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# A new species of *Metacyclops* Kiefer, 1927 (Copepoda, Cyclopidae, Cyclopinae) from the Chihuahuan desert, northern Mexico

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## Abstract

A new species of the freshwater cyclopoid copepod genus *Metacyclops* Kiefer, 1927 is described from a single pond in northern Mexico, within the binational area known as the Chihuahuan Desert. This species belongs to a group of *Metacyclops* species with a 3443 spine formula of swimming legs. It is morphologically similar to *Metacyclops lusitanus* Lindberg, 1961 but differs from this and other congeners by having a unique combination of characters, including a caudal rami length/width proportion of 3.5–3.8, a innermost terminal seta slightly longer than the outermost terminal seta, intercoxal sclerites of legs 1-4 naked, a strong apical spine of the second endopodal segment of leg 1 and one row of 6-8 small spinules at the insertion of this spine. The finding of this species represents also the first record of the genus in Mexico and the third in North America, where only two other species, *M. gracilis* (Lilljeborg, 1853) and *M. cushae* Reid, 1991 have been hitherto reported. This is also the first continental record of a species of *Metacyclops* from an arid environment in the Americas. This species appears to be endemic to the Chihuahuan Desert, thus emphasizing the high endemicity of this area.

**Keywords**
Arid environments, Cyclopoida, freshwater zooplankton, inland water crustaceans, copepod taxonomy

## Introduction

The freshwater copepod genus *Metacyclops* Kiefer, 1927 was revised by Herbst (1988), who recognized 47 species. Many species have been added from investigations in different regions of the world (Brancelj 1987, Reid 1987, 1991, Herbst 1990, Rocha 1994, Galassi and Pesce 1994, Pesce et al. 1996, Karanovic 2004a) and the genus is currently known to contain more than 62 nominal species and subspecies (Dussart and Defaye 2006). In the Americas, the genus is represented by 24 species, most of them occurring in Central and South America; it appears to be quite less diverse in North America, where only two species have been recorded: *Metacyclops gracilis* (Lilljeborg, 1853) from Minnesota (Herrick 1895), Maryland (Wilson 1932), and a cave in Texas (Davis 1979), and *M. cushae* Reid, 1991 (Reid 1991) from a temporary pool in New Orleans Parish, Louisiana. It is probable that the diversity of the genus in North America could be underestimated as result of inadequate sampling of suitable non-planktonic habitats and because of the exclusion of the genus from regional keys (Reid 1991, Dussart and Defaye 2006, Gaviria and Aranguren 2007, J. Reid pers. comm.).

Lindberg (1961) separated the genus into two distinct groups: 1) the "*minutus-planus*" group with one spine on the third endopodal segment of the fourth leg and 2) the "*gracilis-mendocinus*" group with two such spines. Recent taxonomic works (Herbst 1988, Reid 1987, 1991, Fiers 2001, Karanovic 2004a, 2004b) recognize four groups based on the spine formula of the terminal exopodite segment of legs 1-4 (designated as spine formula of legs 1-4). The first group, with a 3443 spine formula contains 52 of the 62 species of the genus. The second (3442) and third (3433) groups each contain one species, *M. mortoni* Pesce, De Laurentiis and Humphreys, 1996 and *M. cushae* Reid, 1991, respectively. The fourth group among the species of *Metacyclops* is the *trispinosus*-group, with a 3333 spine formula (Karanovic, 2004a, 2004 b). Karanovic (2004b) stated that the *trispinosus*-group is an easily recognizable group of species with an Eastern Gondwana connection (Africa, India, Australia, and New Zealand). Until recently, it contained 8 species but Karanovic et al. (2011) reallocated six of them in the new genus *Pescecyclops* (*Pescecyclops pilbaricus* [Karanovic, 2004], *P. laurentiisae* [Karanovic, 2004], *P. pilanus* [Karanovic, 2004], *P. arnaudi* [G. O. Sars, 1908], *P. monacanthus* [Kiefer, 1928] and *P. kimberlyi* [Karanovic, 2004] ), distinguished by the presence of three spines on the distal exopodal segment of all swimming legs, only one apical spine on the fourth leg endopod, and the absence of sexual dimorphism. Thus, *Metacyclops trispinosus* Dumont, 1981 and *M. margaretae* (Lindberg, 1938) are the only two species of the *trispinosus*-group that were retained in the genus *Metacyclops.*

Karanovic (2004a, 2004b) stated that many morphological features in *Metacyclops* have an extreme range of variation, which raises the question as to its monophyly and taxonomic validity. It is highly possible that a more detailed examination of the fifth

leg, along with many other currently neglected characters will result in splitting the genus *Metacyclops* into several different genera. The recent work by Karanovic et al. (2011) included a cladistic analysis and a taxonomic revision of the Australian species. These authors formally recognized the "*Metacyclops* complex" and provided evidence to state that *Metacyclops* s. str. is polyphyletic in nature and that some species (like *M. cushae*) are closer to other genus than they are to *Metacyclops.*

Most of the surveys on the Mexican cyclopoid copepod fauna have dealt with the central and southern regions (Suárez-Morales and Reid 1998, Suárez-Morales et al. 2002). Recent research efforts in arid and semi-arid regions of Central and Northern Mexico (Dodson and Silva-Briano 1996, Mercado-Salas et al. 2006, 2009, Suárez-Morales and Walsh 2009; Mercado-Salas and Suárez-Morales 2009, 2011) indicate that the copepod fauna of these habitats is more diverse than previously thought and that it deserves further study. During a recent revision of zooplankton collections from arid areas of Northern Mexico, several specimens of cyclopoid copepods were identified as representing an undescribed species of *Metacyclops*. The significance of this finding is discussed in terms of currently known diversity and distributional patterns of the genus in the Americas.

## Methods

During the development of a project to estimate the diversity of cyclopoid copepods in arid and semi-arid regions of Mexico, zooplankton samples were collected between 1981 and 2009 in more than 500 water bodies from six states of Central and Northern Mexico (Aguascalientes, Chihuahua, Coahuila, Durango, San Luis Potosí, and Zacatecas). Samples were collected using a conical standard plankton net (250 mm diameter and 50 μm-mesh size) hauled near the shoreline of water bodies. The biological material was then fixed and preserved in 4% formalin solution. Copepods were sorted out from the original samples and then transferred to 70% ethanol with a drop of glycerine for long term preservation. Several female and male specimens of a cyclopoid copepod were collected from Coahuila in northern Mexico. These copepods were tentatively identified as *Apocyclops panamensis* (March, 1913). A second, closer examination of these specimens was performed in the laboratory and differences with respect to *A. panamensis* motivated a deeper analysis which revealed these specimens as members of *Metacyclops*. The taxonomically relevant characters of this genus were evaluated following Reid (1987, 1991), Herbst (1988), Rocha (1994), Karanovic (2004a, 2004b), and Karanovic et al. (2011). Specimens were processed for taxonomical examination following Reid and Williamson (2010). Three females were dissected and 10 females were prepared for SEM examination with a JEOL LV 5900 microscope at facilities of the Universidad Autónoma de Aguascalientes, Mexico. The SEM processing included dehydration in progressively higher ethanol concentrations (60, 70, 80, 96, 100%), drying, and gold coating following standard methods. All dissected specimens were mounted in semi-permanent slides with glycerine sealed with Entellan®, a commercial,

fast drying mounting medium and sealant. Scaled illustrations were done at 100X magnifications with a drawing tube mounted on a standard Olympus CX31 microscope. Type specimens were deposited in the collection of zooplankton held at El Colegio de la Frontera Sur, in Chetumal, Mexico (ECO-CH-Z) and in the Laboratorio de Ecología of the Universidad Autónoma de Aguascalientes, Mexico.

## Results

**Order Cyclopoida Rafinesque, 1815**
**Family Cyclopidae Rafinesque, 1815**
**Subfamily Cyclopinae Rafinesque, 1815**
**Genus *Metacyclops* Kiefer, 1927**

***Metacyclops deserticus* Mercado-Salas & Suárez-Morales, sp. n.**
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http://species-id.net/wiki/Metacyclops_deserticus
Figures 1–5

**Material examined.** Holotype. Adult ♀, specimen dissected, mounted in glycerin sealed with Entellan (ECO-CH-Z-08585). Allotype. Adult ♂, dissected and mounted in glycerin and sealed with Entellan (ECO-CH-Z-08586). Paratypes.15 adult ♀♀ specimens, undissected, ethanol-preserved, vial (ECO-CH-Z-08587). Original plankton samples containing several additional specimens, and the SEM-processed specimens are deposited in the collection of M. Silva-Briano, Laboratorio de Ecología of the Universidad Autónoma de Aguascalientes, Mexico. Samples from the type locality were collected by Alejandro Maeda-Martínez in October 10, 1981.

**Type locality.** Ephemeral pond at El Refugio bridge, Cerro Bola, Km 70, east of Torreón city, federal highway 40, Coahuila (25°35'02"N, 102°45'02"W). This pond is located in a desertic plain in the southwest margin of the ancient Laguna de Mayrán, a system which is part of the endorheic drainage of the Nazas and Parras rivers. The altitude of the type locality is about 1,100 meters above sea level and the average annual precipitation in the area is 200 mm. At the moment of sampling the surface area of the pond was about 55 meters long and 25 meters wide, the water had an average depth of 50 cm and 80 cm at its deepest point.

**Etymology.** The specific epithet makes reference to the arid habitat from which this species was collected. It was used to emphasize that it is the first American record from arid conditions.

**Descriptions.** *Female*: Habitus as in Fig. 1A (dorsal view) and Fig. 4A (lateral view). Length of holotype 0.87 mm from anterior end of cephalothorax to posterior margin of caudal rami (range=0.72–0.87 mm; mean=0.80 mm; n=9). Body robust, cephalothorax relatively long, slightly expanded laterally at midlength of cephalosome in dorsal view; lateral margins of pedigers 3 and 4 straight, produced posteriorly.

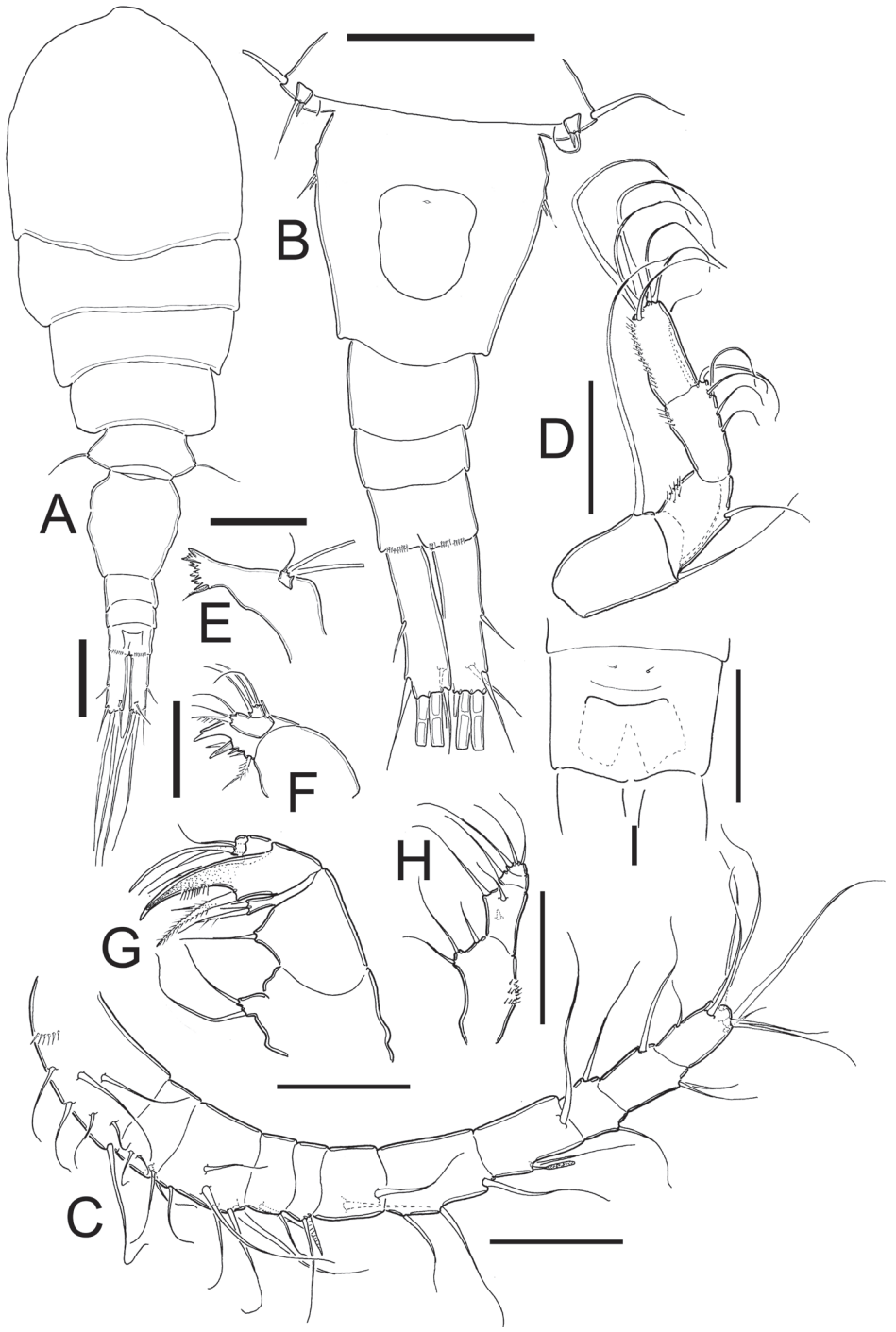


**Figure 1.** *Metacyclops deserticus* sp. n., female holotype from Coahuila, Mexico. **A** habitus, dorsal view **B** urosome, ventral view **C** antennule **D** antenna **E** mandible **F** maxillule **G** maxilla **H** maxilliped **I** anal operculum. Scales bars **A–B**= 100μm; **C–I**= 50 μm.

Cephalothorax length= 0.55 mm, representing 63% of total body length. Dorsal surface smooth, antennules not reaching distal margin of first pediger. Urosome (excluding caudal ramus) (Fig. 1B) representing 37% of body. Posterior margins of genital double-somite, free urosomites, and anal somite smooth both dorsally and ventrally. Relative length of each urosomite (proximal to distal) as: 65.4: 10.3: 10.3: 14.1=100. Genital double-somite (Fig. 5E) representing 17% of body length (excluding caudal rami), somite about 1.1 times longer than broad, with maximum width at proximal half; ventral and dorsal surfaces smooth. Anterior half of genital double-somite expanded laterally. Seminal receptacle with a reduced and narrow anterior part, posterior part rounded and expanding along the somite. Anal somite with distal rows of spines at insertion points of each caudal rami on ventral and dorsal margins. Anal operculum (Fig. 1I) slightly rounded and smooth.

*Caudal ramus* (Fig. 1B, 5F): Ramus representing 8.2% of total body length and 0.3 times as long as urosome. Length/width ratio= 3.5–3.8. Inner and outer margins smooth. Lateral caudal seta (II) inserted at 53% of total length of caudal rami. Outermost terminal seta (III) without ornamentation at point of insertion and 0.6–0.7 times as long as caudal ramus. Dorsal seta (VII) relatively short, 0.4–0.5 times as long as caudal ramus. Innermost terminal seta (VI) about 0.5 times as long as caudal ramus. Innermost terminal seta (VI) about 0.8–0.84 times outermost terminal seta (III). All terminal caudal setae plumose.

*Antennule* (Fig. 1C, 4A): 11-segmented in all specimens examined, armature per segment as follows (s=seta, sp= spine, ae=aesthetasc): 1(7s), 2(4s), 3(6s), 4(2s), 5(1s +1sp), 6(2s), 7(3s), 8(2s + 1ae), 9(2s), 10(3s), 11(7s). Antennule not reaching posterior margin of first thoracic somite.

*Antenna* (Fig. 1D, 4C): Four-segmented, basis without cuticular ornamentation, armed with long exopodal seta and two basipodal setae of different size, outer seta 1.6 times longer than inner seta. First endopodal segment with single outer seta and inner group of spinules. Second segment with 6 setae; inner margin with longitudinal row of spinules. Third endopodal segment with 6 terminal setae; inner margin with row of spinules.

*Mandible* (Fig. 1E)*:* Gnathobase with 7 strongly chitinized teeth and dorsal seta armed with inner row of spinules. Palp reduced, with 2 long and 1 short setae, the later not reaching half-length of former two.

*Maxillule* (Fig. 1F)*:* Precoxal arthrite with 3 strong chitinized claws and 2 spiniform setae on frontal side. Palp 2-segmented, proximal segment armed with 3 inner setae and outer exopodal seta. Distal segment of palp armed with 3 setae.

*Maxilla* (Fig. 1G)*:* Precoxa and coxa not fused; precoxal endite armed with two strong biserially setulated setae. Coxal surface naked, proximal endite well developed, with two subequal apical setae. Claw-like distal endite well developed, with row of 6 spinules and basal seta. Endopodite 2-segmented, proximal segment with 2 robust setae, distal segment with single seta.

*Maxilliped* (Figs. 1H, 4D): Four- segmented. Syncoxa with 3 spiniform setae along inner margin: proximal one without ornamentation at insertion, middle one

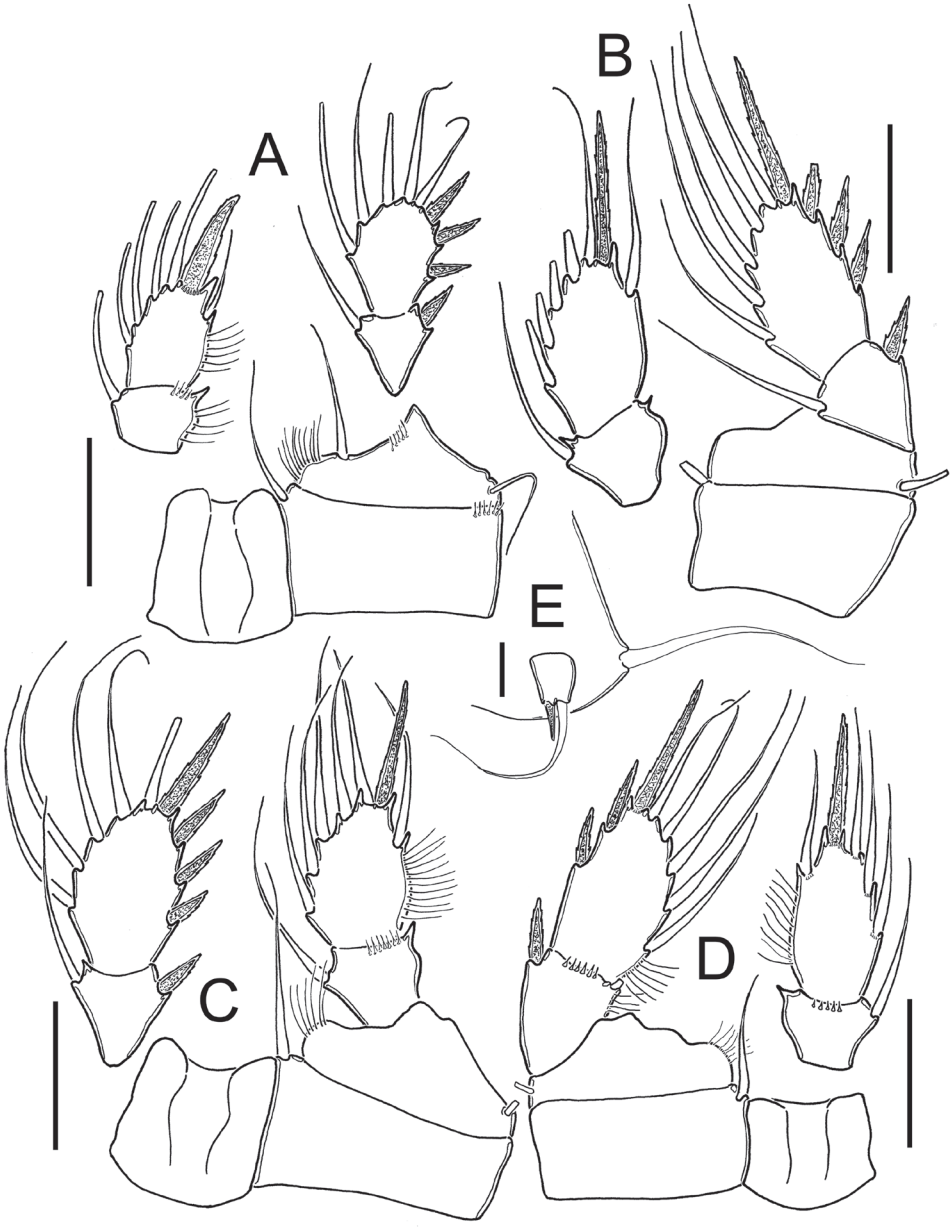


**Figure 2.** *Metacyclops deserticus* sp. n., female holotype from Coahuila, Mexico. **A** Leg 1 **B** Leg 2 **C** Leg 3 **D** Leg 4 **E** Leg 5. Scales bars **A–D**= 50 μm; **E**= 10 μm.

longest, more than twice as long as the other setae. Basis with 2 spiniform setae and transverse row of spines. Endopod reduced, 2-segmented, first segment with single lightly spinulate seta. Second endopodal segment armed with spiniform proximal seta and 2 slender setae.

*Legs P1-P4*: with naked intercoxal sclerites, distal margins with rounded projections. All endopodal and exopodal setae slender and plumose. Armature formula of all swimming legs as in Table 1.

*Leg 1*(Fig. 2A, 5A): Coxa with inner seta and transverse row of 6 spinules on distal outer margin. Basis with inner row of short setae and long slender basipodal seta, reaching middle margin of second endopodal segment, row of hair-like setules along inner margin, row of 5 spines adjacent to insertion of endopodal ramus. Endopod slightly shorter than exopodite. Apical spine of second endopodal segment strong, slightly longer than segment, with spinules at insertion point.

*Leg 2* (Fig. 2B): Coxa with inner seta . Basis with short slender seta on outer margin. Surface of coxa and basis smooth. Endopod slightly shorter than exopodite.

*Leg 3* (Fig. 2C)*:* Coxa with inner seta. Basis with outer seta. Surface of coxa and basis naked. Exopodite slightly longer than endopod.

*Leg 4* (Figs. 2D, 5B): Coxa and basis as in legs 2-3. Endopod shorter than exopodite. Second endopod about two times longer than wide (1.9), with apical spine shorter than bearing segment(0.8 times as long as segment). Spinules at insertion of all elements of second endopodal segment. Second exopodal segment with 2 outer spines and 1 apical spine with small spinules at insertion point.

*Leg 5* (Figs. 1B, 2E, 5C): Basal segment completely fused to somite, dorsal seta stout and plumose, about 1.4 times longer than outer seta of free segment. Free segment subrectangular, 1.2 times longer than wide, inner spine slightly shorter than bearing segment. Outer seta about 4 times longer than inner spine. Inner spine strong and smooth; outer seta plumose on distal half.

*Leg 6* (Figs 1B, 5D): Represented by small, low plate near lateral margin of genital double somite. Leg armed with relatively long plumose seta, and with 2 short, subequal smooth spines.

*Male*: Length of allotype 0.58 mm (excluding caudal ramus) (range=0.58–0.64 mm; mean= 0.61mm; n =2). Body slender than in female, cephalothorax relatively long, slightly expanded laterally at midlength of cephalosome in dorsal view; lateral margins of pedigers 3 and 4 straight, produced posteriorly. Cephalothorax length= 0.40 mm, representing 68% of total body length, dorsal surface smooth. Posterior margins of genital somite, free urosomites, and anal somite smooth ventrally (Fig. 3D) and dorsally. Ventral surface of anal somite smooth; distal ventral margin with rows of 13–15 spines at insertion point of caudal rami. Anal operculum (Fig 3G) slightly rounded, smooth.

*Caudal ramus* (Fig. 3D): Length of ramus 0.07 mm. Length/width ratio= 3.1–3.2. Inner and outer margins smooth, unornamented. Lateral apical seta (II) inserted al 52.3% of total length of caudal ramus. Outermost terminal (III) seta with small spinules at insertion and 0.7–0.8 times as long as caudal ramus. Dorsal seta (VII) longer than in females; about 0.7 times as long as caudal ramus. Innermost terminal seta (VI) 0.5 times as long as caudal ramus and. Innermost terminal seta (III) slightly shorter than outermost terminal seta (VI), III/VI ratio 0.78–0.9. All terminal caudal setae plumose.

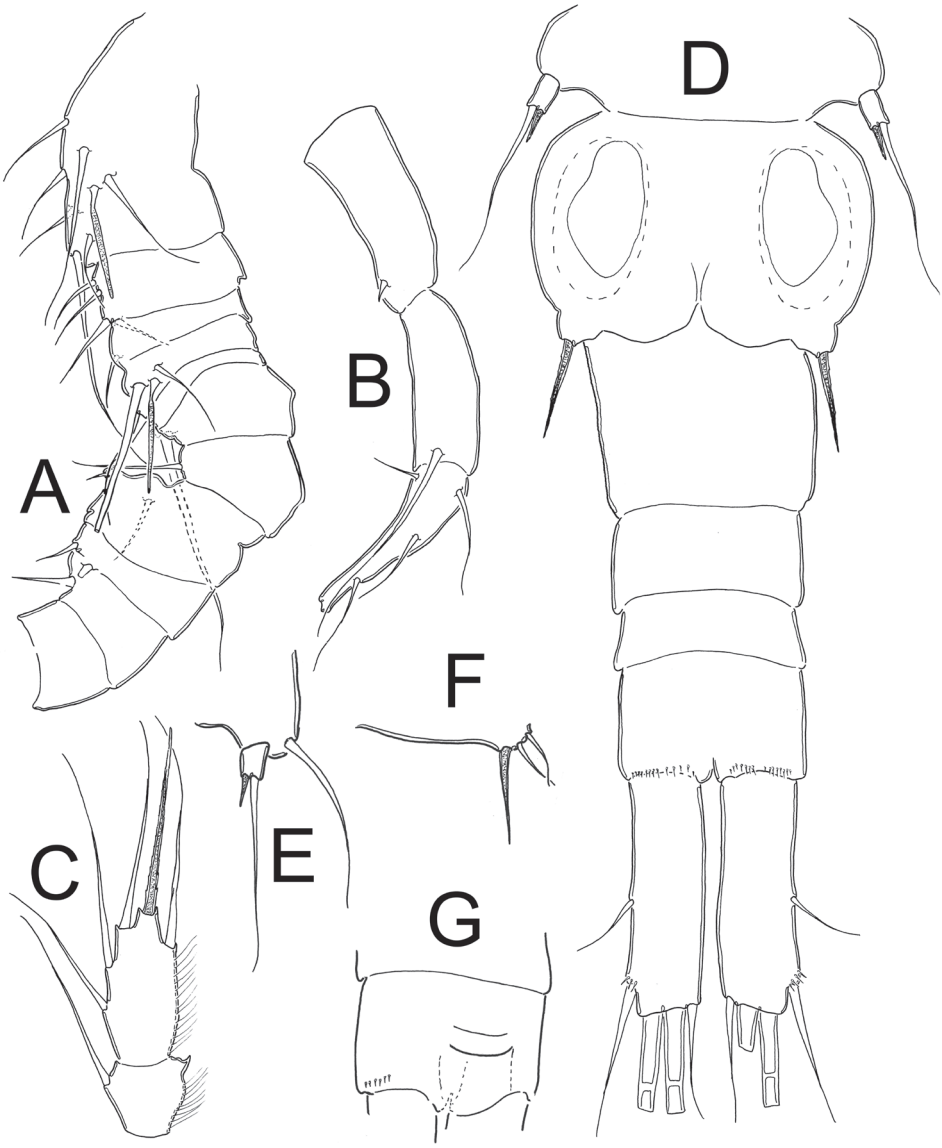


**Figure 3.** *Metacyclops deserticus* sp. n., male allotype from Coahuila, Mexico. **A** antennule (segments 1–11) **B** antennule (segments 12–14) **C** Endopod P4 **D** urosome **E** Leg 5 **F** Leg 6 **G** Anal operculum. Scales bars **A–G** = 50 μm.

*Antennule* (Fig. 3A–B): 14-segmented, geniculate, armature of segments 12, 13 and 14 not seen clearly (they could have more setae). Armature per segment as follows (s=seta; sp= spine ae= aesthetasc): 1(7s+1ae), 2(4s), 3(1s), 4(2s+1ae), 5(1s), 6(1s), 7(1s), 8(1s+ 1sp), 9(2s), 10(1sp), 11(0), 12(1sp), 13(1s), 14(4s).

**Table 1.** Armature of swimming legs 1–4 (spines in Roman numerals, setae in Arabic) of *Metacyclops deserticus* sp. n. Sequence follows external to internal positions.

| | coxa | basis | endopodite | exopodite |
|---|---|---|---|---|
| leg 1 | 0-1 | 1-1 | 0-1;1-I-4 | I-1;III-5 |
| leg 2 | 0-1 | 1-0 | 0-1;1-I-5 | I-1;IV-5 |
| leg 3 | 0-1 | 1-0 | 0-1;1-I-5 | I-1;IV-5 |
| leg 4 | 0-1 | 1-0 | 0-1;1-I-3 | I-1; III-5 |

Antenna, mouthparts and legs 1–3 as in female.

*Leg 4* (Fig. 3C): as in female except for relatively longer exopodite.

*Leg 5* (Fig. 3E): Basal segment completely fused to somite, dorsal seta stout, as long as outer seta of free segment. Free segment subrectangular, 1.5 times longer than wide, spine as long as segment, outer seta about 5 times longer than inner spine. Inner spine strong, smooth; outer seta plumose on distal half.

*Leg 6* (Fig. 3F): Represented by small, low plate near lateral margin of genital somite with relatively strong and long inner spine, two outer setae about the half of length of inner spine. Spine and setae smooth.

**Remarks.** The only two other species of the genus known to occur in North America, *M. cushae* Reid, 1991 and *M. gracilis* (Lilljeborg, 1853), are easily distinguishable from the new species. The former species belongs to the "Group C" (Karanovic 2004a, 2004b), with a 3433 spinal formula, being the only species in the group. *Metacyclops gracilis* belongs, like the new species, to Karanovic´s (2004a, 2004b) "Group A". The new species differs from *M. gracilis* mainly by its having of one apical spine on the second endopodal segment of leg 4, instead of two such spines present in *M. gracilis*.

Following the comprehensive key to the known species of *Metacyclops* (Herbst 1988), the new species was tentatively identified as *M. lusitanus* Lindberg, 1961 from Portugal because both share several characters including: 1) 11-segmented female antennules, 2) margins of all somites smooth, 3) one spine on the apical margin of the second endopodal segment of leg 4, 4) inner apical seta of caudal ramus shorter than the outer seta, 5) length/width proportion of caudal ramus (about. 4.0), 6) apical seta of fifth leg 4 times longer than the apical spine, and 7) apical spine of the second endopodal segment of leg 4 shorter than the segment. However, a closer examination showed several differences between these two species. In *M. lusitanus* the dorsal caudal seta (VII)/outermost terminal seta (III) length ratio (0.7) differs from that found in the new species (0.8). In addition, the length ratio of the outermost terminal seta(III)/innermost terminal seta (VI) of the caudal ramus differs between these species, in *M. lusitanus* it is 1.7 vs. 1.1 in the Mexican species. The length ratio of the basipodal seta/total length of endopod of leg 1 slightly differs in these species, this ratio being 0.9 in the *M. lusitanus* and 0.85 in the new species. Also, the apical spine of the second endopodal segment of leg 1 is clearly stronger in *M. deserticus* sp. n. than it is in *M. lusitanus* (see Lindberg, 1961, fig. 1b). *Metacyclops deserticus* sp. n. has 6-8 small spinules at the insertion of the apical spine whereas such ornamentation is absent in *M. lusitanus*.

