p3 on abdominal segment V (setiform vs. flame-like). The nine existing species of the genus *Paratullbergia* can be distinguished by the following key.

## Key to the species of genus *Paratullbergia* Womersley, 1930 modified from Dunger and Schlitt 2011.

1 Th I–III without pso .......................... ***P. concolor*** **Womersley, 1930** (UK)
– Th I–III with pso .......................................................................... **2**
2 Th II and III with 2+2 pso ................................................................ **3**
– Th II and III with 1+1 pso ................................................................ **4**
3 Pso present on Th I, sensory seta p3 on Abd V setiform ..............................
........................................................... ***P. changfengensis*** **sp. n.**(China)
– Pso absent on Th I, sensory seta p3 on Abd V flame-like ............................
.............................................. ***P. trivandrana*** **Prabhoo, 1971** (India)
4 Abd VI between the crescentic ridges and Asp with 1+1 rounded tubercles ..
.............................................. ***P. callipygos*** **(Börner, 1902)** (Holarctic)
– Abd VI without additional tubercles .................................................. **5**
5 PAO with less than 25 vesicles ......................................................... **6**
– PAO with more than 35 vesicles ....................................................... **7**
6 Abd II and III with pso, PAO with 22–24 vesicles ......................................
........................................................... ***P. indica*** **Salmon, 1965** (India)

– Abd II and III without pso, PAO with 16–18 vesicles.............................................................................................................***P. salmon*** **Prabhoo, 1971** (India)

7 Ant IV with 4 thickened sensilla; on Abd I a4 as microseta, Abd II and III without m3..............................***P. macdougalli*** **Bagnall, 1936** (Palaearctic)

– Ant IV with 5 thickened sensilla; on Abd I a4 as macroseta; Abd II and III with m3.........................................................................................**8**

8 PAO with 35–40 vesicles....***P. caroli*** **Luciáñez, Ruiz & simón, 1991** (Spain)

– PAO with 64–68 vesicles ............................................................................................***P. brevispina*** **Skarżyński & Pomorski, 1999** (Turkey)

## Acknowledgements

We give our cordial gratitude to Dr. Feng Zhang for his generous help with the references. We thank two anonymous reviewers and the subject editor for their valuable comments. This study was supported by the Research Funds for the Introduction of Talents of Shanghai Science and Technology Museum.

## References

Bellinger PF, Christiansen KA, Janssens F (1996–2015) Checklist of the Collembola of the World. http://www.collembola.org [accessed 28 April 2015]

Bu Y, Potapov MB, GaoY (2013) A new species and new records of Pachytullbergiidae and Tullbergiidae (Collembola: Onychiuroidea) from littoral of China, with notes on the variations of postantennal organ. Zootaxa 3669(2): 139–146. doi: 10.11646/zootaxa.3669.2.4

Dunger W, Schlitt B (2011) Synopses on Palaearctic Collembola: Tullbergiidae. Soil Organisms 83(1): 1–168.

Gao Y (2007) Studies on the Systematics of Collembola and Soil Zooecology. PhD Dissertation, Shanghai Institutes for Biological Sciences, Chinese Academy of Sciences, Shanghai, 99 pp.

Prabhoo NR (1971) Soil and litter Collembola of south India 1. Arthropleona. Oriental Insects 5(1): 1–46. doi: 10.1080/00305316.1971.10433988

Rusek J (1967) Beitrag zur Kenntnis der Collembola (Apterygota) Chinas. Acta Entomologica Bohemoslovaca 64: 184–194.

Rusek J (1991) New Holarctic and Palearctic taxa of Tullbergiinae (Collembola). Acta Societatis Zoologicae Bohemoslovacae 55(1/2): 65–75.

Tamura H, Zhao L (1996) Two species of the subfamily Tullbergiinae in Xishuangbanna, southwest China (Collembola; Onychiuridae). Japanese Journal of Entomology 64(4): 790–794.

ZooKeys 534: 61–84 (2015)
doi: 10.3897/zookeys.534.5967
http://zookeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

# The genus *Gymnetron* from China with description of pre-imaginal stages of *G. miyoshii*, *G. auliense* and *G. vittipenne* (Coleoptera,Curculionidae)

Chunyan Jiang[1,2], Runzhi Zhang[1,3]

**1** *CAS Key Laboratory of Zoological Systematics and Evolution, Institute of Zoology, Chinese Academy of Sciences, Beijing 100101, P. R. China* **2** *University of Chinese Academy of Sciences, Beijing 100049, P. R. China* **3** *State Key Laboratory of Integrated Management of Pest Insects and Rodents, Institute of Zoology, Chinese Academy of Sciences, Beijing 100101, China*

Corresponding author: *Runzhi Zhang* (zhangrz@ioz.ac.cn)

Academic editor: *M. Alonso-Zarazaga* | Received 24 January 2015 | Accepted 12 October 2015 | Published 11 November 2015

*http://zoobank.org/32E54F3F-7DE5-4AD3-8757-6BED987EBDE4*

**Citation:** Jiang C, Zhang R (2015) The genus *Gymnetron* from China with description of pre-imaginal stages of *G. miyoshii*, *G. auliense* and *G. vittipenne* (Coleoptera, Curculionidae). ZooKeys 534: 61–84. doi: 10.3897/zookeys.534.5967

## Abstract

There are four species of *Gymnetron* in China recorded to date including *G. miyoshii* Miyoshi, 1922, *G. villosipenne* Roelofs, 1875, *G. auliense* Reitter, 1907 and *G. vittipenne* Marseul, 1876, of which the last two are new country records. The pre-imaginal stages including eggs, mature larvae and pupae of *G. miyoshii*, *G. auliense* and *G. vittipenne* are described and illustrated. In addition, their diagnostic characters (larvae and pupae) are discussed and differentiated, and notes on some of their biological parameters are provided. Potential ecological impacts between *Gymnetron* weevils and their host *Veronica* spp. also are provided.

## Keywords

*Gymnetron*, larva, pupa, Mecinini, Curculioninae, gallmakers, China, protective chemicals, environmental stress

## Introduction

*Gymnetron* Schoenherr, 1825 belongs to the tribe Mecinini Gistel, 1848 in the subfamily Curculioninae Latreille, 1802 (Alonso-Zarazaga et al. 1999, Caldara 2001). These weevils are small, distinguished from other Mecinini by the following features taken together: prosternum without median sulcus; elytral margin covering a large portion of the pygidium; elytral striae 3 and 8 joined at apex (Caldara 2008). This genus is widely distributed in the Palaearctic and Afrotropical regions (Alonso-Zarazaga et al. 1999, Caldara 2001, 2003, 2008); distribution in China of *G. miyoshii* Miyoshi, 1922 and *G. villosipenne* Roelofs, 1875 is recorded by Caldara (2008). The Palaearctic species of *Gymnetron* live on *Veronica* (Caldara 2008), currently included in the Plantaginaceae (Stevens, 2012), while those in the Afrotropical region (Caldara 2003) appear to live on various genera of Scrophulariaceae belonging to the tribes Hemimerideae and Selagineae, *Buddleja* of the Buddlejeae and *Anastrabe* of the Stilbaceae, both families very closely related to Plantaginaceae (Stevens, 2012). The immatures of some species of *Gymnetron* have been studied previously, but without detailed descriptions (van Emden 1938, Scherf 1964, Anderson 1973, May 1993).

The aim of the present study is to describe for the first time all developmental stages of three species of *Gymnetron* living in China in order to provide further characters for the identification of these taxa.

## Materials and methods

Six last instar larvae and ten pupae of *Gymnetron miyoshii*, five last instar larvae and one pupa of *G. villosipenne*, and ten last instar larvae and ten pupae of *G. vittipenne* were examined. Descriptions were made and photographs of pupae were taken with a Canon-5D camera mounted on a Nikon SMZ 1500 microscope. Images of adults were photographed with a CCD Qimagine MicroPublisher 5.0 RTV mounted on a Zeiss SteREO Discovery. V12 microscope; Microscopic slides were studied with a Leica DM 2500 microscope and photos were taken with a Nikon CoolPix 5400. Drawings were made from the original photographs by using the software Adobe Illustrator CS6; photos in the field were taken with Canon G15 and 5D Mark II cameras.

Nomenclature of the larval chaetotaxy mainly follows van Emden (1938), May (1993, 1994), Marvaldi (1999) and Wang et al. (2013), and that of the pupa mainly follows Gosik (2010). The dissecting method used follows May (1979, 1994). Indistinct structures were pigmented with “Chlorazol Black E” for further examination. In pupae, *msns* and *mtns* are used as abbreviations of mesonotal setae and metanotal setae, respectively. As *msns* and *mtns* are different among the three weevils species examined, these can be added as special diagnostic characters in *Gymnetron*; in order to differentiate from alar setae and apical setae of the pupa, *as* and *asp* are used, respectively. In the descriptions, setae of the thorax and abdomen are described for one side only.

After description, all larvae and pupae were mounted using nail polish, a mixture of butyl acetate, ethyl acetate, multipolymer of adipic acid, neopentyl glycol, trimellitic acid and acetyl tributyl citrate. All slides remain together with the adult specimens in the museum of the Institute of Zoology, Chinese Academy of Sciences.

## Descriptions

### *Gymnetron miyoshii* Miyoshi, 1922

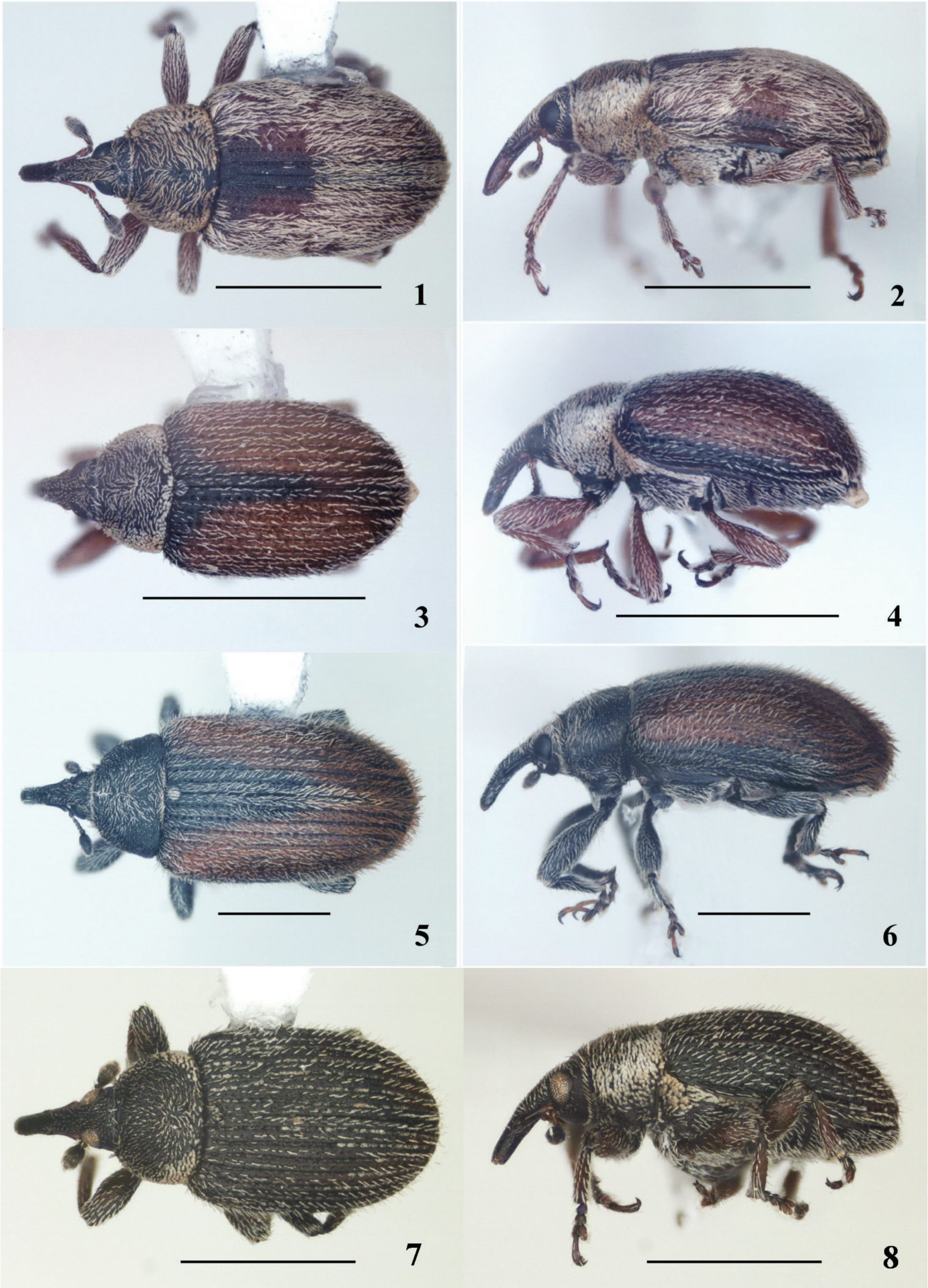
*Gymnetron miyoshii* Miyoshi, 1922: 253
*Gymnetron villosulum* var. *orientale* Voss, 1955: 139

**Description. Adult** (Figures 1–2): sides of pronotum in part, mesothoracic epimera, metasternum and urosternite one covered with broad scales; elytral vestiture forming indistinct spots; rostrum in lateral view slightly curved, in female nearly of same width from base to apex (Caldara 2008).

**Egg:** oval, yellowish, nearly pellucid. Measurements (mm): diameter: 0.11–0.12 (n = 3), length: 0.28 (n = 3).

**Mature larva** (Figure 9)**:** Measurements (mm): body length: 3.25–3.90 (n = 2), width: 1.08–1.30 (n = 2); capsule length (in front view): 0.48–0.50 (n = 4), width: 0.38–0.43 (n = 4); body slender and weakly curved, yellowish, subcylindrical, widest at thorax in lateral view, attenuate posteriorly; head brown with pale stripes at sides and along ecdysial line; cuticle minutely spiculate; pronotum partly pigmented and sclerotized; body segments with minute setae, pedal lobes in conspicuous pigmented knobs.

**Head** (Figures 10–11)**:** free, circular in outline, broader than long, broadest at middle; cranial suture undivided, wide, half length of head; frontal suture distinct, not extending to mandibular membrane; endocarinal line short, no more than half as long as frons; frons with three pairs of *fs*, *fs1* and *fs3* reduced to basal sensilla, *fs*5 longest, laterally positioned on epistoma close to antenna, *fs4* located near epistoma, half as long as *fs5*, *fs2* located in the middle of frons, half as long as *fs4*; dorsal epicranium with four pairs of *des*, *des4* reduced to a basal sensillum, *des3* longest, located on frontal line, *des5* lightly shorter than *des3*, *des2* approximately one quarter as long as *des3*, *des1* slightly shorter than *des2*; epicranium with two pairs of *les*, *les1* long, *les2* short, about half as long as *les1*; posterior epicranium with three pairs of *pes*, *pes1* minute, *pes2* equally as long as *pes3*; ventral epicranium with one pair of *ves*, minute; postoccipital condyles indistinct, hypopharyngeal bracon distinct; tentorial bridge narrow, with two small but moderately acute anterior projections and two large, obtuse-angled posterior projections; clypeus transverse, fused to labrum, bearing two pairs of *cls*, *cls1* nearly same length as *cls2*, located in one line, parallel to clypeus, sensilla absent; antenna (Figure 12) one segment, sensory appendage nearly twice as long as wide, circular in cross-section, contiguous with frontal suture, with



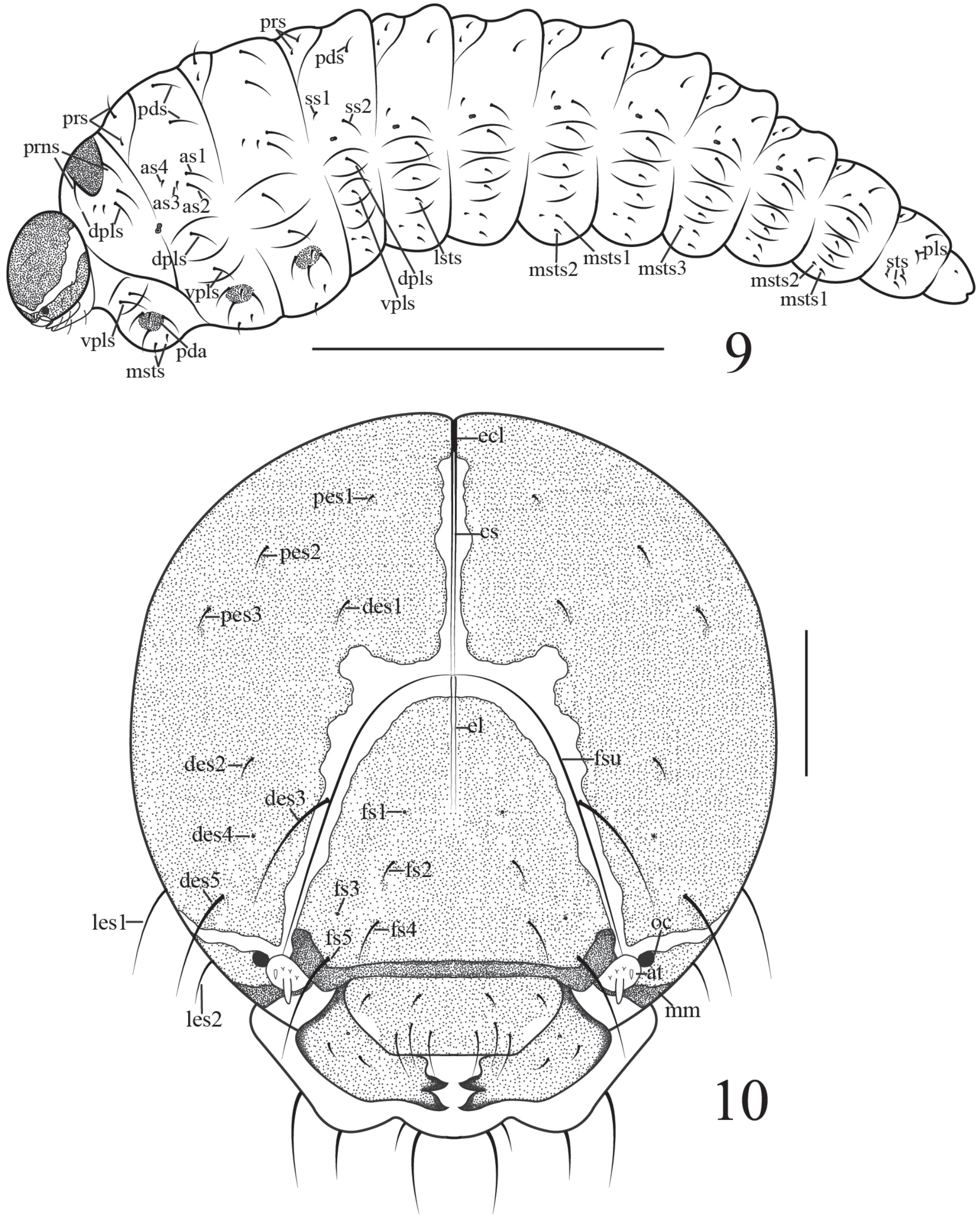
**Figures 1–8.** Adults of *Gymnetron*. **1–2** *G. miyoshii* **3–4** *G. auliense* **5–6** *G. vittipenne* **7–8** *G. villosipenne*. Scale bars: **1–8** 1 mm.

one conical and three minute sensilla; ocellus present, not projecting, located below stripe at side, externally close to antenna.

**Mouthparts** (Figures 13–17)**:** mandibles (Figure 13) symmetric, incisor section with two apical teeth and rounded flange posterior to dorsal tooth, molar section with two *mds*, *mds1* nearly same length as *mds2*, sensilla distinct; labrum (Figure 14) transverse, fused to clypeus, nearly completely sclerotized, with three pairs of *lrms*, *lrms2* slightly shorter than *lrms1*, both centrally localized, *lrms3* same as *lrms1*, close to distal margin of labrum; epipharynx (Figure 15) with all epipharyngeal setae stout and apically rounded, with two pairs of *als*, three pairs of *ams*, epipharyngeal sensilla, *mes* and labral rods (tormae) absent. Labium (Figure 16) membranous excepting the premental sclerite, labial palpus with one segment, slightly longer than wide, apex of palpus flattened with dense short irregular spiculate setae, and one sensillum; premental sclerite (*Pmsc*) distinctly posteriorly and laterally dilated, U-shaped, with one pair of sensilla and one pair of long *prms*. Ligula with two pairs of tiny *ligs*, *ligs1* as long as *ligs2*. Postlabium (*plb*) partly sclerotized, with two pairs of *plbs* at membranous area, *plbs1* long, *plbs2* short, one quarter long as *plbs1*; membranous area sparsely and finely asperate. Maxillae with maxillary palpus (*mxp*) (Figures 16–17) two-segmented, basal segment with one tiny mxps, accessory appendage absent; distal segment sclerotized, apex flattened with dense short irregular spiculate setae, one sensillum; mala with five dorsal robust *dms*, *dms1–5* gradually shorter, with four shorter, more acute *vms*. Stipes bearing one *stps*, two *pfs* and two sensilla, *stps* strong and long, submedian on venter of base. *Pfs1* a little shorter, located near mala, one third as long as *pfs2*, *pfs2* submedian on venter of base, cardo completely divided from stipes.

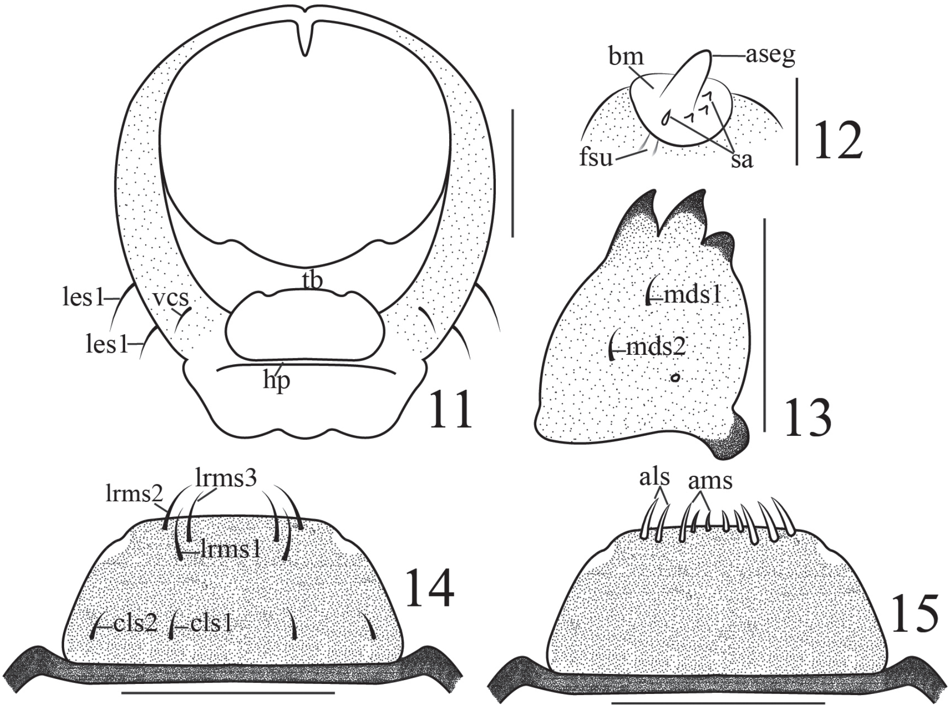
**Thorax** (Figure 9)**:** pronotal shield partly pigmented and sclerotized on pale smooth plate. Pronotum with two setae on sclerotized area, dorsopleurum with four *dpls*; spiracle (Figure 18) intersegmental between pro- and mesothorax, bicameral, air-tube subequal to diameter of circular peritreme; ventropleurum with two *vpls*; pedal area (Figure 19) distinct, pedal lobe present, one-segmented, slightly convex, with four setae; mediosternum with two *msts*. Mesonotum with two folds (prodorsum and postdorsum), prodorsum with two *prs*, postdorsum with two *pds*, two setae transversally aligned; alar area with four *as*, two long, two short; dorsopleurum with one *dpls*, ventropleurum with one *vpls*; setae of pedal area and mediosternum same as prothoracic. Metanotum same as mesonotum.

**Abdomen** (Figure 9): with spiracles on segments I-VII, size similar, all anterolateral and unicameral, each with single annulated air-tube, pointing posteriad, subequal to diameter of circular peritreme. Abdominal segments I-VII with tergites with two folds, prodorsum with two *prs*, *prs1* longer than *prs2*, postdorsum with soft protuberance posteriorly, with one *pds*, all setae shorter than thoracic setae; spiracular area with two *ss*, *ss1* short, one quarter as long as *ss2*; dorsopleurum with one *dpls*, ventropleurum with one *vpls*, laterosternum with one *lsts*, mediosternum with three *msts*, except *msts3* in front of *msts1*, other five setae short and transversally aligned. Abdominal segment VIII with tergite with two folds, prodorsum with one *prs*, postdorsum with one *pds*; spiracular area with two *ss*, *ss1* short, one quarter as long as *ss2*; dorsopleurum with one *dpls*, ventropleurum with one *vpls*, laterosternum with one *lsts*, mediosternum with

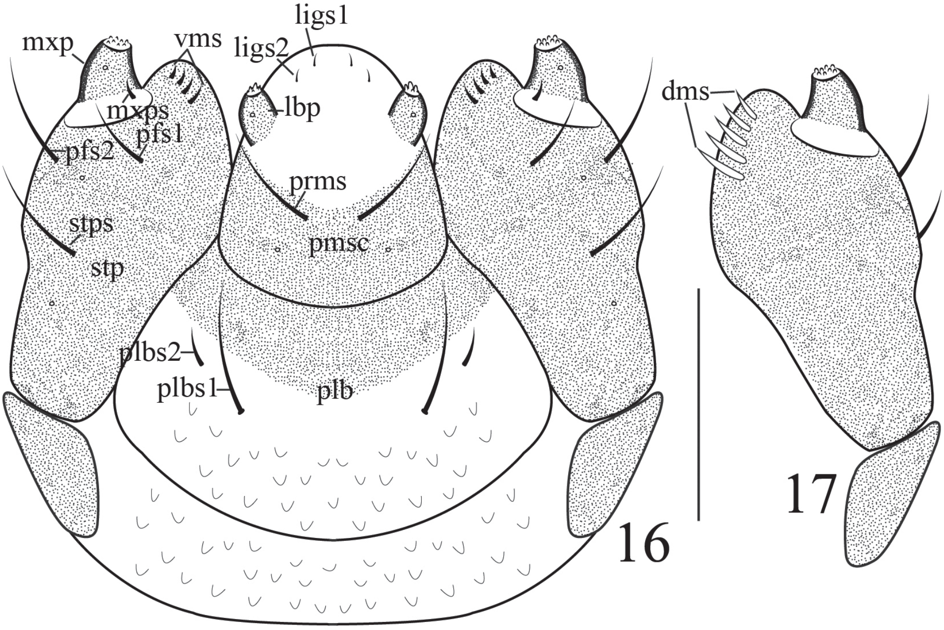


**Figures 9–10.** Larva of *Gymnetron miyoshii*. **9** Mature larva, lateral view **10** Head, dorsal view. Scale bars: 1 mm (**9**), 0.1 mm (**10**).

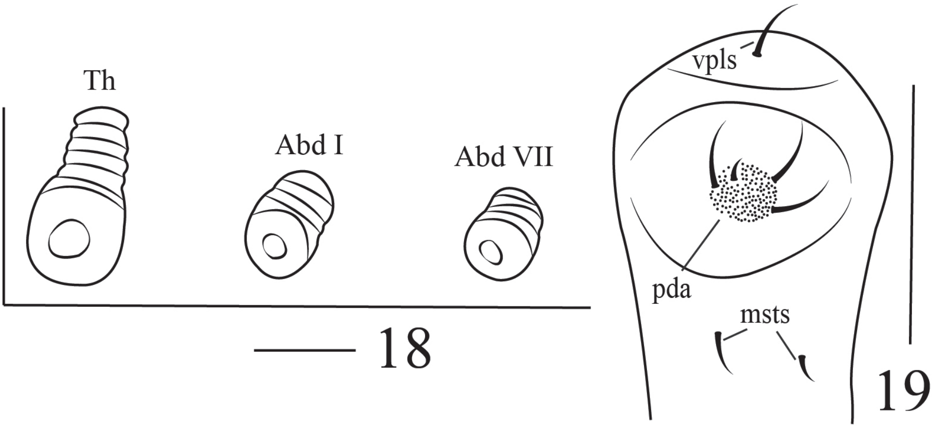
one *msts*, except *msts2* in front of *msts1*, other four setae short and transversally aligned. Abdominal segment IX with tergite with two folds, prodorsum with one *prs*, postdorsum with one *pds*; pleurum with one *pls*, sternum with three *sts*. Abdominal segment X with one tiny seta, anus transverse cleft.



**Figures 11–15.** Larva of *Gymnetron miyoshii*. **11** Head, ventral view **12** Antenna **13** Mandible **14** Labrum and clypeus **15** Epipharynx. Scale bars: 0.1 mm (**11**), 0.025 mm (**12**), 0.1 mm (**13–15**).

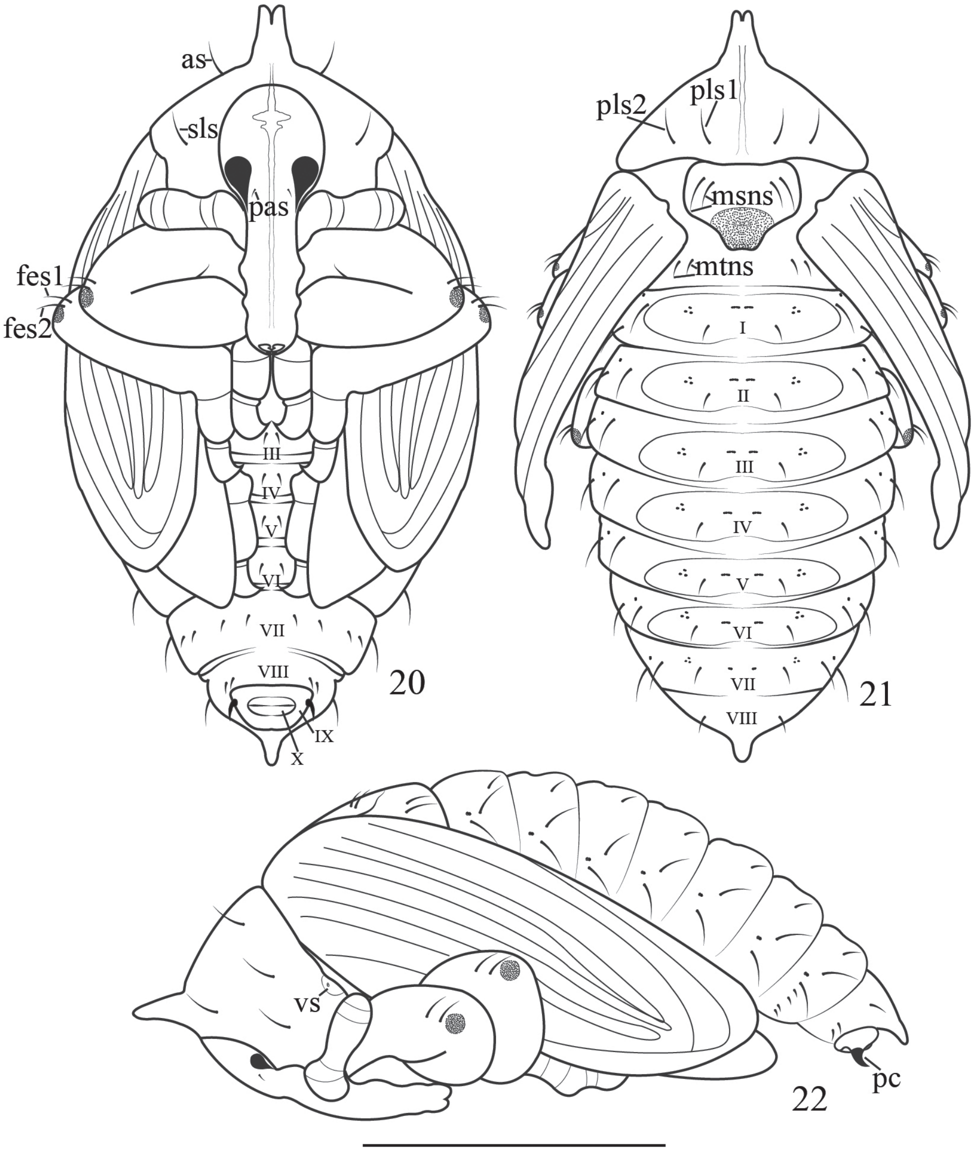


**Figures 16–17.** Larva of *Gymnetron miyoshii*. **16** Labium, ventral **17** Maxilla, dorsal. Scale bars: 0.1 mm.



**Figures 18–19.** Larva of *Gymnetron miyoshii*. **18** Spiracles, showing alignment **19** Pedal and mediosternal setae. Scales bars: 0.0325 mm (**18**), 0.05 mm (**19**).

**Pupa** (Figures 20–22)**:** Measurements (mm): length: 2.65–3.00 (n = 4), width: 1.00–1.60 (n = 4), height: 1.25–1.50 (n = 4). **General appearance:** Theca yellow, grayish at apex of antennae, rostrum, legs, wings, elytra, anus and apex and base of ventrites. Setae greatly reduced in number. Ventrites III-X visible in ventral view, tergum I-VIII visible in dorsal view. **Head:** yellow-gray with one yellow stripe along middle, with one pair of *pas*, situated at middle margin of eyes; eyes large, one third of length of head, not projecting; rostrum long, twice as long as wide, mesorostrum visibly dilated, mandibular theca weakly projecting, setae absent; antennae applied against prosternum and apically extending to propleurum, subparallel to profemur. **Thorax:** prothorax bearing one median, lightly pigmented tubercle, apically shallowly bifurcate, with a spiracle between pronotum and mesonotum, but lacking air-tube; pronotum with one *as* and one *sls* in ventral view, two *pls* in dorsal view, *as*, *sls* and *pls* subequal, strong and long, *pls1* and *pls 2* positioned in one transversal row; mesonotum with two *msns* on scutellum; metanotum bearing two *mtns* near hind margins, half shorter in length than pronotal setae. **Legs:** pro-, meso- and metafemora apically bearing two slightly outcurved *fes*, *fes 1* as long as *fes 2*, apex with grey circular pigmented area. **Abdomen:** segments I-VII with tergite bearing one seta, with transversely oval impression, submedian small transverse macula and lateral maculae, segment VII lacking impression. Spiracles present on segments I-VII, spiracular area with one *ss*, dorsopleurum with one *dpls*, ventropleurum with one *vpls*, laterosternum with one *lsts*, mediosternum with two *msts*; segment VIII with tergite bearing one fleshy, pigmented, apically narrowing rounded process, with two seta on tergite, sternum with two setae; segment IX with sclerotized, bifurcate, elongate and slightly curved outward pseudocerci, subterminally positioned at ventral abdominal segment IX, invisible in dorsal view; segment X with anus transverse cleft, subterminal, invisible in dorsal view.



**Figures 20–22.** Pupa of *Gymnetron miyoshii*. **20** Ventral view **21** Dorsal view **22** Lateral view. Scales bars: 1 mm.

**Specimen examined. CHINA: Hunan:** Food and Drug Administration of Changsha (28°11.85'N; 113°0.36'E, 43m), 18-VIII-1975, *Veronica anagallis-aquatica* L.(8); same except: Hunan Medical University (28°18.05'N; 112°52.14'E, 48m), VII-1979, *Veronica* spp.(3); Institute of Plant Protection of Hunan (28°12.01'N; 113°04.86'E, 45m), 1973, *Veronica anagallis-aquatica* L. (2); 1975 (6); 24-V-1976, *Veronica anagallis-aquatica* L., leg Yangchang Zhao (10); 21-V-1976, *Veronica anagallis-aquatica* L., leg Qiong Zhu (2); 16-V-1976, *Veronica anagallis-aquatica* L. (5). **Inner Mongolia**: Hohhot (40°49.28'N; 111°38.82'E, 1289m), 15-VI-1965, *Veronica undulata* Wall., leg Hongchang Li (5); Molidawanqi, Hulun Buir (48°28.53'N; 124°30.18'E, 335m), 23-VII-1940 (1). **Hebei**: Manzuxiang, Dongling, Zunhua, Tangshan, (40°10.90'N; 117°54.49'E, 120m), 8-VII-1963, *Veronica* spp., leg Wenzhen Ma (1). **Beijing**: Badaling, (40°20.49'N; 115°58.88'E, 669), 20-VI-1963, *Veronica anagallis-aquatica* L., leg Tiesheng Li (9); Sanpu, Yanqing (40°19.65'N; 116°02.18'E, 593m), 28-VII-1980, *Veronica undulata* Wall. (18); 1980-VI-29, *Veronica undulata* Wall., leg Shengqiao Jiang (10); 7-VII-1980, *Veronica anagallis-aquatica* L., leg Subai Liao (29); Beizhaicun, Qiaozizhen (40°19.77'N; 116°33.34'E, 73m), 1-VI-2013, *Veronica anagallis-aquatica* L., leg Chunyan Jiang (26); 24-V-2014, *Veronica anagallis-aquatica* L., leg Chunyan Jiang (4); 14-VI-2014, leg Chunyan Jiang (5 eggs, 13 larvae, 6 adults). **Jiangsu**: Yinqiao, Suyang, Changzhou (31°25.94'N; 119°29.73'E, 8m), 5-VI-1981 (1); Wujin (31°40.16'N; 119°55.93'E, 4m), 12-V-1955 (1); Hangzhou (30°15.33'N; 120°12.50'E, 6m), 1982, leg Guangsheng Li (1). **Heilongjiang**: Harbin (45°45.94'N; 126°38.70'E, 116m), 18-V-1945 (1).

