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Integrative taxonomy revealed four new species and four new records of the genus *Hydropsyche* from China (Trichoptera, Hydropsychidae)

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Abstract

Four new species of the genus *Hydropsyche* Pictet, 1834 from China are diagnosed, described and illustrated, based on male genitalia: *Hydropsyche bangwanglingensis* Ge, **sp. nov.**, *Hydropsyche yangae* Ge, **sp. nov.**, *Hydropsyche suni* Ge, **sp. nov.** and *Hydropsyche zhouzhiensis* Ge, **sp. nov.** In addition, four species are reported as new records from China. Meanwhile, morphological characters of four new species are compared with those of related species. Furthermore, *mtCOI* barcode sequences were obtained for these new species and phylogenetic trees of known congeneric species were inferred to elucidate their species group affiliations.

Key Words

Annulipalpia, barcoding, Hydropsychinae, morphology, taxonomy

Introduction

As the largest family in the Annulipalpia, Hydropsychidae comprises over 2,000 described species and is widely distributed across major zoogeographical regions (Morse et al. 2019). The extant Hydropsychidae are classified into five subfamilies: Arctopsychinae, Diplectroninae, Hydropsychinae, Macronematinae and Smicrideinae (Ge et al. 2022a). Amongst them, the subfamily Hydropsychinae includes the most species, with 1,161 species recorded across all major biogeographical regions, except Antarctica (Oláh and Johanson 2008; Morse 2026). Based on comprehensive taxonomic research (Schefter 2005; Oláh and Johanson 2008; Geraci et al. 2010), the subfamily Hydropsychinae is divided into 11 genera. Within China, four genera are currently documented: *Hydropsyche* F.J.Pictet, 1834; *Cheumatopsyche* Wallengren, 1891; *Hydromanicus* Brauer, 1865; and *Potamyia* Banks, 1900.

The genus *Hydropsyche*, the largest genus in the subfamily Hydropsychinae, comprises at least 651 known species worldwide (Morse 2026). The majority of these species occur predominantly in the Oriental and Palaearctic Regions. Furthermore, their filter-feeding activities provide various critical ecosystem services (Morse et al. 2019), which has led to increasing attention on hydropsychid research in recent years (Karaouzas and Kapakos 2018; Heckenhauer et al. 2019; Orr and Buchwalter 2020). With ongoing research advancements, additional species have been successively discovered and documented. To date, 86 species of this taxon have been formally recorded in China (Yang et al. 2016; Kiss 2017; Oláh and Li 2020). Since its establishment, *Hydropsyche* has been subdivided into numerous subgenera by various authors, reflecting the absence of a unified classification system (McFarlane 1976; Ross and Unzicker 1977; Nielsen 1981; Li and Tian 1989). Some authors argued that some subgenera should be treated as species groups

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within the genus (Mey 1999, 2003; Malicky and Chantaramongkol 2000). Oláh and Johanson (2008) synthesised previous studies, endorsed Malicky's concept of species group and allocated known species from the Oriental and Neotropical Regions to 10 species groups, based on morphological characteristics. Currently, the known Chinese species are classified into seven species groups.

Hydropsyche is widely recognised as one of the most taxonomically challenging trichopteran groups, primarily due to highly similar genital structures amongst species, which render identification particularly difficult (Oláh and Johanson 2008). Taxonomic revisions, based solely on traditional morphological characteristics, often fail to provide clear delineation for certain species. The DNA barcode corresponding to a 658 bp fragment of the mitochondrial cytochrome *c* oxidase I (*mtCOI*) gene has been increasingly employed for species delimitation in aquatic insects (Zang et al. 2022; Xu et al. 2025) and has been extensively applied across Trichoptera (Santos and Takiya 2021; Ge et al. 2022b; Kilian et al. 2022; Laudee et al. 2025; Jaroenchaiwattanachote et al. 2025).

This study describes and illustrates four new species of *Hydropsyche* and reports four new records from China, with the *mtCOI* sequences of the new species provided. Based on the morphology of the male genitalia, the four new species are assigned to their respective species groups. Additionally, a Neighbour-Joining tree was inferred for the new species along with other species of *Hydropsyche*. The results provided strong support for validity of the new species, thereby contributing to a more comprehensive understanding of species diversity within Chinese Hydropsychidae.

Materials and methods

Adult specimens were collected during 2021–2025 using pan traps, equipped with ultraviolet light bulbs and Malaise traps (Suppl. material 1: table S1); all specimens were preserved in 85% ethanol upon collection. Specimen preparation followed Peng et al. (2022). Male abdomens used for illustrations were cleared with 10% sodium hydroxide (NaOH) solution, heated to 80 °C for 20 min to remove non-chitinous tissues and then rinsed in distilled water. The cleared genitalia were subsequently mounted in lactic acid on depression slides for examination. Genitalic structures were photographed using a Leica M205 C stereomicroscope, equipped with a K5C digital camera. Pencil sketches were prepared from digital images and subsequently scanned for use as templates in Adobe Photoshop 2025; final line drawings were digitally rendered using a Gaomon G12 drawing tablet. Following documentation, the cleared genitalia were stored in microvials together with the corresponding specimens in 85% ethanol. Morphological terminology follows Oláh and Johanson (2008). All specimens were deposited in the Insect Collection, Tianjin Normal University, Tianjin, China (TJNU).