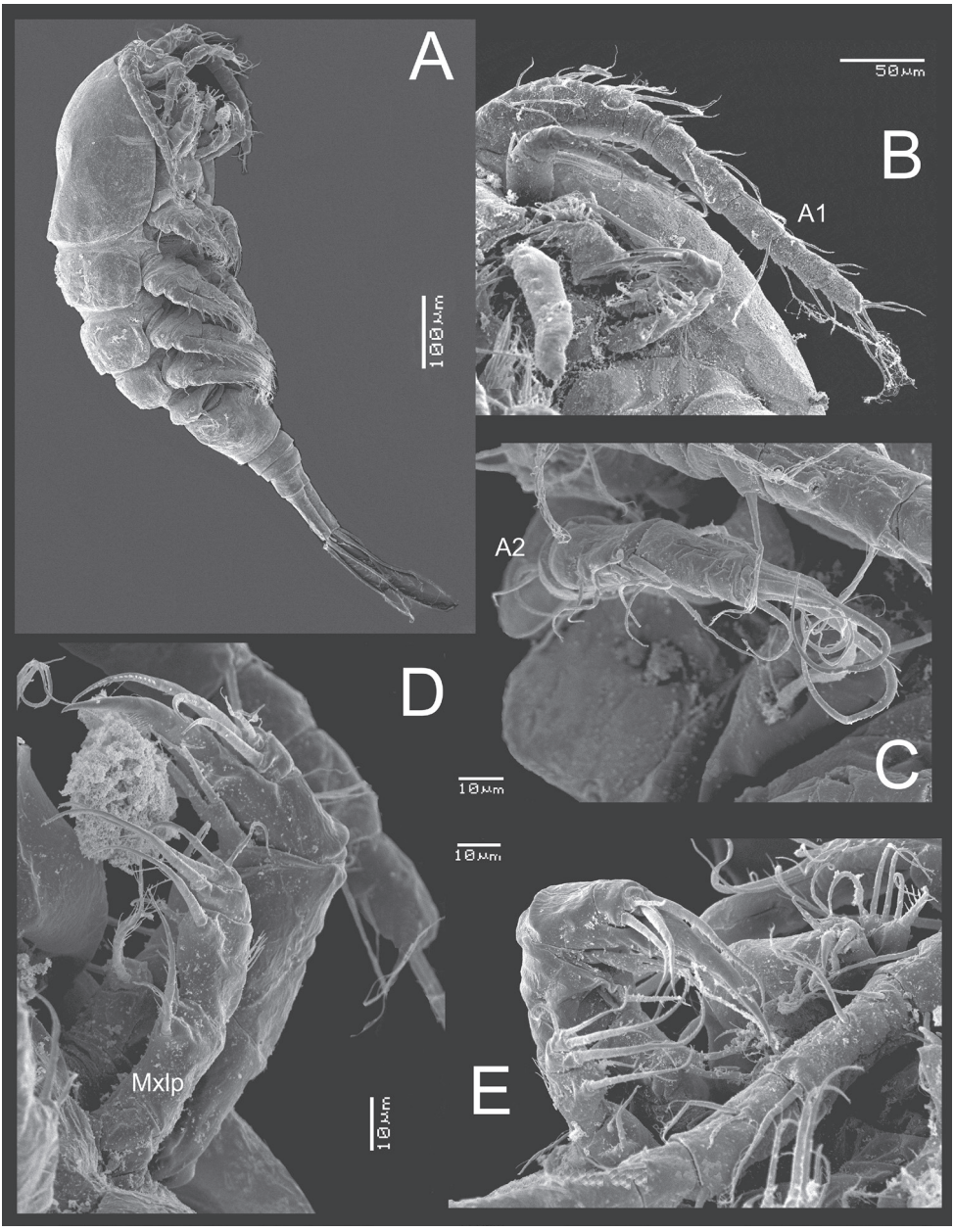


**Figure 4.** *Metacyclops deserticus* sp. n., SEM-processed female from Coahuila, Mexico. **A** habitus, lateral view **B** antennule **C** antenna **D** maxilliped (lateral view) **E** mouthparts.

We also followed Reid's (1987) key to the American species. Our specimens key down to *M. curtispinosus* Dussart, 1984. The new species shares several characters with *M. curtispinosus*, including 11-segmented antennules, also present in *M. agnitus* Herbst, 1988, *M. pectiniatus* Shen and Tai, 1964, *M. subdolus* Pesce, 1978, *M. hannensis*

Defaye, 1992, and *M. gasparoi* Stoch, 1987. All of them belong to Karanovic´s (2004a, 2004b) "Group A". The new species shares with *M. curtispinosus, M agnitus, M. pectiniatus, M. subdolus*, and *M. hannensis* the presence of an exopodal seta on antennal basis, clearly differing from *M. gasparoi* -which lacks the exopodal seta. The naked antennal basis of *Metacyclops deserticus* sp. n. is shared by *M. curtispinosus, M agnitus, M. pectiniatus,* and *M. subdolus* but *M. hannensis* bears a proximal row of spinules on the inner margin of the antennal basis.

Additional differences of the new species with respect to the American congeners include the length of the apical spine of the second endopodal segment of leg 1/length of segment ratio (1.2), vs. about 0.7 in *M. curtispinosus* and *M. agnitus* and about 0.9 in *M. subdolus, M. hannensis*, and *M. gasparoi.* In *M. deserticus* sp. n., *M. curtispinosus, M. subdolus*, and *M. gasparoi,* the length of the basipodal seta of leg 1 exceeds the medial margin of the second endopodal segment of leg, whereas in *M. hannensis* it exceeds the total length of the endopodite and in *M. agnitus* it is absent. All these species have naked coxal sclerites of legs 1–4.

The new species shares a similar length/width ratio of the second endopodal segment of leg4 with *M. curtispinosus*, *M. agnitus*, *M. pectiniatus*, and *M. subdolus* (range= 1.9–2.1), thus differing from the range reported for *M. hannensis* (1.6–1.7), and *M. gasparoi* (3.3). There are additional differences in the length ratio of the apical spine of leg 4 second endopodal segment/length of segment; *M. deserticus* sp. n. shares with *M. curtispinosus* (a value of about 0.7) whereas this value is different in *M. pectiniatus, M. subdolus* and *M. hannensis* (0.9), *M. agnitus* (1.1) and *M. gasparoi* (1.4). The length ratio of external seta of leg 4 second endopodal segment/length of apical spine, is about 0.8 in *M. deserticus* sp. n. and *M. curtispinosus,* thus differing from *M. gasparoi* and *M. hannensis* (0.9–1.1), *M. subdolus M. pectiniatus* and *M. agnitus* (1.2–1.3). An additional difference between these species is the shape of the inner margin of the leg 4 basis. In the new species but also in *M. curtispinosus, M. agnitus, M. pectiniatus*, and *M. hannensis* it is rounded *vs.* triangular- in *M. subdolus* and *M. gasparoi*.

In addition, the new species differs from its congeners in the length of the external seta of free segment of P5/ inner spine length ratio; in the new species, this ratio is 4.0, whereas it ranges between 2.9 and 3.1 in *M. subdolus* and between 5.0 and 5.7 in *M. hannensis, M. pectiniatus* and *M. agnitus.* In *M. gasparoi* this value is 6.6 and in *M. curtispinosus* it is about 8.0. The proportion between inner spine/length of segment of P5 is a character that also differs among these species. In *M. curtispinosus* the ratio is 0.3, in the new species it is about 0.8, in *M. hannensis* and *M. agnitus* the spine is as long as the segment, in *M. pectiniatus* and *M. gasparoi* it is about 1.3, in *M. subdolus* 1.5 times. Also the length proportion of the seta of fifth leg fused to the segment/outer seta of free segment represents a character that differs between species, in *M. gasparoi* it is 0.6, *M. hannensis* and *M. subdolus* have a proportion ranging between 0.8 and 0.9. *M. agnitus* and *M. curtispinosus* shares similar values (1.1–1.2) and both *M. pectiniatus* and the new species have a length ratio close to 1.4 (Herbst 1988, Pesce 1985, Lim and Fernando 1985, Pesce 1978, Defaye 1992, Stoch, 1987).

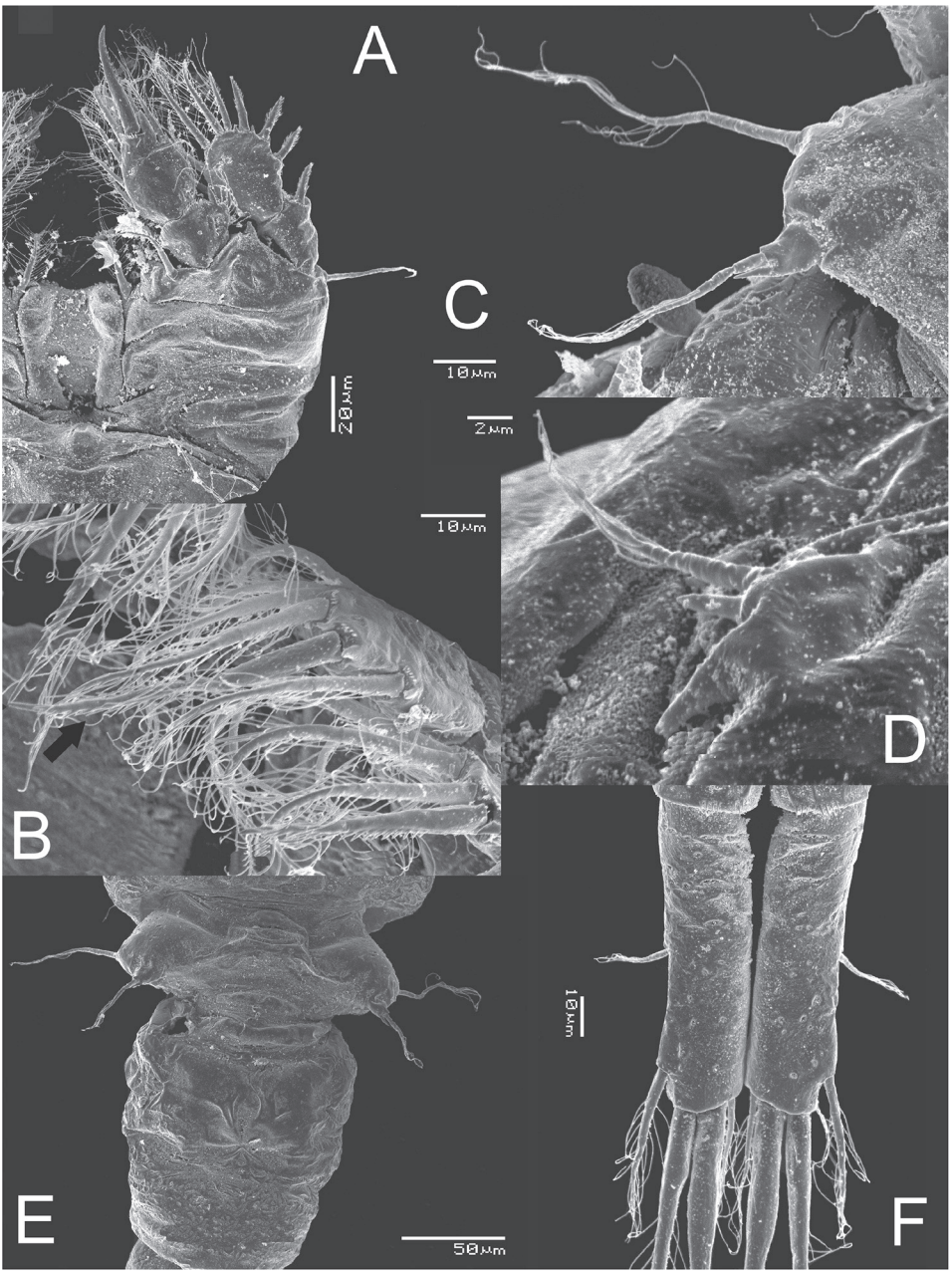


**Figure 5.** *Metacyclops deserticus* sp. n., SEM-processed female from Coahuila, México. **A** leg 1 **B** endopodite 2 leg 4 **C** leg 5 **D** leg 6 **E** genital double somite, ventral view **F** caudal ramus, ventral.

The length/width ratio of the caudal ramus also differs among these species, *M. curtispinosus* has relatively low value (2.4–2.8) that differs from those in *M. agnitus, M. pectiniatus*, and *M. hannensis* (3.2–3.4). *Metacyclops subdolus* has a wide range of variation

(2.9–3.4). The new species has a relatively longer caudal ramus (3.5–3.8), but it is shorter than in *M. gasparoi* (5.5–5.7). Another valuable character is the length ratio of innermost terminal seta/outermost terminal seta; we found two main groups for this character. In the first one the innermost terminal seta is shorter than the outermost terminal seta; this character is present in *M. agnitus* (0.5), *M. pectiniatus* (0.6), *M. hannensis* (0.7), and in the new species (0.8). In the second group the innermost terminal seta is longer than outermost terminal seta: *M. curtispinosus* (1.2), *M. subdolus* (1.5–1.7), and *M. gasparoi* (2.0). In addition, the length dorsal seta/length of caudal ramus ratio also separates two groups. In the first group, the dorsal seta is shorter than the ramus: *M. deserticus* sp. n. (0.4–0.5), *M. curtispinosus* and *M. hannensis* (0.7). In the second group the dorsal seta is longer than caudal ramus like in *M. gasparoi, M. agnitus* (1.1), and *M. subdolus* (1.8–2.1).

## Discussion

*Metacyclops deserticus* sp. n. from northern central Mexico represents the first new species of the genus *Metacyclops* described in this country and is also the third record for North America (Reid 1991, Reid and Williamson 2010). There is a previous record of *M. cushae* by Gutiérrez-Aguirre and Cervantes-Martínez (2013) from southeast Mexico (Chiapas State). Most of the known American species of *Metacyclops* occur in tropical environments of the Neotropical region, mainly in South America and only *M. cushae* and *M. gracilis* have been reported from the Neartic region (Dussart and Defaye 2006). All previous records of species of *Metacyclops* in the Americas are from tropical environments; the North American records are from marshes in Louisiana and the Everglades in Florida (Bruno et al. 2005, Reid 1991). The finding of this species from an arid environment in Mexico represents the first continental record of the genus from this kind of habitat (Dussart and Defaye 2006, Rocha 1994). Members of *Metacyclops* have been recorded from arid environments in other regions of the world like Australia, New Zealand and Africa; some of these species inhabit epigean systems but others are known from subterranean waters (Dussart 1977, Dumont 1981, Defaye 1992, Pesce et al. 1996, Karanovic 2004a, 2004b). According to Defaye (1992) species of *Metacyclops* usually inhabit small pools, wells and ponds rich in vegetation and organic material, and their presumed tolerance to high temperatures and salinities appear to predict a wider distribution in Africa and other places with arid conditions, now including the American desert systems.

The arid areas of north-central Mexico were formed between the Late Oligocene and Middle Miocene (30-20 MYA), and were part of a general trend toward a greater aridity resulting from climate changes associated to the intense volcanic activity and tectonics that characterized the Cenozoic. The Rocky Mountains, the Mexican and Central-American Plateaus, and the sierras Madre were formed as result of tectonic activity during Cenozoic. The formation of the Sierra Madre Occidental and Sierra Madre Oriental during the Eocene and continuing until the middle Miocene provided

a new barrier to the atmospheric flow. This barrier blocked the masses of warm, moist air from the Pacific Ocean and the Gulf of Mexico and caused a severe drought and desertification of the Mexican Plateau. The Mexican Plateau includes the states of Coahuila, Chihuahua, Zacatecas, Durango. The Miocene climate change segregated the species along latitudinal and longitudinal gradients, thus favoring radiation processes of some lineages (Devitt 2006). It has been suggested that some of these areas of Northern Mexico functioned as refugia during the Pleistocene glaciations, thus favoring local process of isolation-speciation of the aquatic biota (Bănărescu 1991, Suárez-Morales et al. 2010, Mercado-Salas et al. 2012).

The cyclopoid copepod fauna of arid areas of central-north of Mexico (Chihuahuan Desert) is currently represented by 39 species belonging to 12 genera. This binational zone is currently deemed as an area with a high endemicity; up to 20% of these species are endemic to these arid areas (Mercado-Salas et al. 2006, 2009, Mercado-Salas and Suárez-Morales 2009, 2011, Suárez-Morales and Walsh 2009, Suárez-Morales et al. 2010). The new species of *Metacyclops* appears to be endemic to the Chihuahuan Desert, thus incrementing the importance of this and other arid systems as refuges of an undescribed diversity that certainly deserves further study. Most interestingly, the type locality harbors at least three endemic crustacean species, the copepod *M. deserticus* and the large branchiopods anostraceans (fairy shrimps) *Branchinecta oterosanvicentei* Obregón-Barboza, Maeda-Martínez, García-Velazco and Dumont, 2002, and *Streptocephalus guzmani* Maeda-Martínez, Belk, Obregón-Barboza and Dumont, 1995.

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# Taxonomic revision of the Elephant Pupinid snail genus *Pollicaria* Gould, 1856 (Prosobranchia, Pupinidae)

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## Abstract

The status of species currently assigned to the Southeast Asian Elephant Pupinid snail genus *Pollicaria* Gould, 1856 is reassessed. Shell, radular and reproductive morphology are investigated and analysed with reference to karyotype patterns previously reported and to distribution patterns among the species. Six previously described species are recognised: *P. gravida* (Benson, 1856), *P. myersii* (Haines, 1855), *P. mouhoti* (Pfeiffer, 1862), *P. elephas* (Morgan, 1885), *P. crossei* (Dautzenberg & d'Hamonville, 1887) and *P. rochebruni* (Mabille, 1887). A new subspecies, *P. mouhoti monochroma* **ssp. n.**, is proposed and a dichotomous key to species is provided.

## Keywords

Systematics, Indochina, Gastropoda, land snail, Southeast Asia, anatomy

## Introduction

Land operculate snails of the family Pupinidae generally possess a pupoid shell shape and exhibit a wide range of shell height from 5–50 mm. Apart from size, their often distinctive shells can also be distinguished from other members of the Cyclophoroidea

by unique features of the genitalia, notably the long bursa copulatrix (Wenz 1938, Tielecke 1940). About 20 extant genera range from South Asia, East Asia to Southeast Asia, Melanesia, Micronesia and part of Australia (Solem 1959, Vaught 1989, Stanisic 1998, Stanisic et al. 2010). Fossil representatives are known from the European Cretaceous (Naggs and Raheem 2005) and British Eocene (Sandberger 1873). They generally occur in tropical forest and most commonly and abundantly in limestone areas. Fourteen pupinid genera have been recorded from Indochina (Kobelt 1902), including the very distinctive Elephant Pupinid genus *Pollicaria* Gould, 1856 which is endemic to the region.

Hitherto, nine nominal species of the *Pollicaria* have been described (Crosse 1885, Kobelt 1902, Gude 1921, Pain 1974). *Pollicaria*, as "*Hybocystis*", was first revised by Crosse (1885) and by Fischer (1885) who detailed the anatomy. Crosse (1885) recognized four species of *Pollicaria* and separated those species into two species groups, which are now unrecognized. Subsequently, two additional species were described from Vietnam (Dautzenberg and d'Hammonville 1887, Mabille 1887a). These six nominal species were revised by Kobelt (1902) and more recently Pain (1974). Relying solely on shell morphology, Kobelt (1902) placed *P. crossei* into synonymy with *P. rochebruni*. Pain (1974), partly followed Kobelt's classification but recognized only three species: *P. gravida* (Benson, 1856), *P. myersii* (Haines, 1855) and *P. elephas* (Morgan, 1885), placing *P. mouhoti* into synonymy with *P. myersii*. However, Pain's study was of limited value because it was based on an examination of few specimens and populations and did not examine the type specimens. Hence the true status of species still remains unresolved. Apart from the studies of Crosse (1885) and Fischer (1885) none of the subsequent studies on *Pollicaria* have used anatomical data or studied type material.

The large shell size (up to 50 mm in height) and distinctive yellow to orange body colour render *Pollicaria* very distinctive and easily recognizable, although some confusion might arise from the helicoid shape exhibited by juveniles. The fact that populations are often widely scattered and highly localized may account for their having been little studied and consequently poorly known (Crosse 1885, Kobelt 1902). Recently, karyotypic studies and preliminary allozyme analysis (Kongim et al. 2009, 2010, Panha unpub. data) have indicated that the species placed in synonymy by Kobelt (1902) and Pain (1974) should be recognized as distinct species.

Herein, we provide the first critical and comprehensive revision of *Pollicaria* based on a detailed morphological study of newly collected specimens and their comparison with type material.

## Materials and methods

Snails were collected and distributions recorded, mostly from limestone areas throughout Thailand, Laos, Vietnam and Peninsular Malaysia. Species identifications were made by comparison with type material, primarily at The Natural History Museum

(London), Muséum National d'Histoire Naturelle (Paris), and University Museum of Zoology Cambridge (Cambridge). Living snails were photographed before examining the external and internal morphological characters. Adult shells were measured for height, diameter and whorl number. Features of the genitalia were examined for between 5 to 10 individuals of each species. Radulae were extracted and examined using a Scanning Electron Microscope (JEOL, JSM-5410 LV), and radular teeth shape and formulae were described.

**Anatomical abbreviation:** The following anatomical terminology used in this study was modified from Fischer (1885), Wenz (1938), Tielecke (1940) and Cox (1964): an, anus; at, atrium; bc, bursa copulatrix; cm, columellar muscle; ct, cephalic tentacles; dg, digestive gland; e, eye spots; ft, foot; h, head-portion of spermatophore; k, kidney; lc, lung cavity; me, mantle edge; op, operculum; ov, oviduct; p, penis; pcd, pericardium; pg, prostate gland; rt, rectum; sg, seminal groove; sr, seminal receptacle; st, stomach; t, tail-portion of spermatophore; ts, testis; ut, uterus; ven, ventricle.

**Institutional abbreviation: NHMUK**, The Natural History Museum, London; **CUMZ**, Chulalongkorn University, Museum of Zoology, Bangkok, Thailand; **MNHN**, Muséum National d'Histoire Naturelle, Paris; **RBINS**, Royal Belgian Institute of Natural Sciences, Brussels, Belgium; **SMF**, Forschungsinstitut und Naturmuseum Senckenberg, Frankfurt, a.m.; **UMZC**, University Museum of Zoology Cambridge, Cambridge; **ZMA**, Zoologische Museum of Amsterdam, Amsterdam; **ZMB**, Zoologisches Museum of Berlin, Berlin; **ZMMSU**, Zoological Museum of Mahasarakham University, Thailand.

## Results of morphological studies

**Shell characters:** *Pollicaria* Gould, 1856 is distinguished from other closely related genera such as *Pupina* Vignard, 1829, *Pupinella* Gray, 1850 and *Raphaulus* Pfeiffer, 1856 by having greater shell size, a breathing device in the form of a shallow posterior angled groove, and with or without a parietal declining shoulder inside the peristome (Fig. 1D). *Pupina* and *Pupinella* have anterior (columellar) and posterior (sutural) canals, with the columellar canal slightly twisted in *Pupinella* (Fig. 1A, B); *Raphaulus* has a complete posterior tube (Fig. 1C). *Pollicaria* differs from *Tortulosa* Gray, 1847 (Fig. 1E) and *Schistoloma* Kobelt, 1902 (Fig. 1F) by having a pupoid shell shape, larger shell size that lacks either an anterior (peristomal) groove (Fig. 1E) or posterior groove (Fig. 1F) respectively.

**External features:** As recorded in the literature, *Pollicaria* was found to possess a yellow-orange to pale orange body, usually with dark orange cephalic tentacles (Fig. 2). Body colour variation within species appeared to be largely confined to patches of dark-brown or blackish spots spread across areas of the head and dorsal foot. Such variation may be present between different populations or can occur on different growth stages within populations.

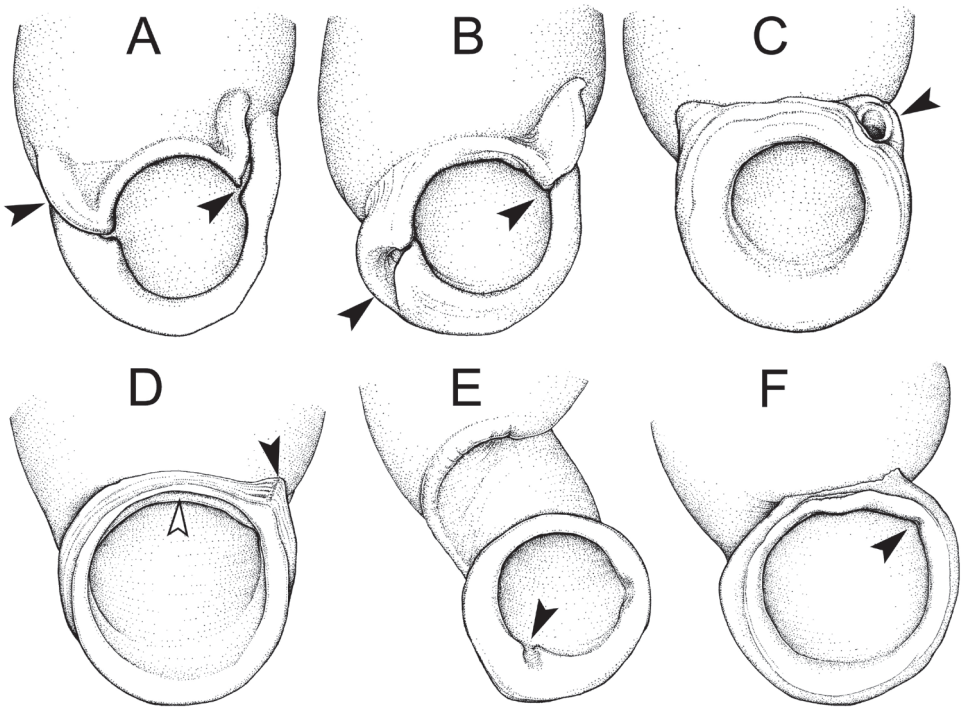


**Figure 1.** Breathing devices of six genera within the Pupinidae; black arrow indicates the position of breathing devices. **A** Anterior and posterior canals of *Pupina* **B** Anterior canal and twisted posterior canal of *Pupinella* **C** Complete posterior tube in *Raphaulus* **D** Shallow posterior angled groove of *Pollicaria,* white arrow indicates the parietal declining shoulder inside peristome **E** Anterior (peristomal) groove inside aperture of *Tortulosa* **F** Thin posterior groove inside aperture of *Schistoloma*.

The foot (ft) is broad and short; cephalic tentacles (ct) long with dark eye spots (e) located at outer base; snout broad. Animal dioecious; genital groove present at right side running downwards from pallial gonoduct. Male with conical external penis (p) on the right side (penis usually broad and enlarged in breeding season) located below cephalic tentacles, and with seminal groove (sg) on penis (Fig. 3A); female with only genital groove on the right side disappear external penis. Operculum (op) attached to opercular lobe or disk posterior-dorsally on foot (Fig. 3B).

No external anatomical features were found to exhibit useful taxonomic characters.

**Internal anatomy:** The internal anatomical description of *P. mouhoti mouhoti* collected form Tam Wungdang, Nern Maprang, Phitsanulok, Thailand serves as being representative of the genus. Kidney (k) a brownish lobule, constricted-triangular in shape. Heart located on the left side of kidney; pericardium (pcd) thin, atrium (at) slightly larger than ventricle (ven). Lung cavity (lc) with reticulated vessels. Stomach (st) embedded in dark brown lobulated digestive gland (dg). Rectum (rt) large, attached to genital apparatus (prostate gland or uterus), and tapering anteriorly to anus


**Figure 2.** Living snails. **A** *Pollicaria myersii* from Pahom, Vang Vieng, Laos (CUMZ 1572; shell height about 40 mm) **B** *Pollicaria mouhoti mouhoti* from Tam Wungdang, Phitsanulok (CUMZ 1533; shell height about 35 mm) **C** *Pollicaria mouhoti monochroma* ssp. n. from the type locality (paratype CUMZ 1548; shell height about 30 mm) **D** *Pollicaria elephas* from Ipoh, Perak, Malaysia (CUMZ 1536; shell height about 45 mm).

(an), which opens close to mantle collar edge. Mantle edge (me) smooth and slightly thickened. Columellar muscle (cm) large, broad, thickened and whitish (Fig. 3A–D).

Testis (ts) with branched tubules, bright orange, occupying around 2-3 whorls from apex. Vas deferens thin and slender-straight tube attached to prostate gland at around two-third of its length proximal to external penis. Prostate gland (pg) large, long and slender, pale yellowish; proximally with genital opening. Seminal groove (sg) small, distinct and connected from genital opening on the right side of snail to external penis. External penis (pen) digitiform, short, located posteriorly, below cephalic tentacles (Fig. 3A, C).

Ovary bright orange multi-lobulated gland embedded in digestive gland. Pale yellow oviduct (ov) extends from ovary to uterus (ut) near the base of seminal receptacle. Bursa copulatrix (bc) cream to whitish long pouch that receives and digests the spermatophore case. Uterus (ut) large, curved pea-pod shape, posterior end rounded and anterior end tapering with genital opening (Fig. 3D).

Spermatophore tadpole shaped, about 20 mm long. Anterior portion or head of spermatophore (h) is a swollen pouch with thickened wall that is packed with sperm. Posterior portion or tail (t) tapering to slender tube is about half of the total length (Fig. 3E).

Both male and female genital organs of all species except *P. gravida* were examined and no distinguishing species-level taxonomic characters were found.

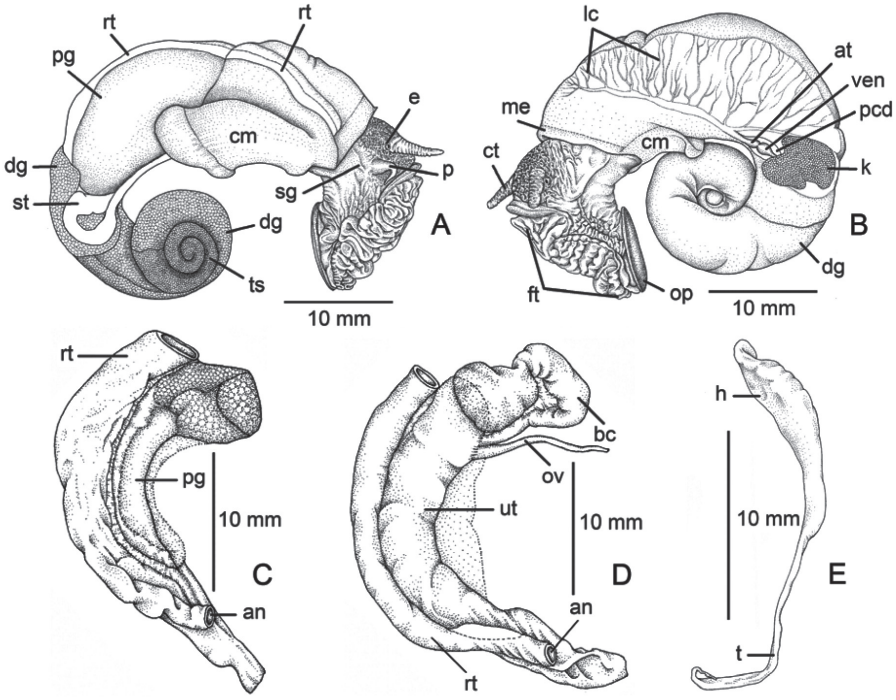


**Figure 3.** General anatomy, genitalia and spermatophore of *Pollicaria mouhoti mouhoti*. **A** Right side of snail showing male genital organ **B** Left side of snail showing pallial cavity and circulatory system **C** Male genital organ **D** Female genital organ **E** Spermatophore from uterus.

## Systematic account

### Family Pupinidae Pfeiffer, 1853

### Genus *Pollicaria* Gould, 1856

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

*Pollicaria* Gould, 1856: 14. Gould 1862: 221. von Martens 1867: 67. Stoliczka 1871: 150. Kobelt 1902: 288. Wenz 1938: 475.
*Hainesia* Pfeiffer, 1856b: 120 (part.).
*Hybocystis* Benson, 1859: 90. Blanford 1864: 460. Crosse 1885: 180. Fischer 1885: 174.