**Biological notes.** *Veronica anagallis-aquatica* L. has been collected with galls on 14-VI-2014 which have been reared in the laboratory. Fifteen pupae were found on 21-VI-2014.

### *Gymnetron auliense* Reitter, 1907

*Gymnetron melinum* var. *auliense* Reitter, 1907: 30.
*Gymnetron auliense*: Caldara 2008: 38.

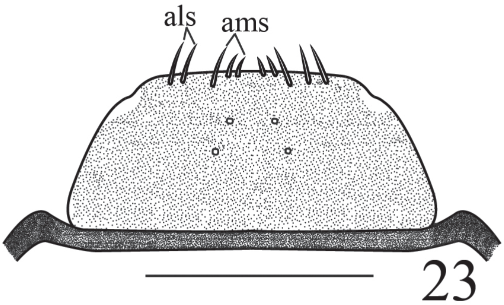
**Description. Adult** (Figures 3–4): Sides of pronotum covered with dense, imbricate, broad scales; elytral integument reddish and black, rarely completely black, interstriae covered with recumbent to suberect seta-like scales arranged in two-three rows; rostrum moderately robust, scarcely sexually dimorphic, in lateral view moderately curved, weakly narrowed at apical third (Caldara 2008).

**Egg:** unknown.

**Mature larva:** measurements (mm): body length: 2.40–2.50 (n = 4), width: 1.20–1.45 (n = 4); capsule length (in dorsal view): 0.50–0.55 (n = 3), width: 0.46–0.50 (n = 3). It differs from *G. miyoshii* by: **Mouthparts:** epipharynx (Figure 23) with two pairs of sensilla, all epipharyngeal setae distinctly slender. **Thorax** (Figure 25): pronotum with four *pns*, dorsopleurum with four *dpls*. Spiracle bicameral, air-tube equal or shorter than diameter of circular peritreme. **Abdomen:** with seven spiracles, size similar, all anterolateral and unicameral, each with single annulated air-tube, shorter to diameter of circular peritreme.

**Pupa:** Measurements (mm): length: 2.80 (n = 1); width: 1.00 (n = 1).

Mesonotum with three pairs of *msns* on scutellum; Pro-, meso- and metafemora of legs apically bearing one slightly outcurved *fes*, apex with grey circular pigmented area.



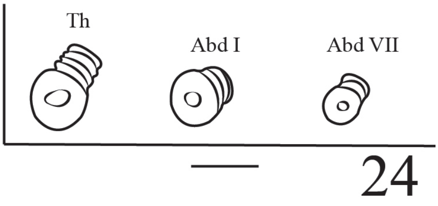


**Figure 23–24.** Larva of *Gymnetron auliense*. **23** Epipharynx **24** Spiracles, showing alignment. Scales bars: 0.1 mm (**23**), 0.025 mm (**24**).

**Specimen examined. CHINA**: **Xinjiang**: Kaerjiaocun, Jimunai (47°13.03'N; 86°24.12'E, 1224m), 3-VII- 2014, leg Chunyan Jiang (6).

**Biological notes.** After collecting specimens of *Veronica oxycarpa* Boiss. on 3-VII-2014, for rearing in the laboratory, 5 larvae were obtained on 9-VII-2014 and 1 pupa on 12-VII-2014.

**Remarks.** This species has been recorded from Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. This species is a new record for China.

### *Gymnetron vittipenne* Marseul, 1876

*Gymnetron vittipenne* Marseul, 1876: 383.
*Gymnetron apicale* Faust 1885: 187.
*Gymnetron vittipenne* var. *suturiferum* Reitter 1907: 32.

**Description. Adult** (Figures 5–6): Sides of pronotum covered with dense, imbricated, broad scales; uncus of metatibiae strongly enlarged at apex in male; first tarsal segment on venter covered with very dense and long setae in male; ductus of spermatheca sclerotized at base near insertion with spermatheca. Elytra parallel-sided, with reddish and black integument covered with moderately dense, recumbent to erect, seta-like scales arranged in three very irregular rows on each interstria; rostrum in lateral view slightly curved, angulate along dorsal margin at antennal insertion and weakly narrowed at apical third in male, strongly curved, cylindrical and of same length from base to apex in female (Caldara 2008).

**Egg:** unknown.

**Mature larva:** measurements (mm): body length: 5.00–5.20 (n = 2), width: 1.60–2.00 (n = 2); capsule length (in dorsal view): 0.70–0.86 (n = 4), width: 0.57–0.68 (n = 4).

It differs from *G. miyoshii* by: **General appearance** (Figure 26): size greater. **Head:** Size greater, endocarinal line long, more than half as long as frons; hypopharingeal bracon distinct; clypeus transverse, bearing two pairs of *cls*, *cls1* nearly same length as *cls2*, located

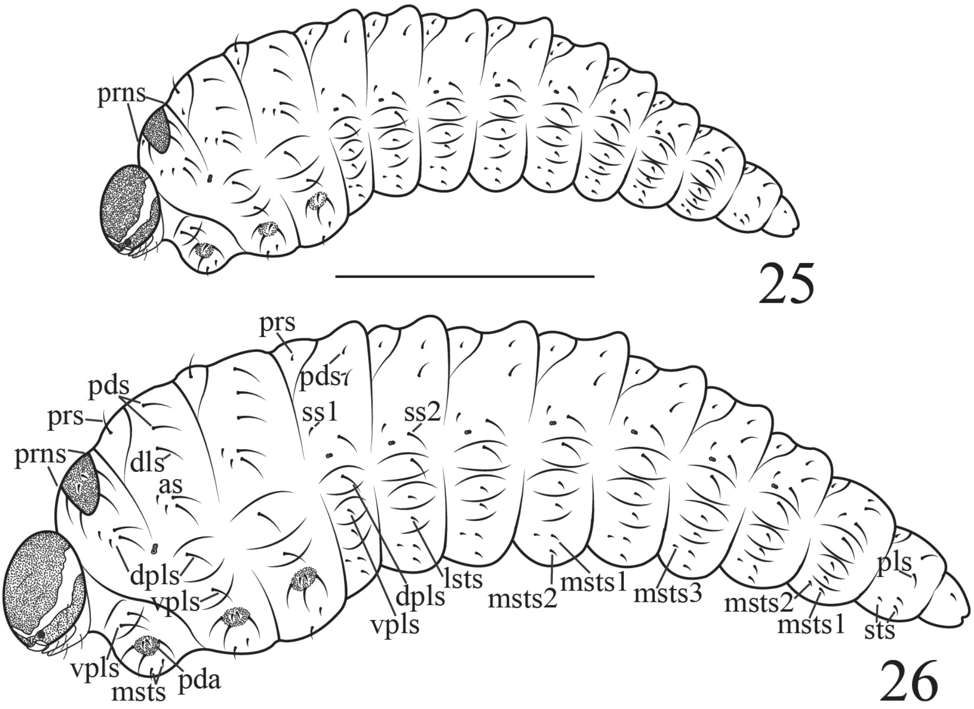
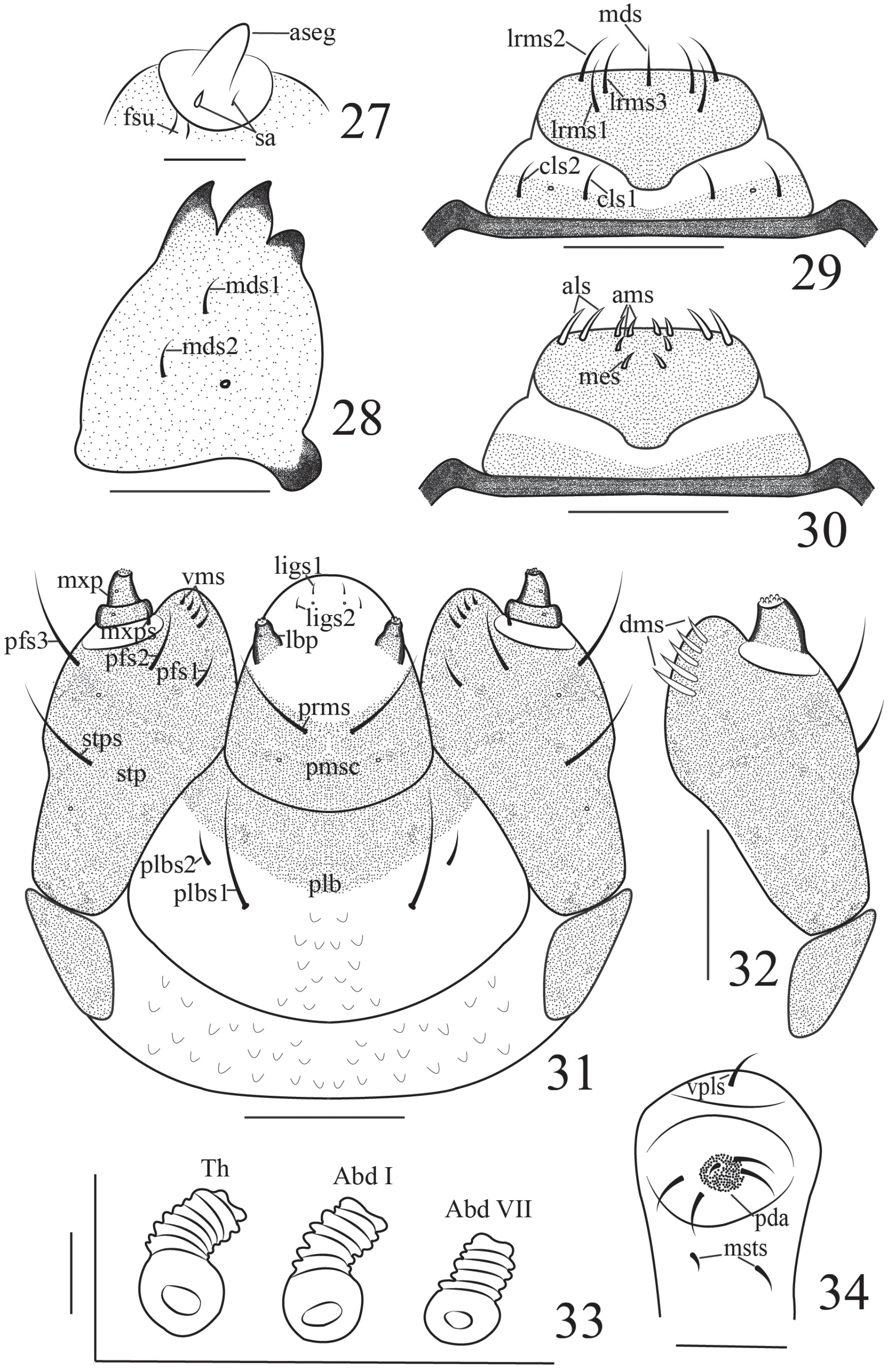


**Figure 25–26.** Two larvae. **25** Larva of *Gymnetron Auliense* **26** Larva of *G. vittipenne*. Scales bars: 1 mm.

in one line, parallel to clypeus, sensilla distinct; antenna (Figure 27) with one segment, contiguous with frontal suture, with one spinose and one tiny seta-like sensilla. **Mouthparts** (Figures 28–32): labrum (Figure 29) transverse, partly sclerotic, anterior margin nearly straight, posterior margin weakly extended medially into clypeal zone, with three pairs of *lrms*, *lrms2* a bit shorter than *lrms1*, both centrally localized, *lrms3* same length as *lrms1*, close to distal margin of labrum, with one *mds*, subequal to *lrms2*; epipharynx (Figure 30) with two pairs of *als*, three pairs of *ams*, one pair of *mes*, sensilla absent. All epipharyngeal setae stout, short and apically rounded; labium (Figure 31) membranous except sclerotized area. Labial palpus with one segment, longer than wide distinctly, with one pair of sensilla, apically flattened with dense crenulate setae. Premental sclerite (*Pmsc*) distinctly posteriorly and laterally dilated, U-shaped, with one pair of sensilla and one pair of long *prms*. Ligulate area with two pairs of tiny *lgs*, *lgs1* same lengtgh as *lgs2*, with one pair of sensilla. Postlabium partly sclerotized, with two pairs of *plbs* at membranous area, *plbs1* long, *plbs2* short, one quarter as long as *plbs1*.; Maxillae with maxillary palpus (*mxp*) (Figures 31–32) two segmented, basal segment distinctly wider than long, with one pair of sensilla and one pair of short *mxps,* accessory appendage absent. Apical segment longer than wide, with one pair of sensilla, apically flattened with dense short irregular speculate setae. Mala with five robust *dms*, *dms1–5* gradually shorter than the former one and four thin *vms*. Stipes bearing one *sts*, three palpiferal *pfs* and two sensilla, *sts* strong and long, basally medioventral, *pfs1* short,



**Figures 27–34.** Larva of *Gymnetron vittipenne*. **27** Antenna **28** Mandible **29** Labrum and clypeus **30** Epipharynx **31** Labium, ventral **32** Maxilla, dorsal **33** Spiracles, showing alignment **34** Pedal area. Scales bars: 0.025 mm (**27, 33**), 0.1 mm (**28–32**), 0.05 mm (**34**).

located near mala, one third as long as *pfs2*, *pfs2* basally medioventral, same length *pfs3*, *pfs3* lateroventral. Cardo completely divided from stipes. **Thorax** (Figure 26): Pronotum with six *pns*. Spiracle (Figure 33) bicameral, air-tube distinctly longer than diameter of circular peritreme, pointing basad. Pedal area (Figure 34) distinct, with five setae; Mesonotum with two folds, prodorsum with one *prs*. Postdorsum with two *pds*, one *dls* transversally aligned. Pedal area same as prothoracic; Metanotum same as mesonotum. **Abdomen** (Figure 26): with seven spiracles on segments I-VII, size similar, all anterolateral and unicameral, each with single annulated air-tube, distinctly longer than diameter of circular peritreme, pointing basad. **Abd I-VII:** tergites with two folds, prodorsum with one tiny *prs*, postdorsum with soft protuberance posteriorly, with two *pds*, *pds1* short, half as long as *pds2*. All setae shorter than thoracic setae; **Abd VIII:** *pds1* short, half as long as *pds2*.

**Pupa** (Figures 35–37): measurements (mm): length: 4.75–4.85 (n = 4), width: 1.60–2.00 (n = 4).

It differs from *G. miyoshii* by: **General appearance**: size greater. **Head:** head yellow-gray with indistinct yellow stripes in middle, two pairs of *pas*, *pas1* situated in middle of frons, *pas2* situated at middle margin of eyes. **Thorax:** prothorax bearing a lightly pigmented tubercle, apically deeply bifurcate. Pronotum with three *as*, two *sls*, one *ds* and two *pls*. *As* and *sls1, pls* subequal, strong and long, *pls1* and *pls2* in one transverse row, *sls2* and *ds* short; Mesonotum with three *msns* on scutellum. **Abdomen:** segment I-VII with tergite bearing two setae. Spiracular area with two *ss*; **Legs:** pro-, meso- and metafemora apically bearing one pair of slightly outcurved *fes*, apex with grey circular pigmented area.

**Specimen examined. CHINA: Xinjiang:** Talaticun, Qinghe (46°40.53'N; 90°27.74'E, 1285m), 28-VII-2013, *Veronica oxycarpa* Boiss., leg Chunyan Jiang (33); Hualin Park (47°51.75'N; 88°07.18'E, 886m), 5-VIII-2013, leg You Li (1).

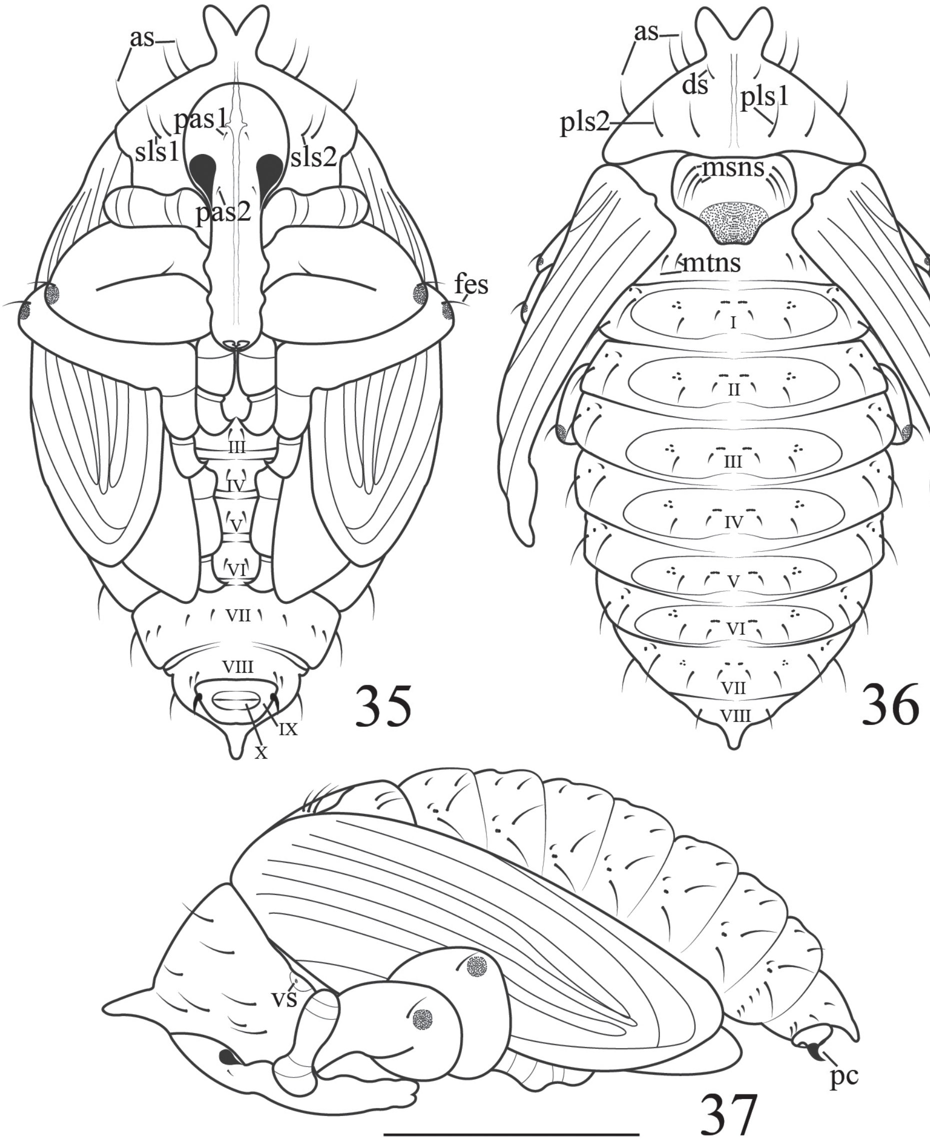
**Biological notes.** After collecting the host plants *Veronica oxycarpa* Boiss. with galls on 28-VII-2013, 10 larvae and 20 pupae were obtained on 1-VIII-2013.

**Remarks.** This species has been recorded from Armenia, Bulgaria, Croatia, Greece, Iran, Iraq, Kazakhstan, Lebanon, Palestine, Slovakia, Syria, Tajikistan, Turkey, Turkmenistan and Uzbekistan. This species is a new record for China.

### *Gymnetron villosipenne* Roelofs, 1875

*Gymnetron villosipenne* Roelofs, 1875: 149.

**Description. Adult** (Figures 7–8): sides of pronotum on basal half and base covered with dense, imbricate, broad scales; elytra with integument black to brown, interstriae covered with suberect seta-like scales arranged in one regular row; rostrum in lateral view straight, weakly narrowed from base to apex, in dorsal view slightly narrowing from antennal insertion to apex; eyes moderately convex (Caldara, 2008).



**Figures 35–37.** Pupa of *Gymnetron vittipenne*. **35** Ventral view **36** Dorsal view **37** Lateral view. Scales bars: 1 mm.

**Specimen examined. CHINA: Jilin:** Dahuanggou, Antu, Yanbian (42°55.18'N; 128°37.53'E, 918m), 13-VIII-1963 (1). **Heilongjiang:** Xigou, Aihui, (49°51.45'N; 127°13.30'E, 154m), 20-VII-1963, leg Hongxing Li (1); Daxiangcun, Great Khingan (52°57.65'N; 122°31.67'E, 600m), 19-VII-1970 (1).

## Keys to *Gymnetron* adults, larvae and pupae from China

Key to adults of *Gymnetron* from China

1 Metathoracic episterna covered with broad scales....................................... **2**
– Metathoracic episterna covered with narrow scales................. ***G. vittipenne***
2 Metasternum and urosternite one covered with narrow scales..................... **3**
– Metasternum and urosternite one covered with broad scales...... ***G. miyoshii***
3 Elytra completely black....................................................... ***G. villosipenne***
– Elytra reddish with only interstria one and ten black ................. ***G. auliense***

Key to larvae of *Gymnetron* from China (details in Table 1)

1 Labrum without middle seta and sensilla, nearly all sclerotic....................... **2**
– Labrum with middle seta and sensilla, partly sclerotic............. ***G. vittipenne***
2 Epipharyngeal setae stout, sensilla absent.................................. ***G. miyoshii***
– Epipharyngeal setae slender, two pairs of sensilla ....................... ***G. auliense***

Key to pupae of *Gymnetron* from China (details in Table 2)

1 Pronotum with one pair of apical setae, one pair of sublateral setae, two pairs of posterolateral setae and discal setae absent ............................................. **2**
– Pronotum with three pairs of apical setae, two pairs of sublateral setae, two pairs of posterolateral setae, one pair of discal setae................ ***G. vittipenne***
2 Pro-, meso- and metafemora apically bearing two setae............. ***G. miyoshii***
– Pro-, meso- and metafemora apically bearing one seta ................ ***G. auliense***

## Biological information

Host plants of *Veronica* in which larvae of the three species live are widely distributed in China (Zhong 1979). *Gymnetron auliense* and *G. vittipenne* were both collected on *Veronica oxycarpa* Boiss., *G. miyoshii* was collected on *Veronica anagallis-aquatica* L.; all host plants live on the banks or in clear slowly flowing streams (Figures 38–40).

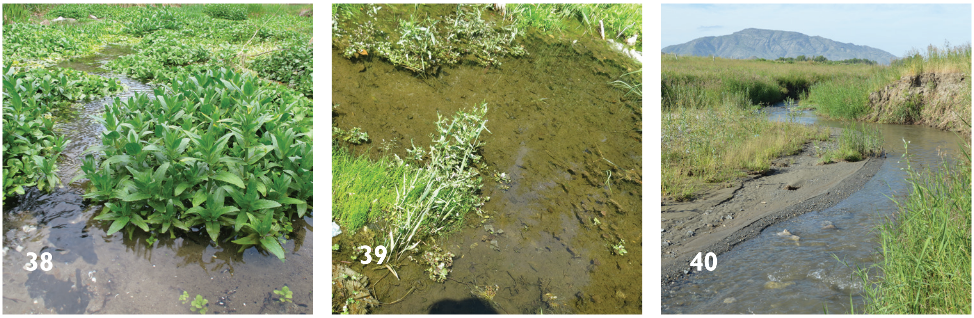
The adults of *G. miyoshii* feed on stems near the axils of their host (Figure 41). Females make holes on petals and calyces with mouthparts on the apex of the rostrum (Figure 42), and lay eggs in ovaries of developing flower buds or flowers (Figure 43). One oviposition hole can be found on the surface of one ovary and one larva develops in an ovary. The oval eggs are mostly surrounded by ovules and are evident on the ovary wall (Figure 44–45). As Howden (1995) reported, after oviposition, females seal the hole with fecal material (Figure 46-47). Larvae feed in the ovaries, stimulating ovaries to develop into galls (Figure 48). Larvae (Figure 49a–b) are active, and if disturbed, their abdomen sways front and back quickly. Mature larvae will not pupate until the ovary

**Table 1.** Diagnostic features of the mature larvae of *Gymnetron* from China (Characters of *G. miyoshi* identical in G. *auliense*/*G. vittipenne* are not repeated, but indicated by "-").

| Trait | Character | *Gymnetron miyoshii* | *Gymnetron auliense* | *Gymnetron vittipenne* |
|---|---|---|---|---|
| **Length (mm)** | | 3.25–3.90 | 2.4–2.5 | 5.00–5.20 |
| **Head** | Dorsal | *3 fs*, 1,3 absent; 4 *des*, 4 absent; 3 minute *pes*; 2 *les*; ventral 1 seta; *oc* present | - | - |
| | Antenna | 1 *aseg*, longer than wide, with 4 *sa* | - | 2 *sa* |
| **Mouthparts** | Mandible | 2 teeth 1 flange, 2 *ms*, 1 sensillum | - | - |
| | Labrum | 2 pairs of *cls*; 3 pairs of *lrms*; nearlly all sclerotic | - | 2 pairs of *cls*, 1 pair of sensilla; 3 pairs of *lrms*, 1 *mds*; partly sclerotic |
| | Epipharynx | 2 pairs of *als*, 3 pairs of *ams*, stout setae | 2 pairs of *als*, 3 pairs of *ams*, 2 pairs of sensilla, slender setae | 2 pairs of *als*, 3 pairs of *ams*, 1 pair of *mes*, stout setae |
| | Maxilla | *1 stps*, 2 sensilla; 2 *pfs*; 4 *vms*, short , 5 *dms*; *mxp* 2 segments, 1 *mxps*, 1 sensillum | - | 3 *pfs*; 1 *mxps*, 2 sensilla |
| | Labium | *lbp* 1 segment, 1 sensillum; 2 *ligs*; *pmsc* "U" sclerotic, 1 *prms*, 1 sensillum; *plb* partly sclerotic, 2 *plbs* | - | - |
| **Thorax (one side)** | Th I | 2 *prns*; 4 *dpls*; 2 *vpls*; 4 *pda* setae; 2 *msts* | 4 *prns* | 6 *prns*; 5 *pda* setae |
| | Th II | 2 *prs*; 2 *pds*; 4 *as*; 1 *dpls*; 1 *vpls*; 4 *pda* setae; 2 *msts* | - | 1 *prs*; 2 *pds*; 1 *dls*; 5 *pda* setae |
| | Th III | same as Th II | - | same as Th II |
| **Abdomen (one side)** | Abd I-VII | 2 *prs*; 1 *pds*; 2 *ss*; 1 *dpls*; 1 *vpls*; 1 *lsts*; 3 *msts*; 7 *s* | - | 1 *prs*; 2 *pds* |
| | Abd VIII | 1 *prs*; 1 *pds*; 2 *ss*; 1 *dpls*; 1 *vpls*; 1 *lsts*; 2 *msts* | - | 2 *pds* |
| | Abd IX | 1 *prs* ; 1 *pds*; 1 *pls*; 3 *sts* | - | - |
| | Abd X (anus) | 1 seta, transverse | - | - |

**Table 2.** Diagnostic features of pupae of *Gymnetron* from China (characters of *G. miyoshii* identical in *G. auliense* are not repeated, but indicated by "-").

| Traits | *Gymnetron miyoshii* | *Gymnetron auliense* | *Gymnetron vittipenne* |
|---|---|---|---|
| **Head** | 1 pair of *pas* | - | 2 pairs of *pas* |
| **Thorax (one side)** | Prothoracic tubercle shallowly split, 1 *as*, 1 *sls*, 2 *pls*; 2 *msns*; 2 *mtns* | 3 *msns*; 2 *mtns* | Prothoracic tubercle deeply split, 3 *as*, 2 *sls*, 2 *pls*; 3 *msns*; 2 mtns |
| **Abdomen (one side)** | Abd I-VII, tergum 1 seta, 1 *ss*, 1 *dpls*, 1 *vpls*,1 *lsts*, 2 *msts*; Abd VIII, tergum with posterior tubercle, 1 seta, Sternum 2 setae; Abd IX, with *pc*; Abd X, anus transverse cleft, subterminal | - | Abd I-VII, tergum 2 setae, 2 *ss* |
| **Legs** | 2 *fes* | 1 *fes* | 1 *fes* |



**Figures 38–40.** Ecological habitats of three weevils. *Gymnetron miyoshii* **39** *G. auliense* **40** *G. vittipenne*.

wall remains as a thin membrane. Pupae (Figure 50) are also active and their abdomen can sway front and back quickly like the larvae. Ovaries attacked by weevils will not produce seeds, but the damage seems not to seriously harm the plant's whole reproductive rate. After observation in the field, we found *G. miyoshii* mostly live in the ovaries in the middle of the inflorescence, while flowers at top and bottom still produce seeds.

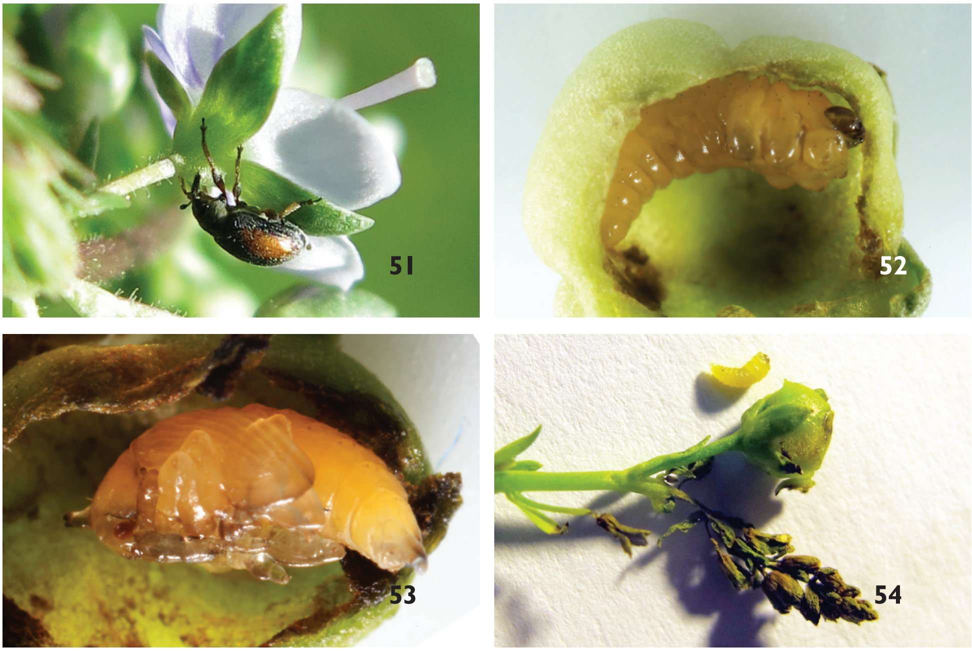
*Gymnetron auliense*, like *G. miyoshii*, also lays eggs in ovaries of host plants (Figure 51), larvae (Figure 52) and pupae (Figure 53) live in galls of ovaries (Figure 54).

*Gymnetron vittipenne* was collected in *Veronica anagallis-aquatica* L., as reported by Ugarte San Vicente et al. (2012), where it lays eggs in stems between two leaf bases. After oviposition, galls formation occur (Figure 55). There are several cells in each gall, which are separated individually, with one larva per cell (Figure 56–57). Damage does not seriously harm the host plants, and plants keep producing flowers and seeds normally (Figure 58).

## Discussion

Lee et al. (1998) described the larva of *G. miyoshii*, but after further study, distinct major differences are observed in the head (ocelli, setae and clypeus), mouthparts (labrum, labium and maxillary palpus), setae of thorax and abdomen, and number of spiracles, with comparison in Table 3. The differences maybe due to a misidentification made by Lee et al. (1998). The character of labrum is important in dividing different group in Curculionidae. Usually labrum with one pair of sensilla is the primitive state, but with 0, 1, 3 sensillae is advanced (van Emden 1938). In our observation, there are 2 sensillae in *G. vittipenne*, but none in *G. miyoshii* or *G. auliense,* which shows the genus of *Gymnetron* may be not monophyletic. The labrum fused with the clypeus and without the epipharygeal rod is an important character of *Gymnetron*; the maxillary palpi of these 3 species are 2-segmented, but the basal segment is incomplete in *G. miyoshii* and *G. auliense*. We did not observe accessory appendages in any of the 3 species. Caldara (2013) used characters of the host plants to build the phylogenetic tree in *Mecinus*

**Figures 41–50.** *Gymnetron miyoshii*. **41** Adult feeds on stems of *Veronica anagallis-aquatica* L. **42** Adult makes holes on bud of host plants **43** Adult lays eggs in buds **44** Egg in ovary surrounded by ovules **45** Egg visible through ovary wall **46** Adult seals the hole with fecal material **47** Dry fecal material **48** Galls of ovaries and normal flowers **49a–b** Larva **50** Pupa.



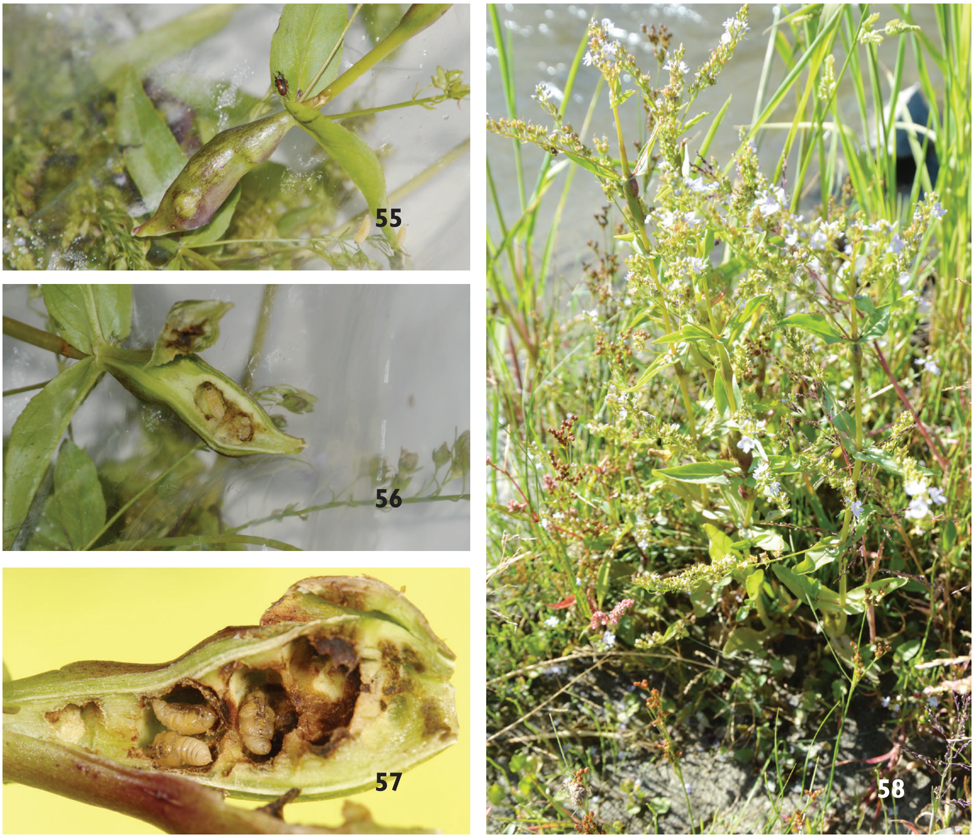
**Figures 51–54.** *Gymnetron auliense*. **51** Adult makes holes on bud of host plants, *Veronica oxycarpa* Boiss. **52** Larva **53** Pupa **54** Galls of ovaries and normal dead flowers.