The three left legs of six individuals (males) were taken from their bodies for DNA extractions. TIANamp Genomic DNA Kit (DP304, TIANGEN, Beijing, China) was used to extract DNA in advance and then PCR amplification was performed. The primers (LCO1490/HCO2198) (Folmer et al. 1994) that were used to amplify the 658 bp fragment of *mtCOI* are listed in Suppl. material 1: table S2. The *mtCOI* sequencing was undertaken by the Beijing Genomics Institute (Beijing, China) and the raw sequences were manually assembled and edited in Sequencher v.4.5 (Gene Codes Corporation, Ann Arbor, Michigan, USA) (Katoh and Standley 2013). The *mtCOI* sequences generated in this study have been submitted to GenBank. A Neighbour-Joining (NJ) tree of the four new species and 31 previously recorded congeneric species of *Hydropsyche* was inferred in Mega 12 (Kumar et al. 2024). The Kimura 2-parameter (K2P) substitution model was applied, branch support was assessed with 1,000 bootstrap replicates and all other parameters were set to default values.

Results

New species

***Hydropsyche bawanglingensis* Ge, sp. nov.**

https://zoobank.org/3C005029-04E0-4567-80FA-65292581184F

Fig. 1, Suppl. material 1: fig. S1

Material examined. ***Holotype.*** CHINA • 1 ♂; Hainan Province, Changjiang Li Autonomous County, downstream of Bawangling; 19°6'18.40"N, 109°6'17.00"E; alt. 197.7 m; 17 Dec 2024; light trap; Xinyu Ge (TJNU) and Xiaolong Lin (Shanghai Ocean University, SHOU) leg.

Paratypes. CHINA • 2 ♂; same data as holotype (TJNU) • 1 ♂ same collection data as for preceding, except 18 Dec 2024 (TJNU) • 1 ♂; Hainan Province, Wuzhishan City, Wuzhishan National Nature Reserve; 18°53'31.60"N, 109°35'17.99"E; alt. 420.1 m; 23 Dec 2024; light trap; Xinyu Ge and Xiaolong Lin leg. • 1 ♂; Hainan Province, Wuzhishan City, Shuiman Township, Mountain Viewing Platform; 18°51'45.73"N, 109°40'56.67"E; alt. 720 m; 15 Apr 2025; light trap; Tianyou Zhao (China Agricultural University) leg.

Diagnosis. The new species belongs to the *Hydropsyche newae* species group because the phallotremal sclerites are nearly spherical, the endothecal spines are absent and the endothecal process is membranous. It is similar to *H. gautamittra* Schmid, 1961, from Pakistan. However, the new species can be easily distinguished by the following characters: (1) The structure anterior of the pale windows of the phallic apparatus is quadrate (much longer than broad in *H. gautamittra*); (2) the pale windows are born on the dorsal margins of the phallic apparatus (on the ventral margins of the phallic apparatus in