**Type species:** *Cyclostoma pollex* Gould, 1856: 14; by monotypy (see ICZN, 1999, Art. 68.3). The type species '*Cyclostoma pollex* Gould, 1856 [October]' is currently recognized as a junior subjective synonym of *Megalomastoma gravidum* Benson, 1856 [March].

**Note.** When describing his new species as *Cyclostoma pollex*, Gould (1856) simultaneously proposed the new generic name *Pollicaria* for this new nominal species. Gould also doubtfully included *Cyclostoma myersii* Haines, 1855 and *Cyclostoma chrysalis* Pfeiffer, 1852 in the *Pollicaria* Gould, 1856. Benson (1859) published a new generic name *Hybocystis* containing a single species from Burma *Megalomastoma gravi-*

*dum* Benson, 1856. Although Benson (1860) noted that *Hybocystis* was a junior subjective synonym of *Pollicaria* Gould, 1856, the name *Pollicaria* was widely overlooked prior to Kobelt's (1902) review of cyclophoroideans and both Wenz (1938) and Pain (1974) continued to mistakenly cite *Megalomastoma gravidum* Benson, 1856 as the type species. With only the doubtful inclusion of *Cyclostoma myersii* Haines, 1855 and *Cyclostoma chrysalis* Pfeiffer, 1852 in the original description of *Pollicaria*, the type species of *Pollicaria* was unequivocally fixed in the original publication by monotypy.

**Diagnosis.** Shell pupoid, small to large (shell height 35–50 mm), thickened and solid. Shell smooth or malleated sculpture from almost white to pale yellow, reddish brown and nearly black; periostracum generally thick. Whorls 5–7, last whorl expanded, body whorl distorted when adult; sutures weakly impressed. Aperture rounded, shallow to absent posterior angled groove; peristome continuous and thickened; lip duplicated and reflexed; umbilicus narrow. Operculum multi-lamellar calcareous plate. Radula taenioglossate with seven teeth in each transverse row.

**Keys to species and subspecies of the genus *Pollicaria* recognized in this study**

1 Peristome with declining shoulder inside peristome (Fig. 1A) ..... **2**
– Peristome without declining shoulder inside peristome (Fig. 1B) ..... **4**
2 Shell small (height < 35 mm) ..... **3**
– Shell large (height > 40 mm), shell ground colour brown to black, periostracum corneous ..... ***P. rochebruni***
3 Shell pale yellow ..... ***P. gravida***
– Shell bright orange ..... ***P. crossei***
4 Shell usually large (height > 40 mm) ..... **5**
– Shell small (height < 35 mm) to medium (35 < height < 40 mm), with bright orange, purple to black ..... **6**
5 Shell dark orange to pale orange, lip duplicated, dorsal part of last whorl pitted ..... ***P. elephas***
– Shell elongate pupoid, brown to red, periostracum thick corneous, lip expanded, dorsal part of last whorl malleated ..... ***P. myersii***
6 Spire and apex bright yellow to orange, shell medium (35 < height < 40 mm) ..... ***P. mouhoti mouhoti***
– Spire monochrome purple to black, shell small (height < 35 mm) ..... ***P. mouhoti monochroma* ssp. n.**

***Pollicaria gravida* (Benson, 1856)**
http://species-id.net/wiki/Pollicaria_gravida
Fig. 4A–E; Tables 1, 2

*Megalostoma gravidum* Benson, 1856 [March]: 229. Type locality: Moulmein. Hanley and Theobald 1870: pl. 7, fig. 1.

*Otopoma blennus* Benson, 1856: 231. Type locality: Moulmein.
*Cyclostoma pollex* Gould, 1856 [October]: 14. Type locality: Tavoy, British Burma. Gould 1862: 221.
*Hybocystis gravida*—Benson, 1859: 91. Pfeiffer 1860: 123, 124, pl. 35, figs 1–4. Blanford 1864: 460. Crosse 1885: 187–190, pl. 11, fig. 2. Fischer 1885: 174.
*Pollicaria gravida*—Stoliczka, 1871: 150. Sowerby 1878: Pupinidae, pl. 8, species 68. Kobelt 1902: 289, 290, fig. 65. Gude 1921: 191, fig. 29. Wenz 1938: 475, fig. 1213. Pain 1974: 174, pl. 6 fig. 7.
*Cyclostoma* (*Pollicaria*) *pollex*—Johnson, 1964: 129.

**Material examined.** Five shells in the type series of W.H. Benson, the specimen with similar shape, size and colour to the original description is designated here as the lectotype of *Megalomastoma gravidum* Benson, 1856 UMZC I.102935.A (height 32 mm, width 18 mm; Fig. 4A) and paralectotypes UMZC I.102935.B-E (4 shells, Fig. 4B); syntype of *Otopoma blennus* Benson, 1856 UMZC I.102930.A-B (2 shells, Fig. 4C).

Burma: NHMUK 79.9.1.5-6 (2 shells), Theobald colln. Acc. no. 1592 (2 shells), B.R. Lucus colln. Acc. no. 2351 (2 shells), Trechmann colln. Acc. no. 2176 (2 shells), 2 lots of E.R. Sykes collns. Acc. no. 1825 (1 shell and 2 shells); ZMA: R.v. Lennep colln. Acc. no. 1876 (1 shell); ZMB: Paetel colln. (1 shell), 2 lots of Dunker collns. (1 shell, 2 shells), Nevill colln. ZMB 20723 (2 shells). Farm Cave, Moulmein: NHMUK 88.124.863.4-5 (3 shells, Fig. 4D, E). Moulmein, Burma: NHMUK 71.9.23.193 (1 shell), 24.06.4.4 (2 shells), 1954.6.2.1231-1 (2 shells), H. Cuming colln. (4 shells), 2 lots of H.F./W.T. Blanford collns. Acc. no. 1944 (5 shells, 2 shells), T. Oldham colln. Acc. no. 1733 (2 shells); ZMA: Schepman colln. (1 shell). Unknown locality: NHMUK V.W. MacAndrew coll. (4 shells), H.E.J. Biggs colln. Acc. no. 2258 (2 shells), H. Cuming colln. (1 shell).

**Description. Shell.** Shell small for *Pollicaria*, pupoid, pale orange, yellow to white. Periostracum thin and transparent; shell surface smooth. Whorls 5–6; sutures moderately impressed; apex slightly inclined to right; spire short. Last whorl large about two-thirds of shell height, distorted and flattened in front. Aperture rounded with a shallow posterior angled groove. Peristome continuous, with distinct parietal declining shoulder internally. Lip thickened, little expanded, and margin moderately duplicated; umbilicus narrow. Operculum thick, calcareous, multispiral.

**Distribution.** Accepted records are confined to Burma: Moulmein, Damontha, Tavoy and Tenasserim (Benson 1856, 1859, Stoliczka 1871, Crosse 1885, Kobelt 1902, Gude 1921, Pain 1974). Records from Northern Vietnam of *P. crossei* and *P. rochebruni* are considered to be distinct species.

**Remarks.** *Otopoma blennus* Benson, 1856 and *Cyclostoma pollex* Gould, 1856 have long been considered as junior synonyms of *P. gravida* and this classification has been followed by a number of authors (Hanley and Theobald 1870, Sowerby 1878, Crosse 1885, Kobelt 1902, Pain 1974). Subsequently, *P. crossei* and *P. rochebruni* from Vietnam were also placed into synonymy with this species (see Pain 1974). However, examination of the type specimens of these three species (Figs 4A, B; 5D, F) dem-

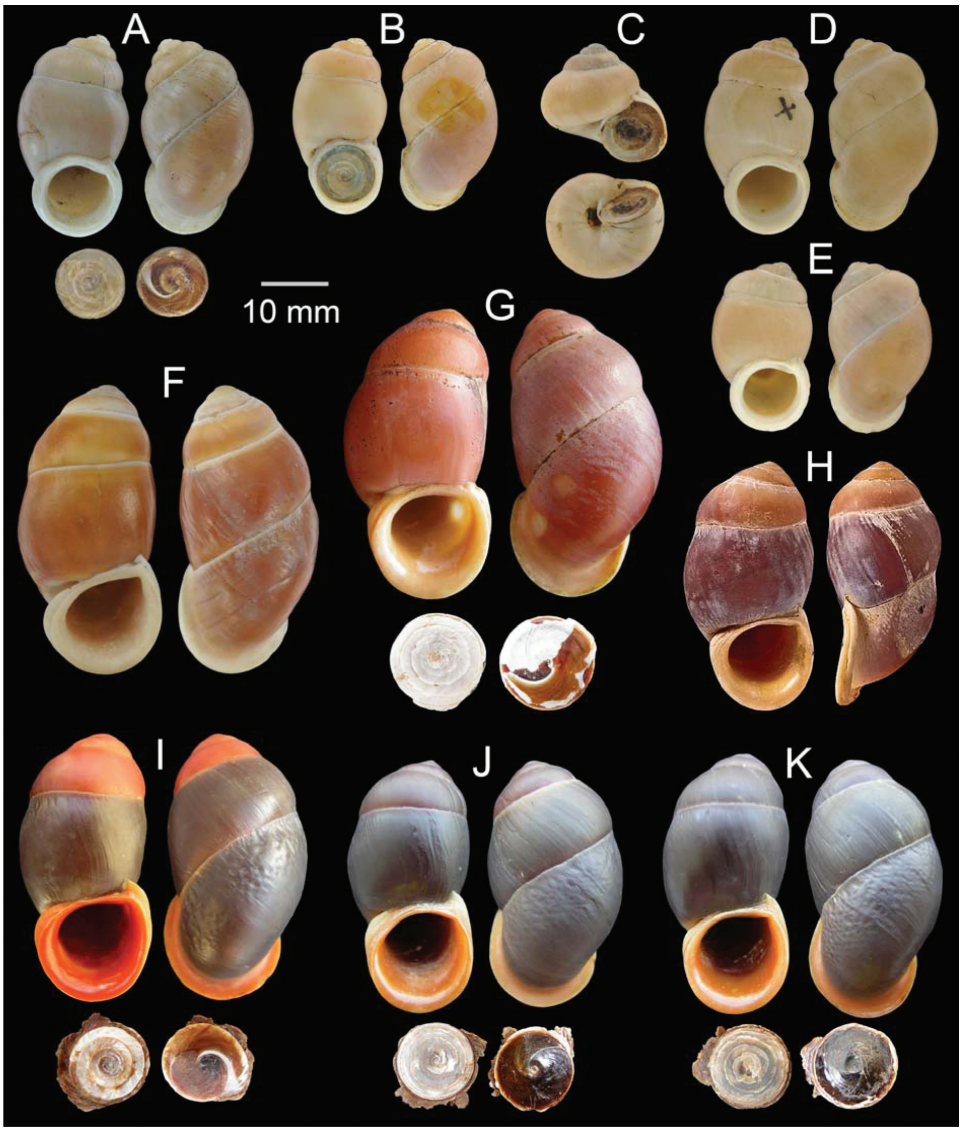


**Figure 4.** Shell morphology of *Pollicaria* spp. **A–E** *Pollicaria gravida* **A** lectotype UMZC I.102935.A **B** paralectotype UMZC I.102935.B-E **C** syntype of *Otopoma blennus* Benson, 1856 UMZC I.102930.A and **D, E** specimens from Farm Caves, Moulmein, Burma (NHMUK 88.124.863.4–5; specimen with 'x' was figured in Gude (1921), fig. 29) **F, G** *Pollicaria myersii* **F** form Siam (NHMUK 20090242; specimen figured in Pfeiffer, 1856a, pl. 19, figs 1, 2), and **G** specimen from Pahom, Vang Vieng, Laos (CUMZ 1572) **H, I** *Pollicaria mouhoti mouhoti* **H** lectotype (NHMUK 20130071/1), and **I** specimen from Tam Wungdang, Phitsanulok (CUMZ 1533) **J, K** *Pollicaria mouhoti monochroma* ssp. n. from the type locality, **J** holotype CUMZ 1577, and **K** paratype CUMZ 1548.

onstrated that *P. gravida* could be distinguished from *P. crossei* and *P. rochebruni* by having a whitish to yellowish shell colour with swollen whorls, impressed sutures and with the last whorl flattened ventrally (Table 1). Furthermore, *P. gravida* is mainly

**Table 1.** Comparative morphological characters and karyotype among *Pollicaria* species recognized in this study.

| Characters | *P. gravida* | *P. myersii* | *P. mouhoti* | *P. elephas* | *P. rochebruni* | *P. crossei* |
|---|---|---|---|---|---|---|
| Shell size (shell height) | small (height <35 mm) | large (height > 40 mm) | small to medium | large (height > 40 mm) | medium (35 < height > 40 mm) | small (height <35 mm) |
| Umbilicus | perforate | narrow | subumbilicate | narrow | narrow | narrow |
| Periostracum; shell colour | transparent; whitish to yellow | transparent; monochrome pale orange | transparent; monochrome black or with orange apex | transparent; yellow to orange | thicken corneous; reddish to orange | transparent; pale to deep orange |
| Sculpture on last whorl | absent | with thin wrinkle sculpture | with prominent wrinkle sculpture | with prominent wrinkle sculpture | absent | absent |
| Peristome shape; colour | rounded; as hell colour | slightly distorted; orange | slightly distorted; bright orange to reddish | rounded; as shell colour | rounded; as shell colour | rounded; as shell colour |
| Apertural groove | present | absent | absent | absent | present | present |
| Karyotype* | not available | 4m+6sm+2st+ 1t | 6m+4sm+2st+ 1t<br>7m+3sm+2st+ 1t | 2m+6sm+2st+ 3t | 3m+7sm+2st+ 1t | 2m+8sm+2st+ 1t |

* Data from Kongim et al. (2009, 2010); the chromosome morphology abbreviations: m, metacentric; sm, submetacentric; st, subtelocentric; t, telocentric.

**Table 2.** Shell size variation among *Pollicaria* species recognized in this study.

| Species, Locality and CUMZ nos. | Number of adult shell examined | Ranges, Mean ± SD in mm of: | | | Whorl ranges |
|---|---|---|---|---|---|
| | | Shell Height | Shell Width | h/d Ratio | |
| *Pollicaria gravida* | | | | | |
| UMZC and NHMUK collections | 14 | 24.7–34.3<br>29.8 ± 2.54 | 14.6–19.0<br>17.4 ± 1.58 | 1.65–1.82<br>1.71 ± 0.12 | 5¾-6¼ |
| *Pollicaria myersii* | | | | | |
| Pahom, Vang Vieng, Laos: 1520, 1572 | 10 | 37.8–50.6<br>43.4 ± 3.94 | 18.6–23.9<br>21.1 ± 1.68 | 1.97–2.16<br>2.06 ± 0.05 | 6¾-7 |
| *Pollicaria mouhoti mouhoti* | | | | | |
| Namnao N. P., Phetchabun: 1538, 1574 | 7 | 36.2–41.5<br>37.6 ± 1.74 | 18.4–21.6<br>19.6 ± 0.96 | 1.85–1.99<br>1.92 ± 0.05 | 6½ |
| Phu Kiew Wildlife Sanctuary, Chaiyaphum: 1551, 1528, 1529, 1571 | 65 | 33.6–44.1<br>37.7 ± 2.26 | 17.8–23.3<br>19.5 ± 1.20 | 1.86–2.14<br>1.94 ± 0.06 | 6–6¾ |
| Tam Wungdang, Phitsanulok: 1533, 1537 | 40 | 33.4–40.8<br>36.7 ± 1.81 | 17.6–21.2<br>19.0 ± 0.83 | 1.86–2.05<br>1.93 ± 0.05 | 6–6½ |
| Wat Pa-Mamuang, Phitsanulok: 1541 | 13 | 33.9–40.4<br>37.7 ± 2.12 | 18.4–20.2<br>19.6 ±0.78 | 1.82–2.04<br>1.92 ± 0.06 | 6–6½ |
| *Pollicaria mouhoti monochroma* ssp. n. | | | | | |
| Phu Phalom, Loei: 1547 | 23 | 31.1–42.6<br>38.2 ± 2.52 | 17.9–21.4<br>19.4 ± 0.97 | 1.55–2.15<br>1.98 ± 0.11 | 6–6½ |
| Tam Pha Bing, Loei: 1561, 1562 | 134 | 30.5–39.1<br>34.5 ± 2.09 | 16.4–20.6<br>18.4 ± 1.03 | 1.78–2.13<br>1.88 ± 0.05 | 5¾-6½ |
| Tam Pha Singh, Loei: 1543 | 33 | 29.6–37.9<br>33.8 ± 2.41 | 15.8–19.5<br>17.6 ± 1.03 | 1.71–2.00<br>1.92 ± 0.06 | 5¾-6¼ |
| Wat Tam Pha Poo, Loei: 1545 | 56 | 30.2–36.7<br>32.5 ± 1.37 | 16.1–19.3<br>17.2 ± 0.64 | 1.76–2.00<br>1.89 ± 0.05 | 5¾-6 |
| *Pollicaria elephas* | | | | | |
| Ampang Baru, Ipoh, Perak, Malaysia: 1535 | 51 | 36.4–51.1<br>43.9 ± 3.12 | 19.4–24.5<br>21.9 ± 1.31 | 1.85–2.12<br>2.01 ± 0.06 | 6–6¾ |
| Gunung Kenting, Ipoh, Perak, Malaysia: 1534, 1536, 1596 | 182 | 36.4–49.9,<br>42.3 ± 2.34 | 11.1–25.6<br>21.9 ± 1.64 | 1.78–3.79<br>1.4 ± 0.15 | 6–6¾ |
| *Pollicaria rochebruni* | | | | | |
| Cuc Phuong N. P., Vietnam: 1521, 1532 | 8 | 32.6–42.3<br>40.1 ± 2.26 | 18.1–22.9<br>20.6 ± 1.66 | 1.80–2.09<br>1.95 ± 0.11 | 6¼ |
| Phuong Nga N. P., Vietnam: 1523, 1539, 1552 | 5 | 37.8–45.0<br>40.8 ± 2.74 | 20.0–21.8<br>20.7 ± 0.71 | 1.89–2.07<br>1.97 ± 0.07 | 6¼-6¾ |
| *Pollicaria crossei* | | | | | |
| Cuc Phuong N. P., Vietnam: 1521, 1522, 1588 | 10 | 32.6–38.0<br>35.3 ± 1.74 | 17.6–18.9<br>18.9 ± 1.01 | 1.82–1.93<br>1.87 ± 0.06 | 6¼ |
| Hulien, Vietnam: 1590 | 5 | 32.7–36.2<br>34.9 ± 1.43 | 18.0–19.8<br>18.7 ± 0.07 | 1.82–1.93<br>1.87 ± 0.05 | 6¼ |

restricted to the western edge of the *Pollicaria* distribution in Tavoy and Tenasserim of Burma, and does not overlap with the two Vietnamese species in the east (Pain 1974). Unfortunately, none of the live specimens of *P. gravida* were examined cytogenetically for additional discrimination of these three species.

***Pollicaria myersii* (Haines, 1855)**
http://species-id.net/wiki/Pollicaria_myersii
Figs 2A; 4F, G; 6A; Tables 1, 2

*Cyclostoma* (*Megalostoma*) *myersii* Haines, 1855: 157, pl. 5, fig. 9–11. Type locality: Siam.
*Megalostoma myersi*—Pfeiffer, 1856a: 67, pl. 19, figs 1, 2.
*Megalostoma* (*Hainesia*) *myersi*—Pfeiffer, 1856b: 120.
*Megalostoma myersii*—von Martens, 1860: 11.
*Pollicaria myersi*—von Martens, 1867: 67. Sowerby 1878: Pupinidae, pl. 8, species 69. Kobelt 1902: 290.
*Hybocystis myersi*—Crosse, 1885: 191–193, pl. 11, fig. 4.
*Pollicaria myersii*—Habe, 1964: 114, pl. 2, fig. 13. Pain 1974: 175, 176, pl. 6, figs 2, 5.

**Material examined.** Siam: NHMUK 20090242 (Fig. 4F). Pahom, Vang Vieng, Laos: CUMZ 1531, 1572 (Fig. 4G), 1591; ZMMSU 0009.

**Description. Shell:** Shell large, reddish brown to light orange. Periostracum thin, corneous; shell surface usually with fine malleations on upper half of last whorl. Aperture almost circular with a shallow posterior angled groove. Peristome yellow, parietal declining shoulder absent. Lip thickened, broadly expanded, reflexed, with concentric margin.

**Radula:** Radular teeth arranged in v-shaped rows, each transverse row with 7 teeth (2-1-1-1-2). Central tooth with well developed central cusp and one smaller lateral cusp on each side; central cusp large, elongate with pointed tip. Lateral teeth with 2 cusps, outer cusp largest and elongate shape with pointed tip, and with relatively small pointed tip of inner lateral cusps. Inner and outer marginal teeth with 2 cusps; central cusp large, flanked by small inner lateral cusps.

**Distribution:** The type locality of this species was given as the broad location of "Siam" (see Haines 1855). Subsequently, *P. mouhoti* was synonymised with *P. myersii* (von Martens 1867, Pain 1974) thus expanding the distribution of *P. myersii* beyond its historical range. However, in this study the distribution of the species is restricted to limestone areas of Vientiane to Luang Prabang, Laos, and probably the northern part of Thailand.

**Remarks:** The syntype AMNH 43629 could not be traced (Siddal and Watson, personal communication). Due to the proximity of the geographic distributions and similarity in shell morphology of the two species, *P. mouhoti* have long been considered a junior synonym of *P. myersii* (see Pain 1974). However, *P. myersii* can be distinguished from *P. mouhoti* by an elongated purple to pale orange shell with thin periostracum, rounded aperture and very fine wrinkles on the dorsal part of the last whorl (Table 1, Fig. 4F, K). *P. myersii* differs from *P. gravida*, *P. rochebruni* and *P. crossei* by having a larger shell, no apertural groove and noticeable wrinkles on last whorl (Tables 1, 2).

***Pollicaria mouhoti* (Pfeiffer, 1862)**
http://species-id.net/wiki/Pollicaria_mouhoti

*Hybocystis mouhoti* Pfeiffer, 1862: 276, pl. 36, fig. 13. Type locality: Laos Mountain, Cambodia. Pfeiffer 1863: 227, 228, pl. 59, figs 5–8. Crosse 1885: 190,191, pl. 11, fig. 3.
*Megalostoma* (*Hybocystis*) *mouhoti*—von Martens, 1867: 67.
*Pollicaria mouhoti*—Sowerby, 1878: Pupinidae, pl. 8, species 67. Kobelt 1902: 290.

**Diagnosis.** Shell small to large, pupoid, solid; monochrome purple to black, sometimes with yellowish to bright orange spire. Periostracum thin; shell surface with distinct malleations on upper half of last whorl. Whorls 5-6; sutures moderately impressed; apex obtuse. Last whorl large about two-thirds of shell height, distorted and flattened in front. Aperture almost circular, shallow posterior angled groove present. Peristome and inside aperture orange to red; parietal declining shoulder absent. Lip thickened, expanded, reflexed, margin slightly duplicated; umbilicus narrow. Operculum calcareous concentric.

**Distribution.** The type locality of *P. mouhoti* was given as Laos Mountain, Cambodia. However, subsequent records of this species were from Thailand, Laos and Cambodia (Pfeiffer 1862, Crosse 1885, Kobelt 1902, Solem 1966).

**Remarks.** von Martens (1867) and Pain (1974) synonymised this species with *P. myersii* and stated that all *Pollicaria* specimens collected from Thailand should be regarded as this species. However, examination of the type specimens of *P. mouhoti* (Fig. 4H) showed that it was clearly distinct from *P. myersii* in shell shape, sculpture and colour pattern. The major distinguishing shell characters of *P. mouhoti* are the smaller shell size, purplish shell colour, bright orange spire, expanded bright orange to red apertural lip and bold wrinkles on the dorsal side of last whorl (Tables 1, 2). In addition, the chromosome analysis shows a clear difference in karyotype patterns between these two species (Kongim et al. 2009, 2010). Hence, *P. mouhoti* is removed from the synonymy of *P. myersii* and reinstated as a distinct species.

***Pollicaria mouhoti mouhoti* (Pfeiffer, 1862)**
http://species-id.net/wiki/Pollicaria_mouhoti_mouhoti
Figs 2B; 3A_E; 4H, I; 6B; Tables 1, 2

**Material examined.** Three syntype shells in H. Cuming collection, the figures and labels with type specimen are designated here as the lectotype of *Hybocystis mouhoti* Pfeiffer, 1862 NHMUK 20130071/1 (height 34.2 mm, width 18.1 mm; Fig. 4H) and paralectotype NHMUK 20130071/2-3 (2 shells). Cambodia: ZMA Wright colln. (2 shells), R.v. Lennep colln. (1 shell). Laos Mountain: ZMB Paetel colln. (1 shell). Phu Kradung, Loei: CUMZ 1586. Namnao National Park, Phetchabun: CUMZ 1574, 1538; ZMMSU 0002. Tam Yai Namnao, Phetchabun: CUMZ 1559. Phu Phaman, Khon Kaen: ZMMSU

0012. Phu Kiew Wildlife Sanctuary, Nongbuadang, Chaiyaphum: CUMZ 1528, 1529, 1551, 1571, 1576, 1582, 1585; ZMMSU 0003, 0020-4, 0027, 0029. Phu Phachit, Chaiyaphum: ZMMSU 0013. Tam Tao, Nernmaprang, Phitsanulok: CUMZ 1558. Tam Wungdang, Nernmaprang, Phitsanulok: CUMZ 1533 (Fig. 4I), 1537, 1544, 1554, 1575. Wat Pa Mamuang, Nernmaprang, Phitsanulok: CUMZ 1541; ZMMSU 0015. Wat Thepitakpunnaram, Pakchong, Nakhon Ratchasima: CUMZ 1583. Tam Pu Loop, Phuphaman, Khon Kaen: CUMZ 1526. Namprom Dam, Khon Kaen: CUMZ 1584.

**Description. Shell:** This nominotypical subspecies is characterized by the large shell size (Table 2). Shell with last whorl and penultimate whorl purple to black; first to third whorls distinct yellow to bright orange. Lip expanded, red to orange.

**Radula:** Taenioglossate radula, teeth arrangement with central, lateral and marginal teeth shape similar to *P. myersii*. Differences include a central tooth with well developed central cusp and lateral cusp on each side; lateral teeth triangular in shape with a pointed tip; inner marginal teeth composed of 3 cusps; central cusp flanked with small inner and outer lateral cusps.

**Distribution.** This subspecies occupies the southern limit of the species' range in Cambodia and several localities in Loei, Phitsanulok, Chaiyaphum, Khon Kaen, Phetchabun Nakhon Ratchasima and Saraburi Provinces in Thailand.

**Remarks.** The characters distinguishing this nominotypical subspecies from *P. myersii* are the smaller shell size and mainly purple coloured shell with whorls 2-3 pale to bright orange and bright orange to red lip (Tables 1, 2), and a distinct karyotype pattern (Kongim et al. 2009, 2010).

***Pollicaria mouhoti monochroma*** **Kongim & Panha ssp. n.**
http://species-id.net/wiki/Pollicaria_mouhoti_monochroma
Figs 2C, 4J, K; 6C; Tables 1, 2

**Type material.** Holotype: CUMZ 1577 (Fig. 4J; height 34.5 mm, width 18.4 mm, 6½ whorls) from the type locality, paratypes CUMZ 1548 (Fig. 4K; 9 shells), 1561 (82 shells), 1562 (85 shells); NHMUK 20130073 (5 shells); MNHN IM-2012-2103; SMF341492 (5 shells).

**Type locality.** Limestone outcrop with dry forest at Wat Tam Pha Bing, Wungsapoong District, Loei Province, Thailand (17°14'1.3"N, 101°44'3.5"E).

**Other material examined.** Phakeng-Phanang, Loei: ZMMSU 0025, 0026. Phu Luang Wildlife Sanctuary, Loei: CUMZ 1524. Phu Phalom, Muang, Loei: CUMZ 1547, 1560, 1565, 1567, 1580. Phu Phasamyod, Loei: ZMMSU 0011. Tam Erawan, Wungsapoong, Loei: CUMZ 1555, 1579. Tam Pha Bing, Wungsapoong, Loei: CUMZ 1548, 1561, 1562, 1577, ZMMSU 0001, 0004, 0006, 0017, 0028. Tam Pha Singh, Wungsapoong, Loei: CUMZ 1543, 1546. Wat Po Thi-sat, Nonghin, Loei: CUMZ 1557. Wat Tam Kuhawari, Nonghin, Loei: CUMZ 1540, 1549. Wat Tam Pha Mak-ho, Wungsapoong, Loei: CUMZ 1530, 1542. Wat Tam Pha Poo, Loei: CUMZ 1545, 1550. Wat Tam Piya, Loei: CUMZ 1527. Khao Wungpha, Nawung,

Nongbua Lumphoo: CUMZ 1563, 1564. Nawung, Nongbua Lumphoo: CUMZ 1581. Tam Suwankuha, Nongbua Lumphoo: ZMMSU 0007.

**Etymology.** From the Greek *monos* = one or single, and *chroma* = color of the skin; referring to the characteristic uniform dark brown to blackish spire color of the shell.

**Description. Shell:** Shell relatively small, pupoid, monochrome purple to black. Periostracum thin and transparent. Whorls 5-6; sutures moderately impressed; apex obtuse; spire short. Last whorl large about two-thirds of shell height, flattened in front. Shell surface rough with malleations on upper half of last whorl. Aperture almost circular, shallow posterior angled groove present; peristome continuous, yellow to pale orange. Lip thickened, broadly expanded; umbilicus narrow. Operculum thick, calcareous, concentric, exterior little concave.

**Radula:** Taenioglossate radula, teeth arrangement with central, lateral and marginal teeth shape similar to the nominotypical subspecies.

**Distribution.** *Pollicaria mouhoti monochroma* ssp. n. is restricted to the northern limit of the species' distribution in Loei, Phetchabun, Chaiyaphum and Nongbua Lumphoo Provinces.

**Remark.** *Pollicaria mouhoti monochroma* ssp. n. can be distinguished from the nominotypical subspecies by having a much smaller, entirely black to purple shell (Tables 1, 2) and a distinct karyotype pattern (see Kongim et al. 2009, 2010). The shell size and shape of this subspecies are similar to that of *P. gravida* and *P. crossei*, but the purple shell is a distinguishing characteristic.

Shell character variations can be observed in the Phu Pha Lom, Loei Province population. These individuals exhibit a relatively larger shell than the typical populations (Table 2), however, the monochrome black shell and similar karyotype pattern indicate that they belong to this subspecies (Kongim et al. 2009).

***Pollicaria elephas* (Morgan, 1885)**
http://species-id.net/wiki/Pollicaria_elephas
Figs 2D; 5A–C; 6D; Tables 1, 2

*Hybocystis elephas* Morgan, 1885b: 70. Type locality: Perak. Morgan 1885a: 404, 405, pl. 7, fig. 1. Crosse 1885: 183–186, pl. 11, fig. 1. Fischer 1885:174. Möllendorff 1886: 314. Möllendorff 1891: 346. Kobelt and Möllendorff 1899: 137.

*Hybocystis jousseaumei* Morgan, 1885b: 70. Type locality: Kinta, Perak. Morgan 1885a: 405, 406, pl. 7, fig. 2. Crosse 1885: 184.

*Pollicaria elephas*—Kobelt, 1902: 289. Laidlaw 1928: 33. van Benthem Jutting 1960: 12. Pain 1974: 176, pl. 6, fig. 1, 3. Abbott 1989: 46, 1 figure. Chan 1997: 11, fig. 1–2.

**Material examined.** Five lots with 13 specimens of syntype deposited in MNHN, the specimen figured in the original publication is designated as the lectotype of *Hybocystis elephas* Morgan, 1885 MNHN 21309 (Fig. 5A), paralectotype MNHN 21310 (5 shells), 21311 (2 shells), 21312 (3 shells), 21313 (2 shells), RBINS 525391 (1 shell).