**Table 3.** Different descriptions of larva of *Gymnetron miyoshii*.

| Trait | Character | Description (Lee et al. 1998) | Review |
|---|---|---|---|
| **Head** | Ocellus | 2 pairs | 1 pair |
| | Setae | *des1, 3, 5* long, equal, *des4* short, *des2* absent; *les*, *ves* absent; 2 *pes*; 2 *cls*, different length | *des3* longest, *des5* long, *des1*, 2 short equal, *des4* absent; 2 *les*; 1 *ves*; 3 *pes; 2 cls*, equal |
| **Mouthparts** | Labrum | posterior margin extended medially into clypeal zone; rods as brownish patches | posterior margin indistinct; rods absent |
| | Labium | 3 *plbs* | 2 *plbs* |
| **Thorax (one side)** | | 6 *prns*; 3 *pds*; 1 *as*; pedal lobe 2 segment, 6 setae | 2 *prns*; 2 *pds*; 4 *as*; pedal lobe 1 segment, 4 setae |
| **Abdomen (one side)** | | 8 spiracles; airtube longer than diameter of peritreme; 3 folds; 1 *prs*; 2 *pds*; 1 *ss*; 2 *msts* | 7 spiracles; airtube subequal as diameter of peritreme; 2 folds; 2 *prs*; 1 *pds*; 2 *ss*; 3 *msts* |

Germar, 1821. The immature stages have a close relationship with host plants. Thus, it will be a great help to add characters of immature stages in the phylogenetic studies.

In addition, setae on the alar area are found to be variable. There are usually four setae of different lengths on the alar area on each side of each larva. Five setae can be found on the alar area of the metathorax of *G. miyoshii*. Thus, the setae of the alar area are not useful diagnostic characters. There is only one middle seta on the labrum of *G. vittipenne* pupae, it is special, and we name it *mds*. The features of the larva of the genus



**Figures 55–58.** *Gymnetron vittipenne*. **55** Galls of stems **56** Larvae **57** Pupae, the two pupae on the left cell, one of them is from the right cell **58** Living host plants *Veronica oxycarpa* Boiss. with galls.

*Gymnetron* are as follows: (1) Frontal suture not extending to mandibular membrane; (2) Antennae contiguous with frontal suture; (3) Postoccipital condyles indistinct; (4) meso-, metathorax and abdomen with two tergal folds; (5) Alar area without sclerotized or pigmented areas; (6) Spiracles bicameral; (7) Head brown with pale stripes at side and *ecl* of head; (8) Accessory sensory appendage of antenna short; (9) Anus, transverse cleft; (10) Living in galls of seeds or stems of Scrophulariaceae or Plantaginaceae.

Parasites of *Gymnetron* are few (May 1993, Gumovsky 2007), and during this study, only one parasite was found in the larvae of *Gymnetron*. Low parasitism may due to the following two reasons. First, galls can be a mechanical barrier for escape from natural enemies. Second, iridoid glycosides in host plants can help *Gymnetron* to protect it from the natural enemies. Iridoid glycosides are unpalatable and denature proteins and DNA (Bowers et al. 1986, Kim et al. 2000). Though there were none of these chemical compounds in adults (Baden et al. 2012), *Gymnetron* still can use them indirectly. Since larvae and pupae live in galls, the ovary walls with iridoid glycosides can also be a protection against invertebrate and vertebrate predators. Chinese have collected *Veronica anagallis-aquatica* L. with *Gymnetron* galls as a Chinese traditional medicine for many years, which can treat some painful and inflammatory human diseases (Zhong 1979). The main active substance in this Chinese traditional medicine is iridoid glycosides (Dong et al. 2011, Guan et al. 2011). *Gymnetron* feeds on host plants, causing the plants to produce more iridoid glycosides. Baden et al. (2012) only reported there are no iridoid glycosides in adults of *Mecinus* Germar, 1821 and *Rhinusa* Stephens, 1829. To confirm whether these chemical substances exist in larvae, pupae and adults of *Gymnetron*, further studies are needed.

While collecting these species from the field, three kinds of host plants only were found, living only in flowing water with little pollution or human disturbance. In spring, there are many host plants in the habitats, but only those with *Gymnetron* living on them can survive as they begin to flower and seed. We collected plants for rearing weevils in the laboratory, and observed the same phenomenon. Plants with galls of *Gymnetron* lasted long after seven days, but those without galls began to wilt on the second day and died on the 7th day. The host plants were reared five times under the laboratory conditions. Based on this study, we formulate the hypothesis that *Gymnetron* feed on *Veronica* causing them to produce more protective chemicals, which can help the plants to resist environmental stress. Species of *Veronica* with *Gymnetron* galls living near water cannot live in unclean polluted water for long, so we can use these two organisms as environmental indicators. So, during the co-evolution of insects and plants, there are relationships not only of plant-herbivores-predator, but herbivores and plants can also help each other to live harmoniously.

## Acknowledgements

We are very thankful to Dr. Ning Liu, Dr. Zhiliang Wang, Dr. Li Ren and Dr. Jing Xu from the Institute of Zoology, Chinese Academy of Sciences for their providing partial support for this research; our thanks also to the following: Dr. Charles O'Brien from the U.S.A., Dr. Roberto Caldara from Italy and Dr. Muhammad Haseeb of the Center for Biological Control, Florida A&M University for review of earlier version of this paper; Dr. Jens Prena from Germany and Dr. Roberto Caldara for identifying some specimens; Dr. Zhenyu Li from the Institute of Botany, Chinese Academy of Sciences for identifying host plants; Mr. Jian Wang from Altay Forestry Research Institute for his help in specimen collections; Dr. Marek Wanat from Wroclaw University in Poland for sending specimens of Mecinini; Dr. Kyungduk Han from Korea University and Youssef M Omar from Assiut University in Egypt for field collecting and literature; Dr. Miguel Alonso-Zarazaga from Museo Nacional de Ciencias Naturales in Madrid, Spain and Dr. Christopher H. C. Lyal from The Natural History Museum in London, UK for their guidance in this research project. This research was supported by National Natural Science Foundation of China (31210103909/31172130/J1210002) and National Special Program for Basic Science and Technology (2013FY110300).

## References

Alonso-Zarazaga M, Lyal CHC (1999) A world catalogue of families and genera of Curculionoidea (Insecta: Coleoptera) (excepting Scolytidae and Platypodidae). Entomopraxis, Barcelona, 315 pp.

Anderson DM (1973) Keys to larvae and pupae of Gymnetrinae of America North of Mexico (Coleoptera: Curculionidae). Proceedings of the Entomological Society of Washington 75: 133–140

Baden CU, Franke S, Dobler S (2012) Differing patterns of sequestration of iridoid glycosides in the Mecininae (Coleoptera, Curculionidae). Chemoecology 22: 113–118. doi: 10.1007/s00049-012-0103-0

Bowers MD, Puttick GM (1986) Fate of ingested iridoid glycosides in lepidopteran herbivores. Journal of Chemical Ecology 12: 169–178. doi: 10.1007/BF01045600

Caldara R (2001) Phylogenetic analysis and higher classification of the tribe Mecinini (Coleoptera: Curculionidae, Curculioninae). Koleopterologische Rundschau 71: 171–203.

Caldara R (2003) Revisione dei *Gymnetron* della Regione Afrotropicale. Memorie della Società Entomologica Italiana 82(1): 87–272.

Caldara R (2008) Revisione delle specie paleartiche del genere *Gymnetron* (Insecta, Coleoptera: Curculionidae). Aldrovandia 4: 27–103.

Dong T, Cui Y, Tian J, Yao K (2011) Advances in studies on natural iridoids. Chinese Traditional and Herbal Drugs 42(1): 185–194.

Emden F van (1938) On the taxonomy of Rhynchophora larvae (Coleoptera). Transactions of the Royal Entomological Society of London 87: 1–37.

Faust J (1885) Turkestanische Rüsselkäfer. Stettiner entomologische Zeitung 46: 149–202.

Gosik R (2010) Morphology of the mature larva and pupa of *Rhinusa bipustulata* (Rossi, 1792) (Coleoptera: Curculionidae) with some remarks on its biology. Baltic Journal of Coleopterology 10: 185–194

Guan T, Liang Y, Li C, Xie L, Wang G, Sheng L (2011) Recent Development in Liquid Chromatography/Mass Spectrometry and Allied Topics for Traditional Chinese Medicine Research. Chinese Journal of Natural Medicines 9(5): 385–400

Gumovsky AV (2007) A taxonomic revision, biology and morphology of immature stages of the *Entedon sparetus* species group (Hymenoptera: Eulophidae), egg-larval endoparasitoids of weevils (Coleoptera: Curculionidae). Bulletin of Entomological Research 97: 139–166. doi: 10.1017/S0007485307004798

Howden AT (1995) Structures related to oviposition in Curculionoidea. Memoirs of the Entomological Society of Washington 14: 53–102.

Kim DH, Kim BR, Kim JY, Jeong YC (2000) Mechanism of covalent adduct formation of aucubin to proteins. Toxicology Letters 114: 181–188. doi: 10.1016/S0378-4274(99)00295-7

Lee CY, Morimoto K (1988) Larvae of the weevil family Curculionidae of Japan. 2. Hyperinae to Cioninae (Insecta, Coleoptera). Journal of the Faculty of Agriculture Kyushu University 33(1–2): 131–152.

Marseul MSA (1876) Coléoptères du Japon recueillis par M. Georges Lewis. Annales de la Societe Entomologique de France (5serie) 6: 383.

Marvaldi AF (1999) Larval morphology in Curculionidae (Insecta: Coleoptera). Morfologia larval en Curculionidae (Insecta: Coleoptera). Acta Zoologica Lilloana 45(1): 7–24.

May BM (1979) A technique for dissecting head capsules of small coleopterous larvae. New Zealand Entomologist 7(1): 99. doi: 10.1080/00779962.1979.9722341

May BM (1993) Larvae of Curculionoidea (Insecta: Coleoptera): a systematic overview. Fauna of New Zealand 28: 1–223.

May BM (1994) An introduction to the immature stages of Australian Curculionoidea. In: Zimmerman EC (Ed.) Australian weevils – (Coleoptera: Curculionoidea). Vol. 2: Brentidae, Eurhynchidae, Apionidae and a chapter on immature stages. CSIRO, Canberra, 365–755.

Miyoshi K (1922) *Gymnetron miyoshii* Mats. n. sp. Konchû Sekai 26: 253–258.

Reitter E (1907) Bestimmungs-Tabellen für die Curculioniden-Gruppe der Mecinini (Gymnetrini) aus Europa und den angrenzender Ländern. Verhandlungen des naturforschenden Vereines in Brünn 45(1906): 7–50.

Roelofs W (1875) Curculionides recueillis au Japan par M. G. Lewies. Torisième et dernière partie. Annales de la Société Entomologique de Belgique 18: 149.

Scherf H (1964) Die Entwicklungsstadien der mitteleuropaischen Curculioniden (Morphologie, Bionomie, Ökologie). Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft 506: 1–335

Stevens PF (2012) Angiosperm Phylogeny Website. Version 12, July 2012 [and more or less continuously updated since]. http://www.mobot.org/MOBOT/research/APweb

Ugarte San Vicente I, Salgueira F, Caldara R (2012) Presencia de *Gymnetron vittipenne* Marseul, 1876 en la Península Ibérica (Insecta, Coleoptera, Curculionidae). Notas sobre su biología y distribución. Graellsia 68(2): 341–345. doi: 10.3989/graellsia.2010.v68.062

Wang Z, Alonso-Zarazaga M, Zhou D, Zhang R (2013) A description of preimaginal stages of *Pseudaspidapion botanicum* Alonso-Zarazaga & Wang, 2011 (Apionidae, Curculionoidea). ZooKeys 260: 49–59. doi: 10.3897/zookeys.260.4450

Zhong B (1979) Scrophulariaceae (I). Editorial Committee for Flora of China Chinese Academy of Sciences, Flora of China, Volume 67(2). Science Press, Beijing, 1–11, 321–322.

ZooKeys 534: 85–102 (2015)
doi: 10.3897/zookeys.534.5997
http://zookeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

# Review of the genus *Hieromantis* Meyrick from China, with descriptions of three new species (Lepidoptera, Stathmopodidae)

Wei Guan[1], Houhun Li[1]

[1] *College of Life Sciences, Nankai University, Tianjin 300071, P. R. China*

Corresponding author: *Houhun Li* (lihouhun@nankai.edu.cn)

Academic editor: *A. Zilli* | Received 31 March 2015 | Accepted 21 September 2015 | Published 11 November 2015

*http://zoobank.org/C4FAE109-113A-4593-BC8B-9CF307B34AF4*

**Citation:** Wei Guan, Houhun Li (2015) Review of the genus Hieromantis Meyrick from China, with descriptions of three new species (Lepidoptera, Stathmopodidae). ZooKeys 534: 85–102. doi: 10.3897/zookeys.534.5997

## Abstract

Six species of the genus *Hieromantis* occurring in China are reviewed. *Hieromantis rectangula* **sp. n.**, *H. arcuata* **sp. n.** and *H. puerensis* **sp. n.** are described as new, and *H. phaeodora* Meyrick, 1929 is newly recorded in China. Photographs of adults and illustrations of genitalia are provided, along with an identification key and a distribution map.

## Keywords

Lepidoptera, Stathmopodidae, *Hieromantis*, new species, new record, China

## Introduction

The genus *Hieromantis* was established by Meyrick (1897) with *H. ephodophora* Meyrick, 1897 as its type species. It includes 17 named species worldwide: ten species were described from the Australian Region (Meyrick 1897, 1913, 1922, 1924, 1927, 1933, Bradley 1957), four from the Oriental Region (Meyrick 1907, 1913, 1929), one from the Palaearctic Region (Yasuda 1988), and two from both the Oriental and Palaearctic regions (Li and Wang 2002).

*Hieromantis kurokoi* Yasuda, 1988 and *H. sheni* Li & Wang, 2002 are the only species that were recorded in China prior to this study (Wang 2006). The aim of this paper is to review the *Hieromantis* species occurring in China. Three species are described as new to science, and one species is firstly recorded to China. The distribution map of *Hieromantis* species in China is shown in Fig. 1.

**Remarks.** The tube-shaped structure arising from the corpus bursae in the female genitalia is termed differently by different authors. It was described as a broad part of the corpus bursae plus the ductus seminalis by Kasy (1973), as ductus seminalis including the broad part and the narrow part by Yasuda (1988), and as the bulla plus the ductus seminalis by Koster and Sinev (2003). Here, we describe the structure between the corpus bursae and the ductus seminalis as the appendix bursae, and the abruptly narrowed distal portion as the ductus seminalis.

## Material and methods

The specimens examined in this study were collected using light traps. Morphological terminology follows Koster and Sinev (2003) except that the term appendix bursae is used instead of the term bulla. Genitalia dissections follow the methods introduced by Li (2002). Photographs of adults were taken with a Leica M205A Stereo microscope plus a Leica Application Suite 4.2 software, and photographs of genitalia were prepared using a Leica DM750 Microscope provided with the same software. All pictures were refined and assembled with Adobe Photoshop® CS6 software.

All the specimens, including the types, are deposited in the Insect Collection, College of Life Sciences, Nankai University, Tianjin, China.

## Taxonomy

### *Hieromantis* Meyrick, 1897

*Hieromantis* Meyrick, 1897: 315. Type species: *Hieromantis ephodophora* Meyrick, 1897, by monotypy.

**Generic characters. Adult.** Head smoothly scaled. Antenna (Figs 2, 5) with scape dilated, concave ventrally and forming an eye-cap; flagellum ciliated in male, simple in female. Labial palpus (Figs 2, 6) with third segment slightly longer than second segment. Maxillary palpus (Fig. 2) four-segmented, extremely short. Forewing lanceolate, usually having a loose patch consisting of scale tufts with metallic luster on dorsum; $R_1$ and $R_2$ arising from before upper angle of cell, $R_3$ arising from upper angle of cell, $R_4$ and $R_5$ stalked, $R_5$ reaching costa near apex; $M_1$ and $M_2$ nearly parallel, $M_3$ arising from lower angle of cell; $CuA_1$ and $CuA_2$ very short, nearly parallel; 1A+2A furcate at base. Hindwing narrowly lanceolate, with long cilia approximately seven times width of wing; $R_{2+3}$ reaching 2/5 of costa, $R_{4+5}$ reaching costa before apex; $M_2$ and $M_3$ usually present (Fig. 3a), but sometimes coincident (Fig. 3b). Hindleg with tibia dorsally bearing tufts of erect scales, with bundles

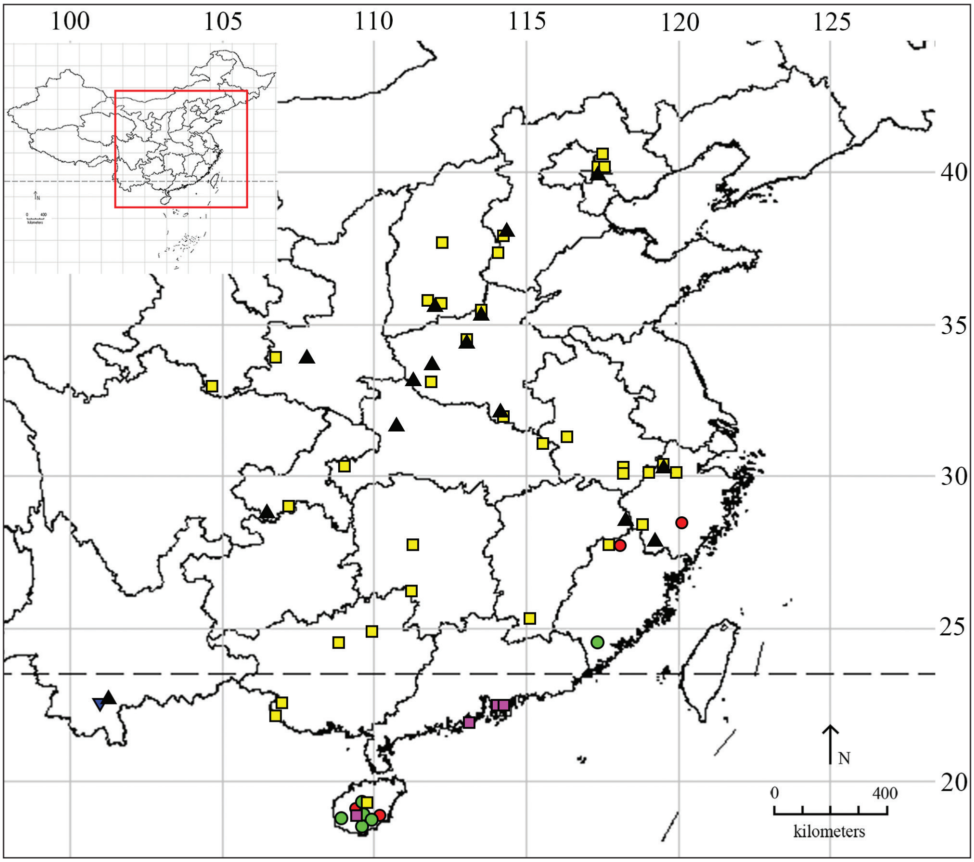


**Figure 1.** Distribution map of *Hieromantis* species in China. ● *H. rectangula* sp. n. ■ *H. arcuata* sp. n. ▼ *H. puerensis* sp. n. ● *H. phaeodora* Meyrick ■ *H. kurokoi* Yasuda ▲ *H. sheni* Li & Wang.

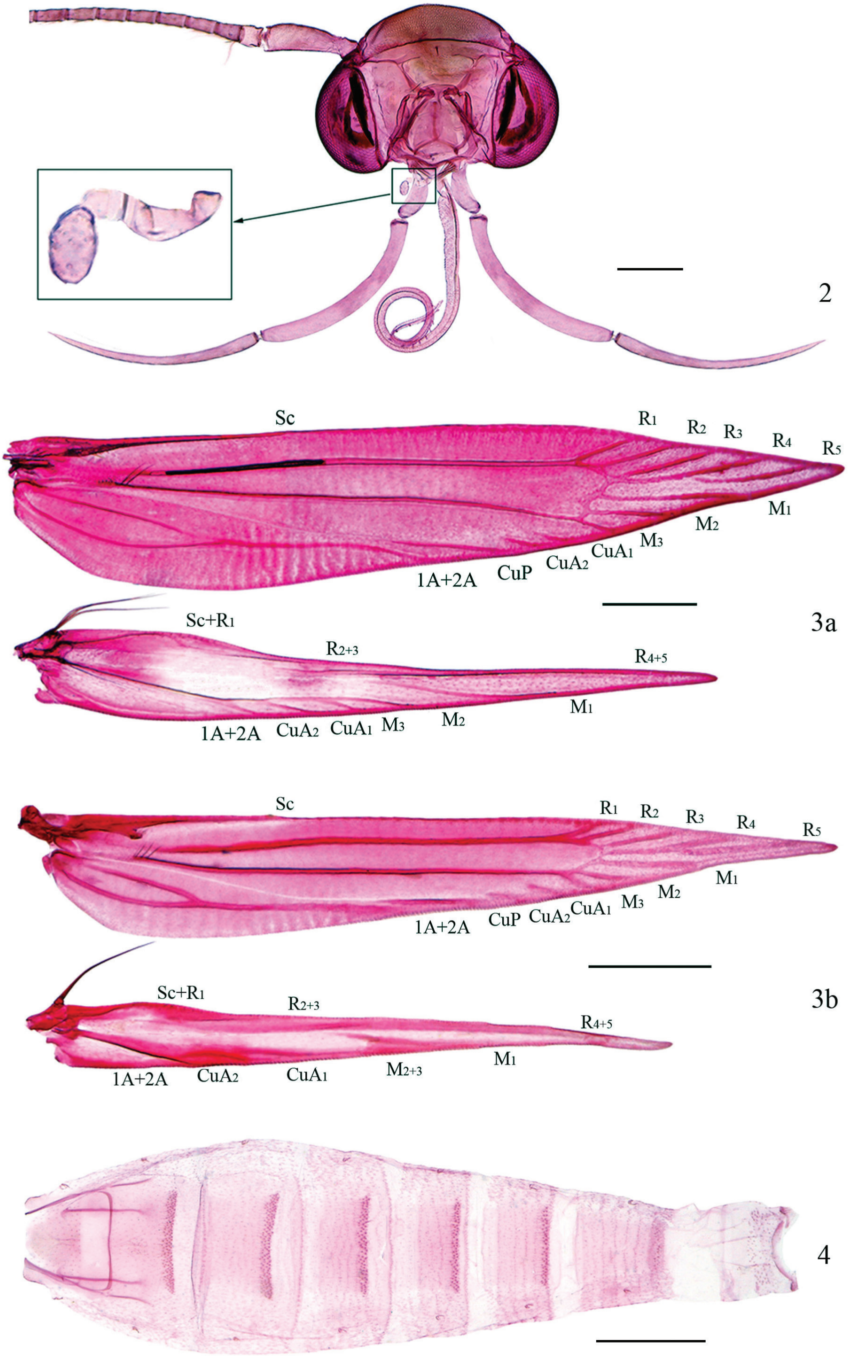
of bristles at apex. Abdominal tergites with second to seventh segments of male and second to sixth segments of female lined with spines on posterior margin (Fig. 4).

**Male genitalia.** Uncus usually subtriangular; gnathos broad tongue-shaped or subtriangular, about same length as uncus. Valva straight or obliquely upturned distally; sacculus weakly sclerotized. anellus lobes developed, usually longer than juxta. Aedeagus with a distal clubbed projection ventrally; cornutus present or absent.

**Female genitalia.** Intersegmental membrane between papilla analis and eighth abdominal segment usually longer than twice length of papilla analis. Antrum usually rectangular. Corpus bursae round or ovate, sometimes elongated; signum present or absent. Appendix bursae long tube shaped, usually with dilation. Ductus seminalis extremely thin.

**Diagnosis.** The genus *Hieromantis* is related to *Stathmopoda* by sharing a ciliated antenna in male. It can be easily separated by the dilated scape that forms an eye-cap and the forewing that usually has a large patch with metallic luster on the dorsum.

**Biology.** Little is known about the biology of *Hieromantis*. Larvae of *H. kurokoi* Yasuda, 1988 were found on *Cuscuta japonica* Choisy in autumn (Murase 2002).



**Figures 2–4.** Morphological features of *Hieromantis* species. **2** *H. kurokoi* Yasuda, head, slide No. NKUGW004 **3a** Ditto, venation, slide No. GW13139W **3b** *H. rectangula* sp. n., venation, slide No. GW13143W **4** *H. kurokoi* Yasuda, abdomen (genitalia removed), slide No. NKUGW004. Scale bars: 0.2 mm (**2**); 0.5 mm (**3, 4**).

**Distribution.** China, Japan, Sri Lanka, the Andaman Islands, Russia, Australia, New Guinea, Samoa, Fiji, Guadalcanal Island.

### Key to Chinese species of *Hieromantis*

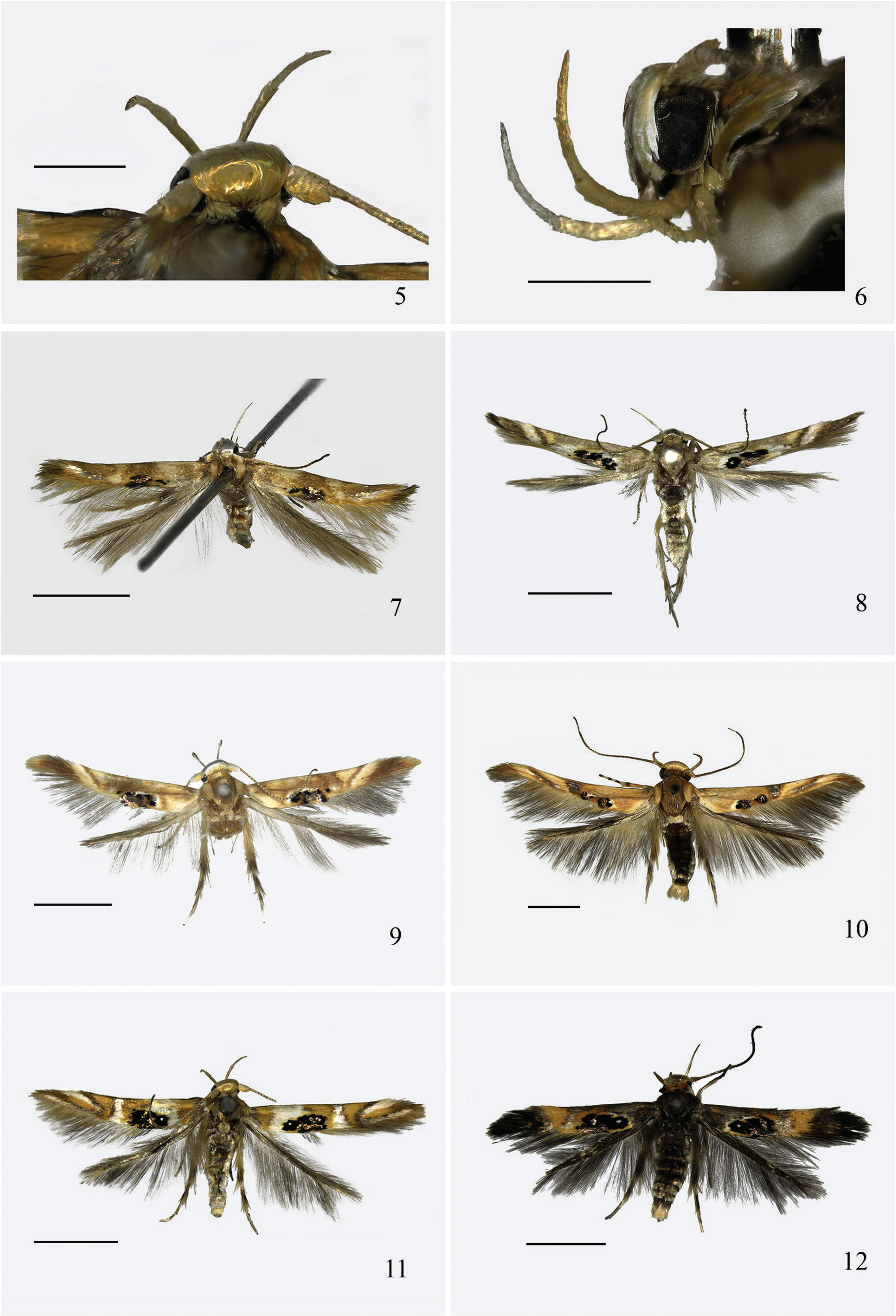
| | | |
|---|---|---|
| 1 | Male | **2** |
| – | Female | **6** |
| 2 | Cucullus rounded, not upturned (Fig. 16) | ***H. kurokoi*** |
| – | Cucullus subtriangular, usually upturned | **3** |
| 3 | Aedeagus without cornutus (Fig. 13) | ***H. rectangula* sp. n.** |
| – | Aedeagus with cornutus | **4** |
| 4 | Uncus clubbed in distal 1/4 (Fig. 14) | ***H. arcuata* sp. n.** |
| – | Uncus subrectangular in distal 1/4 | **5** |
| 5 | Cornutus approximately 3/5 length of aedeagus, extending from basal 1/5 to distal 1/5 (Fig. 15) | ***H. phaeodora*** |
| – | Cornutus approximately 1/3 length of aedeagus, extending from basal 1/3 to distal 1/3 (Fig. 17) | ***H. sheni*** |
| 6 | Corpus bursae with signum | **7** |
| – | Corpus bursae without signum | **10** |
| 7 | Appendix bursae longer than four times length of corpus bursae | **8** |
| – | Appendix bursae about same length as corpus bursae | **9** |
| 8 | Intersegmental membrane between papilla analis and eighth abdominal segment longer than papilla analis, corpus bursae without rowed teeth (Fig. 19) | ***H. arcuata* sp. n.** |
| – | Intersegmental membrane between papilla analis and eighth abdominal segment as long as papilla analis, corpus bursae with two parallel rows of teeth (Fig. 21) | ***H. phaeodora*** |
| 9 | Corpus bursae ovate, signum arcuate (Fig. 22) | ***H. kurokoi*** |
| – | Corpus bursae pyriform, signum linear, consisting of four basally joined teeth (Fig. 23) | ***H. sheni*** |
| 10 | Antrum subrectangular, without lamella antevaginalis (Fig. 18) | ***H. rectangula* sp. n.** |
| – | Antrum indistinct, lamella antevaginalis consisting of a pair of kidney-shaped sclerites (Fig. 20) | ***H. puerensis* sp. n.** |

### *Hieromantis rectangula* sp. n.

http://zoobank.org/6AC5AEDE-2E26-4F50-A3BC-0BAA703420FF

Figs 7, 13, 18

**Type material. CHINA: Holotype** ♂, Mt. Diaoluo (18°28'N, 109°31'E), Hainan Province, 940 m, 31.v.2007, leg. Zhiwei Zhang & Weichun Li, genitalia slide No. GW13134. **Paratypes: Hainan Province:** 4♂, Mt. Wuzhi, 700 m, 19.v.2007, leg.



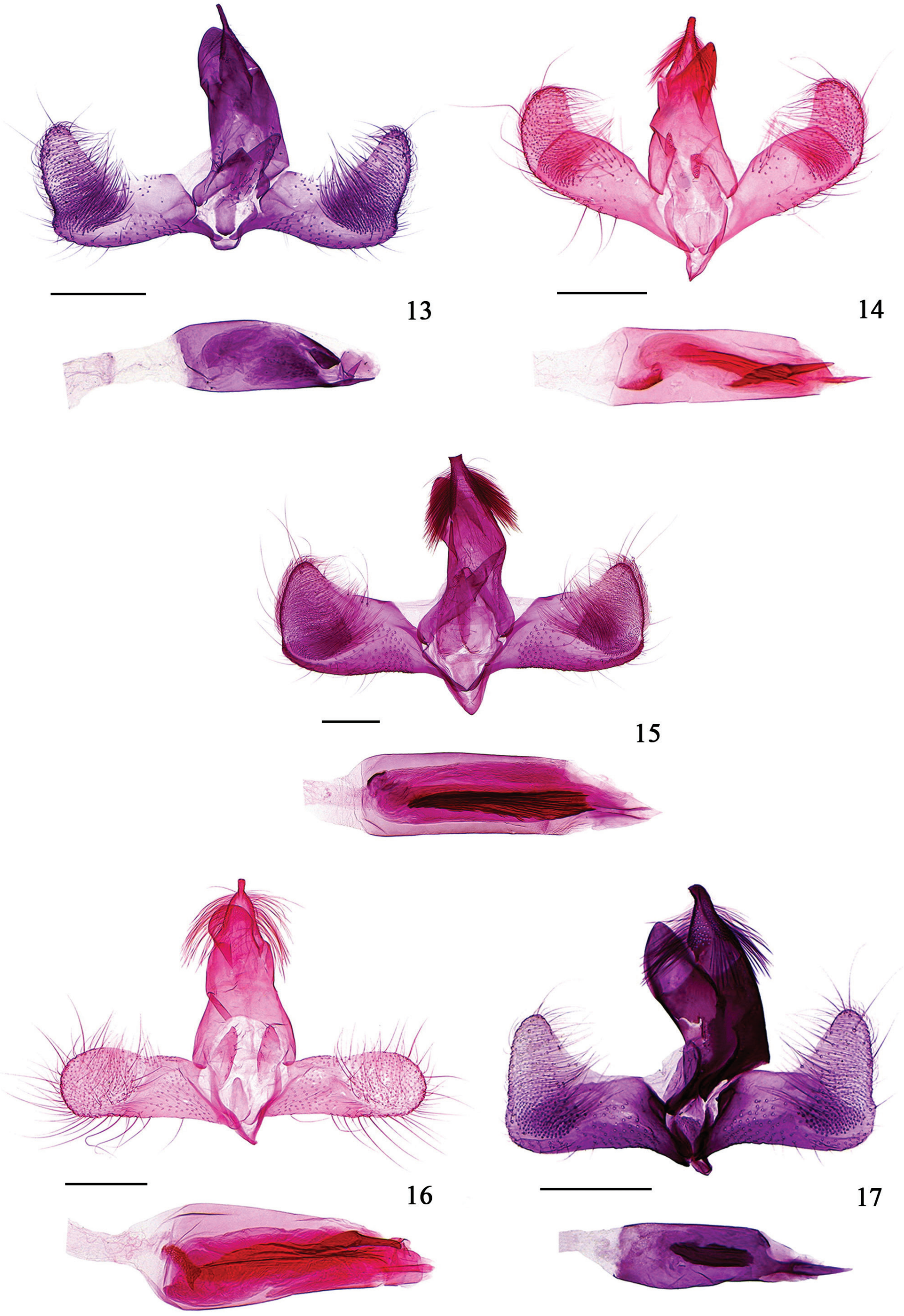
**Figures 5–12.** Adults of *Hieromantis* species. **5** *H. kurokoi* Yasuda, ♀, head (dorsal view) **6** Ditto, (lateral view) **7** *H. rectangula* sp. n., holotype, ♂ **8** *H. arcuata* sp. n., paratype, ♂ **9** *H. puerensis* sp. n., holotype, ♀ **10** *H. phaeodora* Meyrick, ♂ **11** *H. kurokoi* Yasuda, ♀ **12** *H. sheni* Li & Wang, ♀. Scale bars: 2.0 mm, except 0.5 mm (**5–6**).

Zhiwei Zhang & Weichun Li; 5♂, 6♀, Mt. Wuzhi, 742 m, 18–22.v.2015, leg. Peixin Cong, Wei Guan & Sha Hu; 1♂, 2♀, Jianfengling, 940 m, 4–5.vi.2007, leg. Zhiwei Zhang & Weichun Li; 1♀, Jianfengling, 810 m, 30.iii.2008, leg. Bingbing Hu & Haiyan Bai; 1♂, Jianfengling, 770 m, 16.vii.2014, leg. Peixin Cong, Linjie Liu & Sha Hu; 10♂, 13♀, Jianfengling, 770 m, 28.v.–5.vi.2015, leg. Peixin Cong, Wei Guan & Sha Hu; 1♀, Mt. Limu, 607 m, 16.v.2015, leg. Peixin Cong, Wei Guan & Sha Hu; **Zhejiang Province:** 1♂, Mt. Jiulong, 400 m, 6.viii.2011, leg. Linlin Yang & Na Chen; **Fujian Province:** 1♀, Mt. Wuyi, 740 m, 17.v.2004, leg. Haili Yu.

**Diagnosis.** This new species is similar to *H. makiosana* Yasuda, 1988 by the similar forewing markings, but can be distinguished by the inverted triangular costal patch on the forewing having a black dot at its ventral angle; the cucullus slightly concave on the outer margin near the junction with the ventral margin of the valva and the rectangular juxta in the male genitalia; and the ostium without minute spines in the female genitalia. In *H. makiosana*, the similar costal patch on the forewing lacks a black dot at its ventral angle; the cucullus is straight on the outer margin and the juxta is ovate; and the ostium has minute spines.