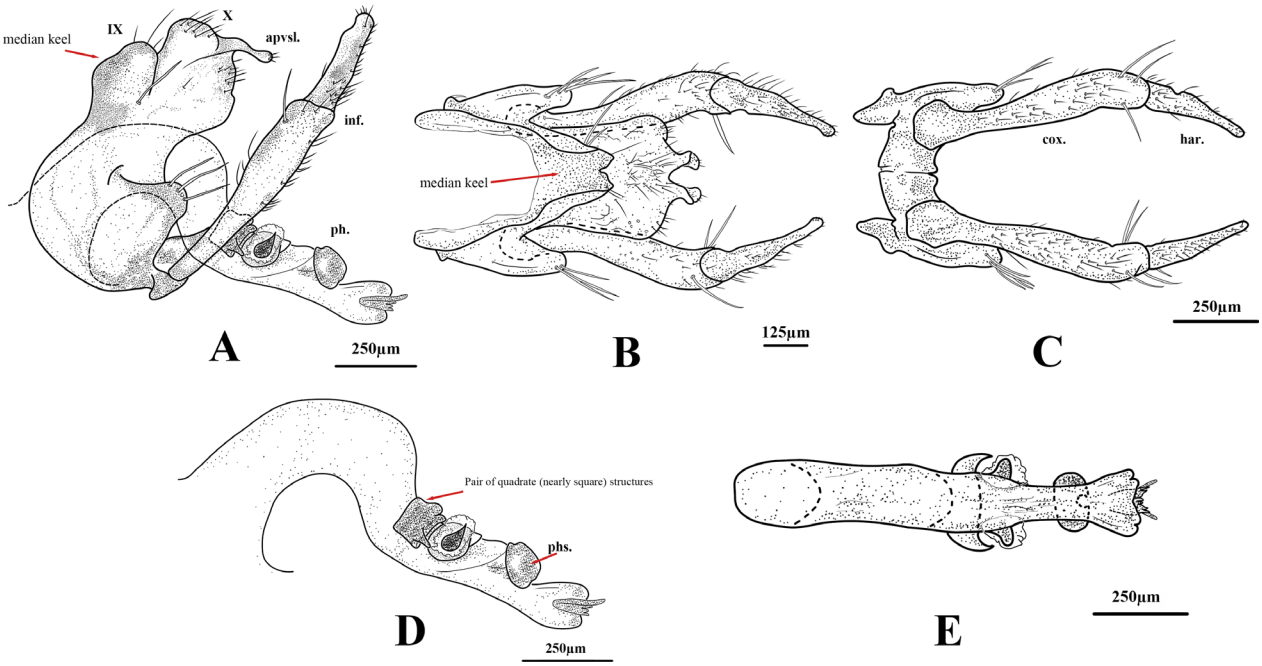

Figure 1. *Hydropsyche bawanglingensis* Ge, sp. nov., Holotype male. **A.** Genitalia, lateral; **B.** Genitalia, dorsal; **C.** Genitalia, ventral; **D.** Phallus, lateral; **E.** Phallus, ventral. Abbreviations: **apvsl.** – apicoventral setose lobe (paired); **cox.** – coxopodite (paired); **har.** – harpago (paired); **inf.** – inferior appendage (paired); **phs.** – phallotremal sclerite (paired); **ph.** – phallus; **IX** – segment IX; **X** – segment X.

H. gautamittra); (3) there is a pair of clusters of spines beyond the endothecal process (a pair of spinous processes in *H. gautamittra*).

Description. Male. Length of whole body 4.5–5.5 mm (n = 6); holotype about 5.5 mm. Specimen in alcohol with compound eyes black, legs and thorax brown, abdomen brown dorsally, yellowish-brown ventrally, wings light brown.

Male genitalia. Abdominal segment IX fully sclerotised and annular, vertically tall, longitudinally short. Dorsal 1/3 of anterior margins concave, anteroventral margins convex. Posterodorsal margins fused with segment X, each posteroventral margin broad, nearly triangular, apically setose. Median keel short, its surface granulose, tergum smooth; in lateral view (Fig. 1A, Suppl. material 1: fig. S1A) projecting slightly dorsad as hump with some evenly distributed setae present at mid-line; in dorsal view (Fig. 1B, Suppl. material 1: fig. S1B) basally wider, its lateral margins gradually converging apically and apex incised mesally in irregular V-shape; posterior spine rows present on lateral keel slopes and apical lobes, absent between lobes.

Segment X in lateral view (Fig. 1A) with dorsal margin directed posterodorsad, longer than ventral margins, dorsal surface finely wrinkled and with few setae dorsally and posteriorly; in dorsal view (Fig. 1B) with base narrower and gradually wider apically. Pair of apicoventral setose lobes (apvsl.) in lateral view (Fig. 1A) extending from terminus and appearing clavate and constricted in middle; in dorsal view (Fig. 1B) with apices slightly curved downwards and folded downwards, apical interlobular gap short and shallow, slightly depressed downward in "V" shape.

Gonocoxites in dorsal and ventral views (Fig. 1B, C) bending slightly inwards in middle. Coxopodites each thick basally, abruptly constricted at basal quarter, then gradually expanding towards apex and becoming distinctly incurved subapically. Harpagones in lateral view (Fig. 1A) each broad, parallel-sided, slightly constricted apically, less than half as long as its coxopodite; in ventral view (Fig. 1C, Suppl. material 1: fig. S1C) robust basally, gradually tapered towards obtusely rounded apex.

Phallic apparatus double sinuate, forming long tube of same diameter along its length in lateral view (Fig. 1D) and almost straight in ventral view (Fig. 1E); tube narrowing dorsally and laterally at phallotremal sclerites and enlarged apically. Pair of quadrate (nearly square) structures near mid-length projecting posterad in ventral view (Fig. 1E). Pair of dorsolateral membranous lobes or pale windows located immediately beyond quadrate structures and enclosing pair of large blunt dark spines (Fig. 1D, E). Pair of phallotremal sclerites (phs.) heavily pigmented, triangular in lateral view (Fig. 1D), fused dorsally and collectively oval with posterior incision in ventral view (Fig. 1E). Membranous endotheca nested in apical pocket, armed with pair of clusters of moderately long spines (Fig. 1D, E).

Etymology. *bawanglingensis*, name derived from the type locality.

Distribution. China (Hainan).