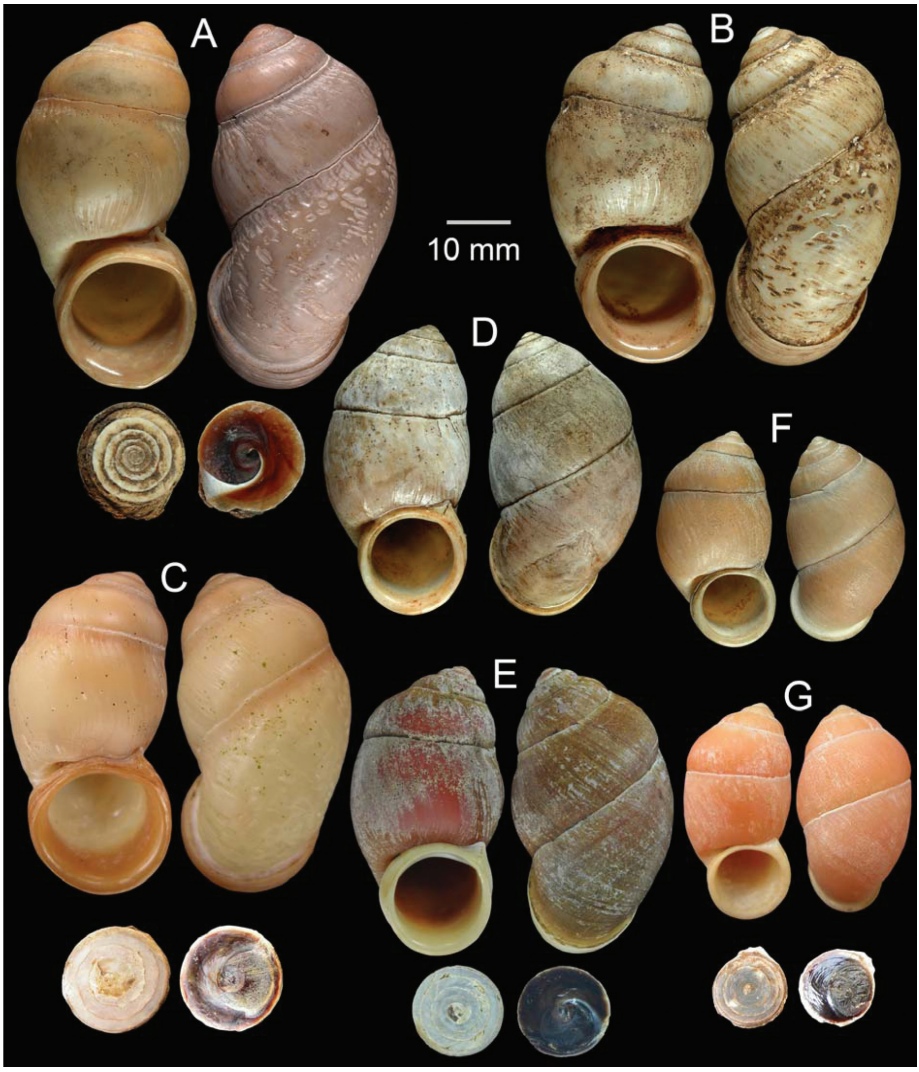


**Figure 5.** Shell morphology of *Pollicaria* spp. **A–C** *Pollicaria elephas* **A** lectotype of *Pollicaria elephas* (MNHN 21309) **B** lectotype of *Hybocystis jousseaumei* Morgan, 1885 (MNHN 21308), and **C** specimen from Gunung Kenting, Ipoh, Perak, Malaysia (CUMZ 1536) **D, E** *Pollicaria rochebruni* **D** lectotype (MNHN 21305), and **E** specimen from Phuong Nga National Park, Vietnam (CUMZ 1568) **F, G** *Pollicaria crossei*, **F** lectotype (MNHN 21304), and **G** specimen from Cuc Phuong National Park, Vietnam (CUMZ 1588).

Single syntype specimen is designated as the lectotype of *Hybocystis jousseaumei* Morgan, 1885 MNHN 21308 (Fig. 5B). Ipoh, Perak, Malaysia: ZMA E.A. Meene colln. Acc. no. 1982 (1 shell). Near bridge over river, road Ipoh to Tanjong Rambutan, Perak, Malaysia: ZMA J. Drijver colln. (5 shells). Perak, Malaysia: ZMB 75821 (2 shells), 38044 (1 shell), M. Schulz colln. 1216 (3 shells, smallest shell excluded). Bukit Chintamani, Selangor, Malaysia: CUMZ 1534. Gunung Kenting, Ampang Baru, Ipoh, Perak, Malaysia: CUMZ 1535, 1536 (Fig. 5C), 1566, 1570.

**Description. Shell:** Shell large, elongate pupoid uniform yellow to orange. Periostracum thin, corneous; shell surface with fine growth lines and last whorl with distinctly strong pitting dorsally. Whorls 6-7 whorls; sutures impressed; apex obtuse. Last whorl large about two-third of shell height, flattened in front. Aperture rounded, with shallow to deep posterior angle groove. Peristome continuous, little elevated, yellow to orange, internal parietal declining shoulder absent. Lip thickened, duplicated, and with distinct growth ridges; umbilicus narrow. Operculum thick, calcareous, concentric.

**Radula:** Taenioglossate radula, teeth arrangement with central, lateral and marginal teeth shape similar to *P. myersii*. Minor differences are the well-developed central cusp with one to three small lateral cusps of the central tooth, and the slightly elongate and slender central cusp of the inner marginal teeth.

**Distribution.** This species has a restricted distribution and is known only from limestone outcrops in Perak, Peninsular Malaysia (Morgan 1885a, b). Material collected for this study was from Kinta valley, Perak, and the southern part of the species' historical range in Bukit Chintamani, Selangor, Peninsular Malaysia is considered to be this locally endemic species.

**Remarks.** The locally endemic *Pollicaria elephas* is confined to a few limestone outcrops in Peninsular Malaysia and shows several unique shell characters that separate it from its congeners. The major distinguishing characters of this species are the very large, monochrome yellowish to pale orange shell with the last whorl distorted ventrally and sculptured with scattered, deep pits dorsally; and rounded and thickened aperture. (Table 2, Fig. 5A–C).

Morgan (1885a, b) proposed two nominal species of *Pollicaria* from Perak, which differed mainly by the shell size (larger shell *Hybocystis elephas* and smaller shell *Hybocystis jousseaumei*). In the first revision of this genus, Crosse (1885) assumed that they were the same species and recognized only *P. elephas*. Thereafter *P. jousseaumei* was recognized as a synonym of *P. elephas* (Kobelt 1902, Pain 1974). Examination of the type specimens (Fig. 5A, B) confirmed *P. jousseaumei* as junior synonym of *P. elephas*. Moreover, the recent land snail survey in Perak, Peninsular Malaysia recorded both large and small shell forms of the species from the same localities.

***Pollicaria rochebruni* (Mabille, 1887)**
http://species-id.net/wiki/Pollicaria_rochebruni
Figs 5D, E; 6E; Tables 1, 2

*Hybocystis rochebruni* Mabille, 1887a: 12. Type locality: Tonkin. Mabille 1887b: 138, 139, pl. 2, figs 12, 13.
*Pollicaria rochebruni*—Kobelt, 1902: 290.

**Material examined.** Four specimens of the syntype deposited in MNHN, the figured specimen in original publication is designated here as the lectotype of *Hybocystis rochebruni* Mabille, 1887 MNHN 21305 (Fig. 5D) and other specimens as paralecto-

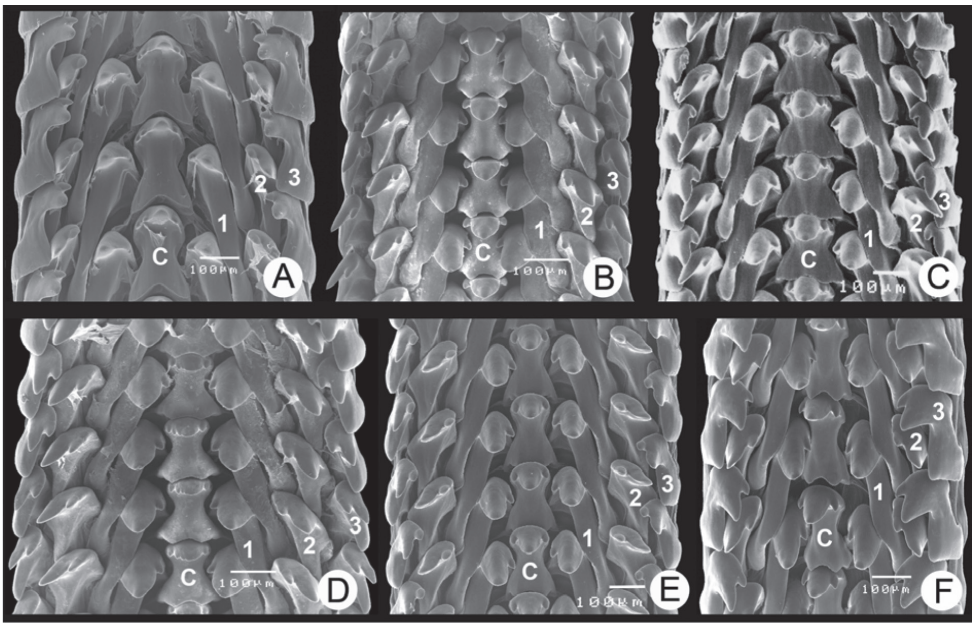


**Figure 6.** Radular morphology of *Pollicaria* spp. **A** *Pollicaria myersii* from Pahom, Vang Vieng, Laos (CUMZ 1572) **B** *Pollicaria mouhoti mouhoti* from Tam Wungdang, Phitsanulok (CUMZ 1533) **C** *Pollicaria mouhoti monochroma* ssp. n. from the type locality (paratype CUMZ 1548) **D** *Pollicaria elephas* from Gunung Kenting, Ipoh, Perak, Malaysia (CUMZ 1536) **E** *Pollicaria rochebruni* from Phuong Nga National Park, Vietnam (CUMZ 1568) **F** *Pollicaria crossei* from Cuc Phuong National Park, Ninh Binh Province, Vietnam (CUMZ 1588). Numbers indicated order of lateral and marginal teeth. Central tooth indicated by '**C**'.

type MNHN 25855. Bac Ma National Park, Vietnam: CUMZ 1556. Hulien Nature reserve, Vietnam: CUMZ 1594. Khe Sen, Danang, Vietnam: CUMZ 1589. Phuong Nga National Park, Quang Binh, Vietnam: CUMZ 1523, 1539, 1552, 1568 (Fig. 5E). Cuc Phuong National Park, Ninh Binh, Vietnam: CUMZ 1532, 1568, 1573, 1587.

**Description. Shell:** Shell medium-sized, pupoid, red-brown. Periostracum thick, corneous; shell surface smooth. Whorls 5-6; sutures moderately impressed; apex obtuse; spire short. Last whorl large about two-thirds of shell height, distorted and flattened in front, ventrally rounded. Aperture rounded, shallow to absent posterior angled groove present. Peristome continuous, with thin parietal declining shoulder internally. Lip thickened, little expanded, margin moderately duplicated with thin growth ridges; umbilicus narrow. Operculum concentric, thick, calcareous, multi-spiral plate.

**Radula:** Taenioglossate radula, teeth arrangement with marginal teeth shape similar to *P. myersii*. Major differences are in the central teeth which have multiple cusps: the central cusp relatively short and small, flanked by 1-3 tapered lateral cusps; and inner marginal teeth with 3 cusps: the central cusp large with a convex tip, flanked by small and pointed inner cusps, the outer lateral cusp very small to nearly wanting.

**Distribution.** The previous records of this species were from Tonkin (Mabille 1887a, b); Babe National Park, Bac Kan, Vietnam (Yamazaki et al. 2007)

**Remarks.** Based on the similarity in shell morphology, Pain (1974) placed *P. rochebruni* into the synonymy of *P. gravida*. However, examination of the type specimens of *P. rochebruni* indicate that it is a distinct species (see also *P. gravida*). *P. rochebruni* can be distinguished from the latter species by having a larger red-brown to purple-black shell with flattened whorls and shallow sutures, while *P. gravida* usually has smaller pale orange shell with convex whorls and impressed sutures (Tables 1, 2). *P. rochebruni* differs from the sympatric *P. crossei* in both shell size and colour (Tables 1, 2, Fig. 5F) as well as having a distinct karyotype pattern (see Kongim et al. 2010).

***Pollicaria crossei* (Dautzenberg and d'Hamonville, 1887)**
http://species-id.net/wiki/Pollicaria_crossei
Figs 5F, G; 6F; Tables 1, 2

*Hybocystis crossei* Dautzenberg and d'Hamonville, 1887: 220, pl. 8, fig. 4. Type locality: Than Moi, Tonkin. Kobelt and Möllendorff 1899: 137. Kobelt 1902: 290.
*Pollicaria crossei*—Kobelt, 1902: 290.

**Material examined.** Single specimens of the syntype deposited in MNHN, the figured specimen in original publication is designated here as the lectotype of *Hybocystis crossei* Dautzenberg and d'Hamonville, 1887 MNHN 21304 (Fig. 5F), and paralectotype RBINS 525390 (3 shells; the biggest one excluded). Cuc Phuong National Park, Ninh Binh, Vietnam: CUMZ 1521, 1522, 1588 (Fig. 5G), 1593. Hulien Nature reserve, Vietnam: CUMZ 1590.

**Description. Shell:** Shell small, pupoid, bright orange. Periostracum thin, corneous; shell surface smooth. Whorls 5-6; sutures moderately impressed; apex obtuse; spire short. Last whorl large about two-thirds of shell height, distorted and flattened in front, ventrally rounded. Aperture rounded, with shallow to absent posterior angled groove. Peristome continuous, with thin parietal declining shoulder internally. Lip thickened, little expanded and duplicated; umbilicus narrow. Operculum thick, calcareous, concentric.

**Radula:** Taenioglossate radula, teeth arrangement with central, lateral and marginal teeth similar in shape to *P. myersii*.

**Distribution.** The previous records of *P. crossei* was from Than-Moi, Tonkin and Cuc Phuong National Park, Ninh Binh, Vietnam (Dautzenberg and d'Hamonville 1887, Vermeulen and Maassen 2003).

**Remarks.** *Pollicaria crossei* has long been recognized as a subjective synonym of either *P. rochebruni* or *P. gravida* (Kobelt 1902, Pain 1974). However, the relatively smaller bright orange shell with thick, brown periostracum of *P. crossei* are a combination of characters that distinguish it from *P. rochebruni.* The bright orange shell with flattened whorls and shallow sutures distinguish it from *P. gravida* (Table 1, Fig. 3A). Moreover, the karyotypic study of the smaller shell form of *P. gravida* sensu lato indicated a distinct species recognized as *P. crossei* (see Kongim et al. 2010).

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# Three new species of the carnivorous snail genus *Perrottetia* Kobelt, 1905 from Thailand (Pulmonata, Streptaxidae)

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## Abstract

Three new species of the streptaxid snail genus *Perrottetia* are described from north and northeastern Thailand, *Perrottetia aquilonaria* **sp. n.**, *P. dermapyrrhosa* **sp. n.** and *P. phuphamanensis* **sp. n.** Each species is endemic to a single or a few limestone mountain ranges. The species are characterized by the morphology of their genital organs, as well as by shell characters. *Perrottetia aquilonaria* **sp. n.** has a club shaped distal penis and large penial hooks are present and penial papillae cover almost the entire penial hook portion; adjacent areas possess low reticulated folds. *Perrottetia dermapyrrhosa* **sp. n.** has a long genital atrium and the penial sheath is about two-thirds of the penis length. Penial hooks are long, scattered and sunken into deep ovate hollows; vaginal hooks are present. *Perrottetia phuphamanensis* sp. n. has a rounded and protruded shell periphery. The aperture is subcircular, peristome is thick and the second parietal lamella is adjacent to the first parietal lamella; a basal lamella is the smaller than in the other Thai species.

## Keywords

Systematics, land snails, taxonomy, genitalia, predator

## Introduction

Terrestrial gastropods are primarily herbivores and only a few groups are carnivorous. Carnivorous snails usually feed on other snail species or on weak individuals of the same species; some feed on insect larvae or earthworms (Gray 1860, Blanford and Godwin-Austen 1908, Benthem Jutting 1954, Berry 1963). Most diverse among tropical Asian carnivorous snails are members of the speciose family Streptaxidae Gray, 1860. Streptaxids can generally be recognized by their eccentric or cylindrical shells, while the animals have a bright yellow to red or orange body with external hook-like structures on the everted penis (Verdcourt 2000, Schileyko 2000, Rowson et al. 2009). The family is widely distributed across the tropical and subtropical areas of South America, Africa and Asia (Bruggen 1967, Schileyko 2000, Sutcharit et al 2010). Currently, the Streptaxidae are divided into 6 subfamilies comprising some 60 genera and about a thousand nominal species (Zilch 1960, Richardson 1988, Schileyko 2000). In the recent decades, most of the taxonomic and systematic research on streptaxids has been performed on sub-Saharan African taxa, where the species diversity reaches its maximum (Rowson et al. 2010). Only a few publications focus on South American or Asian groups (Barbosa et al. 2008, references therein; Clements 2006). Recently, the deep phylogenetic structure of the Streptaxoidea has been revealed, resulting amongst others in the recognition of a Southeast Asian lineage as a distinct family, the Diapheridae Panha and Naggs, 2010 (Sutcharit et al. 2010, Rowson et al. 2010).

With 13 genera and about 130 nominal species, the second most diverse streptaxid fauna can be found in Southeast Asia (Bruggen 1967, 1972, Richardson 1988, Schileyko 2000). *Perrottetia* Kobelt, 1905 is a poorly known genus with 27 nominal species. Most species of *Perrottetia* live in India, but there are additional species of this genus known from Sri Lanka, Laos, Vietnam and Southern China (Gude 1903, Kobelt 1906, Blanford and Godwin-Austen 1908, Zilch 1961, Richardson 1988, Schileyko 2000, 2011). To date, all nominal species of *Perrottetia* were described over a century ago and were often based on brief descriptions with poorly detailed figures.

The most prominent characters of *Perrottetia* are the sub-oblique heliciform shell, often with whorls coiling around an oblique axis. The last whorls do not descend below the preceding whorl, and short longitudinal furrows are present behind the apertural lip. Internally, the aperture possesses two parietal lamellae (Kobelt 1906, Zilch 1960, Richardson 1988, Schileyko 2000). Apart from a description of the anatomy of the Indian species *Perrottetia gudei* (Fulton, 1915) by Schileyko (2000), all other taxonomic studies on *Perrottetia* have solely been based on shell characters. The characters of the genitalia, in particular those proximal to the genital orifice, have proved as useful tools for species recognition, and often can serve for the differentiation on the generic level in many streptaxids groups (Stoliczka 1871, Berry 1963, Sutcharit et al. 2010). Subsequently, these characters were also examined in the current investigation.

## Material and methods

Our faunistic surveys throughout Thailand from 2008–2012 yielded rich collections of both, shells and live streptaxids, from north and northeast Thailand. Based on their distinctive shell characters, three new *Perrottetia* species are recognized. In addition to shell characters we examined the genitalia and radulae. Identifications were provisionally based on Tryon (1885), Blanford (1899), Kobelt (1906) and Blanford and Godwin-Austen (1908) prior to comparison with relevant type specimens. Living snails were photographed, refrigerated in -20 °C for approximately 6 hours prior to preservation in 70% ethanol for anatomical study. Shell height (H), shell width (W) and shell angle (SA) were measured as shown in Figure 1. Shells were digitally imaged using Cell'D Imaging Software. The genitalia of 5–10 specimens of each species were dissected and examined under a stereo-microscope. Representative examples of dissected specimens were drawn using a camera lucida. The buccal mass was removed, and the radulae were soaked in 10% sodium hydroxide, cleaned in distilled water, examined and photographed under SEM (JEOL, JSM-5410 LV). For examination of penial and vaginal hooks under SEM (PHILIPS, XL30), tissues were critical point dried from absolute ethanol.

The nomenclature of the shell apertural dentition follows that of Pilsbry (1916). In the descriptions of features of the genital organs, 'proximal' relates to the genital orifice, and 'distal' to the region furthest away from the genital orifice. The new anatomical terms 'vaginal hook' and 'atrial pore' are introduced. Others characters are as defined by Stoliczka (1871), Berry (1963), Verdcourt (2000), Herbert (2002) and

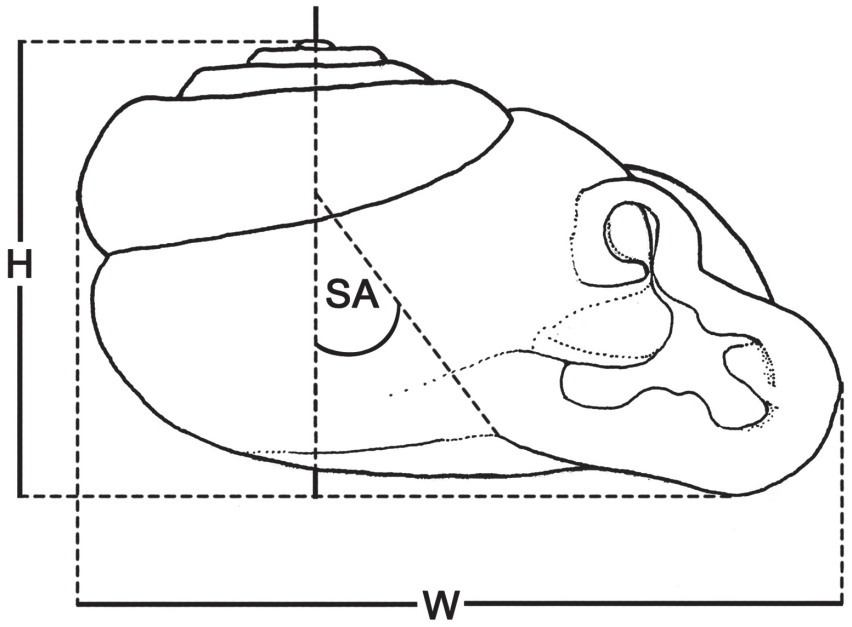


**Figure 1.** Schematic diagram illustrating methods for measuring specimens: **H** shell height **SA** shell angle **W** shell width.

Sutcharit et al. (2010): ag, albumen gland; at, atrium; fo, free oviduct; gd, gametolytic duct; gs, gametolytic sac; hd, hermaphroditic duct; ov, oviduct; p, penis; pr, penial retractor muscle; ps, penial sheath; psr, penial sheath retractor muscle; sv, seminal vesicle; ta, talon; v, vagina; vd, vas deferens.

Material examined in this study is deposited in the following institutions: CUMZ, Chulalongkorn University Museum of Zoology, Bangkok; NHMUK, The Natural History Museum, London; SMF, Forschungsinstitut und Naturmuseum Senckenberg, Frankfurt am Main.

All descriptions of the new species are here attribute to the first and the fourth author, Siriboon and Panha, respectively.

## Systematics

### Family Streptaxidae Gray, 1860

### Genus *Perrottetia* Kobelt, 1905

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

*Odontartemon* (*Perrottetia*) Kobelt 1905[1906]: 91, 108. Thiele 1931: 730. Forcart 1946: 215.
*Oophana* (*Perrottetia*) – Benthem Jutting 1954: 95.
*Perrottetia* – Zilch 1960: 562, 563. Schileyko 2000: 777, 778.

**Type species.** *Helix peroteti* Petit, 1841 by subsequent designation of Forcart (1946: 215).

**Description.** The shell is oblique-heliciform, usually thin and opaque. Its surface is smooth and glossy but fine transverse ridges may be present. The embryonic shell is smooth. The 5–7 whorls increase regularly. The shell periphery is usually rounded and the last whorl does not descend below the preceding whorl but is parallel to the preceding suture. The outer wall of the last whorl generally possesses two short longitudinal furrows that correspond with internal apertural lamellae. The umbilicus is narrow and deep. The semi-ovate aperture has an expanded peristome with a reflexed lip. The apertural dentition consists of two parietal lamellae; palatal, basal and columellar lamellae are usually present; upper palatal and supracolumellar lamellae may also be present.

Living animals possess a yellowish to reddish reticulated skin. The brown digestive gland and the black kidney are visible through the transparent shell. The upper tentacles are longer than the lower pair with a black eye-spot on the tip of the fully extended tentacle; bright red or yellow retractor muscles show though the transparent skin. The foot is narrow, undivided, the tail short.

Genitalia with a long, slender penis; penial sheath short, about half of penis length; internal wall of introverted penis with black to brown penial hooks; vas deferens passes through a short section of penial sheath before connecting distally to penis; vagina and free oviduct short to long, vaginal hooks may be present; gametolytic duct and sac may

not extend as far as albumin gland; seminal vesicle present with about the same length from vesicle to talon.

**Remarks.** *Perrottetia* consists of 27 nominal species distributed across Southern Asia, southern China to northern Vietnam. So far, it was not recorded from Thailand (Kobelt 1906, Yen 1939, Richardson 1988, Panha 1996, Schileyko 2000, Hemmen and Hemmen 2001). "*Streptaxis siamensis* Pfeiffer, 1862" was provisionally placed in *Perrottetia* by Kobelt (1906), but the presence of a single large parietal lamella, and the absence of short longitudinal furrows on the outer wall of the last whorl clearly differentiate this species from *Perrottetia*. Examination of the genitalia of topotype specimens show that this species has a very long penis, with a large proximal gametolytic duct, and short penial hooks that are located on an undulated penial papillae. This indicates that "*Streptaxis siamensis* Pfeiffer, 1862" should be placed in *Oophana* Ancey, 1884 (further details of this will be published elsewhere).

The first description of the genital system of a member of the subfamily Streptaxinae Gray, 1860 was published by Gerlach and van Bruggen (1999). Schileyko (2000) included 21 genera within the Streptaxinae. Two of them, *Streptartemon* Kobelt, 1905, from South America and *Seychellaxis* Schileyko, 2000, from the Seychelles, share the oblique-heliciform shell, and their penis sheath closely resembles that of *Perrottetia*. However, these may be plesiomorphic character states, and no phylogenetic affinity can be inferred.

***Perrottetia dermapyrrhosa* Siriboon & Panha sp. n.**
urn:lsid:zoobank.org:act:029F7FDD-9A8A-4B36-A782-815BFA0D32EB
http://species-id.net/wiki/Perrottetia_dermapyrrhosa
Figs 2A, 3A–C, 4A–C, 5A–G, 6A, Table 1

**Type material:** Holotype CUMZ 5001 (Fig. 3A). Measurement: shell height 6.1 mm, shell width 7.7 mm, and with 6 whorls. Paratypes NHMUK 20130062 (2 shells), SMF 341486 (1 shell), CUMZ 5002 (2 shells).

**Type locality.** Wat Tam Namsrithong, Nong Kungsi, Kalasin, Thailand, 16°48'18.0"N, 103°16'42.5"E.

**Diagnosis.** *Perrottetia mabillei* (Bavay and Dautzenberg, 1903) can be distinguished from *P. dermapyrrhosa* sp. n. by its lower spire with a distinct suture. The left periphery of the penultimate whorl is shouldered and does not extend beyond the diameter of the last whorl. The aperture is triangular and a supracolumellar lamella is absent. In comparison, *P. peroteti* (Petit, 1841) possesses a lower spire with a distinct suture, fine transverse ridges are present and a smaller basal lamella, while upper palatal and supracolumellar lamellae are absent. *Perrottetia gudei* (Fulton, 1915) (syntype Fig. 3L) differs from *P. dermapyrrhosa* sp. n. in its lower spire, the second parietal lamella being smaller and shorter than the first lamella and an upper palatal lamella that is usually present (Petit 1841, Bavay and Dautzenberg 1903, Kobelt 1906, Fulton 1915). In *P. dermapyrrhosa* sp. n. the genital atrium is long, the penial sheath reaches about two-


**Figure 2.** Living snails of **A** *Perrottetia dermapyrrhosa* sp. n. (paratype CUMZ 5002) from the type locality (shell width about 7 mm), and **B** *Perrottetia aquilonaria* sp. n. (paratype CUMZ 5004) from the type locality (shell width about 6 mm).

thirds of the penial length and the gametolytic duct and sac do not extend as far as the albumin gland. The penial hooks are more scattered and, in the introverted penis, are housed in deep ovate depressions; vaginal hooks are present. In comparison, *P. gudei* possesses a short genital atrium and penial sheath, and the gametolytic duct and sac extend as far as the albumin gland; the penial hooks are denser than in *P. dermapyrrhosa* sp. n., and each hook is situated on a small papilla (Schileyko 2000, fig. 1015D).

*Perrottetia dermapyrrhosa* sp. n. differs from *P. aquilonaria* sp. n. in its larger shell, which is less deviated from the vertical axis. A sinulus sensu Schileyko (2000) is absent; the first and second parietal lamellae are connected, and a bifid columellar and supracolumellar lamellae are absent. In comparison, *P. dermaphyrrhosa* sp. n. possesses a long atrium and vagina, and a penial sheath with a club shaped distal penis. The length of vas deferens that enters the penis distally is longer. The penial papillae are located in hollows, the penial hooks are much more scattered, and vaginal hooks are present.

**Description.** Shell oblique-heliciform, white and translucent; whorls 6, spire conical, suture distinct; shell surface glossy, with transverse ridges that diminish below the periphery; embryonic shell large, consisting of about 2 whorls with smooth surface, following whorls regularly expanding; shell periphery rounded, last whorl axially deflected; two deep and short longitudinal furrows present; umbilicus narrow (Fig. 3A); aperture subcircular, peristome discontinuous, thickened and expanded; apertural dentition with a large transverse first parietal lamella, with second parietal lamella adjoined at right angles; one upper palatal lamella, one small palatal lamella, one large basal lamella, one long subcolumellar lamella, one large strong columellar lamella and one small supracolumellar lamella (Fig. 3B).

**Radula:** Teeth arranged in anteriorly V-shaped rows, each row contains 29–31 teeth with formula (14-15)-1-(14-15); central tooth very small and triangular with a pointed cusp; lateral and marginal teeth undifferentiated, unicuspid and lanceolate; lateral teeth gradually reducing in length and size; outer teeth much smaller and shorter than inner teeth (Fig. 6A).

