ZOOLOGICAL SCIENCE **23**: 641–645 (2006) © 2006 Zoological Society of Japan

A New Species of *Thraulus* from Nanjing (Eastern China) with Single First Gill (Insecta: Ephemeroptera: Leptophlebiidae)

Peng Li, Dong Liu and Chang-Fa Zhou*

The Key Laboratory of Jiangsu Bioresource and Biotechnology, College of Life Sciences, Nanjing Normal University, Nanjing 210097, P. R. China

***Thraulus femoratus* sp. nov., a new species found in eastern China, is described from imagos, subimagos, nymphs, and eggs. The nymphs are unique in the genus as well as in the *Thraulus* group because of their single lanceolate gills 1. The imagos can be differentiated from those of related species by the following combination of characters: slightly robust hindwing with a bluntly rounded costal projection that is situated over half the distance from wing base to apex, darkly pigmented basal portion of hindwing, and subapical dark band on hind femur. Subimagos resemble the imagos in color pattern. Eggs have eight pairs of long threads on the polar portion and slight ridges on the surface. The reduced gills 1 in combination with entirely fringed gills 2–7 represent a new evolutionary lineage and ecological type in the *Thraulus* group, but provide limited information regarding phylogenetic relationships.**

Key words: Ephemeroptera, Leptophlebiidae, *Thraulus*, new species, China

INTRODUCTION

The genus *Thraulus sensu lato* was established by Eaton (1881) and redefined by Peters and Edmunds (1970). This genus and closely related species were reviewed by Grant and Peters (1993), who proposed the *Thraulus* group within Leptophlebiidae to include seven genera. At that time, eight species were retained in *Thraulus sensu stricto*. In addition, several other species of this genus have been reported from the eastern hemisphere (Gose, 1980; Jacob, 1988; Soman, 1991; Kang and Yang, 1994).

In the original definition of the *Thraulus* group, the imaginal forewing venation and nymphal fimbriate gills are distinct diagnostic characters of these seven genera in the family. In this group, both imagos and nymphs show some diverse evolutionary trends, although the nymphs of four genera have not yet been described (Peters and Edmunds, 1970; Peters and Tsui, 1972; Grant and Peters, 1993). However, all known nymphs of the group uniformly have seven pairs of gills, each consisting of dorsal and ventral lobes.

In 2004, we collected several nymphs that have gills 1 single and gills 2–7 marginally fringed in a park stream of Nanjing city, Jiangsu Province, Eastern China. This kind of leptophlebiid nymph obviously represents an undescribed taxon of the *Thraulus* group. In 2005, we obtained additional nymphs, more than thirty subimagos, and adults, and deposited them in our collection. Based upon the characters given below, we establish and describe a new species of *Thraulus*.

* Corresponding author. Phone: +86-25-83598388;
Fax : +86-25-83598723;
E-mail: zhouchangfa@njnu.edu.cn
doi:10.2108/zsj.23.641

STUDY AREA AND METHODS

Nymphs and subimagos were collected in early June in small pools of a stream. The width of the stream varies from 1–2 m, but on average, it was only about 1 m wide and less than 30 cm deep at the time of collection. The pools from which the new species was collected measured about 1.5–2.0 m in diameter. The velocity of flow of the current was less than 1 m/s, and the water in the pools was almost still. Heavy silt, many leaves, and some small stones were deposited in the pools, and the substrate had a rotten odor at the time of collection. The stream is in a well-protected forestry park, with bamboo and large trees in the riparian zone on both sides; therefore, the canopy is virtually closed, and little sunshine can reach the stream directly. Water pH was about 5.5–6.0; temperature was around 16.3°C; and air temperature was about 20–24°C at the time of collection. Mayflies collected from the same stream included one *Caenis* species, *Habrophlebiodes zijinensis* You and Gui, 1995, *Parafronurus youi* Zhou and Braasch, 2003, and some baetid species.