***Hydropsyche yangae* Ge, sp. nov.**

https://zoobank.org/ABB031FD-3BF2-4BCA-B6F5-DD45AD38CF58

Fig. 2, Suppl. material 1: fig. S2

Material examined. ***Holotype.*** CHINA • 1 ♂; Yunnan Province, Honghe Hani and Yi Autonomous Prefecture, Pingbian Miao Autonomous County; 23°0'0.00"N, 103°42'10.80"E; alt. 1477.89 m; 13 Jul 2021; light trap; Kun Jiang (Anhui Normal University) leg.

Diagnosis. The new species belongs to the *Hydropsyche pluvialis* species group because the endothecal process is sclerotised and nearly digitiform, with the phallotremal sclerites present and the endothecal spines absent. It resembles *Hydropsyche pallipenne* Banks, 1938, from Malaysia (Peninsular). However, the new species can be easily distinguished by the following characters: (1) Apicoventral setose lobes approximately triangular in lateral view (subrectangular in *H. pallipenne*); (2) harpagones are nearly straight in ventral view (folding in *H. pallipenne*); (3) a pair of sclerotised structures arising from the bilobed phallotremal sclerites are curved downwards in the middle and back (straight in *H. pallipenne*).

Description. Male. Length of holotype about 7 mm. Specimen in alcohol with compound eyes black, legs and thorax yellowish-brown, abdomen yellowishbrown dorsally, pale yellow ventrally, wings light brown.

Male genitalia. Abdominal segment IX annular, vertically tall, longitudinally short. Apical lobe on posterolateral margins nearly triangular, apically setose. Median keel short; in lateral view (Fig. 2A, Suppl. material 1: fig. S2A) projecting dorsad and extending posterad; in dorsal view (Fig. 2B, Suppl. material 1: fig. S2B) projecting posterad, basally wider, with lateral margins abruptly constricted medially and converging apically; overall elliptical, apex bluntly rounded; posterior spine rows present on lateral keel slopes, absent apically.

Segment X in lateral view (Fig. 2A) with dorsal margin directed posterodorsad, longer than ventral margin, dorsal surface finely wrinkled and with few setae dorsally and posteriorly; apicodorsal setose process oval. In dorsal view (Fig. 2B) segment X slightly wider at distal one-third than in other portions, surface densely wrinkled, with many short setae medially and some setae arising from wrinkles. Pair of apicoventral setose lobes (apvsl.) in lateral view (Fig. 2A) extending from terminus, with upper margin smooth and lower margin serrated; in dorsal view (Fig. 2B) with apices slightly incurved, apical interlobular gap shallow and widely arcuate.

Gonocoxites in dorsal and ventral views (Fig. 2B, C) bending slightly inwards in middle. Coxopodites in dorsal view (Fig. 2B) each slightly exceeding apex of segment X; in ventral view (Fig. 2C, Suppl. material 1: fig. S2C) nearly straight, robust basally and gradually broadened from the middle towards the apex. Harpagones in dorsal view (Fig. 2B) each straight, approximately 1/2 as long as coxopodites and 1/3 as wide as coxopodites, apex obtusely rounded; in ventral view (Fig. 2C) curved mediad; one harpago constricted subapically.

Phallic apparatus smooth, forming a long tube of nearly uniform diameter along its length in lateral view (Fig. 2D) and almost straight in ventral view (Fig. 2E).