**Genital organs:** Atrium (at) long and slender; proximal penis (p) long, slender and with solid muscular penis sheath extending distally beyond penis sheath as a narrow tube; penial sheath (ps) reaching about two-thirds of total penis length, penial sheath retractor muscle very thin (psr), originating at atrium and inserting distally on penial sheath (Fig. 4A); vas deferens (vd) passes through about one-sixth of penial sheath length before entering into penis distally (Fig. 4B); penial retractor muscle (pr) thin and very long, inserting at penis and vas deferens junction; internal wall of atrium generally smooth with numerous pores (Fig. 5A); penial wall with scattered and pale brown penial hooks, about 3 hooks/200 $\mu m^2$ (Fig. 5C), and hooks located on conical papillae surrounded by deep ovate hollows; penial hooks of small size (<0.04 mm in length), expanding at base, tip sharp and curved towards genital orifice (Fig. 5E); vagina (v) short, stout, about one third of total penis length; gametolytic duct (gd) a long tube not extending as far as albumin gland, gametolytic sac ovate (gs); free oviduct (fo) very short, oviduct (ov) enlarged and folded; prostate gland inconspicuous and bound to oviduct (Fig. 4A); talon (ta) small, very short and club shaped;

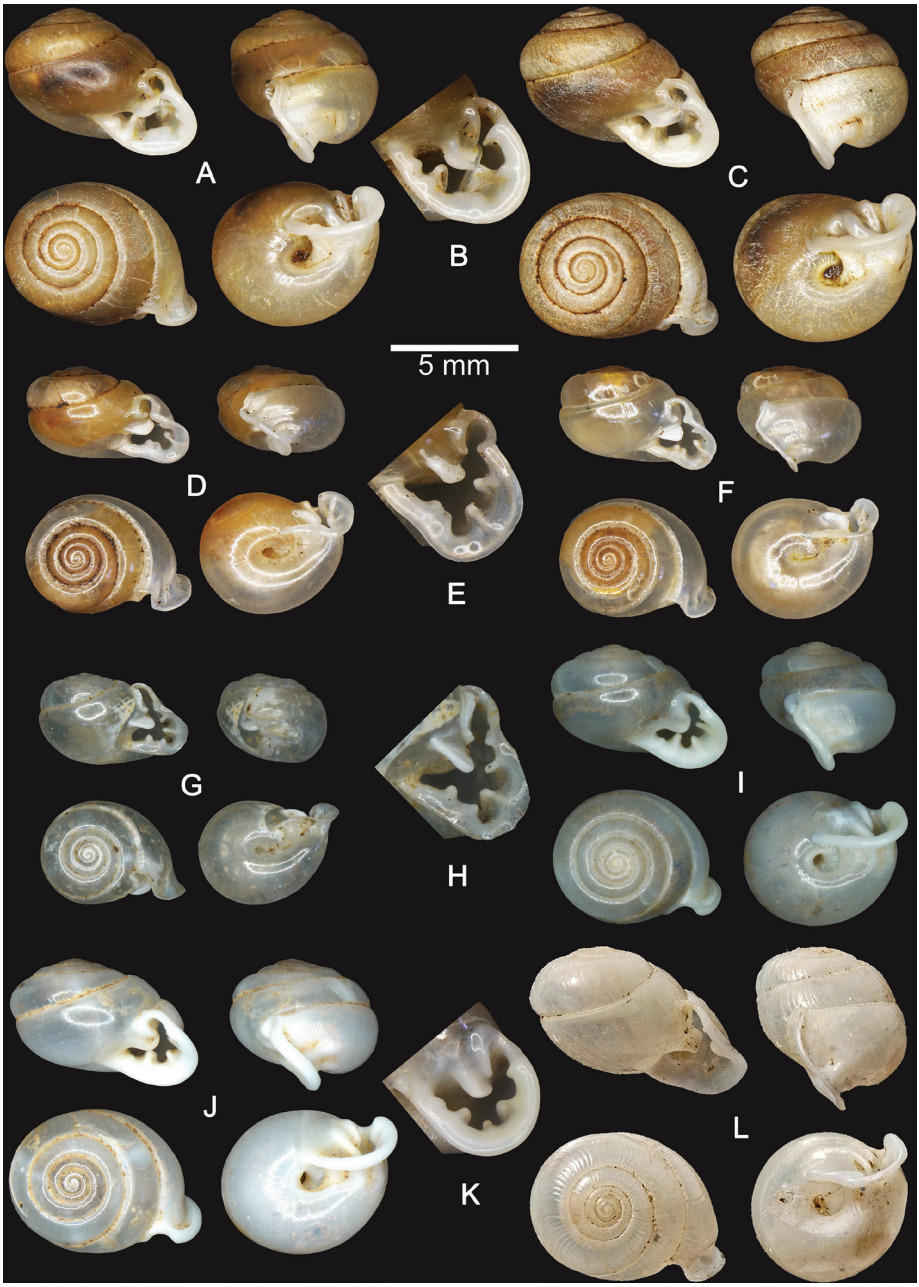


**Figure 3.** Shells of *Perrottetia* spp. **A–C** *Perrottetia dermapyrrhosa* sp. n. **A** holotype CUMZ 5001 **B** apertural dentition of the holotype CUMZ 5001, and **C** paratype CUMZ 5002 **D–H** *Perrottetia aquilonaria* sp. n. **D** holotype CUMZ 5003 **E** apertural dentition of the holotype CUMZ 5003 **F** paratype CUMZ 5004 **G** specimen from Tam Chiangdao, Chiangmai, CUMZ 5008 and **H** apertural dentition of the specimen from Tam Chiangdao, Chiangmai CUMZ 5008 **I–K** *Perrottetia phuphamanensis* sp. n. **I** holotype CUMZ 5011 **J** paratype CUMZ 5012, and **K** apertural dentition of the holotype CUMZ 5011 **L** *Perrottetia gudei* Fulton, 1915, syntype NHMUK 1919.12.31.51.

**Table 1.** Shell measurements of the three new *Perrottetia* species. Specimen collections and catalogue numbers indicated in parentheses.

| Species and locality and CUMZ nos | No. of specimens | Ranges, mean ± S.D. in mm of: | | | | Number of whorls |
|---|---|---|---|---|---|---|
| | | Shell height | Shell width | H/W ratio | Shell angle | |
| *Perrottetia dermapyrrhosa* sp. n. | | | | | | |
| Wat Tam Namsrithong, Nong Kungsi, Kalasin: (5001, 5002) | 7 | 5.4–6.6<br>6.2±0.39 | 7.4–8.1<br>7.7±0.26 | 0.7–0.9<br>0.8±0.06 | 14.2–28<br>21.1±5.01 | 6–6½ |
| *Perrottetia aquilonaria* sp. n. | | | | | | |
| Wat Tam Pha Plong, Chiangdao, Chiangmai: (5003, 5004) | 5 | 3.7–4.3<br>4.0±0.23 | 6.3–6.6<br>6.4±0.13 | 0.6–0.7<br>0.6±0.04 | 19.8–38.0<br>27.5±7.59 | 6 |
| Tam Phra Bumpenboon, Phan, Chiangrai: (5005) | 5 | 4.0–4.3<br>4.2±0.12 | 6.9–7.4<br>7.2±0.20 | 0.6–0.6<br>0.6±0.01 | 23.3–34.9<br>28.7±4.14 | 5½–6 |
| Wat Tam Pha Jaruey, Pa-daet, Chiangrai: (5006) | 6 | 2.9–3.4<br>3.2±0.17 | 5.9–6.3<br>6.1±0.15 | 0.5–0.6<br>0.5±0.02 | 26.4–31.8<br>29.7±2.26 | 5½–6 |
| Tam Maesuai, Maesuai, Chiangrai: (5007) | 13 | 3.9–4.7<br>4.3±0.27 | 6.5–7.5<br>7.1±0.34 | 0.5–0.7<br>0.6±0.05 | 19.3–37.3<br>24.6±5.07 | 6 |
| Km 93+200, Tam Chiangdao, Chiangmai: (5008) | 11 | 3.6–4.1<br>3.7±0.14 | 5.7–6.4<br>6.1±0.26 | 0.6–0.7<br>0.6±0.03 | 21.5–29.4<br>24.9±2.48 | 5½–6 |
| Pha Chu, Nanoi, Nan: (5009) | 21 | 3.4–4.4<br>3.9±0.31 | 6.0–6.9<br>6.4±0.26 | 0.5–0.7<br>0.6±0.05 | 15.6–30.7<br>21.7±3.98 | 5½–6 |
| Tam Pha Nangkoi, Rongkwang, Phrae: (5010) | 25 | 2.9–3.9<br>3.3±0.25 | 5.5–6.1<br>5.7±0.17 | 0.5–0.7<br>0.6±0.04 | 17.6–35.8<br>25.7±3.91 | 5½–6 |
| *Perrottetia phuphamanensis* sp. n. | | | | | | |
| Phuphaman National Park, Khonkaen: (5011, 5012) | 19 | 4.6–5.6<br>5.0±0.24 | 6.8–8.1<br>7.3±0.34 | 0.6–0.8<br>0.7±0.05 | 15.0–38.8<br>25.4±5.09 | 6–6½ |
| Tam Kangkao, Phuphaman, Khonkaen: (5013) | 11 | 4.9–5.5<br>5.1±0.20 | 6.9–7.7<br>7.2±0.28 | 0.7–0.8<br>0.7±0.04 | 16.8–31.1<br>22.6±4.20 | 6–6¼ |

hermaphroditic duct (hd) bearing long seminal vesicle (sv) about one and half times longer than the length from talon to branching point of seminal vesicle (Fig. 4C); vagina wall with a corrugated fold and pale brown vaginal hooks, about 8 hooks/200 $\mu m^2$, hooks small (<0.03 mm in length) with pointed tip slightly curving away from genital orifice (Figs 5F, G).

**Animal:** Live specimens exhibit yellowish-red reticulated skin, and reddish tentacular retractor muscles are visible through the semi-transparent body (Fig. 2A).

**Etymology.** The specific epithet "*dermapyrrhosa*" is derived from the Greek "*derma*" meaning "skin" and "*pyrrhos*" meaning "red or yellowish-red".

**Distribution.** This species is known only from the type locality, which is an isolated limestone hill reaching about 300 meters above mean sea level, and which is surrounded by the Korat Plateau.

**Remarks.** Up to now, the only description of the reproductive system of a *Perrottetia* species was that of *P. gudei* from Vietnam in which the presence of streptaxid vaginal hooks were recorded for the first time, but without being figured (Schileyko 2000).

***Perrottetia aquilonaris* Siriboon & Panha sp. n.**
urn:lsid:zoobank.org:act:2E376204-2D0F-4021-B795-399E33C8A677
http://species-id.net/wiki/Perrottetia_aquilonaris
Figs 2B, 3D–H, 4D–F, 5H–M, 6B, Table 1

**Type material.** Holotype CUMZ 5003 (Fig. 3D). Measurement: height 3.9 mm, shell width 6.6 mm, and with 6 whorls. Paratypes NHMUK 20130064 (2 shells), SMF 341487 (1 shell), CUMZ 5004 (1 shell).

**Other material examined.** Tam Phra Bumpenboon, Phan, Chiangrai: CUMZ 5005. Wat Tam Pha Jaruey, Pa-daet, Chiangrai: CUMZ 5006. Tam Maesuai, Maesuai, Chiangrai: CUMZ 5007. Tam Chiangdao, Chiangmai: CUMZ 5008. Pha Chu, Nanoi, Nan: CUMZ 5009. Tam Pha Nangkoi, Rongkwang, Phrae: CUMZ 5010.

**Type locality:** Wat Tam Pha Plong, Chiangdao, Chiangmai, Thailand, 19°24'7.3"N, 98°55'5.6"E.

**Diagnosis.** *Perrottetia aquilonaris* sp. n. can be distinguished from the similar south Indian species *P. watsoni* (Blanford, 1860) and *P. beddomii* (Blanford, 1899) by its smooth shell surface and the presence of a sinulus and a bifid columellar lamella. In comparison, *P. beddomii* possesses a supracolumellar lamella, while *P. watsoni* has a second parietal lamella adjacent to the first parietal lamella (Blanford 1860, 1899, Kobelt 1906). *Perrottetia gudei* from North Vietnam differs from the new species in its larger, oblique-heliciform shell, which is less deviated from the vertical axis. A fine transverse ridge is present at the suture. A sinulus is absent, the peristome is much thicker, and bifid columellar lamella is absent (Fulton 1915). The genital system of *P. gudei* differs from that of this new species by possession of a long and slender penis, an entirely free long oviduct, a gametolytic duct and sac extending as far as the albumin gland, the absence of seminal vesicles and a more scattered arrangement of penial hooks (Schileyko 2000).

**Description.** Shell suboblique-heliciform, white and translucent; teleoconch with 6 whorls, spire convex, suture indistinct; shell surface glossy, with transverse ridges diminishing below the periphery; embryonic shell large, about 2½ whorls, with smooth surface; following whorls regularly expanding; shell periphery shouldered, in apertural view left periphery of the penultimate whorl extending beyond the diameter of the last whorl; last whorl axially deflected; two deep and short longitudinal furrows present; umbilicus narrow (Fig. 3D); aperture subcircular, peristome discontinuous, thickened and expanded, short sinulus present, sometimes with a longer and tapering sinulus (Fig. 3H); apertural dentition consisting of one strong first parietal lamella, a small second parietal lamella separated at right angles, one small upper palatal lamella, one large palatal lamella, one basal lamella and a bifid columellar lamella (Fig. 3E).

**Radula:** Teeth arranged in anteriorly V-shaped rows, each row containing 21–23 teeth with the formula (10-11)-1-(10-11); central tooth small, sharp, triangular with pointed cusp; lateral and marginal teeth undifferentiated, unicuspid and lanceolate; lateral teeth gradually reduced in length and size, outer teeth much smaller and shorter than inner teeth (Fig. 6B).

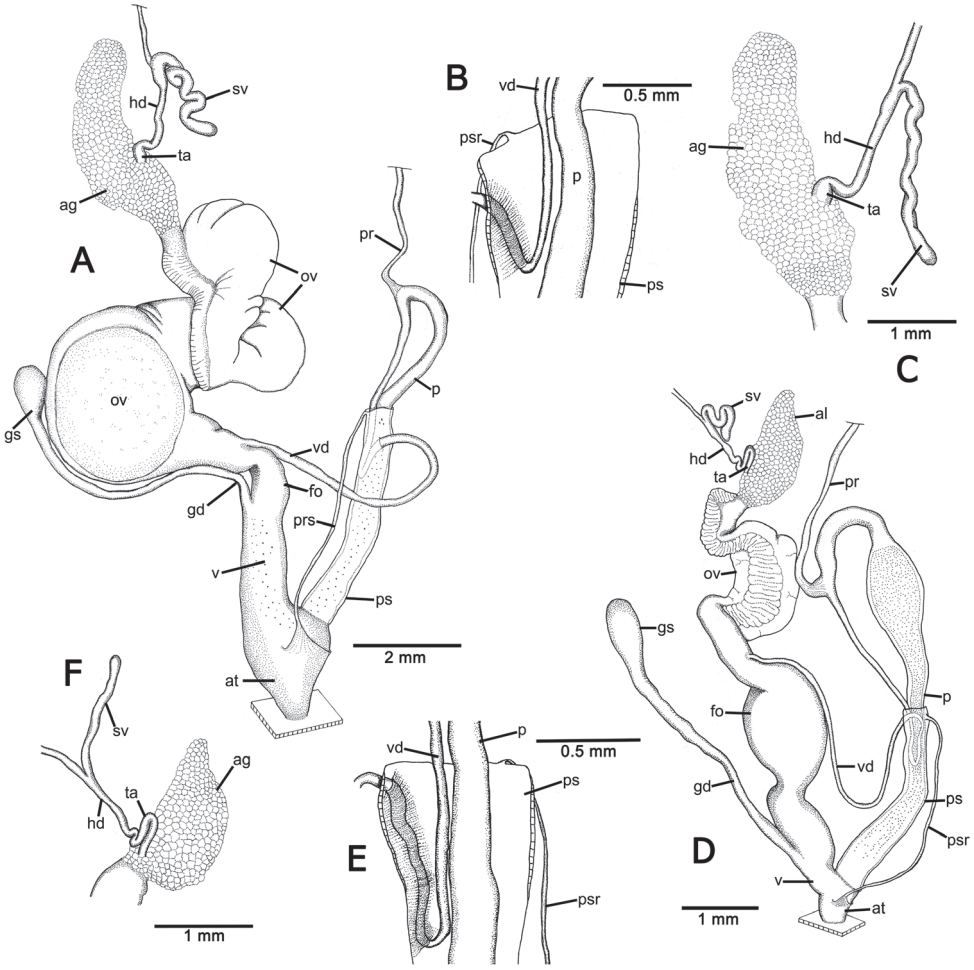


**Figure 4.** Genitalia of *Perrottetia* spp. **A–C** *Perrottetia dermapyrrhosa* sp. n. (paratype CUMZ 5002) **A** reproductive system **B** insertion of vas deferens into penial sheath, and **C** details of hermaphroditic duct and seminal vesicle **D–F** *Perrottetia aquilonaria* sp. n. (paratype CUMZ 5004), **D** reproductive system **E** insertion of vas deferens into penis sheath, and **F** details of hermaphroditic duct and seminal vesicle. Abbreviations: ag, albumen gland; at, atrium; fo, free oviduct; gd, gametolytic duct; gs, gametolytic sac; hd, hermaphroditic duct; ov, oviduct; p, penis; pr, penial retractor muscle; ps, penial sheath; psr, penial sheath retractor muscle; sv, seminal vesicle; ta, talon; v, vagina; vd, vas deferens.

**Genital organs:** Atrium (at) short; penis tripartite, proximal part long and narrow, central section globular with a thick muscular wall, distal section again long and narrow; penial sheath (ps) thin, extends about half of total penis length; penial sheath retractor muscle (psr) very thin, originating at the atrium, inserting distally on penial sheath (Fig. 4D); vas deferens (vd) passes through about one-fifth of penial sheath length before entering into penis distally (Fig. 4E); penial retractor muscle (pr) thin and very long, inserting at penis and vas deferens junction; internal wall of atrium

generally smooth with numerous pores (Fig. 5H); penial wall with scattered and pale brown penial hooks about 24 hooks/200 μm$^2$; hooks located on papillae (pl), papillae separated by low reticulated folds; penial hooks of small size (< 0.02 mm in length), expanding at base, tip sharp and curved towards genital orifice (Figs 5J–L); vagina (v) short, stout, about a seventh of total penis length; gametolytic duct (gd) long but not extending as far as albumin gland; gametolytic sac ovate (gs); proximal free oviduct (fo) stout and distally enlarged; oviduct (ov) enlarged and folded; prostate gland inconspicuous and bound to oviduct (Fig. 4D); talon (ta) small, very short and club shaped; hermaphroditic duct (hd) bearing long seminal vesicle (sv) about one and half times longer than the length from talon to branching point of seminal vesicle (Fig. 4F); vaginal wall with parallel vaginal folds; vaginal hooks absent (Fig. 5M).

**Animal:** Live specimens exhibit yellowish reticulated skin, and pale yellowish tentacular retractor muscles are visible through the semi-transparent body (Fig. 2B).

**Etymology.** The specific epithet is from the Latin "*aquilonaris*" meaning "north or northern". It refers to the distribution range of this new species in northern Thailand.

**Distribution.** This species is known from several limestone areas in northern Thailand. The animals can be found in altitudes up to 200 meters above mean sea level.

**Remarks.** Some variation has been observed in the sinulus and the bifid columellar lamella. Populations from Chiangmai and Chiangrai Provinces possess a longer and tapered sinulus (Figs 3G, H). Specimens collected between those two provinces have a shorter sinulus, and specimens from Chiangmai possess a large bifid columellar lamella (Fig. 3H).

### *Perrottetia phuphamanensis* Siriboon & Panha sp. n.

urn:lsid:zoobank.org:act:4E8CC516-99E8-4652-9B2A-1796689E2456
http://species-id.net/wiki/Perrottetia_phuphamanensis
Figs 3I–K, Table 1

**Type material.** Holotype CUMZ 5011 (Fig. 3I). Measurement: shell height 5.0 mm, shell width 6.9 mm, and with 6¼ whorls. Paratypes NHMUK 20130066 (2 shells), SMF 341488 (2 shells), CUMZ 5012 (14 shells).

**Other material examined.** Tam Kangkao, Phuphaman, Khonkaen: CUMZ 5013.

**Type locality.** Phuphaman National Park, Phuphaman, Khonkaen, Thailand, 16°45'34.0"N, 101°57'50.3"E.

**Diagnosis.** *Perrottetia concinna* (Blanford, 1880) differs from *P. phuphamanensis* sp. n. in its smaller shell, higher spire and more distinct suture. The left periphery of the penultimate whorl does not extend beyond the diameter of the last whorl, the aperture is semi-ovate, and a bifid columellar lamella is present. *Perrottetia peroteti* differs from this new species in its fine transverse ridge at the suture, the smaller second parietal lamella, and the absence of the upper palatal and supracolumellar lamellae.

*Perrottetia gudei* can be distinguished from *P. phuphamanensis* sp. n. by its lower spire, a stronger transverse ridge at the suture, its triangular aperture, the second parietal lamella not being adjacent to the first parietal lamella and the absence of a supra-

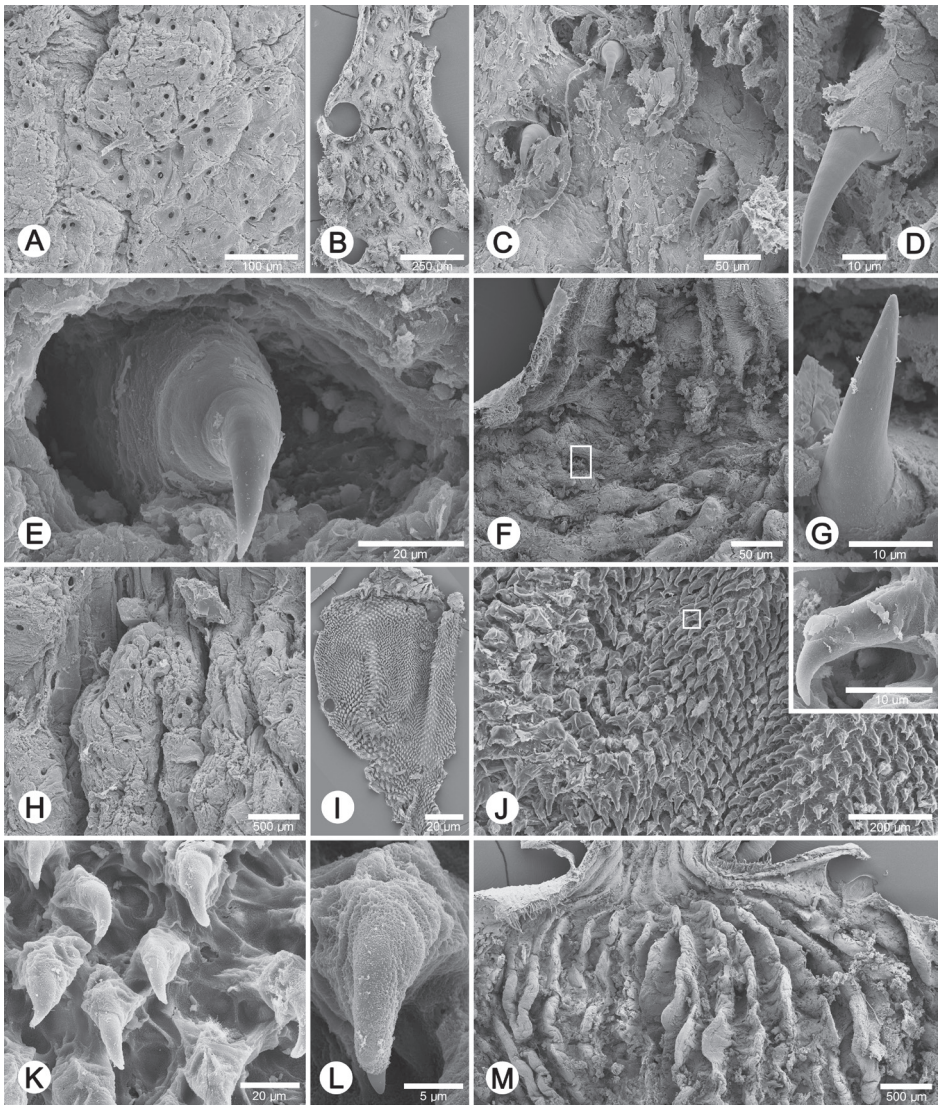


**Figure 5.** Internal sculpture of genitalia of *Perrottetia* spp. **A–G** *Perrottetia dermapyrrhosa* sp. n. (paratype CUMZ 5002) **A** details of atrial pore on the atrium surface **B** low magnification shows arrangement of penial hooks **C** high magnification of penial hooks **D** lateral view of penial hook **E** top view of penial hook situate inside hollow **F** arrangement of vaginal fold with hook in white square, and **G** lateral view of vaginal hook (from white square in **F**) **H–M**. *Perrottetia aquilonaria* sp. n. (paratype CUMZ 5004) **H** details of atrial pore on the atrium surface **I** low magnification shows dense arrangement of penial hooks **J** high magnification of penial hooks with (inset) lateral view of penial hook **K** arrangement of penial hooks **L** top view of penial hook, and **M** arrangement of vaginal folds without vaginal hook.

columellar lamella. Distinguishing features from *P. aquilonaria* sp. n. are the smaller shell and the presence of a sinulus. In addition, the left periphery of the penultimate whorl does not extend beyond the diameter of the last whorl, the peristome is thin-

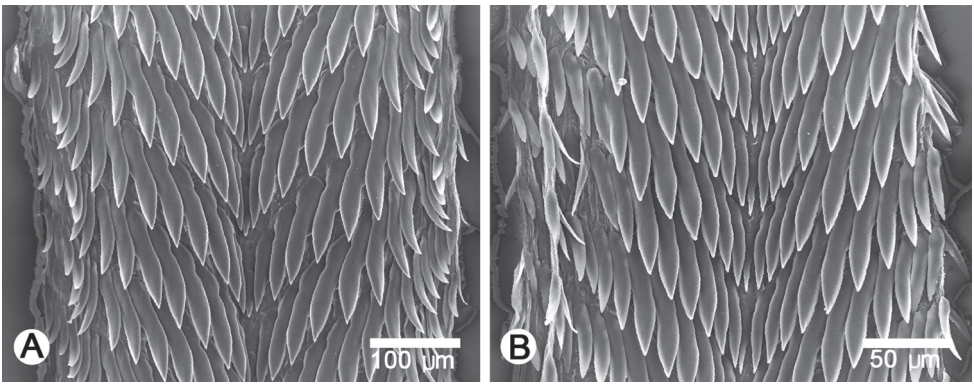


**Figure 6.** Radula morphology of **A** *Perrottetia dermapyrrhosa* sp. n. (paratype CUMZ 5002), and **B** *Perrottetia aquilonaria* sp. n. (paratype CUMZ 5004).

ner, the second parietal lamella is not adjacent to the first parietal lamella, and a bifid columellar and supracolumellar lamellae are both absent.

**Description.** Shell suboblique-heliciform, white and translucent; whorls 6¼, spire convex, suture distinct; shell surface glossy, with a reduced transverse ridge; embryonic shell large consisting of about 2½ whorls, with smooth surface; following whorls regularly expanding; shell periphery shouldered, last whorl axially deflected; two shallow and short longitudinal furrows present; umbilicus narrow (Fig. 3I); aperture subcircular, peristome discontinuous, very thick and slightly expanded; apertural dentition with a large first parietal lamella and with a second parietal lamella adjoining at right angles; one upper palatal lamella, one palatal lamella, one basal lamella, one large strong columellar lamella, one small supracolumellar lamella (sometimes absent) (Fig. 3K).

**Etymology.** The specific epithet is derived from the type locality of this new species, the Phuphaman National Park, Khonkaen Province.

**Distribution.** This species is known only from the type locality.

**Remark.** To date no living examples have been found.

## Discussion

The Streptaxidae were divided into 6 subfamilies and 3 new subfamilies by Schileyko (2000). Prior to Schileyko's revision only two subfamilies, the Streptaxinae and the Enneinae had been recognized, which were primarily based on their shell morphology (Zilch 1960, Richardson 1988). Where material was available, Schileyko (2000) included characters from the genital organs to establish a revised system for the Streptaxidae. The Streptaxinae sensu Schileyko is composed of *Perrottetia* and 20 additional genera with discontinuous distribution patterns in South America, some Indian Ocean Islands, including the Mascarines and Seychelles (but excluding mainland Africa and Madagascar), South and Southeast Asia and the Philippines.

Records in the literature show *Perrottetia* having a tropical distribution in South Asia, Southeast Asia and some parts of East Asia. There is a concentration of 11 species in the Western and Eastern Ghats of peninsular India and two species are recorded from Sri Lanka, one of which is endemic (Naggs and Raheem 2000). Some South Asian species were discovered at high altitudes up to 4000 m above mean sea level. *Perrottetia* has also been recorded from Myanmar, Laos, North to South Vietnam and some parts of China such as Hainan Island and Taiwan, and is now recorded from Thailand.

Anatomical studies of streptaxids that included internal anatomy were pioneered by Stoliczka (1871) but, as pointed out by Sutcharit et al. (2010) and even following Schileyko's (2000) revision, internal anatomy has been described for only 37 of the 60 currently recognized streptaxid genera, many of these in a very superficial way. In addition, in genera where reproductive anatomy has been investigated, only one or very few species may have been examined. Usually it is by chance that the reproductive anatomy of the type species of a genus could be investigated, which however is essential for the definition of the genus. Prior to this study, the reproductive anatomy of *Perrottetia* was only known for *P. gudei*. An important feature to note is that, unlike in other anatomically known members of the Streptaxinae, a part of the vas deferens passes under a section of the penial sheath (Schileyko 2000). There is clearly a long way to go before the system of the Streptaxidae can be considered as stable. For the future, research needs to focus on the accurate description of the morphological variation of both, shells and genital organs. These results should then be corroborated by molecular phylogenetic studies in order to better understand this fascinating group of land-snails.

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RESEARCH ARTICLE

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# The New Caledonian genus *Caledonotrichia* Sykora (Trichoptera, Insecta) reviewed, with descriptions of 6 new species

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## Abstract

The New Caledonian endemic hydroptilid genus *Caledonotrichia* Sykora (Trichoptera) is reviewed and 6 new species are described: *C. bifida*, *C. capensis*, *C. minuta*, *C. ouinnica*, *C. sykorai* and *C. vexilla*. Together with the established species for which revised diagnoses are given, these raise to 11 the number of species known in this genus. The new species, females of 3 species, and several unusual larval cases are examined and described for further insight into relationships of this enigmatic genus. A key to species is provided.

## Keywords

Spicipalpia, Hydroptilidae, New Caledonia, endemic, key, generic relationships

## Introduction

The Trichoptera fauna of freshwaters on the small south-western Pacific island of New Caledonia exhibit high levels of endemism at the species level. In addition, 7 genera are endemic, among which is one hydroptilid genus, *Caledonotrichia* Sykora, 1967. As part of a revision of all New Caledonian Hydroptilidae (Wells and Johanson 2012, and in prep.), this genus is reviewed here. The first 2 species in the genus *Caledonotrichia* Sykora were C. *illiesi* Sykora, 1967and *C. minor* Sykora, 1967, both from a locality near Col d'Amieu in the Province Sud (southern province). Nothing more was published on the genus until J. Marshall in her 1979 review of Hydroptilidae included a brief diagnosis and, not surprisingly given the features identified as diagnostic, was unable to assign the genus to any of the Hydroptilinae tribes that she recognised. In 1989, 2 additional species of *Caledonotrichia* were described by Kelley: *C. charadra* Kelley, 1989*,* smallish and rather similar to *C. minor,* and a distinctive, much larger-bodied species, *C. extensa* Kelley, 1989. Next, several larvae were described by Wells (1995): a curious early instar larva with greatly modified head setae — cephalic 'horns', and mature larvae with dome-shaped cases, both attributed to *Caledonotrichia illiesi*, as well as an unassociated early larva without cephalic horns. Oláh & Johanson (2010) added a fifth species, *C. nyurga* Oláh & Johanson, 2010. Adults of several additional-new species in *Caledonotrichia* were collected by A. Wells in late 1998, and extensive light- and Malaise-trapping by K.A. Johanson and colleagues from 2001–2006 yielded others. This present study is based mainly on these two collections, although between 1996 and 2000, N. Mary collected extensively in her study on macroinvertebrates of New Caledonian streams (Mary 2002). Mary's surveys concentrated on aquatic stages and, as few pharate adults were among the hydroptilids collected, most specimens were identifiable only to genus. This was unfortunate since in addition to the fixed dome-shaped cases of the form described by Wells (1995), the samples included further unusual larval cases, identifiable as those of species of *Caledonotrichia*. These are purse-shaped and cylindrical cases constructed of 2 equal valves, with distinct dorsal and ventral sides, some with dorsal vents. One purse-shaped form is made of sections of moss microphylls placed flat in a manner similar to that described by Cairns & Wells (2008) for *Scelotrichia willcairnsi* Cairns & Wells, 2008, a NE Queensland Stactobiini species, that not only makes its case from moss microphylls, but also feeds upon them. These New Caledonian cases differ, however, in having towards each end of one seam, a protruding 'stalk', presumably for attachment to the substratum; on the outer side of each stalk is a well-defined opening facing towards the end of the case. A pharate adult female has 34 antennal segments. Among known species only *C. illiesi* and *C. nyurga* have antennae with so many segments, and *C. illiesi* has dome-shaped cases. This may be the case of *C. nyurga*. A second purse-shaped case also made of moss microphylls but this time without dorsal vents, is constructed of small moss microphylls, all bristling out neatly from the surface of the case and giving it a porcupine- or echidna-like appearance. The larvae conform with those of *Caledonotrichia*, but no further identification is possible. The third case type, identified from pharate

adults, is that of *C. extensa*. These cases (Fig. 70) comprise two valves, both smoothly rounded, and constructed of silk secretion only. They more or less form a cylinder, but are tapered and flattened towards each end, terminating in a bract-like overhang. Each end has a pair of triangular prominences on the upper seam around openings that face towards each end of the case. Similar dorsal prominences shielding vents occur on the cases of 3 Australian species (see Wells 1997): in *Hellyethira forficata* Wells, 1997, an otherwise ovoid case constructed of sand grains and silk; *Orthotrichia armata* Wells, 1997, a ribbed, secretion case; and *O. tyleri* Wells, 1997, a case that is almost identical in shape to the case of *C. extensa*. These three species have been collected from northern Australian billabongs (anabranchs) and streams, all of which have very warm waters where oxygen levels might be expected to be low at times. The vents may be an adaptation that, together with undulations of the body, assists water circulation in the case and thus improve ventilation. Small dorsal openings are seen also in the dome-shaped cases of *Caledonotrichia illiesi* (Wells 1995: figs 11, 12), possibly serving a similar function for their inhabitants.