**Description.** Adult (Fig. 7). Wingspan 6.0–8.5 mm. Head with frons silvery white; vertex mottled with ochreous yellow scales; occiput yellowish brown. Labial palpus ochreous yellow on outer surface, silvery white on inner surface. Antenna with scape pale yellowish brown, edged with snowy white scales anteriorly; flagellum ochreous yellow, with brown rings. Thorax and tegula pale yellowish brown. Forewing creamy white, with scattered yellowish brown scales, ochreous yellow from dorsal 2/3 along dorsum to apex; trapezoidal ochreous yellow patch extending from between costal 1/3 and 2/5 to between dorsal 1/4 and 1/2; inverted triangular ochreous yellow patch extending from between costal 3/5 and 4/5 to lower angle of cell, bearing an ill-defined black dot posteriorly, with a narrow silvery gray band placed along its outer margin; dorsum with an ovate dark blotch located between basal 1/4 and 2/5 consisting of tufts of shining purple gray scales, its anterior margin cross 2/5 width of wing, near its inner side set a black spot; cilia pale yellowish brown. Hindwing grayish brown; cilia yellowish brown. Legs pale yellowish brown: foreleg with tibia purple brown on inner side, yellowish white on outer side, tarsus ringed with dark brown scales at apices of basal two tarsomeres; mid tibia dorsally with long yellowish brown bristles at middle and at apex, tarsus ringed with blackish brown scales at apices of basal two tarsomeres; hind tibia dorsally with dense pale grayish yellow bristles, ringed with blackish brown bristles at apex, tarsus dorsally with pale grayish yellow bristles on basal two tarsomeres, ringed with blackish brown bristles at apices of basal three tarsomeres. Abdomen ochreous gray on dorsal surface, shining white on ventral surface; lateral sides and anal tuft grayish white.

**Male genitalia** (Fig. 13). Uncus basally broad, gradually narrowed to 2/3, with sparse long hairs laterally, distal 1/3 thin clubbed. Gnathos broad tongue-shaped, bluntly rounded at apex. Tegumen about 1.3 times length of uncus. Valva narrow basally, broadened distally; costa concave at middle; sacculus narrow, slightly concave near base on ventral margin, then convex up to junction with cucullus; cucullus elon-



**Figures 13–17.** Male genitalia of *Hieromantis* species. **13** *H. rectangula* sp. n., holotype, slide No. GW13134 **14** *H. arcuata* sp. n., holotype, slide No. GW13203 **15** *H. phaeodora* Meyrick, slide No. GW14027 **16** *H. kurokoi* Yasuda, slide No. GW13138 **17** *H. sheni* Li & Wang, slide No. GW12299. Scale bars: 0.2 mm.

gate triangular, obliquely upward-oriented, narrowly rounded at apex, slightly concave on outer margin near junction with ventral margin of valva. Vinculum narrowly banded; saccus short rectangular, about 1/6 length of uncus. Juxta rectangular, anterior margin sclerotized, pointed medially, posterior margin bluntly rounded; anellus lobes elongate clubbed, about twice length of juxta. Aedeagus about 1.2 times length of valva, basal 2/3 nearly uniform, distal 1/3 gradually narrowed, produced to a thin clubbed distal projection ventrally, sclerotized near apex dorsally; with numerous tiny spines extending from basal 1/2 to 5/6; cornutus absent.

**Female genitalia** (Fig. 18). Intersegmental membrane between papilla analis and eighth abdominal segment about three times length of papilla analis. Apophysis posterior about 1.5 times length of apophysis anterior. Eighth segment with both anterior and posterior margins straight, with long hairs on posterior margin. Antrum subrectangular, slightly concave on both anterior and posterior margins, width about four times length. Ductus bursae uniformly narrow in posterior 3/4, gradually widened anteriorly, not distinctly separated from corpus bursae. Corpus bursae nearly fusiform, with dense granules near junction with appendix bursae; signum absent. Appendix bursae arising from junction between corpus bursae and ductus bursae, broad tube shaped, longer than four times length of corpus bursae, with several small teeth at base, slightly dilated in medial section.

**Distribution.** China (Fujian, Hainan, Zhejiang).

**Etymology.** The specific name is derived from the Latin *rectangulus*, referring to the rectangular juxta in the male genitalia.

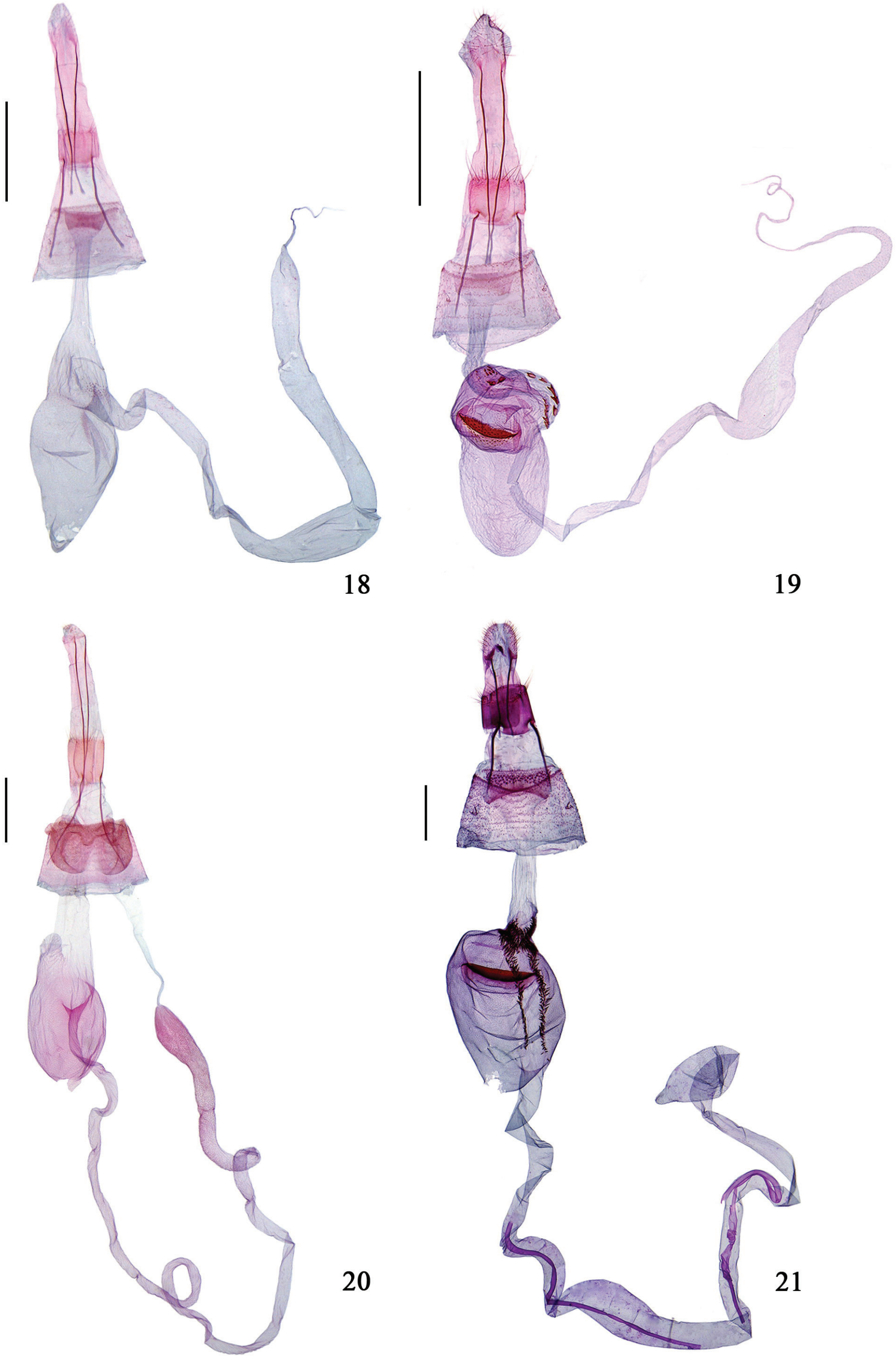
### *Hieromantis arcuata* sp. n.

http://zoobank.org/45E1C0A4-47E7-4044-BD44-2BE214C7D881

Figs 8, 14, 19

**Type material. CHINA: Holotype** ♂, Jiadaoli Farm (22°26'N, 114°07'E), Hong Kong, 210 m, 12.iv.2007, leg. Houhun Li *et al*., genitalia slide No. GW13203. **Paratypes: Hong Kong:** 1♀, same data as holotype; 1♂, same data as holotype except dated 10.iv.2007; 1♂, 340–455 m, 14.iv.2007, other data same as holotype; 2♀, Gaotang, Xigong, 100 m, 25.ix.2009, leg. Houhun Li; 1♂, Kadoorie Agric. Reaearch Centre Shek Kong N. T., 200 m, 5.viii.1998, leg. R. C. Kendrick; **Guangdong Province:** 1♂, Hebao Island, Zhuhai City, 8 m, 19.i.2010, leg. Houhun Li; **Hainan Province:** 1♀, Mt. Diaoluo, 940 m, 1.vi.2007, leg. Zhiwei Zhang & Weichun Li; 1♀, Mt. Wuzhi, 740 m, 14.iv.2009, leg. Qing Jin & Bingbing Hu; 1♀, Yinggeling, 620 m, 21.v.2010, leg. Bingbing Hu & Jing Zhang; 1♀, Yinggeling, 508 m, 15.vi.2015, leg. Peixin Cong, Wei Guan & Sha Hu; 2♀, Jianfengling, 770 m, 14–16.vii.2014, leg. Peixin Cong, Linjie Liu & Sha Hu; 1♀, Jianfengling, 770 m, 30.v.2015, leg. Peixin Cong, Wei Guan & Sha Hu.

**Diagnosis.** This new species is characterized by the valva having a straight wrinkle that extends from 3/4 of the costa directly to the ventral margin and the costa arched in



**Figures 18–21.** Female genitalia of *Hieromantis* species. **18** *H. rectangula* sp. n., paratype, slide No. GW13144 **19** *H. arcuata* sp. n., paratype, slide No. GW13146 **20** *H. puerensis* sp. n., holotype, slide No. GW13142 **21** *H. phaeodora* Meyrick, slide No. GW12266. Scale bars: 0.5 mm.

basal 3/4 in the male genitalia. It is similar to *H. kurokoi* Yasuda, 1988 by having similar forewing markings, but can be distinguished by having a subtriangular cucullus in the male genitalia; and the signum surrounded by dense small teeth and the appendix bursae longer than four times length of the corpus bursae in the female genitalia. In *H. kurokoi*, the cucullus is rounded; there are no small teeth surrounding the signum, and the appendix bursae is approximately as long as the corpus bursae.

**Description.** Adult (Fig. 8). Wingspan 8.0–9.0 mm. Head with frons silvery white; vertex pale yellowish brown, with suffused gray scales; occiput grayish brown. Labial palpus pale yellowish brown, second segment silvery white on inner side, third segment pale brown on outer side. Antenna with scape pale yellowish brown, margined with yellowish white scales; flagellum brown. Thorax grayish brown; tegula grayish brown in anterior half, silvery gray in posterior half. Forewing grayish brown, with scattered yellowish brown scales, distal 1/5 ochreous brown; grayish brown band extending from costal 2/3 obliquely inward to dorsal 3/5, its inner side set an ill-defined ochre-yellow patch neither reaching costa nor dorsum, its outer side placed a broad silvery white band; dorsum with an elliptical spot located between basal 1/4 and 2/5 consisting of tufts of erect silvery gray scales with metallic luster, its inner side placed a rounded black spot with a white dot in centre, anterior to it set two joined black spots along middle of fold, these four spots forming a large elliptical blotch located between dorsal 1/5 and 2/5, margined with silvery white scales except on dorsum and yellowish brown in middle of cell; cilia pale brown. Hindwing and cilia grayish brown. Legs pale yellowish: fore tibia yellowish brown, tarsus brown; mid tibia dorsally with yellowish white scales in basal half and at apex, ringed with pale brown bristles at apex, tarsus ringed with pale brown bristles at apices of basal two tarsomeres; hind tibia dorsally with dense pale gray deepening to grayish brown bristles, with bundles of pale gray bristles at apex, tarsus dorsally with grayish brown scales on first tarsomere, with brassy brown bristles at apices of basal three tarsomeres, black distally. Abdomen dorsally grayish brown; ventrally grayish white; lateral sides and anal tuft pale gray.

**Male genitalia** (Fig. 14). Uncus basally broad, gradually narrowed to 3/4, with long hairs laterally; distal 1/4 short clubbed, bluntly rounded at apex. Gnathos tongue-shaped, with small granules at apex. Tegumen approximately 1.3 times length of uncus. Valva narrow at base, medial portion with dorsal and ventral margins subparallel; with a straight wrinkle extending from 3/4 of costa to ventral margin; costa arched in basal 3/4, concave at 3/4; sacculus straight, apically reaching outer margin of cucullus; cucullus subtriangular, obliquely upturned, rounded at apex, bluntly rounded on outer margin. Vinculum narrowly banded; saccus V shaped, about 1/3 length of uncus. Juxta subrounded, anterior margin sclerotized, with a small pointed medial process; anellus lobes long clubbed, about 2.5 times length of juxta. Aedeagus approximately 1.2 times length of valva, basal 4/5 about uniform, distal 1/5 gradually narrowed, produced to a distal clubbed projection ventrally; with a sclerotized plate placed near base; cornuti consisting of a bunch of fine sclerites extending from basal 1/4 to distal 1/5, and a thick thorn-shaped spine placed between basal 3/5 and near apex centrally.

**Female genitalia** (Fig. 19). Intersegmental membrane between papilla analis and eighth abdominal segment about twice length of papilla analis. Apophysis posterior about 1.5 times length of apophysis anterior. Eighth segment straight on posterior margin, with long hairs; eighth tergite with anterior 1/4 rectangular; eighth sternite straight on anterior margin. Antrum subrectangular, width about three times length, concave on anterior margin. Ductus bursae about 3/4 length of corpus bursae, uniformly narrow in posterior 5/6, gradually widened anteriorly. Corpus bursae ovate, with numerous granules posteriorly; signum crescent, arched on anterior edge, dentate on posterior edge, surrounded by dense small teeth. Appendix bursae arising from junction between corpus bursae and ductus bursae, longer than four times length of corpus bursae, lined with several large teeth at base, dilated elliptically between basal 1/2 and 2/3.

**Distribution.** China (Guangdong, Hainan, Hong Kong).

**Etymology.** The specific name is derived from the Latin *arcuatus*, referring to the costa arched in the basal 3/4 in the male genitalia.

### *Hieromantis puerensis* sp. n.

http://zoobank.org/6E3850E2-699A-446C-B7B4-391AC7A4A216
Figs 9, 20

**Type material. CHINA: Holotype** ♀, Taiyanghe National Forest Park (22°36'N, 101°07'E), Pu'er City, Yunnan Province, 1626 m, 7.vii.2013, leg. Shurong Liu, Yuqi Wang & Kaijian Teng, genitalia slide No. GW13142. **Paratypes:** 2♀, same data as holotype except dated 6–7.vii.2013.

**Diagnosis.** This species is superficially similar to *H. ephodophora* Meyrick, 1897, *H. phaeodora* Meyrick, 1929, *H. kurokoi* Yasuda, 1988 and *H. arcuata* sp. n. It can be easily distinguished from its allies by the female genitalia having a lamella antevaginalis that consists of a pair of posteriorly joined kidney-shaped sclerites and the absence of a signum.

**Description.** Adult (Fig. 9). Wingspan 9.0–10.5 mm. Head with frons shining white; vertex pale yellowish brown; occiput pale ochreous yellow. Labial palpus silvery white, second segment with scattered pale yellow scales on outer side, third segment yellowish brown on outer side. Antenna with scape silvery white, with suffused yellowish brown scales posteriorly; flagellum ochreous yellow, ringed with brown. Thorax ochreous brown, with a longitudinal silvery white band in anterior half medially; tegula grayish yellow. Forewing brown, distal 1/5 ochreous brown; below costal margin set three pale ochreous yellow shades in basal half; broad grayish brown band extending from costal 1/2 slightly obliquely outward to above distal end of fold, ending in a silvery white spot, edged with narrow ochreous brown band along its inner and outer margins, with a rounded black dot placed at end of inner band above fold, its inner side with a few silvery white scales; inverted trapezoidal pale ochreous yellow patch located between outer band and costal 4/5, its posterior margin reaching beyond end of fold; narrow ochreous brown band extending from costal 3/4 obliquely inward to beyond end of fold, edged with scattered silvery white scales along outer side; dorsum with an ill-defined yellowish white patch at base, with a subovate patch located between basal 1/3 and before middle consisting of tufts of erect shining gray scales, surrounded by six not well separated black spots, margined with white scales along inner and anterior margins; cilia pale brown. Hindwing grayish brown, cilia pale brown. Legs pale yellow: foreleg ringed with black scales at apices of tibia and second tarsomere; mid tibia dorsally with yellowish white hairs, with white bristles at apex, tarsus ringed with blackish brown bristles at apex of second tarsomere; hind tibia dorsally with yellowish brown deepening to brown bristles, tarsus dorsally with grayish brown deepening to brown bristles on basal two tarsomeres, ringed with brown bristles at apices of basal two tarsomeres, distal two tarsomeres snowy white, black at apex. Abdomen dorsally ochreous brown; ventrally pale grayish white.

**Female genitalia** (Fig. 20). Intersegmental membrane between papilla analis and eighth abdominal segment about 3.5 times length of papilla analis. Apophysis posterior 1.5 times length of apophysis anterior. Eighth segment straight on both anterior and posterior margins, with long hairs on posterior margin. Lamella antevaginalis consisting of a pair of posteriorly joined kidney-shaped sclerites. Antrum indistinct. Ductus bursae approximately 1.3 times length of corpus bursae, narrow in posterior 1/4, slightly broadened anteriorly. Corpus bursae ovate, with dense granules entirely, with a protrudence carrying dense granules at junction with ductus bursae; signum absent. Appendix bursae arising from junction between corpus bursae and ductus bursae, long, tube shaped, longer than five times length of corpus bursae, slightly dilated near transition with ductus seminalis.

**Male.** Unknown.

**Distribution.** China (Yunnan).

**Etymology.** The specific name is derived from the type locality.

### *Hieromantis phaeodora* Meyrick, 1929

Figs 10, 15, 21

*Hieromantis phaeodora* Meyrick, 1929: 541. Type locality: Andaman Islands.

**Material examined. CHINA: Fujian Province:** 1♀, Hexi Town, Nanjing County, Zhangzhou City, 295 m, 29.v.2011, leg. Jin Zhang; **Hainan Province:** 2♀, Jianfengling, 940 m, 5.vi.2007, leg. Zhiwei Zhang & Weichun Li; 1♂, 1♀, Tianchi, Jianfengling, 1050 m, 29–30.iv.2013, leg. Yinghui Sun, Wei Guan & Tengteng Liu; 1♂, Jianfengling, 1050 m, 27.iv.2014, leg. Tengteng Liu, Wei Guan & Xuemei Hu; 1♂, Jianfengling, 770 m, 14.vii.2014, leg. Peixin Cong, Linjie Liu & Sha Hu; 2♂, 1♀, Mt. Limu, 700 m, 13.iv.2008, leg. Bingbing Hu & Haiyan Bai; 17♂, 17♀, Mt. Limu, 640 m, 1.v.2014, leg. Tengteng Liu, Wei Guan & Xuemei Hu; 1♂, Nanxi Protection Station, Mt. Diaoluo, 250 m, 22.iv.2008, leg. Bingbing Hu & Haiyan Bai; 4♂, 2♀, Mt. Diaoluo, 980 m, 23–24.iv.2014, leg. Tengteng Liu, Wei Guan & Xuemei Hu; 2♂, Hongxin Village, Yuanmen Town, Baisha County, 430 m, 15–18.iv.2014, leg.

Tengteng Liu, Wei Guan & Xuemei Hu; 1♂, Shuiman Town, Wuzhishan City, 620 m, 19.iv.2014, leg. Tengteng Liu, Wei Guan & Xuemei Hu; 2♂, 6♀, Mt. Wuzhi, 710 m, 21.iv.2014, leg. Tengteng Liu, Wei Guan & Xuemei Hu; 1♀, Mt. Wuzhi, 742 m, 20.v.2015, leg. Peixin Cong, Wei Guan & Sha Hu.

**Diagnosis.** Adult (Fig. 10) with wingspan 14.0–15.0 mm. This species is characterized by the forewing having two separated dorsal spots that consist of tufts of erect purple gray scales; and the appendix bursae arising from the anterior 1/5 of the corpus bursae in the female genitalia. It is similar to *H. sheni* Li & Wang, 2002 by the obliquely upward-oriented triangular cucullus, but *H. phaeodora* can be distinguished from the latter by the foliaceous anellus lobes, the aedeagus about 1.8 times length of the valva and the cornutus about 3/5 length of the aedeagus in the male genitalia (Fig. 15); the corpus bursae having two parallel rows of teeth in the female genitalia (Fig. 21). In *H. sheni*, the anellus lobes are long clubbed, the aedeagus is almost as long as the valva, and the cornutus is about 1/3 length of the aedeagus; and the corpus bursae lacks two rows of teeth.

**Distribution.** China (Fujian, Hainan), the Andaman Islands.

**Notes.** This species is recorded for the first time in China.

### *Hieromantis kurokoi* Yasuda, 1988

Figs 11, 16, 22

*Hieromantis kurokoi* Yasuda, 1988: 494. Type locality: Japan.
*Hieromantis nordella* Sinev, 1988: 109.

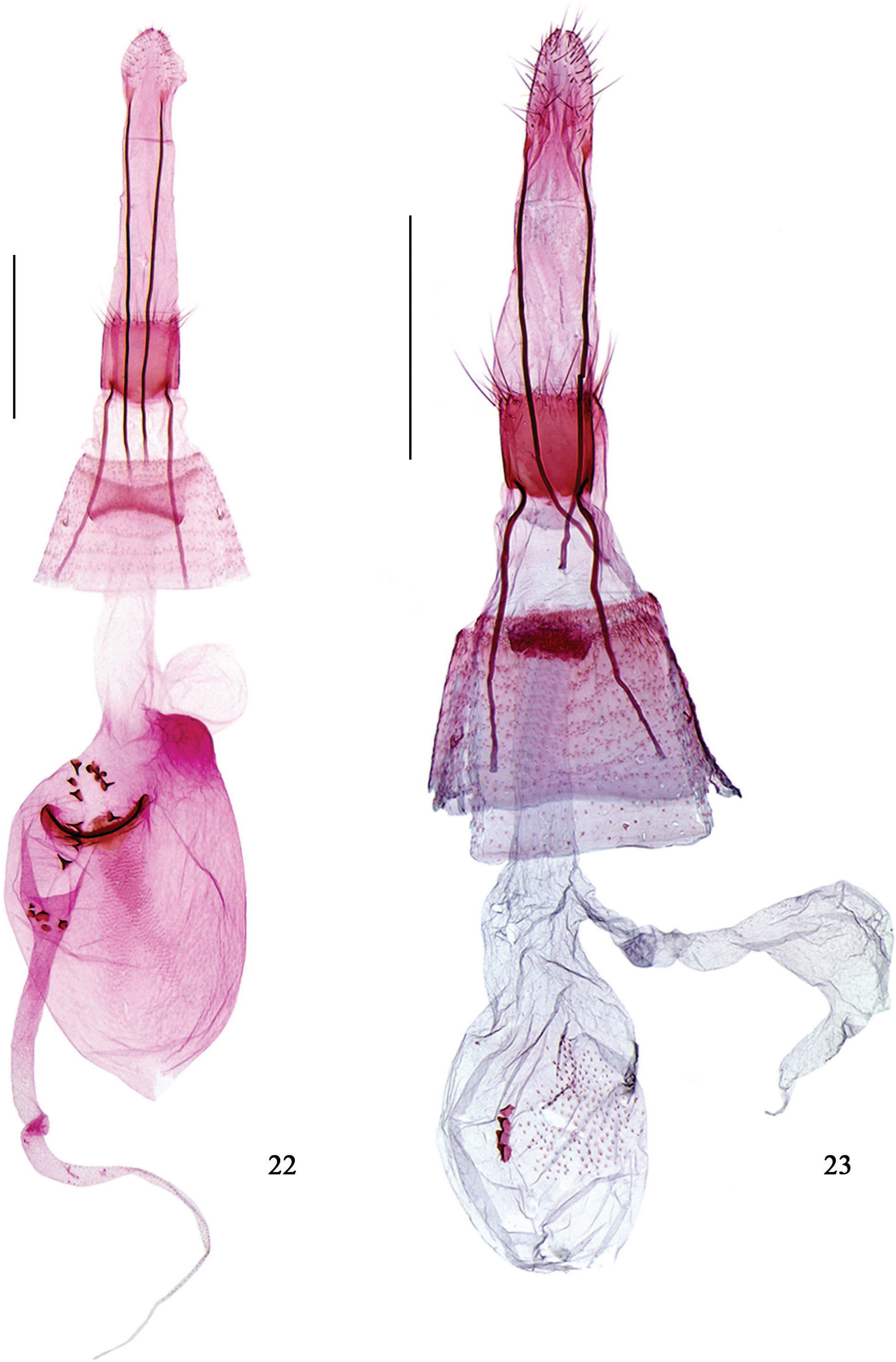
**Material examined. CHINA: Tianjin:** 1♂, Heishuihe, Mt. Baxian, Ji County, 550 m, 10.vi.2009, leg. Bingbing Hu; 1♀, Heishuihe, Mt. Baxian, Ji County, 600 m, 29.viii.2010, leg. Yinghui Mou & Shurong Liu; 1♀, Xiaogang, Ji County, 29.vi.2013, leg. Tengteng Liu; **Hebei Province:** 1♀, Laoniuyu Village, Jingxing County, Shijiazhuang City, 26.vii.2000, leg. Haili Yu; 1♂, Suanzaoping Village, Neiqiu County, Xingtai City, 670 m, 29.vii.2000, leg. Haili Yu; 1♀, Mt. Wuling, Xinglong County, 800 m, 27.vii.2011, leg. Houhun Li & Yanpeng Cai; **Shanxi Province:** 1♀, Dahe Forest Farm, 1340 m, 15.vii.2012, leg. Qiang Gao & Na Chen; 1♀, Dashuang Village, Magedang Town, Lingchuan County, 773 m, 21.vii.2012, leg. Wei Guan & Xiuchun Wang; 1♂, Zhangma Village, Mt. Li Nature Reserves, Qinshui County, Jincheng City (collected using sweep net in the day), 20.vii.2013, leg. Mingjing Li; 1♀, Dahe Forest Farm, Yicheng County, Linfen City, 1202 m, 24.vii.2013, leg. Shulian Hao & Mingjing Li; 1♀, Sijiao Forest Farm, Taikuanhe Nature Reserves, Linfen City, 893 m, 6.viii.2013, leg. Shulian Hao & Yunfei Peng; 1♂, 2♀, Taikuanhe Nature Reserves, Linfen City, 1020 m, 7.viii.2013, leg. Shulian Hao & Yunfei Peng; 3♀, Taikuanhe Nature Reserves, Linfen City, 1020 m, 8.viii.2013, leg. Shulian Hao & Mingjing Li; 1♂, 3♀, Mt. Tianlong, Taiyuan City, 1280 m, 14–15.vii.2013, leg. Tengteng Liu & Peixin Cong; **Zhejiang Province:** 1♂, 1♀, Chanyuan Temple, Mt. Tianmu, 350 m, 15.v.1999, leg. Houhun Li; 1♀, Tianmu Village, Mt. Tianmu, 335 m, 1.vii.2014, leg. Aihui Yin, Xuemei

Hu & Qingyun Wang; 1♀, Laoan, Mt. Tianmu, 555 m, 3.vii.2014, leg. Aihui Yin, Xuemei Hu & Qingyun Wang; 1♀, Xiguan, Mt. Tianmu, 566 m, 19.vii.2014, leg. Aihui Yin, Xuemei Hu & Qingyun Wang; 1♀, Neijiuxian Village, Mt. Jiulong, 430 m, 7.vii.2013, leg. Aihui Yin & Xiuchun Wang; 2♀, Yulingguan, Qingliang Peak, 220 m, 23.vii.2014, leg. Aihui Yin, Xuemei Hu & Qingyun Wang; 2♀, Jiufu Village, Mt. Longtang, 520 m, 26.vii.2014, leg. Aihui Yin, Xuemei Hu & Qingyun Wang; 4♀, Jiufu Village, Mt. Longtang, 520 m, 27–31.viii.2014, leg. Aihui Yin, Qingyun Wang & Suran Li; 1♀, Longxushan Village, Mt. Longxu, 778 m, 22.viii.2014, leg. Aihui Yin, Qingyun Wang & Suran Li; 1♂, Pinggang, Mt. Longxu, 754 m, 23.viii.2014, leg. Aihui Yin, Qingyun Wang & Suran Li; **Anhui Province:** 2♂, 1♀, Tangkou Town, Huangshan City, 5.viii.2004, leg. Jiasheng Xu & Jialiang Zhang; 2♂, 4♀, Tanqiao Town, Huangshan City, 6–7.viii.2004, leg. Jiasheng Xu & Jialiang Zhang; 4♀, Mozitan Town, Huoshan County, 12.viii.2004, leg. Jiasheng Xu & Jialiang Zhang; **Fujian Province:** 2♀, San'gang, Mt. Wuyi, 740 m, 24.v.2004, leg. Haili Yu; **Jiangxi Province:** 1♀, Mt. Jinpen, 18.vii.2006, leg. Jiasheng Xu & Weichun Li; **Henan Province:** 1♂, 1♀, Lingshan Temple, Luoshan County, Xinyang City, 350 m, 23.v.1999, leg. Haili Yu; 2♀, Mt. Song, Dengfeng City, 800 m, 9.vi.2000, leg. Haili Yu; 1♀, Mt. Baotianman, Neixiang County, 1200 m, 13.viii.2006, leg. Hui Zhen & Denghui Kuang; 1♂, Zhuyu Peak, Mt. Yuntai, Jiaozuo City, 1297 m, 11.viii.2014, leg. Peixin Cong, Sha Hu & Linjie Liu; 1♀, Xiuwu Forest Farm, Mt. Yuntai, Jiaozuo City, 1028 m, 14.viii.2014, leg. Peixin Cong, Sha Hu & Linjie Liu; **Hubei Province:** 2♀, Maoba Region, Lichuan City, 700 m, 30.vii.1999, leg. Hounhun Li *et al.*; 1♀, Qingtaiguan Forest Farm, Luotian County, 570 m, 3.vii.2014, leg. Wei Guan & Meiqing Yang; **Hunan Province:** 1♂, 1♀, Cangxi Town, Jinhua County, 8–9.viii.2004, leg. Yunli Xiao; **Guangxi Zhuang Autonomous Region:** 1♀, Qinmu Village, Yongfu County, 160 m, 1.v.2008, leg. Hui Zhen & Li Zhang; 2♀, Qingshan Forest Farm, Pingxiang City, 300 m, 21.vii.2011, leg. Bingbing Hu *et al.*; 1♂, Zhoutong Village, Nanping Town, Yizhou City, 450 m, 17.viii.2011, leg. Shulian Hao & Yinghui Sun; 2♂, 6♀, Shaoping Forest Farm, Pingxiang City, 280 m, 28.iii.2012–19.iv.2012, leg. Xiaofei Yang; 1♀, Nonggang Protection Station, Longzhou County, 25.vii.2013, leg. Xiaofei Yang; 2♀, Miaotou Town, Quanzhou County, Guilin City, 100 m, 26.vii.2013, leg. Xiaofei Yang; **Hainan Province:** 1♀, Mt. Limu, Qiongzhou County, 640 m, 2.v.2014, leg. Tengteng Liu, Wei Guan & Xuemei Hu; **Chongqing:** 1♀, Mt. Jinfo, 1100 m, 6.vi.2013, leg. Xiaofei Yang; **Shaanxi Province:** 1♀, Shuangshipu Town, Feng County, 1050 m, 23.viii.1987, leg. Houhun Li; **Gansu Province:** 1♀, Bifenggou, Wen County, 860 m, 9.vii.2005, leg. Haili Yu.

**Diagnosis.** Adult (Fig. 11) with wingspan 6.0–11.0 mm. This species is similar to *H. ephodophora* Meyrick, 1897 by having similar forewing markings, but *H. kurokoi* can be separated by the valva having a rounded cucullus in the male genitalia (Fig. 16); and the appendix bursae about the same length as the corpus bursae in the female genitalia (Fig. 22). In *H. ephodophora*, the cucullus is subtriangular, and the appendix bursae is about four times length of the corpus bursae (Kasy 1973: Figs. 97-98).

**Distribution.** China (Anhui, Chongqing, Fujian, Gansu, Guangxi, Hainan, Hebei, Henan, Hubei, Hunan, Jiangxi, Shaanxi, Shanxi, Tianjin, Zhejiang), Japan, Russia.

**Host plant.** *Cuscuta japonica* Choisy (Convolvulaceae).



**Figures 22–23.** Female genitalia of *Hieromantis* species. **22** *H. kurokoi* Yasuda, slide No. GW13141 **23** *H. sheni* Li & Wang, slide No. GW14030. Scale bars: 0.5 mm.

### ***Hieromantis sheni*** **Li & Wang, 2002**

Figs 12, 17, 23

*Hieromantis sheni* Li & Wang, 2002: 503. Type locality: China (Henan).

**Type material. CHINA: Holotype** ♂, Huangshian Village, Xixia County, Henan Province, 890 m, 17.vii.1998, leg. Houhun Li. **Paratypes: Henan Province**: 2♀, Mt. Jigong, Xinyang City, 700 m, 9.v.1997, leg. Houhun Li; 12♂, 5♀, Mt. Song, Dengfeng City, 800 m, 9.vi.2000, leg. Haili Yu; **Hebei Province:** 2♂, 3♀, Mt. Xiantai, Jingxing County, 1200 m, 23–24.vi.2000, leg. Haili Yu; **Jiangxi Province:** 1♀, Yushan County, 19.vi.1985, leg. Guangpu Shen.

**Additional material. CHINA: Tianjin:** 1♀, Heishuihe, Mt. Baxian, Ji County, 550 m, 11.viii.2009, leg. Jing Zhang *et al.*; 3♂, 2♀, Heishuihe, Mt. Baxian, Ji County, 550 m, 2–14.viii.2010, leg. Yinghui Mou & Shurong Liu; **Hebei Province:** 1♂, Mt. Xiantai, Jingxing County, 1200 m, 24.vii.2000, leg. Haili Yu; **Shanxi Province:** 1♀, Dahe Forest Farm, 1340 m, 12.vii.2012, leg. Qiang Gao & Na Chen; 1♂, 1♀, Dashuang Village, Magedang Town, Lingchuan County, 773 m, 22.vii.2012, leg. Wei Guan & Xiuchun Wang; **Zhejiang Province:** 1♀, Mt. Fengyang, Longquan County, Lishui City, 1470 m, 31.vii.2007, leg. Qing Jin; 3♀, Sanmuping, Mt. Tianmu, 789 m, 15.vii.2014, leg. Aihui Yin, Xuemei Hu & Qingyun Wang; **Henan Province:** 2♀, Mt. Baiyun, Luoyang City, 1560 m, 21.vii.2001, leg. Dandan Zhang; 7♂, 13♀, Shaolin Temple, Mt. Song, Dengfeng City, 700 m, 15–17.vii.2002, leg. Xinpu Wang; 8♂, 5♀, Mt. Baiyun, Song County, 1580 m, 18–23.vii.2002, leg. Xinpu Wang; 1♀, Zhuyu Peak, Mt. Yuntai, Jiaozuo City, 1297 m, 5.viii.2014, leg. Peixin Cong, Sha Hu & Linjie Liu; **Hubei Province:** 1♀, Songbai Town, Shennongjia Forest, 1400 m, 17.vii.2003, leg. Shulian Hao; **Chongqing:** 2♀, Laosimianshan Village, Mt. Simian, 14.vii.2012, leg. Yinghui Sun & Aihui Yin; 2♀, Laosimianshan Village, Mt. Simian, 1280 m, 10.viii.2012, leg. Xiaofei Yang & Tengteng Liu; **Yunnan Province:** 1♀, Taiyanghe Nature Reserves, 1450 m, 30.vii.2014, leg. Zhenguo Zhang; **Shaanxi Province:** 7♂, 3♀, Haoping Temple, Mt. Taibai, 13–16.vii.2005, leg. Ping You.

**Diagnosis.** Adult (Fig. 12) with wingspan 7.0–10.5 mm. This species is similar to *H. makiosana* Yasuda, 1988 by having an obliquely upward-oriented triangular cucullus, but can be separated by having a leaden gray thorax and the distal 1/4 of the forewing dark brown; and the uncus truncate apically in the male genitalia (Fig. 17); the presence of a signum and the appendix bursae about the same length as the corpus bursae in the female genitalia (Fig. 23). In *H. makiosana*, the thorax is white, and the forewing is ochreous yellow in the distal 1/5; the uncus is pointed at apex; the corpus bursae lacks a signum, and the appendix bursae is longer than four times length of the corpus bursae. This species is also similar to *H. phaeodora* Meyrick, 1929, and the differences between them are stated under the latter species.

**Distribution.** China (Chongqing, Hebei, Henan, Hubei, Jiangxi, Shaanxi, Shanxi, Tianjin, Yunnan, Zhejiang).

## Acknowledgements

We express our cordial thanks to Dr. Roger Kendrick (Hong Kong) for the convenience and assistance given to the corresponding author during the entomological expedition in Hong Kong, and to those who participated in the field work when they were studying in the Lepidoptera Laboratory, Nankai University, Tianjin. We also thank Dr. Sergey Sinev (St. Petersburg) and an anonymous reviewer for their useful comments. This study was supported by the National Natural Science Foundation of China (No. 31272356) and the Research Fund for the Doctoral Program of Higher Education of China (No. 20130031110008).