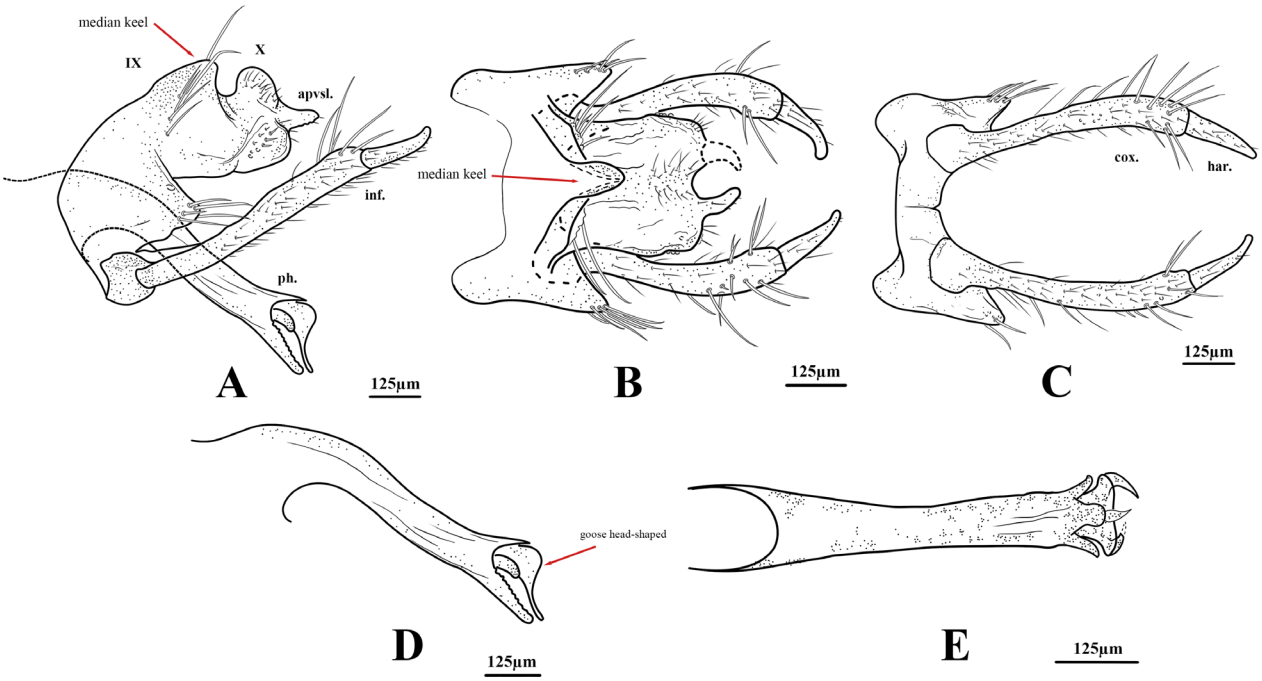

Figure 2. *Hydropsyche yangae* Ge**,** sp. nov., Holotype male. **A.** Genitalia, lateral; **B.** Genitalia, dorsal; **C.** Genitalia, ventral; **D.** Phallotheca, lateral; **E.** Phallus, ventral. Abbreviations: **apvsl.** – apicoventral setose lobe (paired); **cox.** – coxopodite (paired); **har.** – harpago (paired); **inf.** – inferior appendage (paired); **ph.** – phallus; **IX** – segment IX; **X** – segment X.

Endophallus in lateral view (Fig. 2D) forming narrow tube attached to dorsal wall of phallotheca and reaching bend of phallic apparatus. Pair of phallotremal sclerites (phs.) separated into stout, claw-like processes with blunt apices; goose head-shaped in lateral view (Fig. 2D) and pincer-like in ventral view (Fig. 2E). Pair of sclerotised structures in lateral view (Fig. 2D) arising from bilobed phallotremal sclerites, about one-third length of phallotheca, darker than phallotheca, curved downwards medially and posteriorly, with apices smooth; in ventral view, broad basally, slightly concave medially, with apices circular.

Etymology. Name after Prof. Lianfang Yang for her outstanding contribution to the knowledge of Trichoptera taxonomy; noun in nominative case.

Distribution. China (Yunnan).

Hydropsyche suni Ge, sp. nov.

https://zoobank.org/E8E4DBD6-0542-48F1-B4C2-E1A883EAFEAF

Fig. 3, Suppl. material 1: fig. S3

Material examined. ***Holotype.*** CHINA • 1 ♂; Hainan Province, Ledong Li Autonomous County, Zijing Waterfall, Jianfengling; 18°44'24.32"N, 108°55'36.73"E; alt. 692 m; 16 Feb 2025; light trap; Yili Zheng (Nanjing Agricultural University, NJAU) leg.

Diagnosis. The new species belongs to the *Hydropsyche hamifera* species group because the phallotremal sclerites are fused dorsally, the endothecal process is membranous and the endothecal spines are absent. It is similar to *Hydropsyche atropos* Malicky & Chantaramongkol, 2000, from Thailand. However, the new species can be easily distinguished by the following characters: (1) The dorsal margin of abdominal segment IX is simply convex upwards (convex upwards and curved anteriorly in *H. atropos*); (2) the apex of abdominal segment X is gradually constricted (abruptly constricted in *H. atropos*); (3) the lateral setose areas are rounded in lateral view (distinctly clavate in *H. atropos*); (4) the harpagones are curved in a sinuous shape in lateral view (nearly straight in *H. atropos*).

Description. Male. Length of holotype about 7.5 mm. Head yellowish-brown, compound eyes black; thorax and legs yellowish-brown, tergum smooth; forewings and hind-wings yellowish-brown, without distinct patterns.

Male genitalia. Abdominal segment IX annular, nearly as tall as long. Anterior margin rounded dorsally and concave near anteroventral portion. Posterodorsal margin fused with segment X; apical lobe on posterolateral margins distinctly protruded outwards, elliptical, densely covered with long setae, broad basally and slightly tapering apically. Median keel short; in lateral view (Fig. 3A, Suppl. material 1: fig. S3A) projecting dorsad as a rectangular elevation at mid-line and extending posterad; in dorsal view (Fig. 3B, Suppl. material 1: fig. S3B) broad basally, with lateral margins gradually converging apically, apex darker in colour and bluntly rounded; posterior spine rows present on lateral keel slopes, absent apically.