Sorting of *Caledonotrichia* adults is fraught. Females are generally very closely similar in appearance and usually we have made little attempt to sort them. To illustrate general form we figure and describe several that have been associated tentatively. Males of most species are difficult to identify, too, without close scrutiny of individual specimens under a compound microscope; this is not feasible for sizeable samples. However, on the basis of morphology of male genitalia the species fall into two distinct species groups — an '*illiesi* group' and an '*extensa* group'. The three '*extensa* group' species are relatively easy to identify when in alcohol. The males all have abdominal segment IX strongly triangular in shape and *C. extensa* is the largest of all congeners. *Caledonotrichia nyurga* and *C. sykorai* have elongate processes apico-mesally on abdominal sternite VIII, and *C. nyurga* has antennae with distinctive rounded to urn-shaped distal segments. Identifying males of the other group is more difficult — mainly because the genitalia are very hairy and often withdrawn into abdominal segment IX, and in preserved specimens the two lobes of the gonopods are usually folded tightly towards the body, obscuring all other genitalic structures. The only way to identify them with certainty is by macerating the genitalia. Males of four species, however, can be identified by the scales on the wings, although these may be deciduous or simply lost due to abrasion when collected. *Caledonotrichia minor*, *C. ouinnica* sp. n. and *C. capensis* sp. n. all have scales on the forewing only; *C. charadra* has them on both fore- and hind wings. The extent of the scale patches can be used to separate these first three listed species. The scales are possibly androconial scales, involved in scent dispersal and in the male lekking behaviour was observed in the field in this group that appear to be primarily diurnal in behaviour. Specimens of several species were collected (by AW) in bright sunlight as they (predominantly males) rested, ran or flew around on emergent rocks or on riparian vegetation, usually in small groups. Similar diurnal behaviour is exhibited by some species in the Stactobiinae genera *Chrysotrichia* Schmid, 1958 and *Scelotrichia* Ulmer, 1951, and some of these have scales on their wings (Wells and Huisman 1993).

The peculiarly diverse case forms seen in *Caledonotrichia* are more or less paralleled in the Stactobiinae, which share with *Caledonotrichia* features such as head with tentorium complete, mesoscutellum with transverse suture and, on the forewing, a well-developed jugal lobe, features not noted by Marshall (1979), possibly because they are probably plesiomorphic.

Recent authors such as Morse (2012) and Holzenthal et al. (2007), when considering Hydroptilidae relationships or classification, have also failed to place *Caledonotrichia*, leaving it in *incertae sedis* in family Hydroptilidae. A sister group relationship between *Caledonotrichia* and the Australian *Maydenoptila* was postulated by Wells (1995). Both have the above plesiomorphic features and their males have bilobed gonopods, with one lobe of the pair with a mesal process of some kind; in both the phallic apparatus varies in form between species, some with one or more associated parameres, others simple; and most species of *Maydenoptila* and at least three of *Caledonotrichia* have abdominal segment IX strongly triangular in ventral view. Females in both genera have similar slender, elongate abdominal terminalia. Although *Caledonotrichia* and *Maydenoptila* share many features, they exhibit some notable differences. The wings of *Caledonotrichia* are narrower than those of *Maydenoptila*, with the venation considerably reduced. No known species of *Maydenoptila* is modified in this way; indeed, most have wings that are somewhat broader than those of many Hydroptilinae, and with venation more complete than most. Another notable difference is the occurrence of scent scales or androconia on wings of males of some *Caledonotrichia*; these are not known to occur species of *Maydenoptila*. Evolution of scales on wings may be a phenomenon that sometimes occurs when species diverge in sympatry such as may be the situation from time to time on islands — wing scales are found in a Lord Howe Island species of *Orphninotrichia* Mosely, but not in any of the Australian mainland species (Wells 1999, 2010); an *Oxyethira* species with scattered scales on the hind wing was described by Johanson et al. (2011) from the island of Espiritu Santo, Vanuatu. Wing scales occur also in stactobiine taxa such as *Chrysotrichia* and on wings of a number of Neotropical leucotrichiine species, too.

The distribution of *Maydenoptila* in south-western and eastern Australia suggests that it could be Gondwanan in origin and *Caledonotrichia* could have a similar origin. Thus, if *Caledonotrichia* and *Maydenoptila* are members of the Stactobiinae, they probably evolved from an early stactobiine lineage. Note, however, that contrary interpretations are given by Harris & Armitage (1997) who, in their study of the Neotropical genus *Nothotrichia* Flint, 1967 concurred with Kelley (1992) in placing that genus with *Caledonotrichia* and *Maydenoptila* in the basically Neotropical 'tribe [sic] Ochrotrichiinae'. Relationships of these genera remain to be tested by studies based on molecular data.

In support of future studies on New Caledonian Hydroptilidae, we provide diagnoses and descriptions for all known species of *Caledonotrichia*, along with an identification key to adult males. Other hydroptilid genera found in New Caledonian freshwater systems — *Paroxyethira*, *Hellyethira*, *Acritoptila* and *Oxyethira* — are (Wells & Johanson 2012), or will be, treated elsewhere.

## Material and methods

Adult specimens were collected in light traps and Malaise traps situated near running waters, swept from riparian vegetation or from emergent boulders and cobbles in streams, or 'dabbed' using an alcohol-dipped finger tip. Specimens were prepared for study as Canada balsam slide mounts following the methods of Wells (1980). Male genitalia are illustrated in line drawings and also, for species for which suitable slides are available, as images derived using the digital imaging software AutoMontage. This duplication of effort allow readers to understand the morphology of the male genitalia of *Caledonotrichia* species and will aid identifications. Descriptions are based primarily on males. Specimens in this study are deposited in the following repositories:

**MNHP** Muséum National d'Histoire Naturelle, Paris, France
**NHRS** Naturhistoriska riksmuseet, Stockholm, Sweden
**ANIC** Australian National Insect Collection, CSIRO Ecosystem Sciences, Canberra, Australia
**QM** Queensland Museum, Brisbane, Australia
**ROM** Royal Ontario Museum.
**BPBM** Bishop Museum, Hawaii, USA

## Descriptions

***Caledonotrichia* Sykora**
http://species-id.net/wiki/Caledonotrichia

*Caledonotrichia* Sykora (1967: 585); Marshall (1979: 221); Kelley (1989: 194); Wells (1995: 224).

**Type species.** *Caledonotrichia illiesi* Sykora, by original designation.

**Revised description, male.** Head wider than long, in dorsal view variably rounded to subrectangular; 3 ocelli present; antennae with 22–37 flagellomeres in male, 20–24 flagellomeres in female; tentorium complete, posterior bridge well developed, dorsal arms vestigial; maxillary palps with 2 basal and fourth segments short, other segments elongate; clypeus bearing a dense brush of setae. Forewing length 1.0–3.5 mm, broad to narrowly acuminate, with or without patches of specialised scent scales (androconial scales); jugal lobe present; hind wing with or without scales; venation of both wings modified to a greater or lesser extent, width of wings variable, generally slender with apices acuminate. On thorax, mesoscutellum with transverse suture; metascutellum triangular. Tibial spur formula 0,3,4. Female terminalia forming slender, elongate oviscapt. Male genitalia with abdominal segment IX well developed, broadly to narrowly shield-shaped, or triangular in ventral view and triangular in lateral view. Tergite X membranous, short, longer than wide. Gonopods bilobed, dorsal lobe irregularly

elongate, subquadrate to rectangular or rounded, usually longer than ventral lobe, usually bearing a digitiform mesal process, ventral lobe triangular to bean-shaped, or narrowly leaf-shaped; in axil between dorsal and ventral lobe usually a small, rounded, setate process and basally on ventral lobe, a strong elongate seta. Subgenital processes (or plate) in form of pair of sclerotised rods which, in lateral aspect, strongly sinuate. Phallic apparatus elongate, with or without associated parameres.

**Larva.** Diagnoses are given for larvae by Marshall (1979) and Wells (1995: 228). Mature larvae are basically plesiomorphic, with or without dorsal abdominal sclerites; cases highly variable in shape and materials.

***Caledonotrichia illiesi* Sykora**
http://species-id.net/wiki/Caledonotrichia_illiesi
Figs 20–22, 30–32, 71

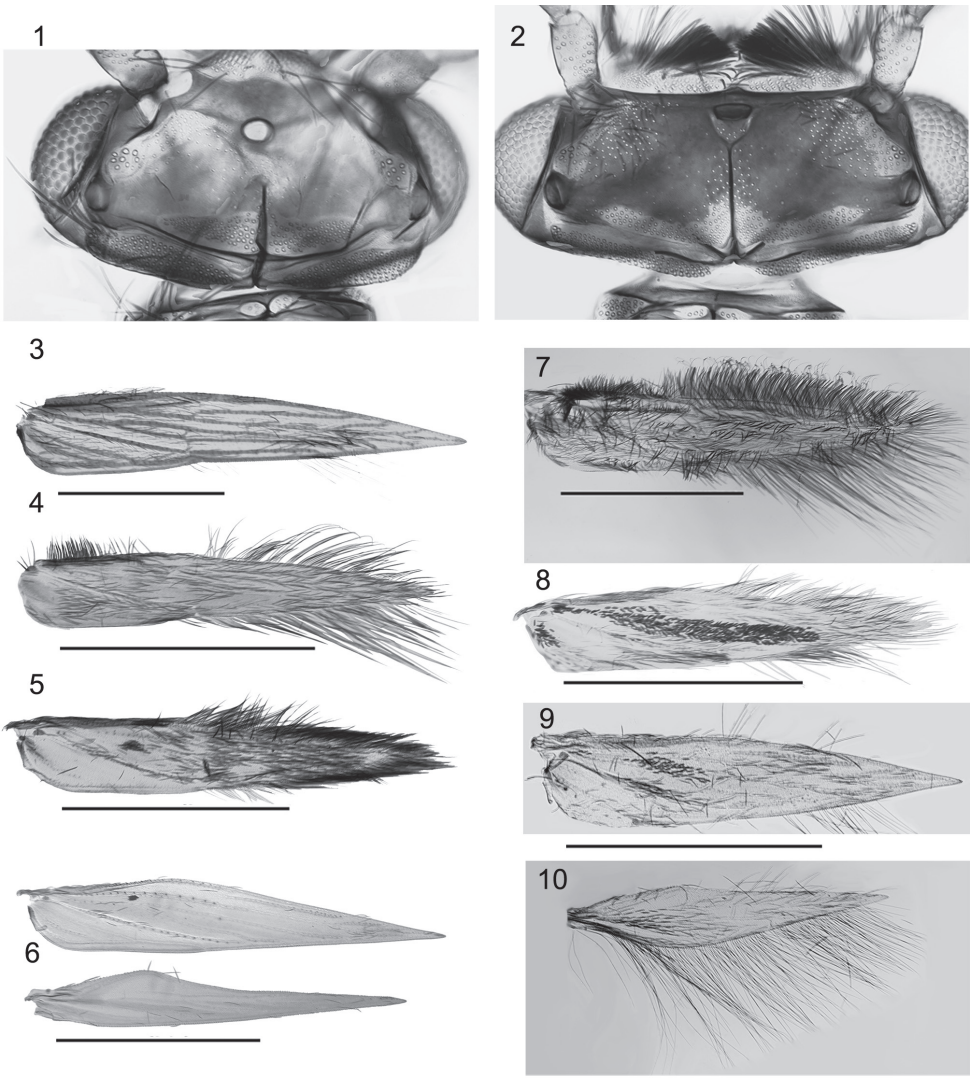
*Caledonotrichia illiesi* Sykora (1967: 585–595); Wells (1995: 229).

**Revised diagnosis.** In many respects males of *C. illiesi* resemble the smaller *C. minuta* sp. n., and *C. bifida* sp. n., having wings without scales and both lobes of gonopods are rounded, but are readily recognized by their large size, more robust in appearance, have thick brushes of short black setae dorsally on head and have elongate antennae about equal in length to body. In the male genitalia (Figs 21–22, 30–32) the subgenital process forms simple, straight sclerotised rods, and the elongate seta in the axil between the upper and lower lobes of each gonopod terminates in a round apical knob (arrow in Figs 21, 22). In the female terminalia (Fig. 71) abdominal sternite VII has a triangular prominence apico-medially, and a membranous collar; segment X is triangular.

**Revised description, male.** Head rounded in dorsal view, as in *C. capensis* sp. n. (Fig. 1). Antennae with 35–37 flagellomeres; flagellomeres (Fig. 20) elongate cylindrical, length about 2× width. Maxillary palps with basal 2 segments short and rounded, rest cylindrical: segment 3 about 4× maximum width, segment 4 length about 2× width, and segment 5 elongate slender, length almost 6n width. Forewing length, 2.1–3.0 mm (n=10). Wings without scales, forewing costa with brush of straight setae on proximal third, then longer, curved setae to tip of wing.

**Additional information, female.** Antennae with 33 flagellomeres. Forewing length, 2.0–3.2 mm (n=10).

**Material examined.** Holotype male: New Caledonia: River near Col d'Amieu (BPBM), examined. 1 pharate male pupa, upper Hienghène R. at Kavatch, 6.ix.1965, F. Starmühlner (ROM); 1 pharate male pupa, tributary Hienghène R. at Castex Station 5 km below Kavatch, 6.viii.1965, F. Starmühlner (ROM); 1 male, creek at end of Col de Petchékara, 19.xii.1983, A. Wells (ANIC); 3 males, larvae and pupae, Bopope, 18.xii.1983, A. Wells, ANIC; 1 larva, Ck between Négropa and Koh on La Foa-Canal Road, 19.xii.1983,A. Wells (ANIC); 2 males, Forêt Thy Reserve, 150 m, 21.v.1984, G. Monteith, D. Cook, QM; 2 males, 1 female, stream beside Farino road, 20.xii.1998,




**Figures 1–10.** Male *Caledonotrichia* head and wings from Automontage photo. **1** Head of *C. capensis* sp. n. dorsal view **2** Head of *C. vexilla* sp. n. dorsal view **3** *C. extensa* Kelley right forewing **4** *C. minuta* right forewing **5** *C. minor* Sykora right forewing **6** *C. ouinnica* sp. n. right fore and hind wing **7** *C. vexilla* sp. n. right forewing **8** *C. capensis* sp. n, right forewing **9** *C. charadra* Kelley right forewing **10** *C. charadra* Kelley right hind wing. Scale bars = 1.0 mm.

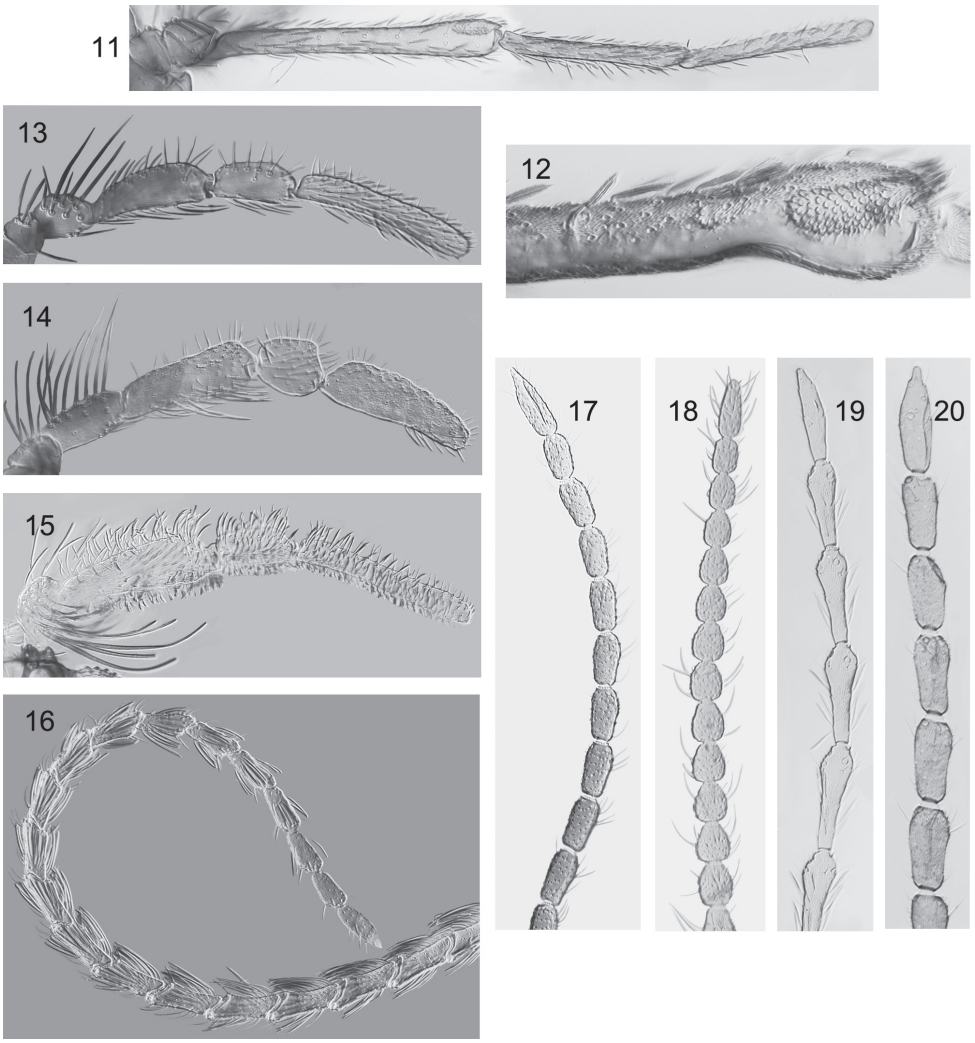
A. Wells, ANIC; 2 males, approx 15 km SW of Houailou on Houailou-Bourail road, small fall, 26.xii.1998, A. Wells (ANIC); 3 males, ~10 km NW Hienghène, small stream, 25.xii.1998, A. Wells (ANIC); 4 males, 2 females Rivière du Cap, Pont du Cap, ~8 km NW Naindai on Bourail-Poya road, 22.xii.1998, A. Wells (ANIC); 11 males, 12 females, stream approx. 20 km SW Thio on Boulouparis-Thio road, 28.xii. 1998, A. Wells (ANIC); 2 males, UFP-LERVEM, Tay 2, 18.x.1999, N. Mary (ANIC);

24 males, 17 females, Province Sud, Monts Kwa Ne Mwa, on road between Noumea and Yaté, Rivière des Pirogues, 22°11.225'S, 166°43.338'E, 100 m, 7.xi.2003, light trap, loc#016, K. A. Johanson (NHRS); numerous males & females, Province Sud, side stream to Rivière Blanche, 10.75 km SW Pont Pérignon, 22°10.073'S, 166°39.903'E, 180 m, 6–16.xi.2003, Malaise trap, loc#012, K. A. Johanson (NHRS); 15 males, 8 females, Province Sud, Mt. Dzumac, source stream of Ouinne River, near crosspoint to mountain track, 22°02.439'S, 166°28.646'E, 805 m, 18.xi–4.xii.2003, Malaise trap, loc#029, K. A. Johanson (NHRS); 7 males, 4 females, Province Sud, Mt. Dzumac, source stream of Ouinne River, near crosspoint to mountain track, 22°02.073'S, 166°28.460'E, 810 m, 18.xi–4.xii.2003, Malaise trap, loc#030, K. A. Johanson (NHRS); 1 male, on slide, Province Sud, Mt. Dzumac, source stream of Ouinne River, downstream crosspoint to mountain track, 22°01.997'S, 166°28.486'E, 795 m, over about 30 m waterfall, 18.xi–4.xii.2003, Malaise trap, loc#031, K. A. Johanson (NHRS); 13 males, 8 females, Province Sud, W slope Mt. Ningua, Kwé Néco Stream, at Camp Jacob, 3.9 km W summit of Mt. Ningua, on Boulouparis–Thio Road, about 50 m upstream road, 21°44.083'S, 166°06.298'E, 117 m, 29.xi–12.xii.2003, Malaise trap, loc#053, K. A. Johanson (NHRS); numerous males, females, Province Sud, W slope Mt. Ningua, Kwé Néco Stream, 3.9 km W summit of Mt. Ningua, on Boulouparis–Thio Road, about 50 m upstream road, 21°44.359'S, 166°06.009'E, 117 m, 20.xi–12.xii.2003, Malaise trap, loc#035, K. A. Johanson (NHRS); males, females, Province Sud, W slope Mt. Ningua, Kwé Néco, Stream, at Camp Jacob, 3.7 km WNW summit of Mt. Ningua, on Boulouparis–Thio Road, about 50 m upstream road, 21°43.613'S, 166°06.567'E, 150 m, 29.xi–12.xii.2003, Malaise trap, loc#054, K. A. Johanson (NHRS); 6 males, Province Sud, Mt Rembai, River Xwâ Be, upstream bridge on road Sarraméa-Koh, 21°33.877'S, 165°49.922'E, loc 157F-k, Malaise trap, 8.vii–4.viii.2007, R. Pöllabauer (NHRS); 6 males, loc 157 F-K, 8.vii–4.viii.2007; 1 male, New Caledonia, Chute S of Col d'Amieu on Sarraméa-Thio road, 2.iv.2012, A. Wells & S. Cazères (ANIC); 7 males, 1 female, Chute de Farina, ~5 km N of Farino, 15.iv.2012, A. Wells (ANIC).

***Caledonotrichia minuta* sp. n.**
urn:lsid:zoobank.org:act:383499C5-C46C-4F4A-99B7-DD93A865AA64
http://species-id.net/wiki/Caledonotrichia_minuta
Figs 4, 13, 23–26, 33–35, 72

**Diagnosis.** Males very closely resemble *C. illiesi* and *C. bifida* sp. n., both of which have wings without scales and both lobes of gonopods rounded, but *C. minuta* differs from *C. illiesi* by smaller size and far less robust appearance, antennae shorter than wings, and in male genitalia dorsal lobe of gonopods more broadly rounded and bat-shaped, and from *C. bifida* sp. n. by having ventral lobes of gonopods almost equal length to dorsal lobes, dorsal lobes more broadly rounded, and sclerotised rods of subgenital process with only small irregularity subapically, not bifid apically as in *C. bifida* sp. n.

**Description, male.** Head rounded in dorsal view, as in *C. capensis* sp. n. (Fig. 1).




**Figures 11–20.** Male *Caledonotrichia* maxillary palp and distal part of antenna from Automontage photo. **11** *C. extensa* Kelley maxillary palp ventral view **12** male maxillary palp ventral view showing area of sensilla on segment 3 **13** *C. minuta* sp. n. maxillary palp ventral view **14** *C. bifida* sp. n. maxillary palp ventral view **15** *C. ouinnica*, sp. n. maxillary palp ventral view **16** *C. bifida*, sp. n. antennae **17**, *C. sykorai*, sp. n. antenna **18** *C. nyurga* Oláh & Johanson antenna **19** *C. extensa* Kelley antenna **20** *C. illiesi* Sykora antenna.

Antennae, male with 23–24 flagellomeres, female with 22 flagellomeres; in male, proximal flagellomeres elongate cylindrical, length not more than 2× width, more distal flagellomeres subquadrate. Male maxillary palps (Fig. 13) similar to those of *C. illiesi*, with basal 2 segments short and rounded, rest cylindrical: segment 3 about 4× maximum width, segment 4 length about 2× width, segment 5 elongate, length almost 6× width. Forewing length, male 1.5–2.2 mm (n=10); female 2.0–2.5 mm (n=10). Male forewing (Fig. 4) without scales, narrow, apically acute, with up-

right bristles on costal vein, hair on distal two thirds of costal margin with strongly curved tips as in *C. illiesi*.

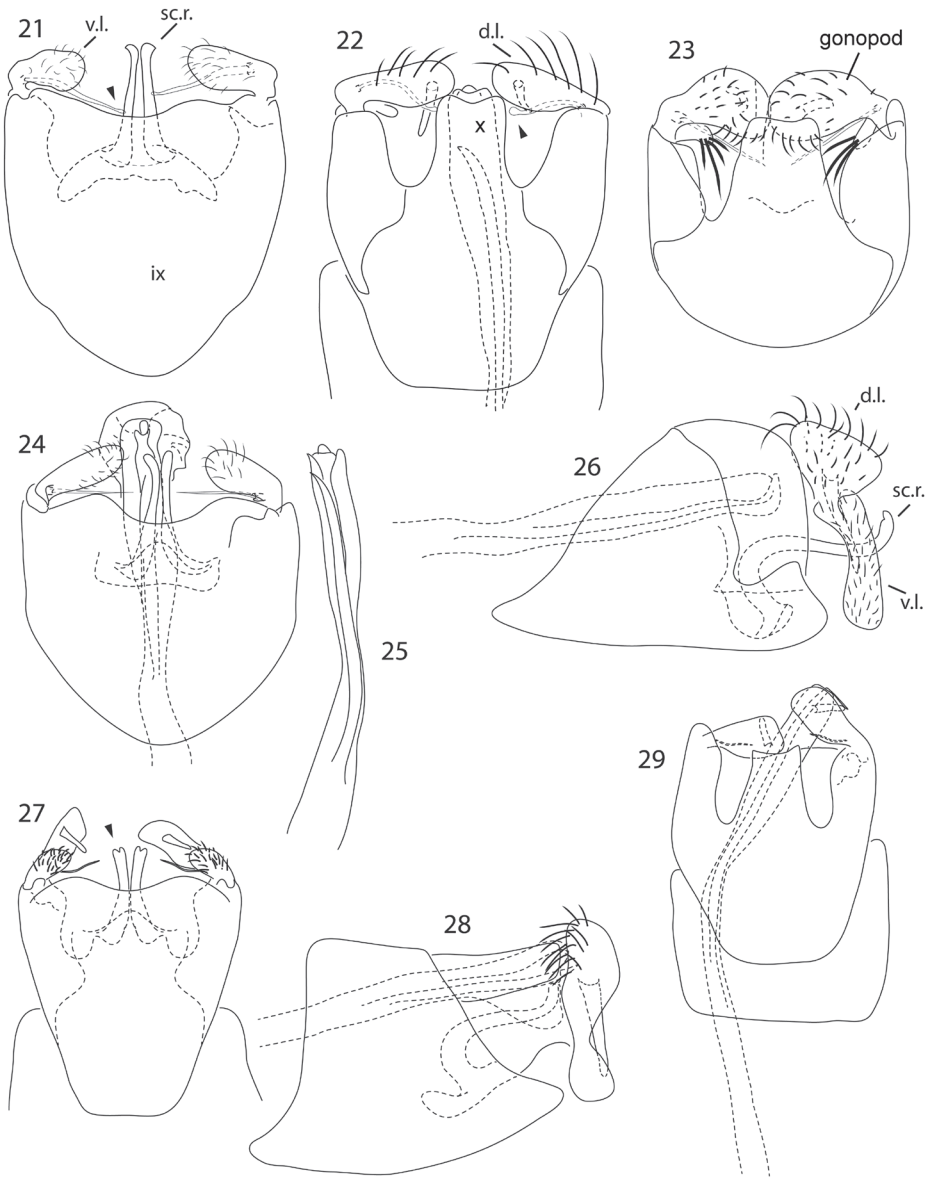
Genitalia (Figs 23–26, 33–35): Abdominal segment IX broadly rounded proximally, distal margin of sternite shallowly excavated medially. Tergite X, tapered slightly to broad, slightly concave apex. Gonopods in ventral view with ventral lobes elongate club-shaped, dorsal lobes broadly rounded, mesal process digitiform, well developed, without setae; axillary seta well developed, acute apically. Sclerotised rods of subgenital process, simple, a slight irregularity below apex. Phallic apparatus elongate, almost straight, broadly rounded distally, with a slender almost straight spiny paramere.

Female terminalia (Fig. 72). Abdominal segment VII bearing fringe of dense short setae distally and apically a short, membranous collar bearing sparsely arranged setae marginally, sternite with a small medial prominence apically; abdominal segments VIII–X forming slender telescopic oviscapt.

**Material examined.** Holotype male: New Caledonia: approx 10 km SW of Houailou on Houailou-Bourail road, small fall, 26.xii.1998, A. Wells (MNHP).

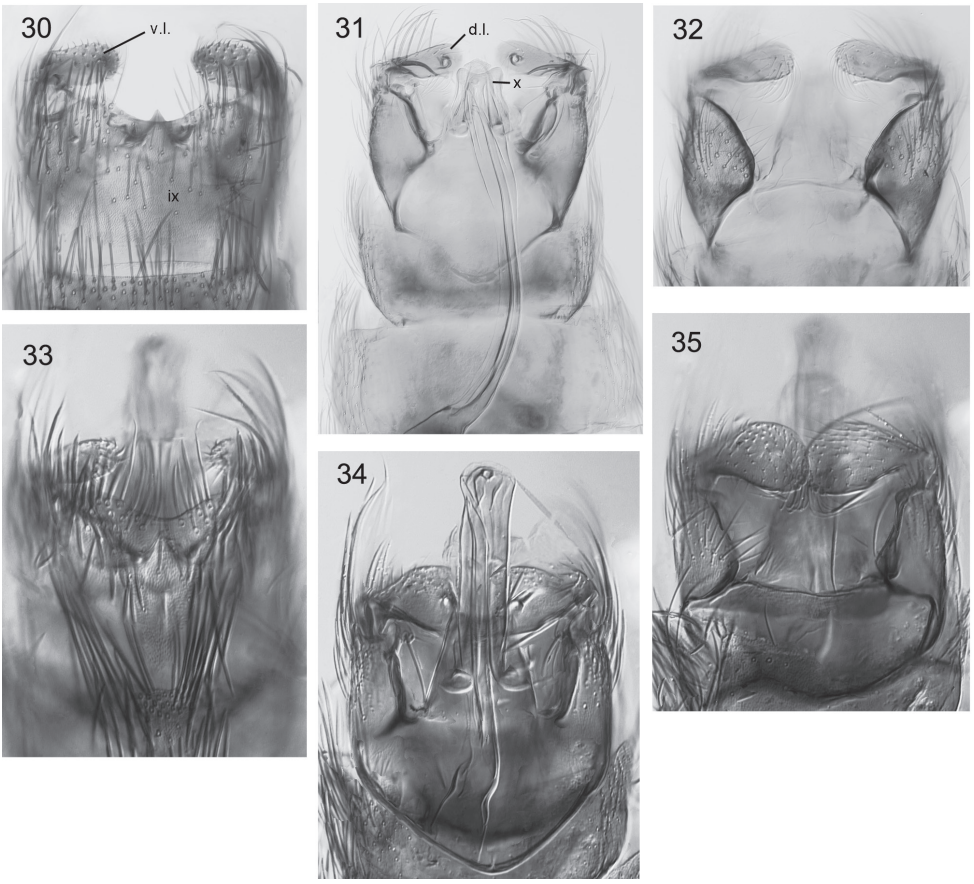
Paratypes: 10 males, same data as for holotype (ANIC); 4 males, approx 10 km NW Hienghène, small stream, 25.xii.1998, A. Wells (ANIC); 3 males, approx 15 km SW Thio on Boulouparis-Thio road, 28.xii.1998, A. Wells (ANIC); 1 male, 1 female (on slides), Province Sud, Mt. Dzumac, source stream of Ouinne River, near crosspoint to mountain track, 22°02.073'S, 166°28.460'E, 810 m, 18.xi–4.xii.2003, Malaise trap, loc#030, K. A. Johanson (SMNH); 11 males, Province Sud, Mt Rembai, River Xwâ Be, upstream bridge on road Sarraméa-Koh, 21°33.877'S, 165°49.922'E, loc 157F-k, Malaise trap, 8.vii–4.viii.2007, R. Pöllabauer (SMNH); 28 males, Chute S of Col d'Amieu on Sarraméa-Thio road, 2.iv.2012, A. Wells & S. Cazères (ANIC).