## References

Bradley JD (1957) Microlepidoptera from Rennell and Bellona Islands. In: Bradley JD (Ed.) The Natural History of Rennell Island, British Solomon Islands 2: 87–112, pls. 1–12.

Kasy F (1973) Beitrag zur Kenntnis der Famillie Stathmopodidae Meyrick, 1913 (Lepidoptera, Gelechioidea). Tijdschrift voor Entomologie 116(13): 227–299.

Koster JC, Sinev SYu (2003) Family Stathmopodidae. In: Huemer P, Karsholt O, Lyneborg L (Eds) Microlepidoptera of Europe. Vol. 5. Apollo Books, Stenstrup, 59–67.

Li HH (2002) The Gelechiidae of China (I) (Lepidoptera: Gelechioidea). Nankai University Press, Tianjin, 504 pp.

Li HH, Wang SX (2002) First record of the genus *Hieromantis* Meyrick from China, with a description of one new species (Lepidoptera: Oecophoridae, Stathmopodinae). Acta Entomologica Sinica 45(4): 503–506.

Meyrick E (1897) Description of Australian Micro-Lepidoptera. XVII. Elachistidae. Proceedings of the Linnean Society of New South Wales 22: 297–435.

Meyrick E (1907) Description of Indian Microlepidoptera, II. Journal of Bombay Natural History Society 17: 403–417.

Meyrick E (1913) Exotic Microlepidoptera 1: 65–160.

Meyrick E (1922) Exotic Microlepidoptera 2: 481–608.

Meyrick E (1924) Exotic Microlepidoptera 3: 65–128.

Meyrick E (1927) Microlepidoptera. Insects of Samoa, British Museum (Natural History), London 3: 65–116.

Meyrick E (1929) Exotic Microlepidoptera 3: 481–541.

Meyrick E (1933) Exotic Microlepidoptera 4: 353–448.

Murase M (2002) *Hieromantis kurokoi* Yasuda (Stathmopodidae) and two geometrines, reared on *Cuscuta japonica*. Japan Heterocerists' Journal 220: 383.

Wang SX (2006) Oecophoridae of China (Insecta: Lepidoptera). Science Press, Beijing, 258 pp.

Yasuda K (1988) Two new species of the Genus Hieromantis (Lepidoptera, Stathmopodidae) from Japan. Kontyû, Tokyo 56(3): 491–497.

ZooKeys 534: 103–134 (2015)
doi: 10.3897/zookeys.534.6169
http://zookeys.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

# Description of a new genus and three new species of Otothyrinae (Siluriformes, Loricariidae)

Fábio F. Roxo[1], Gabriel S. C. Silva[1], Luz E. Ochoa[1], Claudio Oliveira[1]

[1] *Universidade Estadual Paulista, Departamento de Morfologia, Laboratório de Biologia e Genética de Peixes, Rubião Júnior s/n, 18618–970 Botucatu, São Paulo State, Brazil*

Corresponding author: *Fábio F. Roxo* (roxoff@hotmail.com.br)

Academic editor: *N. Bogutskaya* | Received 8 August 2015 | Accepted 16 October 2015 | Published 11 November 2015

*http://zoobank.org/208117D1-BCAC-4EA8-8421-14DA5C561701*

**Citation:** Roxo FF, Silva GSC, Ochoa LA, Oliveira C (2015) Description of a new genus and three new species of Otothyrinae (Siluriformes, Loricariidae). ZooKeys 534: 103–134. doi: 10.3897/zookeys.534.6169

## Abstract

The genus *Hisonotus* was resurrected as a member of the tribe Otothyrini (actually subfamily Otothyrinae). However, phylogenetic studies based on morphological and molecular data showed that *Hisonotus* is not monophyletic and independent lineages can be identified, such as the group composed of the species *H. insperatus*, *H. luteofrenatus*, *H. oliveirai*, *H. paresi* and *H. piracanjuba*, a lineage unrelated to that containing the type species of the genus *Hisonotus* (*H. notatus*). Herein, based in molecular and morphological data, a new genus is described to accommodate the lineage mentioned above, into which are also added three new species. This new genus can be distinguished from other genera of Otothyrinae by the following combination of characters: (1) a pair of rostral plates at the tip of the snout; (2) two large pre-nasal plates just posterior to the rostral plates; (3) a supra-opercular plate that receives the laterosensory canal from the compound pterotic before the preopercle; (4) a well developed membrane at anal opening in females; and (5) a V-shaped spinelet. A key to species of *Curculionichthys* is provided.

## Keywords

Cascudinhos, freshwater fishes, systematic, *Hisonotus*, taxonomy

## Introduction

The subfamily Otothyrinae (*sensu* Chiachio et al. 2008 and Roxo et al. 2014a) is one of the most diverse members of Loricariidae, distributed through almost all South America, in hydrographic systems from the Amazon to northern Argentina. Within this subfamily, the genus *Hisonotus* Eigenmann & Eigenmann, 1889 is composed of 35 species (Eschmeyer 2015) in drainages of southern and southeastern Brazil, from the Rio Uruguay basin, upper Rio Paraná, Laguna dos Patos and Coastal drainages extending from Rio Grande do Sul State to Rio de Janeiro State and the Amazon basin. This genus was resurrected by Schaefer (1998a) with the combination of the following characters: reduced or absent snout plates in the anterior portion of the nostril, rostrum with enlarged odontodes, and thickened plates forming the lateral rostral margin. However, Britski and Garavello (2007) argued that the characters used by Schaefer (1998a) for the definition of *Hisonotus*, as well as other genera of the Otothyrinae, needed to be redefined. For example, Britski and Garavello (2007) observed that a rostrum with enlarged odontodes is present in several genera and species of Otothyrinae, as well as in *Parotocinclus* Eigenmann & Eigenmann, 1889. Furthermore, Britski and Garavello (2007) suggested that the other two characters were also unsatisfactory to define *Hisonotus*.

Several molecular (e.g. Chiachio et al. 2008; Cramer et al. 2011; Roxo et al. 2014a) and morphological (e.g. Martins et al. 2014) studies suggested that *Hisonotus* was polyphyletic, with *H. insperatus* Britski & Garavello, 2003, *H. luteofrenatus* Britski & Garavello, 2007, *H. oliveirai* Roxo, Zawadzki & Troy, 2014b, *H. paresi* Roxo, Zawadzki & Troy, 2014b and *H. piracanjuba* Martins & Langeani, 2012 belonging to a lineage unrelated to the one that includes the type species, *H. notatus* Eigenmann & Eigenmann, 1889. In this way, the elucidation of the relationships of the members of the *Hisonotus* is important to understand the evolution of Otothyrinae as a whole, considering that this genus represents about 35% of the diversity of this subfamily. Herein, a new genus is proposed to accommodate the above-cited species of *Hisonotus* and three additional new species are described in this new genus.

## Material and methods

Measurements and counts were taken from the left side of the fish, and were made from point to point to the nearest 0.01 mm with a digital caliper. Body plate and osteology nomenclature follows Schaefer (1997) and measurements follow Carvalho and Reis (2009), except for body depth at dorsal fin origin. Abbreviations used in the text followed Carvalho and Reis (2009). Morphometrics are given as percentages of standard length (SL), except for subunits of the head region that are expressed as percentages of head length (HL). Specimens were cleared and double stained (c&s) according to the method of Taylor and Van Dyke (1985). Vertebral counts also include the five vertebrae that comprise the Weberian apparatus and the compound caudal centrum

(PU1 + U1) as one element. Dorsal fin ray counts include the spinelet as the first unbranched ray. Institutional acronyms follow Fricke and Eschmeyer (2015). Specimens are deposited at the LBP, Laboratório de Biologia e Genética de Peixes, Universidade Estadual Paulista, Botucatu; MZUSP, Museu de Zoologia, Universidade de São Paulo, São Paulo; NUP, Coleção Ictiológica do Nupelia, Universidade Estadual de Maringá, Maringá. Zoological nomenclature follows the International Code of Zoological Nomenclature (International Commission on Zoological Nomenclature 1999).

## Results

### Description of the new genus *Curculionichthys*

#### *Curculionichthys* gen. n.

http://zoobank.org/B074B13E-26CB-41FB-B319-FBF81A58F6DC

**Type species.** *Curculionichthys insperatus* (Britski & Garavello, 2003), new combination.

**Diagnosis.** The new genus can be distinguished from all other Otothyrinae species by the following combination of characters: (1) a pair of rostral plates at the tip of the snout; (2) the presence of two large pre-nasal plates just posterior to the rostral plates; (3) a supra-opercular plate that receives the laterosensory canal from the compound pterotic before the preopercle; (4) a well developed membrane at anal opening in females; and (5) the presence of a V-shaped spinelet.

**Etymology.** *Curculionichthys*, from the Latin “curculionem” (elongated snout) and from the Greek “ichthys” (fishes) related to the relatively elongated snouts of the fish species included in this genus.

**Discussion of the new genus.** Schaefer (1998a) resurrected *Hisonotus* using characters that were considered ambiguous by Britski and Garavello (2007) and needed to be redefined. The hypothesis of monophyly of *Hisonotus* was rejected by Roxo et al. (2014a) and Martins et al. (2014). Roxo et al. (2014a) found *H. acuen* (*Hisonotus* sp. 3, Fig. 3 in Roxo et al. 2014a) closely related to *H. chromodontus*, *Parotocinclus* sp. 3 and *P. aripuanensis*. The species *H. vespuccii* (*Hisonotus* sp. 1, Fig. 3 in Roxo et al. 2014a) appeared closely related to *Parotocinclus* aff. *spilurus* and a new species of Otothyrinae (*Hisonotus* sp. 2 from municipality of Jaíba, Minas Gerais State in Rio São Francisco basin). The species *H. bocaiuva* appeared closely related to species of *Parotocinclus* from Rio São Francisco (i.e. *P. prata* and *P. robustus*, Fig. 4 in Roxo et al. 2014a), *P. bahiensis* and two new taxa (New taxon 1 and New taxon 2).

On the other hand, the species *Curculionichthys insperatus*, *C. luteofrenatus*, *C. oliveirai*, *C. paresi* and *C. piracanjuba* form a monophyletic group that is unrelated with the type species *H. notatus*, but instead with species of *Corumbataia* in Roxo et al. (2014a – using molecular data) and with *Hypoptopoma inexspectatum*, *Niobichthys ferrarisi*, *Otocinclus affinis*, *Oxyropsis acutirostra* and *Acestridium martini* in Martins et al. (2014 - using morphological data) (see Fig. 1 in the present paper for illustration of the

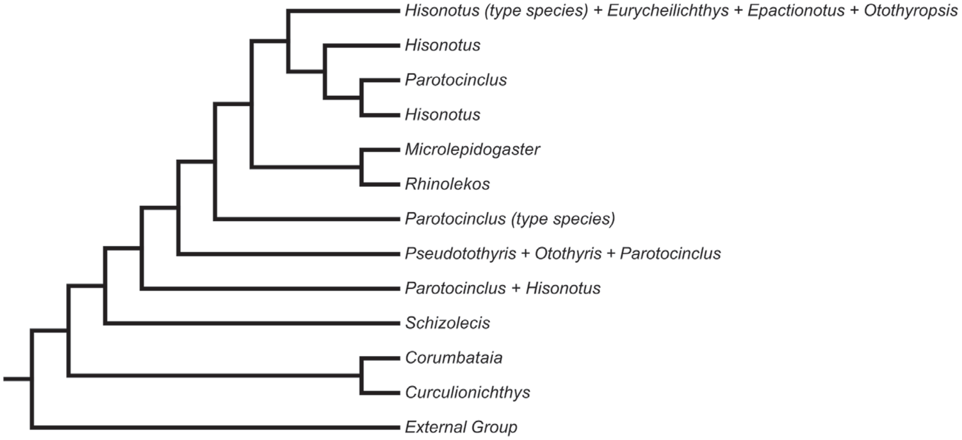


**Figure 1.** Dendrogram showing the phylogenetic relationship among Otothyrinae genera from the work of Roxo et al. (2014a). This figure shows the position of *Curculionichthys* close related with the genus *Corumbataia* and not related with the type species of the genus *Hisonotus* (i.e. *H. notatus*).

phylogenetic position of *Curculionichthys* with the subfamily Otothyrinae according to Roxo et al. 2014a). In the present study, based in the information published in Roxo et al. (2014a) and in new morphological analyses, we propose the new genus, *Curculionichthys*, for re-allocation of five species described within *Hisonotus*: *C. insperatus*, *C. luteofrenatus*, *C. oliveirai*, *C. paresi* and *C. piracanjuba* (see Table 2) and include three new species: *C. sabaji*, *C. coxipone*, and *C. sagarana*. Four putative additional species are recognized in the analyzed material, but these species cannot be described yet due to the lack of sufficient specimens.

The new genus *Curculionichthys* is defined by the following combination of characters: (1) a pair of rostral plates at the tip of the snout; (2) the presence of two large pre-nasal plates just posterior to the rostral plates; (3) a supra-opercular plate that receives the laterosensory canal from the compound pterotic before the preopercle; (4) a well developed sexual dimorphic membrane at anal opening in females; and (5) the presence of a V-shaped spinelet. The tip of the snout that is composed of a pair of rostral plates (Fig. 2) was first reported in species of *Hisonotus* by Britski and Garavello (2003) in the description of *H. insperatus* (*C. insperatus*), the type species of the new genus *Curculionichthys*. This character state according to Martins and Langeani (2012) is shared with *Corumbataia cuestae* Britski, 1997, species of *Microlepidogaster* Eigenmann & Eigenmann, 1889 (except *M. longicolla* Calegari & Reis, 2010), *Otothyris* Myers, 1927, and in all genera of Hypoptopomatinae (except in *Hypoptopoma* Gunther, 1868). We also observed that *Rhinolekos capetinga*, a species recently described from the Rio Tocantins basin, also have a pair of rostral plates. However, the morphology of this character in the species of *Curculionichthys* is different, as described by Martins and Langeani (2012), since the rostral plates are very large, the length of each plate is greater than their width and are more conspicuous when compared with

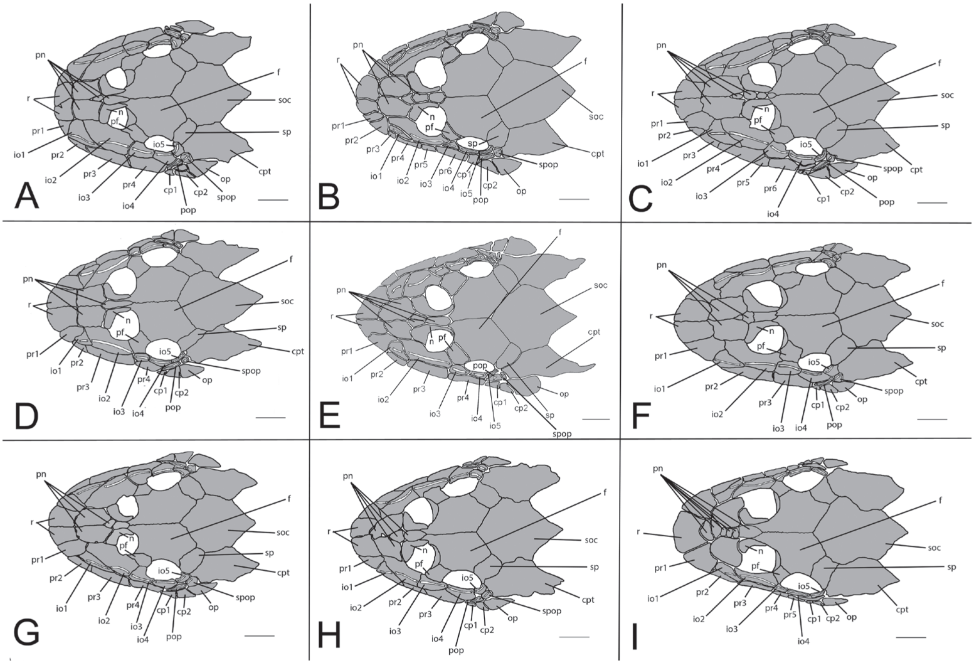


**Figure 2.** Cranial bones plates of the head in dorsal view of *Curculionichthys* species and the type species of the genus *Hisonotus*. **A** *C. coxipone* **B** *C. insperatus* **C** *C. luteofrenatus* **D** *C. oliveirai* **E** *C. paresi* **F** *C. piracanjuba* **G** *C. sabaji* **H** *C. sagarana* **I** *H. notatus*. Scale bar: 1 mm.

all species listed previously in which the pair of rostral plates is smaller and have a quadrangular form.

The second character used to diagnose the new genus is the presence of two large pre-nasal plates just posterior to the rostral plates (Fig. 2). The pre-nasal plates present some variation in members of Otothyrinae, with respect to their numbers and shapes. In most species of Otothyrinae the pre-nasal plates are small or very tiny, however in species of *Curculionichthys* we found two very large pre-nasal plates just posterior to the rostral plates. However, even in species of *Curculionichthys* we can find variation in pre-nasal plates contacting the frontal and the nasal plates, but the two large pre-nasal plates just posterior to the rostral plate apparently is a synapomorphic character exclusive to *Curculionichthys*.

The presence of a supra-opercular plate that receives the laterosensory canal from the compound pterotic before the preopercle is the third character used to diagnose the new genus. According to Martins and Langeani (2012) this character is present in a large number of species of Loricariidae, but absent in the Hypoptopomatinae and Otothyrinae, except in the new genus *Curculionichthys*. The fourth character is the presence of a well developed membrane at anal opening in females. Both sex of *Curculionichthys* species have a membrane on the anal opening, however, it is more developed in females than in males, covering almost the entire urogenital opening. This character was first reported by Roxo et al. (2014b) in the description of *C. oliveirai* and *C. paresi* and it is absent in all other species of Otothyrinae, in which the membrane at anal opening is poorly developed (see Fig. 4 in Roxo et al. 2014b for illustration about this character states).

The fifth character used to diagnose *Curculionichthys* was the presence of a V-shaped spinelet in the dorsal fin. This character was first reported by Carvalho and Datovo (2012) in the description of *H. bockmanni* in personal communication with Roberto E. Reis. This character is not exclusive to *Curculionichthys* and it is shared with *H. acuen*, *H. chromodontus*, *H. vespuccii* and two new species of *Parotocinclus*, one from Xingu basin (LBP 15894) and the other one from Barra do Garça (LBP 12274). Furthermore, the V-shaped spinelet is shared with vast majority of Hypostominae species (Silva et al. 2014). However, within Otothyrinae it is good character that distinguishes the new genus.

In the description of *C. oliveirai* and *C. paresi*, Roxo et al. (2014b) found variation in head plate shape and number in the last two species and in *C. insperatus*, even though osteological characters are generally conserved within Otothyrinae and Hypoptopomatinae (Schaefer 1987, 1997, 1998b; Garavello 1977; Mo 1991; de Pinna 1998; Diogo et al. 2001; Ribeiro et al. 2005). Roxo et al. (2014b) analyzed 18 specimens of *C. insperatus* from type localities in Rio Capivara and Rio Araquá, from Botucatu, São Paulo State, three individuals presented a single rostral plate, instead of a pair of rostral plates (see Fig. 8 in Roxo et al. 2014b for variation of all characters). In *C. oliveirai* and *C. insperatus* the authors found bilateral asymmetry in the first infraorbital and the first and second posterior rostral plates and in an extra plate is found between preopercle and compound pterotic (known in the present study as our third character: a supra-opercular plate that receives the laterosensory canal from the compound pterotic before the preopercle). Despite the variation observed among specimens of *Curculionichthys*, those characters appear to be conserved enough to be used as synapomorphies and delimit this new genus of all remaining Otothyrinae.

## Description of three new species

### *Curculionichthys sabaji* sp. n.

http://zoobank.org/48C22C5D-2C7E-4ED5-AD1C-C3DF6568F322
Figure 3; Table 1

**Holotype.** MZUSP 117379, female, 23.3 mm SL, Pará State, municipality of Altamira, Rio 13 de Maio, tributary of Rio Curuá, Rio Iriri drainage, 08°43'41"S, 55°01'38"W, 22 October 2007, coll. Birindelli JLO, Netto-Ferreira AL, Sabaj-Perez MH, Lujan NK.

**Paratypes.** All from Brazil, Rio Xingu basin. LBP 19763 (1, female, 23.4 mm SL), Pará State, municipality of Altamira, Rio Curuá, Rio Iriri drainage, 08°19'07"S, 55°05'23"W, 22 October 2007, coll. Birindelli JLO, Netto-Ferreira AL, Sabaj-Perez MH, Lujan NK.

**Figure 3.** *Curculionichthys sabaji*, MZUSP 117379, holotype, female, 23.3 mm SL, from Pará State, municipality of Altamira, Rio 13 de Maio, Rio Xingu basin, 08°43'41"S 55°01'38"W.

MZUSP 95711 (5, 16.3–20.0 mm SL, 2 c&s, sex not determined, 18.7–19.9 mm SL), Mato Grosso State, municipality of Gaúcha do Norte, Rio Coronel Vanick, 13°31'34"S, 52°43'52"W, 08 October 2007, coll. Lima FCT, Moreira CR, Ribeiro AC, Moraes L, Leite CMC. MZUSP 96959 (2, 19.1–20.7 mm SL), Pará State, municipality of Altamira, Rio 13 de Maio, tributary of Rio Curuá, Rio Iriri drainage, 08°38'53"S, 55°01'41"W, 22 October 2007, coll. Birindelli JLO, Netto-Ferreira AL, Sabaj-Perez MH, Lujan NK. MZUSP 97039 (5, 17.0–19.2 mm SL), Mato Grosso State, municipality of Campinápolis, Rio Couto de Magalhães, 13°48'02"S, 53°03'43"W, 10 October 2007, coll. Lima FCT, Moreira CR, Ribeiro AC, Moraes L, Leite CMC. MZUSP 97138 (1, 23.6 mm SL), collected with holotype. MZUSP 97198 (2, 20.0–22.3 mm SL), Pará State,

**Table 1.** Morphometrics and meristic data for *Curculionichthys* species. SD = Standard deviation.

| | ***Curculionichthys sabaji*, n = 17** | | | | | ***Curculionichthys coxipone*, n = 38** | | | | | ***Curculionichthys sagarana*, n = 10** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Holotype** | **Low** | **High** | **Mean** | **SD** | **Holotype** | **Low** | **High** | **Mean** | **SD** | **Holotype** | **Low** | **High** | **Mean** | **SD** |
| SL (mm) | 23.3 | 16.3 | 23.6 | 19.5 | 2.24 | 29.0 | 20.1 | 29.9 | 24.8 | 2.6 | 23.7 | 20.5 | 24.2 | 22.4 | 1.1 |
| **Percents of SL** | | | | | | | | | | | | | | | |
| Head length | 35.5 | 34.3 | 38.6 | 36.3 | 1.37 | 33.5 | 32.0 | 37.4 | 34.5 | 1.4 | 36.8 | 34.8 | 40.5 | 37.1 | 1.4 |
| Predorsal length | 47.4 | 41.1 | 47.7 | 44.5 | 1.87 | 44.2 | 42.6 | 51.6 | 45.6 | 1.9 | 46.9 | 40.1 | 49.3 | 46.5 | 2.6 |
| Dorsal fin spine length | 22.4 | 18.5 | 22.7 | 20.8 | 1.12 | 21.4 | 14.9 | 24.8 | 21.2 | 1.6 | 22.9 | 19.9 | 24.4 | 21.8 | 1.5 |
| Anal fin unbranched ray length | 17.9 | 13.5 | 20.1 | 16.6 | 1.86 | 22.5 | 18.0 | 22.5 | 20.4 | 1.0 | 18.8 | 16.6 | 20.5 | 18.5 | 1.2 |
| Pectoral fin spine length | 21.9 | 18.9 | 23.4 | 21.4 | 1.29 | 22.3 | 19.0 | 25.2 | 22.3 | 1.6 | 22.9 | 21.5 | 25.2 | 23.2 | 1.1 |
| Pelvic fin unbranched ray length | 18.6 | 15.1 | 19.2 | 17.3 | 1.13 | 20.9 | 17.4 | 25.4 | 21.3 | 1.9 | 19.1 | 16.2 | 23.5 | 19.9 | 2.3 |
| Cleithral width | 22.9 | 21.3 | 24.1 | 22.6 | 0.66 | 23.3 | 22.9 | 26.0 | 24.3 | 0.7 | 24.1 | 20.8 | 25.2 | 23.4 | 1.2 |
| Thoracic length | 17.4 | 12.3 | 22.7 | 15.1 | 2.90 | 16.5 | 14.6 | 23.9 | 16.6 | 1.4 | 19.2 | 14.8 | 19.4 | 17.2 | 1.5 |
| Abdominal length | 18.9 | 15.5 | 21.1 | 17.7 | 1.42 | 21.7 | 18.5 | 22.7 | 21.0 | 1.1 | 20.5 | 16.4 | 21.9 | 20.3 | 1.5 |
| Caudal peduncle length | 26.0 | 22.7 | 32.2 | 27.3 | 2.78 | 27.6 | 26.8 | 32.7 | 29.9 | 1.3 | 27.7 | 27.3 | 32.2 | 29.6 | 1.5 |
| Caudal peduncle depth | 7.9 | 7.0 | 10.0 | 8.7 | 0.83 | 10.1 | 8.8 | 10.9 | 10.1 | 0.4 | 9.6 | 8.4 | 9.6 | 9.2 | 0.4 |
| **Percents of HL** | | | | | | | | | | | | | | | |
| Snout length | 54.7 | 45.5 | 56.9 | 51.2 | 3.04 | 51.1 | 48.0 | 52.9 | 50.5 | 1.1 | 52.4 | 46.3 | 52.4 | 49.0 | 2.0 |
| Orbital diameter | 12.3 | 10.2 | 17.9 | 12.9 | 2.06 | 14.0 | 12.0 | 16.4 | 13.9 | 1.0 | 15.1 | 13.8 | 16.3 | 15.0 | 0.6 |
| Interorbital width | 32.7 | 30.3 | 35.7 | 32.0 | 1.24 | 35.6 | 33.8 | 37.8 | 36.0 | 1.1 | 31.9 | 27.4 | 33.6 | 31.3 | 2.0 |
| Head depth | 41.4 | 40.9 | 49.1 | 43.5 | 2.39 | 51.1 | 43.4 | 53.5 | 48.6 | 2.3 | 48.5 | 41.2 | 49.1 | 45.9 | 2.4 |
| Suborbital depth | 20.5 | 15.1 | 21.2 | 18.4 | 1.78 | 22.8 | 19.4 | 27.3 | 22.7 | 1.6 | 20.7 | 16.9 | 21.1 | 19.5 | 1.3 |
| Mandibular ramus | 8.6 | 2.9 | 8.66 | 5.0 | 1.55 | 10.8 | 8.2 | 12.5 | 10.0 | 1.0 | 9.7 | 6.6 | 9.7 | 8.7 | 0.9 |
| | **Holotype** | **Low** | **High** | **Mode** | **SD** | **Holotype** | **Low** | **High** | **Mode** | **SD** | **Holotype** | **Low** | **High** | **Mode** | **SD** |
| **Meristics** | | | | | | | | | | | | | | | |
| Left lateral scutes | 24 | 24 | 25 | 24 | - | 14 | 25 | 27 | 26 | - | 16 | 24 | 25 | 24 | - |
| Left premaxillary teeth | 12 | 7 | 12 | 7 | - | 11 | 7 | 15 | 13 | - | 16 | 15 | 19 | 16 | - |
| Left dentary teeth | 9 | 5 | 12 | 7 | - | 8 | 7 | 16 | 12 | - | 14 | 12 | 18 | 13 | - |

**Table 2.** Species reallocated from *Hisonotus* to the newly described genus *Curculionichthys*.

| Original description | New generic allocation |
|---|---|
| *Hisonotus insperatus* Britski & Garavello, 2003 | *Curculionichthys insperatus* (Britski & Garavello, 2003) |
| *Hisonotus luteofrenatus* Britski & Garavello, 2007 | *Curculionichthys luteofrenatus* (Britski & Garavello, 2007) |
| *Hisonotus oliveirai* Roxo, Zawadzki & Troy, 2014 | *Curculionichthys oliveirai* (Roxo, Zawadzki & Troy, 2014) |
| *Hisonotus paresi* Roxo, Zawadzki & Troy, 2014 | *Curculionichthys paresi* (Roxo, Zawadzki & Troy, 2014) |
| *Hisonotus piracanjuba* Martins & Langeani, 2012 | *Curculionichthys piracanjuba* (Martins & Langeani, 2012) |

municipality of Altamira, Rio Curuá, Rio Iriri drainage, 08°19'07"S, 55°05'23"W, 22 October 2007, coll. Birindelli JLO, Netto-Ferreira AL, Sabaj-Perez MH, Lujan NK.

**Diagnosis.** *Curculionichthys sabaji* differs from all congeners by having several dark-brown spots distributed on the body (*vs.* a variety of pigment patterns, but none of which includes dark-brown spots). Moreover, the new species differs from all congeners, except *C. coxipone* and *C. paresi* by having the cleithrum with an area free of odontodes, Fig. 4A (*vs.* cleithrum completely covered with odontodes, Fig. 4D–F). The new species further differs from *C. piracanjuba*, *C. sagarana*, and *C. oliveirai* by having some papillae of the lower lip arranged in a medial longitudinal series extending posterior to dentaries through the middle portion of the lower lip (*vs.* lower lip with all papillae randomly distributed); from *C. coxipone* and *C. oliveirai* by having the anterior profile of the head pointed (*vs.* rounded); from *C. piracanjuba* by having odontodes forming longitudinally aligned rows on head and trunk (*vs.* odontodes not forming longitudinally aligned rows on head and trunk); from *C. insperatus* and *C. sagarana* by having the caudal fin hyaline, with one dark strip extending from caudal peduncle base to the median caudal fin rays, and for dark chromatophores irregular distributed almost forming two bands, Fig. 5A (*vs.* caudal fin hyaline, with dark blotch limited to caudal peduncle base, Fig. 5B and 5C respectively); from *C. sagarana* by the absence of one unpaired platelet on the dorsal portion of caudal peduncle (*vs.* one unpaired platelet on the dorsal portion of the caudal peduncle, Fig. 6); from *C. insperatus* by having small, inconspicuous odontodes forming rows on the head and trunk (*vs.* large, conspicuous odontodes forming rows on the head and the trunk); from *C. oliveirai* by having 6–9 lateral abdomen plates (*vs.* 4–5 lateral abdomen plates); from *C. paresi* by lacking contrasting dark geometric spots on the anterodorsal region of body (*vs.* presence of geometric spots); from *C. piracanjuba* by not having hypertrophied odontodes on the snout tip (*vs.* hypertrophied odontodes on the snout tip). Additionally, *Curculionichthys sabaji* is distinguished by having a shorter dorsal fin spine (18.5–22.7% of SL, *vs.* 25.2–27.0% of SL in *C. paresi*; 23.2–26.9% of SL in *C. insperatus*); a shorter pectoral-fin spine (18.9–23.4% of SL, *vs.* 27.0–30.1% of SL in *C. paresi*); a deeper caudal peduncle (7.0–10.0% of SL, *vs.* 10.8–12.5% of SL in *C. oliveirai*; 10.2–11.3% of SL in *H. paresi*); a deeper head (40.9–49.1% of HL, *vs.* 51.6–59.2% of HL in *C. oliveirai*); a longer head (34.3–38.6% of SL, *vs.* 27.9–32.2% of SL in *C. piracanjuba*; 28.8–33.3% of SL in *C. luteofrenatus*); a shorter snout (45.5–56.9% of HL, *vs.* 67.7–72.7% of HL in *C. piracanjuba*; 67.0–75.3% of HL in *C. luteofrenatus*) and a

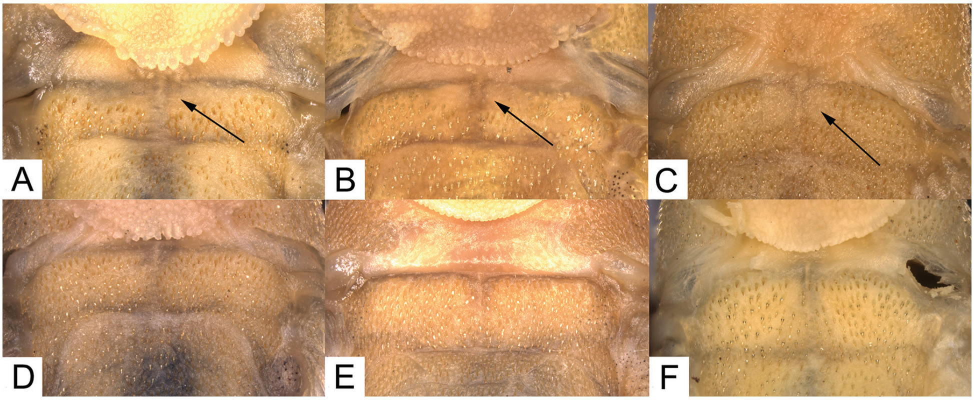


**Figure 4.** Photographs showing the cleithrum with an area free of odontodes (black arrow) in species of **A** *C. sabaji*, MZUSP 117379, holotype, 23.3 mm SL **B** *C. coxipone*, NUP 14947, paratype, 23.9 mm SL and **C** *C. paresi*, LBP 13351, paratype, 23.4 mm SL; and the cleithrum completely covered with odontodes in **D** *C. sagarana*, NUP 9714, paratype, 24.2 mm SL **E** *C. oliveirai*, LBP 14917, paratype, 29.9 mm SL; and **F** *C. insperatus*, LBP 6770, 25.0 mm SL.

shorter interorbital width (30.3–35.7% of HL, *vs.* 36.7–40.9% of HL in *C. piracanjuba*; 67.0–75.3% of HL in *C. luteofrenatus*).

**Description.** Morphometric and meristic data are given in Table 1. Small-size loricariid; maximum body length reached 23.6 mm SL. In lateral view, dorsal profile of body straight from snout tip to interorbital region; slightly convex to dorsal fin origin; and almost straight and decreasing to end of caudal peduncle. Ventral surface of body concave at tip of snout to anal fin insertion; concave to caudal fin insertion. Greatest body depth at dorsal fin origin. Greatest body width at opercular region; progressively narrowing towards snout and caudal fin. Trunk and caudal peduncle almost ellipsoid; rounded laterally and almost flat dorsally and ventrally.

Head elliptical in dorsal view; snout long (45.5–56.9% HL), slightly pointed, its tip rounded, flat to slightly convex between orbits. Dorsal and ventral series of odontodes completely covering anterior margin of snout; odontodes of snout slightly larger in size than remaining ones found on head. Snout tip completely covered with odontodes. Odontodes on head and trunk well defined and arranged into longitudinal rows (one odontode after the other, but not necessarily forming parallel series). Eye small and round (10.2–17.9% HL), situated dorsolaterally in midpoint of head. Iris operculum present but poorly developed. No ridge between eyes and nares. Nostril small. Supraoccipital process not elevated and without tuft of odontodes in specimens of all size. Mouth wide; oral disk roundish with papillae arranged in a medial longitudinal series extending posterior to dentaries through middle portion of lower lip. Lower lip larger than upper; almost reaching cleithrum region; its border strongly fringed. Maxillary barbel short, slender and free distally. Teeth slender and bicuspidate. Cusps symmetrical; medial cusp larger than lateral. Premaxillary teeth 7–12. Dentary teeth 5–12.