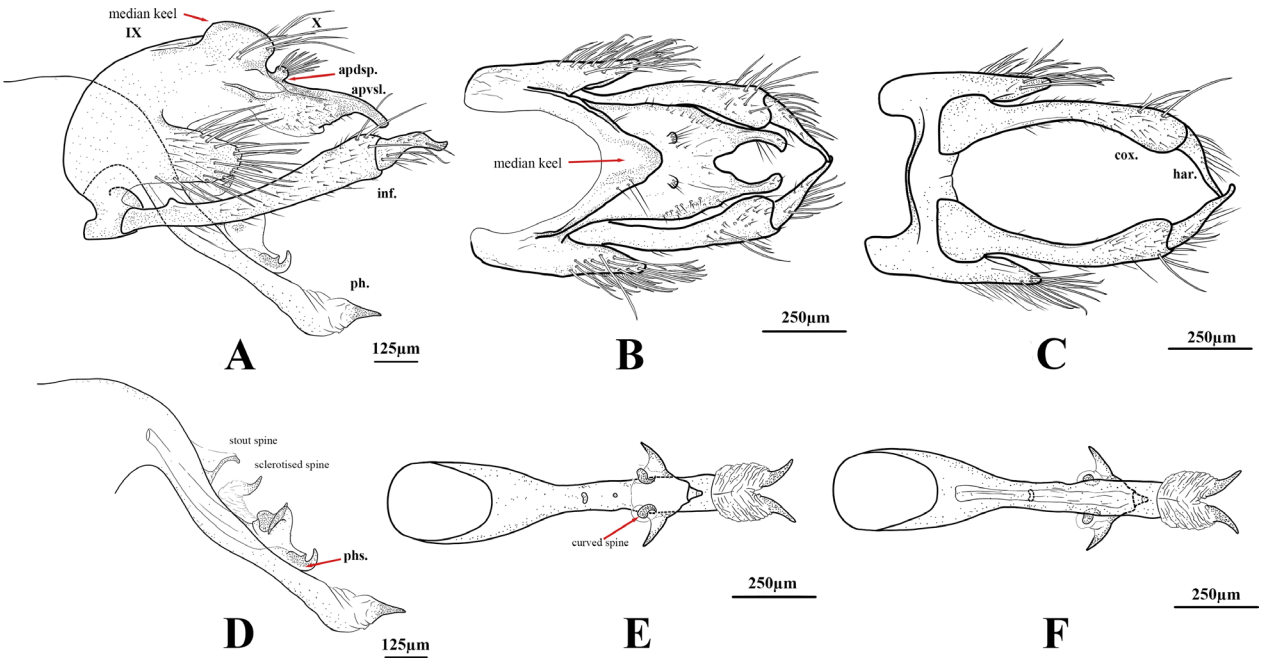

Figure 3. *Hydropsyche suni* Ge, sp. nov., Holotype. **A.** Genitalia, left lateral; **B.** Genitalia, dorsal; **C.** Genitalia, ventral; **D.** Phallotheca, lateral; **E.** Phallus, dorsal; **F.** Phallus, ventral. Abbreviations: **apdsp.** – apicodorsal setose process (paired); **apvsl.** – apicoventral setose lobe (paired); **cox.** – coxopodite (paired); **har.** – harpago (paired); **inf.** – inferior appendage (paired); **phs.** – phallotremal sclerite (paired); **ph.** – phallus; **IX** – segment IX; **X** – segment X.

Segment X in lateral view (Fig. 3A) slender at base, thickened medially and projecting ventrad, narrowed again apically; apicodorsal setose processes short, nearly round, with several long setae. In dorsal view (Fig. 3B), segment X rectangular at base and gradually tapering apically; apicodorsal setose processes bilaterally symmetrical and rounded. Pair of apicoventral setose lobes (apvsl.) in lateral view, (Fig. 3A) extending from terminus, clavate and curved downwards; in dorsal view, (Fig. 3B) curved bracket-like towards apex, apical interlobular gap deep and depressed downward in "U"-shape.

Gonocoxites in dorsal and ventral views (Fig. 3B, C) bending slightly inwards at distal one-third. Coxopodites in lateral view (Fig. 3A) slender at base, thickened at apex; in ventral view (Fig. 3C, Suppl. material 1: fig. S3C) robust basally, narrowed medially and thickened apically. Harpagones in lateral view (Fig. 3A) short, 1/4 as long as coxopodites, slightly "S"-shaped overall, basal width approximately equal to base of coxopodites, apices distinctly tapering; in ventral view (Fig. 3C) broad basally, narrowed apically and slightly curved overall.

Phallic apparatus (Fig. 3D, F) robust basally, curved ventrad near basal region, slender and nearly straight medially. A single, dorsomedian, membranous endothecal process present nearly mid-length of phallotheca, bearing a stout spine (Fig. 3E). Dorsolateral membranous endothecal process with a single apical sclerotised spine, short and slightly curved. Phallotremal sclerite hooked in lateral view (Fig. 3D); tapering distad in dorsal view (Fig. 3F), with a pair of curved spines at base. Apex membranous, bearing a pair of short stout spines; horizontal in lateral view (Fig. 3D) and curved laterally in dorsal and ventral views (Fig. 3E, F).

Etymology. Name after Dr. Changhai Sun, for his outstanding contribution to the knowledge of Trichoptera taxonomy; noun in nominative case.