Other material examined: 1 male, Chute approx 15 km N Col d'Amieu on Boulouparis-Thio road, 27.xi.1998, A. Wells, ANIC; 1 male, Province Sud, stony stream draining Lac Yaté, 200 m, loc 5, 22°08.795'S, 166°42.313'E, Malaise trap 13–16.xi.2001, Johanson, Pape & Viklund (NHRS); 9 males, 14 females, Province Sud, Sarraméa, 290 m, stony forest stream, loc 13 21°37.097'S 165°49.351'E, Malaise trap, 18–21.xi.2001, Johanson, Pape & Viklund (NHRS); 55 males, 18 females, Province Sud, Col d'Amieu, 323 m, small stony river, loc 24, 21°34.844'S, 165°49.677'E, Malaise trap, 30.xi–5.xii.2001, Johanson, Pape & Viklund (NHRS); numerous males, females, Province Sud, Col d'Amieu, 319 m, small stony river, loc 23, 21°34.720'S, 165°49.620'E, Malaise trap, 30.xi–5.xii.2001, Johanson, Pape & Viklund (NHRS); numerous males, females, Province Sud, Monts des Koghis, ca 300 m S Koghi Restaurant, 22.18288°S, 166.50167°E, 417 m, 2–16.xi.2003, Malaise trap, loc#004, K. A. Johanson (NHRS); 1 male, Province Sud, stream draining to Marais de la Rivière Blanche, 1.35 km S Pont Pérignon, 22°08.496'S, 166°42.152'E, 180 m, 6–16.xi.2003, Malaise trap, loc#009, K. A. Johanson (NHRS); 8 males, 29 females, Province Sud, stream draining to Marais de la Rivière Blanche, 2.25 km SW Pont Pérignon, 22.14158°S, 166.67993°E, 157 m, 6–16.xi.2003, Malaise trap, loc#010, K. A. Johanson (NHRS); males, females, Province Sud, side stream to Rivière Blanche, 10.75 km SW Pont Pérignon, 22°10.073'S, 166°39.903'E, 180 m, 6–16.xi.2003, Malaise trap, loc#012, K. A. Johanson (NHRS);




**Figures 21–29.** *Caledonotrichia*, male genitalia. **21** *C. illiesi* Sykora ventral view **22** *C. illiesi* Sykora dorsal view **23** *C. minuta* sp. n. dorsal view **24** *C. minuta* sp. n. ventral view **25** *C. minuta* sp. n. phallic apparatus dorsal view **26** *C. minuta* sp. n. lateral view **27** *C. bifida*, sp. n. ventral view **28** *C. bifida*, sp. n. lateral view **29** *C. bifida* sp. n. dorsal view. Abbreviations: ix = segment IX, x = tergite X, v.l. = ventral lobe of gonopod, d.l. = dorsal lobe of gonopod, s.r. = sclerotised rod of subgenital process.

males, Province Sud, Monts Kwa Ne Mwa, on road between Noumea and Yaté, 2.0 km E Pic Mouirange, 22°12.356'S, 166°40.798'E, 220 m, 7–16.xi.2003, Malaise trap, loc#014, K. A. Johanson (NHRS); 6 males, Province Sud, Monts des Koghis, ca 800 m




**Figures 30–35.** *Caledonotrichia*, male genitalia from Automontage photo. **30** *C. illiesi* Sykora ventral view **31** *C. illiesi* Sykora ventral side of dorsal lobes of gonopods **32** *C. illiesi* Sykora dorsal view **33** *C. minuta* sp. n. ventral view **34** *C. minuta* sp. n. ventral view of ventral side of dorsal lobes of gonopods **35** *C. minuta* sp. n. dorsal view. Abbreviations: ix = segment IX, x = tergite X, v.l. = ventral lobe of gonopod, d.l. = dorsal lobe of gonopod.

S Koghi Restaurant, 22.18311°S, 166.50564°E, 460 m, 10–26.xi.2003, Malaise trap, loc#019, K. A. Johanson (NHRS); 1 male, 4 females (male, female on slides), Province Sud, Mt. Dzumac, source stream of Ouinne River, near crosspoint to mountain track, 22°02.073'S, 166°28.460'E, 810 m, 18.xi–4.xii.2003, Malaise trap, loc#030, K. A. Johanson (NHRS); 2 males, 5 females, Province Sud, Monts des Koghis, ca 800 m S Koghi Restaurant, 22.18406°S, 166.50383°E, 420 m, 1126.xi.2003, Malaise trap, loc#022, K. A. Johanson (NHRS); 3 males, 2 females, Province Sud, Hwa Hace Mt., Hwa Motu River, at Pont Wamuttu, 1.0 km E Nassirah, about 200 m upstream bridge, 21°48.094'S, 166°04.298'E, 137 m, 20.xi–12.xii.2003, Malaise trap, loc#034, K. A. Johanson (NHRS); 2 males, 1 female, Province Nord, Wemwâdiu stream, 850 m E summit Kögi Mt., 5 m upstream road, about 200 m S Tiwaka River, 20°49.020'S, 165°14.165'E, 24 m, 6–27.xii.2003, Malaise trap, loc#067, K. A. Johanson (NHRS); 3

males, Province Nord, Wé Caot Stream, draining NNE side of Mt. Panié, 0.9 km NW Cascade de Tao, 20°33.311'S, 164°48.064'E, 18.xii.2003, light trap, loc#084, K. A. Johanson (NHRS); numerous males, females, Province Sud, W slope Mt. Ningua, Kwé Néco Stream, at Camp Jacob, 3.9 km W summit of Mt. Ningua, on Boulouparis–Thio Road, about 50 m upstream road, 21°44.083'S, 166°06.298'E, 117 m, 29.xi.2003–12.xii.2003, Malaise trap, loc#053, K. A. Johanson (NHRS); numerous males, females, Province Nord, Ponandou Tiôgé River at Kögi, 3.9 km SSW Touho, 20°49.043'S, 165°13.551'E, 25 m, 26.xii.2003, light trap, loc#100, K. A. Johanson (NHRS); males, females, Province Sud, W slope Mt. Ningua, Kwé Néco Stream, 3.9 km W summit of Mt. Ningua, on Boulouparis–Thio Road, about 50 m upstream road, 21°44.359'S, 166°06.009'E, 117 m, 20.xi–12.xii.2003, Malaise trap, loc#035, K. A. Johanson (NHRS); 3 males, Province Nord, 50 m upstream bridge on Hienghène-Tnèdo road, 3.9 km S summit of Mt. Tnèda, 2.2 km E Tnèdo, 20°43.085'S, 164°49.928'E, 29 m, 7.xii.2003, light trap, loc#071, K. A. Johanson (NHRS); 6 males, 15 females, Province Sud, stream crossing way to sanatorium 2.3 km E St Laurent, ca. 150 m upstream bridge, 22°04.484'S, 166°19.910'E, loc 027, Malaise trap, 17–19.x.2006, K. A. Johanson & M. Espeland (NHRS); 2 males, 2 females, Province Sud, stream crossing way to sanatorium 2.3 km E St Laurent, ca. 150 m upstream bridge, 22°04.484'S, 166°19.910'E, loc 027, Malaise trap, 17–19.x.2006, K. A. Johanson & M. Espeland (NHRS); 11 males, numerous females, Province Nord, Ponandou Tiôgé River at Kögi, 3.9 km SSW Touho, 20°49.043'S, 165°13.551'E, 25 m, 26.xii.2003, light trap, loc#100, K. A. Johanson (NHRS).

**Etymology.** *Minuta*, name referring to the small size of the species.

**Remarks.** This species appears to be widespread and often abundant but, like most of the *Caledonotrichia* species, is hard to identify with certainty unless it is mounted on a microscope slide. Thus, only a small number of specimens are designated as paratypes. Considerable numbers of these tiny mostly jet black caddisflies, with shiny silver areas of setae on their wings, most of them males, were seen running around in bright sunlight on exposed rocks at waterfalls. Fig. 74 shows a locality where a large number of specimens, mostly males, of this species were collected by sweep net.

### ***Caledonotrichia bifida*** **sp. n.**

urn:lsid:zoobank.org:act:66E69363-3948-43E6-8920-23136A78D4AA
http://species-id.net/wiki/Caledonotrichia_bifida
Figs 14, 16, 27–29, 44

**Diagnosis.** Males very closely resembling *C. illiesi* and *C. minuta* sp. n., with which they share the features of wings without scales and both lobes of gonopods rounded. Like *C. minuta*, they differ from *C. illiesi* by their smaller size and far less robust appearance, and shorter antennae; they are distinguished from *C. minuta* by having the ventral lobes of gonopods about half as long as dorsal lobes, dorsal lobes less broadly rounded, and sclerotised rods of subgenital process bifid apically, but not dilated as in *C. minor*.

**Description, male.** Head. Rounded in dorsal view, as in *C. capensis* sp. n. (Fig. 1). Antennae (Fig. 16) with 22–23 flagellomeres; most flagellomeres elongate-cylindrical with ends angled obliquely, not more than 2.5× width. Maxillary palps (Fig. 14) with basal segment short and rounded, segments 2, 3 and 5 cylindrical, segments 3 and 5 length about 3× maximum width, segment 4 subquadrate.

Wings. Forewing length, 1.8–2.0 mm (n=5); forewing without scales.

Genitalia (Figs 27–29, 44). Abdominal segment IX truncate proximally, distal margin of sternite shallowly excavated medially, bearing robust elongate setae. Tergite X, tapered slightly, apical margin concave. Gonopods in ventral view with ventral lobes scarcely longer than wide, dorsal lobes about with length about 2× width, twice length of ventral lobes, mesal process digitiform, well developed, without setae; axillary seta slender, acute apically. Sclerotised rods of subgenital process narrowly bifid apically (arrow in Fig. 27). Phallic apparatus elongate, slender in proximal 2/3, stouter distally, with a slender spiny paramere.

**Material examined.** Holotype male: New Caledonia: Province Sud, Sarraméa, 220 m, forest stream, loc 10 21°37.883'S, 165°51.958'E, Malaise trap, 18–21.xi.2001, Johanson, Pape & Viklund (MNHP).

Paratypes: New Caledonia: 1 male, collected with holotype; 3 males, Province Sud, W slope Mt. Ningua, Kwé Néco, Stream, at Camp Jacob, 3.7 km WNW summit of Mt. Ningua, on Boulouparis—Thio Road, about 50 m upstream road, 21°43.613'S, 166°06.567'E, 150 m, 29.xi–12.xii.2003, Malaise trap, loc#054, K. A. Johanson (NHRS); 2 males, Province Nord, Wan Pwé On Stream, draining NNE side of Mt. Panié, 3.9 km NW Cascade de Tao, 20°31.820'S, 164°47.016'E, 18.xii.2003, light trap, loc#085, K. A. Johanson (NHRS).

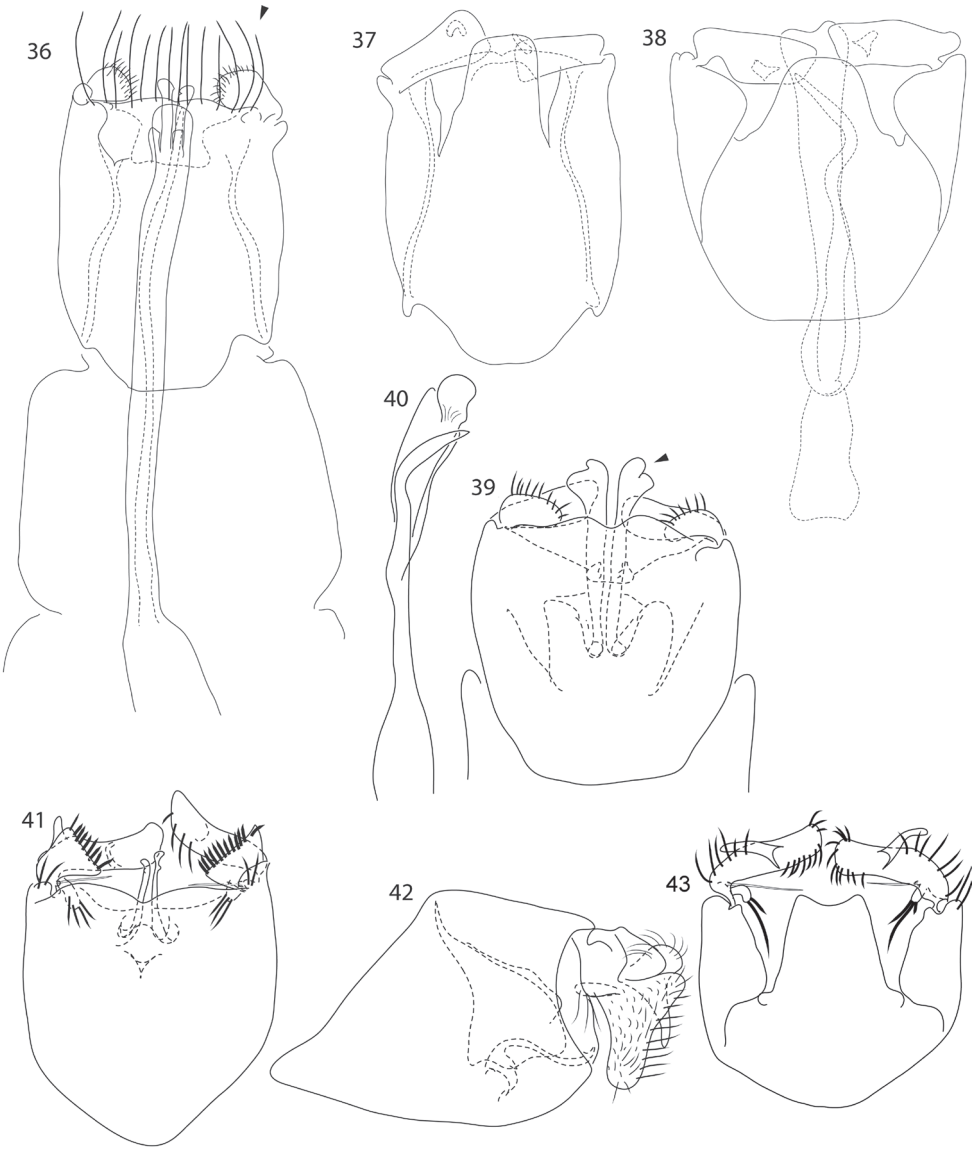
**Etymology.** In reference to the bilobed apices of the sclerotised rods in the male genitalia.

### *Caledonotrichia ouinnica* sp. n.

urn:lsid:zoobank.org:act:DC29045A-A990-4F62-BB01-1C4BDD6136B4
http://species-id.net/wiki/Caledonotrichia_ouinnica
Figs 6, 15, 36–37, 45

**Diagnosis.** Males are recognised by the presence of a tiny jet black spot on the forewing between veins R and M, formed by a cluster of androconial scales; but it is particularly distinguished from all other species by maxillary palps with dense brush of elongate setae on the first segment and bristle-like setae on other segments which give the palps a bottlebrush-like appearance (Fig. 15), including the otherwise closely similar *C. minor* which has maxillary palps of the usual form with fewer and shorter straight setae, the forewings are less attenuate apically and the area of scales over the fork in M larger.

**Description, male.** Head rounded in dorsal view, as in *C. capensis* sp. n. (Fig. 1). Forewing (Fig. 6) length, 2.2–2.4 mm (n=5); wing acute apically; small cluster




**Figures 36–43.** *Caledonotrichia*, male genitalia. **36** *C. ouinnica*, sp. n. ventral view **37** *C. ouinnica*, sp. n. dorsal view **38** *C. minor* Sykora dorsal view **39** *C. minor* Sykora ventral view **40** *C. minor* Sykora phallic apparatus ventral view **41** *C. vexilla* sp. n. ventral view **42** *C. vexilla* sp. n. lateral view **43** *C. vexilla* sp. n. dorsal view.

of slender jet black androconia proximally. Maxillary palps densely hairy (Fig. 15), with basal 2 segments short and rounded, segment 2 bearing a tuft of long setae, segment 3–5 cylindrical, segment 3 length almost 3× maximum width, segment 4 length about 2× width, segment 5 length approximately 6× width. Antennae with 23–24 flagellomeres, median flagellomeres slender with length around 4–6× width.

Genitalia (Figs 36, 37, 45). Abdominal segment IX rounded anteriorly, sternite slightly cleft medially on posterior margin, a row of elongate setae on distal margin (arrow in Fig. 36). Tergite X tapered to broadly rounded apex. Each gonopod with ventral lobe club-shaped, dense short setae towards tip, dorsal lobe rectangular. Sclerotised rods of subgenital process in ventral view simple, rounded apically. Phallic apparatus elongate, almost length of abdominal segments VII–IX, without associated parameres.

**Material examined.** Holotype, male: New Caledonia: Province Sud, Mt. Dzumac, source stream of Ouinne River, near crosspoint to mountain track, 22°02.073'S, 166°28.460'E, 810 m, 18.xi–4.xii.2003, Malaise trap, loc#030, K. A. Johanson (MNHP).

**Paratypes.** New Caledonia. 3 males, collected with holotype, (NHRS); 1 male (dissected) Province Sud, Monts Kwa Ne Mwa, on road between Noumea and Yaté, 1.5 km E Pic Mouirange, 22°12.545'S, 166°40.246'E, 143 m, 9.xi.2003, light trap, loc#018, K. A. Johanson (NHRS); 3 males, 5 females, Province Sud, Mt. Dzumac, source stream of Ouinne River, near crosspoint to mountain track, 22°02.439'S, 166°28.646'E, 805 m, 18.xi–4.xii.2003, Malaise trap, loc#029, K. A. Johanson (NHRS).

**Etymology.** In reference to the river at the type locality.

### *Caledonotrichia minor* Sykora

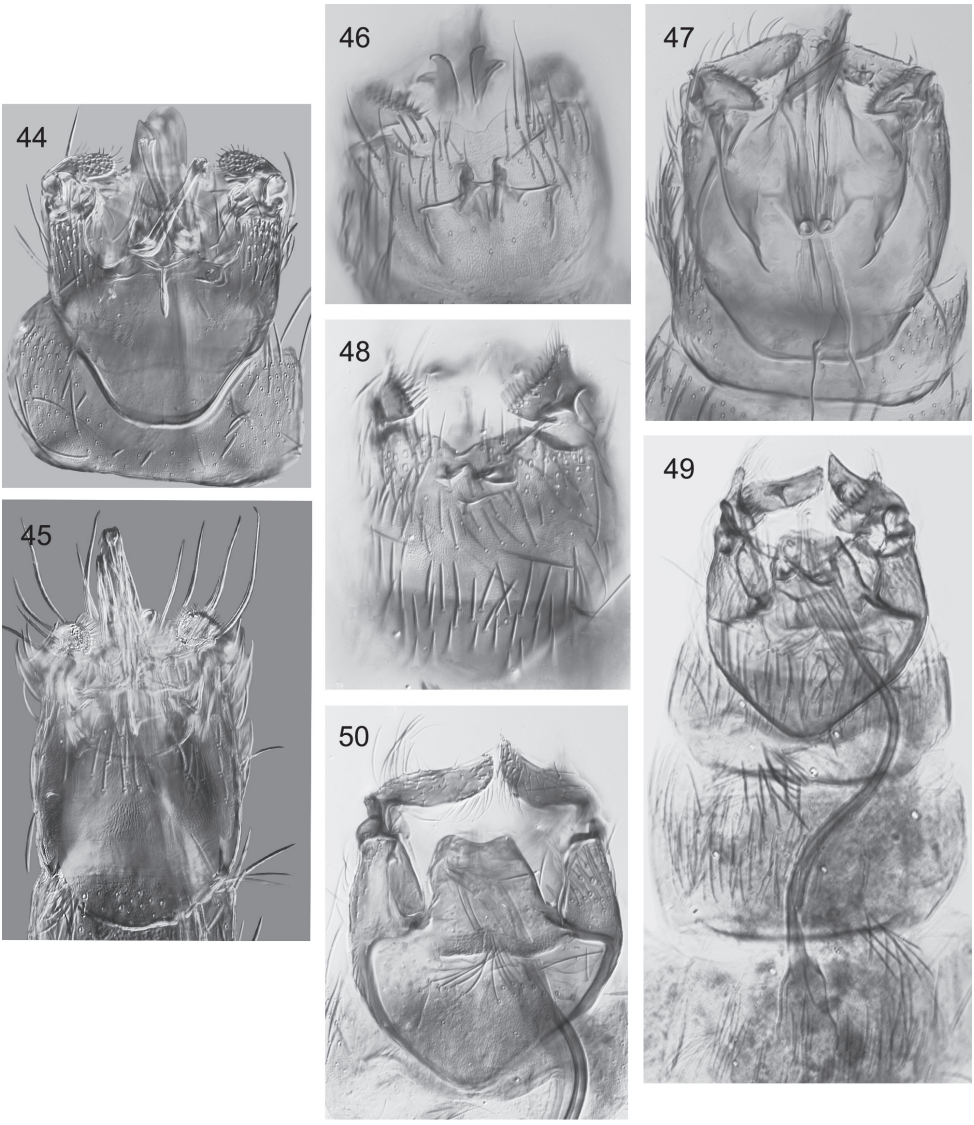
http://species-id.net/wiki/Caledonotrichia_minor
Figs 5, 38–40, 46–47

*Caledonotrichia minor* Sykora (1967: 585–595); Wells (1995: 230).

**Revised diagnosis.** Males of *C. minor* share with those of *C. charadra*, *C. capensis* sp. n. and *C. ouinnica* sp. n. the presence of androconia on the forewing only (Fig. 5), and are distinguished from these species by the size of the single patch of scales, which forms a small dark area proximally, though larger than the tiny black spot of *C. ouinnica*, whereas *C. charadra* and *C. capensis* sp. n. have large areas; in the male genitalia (Figs 38–40, 46–47), as in *C. charadra* and *C. capensis*, the ventral lobes of the gonopods in ventral view are triangular, but the sclerotised rods of the ventral processes are bilobed and broadly flared apically (arrow in Fig. 39), whereas the other two species have just a small subapical irregularity. The forewing of *C. minor* is not as slender as that of *C. ouinnica*, which tapers to an acute apex.

**Revised description, male.** Male head rounded as in *C. capensis* sp. n. (Fig. 1).

Antennae with 24–28 flagellomeres (n=5); flagellomeres elongate cylindrical. Maxillary palps with basal 2 segments short and rounded, rest cylindrical: segment 3 about 3× maximum width, segment 4 length about 2× width, and 5 elongate slender, length almost 6× width. Forewing (Fig. 5) length, 1.6–2.1 mm (n=5); small patch of slender scales medially at about one third length, some upright bristles on veins, costal margin hairs straight.




**Figures 44–50.** *Caledonotrichia*, male genitalia from Automontage photo. **44** *C. bifida* sp. n. ventral view **45** *C. ouinnica* sp. n. ventral view **46** *C. minor* Sykora ventral view **47** *C. minor* Sykora dorsal view **48** *C. vexilla* sp. n. ventral view **49** *C. vexilla* sp. n. ventral side of dorsal lobes of gonopods **50** *C. vexilla* sp. n. dorsal view.

**Material examined.** Holotype, male: New Caledonia: River near Col d'Amieu (BPBM) (examined).

**Other material examined:** New Caledonia: 1 male, Nékliai River, 5 km above Mission Station [near Poya], 10.viii.1965, F. Starmühlner (ROM); 1 pharate male pupa, larvae, Nerihouen River, St Ives, Reg. Ponérihouen, 27.viii. 1965, F. Starmühlner (ROM); 30 males, 7 females, Ouenghi River nr Boulouparis, 14.xii.1983, A. Wells

(ANIC); 13 males, 8 females, same locality, 19.xii.1983, A. Wells (ANIC); 34 males, 7 females, Bopope, 18.xii.1983, A. Wells (ANIC); 28 males, ~10 km NW Hienghène, small stream, 25.xii.1998, A. Wells (ANIC); 2 males (on slides), Prov. Sud, Sarraméa, 220 m, forest stream, loc 10 21°37.883'S 165°51.958'E, Malaise trap, 18–21.xi.2001, Johanson, Pape & Viklund (NHRS).

**Remarks.** The mature larva illustrated by Wells (1995: 226, fig. 2) is typically stactobiine, its case a round dome that is attached to the rock surface.

### *Caledonotrichia vexilla* sp. n.

urn:lsid:zoobank.org:act:D873D57C-42C8-4BBC-A1A4-E8F10DBCDCEB
http://species-id.net/wiki/Caledonotrichia_vexilla
Figs 2, 7, 41–43, 48–50

**Diagnosis.** Males lack scales on wings but otherwise in features of male genitalia resemble closely those of *C. charadra* and *C. capensis* sp. n., having ventral lobes of gonopods triangular but in *C. charadra* dorsal lobes are somewhat rounded, in *C. capensis* they are rectangular, while in *C. vexilla* they are tapered apically; *C. capensis* has the phallic apparatus short with a sharply angled paramere, while *C. vexilla* has the phallic apparatus elongate, about length of 3 abdominal segments, and the paramere spine strongly sinuous.

**Description, male.** Head (Fig. 2) rectangular in dorsal view, length about one-third the width. Antennae with 24–25 flagellomeres; flagellomeres elongate-cylindrical, with length 2.5–3× width. Maxillary palps with basal 2 segments round, segments 3–5 cylindrical, segment 3 relatively stout, slightly longer than segment 5, segment 5 length about 6× width, apical margin truncate.

Forewing (Fig. 7), length 2.2 mm (n=3); wings without scales, forewing densely hairy, with upright bristle-like hairs on veins, and on distal two-thirds costal margin long slender hairs with strongly curved tips.

Genitalia (Figs 41–43, 48–50). Abdominal segment IX in ventral view shield-shaped, distal margin shallowly excavated medially. Tergite X, subquadrate, apical margin concave. Gonopods bilobed, ventral lobe sharply triangular with row of stout setae on apical margin, dorsal lobe subrectangular, tapered slightly towards outer apical angle, mesal process spur-shaped, sclerotised; axillary seta short. Sclerotised rods of subgenital process with a slight irregularity laterally below apex. Phallic apparatus elongate, sinuous, with a stout, sinuous spiny paramere.

**Material examined.** Holotype male (on slide): New Caledonia: Parc de Rivière Bleu, approx 1 km W Kaori Giant, 19.xii.1998, A. Wells (MNHP).

Paratypes: New Caledonia. 2 males (1 on slide), collected with holotype (ANIC); 6 males, Parc de Rivière Bleu, Rivière Bleue, approx 1 km W Kaori Giant, 19.xii.1998, A. Wells (ANIC); 4 males, Rivière du Cap, approx 8 km NW Naindai, Bourail to Poya road, 22.xii.1998, A. Wells (ANIC).

**Other material examined:** New Caledonia 1 pharate male pupa (damaged), 3 cases, Rivière Bleue, bridge forest road, 21.vii.1965, F. Starmühlner (ROM).

**Etymology.** In reference to the vexatious problem of distinguishing this species from others primarily on the basis of internal features.

**Remarks.** Males of this small jet black species were collected in bright sunlight as they ran about on an emergent rock in the stream. The three cases collected with the single pharate male pupa from Rivière Bleue, resemble closely those described by Wells (1985: 11) for *C. illiesi*, having a broad flat margin to the case; however, they lack dorsal vents on the dome seen in that species.

### *Caledonotrichia capensis* sp. n.

urn:lsid:zoobank.org:act:321477EA-EB4F-457F-BF45-0963BA37E082
http://species-id.net/wiki/Caledonotrichia_capensis
Figs 1, 8, 51–53, 64–65

**Diagnosis.** Males of this species are readily recognised by the band of elongate-ovoid black scales that stretches almost the length of the forewing; in features of genitalia they closely resemble *C. minor* and *C. vexilla* sp. n. Females not associated.

**Description, male.** Head rounded (Fig. 1). Antennae with 24 flagellomeres; flagellomeres elongate cylindrical, longest with length about 3× width. Maxillary palps with basal 2 segments short and rounded, rest cylindrical: segment 3 about 4× maximum width, segment 4 length about 2.5× width, segment 5 elongate slender, length almost 6× width.

Wings. Forewing (Fig. 8) length, 1.0–1.7 mm (n=5); bearing elongate patch of black scales (androconia) medially reaching almost from leading proximal angle to about two-thirds wing length, and separate small patch close to proximal margin; costal margin hairs straight. Hind wing bearing small rather scattered black scales, more slender than those of forewing.

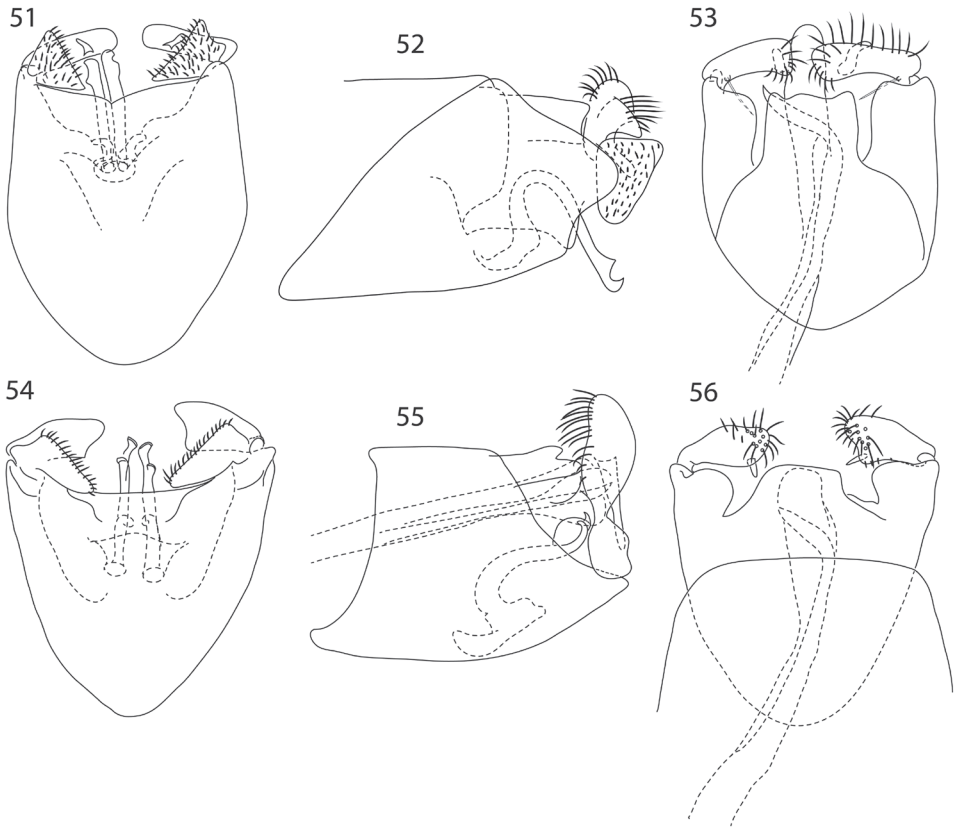
Genitalia (Figs 51–53, 64–65). Abdominal segment IX rounded proximally, apical margin cleft medially. Tergite X with lateral margins slightly rounded, apically concave. Gonopods with ventral lobes triangular, apical margin slightly concave, dorsal lobes elongate rectangular; axillary seta not apparent. Sclerotised rods of subgenital process in ventral view with small cap-like irregularity apically and another subapically, in lateral view dilated apically. Phallic apparatus elongate, slender, strongly curved at about two-thirds length, with stout parameres.