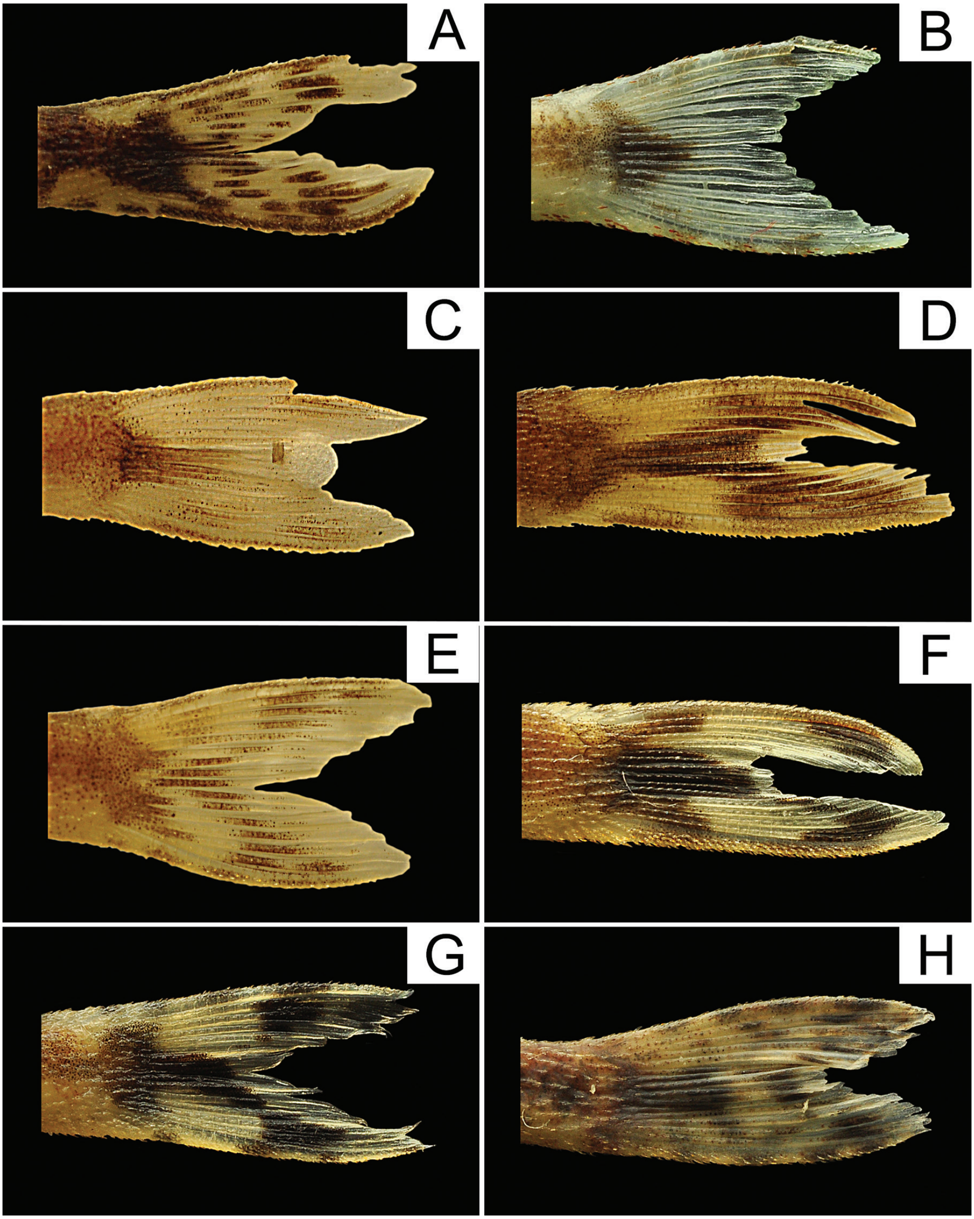


**Figure 5.** Coloration pattern of caudal fin of *Curculionichthys* species. **A** *C. sabaji*, MZUSP 117379, holotype, 23.3 mm SL **B** *C. insperatus*, LBP 17432, 26.9 mm SL **C** *C. sagarana*, NUP 9715, paratype, 21.7 mm SL **D** *C. coxipone*, MZUSP 117380, holotype, 29.0 mm SL **E** *C. oliveirai*, LBP 13332, paratype, 23.8 mm SL **F** *C. luteofrenatus*, LBP 19534, 30.5 mm SL **G** *C. paresi*, LBP 13351, paratype, 24.6 mm SL **H** *C. piracanjuba*, LBP 17256, 22.1 mm SL.

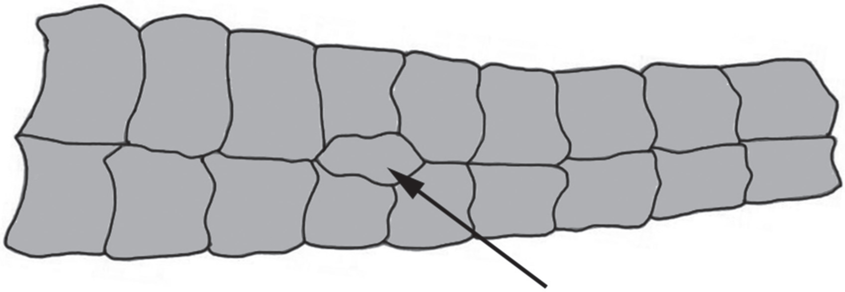


**Figure 6.** Diagram of dorsal view of the caudal peduncle of *C. sagarana* showing the presence of one unpaired platelet on dorsal portion of caudal peduncle (black arrow).

Dorsal fin rays ii, 7; in lateral view dorsal fin originating slightly posterior through origin of pelvic fin; distal margin slightly convex. Tip of adpressed dorsal fin rays surpassing end of anal fin base. Dorsal fin spinelet short and V-shaped (Fig. 7A); lock mechanism functional. Pectoral fin rays i, 6; tip of longest tip of longest pectoral-fin ray almost reaching pelvic fin insertion, when adpressed. Pectoral axillary slit present between pectoral fin insertion and lateral process of cleithrum. Pelvic fin rays i, 5; distal margin slightly convex; tip of adpressed pelvic fin almost reaching anal fin origin. Adipose-fin absent. Anal fin rays i, 4; distal margin slightly convex. Caudal fin rays i, 7-7, i; slightly emarginate; both unbranched rays of same size. Adpressed rays of all fins covered with pointed odontodes. Total vertebrae 28.

Body completely covered by bony plates, except on ventral part of head, around pectoral and pelvic fin origins and on dorsal fin base. Abdomen entirely covered by plates (Fig. 7B), abdomen formed by lateral plate series with elongate and large plates, formed by two lateral plates series, similar in size; median plates formed by one to three plates series reaching anal shield. Lateral of body entirely covered by plates (Fig. 7C); mid-dorsal plates poorly developed, almost reaching end of dorsal fin base; median plates not interrupted in median portion of body; mid-ventral plates almost reaching middle of caudal peduncle. Cleithrum and coracoid totally exposed. Arrector fossae partially enclosed by ventral lamina of coracoids.

Parts of dorsal head bone plates presented in Fig. 7D. Snout tip formed by one pair of rostral square-shaped plates (r). Nasal (n) almost rectangular forming anterior medial nostril margin in contact posteriorly with frontals (f) and anteriorly and laterally with pre-nasals (pn). Pre-nasals (pn) positioned posteriorly of rostral plates (r), formed by two large and two small rounded-shaped plates between nares. Top of head composed by compound pterotic (cpt), parieto supraoccipital (soc) and frontal (f), largest bones of head, and prefrontal (pf) and sphenotic (sp). Compound pterotic (cpt) fenestrated randomly distributed. Posterior rostrum plates pr1-pr2 small, and rectangular shaped; pr4-pr3 largest, and rectangular shaped. Infraorbital plate series complete (io1-io5), present just above posterior rostrum series, all covered by latero-sensory canal system; io2 largest and io5 smallest; io3, io4 and io5 forming inferior orbital margin of

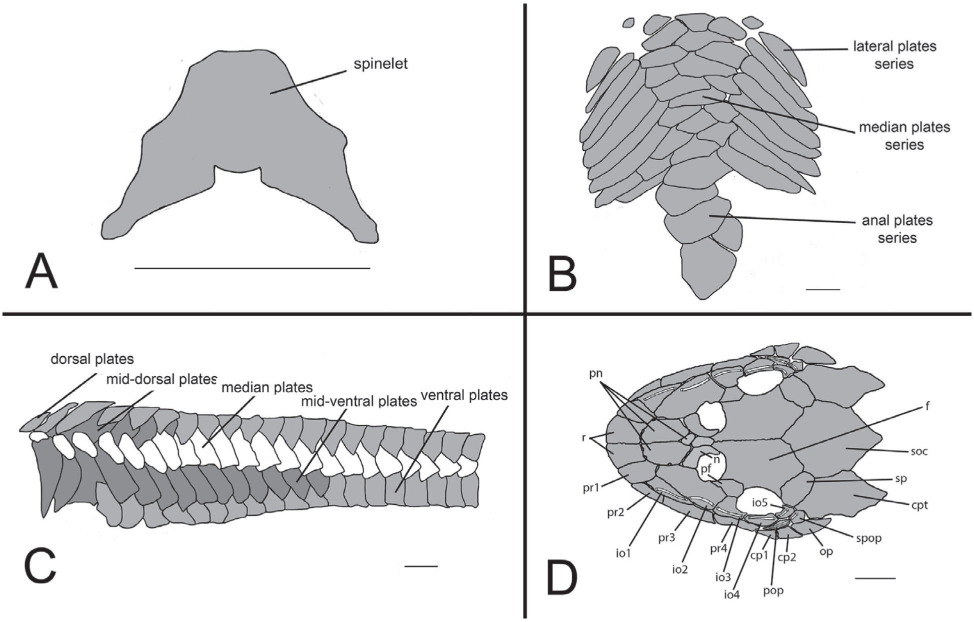


**Figure 7.** *Curculionichthys sabaji,* MZUSP 95711, 19.9 mm SL **A** Spinelet shape; **B** Ventral view of abdominal plates **C** Lateral trunk plates **D** Cranial bones plates of the head in dorsal view. Scale bar: 0.5 mm (**A**); 1 mm (**B, C, D**).

eyes; preopercle (pop) elongated and rectangular, covered by latero-sensory canal; preopercle present under io4 and io5, and upper cp1, cp2. Supra-opercular plate (spop) present just above preopercle, covered by latero-sensory canal. Subocular cheek plates (cp1-cp2) and opercle (op) form posterior lateral margin of head.

**Color in alcohol.** Ground color of dorsal and ventral region of head and trunk pale yellowish; dorsal portion darker than ventral. Four dark saddle along dorsal portion of body: one at dorsal fin origin; second at end of dorsal fin; third at middle of caudal peduncle; and fourth at upper caudal peduncle adpressed ray origin. Dorsal end ventral surface covered with small dark-dots smaller then eyes diameter. Unpigmented portion of snout appears as two hyaline parallel stripes from rostral plate to nares. Dorsal, pectoral, and pelvic fins with dark chromatophores forming irregular sets of bands: three on dorsal and pectoral fin, two on pelvic fin and one on anal fin. Caudal fin hyaline, except for dark stripe on origin of rays, and for dark chromatophores irregularly distributed forming two diffuse bands.

**Sexual dimorphism.** Adults males have a papilla in urogenital opening (*vs.* absent in females); have a long pelvic fin that extends beyond anal fin origin (*vs.* pelvic fin not reaching anal fin origin in females); and have an unbranched pelvic fin ray supporting a dermal flap along its dorsal surface. Both sexes have a membrane on anal opening; however, this membrane is more developed in females than in males, covering almost the entire urogenital opening (see reference to this last character in Roxo et al. 2014b).

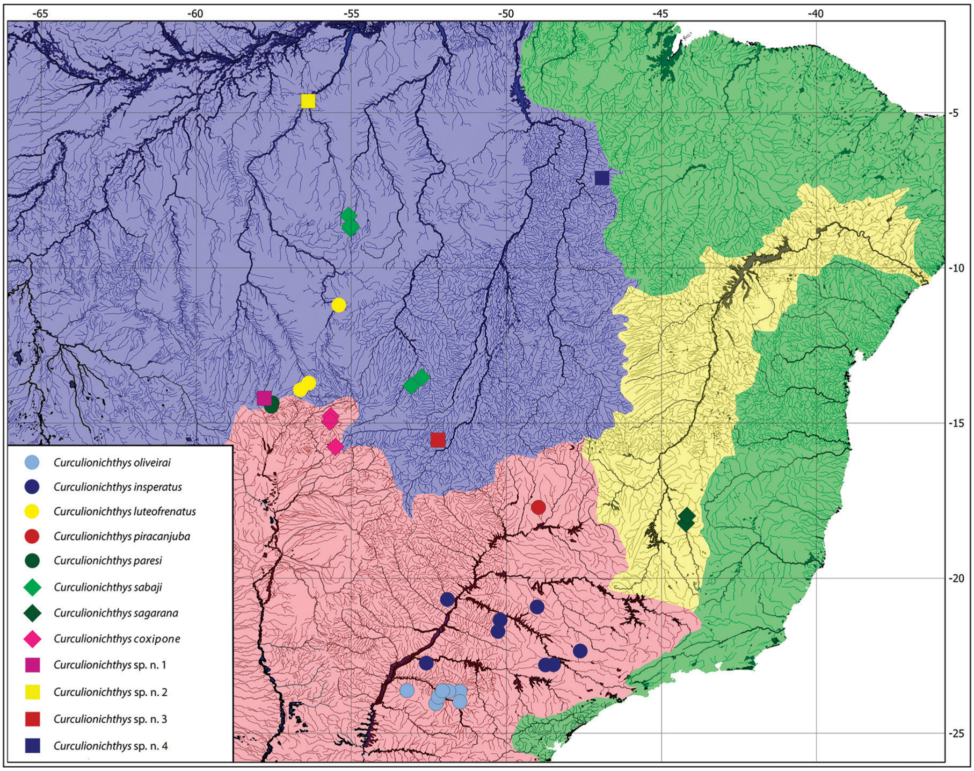


**Figure 8.** Map showing the distribution of *Curculionichthys* species. Red – La Plata basin; Blue – Amazon basin; Yellow – Rio São Francisco basin; Green – Coastal Drainages to Atlantic.

**Distribution.** The new species *C. sabaji* are known from five localities in the Rio Xingu basin: two at Rio 13 de Maio, one at Rio Coronel Vanick, one at Rio Couto de Magalhães and one at Rio Curuá (Fig. 8).

**Etymology.** The specific name "sabaji" is a patronym honoring Dr. Mark Henry Sabaj Pérez, Collection Manager of Ichthyology, Academy of Natural Sciences of Philadelphia, in recognition of his dedication and contributions to study of Neotropical fishes especially from Rio Xingu basin (iXingu Project).

**Comparative remarks.** *Curculionichthys sabaji* from the Xingu basin is morphologically very similar to *C. paresi* from Rio Paraguai basin. Both species share a low number of teeth in the premaxillaries and dentaries, the form of papillae in the lower lip and the general pattern of body coloration. However, *C. sabaji,* can be distinguished from *C. paresi* by having several dark-brown spots distributed on the body, a shorter dorsal fin spine, a shorter pectoral fin spine, a deeper caudal peduncle and the lack of dark geometric spots on the anterodorsal region of body. The similarity in morphology among both species suggests a close relationship between them and that they may have once shared a common ancestor. Furthermore, the presence of these close related species in the Rio Paraguay and the Rio Xingu is not a surprise, since several authors (e.g. Pearson 1937; Carvalho and Albert 2011) historically have reported that those two hydrographic systems share several lineages of fishes, and that most species lineage present in the Rio Paraguay originated in Amazonian drainages (Carvalho and Albert 2011).

### ***Curculionichthys coxipone*** **sp. n.**

http://zoobank.org/66B213A7-69B9-4980-B4EB-B7AFEEE43D5F
Figure 9; Table 1

*Hisonotus* sp. 5 – Roxo et al. 2014a: 9(8) e105564 (phylogenetic relationships).

**Holotype.** MZUSP 117380, female, 29.0 mm SL, Mato Grosso State, municipality of Cuiabá, tributary of Rio Aricá Mirim, Rio Cuiabá drainage, Rio Paraguai basin, 15°46'03"S, 55°30'44"W, September 2011, coll. Mehanna MN, Ferreira AT.

**Paratypes.** All from Brazil, Mato Grosso State, Rio Cuiabá drainage, Rio Paraguai basin. LBP 5061 (3 females, 21.7–30.0 mm SL, 2 males, 25.8–27.9 mm SL), municipality of Cuiabá, tributary of Rio Aricá Mirim, 15°46'03"S, 55°30'44"W, 07 September 2007, coll. Mehanna MN, Ferreira AT. LBP 5062 (3 females, 22.5–28.7 mm SL), municipality of Cuiabá, tributary of Rio Aricá Mirim, 15°46'03"S, 55°30'44"W, 07 September 2007, coll. Mehanna MN, Ferreira AT. LBP 5069 (9 females, 22.5–29.6 mm SL, 3 males, 25.6–26.9 mm SL, 1 c&s, sex not determined, 25.6 mm SL), municipality of Cuiabá, tributary of Rio Aricá Mirim, 15°46'03"S, 55°30'44"W, 08 November 2007, coll. Mehanna MN, Ferreira AT. LBP 5646 (11 females, 21.8–28.8 mm SL, 7, males, 24.9–28.0 mm SL, 3 c&s, sex not determined, 26.8–28.2 mm SL), municipality of Cuiabá, tributary of Rio Aricá Mirim, 15°46'03"S, 55°30'44"W, 11 November 2007, coll. Mehanna MN, Ferreira AT. NUP 2264 (6 females, 18.2–25.3 mm SL, 6 males, 23.4–23.7 mm SL), municipality of Chapada dos Guimarães, Córrego São Joaquim, 14°46'53"S, 55°39'57"W, 26 March 2014, coll. NUPELIA´s team. NUP 14947 (6 females, 21.2–25.1 mm SL, 21.9–25.0 mm SL, 3 juveniles), municipality of Chapada dos Guimarães, Córrego Laranjinha, tributary of Rio Manso, 14°57'18"S, 55°41'15"W, June 2013, coll. NUPELIA´s team. NUP 16442 (6 females, 23.4–28.7 mm SL, 1 c&s sex not determined, 28.7 mm SL), collected with holotype.

**Diagnosis.** *Curculionichthys coxipone* differs from all congeners by having a higher number of vertebrae 29–30 (*vs.* 28 in all other species of *Curculionichthys*). The new species differs from all congeners, except *C. sabaji* and *C. paresi* by having the cleithrum with an area free of odontodes, Fig. 4B (*vs.* cleithrum completely covered with odontodes, Fig. 4D–F). The new species further differs from all congeners, except *C. oliveirai* by having the anterior profile of the head rounded (*vs.* pointed); from *C. piracanjuba*, *C. sagarana*, and *C. oliveirai* by having lower lip with some papillae arranged in a medial longitudinal series extending posterior to dentaries through middle portion of lower lip (*vs.* lower lip with all papillae randomly distributed); from *C. insperatus* and *C. oliveirai* by having the caudal fin hyaline, with one dark stripe extending from

**Figure 9.** *Curculionichthys coxipone*, MZUSP 117380, holotype, female, 29.0 mm SL, from Mato Grosso State, municipality of Cuiabá, tributary of Rio Aricá Mirim, Rio Cuiabá drainage, 15°46'03"S, 55°30'44"W.

the caudal peduncle base to the middle caudal fin rays, and dark chromatophores irregular distributed almost forming one band, Fig. 5D (*vs.* caudal fin hyaline, with dark blotch limited to caudal peduncle base, Fig. 5B and E, respectively); from *C. paresi* by lacking contrasting dark-brown geometric spots on the anterior region of the body (*vs.* presence of dark-brown geometric spots); from *C. sabaji* by lacking several dark-brown spots distributed on the body (*vs.* presence of dark-brown spots); from *C. oliveirai* and *C. coxipone* by having the anterior profile of the head pointed (*vs.* rounded); from *C. oliveirai* by having 7–9 lateral abdomen plates (*vs.* 4–5 lateral abdomen plates); from *C. paresi* by having more dentary teeth 9–13 (*vs.* 4–7); from *C. oliveirai* by having 6–9 lateral abdomen plates (*vs.* 4–5 lateral abdomen plates); from *C. sagarana* by absence of one unpaired platelets on dorsal portion of caudal peduncle (*vs.* presence of one unpaired platelets on dorsal portion of caudal peduncle, Fig. 6); from *C. piracanjuba* by having some papillae on the lower lip arranged in a medial longitudinal series extending posterior to the dentaries through the middle portion of lower lip (*vs.* lower lip with all papillae randomly distributed) and by not having hypertrophied odontodes on the snout tip (*vs.* hypertrophied odontodes on the snout tip); from *C. insperatus* by having small, inconspicuous odontodes forming rows on the head and trunk (*vs.* large, conspicuous odontodes forming rows on the head and the trunk). Additionally, *C. coxipone* is distinguished by having a shorter interorbital distance (33.8–37.8% of HL, *vs.* 27.4–33.6% of HL in *C. sagarana*); a shorter dorsal fin spine (14.9–24.8% of SL, *vs.* 25.2–27.0% of SL in *C. paresi*); a shorter pectoral fin spine (19.0–25.2% of SL, *vs.* 27.0–30.1% of SL in *C. paresi*); a longer mandibular ramus (8.2–12.5% of HL, *vs.* 6.0–8.0% of HL in *C. paresi*); and a shorter snout (48.0–58.9% of HL, *vs.* 67.7–72.7% of HL in *C. piracanjuba*; 67.0–75.3% of HL in *C. luteofrenatus*).

**Description.** Morphometric and meristic available in Table 1. Small loricariid; bigger specimen examined reached 29.9 mm SL. In lateral view, dorsal profile of head convex from snout tip to posterior margin of parieto supraoccipital, and straight to dorsal fin origin. Dorsal profile of trunk slightly concave and descending from dorsal fin origin to end of dorsal fin base, straight to caudal peduncle. Ventral profile concave from snout tip to opercular region; convex from opercular region to anal fin origin; concave to caudal fin insertion. Greatest body depth at dorsal fin origin. Greatest body width at opercular region, gradually decreasing towards snout and caudal fin. Cross-section of trunk and caudal peduncle almost ellipsoid; rounded laterally and almost flat dorsally and ventrally.

Head rounded in dorsal view; snout round to slightly pointed, its tip rounded, elongated (48.0–52.9% HL), slightly convex between orbits. Dorsal and ventral series of odontodes along anterior margin of snout completely covering its tip; odontodes at same size than remaining ones on head. Odontodes on head and trunk hypertrophied and arranged in longitudinal rows (most prominent on head). Eyes moderately small (12.0–16.4% HL), dorsolaterally positioned. Lips roundish with papillae arranged in a medial longitudinal series extending posterior to dentaries through middle portion of lower lip. Lower lip larger than upper lip; its border fringed. Maxillary barbel present; joined to lower lip. Teeth slender and bicuspid; medial cusp larger than lateral cusp. Premaxillary teeth 7–15. Dentary teeth 7–16.

Dorsal fin ii, 7; dorsal fin spinelet short and V-shaped (Fig. 10A); dorsal fin lock functional; dorsal fin origin slightly posterior to pelvic fin origin. Tip of adpressed dorsal fin reaching anal fin insertion. Pectoral fin i, 6; its tip reaching beyond pelvic fin insertion when depressed. Presence of pectoral axillary slit between pectoral fin insertion and lateral process of cleithrum variable; absent in some specimens. Pectoral spine supporting odontodes on ventral, anterior and dorsal surfaces. Pelvic fin i, 5; tip of pelvic fin unbranched ray almost reaching anal fin origin when depressed in females and reaching anal fin origin in males. Pelvic fin unbranched ray with dermal flap along dorsal surface in males. Anal fin i, 5; distal margin slightly convex. Caudal fin i, 7-7,

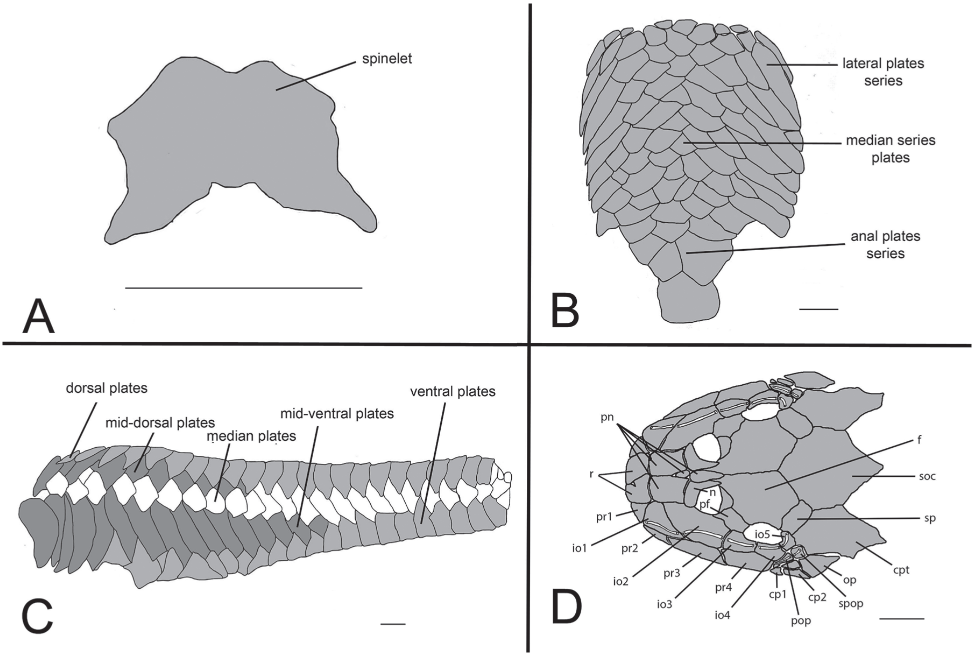


**Figure 10.** *Curculionichthys coxipone,* LBP 5646, 27.5 mm SL. **A** Spinelet shape **B** Ventral view of abdominal plates **C** Lateral trunk plates **D** Cranial bones plates of the head in dorsal view. Scale bar: 0.5 mm (**A**); 1 mm (**B, C, D**).

i; slightly emarginate; both unbranched rays of same size. Adipose fin absent. Total vertebrae 29–30 (1 c&s 29 vertebrae and 3 c&s 30 vertebrae).

Body covered with bony plates, except above head, around pectoral and pelvic fin origins and on dorsal fin base. Cleithrum and coracoid partially exposed. Arrector fossae partially to completely enclosed by ventral lamina of coracoids. Abdomen entirely covered by plates (Fig. 10B); lateral plates series with elongated and large plates formed by two lateral plate series, similar in size; median plates formed by six to seven irregular plate series reaching anal shield and lateral plate series; anal plates series covered by large square plates. Body entirely covered laterally by plates (Fig. 10C); mid-dorsal plates poorly developed and reaching middle of dorsal fin base; median plates series continuous in median portion of body; mid-ventral plates reaching of caudal peduncle origin.

Parts of dorsal head bone plates presented in Fig. 10D. Snout tip formed by one pair of rostral rectangular-shaped plates (r). Nasal (n) almost rectangular forming anterior medial nostril margin in contact posteriorly with frontals (f) and anteriorly and laterally with pre-nasals (pn). Pre-nasals (pn) positioned posteriorly of rostral plates (r), formed by two large and one small oval-shaped plates, and one elongate oval shaped between nares. Top of head composed by compound pterotic (cpt), parieto supraoccipital (soc) and frontal (f), largest bones of head, and prefrontal (pf) and sphenotic (sp). Compound pterotic (cpt) fenestrated randomly distributed. Posterior rostrum plates pr1-pr2 small, first triangular and second rectangular-shaped; pr4-pr3 largest, and rectangular shaped. Infraorbital plate series complete (io1-io5), present just above posterior rostrum series, all covered by latero-sensory canal system; io2 largest and io5 smallest; io3, io4 and io5 forming inferior orbital margin of eyes; preopercle (pop) elongated and rectangular, covered by latero-sensory canal; preopercle present under io4, and upper cp1, cp2 and op. Supra-opercular plate (spop) present just above preopercle, covered by latero-sensory canal. Subocular cheek plates (cp1-cp2) and opercle (op) form posterior lateral margin of head.

**Color in alcohol.** Ground color of dorsal and ventral region of head and trunk pale yellowish; dorsal portion darker than ventral. Four dark saddle along dorsal portion of body: first at dorsal fin origin; second at end of dorsal fin; third at middle of caudal peduncle; and fourth at end of caudal peduncle. Unpigmented portion of snout appears as two hyaline parallel stripes from rostral plate to nares. Dorsal, pectoral, and pelvic fins hyaline. Caudal fin hyaline, with dark stripe extending from caudal peduncle base onto base of median caudal fin rays, and with dark chromatophores forming one large band.

**Sexual dimorphism.** Adults males have a papilla in urogenital opening (*vs.* absent in females); and have an unbranched pelvic fin ray supporting a dermal flap along its dorsal surface. Both sexes have a membrane on the anal opening; however, this membrane is more developed in females than in males, covering almost the entire urogenital opening (see reference to this last character in Roxo et al. 2014b).

**Distribution.** The new species *C. coxipone* is known from Rio Cuiaba drainage, Rio Paraguay basin, Mato Grosso State in Brazil (Fig. 8).

**Etymology.** The specific name “coxipone” refers to the Coxiponé indigenous people who inhabit the margins of Rio Cuiabá, near to the municipality of Cuiabá in Mato Grosso State, Brazil. A noun in opposition.

**Comparative remarks.** *Curculionichthys coxipone* is similar in external morphology with *C. oliveirai* from Rio Ivaí, upper Rio Paraná basin. However, the new species *C. coxipone* can be distinguished from *C. oliveirai* by having the cleithrum with an area free of odontodes, a higher number of vertebrae 29–30 and by a hyaline caudal fin, with one dark stripe extending from the caudal peduncle base to the median caudal fin rays, and for dark chromatophores irregular distributed almost forming one band. Furthermore, the presence of a higher number of vertebrae appears to be unique to *C. coxipone*.

### ***Curculionichthys sagarana*** **sp. n.**

http://zoobank.org/DA95A052-B969-4650-BE03-683303C644D0
Figure 11; Table 1

**Holotype.** MZUSP 117381, female 23.7 mm SL, Minas Gerais State, municipality of Santo Hipólito, Rio Pardo Grande, Rio das Velhas drainage, Rio São Francisco basin, 18°13'43"S, 44°13'03"W, 17 September 2007, coll. Leal CG, Junqueira NT, Pompeu PS.

**Paratypes.** All from Brazil, Minas Gerais State, Rio das Velhas drainage, Rio São Francisco basin: LBP 19983 (1 male, 21.9 mm SL), municipality of Santo Hipólito,

**Figure 11.** *Curculionichthys sagarana*, MZUSP 117381, holotype, female, 23.7 mm SL, from Minas Gerais State, municipality of Santo Hipólito, Rio Pardo Grande, tributary of Rio das Velhas, Rio São Francisco basin, 18°13'43"S, 44°13'03"W.

Rio Pardo Grande, 18°13'43"S, 44°13'03"W, 11 September 2007, coll. Leal CG, Junqueira NT, Pompeu PS. NUP 9714 (1 female, 24.4 mm SL, 1 male, 22.5 mm SL), municipality of Augusto de Lima, Rio Curimataí, 17°59'33"S, 44°10'48"W, 23 March 2008, coll. Leal CG, Junqueira NT, Pompeu PS. NUP 9715 (2 females, 17.5–18.4 mm SL, 1 male, 21.7 mm SL, 1 c&s sex not determined, 23.3 mm SL), municipality of Santo Hipólito, Rio Pardo Grande, 18°13'43"S, 44°13'03"W, 25 March 2010, coll. Leal CG, Junqueira NT, Pompeu PS. NUP 9716 (4 juveniles, sex not determined, 10.5–17.1 mm SL), municipality of Santo Hipólito, Rio Pardo Grande, 18°13'43"S, 44°13'03"W, 25 March 2010, coll. Leal CG, Junqueira NT, Pompeu PS. NUP 12595 (1 male, 23.0 mm SL), collected with holotype. NUP 12596 (1 female, 24.1 mm SL), municipality of Santo Hipólito, Rio Pardo Grande, 18°13'43"S, 44°13'03"W, 24 March 2008, coll. Leal CG, Junqueira NT, Pompeu PS. NUP 12597 (1 male, 21.7 mm SL), municipality of Santo Hipólito, Rio Pardo Grande, 18°13'43"S, 44°13'03"W, 24 March 2008, coll. Leal CG, Junqueira NT, Pompeu PS. NUP 12614 (1 female, 21.7 mm SL), municipality of Santo Hipólito, Rio Pardo Grande, 18°13'43"S, 44°13'03"W, 11 September 2007, coll. Leal CG, Junqueira NT, Pompeu PS.

**Diagnosis.** *Curculionichthys sagarana* differs from all congeners by having one unpaired platelet on the dorsal portion of the caudal peduncle, Fig. 6 (*vs.* dorsal portion of caudal peduncle without unpaired platelets). The new species can be further distinguished from all congeners, except *C. insperatus* and *C. luteofrenatus* by having the caudal fin hyaline, with dark blotch limited to caudal peduncle base, Fig. 5C (*vs.* caudal fin hyaline, with one dark stripe extending from caudal peduncle base to the middle caudal fin rays, and for dark chromatophores irregularly distributed almost forming one or two bands); from *C. insperatus*, *C. paresi* and *C. sabaji* by having more premaxillary teeth 15–19 (*vs.* 10–12 in *C. insperatus*; 6–10 in *C. paresi* and 7–12 in *C. sabaji*) and more dentary teeth 12–18 (*vs.* 8–12 in *C. insperatus*, 4–7 in *C. paresi* and 7–12 in *C. sabaji*); from all congeners, except *C. piracanjuba* and *C. oliveirai*, by having all papillae on the lower lip randomly distributed (*vs.* lower lip with some papillae arranged in a medial longitudinal series extending posterior to dentaries through middle portion of lower lip); from *C. oliveirai* and *C. coxipone* by having the anterior profile of the head pointed (*vs.* rounded); from *C. paresi* by lacking contrasting dark-brown geometric spots on the anterodorsal region of the body (*vs.* presence); from *C. piracanjuba* by having odontodes forming longitudinally aligned rows on the head and trunk (*vs.* odontodes not forming longitudinally aligned rows on the head and trunk); from *C. sabaji*, *C. coxipone* and *C. paresi* by having the cleithrum completely covered with odontodes, Fig. 4D (*vs.* the cleithrum with an area free of odontodes, Fig. 4A–C); from *C. insperatus* by having small, inconspicuous odontodes forming rows on the head and trunk (*vs.* large, conspicuous odontodes forming rows on the head and the trunk); from *C. oliveirai* by having 6–9 lateral abdomen plates (*vs.* 4–5 lateral abdomen plates); from *C. piracanjuba* by not having hypertrophied odontodes on the snout tip (*vs.* hypertrophied odontodes on the snout tip). Additionally, *C. sagarana* is distinguished by having a deeper caudal peduncle (8.4–9.6 % of SL, *vs.* 10.8–12.5% of SL in *C. oliveirai*; 10.2–11.3% in *C. paresi*); a greater head length (34.8–40.5% of SL, *vs.* 28.8–33.3% of SL in *C. luteofrenatus*; 27.9–32.2% of SL in *C. piracanjuba*); a shorter snout (46.3–52.4% of HL, *vs.* 67.0–75.3% of HL in *C. luteofrenatus*; 67.7–72.7% of HL in *C. piracanjuba*); a shorter interorbital width (27.4–33.6% of SL, *vs.* 33.3–45.4% of HL in *C. luteofrenatus*; 36.7–40.9% of HL in *C. piracanjuba*; 33.8–37.8% of HL in *C. coxipone*); a deeper head (41.2–49.1% of HL, *vs.* 51.6–59.2% of HL in *C. oliveirai*); a shorter dorsal-spine (19.9–24.4% of SL, *vs.* 25.2–27.0% of SL in *C. paresi*); and a shorter pectoral-spine (21.5–25.2% of SL, *vs.* 27.0–30.1% of SL in *C. paresi*).

**Description.** Morphometric and meristic available in Table 1. Small loricariid; largest examined specimen reaching 24.2 mm SL. In lateral view, dorsal profile of head convex from snout tip to posterior margin of parietosupraoccipital, and straight to dorsal fin origin. Dorsal profile of trunk slightly concave and descending from dorsal fin origin to end of dorsal fin base, straight to caudal peduncle. Ventral profile concave from snout tip to opercular region; convex from opercular region to anal fin origin; concave to caudal fin insertion. Greatest body depth at dorsal fin origin. Greatest body width at opercular region, gradually decreasing towards snout and caudal fin. Cross-section of trunk and caudal peduncle almost ellipsoid; rounded laterally and almost flat dorsally and ventrally.

Head elliptical in dorsal view; snout round to slightly pointed, its tip rounded, elongated (46.3–52.4% HL), slightly convex between orbits. Dorsal and ventral series of odontodes along anterior margin of snout completely covering its tip; odontodes at same size than remaining ones on head. Odontodes on head and trunk hypertrophied and arranged in longitudinal rows (most prominent on head). Eyes moderately small (13.8–16.3% HL), dorsolaterally positioned. Lips roundish with papillae arranged in a medial longitudinal series extending posterior to dentaries through middle portion of lower lip. Lower lip larger than upper lip; its border fringed. Maxillary barbel present; joined to lower lip. Teeth slender and bicuspid; medial cusp larger than lateral cusp. Premaxillary teeth 15–19. Dentary teeth 12–18.

Dorsal fin ii, 7; dorsal fin spinelet short and V-shaped (Fig. 12A); dorsal fin lock functional; dorsal fin origin slightly posterior to pelvic fin origin. Tip of adpressed dorsal fin reaching anal fin insertion. Pectoral fin i, 6; its tip reaching beyond pelvic fin insertion when depressed. Presence of pectoral axillary slit between pectoral fin insertion and lateral process of cleithrum variable; absent in some specimens. Pectoral spine supporting odontodes on ventral, anterior and dorsal surfaces. Pelvic fin i, 5; tip of pelvic fin unbranched ray almost reaching anal fin origin when depressed in females and reaching anal fin origin in males. Pelvic fin unbranched ray with dermal flap along dorsal surface in males. Anal fin i, 5; distal margin slightly convex. Caudal fin i, 7-7, i; slightly emarginate; both unbranched rays of same size. Adipose fin absent. Total vertebrae 28.