Distribution. China (Hainan).

Hydropsyche zhouzhiensis Ge, sp. nov.

https://zoobank.org/C0628182-85CF-4F46-AE27-21999A5EAF3C

Fig. 4, Suppl. material 1: fig. S4

Material examined. ***Holotype.*** CHINA • 1 ♂; Shaanxi Province, Xi'an City, Zhouzhi County, Taiping River; 33°51'7.92"N, 107°53'43.80"E; alt. 1094 m; 24 Jun 2024; light trap; Haoming Zang and Zhen Deng (NJAU) leg.

Diagnosis. The new species belongs to the *Hydropsyche newae* species group because the phallotremal sclerites are nearly spherical, the endothecal spines are absent and the endothecal process is membranous. It resembles *Hydropsyche suriel* Malicky, 2015, from China. However, the new species can be easily distinguished by the following characters: (1) Phallotremal sclerites are reniform in lateral view (subquadrate in *H. suriel*); (2) the end of sclerotised structure is truncate (apex emarginate, with rounded lateral corners in *H. suriel*); (3) there are one or three spikes at the end of membrane structure (two spikes on each side in *H. suriel*).

Description. Male. Length of holotype about 10 mm. Specimen in alcohol with compound eyes black, legs yellowish-brown and thorax brown, abdomen brown dorsally, yellowish-brown ventrally, wings light brown.

Male genitalia. Abdominal segment IX fully sclerotised and annular, vertically tall and longitudinally short. Anterior margin slightly undulate dorsally, with a concavity on anteroventral margin. Posterodorsal margin fused with segment X; apical lobe on posterolateral margins robust and broad, circular-arc-shaped, with margin uniformly covered with long setae. Median keel short, surfaces granulose; in lateral view (Fig. 4A, Suppl. material 1: fig. S4A) slightly projecting dorsad at mid-line, with several setae along margin; in dorsal view (Fig. 4B, Suppl. material 1: fig. S4B) lateral margins protruding outwards medially, apex incised mesally in irregular "V"-shape; posterior spine rows present on lateral keel slopes; apical lobes bearing two posteriorly directed spines.

Segment X in lateral view (Fig. 4A) with body broad and quadrangular, dorsal margin relatively long, ventral margin short and bearing a downwards projection. In dorsal view (Fig. 4B), segment X gradually widening outwards from base; two dorso-apical setose areas located medially, surfaces covered with short setae and remaining areas covered with setae of varying lengths. Pair of apicoventral setose lobes in lateral view (Fig. 4A) long and slender, dorsal margin slightly concave, apex rounded; in dorsal view (Fig. 4B), curved inwards medially, with truncate apices; dorsal interlobular gap short and shallow, only slightly depressed downwards.

Gonocoxites in dorsal and ventral views (Fig. 4B, C) bending slightly inwards at distal one-third. Coxopodites in lateral view (Fig. 4A) slightly shorter than apex of segment X; in ventral view (Fig. 4C, Suppl. material 1: fig. S4C) nearly straight, with inner margin slightly curved. Harpagones in lateral view (Fig. 4A) wavy along ventral margin; in dorsal view (Fig. 4B) exceeding half-length of coxopodites; in ventral view (Fig. 4C) basal width slightly narrower than width of coxopodites, gradually tapering towards apex, with apex obtusely rounded.

Phallic apparatus double sinuate, forming long tube with nearly uniform diameter along its length dorsolateral membranous endothecal process arising posterior to phallotremal sclerites and extending posteriorly, with apex bearing a long, stout and sinuous spine (Fig. 4D). Phallotremal sclerites heavily pigmented, reniform in lateral view (Fig. 4D); heart-shaped in ventral and dorsal view (Fig. 4E, F), lateral spines slender and curved outwards, with a circular posterior projection present on