The nymphs were collected by hand screen, and subimagos were collected by mosquito net near the same stream. Adults and some subimagos were obtained by rearing the nymphal stage in the laboratory. The water used in rearing was obtained from the same stream. The nymphs usually hid under leaves and stones when they were put into the collecting pan or rearing barrel. The gills were observed to move very rapidly.

TAXONOMIC DESCRIPTION

Thraulus femoratus sp. nov.

(Figs. 1–30)

Material examined. Holotype ♂, China, Jiangsu Province, Nanjing, Zijin Mountain (118°51'231"E, 32°03'461"N, alt. 86 m), stream near Ling-gu temple, 1-VI-2005, Leg. Peng LI, Dong LIU and Chang-Fa ZHOU. Paratypes: 15 ♂♂ 10 ♀♀ imagos, 4 ♂♂ 3 ♀♀ subimagos, 30 larvae, same data as for holotype; other materials: 4 larvae, 10-VI-2004,

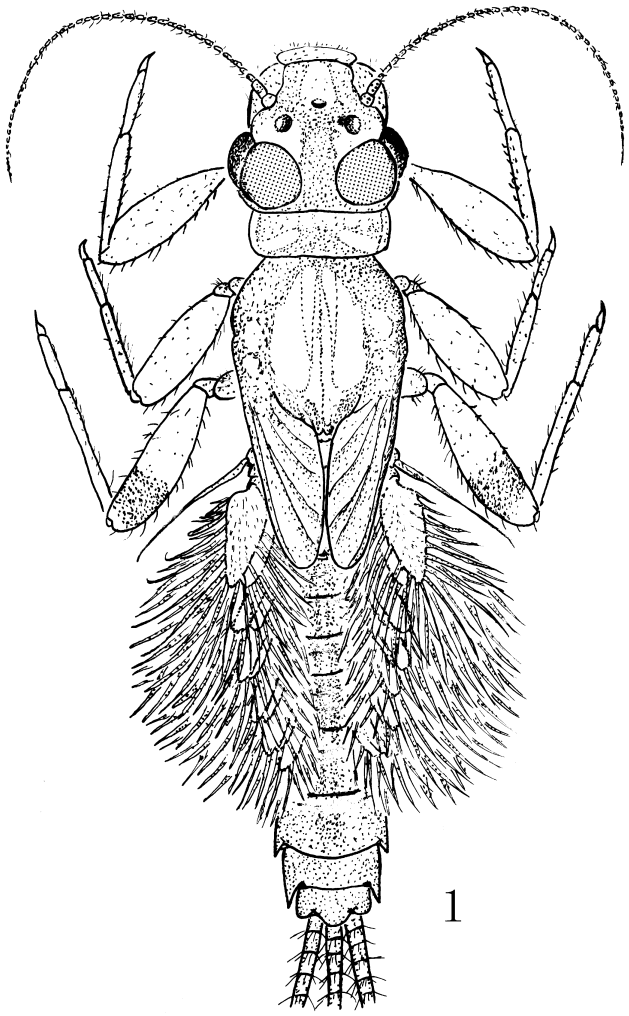


Fig. 1. *Thraulus femoratus* sp. nov.: habitus of male nymph.

other information same as for types. All types deposited in the Institute of Genetic Resources, College of Life Sciences, Nanjing Normal University, P. R. China. Two nymphs collected in 2004 have been deposited in Entomology, Florida A & M University, USA.

Etymology. The specific epithet is derived from the Latin adjective *femoratus* (femur), in reference to the color pattern of the hindlegs.