Body covered with bony plates, except above head, around pectoral and pelvic-fin origins and on dorsal fin base. Cleithrum and coracoid entirely exposed. Arrector fossae partially to completely enclosed by ventral lamina of coracoids. Abdomen entirely covered by plates (Fig. 12B); lateral plates series with elongate and large plates formed by two lateral plate series, similar in size; median plates formed by two to three irregular plate series reaching anal shield and lateral plate series; anal plates series covered by large square plates. Body entirely covered laterally by plates (Fig. 12C); mid-dorsal plates poorly developed and reaching end of dorsal fin base; median plates series continuous in median portion of body; mid-ventral plates reaching caudal peduncle origin. Dorsal portion of caudal peduncle with one unpaired platelet.

Parts of dorsal head bone plates presented in Fig. 12D. Snout tip formed by one pair of rostral rectangular-shaped plates (r). Nasal (n) almost rectangular forming anterior medial nostril margin in contact posteriorly with frontals (f) and anteriorly and laterally with pre-nasals (pn). Pre-nasals (pn) positioned posteriorly of rostral plates (r), formed by two large and one small triangular-shaped plates, and one elongate oval shaped between nares. Top of head composed by compound pterotic (cpt), parieto supraoccipital (soc) and frontal (f), largest bones of head, and prefrontal (pf) and sphenotic (sp). Compound pterotic (cpt) fenestrated randomly distributed. Posterior rostrum plates pr1-pr2 small and triangular-shaped; pr4-pr3 largest, and rectangular-shaped. Infraorbital plate series complete (io1-io5), present just above posterior ros-

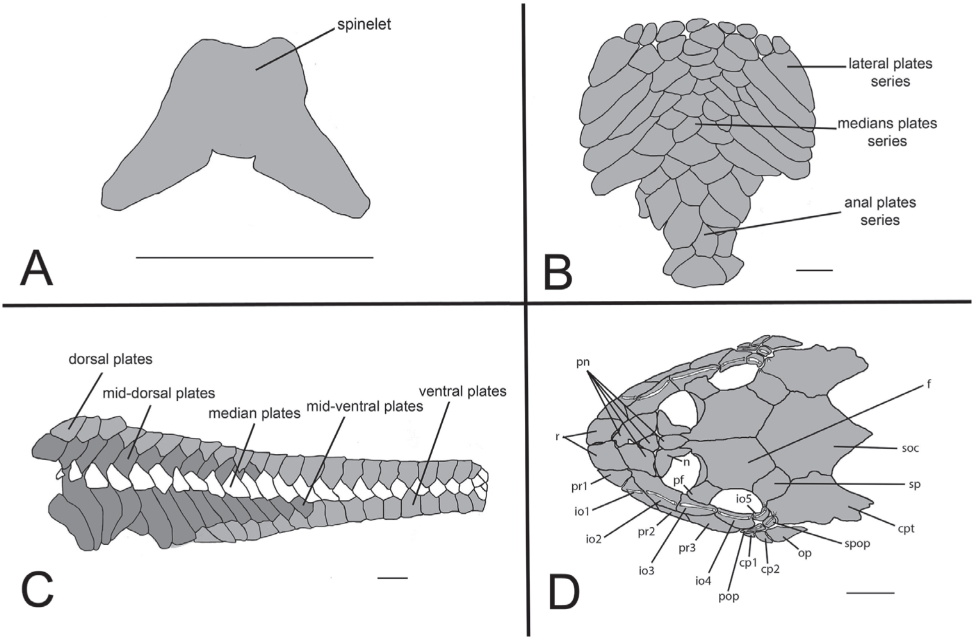


**Figure 12.** *Curculionichthys sagarana,* NUP 9715, 23.3 mm SL. **A** Spinelet shape **B** Ventral view of abdominal plates **C** Lateral trunk plates **D** Cranial bones plates of the head in dorsal view. Scale bar: 0.5 mm (**A**); 1 mm (**B, C, D**).

trum series, all covered by latero-sensory canal system; io2 largest and io5 smallest; io3, io4 and io5 forming inferior orbital margin of eyes; preopercle (pop) elongated and rectangular, covered by latero-sensory canal; preopercle present under io4, and upper cp1, cp2 and op. Supra-opercular plate (spop) present just above preopercle, covered by latero-sensory canal. Subocular cheek plates (cp1-cp2) and operculum (op) form posterior lateral margin of head.

**Color in alcohol.** Ground color of dorsal and ventral region of head and trunk pale yellowish; dorsal portion darker than ventral. Four dark saddles along dorsal portion of body: first at dorsal fin origin; second at end of dorsal fin; third at middle of caudal peduncle; and fourth at upper caudal peduncle adpressed ray origin. Dorsal, pectoral, and pelvic fins hyaline. Caudal fin hyaline, with dark blotch limited to caudal peduncle base, and with dark chromatophores irregular distributed almost forming one band.

**Sexual dimorphism.** Adults males have a papilla in urogenital opening (*vs.* absent in females); a longer pelvic fin that extends beyond anal fin origin (*vs.* pelvic fin not reaching anal fin origin in females); nares opening wider (*vs.* nares opening narrower); and an unbranched pelvic fin ray supporting a large dermal flap along its dorsal surface. Both sex have a membrane on anal opening; however, this membrane is more developed in females than in males, covering almost the entire urogenital opening (see reference to this last character in Roxo et al. 2014b).

**Distribution.** The new species *C. sagarana* are known from two localities along Rio das Velhas drainage: one at Rio 13 de Maio, one at Pardo Grande, and one at Rio Curimataí, all in Rio São Francisco basin, Minas Gerais State, Brazil (Fig. 8).

**Etymology.** The specific name “sagarana” is a hybrid of two words, “saga” of Germanic origin that means heroic song and “rana” from Tupi-Guarani language that means “similarity”. The word sagarana is in reference to the book of a Brazilian author João Guimarães Rosa published in 1946 about the history of people from Minas Gerais State living in the region of Rio das Velhas.

**Comparative remarks.** The new species *C. sagarana* is similar in external morphology with *C. insperatus*, primarily the general pattern of coloration of the body. However, *C. sagarana* can be distinguished by the presence of one unpaired platelet on the dorsal portion of caudal peduncle, a character apparently present only in this new species, more premaxillary and dentary teeth, and small, inconspicuous odontodes forming rows on the head and trunk.

## Key to species of *Curculionichthys*

1 Odontodes forming longitudinally aligned rows (one odontode after the other, but not necessarily forming parallel series) on head (more prominent) and trunk ........ **2**

– Odontodes not forming longitudinally aligned rows on head and trunk (Rio Paranaíba basin) ........ ***C. piracanjuba***

2 Cleithrum with an area free of odontodes ........ **3**

– Cleithrum completely covered with odontodes ........ **5**

3 Presence of contrasting dark geometric spots on the anterodorsal region of the body (Rio Paraguai basin) ........ ***C. paresi***

– Absence of geometric spots on the anterodorsal region of the body ........ **4**

4 Presence of several dark-brown spots distributed on the body; the anterior profile of the head pointed; presence of 28 vertebrae (Rio Xingu basin) ........ ***C. sabaji***

– Lacking of several dark-brown spots distributed on the body; the anterior profile of the head rounded; presence of 29 to 30 vertebrae (Rio Cuiabá basin) ........ ***C. coxipone***

5 Presence of one unpaired platelet on dorsal portion of caudal peduncle (Rio das Velhas basin) ........ ***C. sagarana***

– Dorsal portion of caudal peduncle without unpaired platelets ........ **6**

6 Caudal fin hyaline, with dark blotch limited to caudal peduncle base; six to nine lateral abdomen plates ........ **7**

– Caudal fin hyaline, with one dark strip extending from caudal peduncle base to the median caudal fin rays; four to five lateral abdomen plates (Rio Ivaí basin) ........ ***C. oliveirai***

7 Small and inconspicuous odontodes forming rows on the head and trunk; caudal fin hyaline, with one dark stripe extending from caudal peduncle base

to the median caudal-fin rays, and for irregularly distributed dark chromatophores almost forming one band (Rio Tapajós basin) ......... ***C. luteofrenatus***

– Conspicuous odontodes forming rows on the head and the trunk; caudal fin hyaline, with dark blotch limited to caudal peduncle base (Rio Paranapanema, Tietê and Grande basins) ............................................ ***C. insperatus***

## Comparative material

All from Brazil, except when stated otherwise:

*Corumbataia cuestae* Britski, 1997: LBP 3688, 3, 28.5–29.9 mm SL; Rio Araquá, municipality of Botucatu, São Paulo State.

*Curculionichthys insperatus* (Britski & Garavello, 2003): LBP 4945, 7, 27.3–29.9 mm SL, Rio Araquá, municipality of Botucatu, São Paulo State; LBP 6770, 8, 20.0–28.2 mm SL, ribeirão Cubatão, municipality of Marapoama, São Paulo State; LBP 13336, 1 female c&s, 26.0 mm SL, Rio Capivara, municipality of Botucatu, São Paulo State; LBP 13337, 2 females c&s, 27.4–28.6 mm SL, Rio Araquá, municipality of Botucatu, São Paulo State; MZUSP 22826, 1, 25.4 mm SL, paratype, Córrego Água Tirada, municipality of Três Lagoas, Minas Gerais State; MZUSP 24832, 1, 23.8 mm SL, paratype, Rio Corumbataí, municipality of Corumbataí, São Paulo State; MZUSP 78957, 29.6 mm SL, holotype, Rio Capivara, municipality of Botucatu, São Paulo State; MZUSP 78960, 31, 12.6–26.0 mm SL, paratypes, 5 c&s, 22.7–24.7 mm SL, Rio Pardo, municipality of Botucatu, São Paulo State; MZUSP 78965, 10, 15.6–28.6 mm SL, paratypes, 3 c&s, not measured, Rio Araquá, municipality of Botucatu, São Paulo State; MZUSP 78968, 5, 24.1–27.3 mm SL, paratypes, Córrego da Figueira, municipality of Lins, São Paulo State.

*Curculionichthys luteofrenatus* (Britski & Garavello, 2007): MZUSP 62593, 28.6 mm SL, holotype, Córrego Loanda, municipality of Cláudia, Mato Grosso State; MZUSP 62594, 8, 22.4–30.5 mm SL, paratypes, riacho Selma, municipality of Sinop, Mato Grosso State; MZUSP 87144, 8, 16.8–27.9 mm SL, paratypes, Córrego Loanda, municipality of Cláudia, Mato Grosso State.

*Curculionichthys oliveirai* (Roxo, Zawadzki & Troy, 2014b): MZUSP 115061, 26.4 mm SL, holotype, ribeirão Cambira, municipality of Cambira, Paraná State; LBP 13332, 1 male, 23.2 mm SL, 1 unsexed c&s, 23.7 mm SL, paratype, Rio Mourão, municipality of Campo Mourão, Paraná State; LBP 17578, 5, 25.4–30.4 mm SL, paratypes, Rio Mourão, between municipality of Engenheiro Beltrão and Quinta do Sol, Paraná State; NUP 3578, 15, 24.7–28.1 mm SL, 2 c&s, 25.5–27.6 mm SL, , paratypes, ribeirão Salto Grande, municipality of Maria Helena, Paraná State.

*Curculionichthys paresi* (Roxo, Zawadzki & Troy, 2014b): MZUSP 115062, 26.2 mm SL, holotype, riacho Águas Claras, municipality of Santo Afonso, Mato Grosso State; LBP 13351, 9, 14.7–24.3 mm SL, paratype, riacho Águas Claras, municipality of Santo Afonso, Mato Grosso State; LBP 13352, 1, 23.7 mm SL, paratype, riacho Águas Claras, municipality of Santo Afonso, Mato Grosso State; NUP

10928, 2 males, 23.2–24.2 mm SL, paratype, 2 c&s, 23.6–24.2 mm SL, riacho Águas Claras, municipality of Santo Afonso, Mato Grosso State.

*Curculionichthys piracanjuba* (Martins & Langeani, 2012): LBP 17256, 9, 17.2–26.3 mm SL, 1, c&s 27.1 mm SL, córrego sem nome, municipality of Morrinhos, Goiás State; NUP 5059, 1, 24.7 mm SL, Córrego Posse, municipality of Anápolis, Goiás State; MZUSP 110491, 3, 17.5–24.4 mm SL, paratypes, Rio Quente, municipality of Marcelânia, Goiás State; NUP 10979, 3, 21.4–21.8 mm SL, ribeirão Bocaina, municipality of Piracanjuba, Goiás State.

*Curculionichthys* sp. 1: LBP 17531, 3, 23.3–25.8 mm SL, Rio Russo I, municipality of Tangará da Serra, Mato Grosso State.

*Curculionichthys* sp. 2: LBP 17485, 7, 19.0–24.1 mm SL, Igarapé Imambuaí, municipality of Itaituba, Pará State.

*Curculionichthys* sp. 3: LBP 1856, 2, 21.0–23.2 mm SL, Rio Insula, Barra do Garça, Mato Grosso State.

*Curculionichthys* sp. 4: MZUSP 87452, 3, 22.4–24.5 mm SL, unknown river, municipality of Streito, Maranhão State; MZUSP 87553: 3, 21.7–24.3 mm SL, unknown river, municipality of Feira Nova do Maranhão, Maranhão State.

*Hisonotus acuen* Silva, Roxo & Oliveira, 2014: MZUSP 115350, 25.9 mm SL, holotype, affluent of Rio Toguro, municipality of Querência, Mato Grosso State; LBP 15755, 16, 19.5–26.0 mm SL, paratypes, affluent of Rio Suiá-Missu, municipality of Ribeirão Cascalheira, Mato Grosso State; LBP 16274, 27, 20.2–29.1 mm SL, 2 c&s 23.6–24.2 mm SL, paratypes, affluent of Rio Culuene, municipality of Gaúcha do Norte, Mato Grosso State; LBP 16275, 29, 16.7–25.2 mm SL, 2 c&s 19.3–20.8 mm SL, paratypes, affluent of Rio Feio, municipality of Querência, Mato Grosso State; LBP 16278, 12, 18.8–25.1 mm SL, 2 c&s 26.8–27.1 mm SL, paratypes, Córrego Xavante, municipality of Primavera do Leste, Mato Grosso State.

*Hisonotus aky* (Azpelicueta, Casciotta, Almirón & Koerber, 2004): MHNG 2643.039, 2, 33.1–34.2 mm SL, paratypes, arroio Fortaleza, Argentina.

*Hisonotus armatus* Carvalho, Lehmann, Pereira & Reis, 2008: MZUSP 93884, 5, 37.6–44.4 mm SL, paratypes, arroio Arambaré, municipality of Pedro Osório, Rio Grande do Sul State.

*Hisonotus bocaiuva* Roxo, Silva, Oliveira & Zawadzki, 2013: MZUSP 112204, 24.2 mm SL, holotype, Córrego Cachoeira, municipality of Bocaiúva, Minas Gerais State; LBP 9817, 9, 3 c&s, 18.3–23.2 mm SL, paratypes, Córrego Cachoeira, municipality of Bocaiúva, Minas Gerais State.

*Hisonotus brunneus* Carvalho & Reis, 2011: MZUSP 104947, 4, 37.2–41.3 mm SL, paratypes, Rio Passo Novo, municipality of Cruz Alta, Rio Grande do Sul State.

*Hisonotus carreiro* Carvalho & Reis, 2011: MCP 40943, 3, 33.6–35.8 mm SL, arroio Guabiju, municipality of Guabiju, Rio Grande do Sul State.

*Hisonotus charrua* Almirón, Azpelicueta, Casciotta & Litz, 2006: LBP 4861, 1, 35.9 mm SL, arroio Guaviyú, Artigas, Uruguay; MHNG 2650.051, 1, 34.2 mm SL, paratype, arroio Aspinillar, Uruguay.

*Hisonotus chromodontus* Britski & Garavello, 2007: LBP 7964, 25, 24.0–28.3 mm SL, 4 c&s, 24.9–28.9 mm SL, Rio dos Patos, municipality of Nova Mutum, Mato

Grosso State; LBP 7974, 26, 17.7–24.8 mm SL, Rio dos Patos, municipality of Nova Mutum, Mato Grosso State; LBP 12278, 2, 26.7–28.7 mm SL, 1 c&s, 26.7 mm SL, Rio Sumidouro, municipality of Tangará da Serra, Mato Grosso; MZUSP 45355, 25.9 mm SL, holotype, affluent of Rio Preto, municipality of Diamantino, Mato Grosso State; MZUSP 70758, 7, 19.4–23.9 mm SL, paratype, riacho Loanda, municipality of Sinop, Mato Grosso State; NUP 10924, 24, 19.5–31.5 mm SL, Rio Preto, municipality of Diamantino, Minas Gerais State.

*Hisonotus depressicauda* (Miranda Ribeiro, 1918): MZUSP 5383, 24.4 mm SL, paralectotype, municipality of Sorocaba, São Paulo State; LBP 17474, 5 c&s, 18.1–24.0 mm SL, Rio Araquá, municipality of Botucatu, São Paulo State.

*Hisonotus francirochai* (Ihering, 1928): LBP 13923, 22, 25.7–35.7 SL, córrego sem nome, municipality of Capitinga, Minas Gerais State; MZUSP 3258, 29.4 mm SL, lectotype, Rio Grande, São Paulo State.

*Hisonotus heterogaster* Carvalho & Reis, 2011: LBP 3335, 39, 20.8–30.1 mm SL, arroio sem nome, municipality of Rio Grande, Rio Grande do Sul State; MZUSP 104948, 3, 40.3–43.0 mm SL, paratypes, arroio Felício, municipality of Júlio de Castilho, Rio Grande do Sul State.

*Hisonotus iota* Carvalho & Reis, 2009: LBP 13072, 5, 32.3–33.0 mm SL, Rio Chapecó, municipality of Coronel Freitas, Santa Catarina State.

*Hisonotus laevior* Cope, 1894: LBP 3377, 1, 25.2 mm SL, arroio dos Corrientes, municipality of Pelotas, Rio Grande do Sul State; LBP 6037, 8, 33.4–47.0 mm SL, Rio Maquiné, municipality of Osório, Rio Grande do Sul State; LBP 13187, 7, 19.4–45.8 mm SL, córrego sem nome, municipality of Camaquá, Rio Grande do Sul State.

*Hisonotus leucofrenatus* (Miranda Ribeiro, 1908): LBP 2085, 7, 38.3–50.6 mm SL, Rio Sagrado, municipality of Morretes, Paraná State; LBP 6837, 36, 35.1–43.5 mm SL, Rio Fau, municipality of Miracatu, São Paulo State.

*Hisonotus leucophrys* Carvalho & Reis, 2009: LBP 13065, 6, 17.2–33.6 mm SL, Rio Ariranhas, municipality of Xavantina, Santa Catarina State; LBP 13073, 1, 36.8 mm SL, Rio Guarita, municipality of Palmitinho, Rio Grande do Sul State.

*Hisonotus megaloplax* Carvalho & Reis, 2009: LBP 13108, 6, 36.4–37.8 mm SL, córrego sem nome, municipality of Saldanha Marinho, Rio Grande do Sul State.

*Hisonotus montanus* Carvalho & Reis, 2009: LBP 13051, 3, 26.4–27.2 mm SL, Rio Goiabeiras, Vargem, SC; LBP 13055, 5, 24.8–31.9 mm SL, Rio Canoas, municipality of Vargem, Santa Catarina State.

*Hisonotus nigricauda* (Boulenger, 1891): LBP579, 16, 34.1–40.1 mm SL, Rio Guaíba, municipality of Eldorado do Sul, Rio Grande do Sul State.

*Hisonotus notatus* Eigenmann & Eigenmann, 1889: LBP 3472, 20, 21.0–34.3 mm SL, 3 c&s 25.0–26.5 mm SL, Rio Aduelas, municipality of Macaé, Rio de Janeiro; LBP 10742, 25, 24.4–43.3 mm SL, Rio Macabu, municipality of Conceição de Macabu, Rio de Janeiro State.

*Hisonotus notopagos* Carvalho & Reis, 2011: MZUSP 104943, 4, 35.3–37.3 mm SL, arroio Boici, municipality of Pinheiro Machado, Rio Grande do Sul State.

*Hisonotus prata* Carvalho & Reis, 2011: MCP 40492, 18, 19.5–33.2 mm SL, Rio da Prata, municipality of Nova Prata, Rio Grande do Sul State; LBP 9918, 14, 21.7–32.6 mm SL, Laguna dos Patos system, municipality of Nova Prata, Rio Grande do Sul State.

*Hisonotus ringueleti* Aquino, Schaefer & Miquelarena, 2001: FMNH 108806, 2, 25.7–32.2 mm SL, Rio Quaraí basin, Uruguay; LBP 13148, 1, 24.5 mm SL, arroio Putiá, municipality of Uruguaiana, Rio Grande do Sul State.

*Hisonotus vespuccii* Roxo, Silva & Oliveira, 2015a: MZUSP 115274, 32.6 mm SL, holotype, Rio São Francisco, municipality of Pirapora, Minas Gerais State; LBP 10421,18, 23.6–30.3 mm SL, 5 c&s sex not determined 20.2–29.6 mm SL, Rio São Francisco, municipality of Pirapora, Minas Gerais State.

*Hisonotus vireo* Carvalho & Reis, 2011: MZUSP 104946, 4, 30.4–39.5 mm SL, Rio dos Sinos, municipality of Caraá, Rio Grande do Sul State.

*Microlepidogaster arachas* Martins, Calegari & Langeani, 2013: LBP 10882, 3, 22.8–35.3 mm SL, Rio Paraná basin, municipality of Araxás, Minas Gerais State;

*Microlepidogaster dimorpha* Martins & Langeani, 2011: LBP 10683, 2, 28.8–35.6 mm SL, Rio Uberaba, municipality of Uberaba, Minas Gerais State.

*Otothyropsis marapoama* Ribeiro, Carvalho & Melo, 2005: LBP 4698, 6, 23.9–36.3 mm SL, ribeirão Cubatão, municipality of Marapoama, São Paulo State.

*Parotocinclus maculicauda* (Steindachner, 1877): LBP 2869, 15, 20.2–44.7 mm SL, Rio Fau, municipality of Miracatu, São Paulo State;

*Parotocinclus prata* Ribeiro, Melo & Pereira, 2002: LIRP 1136, 38, 19.8–41.9 mm SL, paratypes, ribeirão Quiricó, municipality of Presidente Olegário, Minas Gerais State.

*Parotocinclus robustus* Lehmann & Reis, 2012: LBP 8258, 29, 18.7–39.1 mm SL, Córrego Cachoeira, municipality of Bocaiúva, Minas Gerais State.

*Pseudotothyris obtusa* (Miranda Ribeiro, 1911): LBP 6822, 70, 22.5–31.7 mm SL; tributary of Rio Preto, municipality of Itanhaém, São Paulo State.

*Rhinolekos britskii* Martins & Langeani, 2011: LBP 7253, 21.9–34.7 mm SL; tributary of Rio Paranaíba, municipality of Pires do Rio, Goiás State.

*Rhinolekos capetinga* Roxo, Ochoa, Silva & Oliveira, 2015b: MZUSP 116102, holotype, 37.5 mm SL, Córrego da Branca, municipality of Água Fria de Goiás, Goiás State; LBP 19001, paratypes (35, 26.8–39.5 mm SL, 3 c&s, 37.2–32.6 mm SL, 9 sex not determined and not measured), Córrego da Branca, municipality of Água Fria de Goiás, Goiás State.

*Schizolecis guntheri* (Miranda Ribeiro, 1918): LBP 2123, 21, 28.4–36.3 mm SL, Rio Parati-Mirim, municipality of Parati, Rio de Janeiro State; LBP 3546, 77, 20.9–35.8 mm SL, coastal drainage, municipality of Ubatuba, São Paulo State.

## Acknowledgements

We wish to thank Birindelli JLO, Ferreira AT, Junqueira NT, Leal CG, Leite CMC, Lima FCT, Lujan NK, Mehanna MN, Moraes L, Moreira CR, Netto-Ferreira AL, Pompeu PS, Ribeiro AC and Sabaj-Perez MH for their help during the collection expeditions. This research was supported by the Brazilian agencies FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo, proc. 2014/05051–5 to FFR, 2012/01622–2 to GSCS and 2014/06853–8 to LEO) and MCT/CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) (Edital Universal, proc. N. 441347/2014–2 coord. FFR).

## References

Almirón AE, Azpelicueta MM, Casciotta JR, Litz T (2006) A new species of *Hisonotus* (Siluriformes, Loricariidae, Otothyrini) from the República Oriental del Uruguay. Revue suisse de Zoologie 113(1): 87–94. doi: 10.5962/bhl.part.80342

Aquino AE, Schaefer SA, Miquelarena AM (2001) A new species of *Hisonotus* (Siluriformes, Loricariidae) of the Upper Río Uruguay Basin. American Museum Novitates 3333: 1–12. doi: 10.1206/0003-0082(2001)333<0001:ANSOHS>2.0.CO;2

Azpelicueta MM, Casciotta JR, Almirón AE, Koerber S (2004) A new species of Otothyrini (Siluriformes: Loricariidae: Hypoptopomatinae) from the Río Uruguay basin, Argentina. Verhandlungen der Gesellschaft für Ichthyologie 4: 81–90.

Boulenger GA (1891) An account of the siluroid fishes obtained by Dr. H. von Ihering and Herr Sebastian Wolff in the Province Rio Grande do Sul, Brazil. Proceedings of the Zoological Society of London 2: 231–235.

Britski HA (1997) Descrição de um novo gênero de Hypoptopomatinae, com duas espécies novas (Siluriformes, Loricariidae). Papéis Avulsos de Zoologia, São Paulo 40(15): 231–255.

Britski HA, Garavello JC (2003) *Hisonotus insperatus*: new species, from the upper Rio Paraná basin (Pisces: Ostariophysi: Loricariidae). Copeia 2003(3): 588–593. doi: 10.1643/CI-02-23R

Britski HA, Garavello JC (2007) Description of two new sympatric species of the genus *Hisonotus* Eigenmann and Eigenmann, 1889, from upper rio Tapajós, Mato Grosso state, Brazil (Pisces: Ostariophysi: Loricariidae). Brazilian Journal of Biology 67(3): 413–420. doi: 10.1590/S1519-69842007000300005

Calegari BB, Reis RE (2010) A new species of *Microlepidogaster* (Siluriformes: Loricariidae: Hypoptopomatinae) from the upper rio Paraná basin, Brazil. Neotropical Ichthyology 8(3): 625–630.

Carvalho TP, Albert JS (2011) The Amazon-Paraguay divide. In: Albert JS, Reis RE (Eds) Historical Biogeography of Neotropical Freshwater Fishes. University of California Press, Berkeley, California, 193–202. doi: 10.1525/california/9780520268685.003.0011

Carvalho M, Datovo A (2012) A new species of cascudinho of the genus *Hisonotus* (Siluriformes: Loricariidae: Hypoptopomatinae) from the upper Rio Tapajós basin, Brazil. Copeia 2012(2): 266–275. doi: 10.1643/CI-11-016

Carvalho TP, Lehmann PA, Pereira EHL, Reis RE (2008) A New Species of *Hisonotus* (Siluriformes: Loricariidae: Hypoptopomatinae) from the Laguna dos Patos basin, Southern Brazil. Copeia 3(3): 510–516. doi: 10.1643/CI-07-130

Carvalho TP, Reis RE (2009) Four new species of *Hisonotus* (Siluriformes: Loricariidae) from the upper rio Uruguay, southeastern South America, with a review of the genus in the rio Uruguay basin. Zootaxa 2113: 1–40.

Carvalho TP, Reis RE (2011) Taxonomic review of *Hisonotus* Eigenmann and Eigenmann (Siluriformes: Loricariidae: Hypoptopomatinae) from the laguna dos Patos system, southern Brazil. Neotropical Ichthyology 9(1): 1–48. doi: 10.1590/S0074-02762011000900001

Chiachio MC, Oliveira C, Montoya-Burgos JI (2008) Molecular systematic and historical biogeography of the armored Neotropical catfishes Hypoptopomatinae and Neoplecostominae (Siluriformes: Loricariidae). Molecular Phylogenetic and Evolution 49(2): 606–617. doi: 10.1016/j.ympev.2008.08.013

Cope ED (1894) On the fishes obtained by the Naturalist Expedition in Rio Grande do Sul. Proceedings of the American Philosophical Society 33: 84–108, Pls. 4–9.

Cramer CA, Bonatto SL, Reis RE (2011) Molecular phylogeny of the Neoplecostominae and Hypoptopomatinae (Siluriformes: Loricariidae) using multiple genes. Molecular Phylogenetics and Evolution 59(1): 43–52. doi: 10.1016/j.ympev.2011.01.002

Diogo R, Oliveira C, Chardon M (2001) On the homologies of the skeletal components of catfish (Teleostei: Siluriformes) suspensorium. Belgian Journal of Zoology 131: 155–171.

Eigenmann CH, Eigenmann RS (1889) Preliminary notes on South American Nematognathi. II. Proceedings of the California Academy of Sciences (Series 2) 2: 28–56.

Eschmeyer W (2015) Catalog of fishes. Electronic publication in "World Wide Web". http://www.calacademy.org/research/ichthyology/catalog [accessed 23 June 2015]

Fricke R, Eschmeyer WN (2015) Catalog of fishes. http://research.calacademy.org/research/ichthyology/catalog/collections.asp [accessed January 2015]

Garavello JC (1977) Systematics and geographical distribution of the genus *Parotocinclus* Eigenmann and Eigenmann, 1889 (Ostariophysi, Loricariidae). Arquivos de Zoologia 28: 1–37. doi: 10.11606/issn.2176-7793.v28i4p1-37

Günther A (1868) Diagnoses of some new freshwater fishes from Surinam and Brazil, in the collection of the British Museum. Annals and Magazine of Natural History 1(6): 475–481. doi: 10.1080/00222936808695733

Ihering R von (1928) Uma nova espécie de *Otocinclus* (Pisces. Nematognatha) "cascudinho" de S. Paulo. Boletim Biologia, Trabalho Laboratório de Parasitologia Faculdade de Medicina, São Paulo 11(42): 1–3.

International Commission on Zoological Nomenclature (1999) International code of zoological nomenclature. Fourth Edition. The International Trust for Zoological Nomenclature, London.

Lehmann PA, Reis RE (2012) A new species of *Parotocinclus* (Siluriformes: Loricariidae) from the upper Rio São Francisco, Brazil. Zootaxa 3390: 56–64.

Martins FO, Calegari BB, Langeani F (2013) *Microlepidogaster arachas*, a new species of hypoptopomatine catfish (Siluriformes: Loricariidae) from the upper rio Paraná basin, Brazil. Zootaxa 3608(5): 379–388. doi: 10.11646/zootaxa.3608.5.6

Martins FO, Langeani F (2011) *Rhinolekos*, a new genus with three new species of Hypoptopomatinae (Siluriformes: Loricariidae) from upper Rio Paraná. Neotropical Ichthyology 9(1): 65–78. doi: 10.1590/S1679-62252011000100004

Martins FO, Langeani F (2012) *Hisonotus piracanjuba*, a new species of Hypoptopomatinae (Siluriformes: Loricariidae) from the rio Paranaíba, upper rio Paraná system, central Brazil. Ichthyological Exploration of Freshwaters 23: 29–36.

Martins FO, Britski HA, Langeani F (2014) Systematics of *Pseudotothyris* (Loricariidae: Hypoptopomatinae). Zoological Journal of the Linnean Society 170(4): 822–874. doi: 10.1111/zoj.12107

Miranda Ribeiro A de (1908) Peixes da Ribeira. Resultados de excursão do Sr. Ricardo Krone, membro correspondente do Museu Nacional do Rio de Janeiro. Kosmos, Rio de Janeiro 5(2): 5.

Miranda Ribeiro A de (1911) Fauna brasiliense. Peixes. Tomo IV (A) [Eleutherobranchios Aspirophoros]. Arquivos do Museu Nacional de Rio de Janeiro 16: 1–504.

Miranda Ribeiro A de (1918) Três gêneros e dezessete espécies novas de peixes Brasileiros. Revista do Museu Paulista 10: 631–646.

Mo T (1991) Anatomy, relationships and systematics of the Bagridae (Teleostei: Siluroidei) with a hypothesis of siluroid phylogeny. Theses Zoologicae 17. Koeltz Scientific Books, Königstein.

Myers GS (1927) Descriptions of new South American fresh-water fishes collected by Dr. Carl Ternetz. Bulletin of the Museum of Comparative Zoology 68(3): 107–135.

Pearson NE (1937) The fishes of the Beni-Mamoré and Paraguay basin, and a discussion of the origin of the Paraguayan fauna. Proceedings of the California Academy of Sciences 23: 99–114.

de Pinna MCC (1998) Phylogenetic relationships of Neotropical Siluriformes (Teleostei: Ostariophysi): historical overview and synthesis of hypotheses. In: Malabarba LR, Reis RE, Vari RP, Lucena ZMS, Lucena CAS (Eds) Phylogeny and classification of Neotropical fishes. Edipucrs, Porto Alegre, RS, 279–330.

Ribeiro AC, Carvalho M, Melo ALA (2005) Description and relationships of *Otothyropsis marapoama*, a new genus and species of Hypoptopomatinae catfish (Siluriformes: Loricariidae) from rio Tietê basin, southeastern Brazil. Neotropical Ichthyology 3(4): 489–498. doi: 10.1590/S1679-62252005000400006

Ribeiro AC, Melo ALA, Pereira EHL (2002) A new species of *Parotocinclus* (Siluriformes: Loricariidae) from the rio São Francisco basin, southeastern Brazil. Ichthyological Exploration of Freshwaters 13(3): 217–224.

Roxo FF, Silva GSC, Oliveira C, Zawadzki CH (2013) *Hisonotus bocaiuva*, a new species from the rio São Francisco basin, Brazil (Teleostei: Loricariidae). Ichthyological Exploration of Freshwaters 23(4): 319–326.

Roxo FF, Albert JS, Silva GS, Zawadzki CH, Foresti F, Oliveira C (2014a) Molecular Phylogeny and Biogeographic History of the Armored Neotropical Catfish Subfamilies Hypoptopomatinae, Neoplecostominae and Otothyrinae (Siluriformes: Loricariidae). PLoS ONE 9(8): e105564. doi: 10.1371/journal.pone.0105564

Roxo FF, Zawadzki CH, Troy WP (2014b) Description of two new species of *Hisonotus* Eigenmann & Eigenmann, 1889 (Ostariophysi, Loricariidae) from the rio Paraná-Paraguay basin, Brazil 395: 57–78. doi: 10.3897/zookeys.395.6910

Roxo FF, Silva GSC, Oliveira C (2015a) A new species of *Hisonotus* (Siluriformes, Loricariidae) from rio São Francisco basin, Brazil. ZooKeys 498: 127–143. doi: 10.3897/zookeys.498.6896

Roxo FF, Ochoa LE, Silva GSC, Oliveira C (2015b) *Rhinolekos capetinga*: a new cascudinho species (Loricariidae, Otothyrinae) from the rio Tocantins basin and comments on its ancestral dispersal route. ZooKeys 481: 109–130. doi: 10.3897/zookeys.481.8755

Schaefer SA (1987) Osteology of *Hypostomus plecostomus* (Linnaeus), with a phylogenetic analysis of the loricariid subfamilies (Pisces: Siluroidei). Contributions in Science 394: 1–31.

Schaefer SA (1997) The Neotropical cascudinhos: systematics and biogeography of the *Otocinclus* catfishes (Siluriformes: Loricariidae). Proceedings of the Academy of Natural Sciences of Philadelphia 148: 1–120.

Schaefer SA (1998a) Conflict and resolution: impact of new taxa on phylogenetic studies of the Neotropical cascudinhos (Siluroidei: Loricariidae). In: Malabarba LR, Reis RE, Vari RP, Lucena ZMS, Lucena CAS (Eds) Phylogeny and classification of Neotropical fishes. Edipucrs, Porto Alegre, 375–400.

Schaefer SA (1998b) The Neotropical cascudinhos: systematic and biogeography of the *Otocinclus* catfishes (Siluriformes: Loricariidae). Proceedings of the Academy of Natural Sciences of Philadelphia 148: 1–120.

Silva GSC, Roxo FF, Oliveira C (2014) *Hisonotus acuen*, a new and phenotypically variable cascudinho (Siluriformes, Loricariidae, Hypoptopomatinae) from the upper rio Xingu basin, Brazil. ZooKeys 442: 105–125. doi: 10.3897/zookeys.442.7870

Steindachner F (1877) Die Süsswasserfische des südöstlichen Brasilien. (IV). Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften. Mathematisch-Naturwissenschaftliche Classe 76 (1): 217–230.