**Material examined.** Holotype male: New Caledonia: Rivière du Cap, Pont du Cap, ~8 km NW Naindai on Bourail-Poya road, 22.xii.1998, A. Wells (MNHP).

Paratypes: 5 males, same data as for holotype (one on slide) (ANIC).

**Etymology.** Named for the type locality, Rivière du Cap.

**Remarks.** The specimens of this species were collected as they ran about in sunlight on the surfaces of emergent rocks in the stream.




**Figures 51–56.** *Caledonotrichia*, male genitalia. **51** *C. capensis* sp. n. ventral view **52** *C. capensis* sp. n. lateral view **53** *C. capensis* sp. n. dorsal view **54** *C. charadra* Kelley ventral view **55** *C. charadra* Kelley lateral view **56** *C. charadra* Kelley dorsal view.

### *Caledonotrichia charadra* Kelley

http://species-id.net/wiki/Caledonotrichia_charadra
Figs 9–10, 54–56

*Caledonotrichia charadra* Kelley (1989: 194).

**Revised diagnosis.** Like *C. capensis* males have scale patches on both fore- and hind wings (Figs 9–10), a feature that distinguishes it from *C. minor* and *C. ouinnica*, both of which have scale patches on the forewings only; in the genitalia (Figs 54–56) the triangular shape of ventral lobes of the gonopods of *C. charadra* closely resembles the arrangement in *C. capensis* sp. n. and *C. vexilla* sp. n. but in *C. charadra* the dorsal lobes are quadrilateral, rather than elongate rectangular or subrectangular as in those two species, and the paramere associated with the phallic apparatus is more gently curved.

**Additional information, male.** Male head rounded as in *C. capensis*. Male antennae with 24–26 flagellomeres; flagellomeres elongate rectangular. Male maxillary

palps as for *C. capensis*. Male forewing length, 1.5–1.9 mm (n=10). Fore- and hind wings both bear rectangular patch of black scales proximally (Figs 9–10), although these may be shed or lost due to abrasion.

**Remarks.** Several features noted on examination of the type specimen of *C. charadra* that were not mentioned by Kelley (1989) were scales on wings and the subapical irregularity on the ventral processes, that gives the apex a hooked appearance when seen in lateral view. In addition, while the type specimen has scales on the forewing only, we are assuming that the scales were lost from the hind wing as, in other respects, the more recently collected specimens conform to the type but have scales on both wings.

**Material examined.** Holotype male: New Caledonia: mountain stream up Boulari River (BPBM) [entire animal macerated and stored in vial].

**Other material examined.** 1 male, Ouenghi River nr Boulouparis, 14.xii.1983, A. Wells (ANIC); 37 males, 1 female, Parc de la Rivière Bleue, approx 1 km W Kaori Giant, 19.xii.1998, A. Wells (ANIC).

### ***Caledonotrichia extensa*** **Kelley**

http://species-id.net/wiki/Caledonotrichia_extensa
Figs 3, 11–12, 19, 57–58, 66, 70

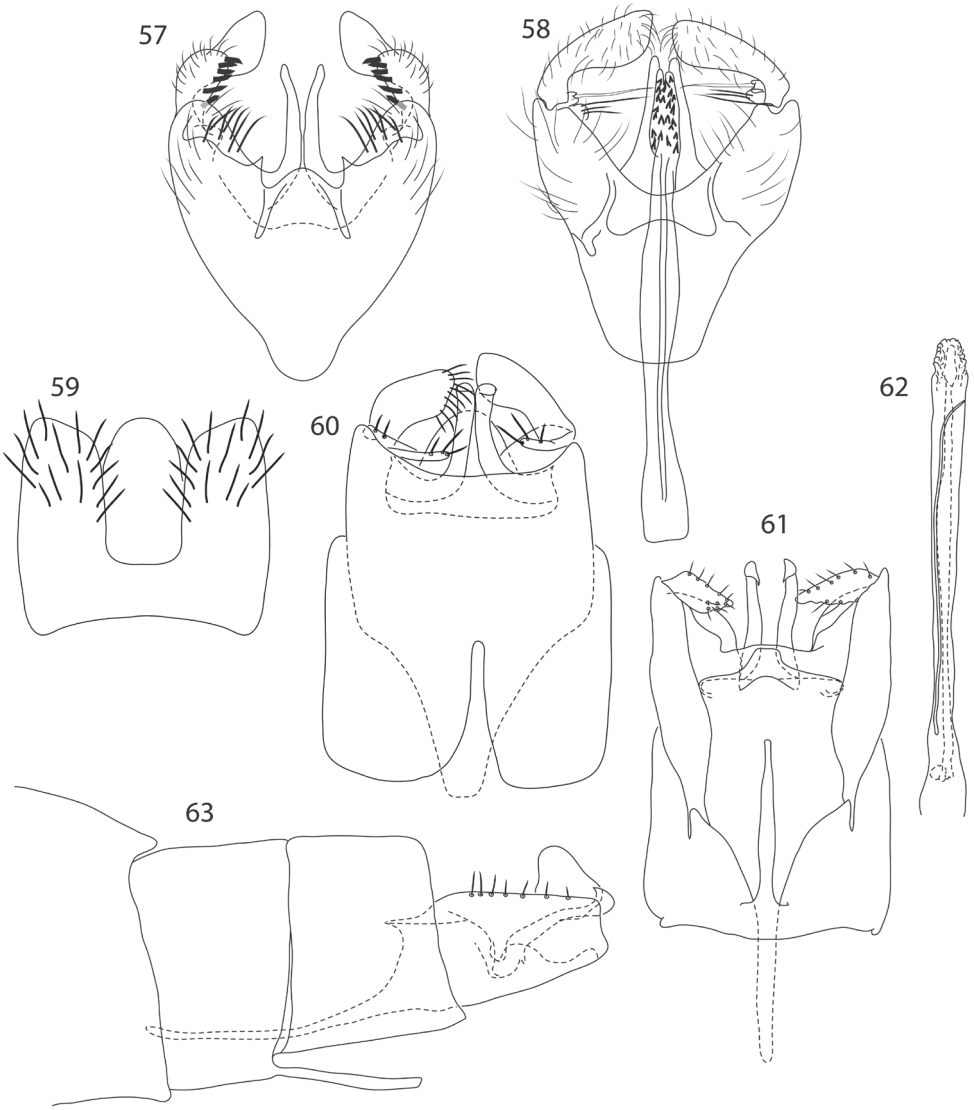
*Caledonotrichia extensa* Kelley (1989: 195).

**Revised diagnosis.** As noted by Kelley (1989) *C. extensa* is distinctive in being larger than any other species; as in males of *C. nyurga* antennae are extremely long, just exceeding length of body, but in contrast to that species the segments (Fig. 19) tend to be more elongate, inverted urn-shaped, not bead-like, and the longest segments are about 6× as long as wide; maxillary palps (Figs 11–12) with segments 1 and 2 round, segments 4 and 5 length about 8× width, segment 3 length about 1.5× length of each of terminal segments, swollen apically and bearing area of sensilla apico-dorsally (Fig. 12); male genitalia are clearly visible under a dissecting microscope, with abdominal sternite IX deeply concave distally, ventral lobes of gonopods rounded, bearing row of stout dark setae on mesal margin, not narrowly membranous and leaf-like as in *C. nyurga*, or slender and finger-like as in *C. sykorai* sp. n.

**Additional information, male.** Head subquadrate; antennae (Fig. 19) with 25–26 flagellomeres (n=10); scape elongate-rounded, pedicel short, rounded, other flagellomeres elongate-cylindrical to flask-shaped, bearing numerous *sensilla coeloconica*.

Forewing (Fig. 3) without scales or specialised setae, venation more complete than in other congeners; length: 2.2–3.6 mm (n=10).

Genitalia (Figs 57–58, 66). Abdominal segment IX in ventral view almost triangular, strongly tapered and narrowly rounded anteriorly, a deep concavity on posterior margin of sternite. Tergite X narrow, elongate, straight sided, rounded apically. Gonopods with ventral lobe length 1.5X width, bearing stout setae on mesal margin and




**Figures 57–63.** *Caledonotrichia*, male genitalia. **57** *C. extensa* Sykora ventral view **58** *C. extensa* Sykora dorsal view **59** *C. sykorai* sp. n. dorsal view **60** *C. sykorai* sp. n. ventral view **61** *C. nyurga* Oláh & Johanson ventral view **62** *C. nyurga* Oláh & Johanson phallic apparatus ventral view **63** *C. nyurga* Oláh & Johanson lateral view.

apically, dorsal lobe elongate club-shaped, a row of sclerotised short setae subapicomesally, most distal pair bent sharply, axillary seta long, slender, apically acute. Sclerotised rods of subgenital process straight, slightly sculptured apically. Phallic apparatus straight, elongate, slender, with a dorsal crease along two-thirds length and with associated spine-covered apical membrane.

Case of mature larva (Fig. 70). Cigar-shaped, with a pair of dorsal vents and at each end a bract-like overhang. Cased larvae of *C. extensa* were associated via pharate adults, and demonstrate that unlike the larvae of *C. illiesi* that live in fixed dome-shaped cases, larvae of *C. extensa* are mobile, carrying their cases about. These portable cases are cigar-shaped, tapered at each end and comprise two identical secretion valves, clearly with an upper and lower side. In common with cases of *C. illiesi*, however, cases of *C. extensa* have dorsal vents, although in *C. extensa* these are larger openings, situated near the ends of the dorsal seam of the two valves and opening away from the case.

**Material examined.** Holotype male: New Caledonia: mountain stream up Boulari River (BPBM).

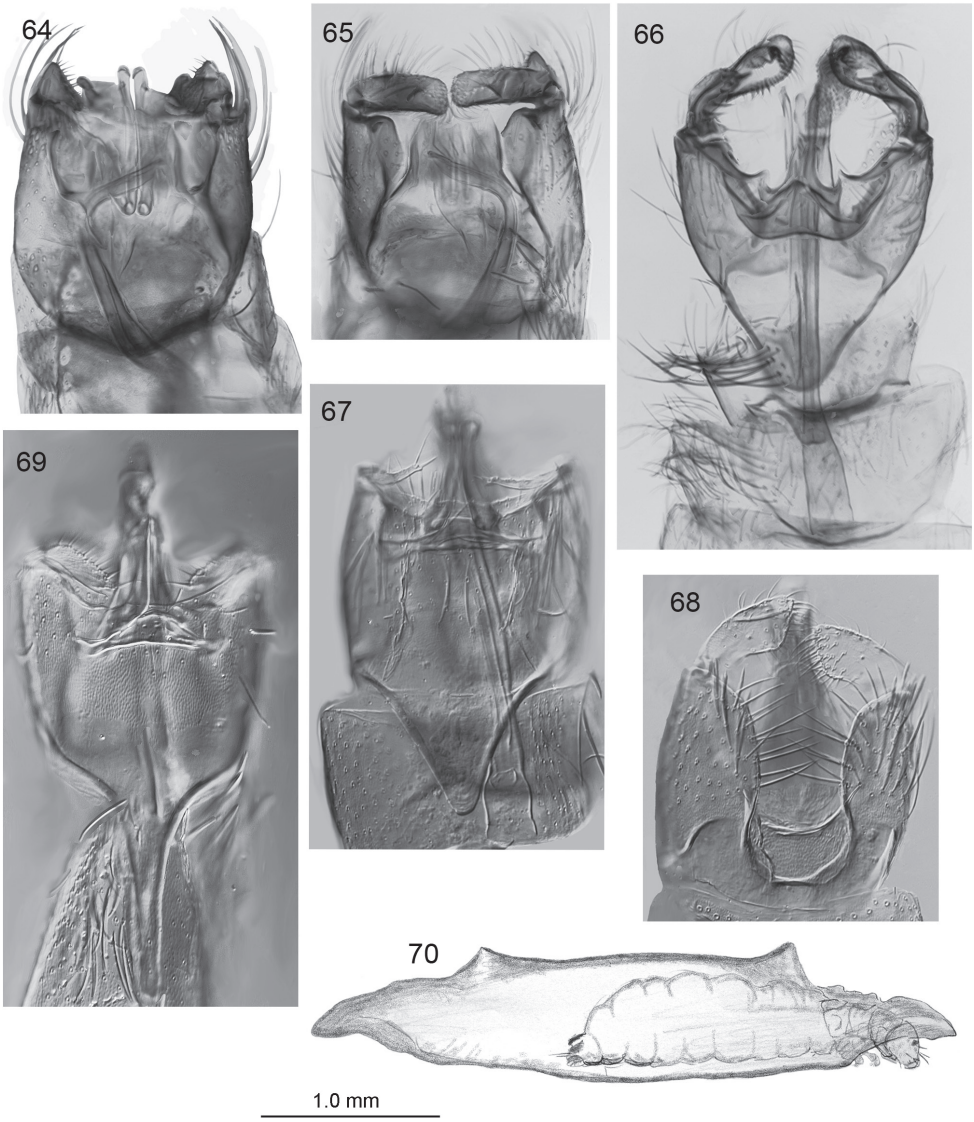
**Additional material examined.** New Caledonia: 1 cased larva, Ouarou River, source of Tchamba R., N of Ponerinouen, 25.viii.1965, F. Starmühlner (ROM); prepupae, pupae, middle Tchamba R., below Tchamba, 26.viii.1965, F. Starmühlner (ROM); 8 males, Nerihouen River, St Ives, Reg. Ponérihouen, 27.viii. 1965, F. Starmühlner (ROM); larvae, pupae, St Ives Reg. Ponérihouen, 27.viii. 1965, F. Starmühlner (ROM); larvae, pupae, 1 female, 3 km from mouth of Mou River, Reg. Ponérihouen, 28.viii. 1965, F. Starmühlner (ROM); 1 prepupa, river Col d'Boa, [no date], F. Starmühlner (ROM); 1 male, Yaté turnoff, 24.viii.1973, A.G. McFarlane & R.A. Savill; 1 male, 1 female, 4 km SW Col de Mouirange, 20 m, 10.viii.1979, G.M. Nishida (BPBM); larvae, pupae, Boghen, Oct. 1996, N. Mary (ANIC); 45 males, Rivière du Cap, Pont du Cap, approx 8 km NW Naindai on Bourail-Poya road, 22.xii.1998, A. Wells; 3 males, stream, approx 15 km SW Thio on Boulouparis-Thio road, 28.xii.1998, A. Wells (ANIC); pupae, River Ni, 25 July 2000, N. Mary (ANIC); 1 male, Province Nord, Ponandou Tiôgé River at Kögi, 3.9 km SSW Touho, 20°49.043'S, 165°13.551'E, 25 m, 26.xii.2003, light trap, loc#100, K. A. Johanson (NHRS).

### *Caledonotrichia nyurga* Oláh & Johanson

http://species-id.net/wiki/Caledonotrichia_nyurga
Figs 18, 61–63, 69

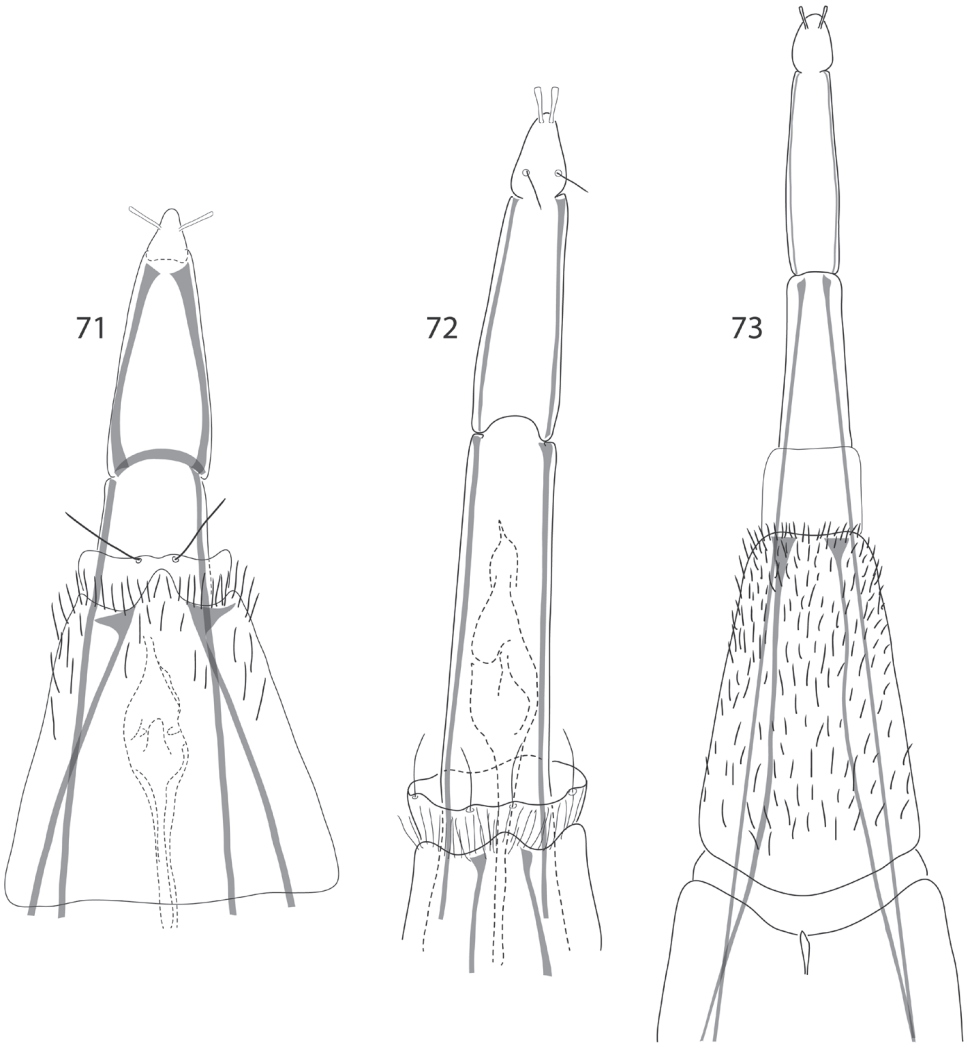
*Caledonotrichia nyurga* Oláh & Johanson (2010: 101).

**Revised diagnosis.** Males of this species are recognised in mixed collections by the clearly visible genitalia (Figs 61–63, 69), a consequence of the deep excision of the posterior margin of sternite IX, and also by the moniliform distal segments of the antennae. *Caledonotrichia nyurga* is smaller-bodied than both *C. extensa* and the otherwise similar *C. sykorai* sp. n. with which it shares the feature of a pronounced mesal process on the posterior margin of sternite VII, though in the latter species the mesal process is far shorter than in *C. nyurga* and elongate triangular. *Caledonotrichia nyurga* also differs from *C. sykorai* by the very slender anterior extension of abdominal segment IX, broader ventral lobes of gonopods, and the less sharply excised abdominal tergite IX.




**Figures 64–70.** *Caledonotrichia*, male genitalia from Automontage. **64** *C. capensis* sp. n. ventral view **65** *C. capensis* sp. n. dorsal view **66** *C. extensa* Kelley ventral side of dorsal lobes of gonopods **67** *C. sykorai* sp. n. ventral view **68** *C. sykorai* sp. n. dorsal view **69** *C. nyurga* Oláh & Johanson dorsal view **70** *C. extensa* Kelley final instar larva in case in lateral view.

Additional information, male. Head, rounded as in *C. capensis*. Antennae (Fig. 18) with 25–39 flagellomeres; flagellomere shape variable; distal flagellomeres moniliform, proximal flagellomeres elongate cylindrical. Maxillary palps with basal 2 segments short and rounded, rest cylindrical: segment 3 slightly shorter than segment 4, segment 5 slender, elongate with length about 10× as long as width and equal to length of




**Figures 71–73.** *Caledonotrichia*, female terminalia. **71** *C. illiesi* Sykora ventral view **72** *C. minuta*, sp. n. ventral view **73** *C. sykorai* sp. n. ventral view.

segments 3 and 4 together. Forewing length, 1.4–2.0 mm (n=10), apically less sharply tapered than other congeners.

**Material examined.** New Caledonia: Holotype male, Province Sud, W slope Mt. Ningua, Kwé Néco, Stream, at Camp Jacob, 3.7 km WNW summit of Mt. Ningua, on Boulouparis–Thio Road, about 50 m upstream road, 21°43.613'S, 166°06.567'E, 150 m, 29.xi–12.xii.2003, Malaise trap, loc#054, K. A. Johanson (MNHN); 3 males (on slides), Province Sud, Rivière Bleue, 282 m, stony river, loc 4, 22°05.705'S, 166°38.225'E, Malaise trap, 13–16.xi.2001, Johanson, Pape & Viklund (NHRS); 2 males (1 male on slide), Province Sud, Sarraméa, 2907 m, stony forest stream, loc 13 21°37.097'S 165°49.351'E, Malaise trap, 18–21.xi.2001, Johanson, Pape & Viklund (NHRS); 4


**Figure 74.** Steep waterfall at Col d'Amieu, Southern Province, New Caledonia, 2.iv.2012, where adults of *C. minuta* sp. n. were collected by Sylvie Cazères (on photo) using a sweep-net and aspirator.

males, Province Nord, Mt. Panié, 350 m, loc. 16 rocky river downstream waterfall, 20°35.864'S, 164°49.780'E, Malaise trap, 22–26.xi.2001, Johanson, Pape & Viklund (NHRS); 4 males, Province Sud, Monts Kwa Ne Mwa, on road between Noumea and Yaté, Rivière des Pirogues, 22°11.225'S, 166°43.338'E, 100 m, 7.xi.2003, light trap, loc#016, K. A. Johanson (NHRS); 1 male, Province Sud, Mt. Dzumac, source stream of Ouinne River, near crosspoint to mountain track, 22°02.439'S, 166°28.646'E, 805 m, 18.xi–4.xii.2003, Malaise trap, loc#029, K. A. Johanson (NHRS); 10 males, 11 females, Province Sud, Mt. Dzumac, source stream of Ouinne River, near crosspoint to mountain track, 22°02.073'S, 166°28.460'E, 810 m, 18.xi–4.xii.2003, Malaise trap, loc#030, K. A.

Johanson (NHRS); 4 males, Province Sud, Mt. Dzumac, source stream of Ouinne River, downstream crosspoint to mountain track, 22°01.997'S, 166°28.486'E, 795 m, over about 30 m waterfall, 18.xi–4.xii.2003, Malaise trap, loc#031, K. A. Johanson (NHRS); 15 males, Province Sud, W slope Mt. Ningua, Kwé Néco, Stream, at Camp Jacob, 3.7 km WNW summit of Mt. Ningua, on Boulouparis–Thio Road, about 50 m upstream road, 21°43.613'S, 166°06.567'E, 150 m, 29.xi–12.xii.2003, Malaise trap, loc#054, K. A. Johanson (NHRS); 1 male, Province Sud, Creek Froid, 10 m upstream bridge on La Foa–Koindé road, 200 m W crossroad to Ouipouin, 21°38.581'S, 165°56.672'E, 180 m, 4.i.2004, light trap, loc#105, K. A. Johanson (NHRS).

**Holotype male (examined):** New Caledonia, Provence Sud, W. slope of Mt Ningua, Kwe Néco Stream, at Camp Jacob, 3.7 km WNW summit of Mt. Ningua, on Boulouparis-Thio Road, 21°43.613'S, 166°06.567'E, 29.xi–12.xii.2003, K. A. Johanson (alcohol, MNHP).

***Caledonotrichia sykorai* sp. n.**
urn:lsid:zoobank.org:act:7D4B7BA3-BCDC-4C2B-9245-267182788C4C
http://species-id.net/wiki/Caledonotrichia_sykorai
Figs 17, 59–60, 67–68, 73

**Diagnosis.** Closely resembling *C. nyurga*, but males differing in having the posterior margin of sternite IX only shallowly concave, the anterior extension of abdominal segment IX shorter and broader; and gonopods with ventral lobes narrower and dorsal lobes stout, as wide at apex as close to base; both *C. sykorai* and *C. nyurga* can be separated from *C. extensa* by their smaller size and presence of the elongate ventral process on the posterior margin of sternite VII. Females have the apical margin of abdominal sternite VII rounded, without the membranous collar seen in *C. illiesi* and *C. minuta*.

**Description, male, female.** Head rounded, as in *C. capensis* (Fig. 1). Antennae (Fig. 17) with 24–25 flagellomeres, of form seen in *C. illiesi* and most other species of *Caledonotrichia* with flagellomeres elongate cylindrical. Maxillary palps similar to those in males of *C. nyurga*, but terminal segment shorter, relatively, but still exceeding length of segments 3 or 4 which are subequal.

Wings. Forewing length, 2.2–2.8 mm (n=5).

Male genitalia (Figs 59, 60, 67, 68). Posterior margin of abdominal sternite VII bearing elongate triangular, mesal process. Abdominal segment IX ventrally subquadrate posteriorly, anteriorly rounded triangular; dorsally with deep parallel-sided excision. Tergite X convex apically. Sclerotised rods of ventral processes stout, simple. Gonopods with ventral lobe in form of narrow filaments, dorsal lobes stout, without mesal processes. Ventral processes stout, strongly curved at base. Phallic apparatus with associated slender parameres.

Female terminalia (Fig. 73). Forming a slender, telescopic oviscapt, but lacking the medial process on sternite VII seen in *C. illiesi* and *C. nyurga*.

**Material examined.** Holotype male: New Caledonia: Province Sud, stream crossing way to sanatorium 2.3 km E St Laurent, ca. 150 m upstream bridge, 22°04.484'S, 166°19.910'E, loc 027, Malaise trap, 17–19.x.2006, K. A. Johanson & M. Espeland (NHRS).

**Paratypes:** New Caledonia: 6 males, 30 females, Province Sud, Col d'Amieu, 319 m, small stony river, loc 23, 21°34.720'S, 165°49.620'E, Malaise trap, 30.xi–5.xii.2001, Johanson, Pape & Viklund (NHRS); 2 males (on slides), Province Sud, Monts des Koghis, ca 800 m S Koghi Restaurant, 22.18406°S, 166.50383°E, 420 m, 11–26.xi.2003, Malaise trap, loc#022, K. A. Johanson (NHRS); 1 male, 1 female, Province Sud, Hwa Hace Mt., Hwa Motu River, at Pont Wamuttu, 1.0 km E Nassirah, about 200 m upstream bridge, 21°48.094'S, 166°04.298'E, 137 m, 20.xi–12.xii.2003, Malaise trap, loc#034, K. A. Johanson (NHRS); 4 males, 4 females (2 males 1 female on slide), Province Sud, stream crossing way to sanatorium 2.3 km E St Laurent, ca. 150 m upstream bridge, 22°04.484'S, 166°19.910'E, loc 027, Malaise trap, 17–19.x.2006, K. A. Johanson & M. Espeland (NHRS).

**Etymology.** *Sykorai*, named for Dr Jan Sykora, who described the first two species in this genus**.**

## Key to adult males of *Caledonotrichia*

1 Forewing bearing at least one area of scales (scent scales or androconia) (Figs 5, 6, 8, 9) ..... **2**

– Forewing without scales (Figs 3, 4, 7) ..... **5**

2 Scale patches on forewing large (Figs 8, 9); ventral lobe of gonopods more or less triangular in ventral view with apical margin slightly concave (Figs 51, 54); ventral processes in ventral view with subapical irregularity (Figs 51, 54) ..... **3**

– Scale patches on forewing small (Figs 5, 6); ventral lobe of gonopods with apical margin rounded (Figs 36, 39); ventral processes with apices rounded, or bifid and dilated (Figs 36, 39, 46) ..... **4**

3 Scales on forewing in long band extending in a band for about two-thirds the length of wing, and small patch anteriorly of jugal region (Fig. 8); dorsal lobe of gonopods rectangular in dorsal view (Figs 53, 65) ..... ***C. capensis*, sp. n.**

– Scale patches on only proximal one-third of forewing (Fig. 9); dorsal lobe of gonopods quadrangular in dorsal and ventral views (Figs 54, 56)..... ..... ***C. charadra* Kelley, 1989**

4 Patch of scales on forewing tiny, appearing as small, jet black spot (Fig. 6); maxillary palps bearing dense cover of curved setae, giving bottle brush-like appearance (Fig. 15); ventral lobe of gonopods round in ventral view (Fig. 36) ..... ***C. ouinnica* sp. n.**

– Patch of scales on forewing more diffuse, not forming a small jet black spot (Fig. 5); maxillary palps bearing sparse, short straight setae; ventral lobe of gonopods in ventral view more or less triangular, with apical margin rounded (Figs 39, 46) ..... ***C. minor* Sykora, 1967**

5 Abdominal segment IX in ventral view anteriorly triangular (Figs 57, 60, 61); abdominal sternite VII usually bearing slender, elongate caudally directed process on proximal margin (Figs 60, 61, 63) ..... **6**

– Abdominal segment IX shield-shaped, or anteriorly subquadrate (e.g. Figs 21, 24, 27); abdominal sternite VII without ventral process (Fig. 49) ..... **8**

6 Abdominal sternite VII without digitate process on proximal margin; ventral lobe of gonopods well developed, club-shaped, bearing row of short, stout, dark setae (Fig. 57) ..... ***C. extensa* Kelley, 1989**

– Abdominal sternite VII bearing digitate process on proximal margin (Figs 60, 61, 63); ventral lobe of gonopods slender, leaf-like to narrow (Figs 60, 61, 67, 69) ..... **7**

7 In ventral and lateral view abdominal segment IX greatly extended anteriorly in a slender, elongate process (Figs 61, 63, 69); antennae elongate, with 37 flagellomeres, distal segments no longer than wide, urn-shaped (Fig. 18) ..... ***C. nyurga* Oláh & Johanson, 2010**

– In ventral view abdominal segment IX slightly extended anteriorly, coarsely triangular (Figs 60, 67); antennae with 24 flagellomeres with length 1.5–2.5× width (Fig. 17) ..... ***C. sykorai* sp. n.**

8 Antennae with 33–38 flagellomeres; ventral lobes of gonopods rounded, only slightly longer than wide (Figs 21, 30); seta dorsally on ventral lobe of gonopods elongate, slender, a round knob at tip (Figs 21, 22) ..... ***C. illiesi* Sykora, 1967**

– Antennae with 22–25 flagellomeres; ventral lobes of gonopods rounded (Figs 24, 27, 33, 44) or triangular (Figs 41, 48); if present seta dorsally on ventral lobe of gonopods elongate, slender, without knob at tip (Figs 24, 27) ..... **9**

9 Ventral lobe of gonopods triangular, setae on posterior margin stout (Figs 41, 48); dorsal lobe tapered apically (Figs 43, 49, 50) ..... ***C. vexilla*, sp. n.**

– Ventral lobe of gonopods rounded apically, setae on posterior margin fine, short (Figs 24, 27, 33); dorsal lobe bat-shaped or broadly rounded (Figs 23, 29, 35) ..... **10**

10 Ventral lobe of gonopods about half length of dorsal lobe (Fig. 27); dorsal lobe broad, longer than wide (Figs 29, 44), mesal processes close to proximal margin; sclerotised rods of subgenital processes bifid apically (Figs 27, 44), not flared ..... ***C. bifida* sp. n.**

– Ventral lobe of gonopods about same length as dorsal lobe; dorsal broadly rounded (Figs 23, 35), with mesal process situated in middle of lobe; sclerotised rods of subgenital processes with small lateral irregularity close to apex (Fig. 26) ..... ***C. minuta* sp. n.**

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