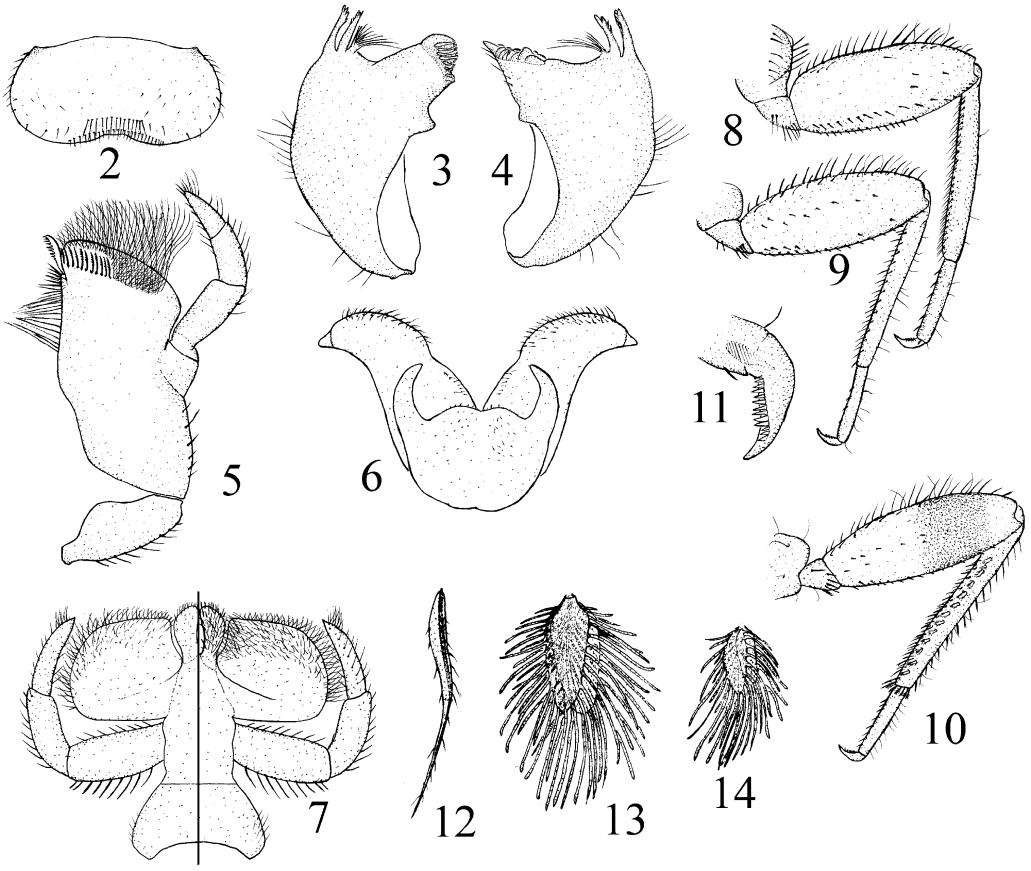
Mature nymph. In ethanol; body length 6.0–7.0 mm, antennae 3.0–4.0 mm, terminal filament 12.0–13.0 mm, cerci 11.0–12.0 mm. Head capsule with area between ocelli washed with dark brown; area between median ocellus and frons pale; median line of vertex pale; margins of clypeus parallel (Fig. 1). Mouthparts: labrum with posterior margin slightly convex, irregular sparse setae on both dorsal and ventral surfaces, additionally median and apical row of hairs dorsally along the anterior margin; width slightly greater than clypeus; anteromedian emargination broad (Figs. 1, 2). Mandibles with sparse lateral setae, prostheca of left mandible with two thicker spines than others (Figs. 3, 4). Maxilla: segment 1 of maxillary palpi length 1.2–1.4 times segment 2 length, outer margin with a few setae; segment 3 length 0.8–0.9 times segment 2 length, outer and inner margins of both with setae, a small tuft of apical setae on third segment; anterior margin of maxilla with dense thick spines and fine setae, an additional row of 30 pectinate setae present below these, a large thicker pectinate projection on inner corner; outer margin of maxilla and cardo with setae (Fig. 5). Hypopharynx with a projection and a row of setae on lateral arms of superlingua (Fig. 6). Labium: glossa with thick plate-like setae on ventral surface, fewer setae on dorsal surface; paraglossa with denser but fewer setae on dorsal surface; first segment of labial palp with thick setae on margins, second segment with setae on outer margin, apical segment with thick and fine setae on margin and surface, those near apex of apical segment gathered into small tufts; segment 1 length ca. 1.2 times segment 2 length, segment 3 length 0.9 times segment 2 length (Fig. 7).