Taylor WR, Van Dyke GC (1985) Revised procedures for staining and clearing small fishes and other vertebrates for bone and cartilage study. Cybium 9: 107–109.

ZooKeys 534: 135–146 (2015)
doi: 10.3897/zookeys.534.5953
http://zookeys.pensoft.net

SHORT COMMUNICATION

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

# Genetic divergence analysis of the Common Barn Owl *Tyto alba* (Scopoli, 1769) and the Short-eared Owl *Asio flammeus* (Pontoppidan, 1763) from southern Chile using COI sequence

Nelson Colihueque[1], Alberto Gantz[2], Jaime Ricardo Rau[2], Margarita Parraguez[3]

**1** *Laboratorio de Biología Molecular y Citogenética, Departamento de Ciencias Biológicas y Biodiversidad, Universidad de Los Lagos, Avenida Alcalde Fuchslocher 1305, Casilla 933, Osorno, Chile* **2** *Laboratorio de Ecología, Departamento de Ciencias Biológicas y Biodiversidad, Universidad de Los Lagos, Osorno, Chile* **3** *Laboratorio de Genética, Acuicultura y Biodiversidad, Universidad de Los Lagos, Osorno, Chile*

Corresponding author: *Nelson Colihueque* (ncolih@ulagos.cl)

Academic editor: *G. Sangster* | Received 27 October 2014 | Accepted 4 October 2015 | Published 11 November 2015

*http://zoobank.org/6D68AA98-C5E1-4E5C-89EE-295D9F5E8C0D*

**Citation:** Colihueque N, Gantz A, Rau JR, Parraguez M (2015) Genetic divergence analysis of the Common Barn Owl *Tyto alba* (Scopoli, 1769) and the Short-eared Owl *Asio flammeus* (Pontoppidan, 1763) from southern Chile using COI sequence. ZooKeys 534: 135–146. doi: 10.3897/zookeys.534.5953

## Abstract

In this paper new mitochondrial COI sequences of Common Barn Owl *Tyto alba* (Scopoli, 1769) and Short-eared Owl *Asio flammeus* (Pontoppidan, 1763) from southern Chile are reported and compared with sequences from other parts of the World. The intraspecific genetic divergence (mean p-distance) was 4.6 to 5.5% for the Common Barn Owl in comparison with specimens from northern Europe and Australasia and 3.1% for the Short-eared Owl with respect to samples from north America, northern Europe and northern Asia. Phylogenetic analyses revealed three distinctive groups for the Common Barn Owl: (*i*) South America (Chile and Argentina) plus Central and North America, (*ii*) northern Europe and (*iii*) Australasia, and two distinctive groups for the Short-eared Owl: (*i*) South America (Chile and Argentina) and (*ii*) north America plus northern Europe and northern Asia. The level of genetic divergence observed in both species exceeds the upper limit of intraspecific comparisons reported previously for Strigiformes. Therefore, this suggests that further research is needed to assess the taxonomic status, particularly for the Chilean populations that, to date, have been identified as belonging to these species through traditional taxonomy.

## Keywords

Aves, Common Barn Owl, Short-eared Owl, COI, taxonomy

## Introduction

The Common Barn Owl *Tyto alba* (Scopoli, 1769) (Strigiformes, Tytonidae) and the Short-eared Owl *Asio flammeus* (Pontoppidan, 1763) (Strigiformes, Strigidae) are nocturnal owls usually found in open habitats such as farmland and grassland associated with humanized areas (Weick 2006). The range of both species extends across several continents. In Chile, these owls are sympatric over most of their geographic range, and are considered opportunistic generalists, feeding mainly on small mammals (Rau et al. 1992, Martínez et al. 1998, Figueroa et al. 2009). Although the Common Barn Owl and the Short-eared Owl have been widely studied throughout most of their geographic range in Chile, studies have concentrated mainly on ecological aspects, e.g. diet, conservation and habitat (Raimilla et al. 2012). In contrast, their levels of genetic divergence in comparison with populations in other geographic ranges, have received little attention. This is especially important given that Chilean populations of both species are peripheral populations in the southern hemisphere whose geographic isolation, as a consequence of the Andean mountains that act as a geographic barrier, may have led to evolutionary divergence.

The Common Barn Owl includes several subspecies, some of which may represent distinct and endemic species. To date, up to 25 distinct species have been recognized within the *Tyto* complex but the status of many of these forms remains poorly documented (Weick 2006). Based on morphological data, the Common Barn Owl in Chile has been assigned to the subspecies *T. a. tuidara* (J.E. Gray, 1829) (Figueroa et al. 2014). In the Short-eared Owl, nine subspecies have been recognized across its geographic range (Weick 2006), of which the subspecies *A. f. suinda* (Vieillot, 1817) occurs in Chile (Figueroa et al. 2014). Nevertheless, no molecular data supporting the taxonomic identity of the populations of these species in Chile are available yet.

The mitochondrial cytochrome c oxidase subunit I (COI) gene is considered a powerful molecular tool for molecular identification ('barcoding') of bird species and may also help to clarify taxonomic relationships (Hebert et al. 2004, Kerr et al. 2007, 2009, Aliabadian et al. 2009). This gene includes a 648-bp region of the mitochondrial genome that provides reasonably good resolution for identifying animal species, as shown by the fact that deep sequence divergences are found between most closely related pairs of animal species (Hebert et al. 2003). Given this property, i.e. its ability to capture species boundaries, this marker has been widely used as a method for identifying species, using a library of sequences linked to taxonomically verified voucher specimens (Ratnasingham and Hebert 2007).

In this study, we sequenced a 648-bp region of the COI gene of the Common Barn Owl and the Short-eared Owl specimens from southern Chile with the aim of comparing these data with the COI sequences published for these species from other geographic areas. Given that no major information on genetic divergence of owls from Chile based on the COI gene is available, this study may contribute to clarifying the taxonomic status and evolutionary divergence at regional and global scales.

## Methods

### Samples collection and DNA extraction

Owl samples (Common Barn Owl, n = 9; and Short-eared Owl, n = 1) were collected in 2012 and 2013 from dead birds found along the highways (Ruta 5, Ruta 215 and Ruta 207) that connect Osorno with neighboring cities, which run through the provinces of Valdivia, Ranco and Osorno in southern Chile (40°-41° S latitude) (Figure 1). Photographs illustrating the plumage and overall external appearance of Common Barn Owls and Short-eared Owls collected in southern Chile are provided in the Suppl. material 1. DNA was extracted from fixed muscle using the phenol–chloroform method, as described in Taggart et al. (1992). Extracts were standardized at 100 ng/µL using Tris-EDTA buffer pH 8.0.

### PCR and sequencing

COI sequences were amplified using the primer pair of BirdF1 (5’-TTCTCCAAC-CACAAAGACATT GGCAC-3’) and BirdR1 (5’-ACGTGGGAGATAATTCCA AATCCTG-3’) (Hebert et al. 2004). PCR amplification was carried out in 50 µL using a reaction mix composed of 10 µL Taq polymerase buffer (1 x), 1 µL of dNTPs (0.2 µM), 1.5 µL of $MgCl_2$ (1.5 mM), 2 µL of each primer (0.4 µM), 0.5 µL of Taq DNA polymerase (0.05 U/ µL) (Kapa Biosystems), 7.5 µL of template DNA (100 ng/µL), and 25.5 µL of distilled water DNAse, RNAse free (Gibco). The thermal cycling was performed as follows: initial denaturation at 94 °C for 2 min followed by 40 cycles of 94 °C for 45 s, annealing temperature of 58 °C for 45 s, 72 °C for 45 s and a final extension step at 72 °C for 5 min. PCR products were visualized on 2% agarose gels, and prior to sequencing, these were cleaned with QIA quick gel extraction kit (Qiagen). PCR products were bi-directionally sequenced on an Applied Biosystems ABI377 automated sequencer. Sequence records were assembled from forward and reverse reads, and aligned and edited using GENEIOUS 4.0.2 software (Biomatters Ltd.). The sequences are deposited at GenBank (accession numbers KM377628–KM377638).

### Phylogenetic and sequence divergence analyses

Summary statistics, variable and parsimony informative sites, and p-distances were calculated with MEGA 5.05 (Tamura et al. 2011). Relationships among COI haplotypes were reconstructed based on the median joining network implemented in the Network program ver. 4.6.1 (Bandelt et al. 1999). Phylogenetic analyses were carried out using Maximum Likelihood (ML) and Bayesian Inference (BI) approaches. The best-fit nucleotide substitution model was selected using Akaike’s information criterion (AIC). The best model was then used with the ML analyses to construct a ML tree

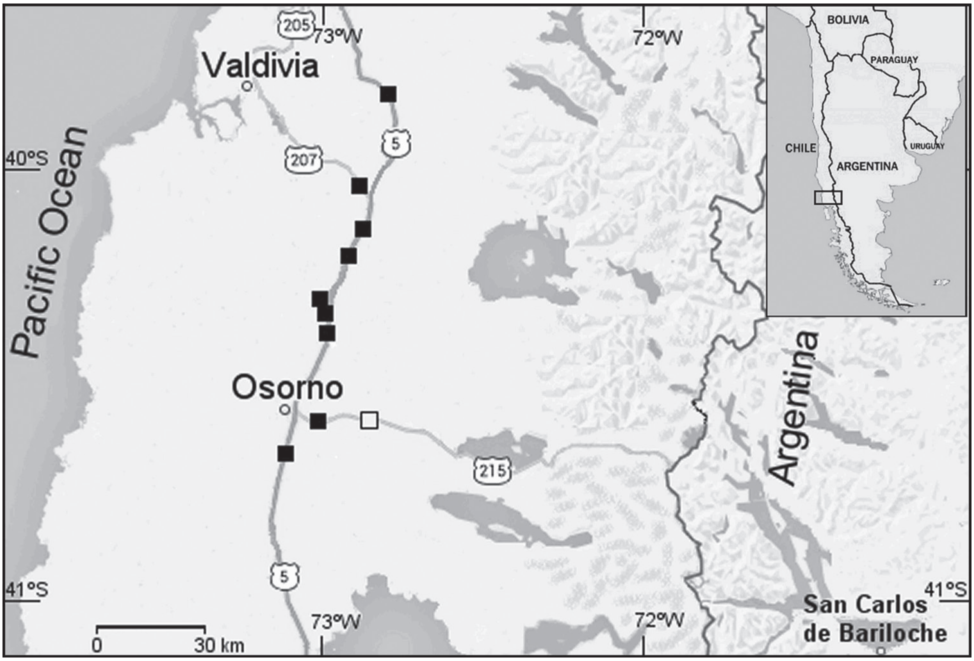


**Figure 1.** Map of southern Chile, illustrating the collection places of Common Barn Owl and Short-eared Owl specimens. Black squares- Common Barn Owl (n = 9), white square- Short-eared Owl (n = 1).

using MEGA 5.05. The consistency of topologies (nodal support) was estimated using a bootstrap approach with 1000 bootstrap replications (Felsenstein 1985). A Bayesian tree was determined using MrBayes v3.1.2 (Huelsenbeck and Ronquist 2001). The analysis was performed using two simultaneous runs of 1,000,000 generations, a random starting tree with four independent Markov chains (MCMC), and tree sampling every 500 generations. The evolutionary model selected for BI analysis was the GTR + $\Gamma$ + I. The first 25% of the generations were discarded as burn-in, and posterior probabilities were determined by constructing a 50% majority rule consensus for the remaining trees. The trees were visualized using FigTree ver. 1.3.1 (Rambaut 2009).

## Results

### Sequence divergence and phylogenetic relationship of common Barn Owl

The sequence alignment of the COI gene obtained had 582 positions in nine specimens of Common Barn Owl from southern Chile, and 12 representative sequences from other regions (one from Argentina, five from North America, two from Central America, two from northern Europe and two from Australasia) obtained from Genbank (http://www.ncbi.nlm.nih.gov/Genbank) (Table 1). For this alignment, five haplotypes, defined by 47 variable positions, were found (Figure 2a). In this align-

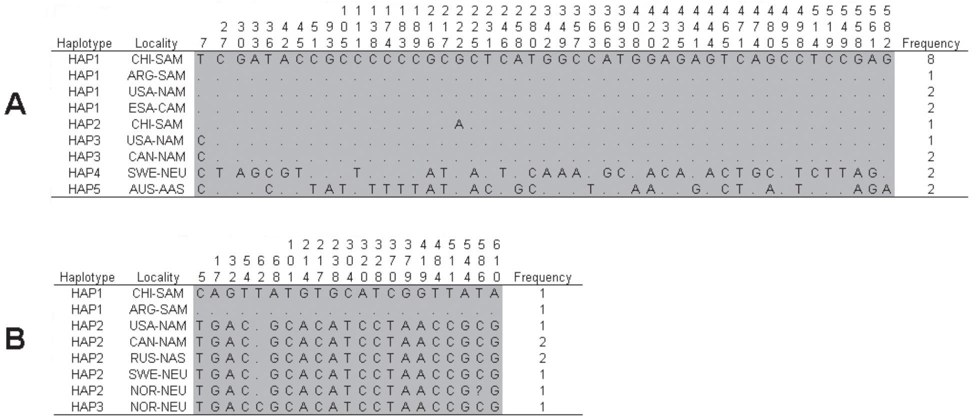
**Table 1.** List of all owl analysed in this study, with collection localities, coordinates and GenBank accession numbers of COI gene.

| Species | Locality (Country/Continent) | Locality abbreviation | Coordinates† (Lat., Long.) | Accession numbers‡ |
|---|---|---|---|---|
| *Tyto alba* | Chile/ South America | CHI-SAM | 40.60S, 73.04W | **KM377629** |
| *Tyto alba* | Chile/ South America | CHI-SAM | 40.08S, 72.87W | **KM377630** |
| *Tyto alba* | Chile/ South America | CHI-SAM | 40.29S, 72.97W | **KM377631** |
| *Tyto alba* | Chile/ South America | CHI-SAM | 40.41S, 73.00W | **KM377632** |
| *Tyto alba* | Chile/ South America | CHI-SAM | 40.35S, 72.99W | **KM377633** |
| *Tyto alba* | Chile/ South America | CHI-SAM | 40.29S, 72.94W | **KM377635** |
| *Tyto alba* | Chile/ South America | CHI-SAM | 40.18S, 72.91W | **KM377636** |
| *Tyto alba* | Chile/ South America | CHI-SAM | 39.84S, 72.81W | **KM377637** |
| *Tyto alba* | Chile/ South America | CHI-SAM | 40.69S, 73.13W | **KM377638** |
| *Tyto alba* | Argentina /South America | ARG-SAM | 41.11S, 70.37W | FJ028529 |
| *Tyto alba* | Canada/ North America | CAN-NAM | 49.10N, 121.57W | DQ434212 |
| *Tyto alba* | Canada/ North America | CAN-NAM | 49.05N, 123.05W | DQ434213 |
| *Tyto alba* | USA/ North America | USA-NAM | 25.48N, 80.38W | DQ433249 |
| *Tyto alba* | USA/ North America | USA-NAM | NA | JN850741 |
| *Tyto alba* | USA/ North America | USA-NAM | 21.97N, 159.33W | JF498906 |
| *Tyto alba* | El Salvador/ Central America | ESA-CAM | 13.44N, 89.05W | KM894402 |
| *Tyto alba* | El Salvador/ Central America | ESA-CAM | 13.44N, 89.05W | KM894403 |
| *Tyto alba* | Sweden/ northern Europe | SWE-NEU | 55.60N, 13.06E | GU572154 |
| *Tyto alba* | Sweden/ northern Europe | SWE-NEU | 55.65N, 13.14E | GU572155 |
| *Tyto alba* | Australia/ Australasia | AUS-AAS | NA | JN801466 |
| *Tyto alba* | Australia/ Australasia | AUS-AAS | NA | JN801467 |
| *Asio flammeus* | Chile/ South America | CHI-SAM | 40.60S, 72.88W | **KM377628** |
| *Asio flammeus* | Argentina/ South America | ARG-SAM | NA | FJ027172 |
| *Asio flammeus* | USA/ North America | USA-NAM | 21.31N, 157.95W | JF498831 |
| *Asio flammeus* | Canada/ North America | CAN-NAM | 60.43N, 135.04W | DQ433331 |
| *Asio flammeus* | Canada/ North America | CAN-NAM | 44.26N, 81.24W | DQ433330 |
| *Asio flammeus* | Sweden/ northern Europe | SWE-NEU | 59.20N, 18.12E | GU571744 |
| *Asio flammeus* | Norway/ northern Europe | NOR-NEU | 68.49N, 16.67E | GU571269 |
| *Asio flammeus* | Norway/ northern Europe | NOR-NEU | NA | GU571270 |
| *Asio flammeus* | Russia/ northern Asia | RUS-NAS | 51.38N,136.55E | GQ481380 |
| *Asio flammeus* | Russia/ northern Asia | RUS-NAS | 59.70N, 151.23E | GQ481381 |

†Coordinates are given in decimal degrees

‡GenBank Accession numbers in bold were sequenced in this study

ment, 46 positions were parsimony informative, and 45 out of 47 changes were synonymous. The best fit-model of nucleotide substitution was Tamura-Nei (TN93) with 2165.3 Akaike value and parameter estimates for base frequencies of A = 0.2494, T = 0.2403, C = 0.3292 and G = 0.1810, relative substitution rates of AC = 0.0130, AG = 0.2033, AT = 0.0094, CG = 0.0071 and CT = 0.1846, and proportion of invariables sites of 0.9192.



**A**

| Haplotype | Locality | 7 | 27 | 30 | 33 | 36 | 42 | 45 | 51 | 93 | 105 | 111 | 138 | 174 | 183 | 189 | 216 | 217 | 222 | 225 | 231 | 246 | 258 | 280 | 342 | 349 | 357 | 363 | 366 | 393 | 408 | 420 | 432 | 435 | 441 | 444 | 465 | 471 | 474 | 480 | 495 | 498 | 514 | 519 | 549 | 558 | 561 | 582 | Frequency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HAP1 | CHI-SAM | T | C | G | A | T | A | C | C | G | C | C | C | C | C | C | G | C | G | C | T | C | A | T | G | G | C | C | A | T | G | G | A | G | A | G | T | C | A | G | C | C | T | C | C | G | A | G | 8 |
| HAP1 | ARG-SAM | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 |
| HAP1 | USA-NAM | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 2 |
| HAP1 | ESA-CAM | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 2 |
| HAP2 | CHI-SAM | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | A | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 |
| HAP3 | USA-NAM | C | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 |
| HAP3 | CAN-NAM | C | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 2 |
| HAP4 | SWE-NEU | C | T | A | G | C | G | T | . | . | . | T | . | . | . | . | A | T | . | A | . | T | . | C | A | A | A | . | G | C | . | A | C | A | . | A | C | T | G | C | . | T | C | T | T | A | G | . | 2 |
| HAP5 | AUS-AAS | C | . | . | . | C | . | . | T | A | T | . | T | T | T | T | A | T | . | A | C | . | G | C | . | . | . | T | . | . | A | A | . | . | G | . | C | T | . | A | . | T | . | . | . | A | G | A | 2 |

**B**

| Haplotype | Locality | 5 | 17 | 32 | 54 | 62 | 68 | 101 | 214 | 217 | 238 | 304 | 320 | 328 | 370 | 379 | 419 | 484 | 511 | 544 | 586 | 610 | Frequency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HAP1 | CHI-SAM | C | A | G | T | T | A | T | G | T | G | C | A | T | C | G | G | T | T | A | T | A | 1 |
| HAP1 | ARG-SAM | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 |
| HAP2 | USA-NAM | T | G | A | C | . | G | C | A | C | A | T | C | C | T | A | A | C | C | G | C | G | 1 |
| HAP2 | CAN-NAM | T | G | A | C | . | G | C | A | C | A | T | C | C | T | A | A | C | C | G | C | G | 2 |
| HAP2 | RUS-NAS | T | G | A | C | . | G | C | A | C | A | T | C | C | T | A | A | C | C | G | C | G | 2 |
| HAP2 | SWE-NEU | T | G | A | C | . | G | C | A | C | A | T | C | C | T | A | A | C | C | G | C | G | 1 |
| HAP2 | NOR-NEU | T | G | A | C | . | G | C | A | C | A | T | C | C | T | A | A | C | C | G | ? | G | 1 |
| HAP3 | NOR-NEU | T | G | A | C | C | G | C | A | C | A | T | C | C | T | A | A | C | C | G | C | G | 1 |

**Figure 2.** Haplotype designation, variable nucleotide positions of COI gene sequence analysis, with the haplotype frequency observed in each locality. **A** Haplotypes of Common Barn Owls (n = 21) **B** haplotypes of Short-eared Owl (n = 10). Number refers to positions identified in the alignment. For all haplotypes, variable nucleotides are indicated while identity is indicated by slashes.

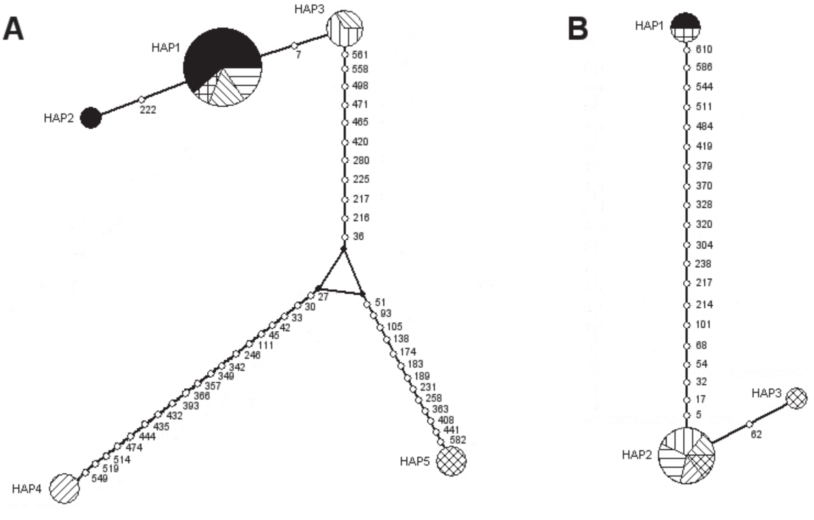


**Figure 3.** Unrooted haplotype network of COI gene sequence, based on a median-joining network for the Common Barn Owl and the Short-eared Owl. The area of each circle is proportional to the number of individuals containing the haplotype. Open circles indicate mutational events and numbers refer to the variable nucleotide positions. **A** Common Barn Owl; Solid black: Chile/South America; white with cross lines: Argentina/South America; white with forward diagonal lines: USA/ North America; white with horizontal lines: El Salvador/ Central America; white with vertical lines: Canada/ North America; white with backward diagonal lines: Sweden/ northern Europe; white with backward diagonal cross lines: Australia/ Australasia. **B** Short-eared Owl; Solid black: Chile/South America; white with cross lines: Argentina/South America; white with forward diagonal lines: USA/ North America; white with horizontal lines: Canada/ North America; white with backward diagonal lines: Sweden/ northern Europe; white with horizontal lines: Russia/ northern Asia; white with cross diagonal lines: Norway/ northern Europe.

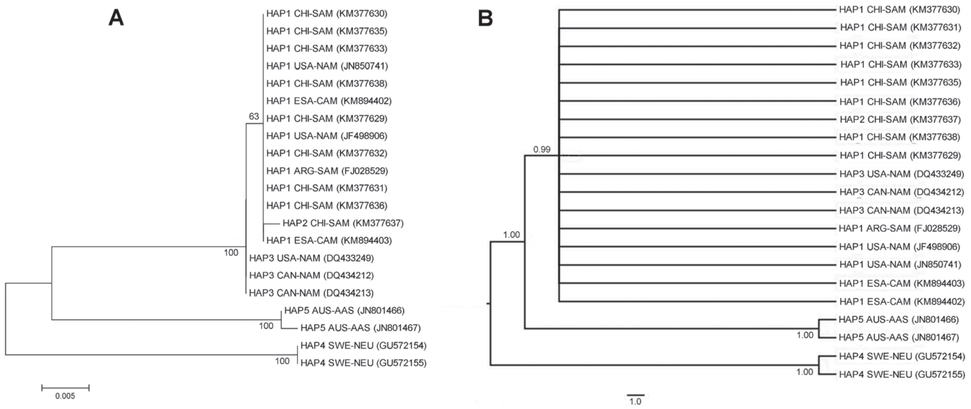


**Figure 4.** Phylogenetic estimate of relationships among specimens of the Common Barn Owl from different locations based on analysis of 582 bp of the mitochondrial cytochrome c oxidase subunit I gene (COI). The haplotype, locality and Genbank accession number (in parentheses) for each specimen are shown. The branch lengths are drawn proportional to the relative amount of volutionary change. Scale indicates the sequence divergence estimated from the number of nucleotide substitutions per site **A** Maximum likelihood tree with the bootstrap support (%) indicated for each node **B** Bayesian tree with the posterior probability values indicated for each node.

Five haplotypes for the Common Barn Owl specimens were observed, considering all studied localities, with haplotype 1 being exclusive to the New World (including Chile), and representing more than half of the individuals in the data set (61.9%) (Figure 3a). The remaining haplotypes were mostly restricted to a single locality, as were haplotypes 3, 4 and 5, of North America, northern Europe and Australasia, respectively. Of note is that haplotype 2 was exclusive to Chile.

The nine sequences of Common Barn Owl from Chile showed low levels of sequence divergence, ranging from 0 to 0.2% uncorrected p-value. Similarly, genetic divergence between Common Barn Owls from Chile and those from elsewhere in the New World was low, ranging from 0.0 to 0.2%. In contrast, genetic divergence between Common Barn Owls from Chile and those from northern Europe and Australasia was much higher, with p-values ranging from 4.6 to 5.5%. The ML tree showed a cluster of sequences from the New World (including Chile), with a clear separation of sequences from northern Europe and Australasia; this tree had nodes with high (100%) bootstrap values (Figure 4a). The BI tree showed a concordant topology, exhibiting high (0.99–1.00) posterior probability values for each node (Figure 4b).

## Sequence divergence and phylogenetic relationship of Short-eared Owl

The sequence alignment of the COI gene for Short-eared Owl had 611 positions in one specimen from Chile, and nine representative specimens from other regions (one from Argentina, four from North America, two from northern Europe and two from northern Asia) (Table 1). Three haplotypes, defined by 20 variable positions, were identified (Figure 2b). Moreover, in this alignment, 19 positions were parsimony informative, and 17 out of 20 changes were synonymous. The best fit-model of nucleotide substitution was Tamura-Nei (TN93) with 1871.5 Akaike value and parameter estimates for base frequencies of A = 0.2594, T = 0.2507, C = 0.3401 and G = 0.1498, relative substitution rates of AC = 0.0083, AG = 0.2110, AT = 0.0061, CG = 0.0036 and CT = 0.1591, and proportion of invariables sites of 0.9673.

Three haplotypes were found, with haplotype 1 (n = 2 individuals) being exclusive to Chile and Argentina, haplotype 2 (n = 5) exclusive to North America, northern Europe and northern Asia and haplotype 3 (n = 1) exclusive to northern Europe.

COI sequences from Chile and Argentina were identical. However, sequences from Chile/Argentina were highly divergent (3.1%) from those from North America, northern Europe and northern Asia. The ML and BI trees (results not shown) showed one cluster for specimens from Chile and Argentina and another cluster for specimens from North America, northern Europe and northern Asia.

## Discussion

The three major groups of Common Barn Owls inferred here by means of phylogenetic analysis of COI sequences (South America plus North America, Australasia and northern Europe) are similar to those identified in previous phylogenetic studies using other molecular markers (mitochondrial *cyt b* and nuclear *LDHb*) (Wink et al. 2004, Alaie and Aliabadian 2012). In particular, these studies observed a consistent separation between the New World and Old World Common Barn Owls. Moreover, this topology is in accordance with a recent study that used the COI sequence (Nijman and Aliabadian 2013), where strong evidence of a major divergence between New World (*furcata* clade) and Old World (*alba* clade) clades was found. The combined DNA evidence is consistent with the recognition of New and Old World Common Barn Owls as two different species (*Tyto furcata* and *Tyto alba*, respectively) as was originally proposed by König and Weick (2008). However, more extensive studies of morphological, molecular and acoustic divergence among New and Old World populations are highly desirable.

In addition, the genetic distance among the Common Barn Owls from Chile and northern Europe and Australasia, from 4.6 to 5.5%, is not surprising, given that previous studies have also documented high levels of sequence divergence among American and Old World populations of this species, ranging from 5.3 to 7.2% (Alaie and Aliabadian 2012, Nijman and Aliabadian 2013). Therefore, our results support the view that the Common Barn Owl shows strong genetic differentiation across its geographic range, in particular among populations from distant geographic areas.

With regard to the Short-eared Owl, the intraspecific divergence of 3.1% is in accordance with previous studies that also used the COI gene, which reported a maximum divergence of 3.3% for the species (Nijman and Aliabadian 2013) or a mean distance of 3.2% between a single specimen from Argentina and multiple specimens from North America, Europe and northern Asia (Kerr et al. 2009). The divergence between Short-eared Owls from (southern) South America and those sampled elsewhere is interesting and indicates that the taxonomic status of South American populations requires detailed taxonomic study. Again, this should include multiple lines of evidence, including morphology and acoustics, in addition to molecular data.

The levels of sequence variation observed for the Common Barn Owls and the Short-eared Owl from Chile compared to those from other continents was well above the mean intraspecific distance reported for bird species, which ranges from 0.23% to 0.43% (Aliabadian et al. 2009, Hebert et al. 2004, Kerr et al. 2007, 2009). These values are higher than any other owl species analysed so far using COI sequence data, given that in these it has been reported a value of average distance less than 2% (Nijman and Aliabadian 2013).

In previous studies, high levels of sequence divergence have often been interpreted as a possible taxonomic artifact, i.e. as an indication that more taxonomic study is warranted. For instance, Hebert et al. (2004) found four out of 260 species of North American birds with intraspecific divergence ranging from 3.7 to 7.2%, and Kerr et al. (2009), studying the birds of Argentina, observed 13 out of 389 species with sequence divergences exceeding 2.4%. In birds, disjunct ranges, differences in ecology, non-migratory behaviour and rapid speciation may be important factors associated with this phenomenon (Kerr et al. 2009). In the case of the Common Barn Owl, the existence of geographic barriers to gene flow among populations on different continents is to be expected, and this in combination with its non-migratory or short-distance migratory behaviour (Matics 2003), should contribute to promote the genetic divergence. However, all New World Common Barn Owls studied in this work were very similar given that no major genetic divergences were observed. This result agrees with Nijman and Aliabadian (2013), who found no latitudinal clusters for Common Barn Owl sequences from different places of America (North America, the Caribbean, northern South America and southern South America). Although further analysis with other molecular markers is needed to support this result; even so, it is likely that the scarce genetic variation of the Common Barn Owl registered across America may reflect the existence of a particular process of divergence.

In conclusion this study provides further evidence that the Common Barn Owl and the Short-eared Owl show high levels of intraspecific COI sequence divergence across their geographic range. The level of genetic differentiation of both species collected in South America was above the upper limit of species reported for Strigiformes, suggesting that further studies are needed to evaluate the taxonomic position of these populations.

## Acknowledgments

The suggestions and constructive comments of all those who helped to improve the final version of this manuscript are gratefully acknowledged, particularly, to the editor and two reviewers for their efforts that greatly improved the quality and clarity of the work. The English language editing of the manuscript by Susan Angus from the Dirección de Investigación of the Universidad de Los Lagos, is also appreciated.

## References

Alaie K, Aliabadian M (2012) Mitochondrial DNA (CYTB) divergences in two distinct, Old World and New World Barn Owls. Iranian Journal of Animal Biosystematics 8: 47–55.

Aliabadian M, Kaboli M, Nijman V, Vences M (2009) Molecular identification of birds: Performance of distance-based DNA barcoding in three genes to delimit closely related species. PLoS ONE 4: e4119. doi: 10.1371/journal.pone.0004119

Bandelt HJ, Forster P, Rohl A (1999) Median-joining networks for inferring intraspecific phylogenies. Molecular Biology and Evolution 16: 37–48. doi: 10.1093/oxfordjournals.molbev.a026036

Felsenstein J (1985) Confidence limits on phylogenies: An approach using the bootstrap. Evolution 39: 783–791. doi: 10.2307/2408678

Figueroa RA, Alvarado S, Corales ES, González-Acuña D, Schlatter R, Martínez DR (2014) Los búhos de Chile. In: Enríquez-Rocha P (Ed.) Los búhos neotropicales: diversidad y conservación, Ecosur, México, 163–267.

Figueroa RA, Rau JR, Mayorga S, Martínez DR, Corales S, Mansilla A, Figueroa R (2009) Rodent prey of the barn owl *Tyto alba* and short-eared owl *Asio flammeus* during winter in agricultural lands in southern Chile. Wildlife Biology 15: 129–136. doi: 10.2981/08-005

Hebert PDN, Ratnasingham S, DeWaard JR (2003) Barcoding animal life: Cytochrome c oxidase subunit 1 divergences among closely related species. Proceedings of The Royal Society B: Biological Sciences 270: S596–S599. doi: 10.1098/rsbl.2003.0025

Hebert PDN, Stoeckle MY, Zemlak TS, Francis CM (2004) Identification of birds through DNA barcodes. Plos Biology 2: 1657–1663. doi: 10.1371/journal.pbio.0020312

Huelsenbeck JP, Ronquist F (2001) MRBAYES: Bayesian inference of phylogenetic trees. Bioinformatics 17: 754–755. doi: 10.1093/bioinformatics/17.8.754

König C, Weick F (2008) Owls of the world. Second edition. Christopher Helm, London.

Kerr KCR, Lijtmaer DA, Barreira AS, Hebert PDN, Tubaro PL (2009) Probing evolutionary patterns in Neotropical birds through DNA barcodes. PLoS ONE 4: e4379. doi: 10.1371/journal.pone.0004379

Kerr KCR, Stoeckle MY, Dove CJ, Weigt LA, Francis CM, Hebert PDN (2007) Comprehensive DNA barcode coverage of North American birds. Molecular Ecology Notes 7: 535–543. doi: 10.1111/j.1471-8286.2007.01670.x

Matics R (2003) Direction of movements in Hungarian Barn Owls (*Tyto alba*): gene flow and barriers. Diversity and Distributions 9: 261–268. doi: 10.1046/j.1472-4642.2003.00018.x

Martínez DR, Figueroa RA, Ocampo CL, Jaksic F (1998) Food habits and hunting ranges of Short-eared Owl (*Asio flammeus*) in agricultural landscapes of southern Chile. Journal of Raptors Research 32: 111–115.

Nijman V, Aliabadian M (2013) DNA Barcoding as a Tool for Elucidating Species Delineation in Wide-ranging Species as Illustrated by Owls (Tytonidae and Strigidae). Zoological Science 30: 1005–1009. doi: 10.2108/zsj.30.1005

Rambaut A (2009) FigTree, ver. 1.3.1. http://tree.bio.ed.ac.uk/software/figtree/ [5.05.15]

Raimilla V, Rau JR, Muñoz-Pedreros A (2012) Estado de arte del conocimiento de las aves rapaces de Chile: situación actual y proyecciones futuras. Revista Chilena de Historia Natural 85: 469–480. doi: 10.4067/S0716-078X2012000400009

Ratnasingham S, Hebert PDN (2007) BOLD: The Barcode of Life Data System (www.barcodinglife.org). Molecular Ecology Notes 7: 355–364. doi: 10.1111/j.1471-8286.2007.01678.x

Rau JR, Villagra MC, Mora ML, Martínez DR, Tillería MS (1992) Foods habit of the Short-eared Owl (*Asio flammeus*) in southern South America. Journal of Raptors Research 26: 35–36.

Taggart JB, Hynes RA, Prodohl PA, Fergusson A (1992) A simplified protocol for routine total DNA isolation from salmonid fishes. Journal of Fish Biology 40: 963–965. doi: 10.1111/j.1095-8649.1992.tb02641.x

Tamura K, Peterson D, Peterson N, Stecher G, Nei M, Kumar S (2011) MEGA5: Molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. Molecular Biology and Evolution 28: 2731–2739. doi: 10.1093/molbev/msr121

Weick F (2006) Owls (Strigiformes). Annotated and illustrated checklist. Springer, Berlin.

Wink M, Sauer-Gürth H, Fuchs M (2004) Phylogenetic relationships in owls based on nucleotide sequences of mitochondrial and nuclear marker genes. In: Chancellor RD, Meyburg B-U (Eds) Raptors Worldwide, WWGBP, Berlin, 517–526.

## Supplementary material 1

**Pictures of external morphology of specimens of *Tyto alba* and *Asio flammeus* collected in southern Chile**

Authors: Nelson Colihueque, Alberto Gantz, Jaime Ricardo Rau, Margarita Parraguez

Data type: Specimens data

Explanation note: Pictures of ventral and dorsal views of specimens showing plumage color and overall appearance. Data on body mass of these specimens are also provided.