Pronotum brown, washed with pale irregular markings on dorsal surface. Mesonotum brown, median area pale. Legs pale but fore femora gray and hind femora with conspicuous brown subapical band (Fig. 10). Femora with thick setae, those on outer margin longer than others; additional setae on outer margin. Tibiae have fine and thick setae on inner margin, and very sparse and thin setae on outer margin, but hind tibiae have more and denser thick setae on surface. Tarsi of all legs with several thick setae on inner margin and sparse setae on outer margins (Figs. 8, 9, 10). Claws of all legs similar, with a row of denticles, middle denticles slightly larger than basal and apical ones (Fig. 11).

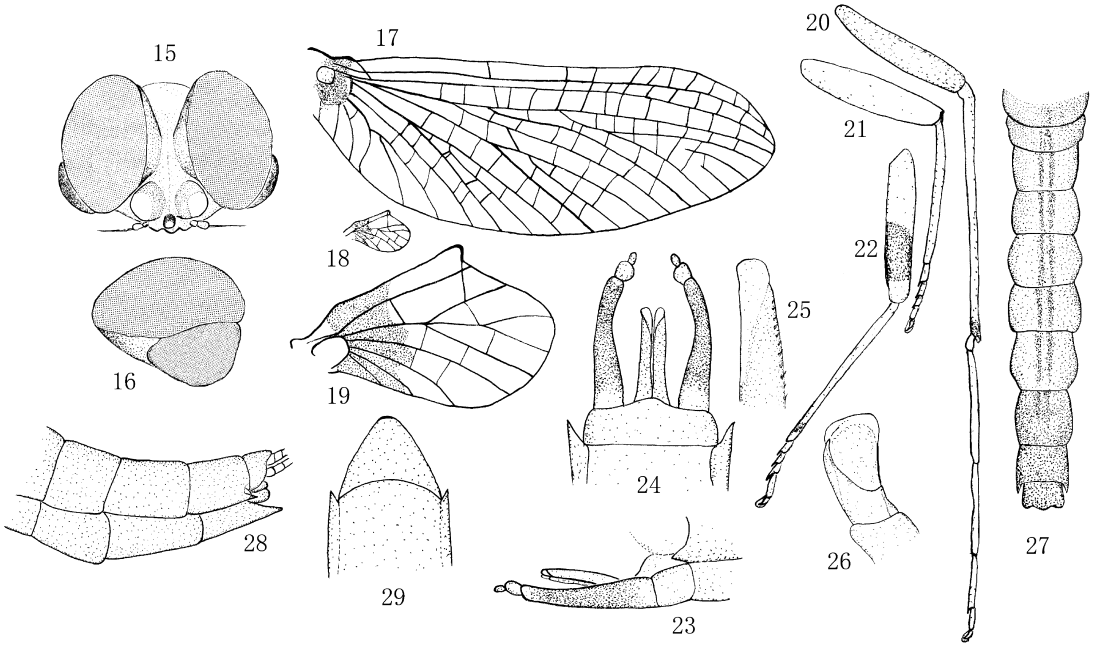
Abdomen brown, with indistinct paired submedian stripe along body axis. Terga 3–9 with posterolateral projections, those of terga 8–9 larger (Fig. 1). Gills gray, on segments 1–7; gills 1 single, slender, lanceolate (Fig. 12); gills 2–7 similar in shape, with dorsal and ventral lamellae; each lamella elongated-ovate, with entire margins fimbriate; tracheae of gills clear (Figs. 13–14). Caudal filaments with spines and setae at articulations.

Male. In ethanol; body length 7.0–8.0 mm, forewing 6.0–7.0 mm, terminal filament 12.0–13.0 mm, cerci 10.0–11.0 mm, foreleg 5.0–6.0 mm. Body reddish brown, compound eyes pale orange, upper portion oval in dorsal view; major axis nearly perpendicular to longitudinal body axis; distance between compound eyes less than half width of eye. Lateral ocelli located closely to eyes but not contiguous (Figs. 15, 16). Thorax reddish dark brown. Forewings: base with clear, dark transverse band; vein Rs forked at 0.2 distance from base of vein to margin; vein MA forked at 0.5 distance from base of vein to wing margin; vein MP forked at 0.3 distance from base of vein to margin, fork symmetrical, 2 intercalaries present between CuA and CuP (Fig. 17). Hindwings much smaller than forewings, with conspicuous color markings at base of wings; costal projection bluntly rounded, apex of projection situated at ca. 0.6 to 0.7 distance from base to apex of wings; apex of wings blunt, with apical and posterior areas expanded slightly (Figs. 18–19). Legs: fore tarsus slightly longer than tibia, both of them much longer than femur; fore femur and apex portion of fore tibiae reddish brown, other parts of forelegs pale, mid- and hindlegs pale except hind femora with large brown subapical band (Figs. 20–22). Claws dissimilar: one blunt, pad-like; one apically hooked; hooked claw narrowed abruptly at apex (Fig. 26).

Each tergum of abdomen has one pair of straight dark



Figs. 2–14. Mature nymph of *Thraulus femoratus* sp. nov.: **2)** labrum; **3)** left mandible; **4)** right mandible; **5)** maxilla; **6)** hypopharynx; **7)** labium dorsal (left) and ventral (right); **8)** foreleg; **9)** midleg; **10)** hindleg; **11)** foreclaw, enlarged; **12)** gill 1; **13)** gill 2; **14)** gill 7.



Figs. 15–29. Imago of *Thraulus femoratus* sp. nov.: Figs. 15–27, male: **15)** head, dorsal view; **16)** eye, lateral view; **17)** forewing; **18)** hindwing; **19)** detail of hindwing, enlarged; **20)** foreleg; **21)** midleg; **22)** hindleg; **23)** genitalia, lateral view; **24)** genitalia, ventral view; **25)** detail of penes, dorsal view; **26)** foreclaw, enlarged; **27)** abdomen, dorsal view). Figs. 28–29, female: **28)** lateral view of terminal segments of abdomen; **29)** sternum 9, ventral view.

Fig. 30. Egg of *Thraulus femoratus* sp.nov.: SEM photograph.

stripes at middle dorsally, those on terga 1–6 clearer than others; tergum 10 with truncated apex (Fig. 27). Caudal filaments pale apically with reddish basal articulations.

Genitalia (Figs. 23–25): Styliger plate with slightly convex posterior margin. Forceps segment 1 narrowing gradually from base to apex; apical one third curved mesally; segment 1 length ca. 6.0 times segment 2 length; segment 3 length ca. 0.8 times segment 2 length; basal portion of forceps pale, most parts of segment 1 dark brown; apical segment of forceps small. Penes straight, narrow; inner margins straight, outer margins converging apically; short spine-like setae along outer margin dorsally.

Female. In ethanol; body length 8.0–9.0 mm, cerci 10.0–11.0 mm, and terminal filament 12.0–13.0 mm. Body color pattern resemble that of male. Posterior margin of sternum 7 straight (Fig. 28), sternum 9 extended posteriorly (Fig. 29).

Male subimago. In ethanol; body length 6.7–8.0 mm, forewing 6.0–7.5 mm, hindwing 0.6–1.0 mm, terminal filament 11.5–13.5 mm, cerci 10.5–12.0 mm. Foreleg 4.0–5.0 mm, midleg 2.8–4.0 mm, hindleg 3.0–4.0 mm. Antennal length 1.2–1.5 mm and sockets outlined with light brown. Eyes occupy most of head, upper portion orange gray, basal portion dark brown. Wings semi-hyaline, outer margins with a row of light setae. In other characters, male subimagos resemble male imagos.

Female subimago. In ethanol; body length 8.5–9.5 mm, forewing 8.0–9.0 mm, hindwing 0.8–1.2 mm, cerci 10.5–11.5 mm, and terminal filament 11.0–13.0 mm. Foreleg 4.5–5.0 mm, midleg 3.5–4.5 mm, hindleg 3.5–4.5 mm. Antennal length 0.7–1.0 mm and sockets outlined with light brown. Eyes dark brown. In other characters, resembling female imagos.

Egg. (Fig. 30, dissected from female body). Length 0.2 mm, breadth 0.1 mm. Egg ovoid, some drum-like; exochorion with tiny irregular ridges, polar portions with eight pairs of thread-like structure on surface, length of thread about a third of egg longitudinal length; no visible micropyle on chorionic surface found.

Taxonomic comparisons. Nymphs of the new species resemble those of congeners in having superlingua with lateral projection on its arms and similar fimbriate gills 2–7. However, the nymphs of *Thraulus femoratus* sp. nov. are unique in the genus, as well as in the *Thraulus* group, because of their single, slender, lanceolate gills 1. All previously reported species in the group have gills 1 with double lamellae, though according to Peters and Edmunds (1970), the first gills of *Thraulus* are highly variable. For example, gill 1 may consist of either a single dorsal lanceolate portion with a ventrally fringed lamella (as in most species in the genus, such as *T. torrentis*), two ovate lamellae with fringed margins (as in the first undescribed species of Peters and Tsui (1972)), or two lanceolate lamellae (such as in *T. bellus* and *T. bishopi*). Single gills 1, as described herein, are a new variation. Furthermore, the dark banding of the hind femora may help to distinguish the new species.

The males are similar to congeners with regard to their separated compound eyes, bluntly rounded costal projection of the hindwing, and the pattern of the genitalia. However, the shape of the hindwing of the new species is peculiar, too, because of its costal projection situated over half the distance from the wing base to the apex, the darkly pigmented basal portion, and the slightly expanded apical and outer margins. Other species of *Thraulus* usually have the costal projection located at most half the distance from the base to the apex of the leading margin or have an acute costal projection. Although *T. bellus* has a robust hindwing, several species of *Thraulus* have dark basal portions of the hindwing (*e.g., T. fasciatus* and *T. gopalani*), and *T. bishopi* and *T. demoulini* have a more apically situated costal projection. *Thraulus femoratus* sp. nov. is the first with this combination of characters. The hindwing of *T. femoratus* sp. nov. is similar to that of species of the genus *Sulu* Grant and Peters, but the respective costal projections are not alike: the former has bluntly rounded projections, whereas the latter have acute or acutely rounded projections. In addition, their male genitalia differ considerably. The adults of *T. femoratus* sp. nov. also have a dark subapical band on their hind femora.

Koss and Edmunds (1974) reported that leptophlebiid eggs have the greatest diversity in the order, with the lack

of polar caps and the presence of an entirely chorionic funnelform micropyle being considered the only features shared by all known species. Within *Thraulus*, eggs have been documented by Mazzini and Gaino (1990) and Kang and Yang (1994), who provided clear SEM photographs of eggs for five species. Eggs of our new species are very similar to those of *T. fatuus* Kang and Yang with regard to their shape and thread length and location. However, eggs of the former species have fewer distinct ridges on surface than those of the latter species.

DISCUSSION

Although the single gills of the new species provide a good diagnostic character, they should be used with caution in phylogenetic reconstruction. Riek (1973) suggested that the double gills of mayflies originally derived from a primitive single gill plate. In Leptophlebiidae, Peters and Edmunds (1970) provided some interpretation of these characters in order to discuss the phylogeny of the genera. According to their hypothesis, the gill with single lamella may be interpreted as plesiomorphic, and the gill with double lamellae may be interpreted as apomorphic. On the other hand, degeneration of gills 1 is a common phenomenon in mayflies. Vestigial or reduced gills 1 have been found in several families, including Ephemeridae, Potamanthidae, Ephemerellidae, Caenidae, and Neoephemeridae.

Peters and Edmunds (1970) recognized three species groups in the genus *Thraulus sensu lato* based on the structure of gills 1. Peter and Tsui (1972) later separated them into four ecological types based upon abdominal gill structure (similar double gills 1–7, gills 1 dissimilar to others, ventral lamella reduced, and dorsal lamella reduced). These authors pointed out that gill shape is correlated with water movement and aquatic oxygen concentration, and suggested that the last three types derived from the first one. Obviously, the new species represents a new ecological type, and the reduced gills 1 and well-developed gills 2–7 suggest a new lineage adapted to quiet water, silty substrate, and probably low aquatic oxygen concentration.

ACKNOWLEDGMENTS

We thank two reviewers for their valuable advice, constructive criticism, and improvement of the manuscript. We express special appreciation to Mrs. Janice Peters (Florida A & M University, USA) for her encouragement of this study, to Mr. Luke Jacobus (Purdue University, USA) for linguistic corrections, and to Mr. Ke-Yu WANG (Nanjing Normal University, China) for his help in scanning eggs. This work was financially supported by the National Natural Science Foundation of China (Grant Nos. 30570200 and 30300037) and a fund from Nanjing Normal University (No. 2005104XGQ2B70).

REFERENCES

Eaton AE (1881) An announcement of new genera of the Ephemeridae. Entomol Mon Mag 17: 191–197

Gose K (1980) The mayflies of Japan. (7) Key to the families, genera, and species. Aquabiology 8: 211–215 (in Japanese)

Grant PM, Peters WL (1993) Description of four new genera of *Thraulus* group mayflies from the eastern hemisphere and redescription of *Simothraulus* and *Chiusanophlebia* (Ephemeroptera: Leptophlebiidae: Atalophlebiinae). Trans Amer Entomol Soc 119: 131–168

Jacob U (1988) *Thraulus thraker* sp. n. aus Bulgarien (Insecta, Ephemeroptera: Leptophlebiidae). Reichenbachia 26: 1–3

Kang SC, Yang CT (1994) Leptophlebiidae of Taiwan (Ephemeroptera). J Taiwan Mus 47: 57–82

Koss RW, Edmunds GF Jr (1974) Ephemeroptera eggs and their contribution to phylogenetic studies of the order. Zool J Linn Soc 55: 267–349

Mazzini M, Gaino E (1990) Oogenesis and involvement of chorionic structures in Ephemeroptera taxonomy. In "Mayflies and Stoneflies: Life Histories and Biology" Ed by IC Campbell, Kluwer Academic Publishers, Dordrecht, pp 95–104

Peters WL, Edmunds GF Jr (1970) Revision of the generic classification of the eastern hemisphere Leptophlebiidae (Ephemeroptera). Pacific Insects 12: 157–240

Peters WL, Tsui PTP (1972) New species of *Thraulus* from Asia (Leptophlebiidae Ephemeroptera). Oriental Insects 6: 1–17

Riek EF (1973) Classification of the Ephemeroptera. In "Proceedings of the First International Conference on Ephemeroptera" Ed by WL Peters, JG Peters, Leiden, Brill, pp 160–178

Soman AK (1991) A new species of *Thraulus* (Ephemeroptera: Leptophlebiidae: Atalophlebiinae) from Nilgiris, South India. J Bombay Nat Hist Soc 88: 99–102

(Received October 30, 2005 / Accepted March 21, 2006)