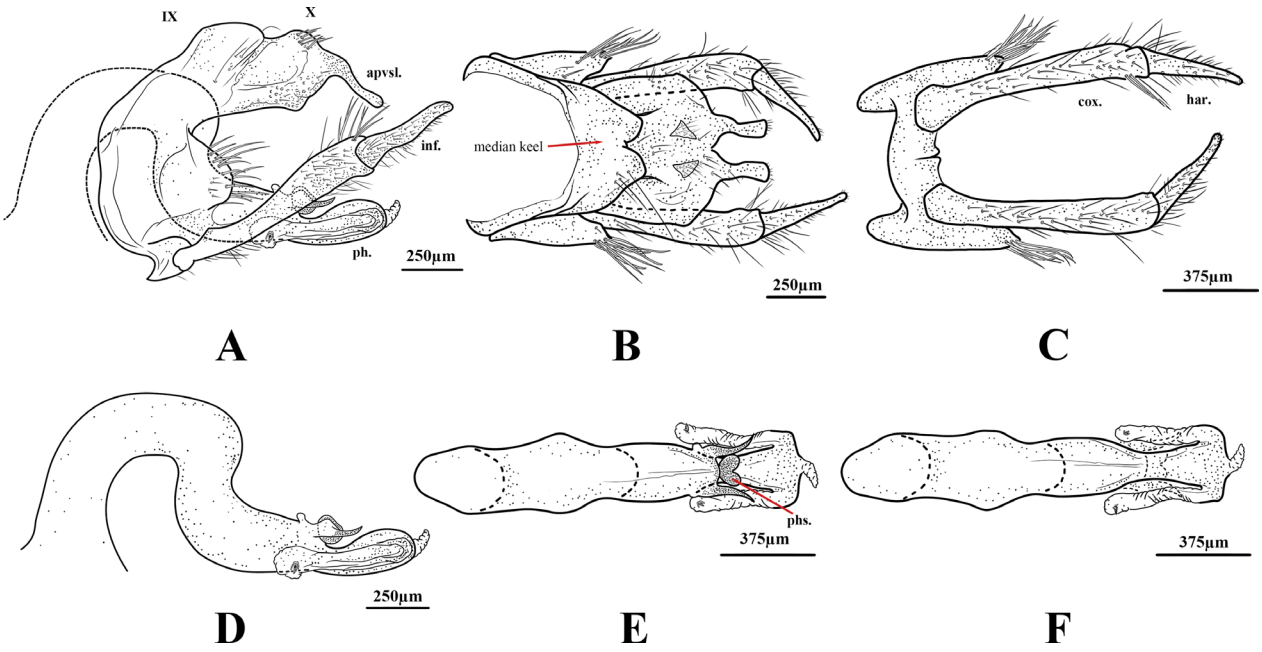

Figure 4. *Hydropsyche zhouzhiensis* Ge, sp. nov., Holotype. **A.** Genitalia, left lateral; **B.** Genitalia, dorsal; **C.** Genitalia, ventral; **D.** Phallus lateral; **E.** Phallus, dorsal; **F.** Phallus, ventral. Abbreviations: **apvsl.** – apicoventral setose lobe (paired); **cox.** – coxopodite (paired); **har.** – harpago (paired); **inf.** – inferior appendage (paired); **phs.** – phallotremal sclerite (paired); **ph.** – phallus; **IX** – segment IX; **X** – segment X.

both sides (Fig. 4E, F). In dorsal view (Fig. 4E), tube structure narrowed at phallotremal sclerites and in lateral view (Fig. 4D), extending anteriorly with spines present at both distal ends. Membranous structure extending anteriorly to about one-third of phallic apparatus, right end bearing a stout spine and left end bearing three smaller spines (Fig. 4F).

Etymology. *zhouzhiensis*, name derived from the type locality.

Distribution. China (Shaanxi).

New distributional records

Hydropsyche stimulans McLachlan, 1878

Material examined. 5 ♂; Xinjiang Uygur Autonomous Region, Xinyuan County, Kurdenin Nature Reserve; 43°09'06.12"N, 82°52'22.08"E; alt. 1456.4 m; 27 Jul 2024; light trap; Xinyu Ge leg.

Distribution. China (Xinjiang) [**first record from China**], Uzbekistan, Afghanistan, Kazakhstan, Kyrgyzstan.

Hydropsyche binaria Mey, 1996

Material examined. 1 ♂; Yunnan Province, Cangyuan Va Autonomous County; 23°15'13.5570"N, 98°57'4.1464"E; alt. 1035 m; 22 Nov 2024; light trap; Xinyu Ge leg.

Distribution. China (Yunnan) [**first record from China**], Thailand, Nepal, Bhutan, India.

Hydropsyche pallipenne Banks, 1938

Material examined. 1 ♂; Yunnan Province, Jinghong City, Mengla County; 21°58'7.96"N, 101°4'56.91"E; alt. 1271.9 m; 25 Aug 2025; light trap; Wei Cao (TJNU) leg.; 1 ♂; Yunnan Province, Jinghong City, Mengla County; 21°25'11.87"N, 101°29'22.64"E; alt. 770 m; 29 Mar. 2025; light trap; Haoming Zang leg.

Distribution. China (Yunnan) [**first record from China**], Malaysia, Thailand, Nepal, India, Pakistan, Cambodia, Myanmar.

Hydropsyche battos Malicky & Chantaramongkol, 2000

Material examined. 1 ♂; Hainan Province, Qiongzhong Li and Miao Autonomous County, Yingge Ling; 19°01'33.20"N, 109°34'11.69"E; alt. 537.2 m; 21 Dec 2024; light trap; Xinyu Ge and Xiaolong Lin leg.

Distribution. China (Hainan) [**first record from China**], Thailand.

Classification and barcoding analysis

The Neighbour-Joining tree provides additional molecular support for the placement of the four new species within *Hydropsyche* (Fig. 5) and genetic distances are shown in Suppl. material 1: table S3. Its topology supports the validity of the new species and is congruent with morphological classifications, demonstrating that DNA barcoding and traditional morphology are concordant in delineating these taxa.

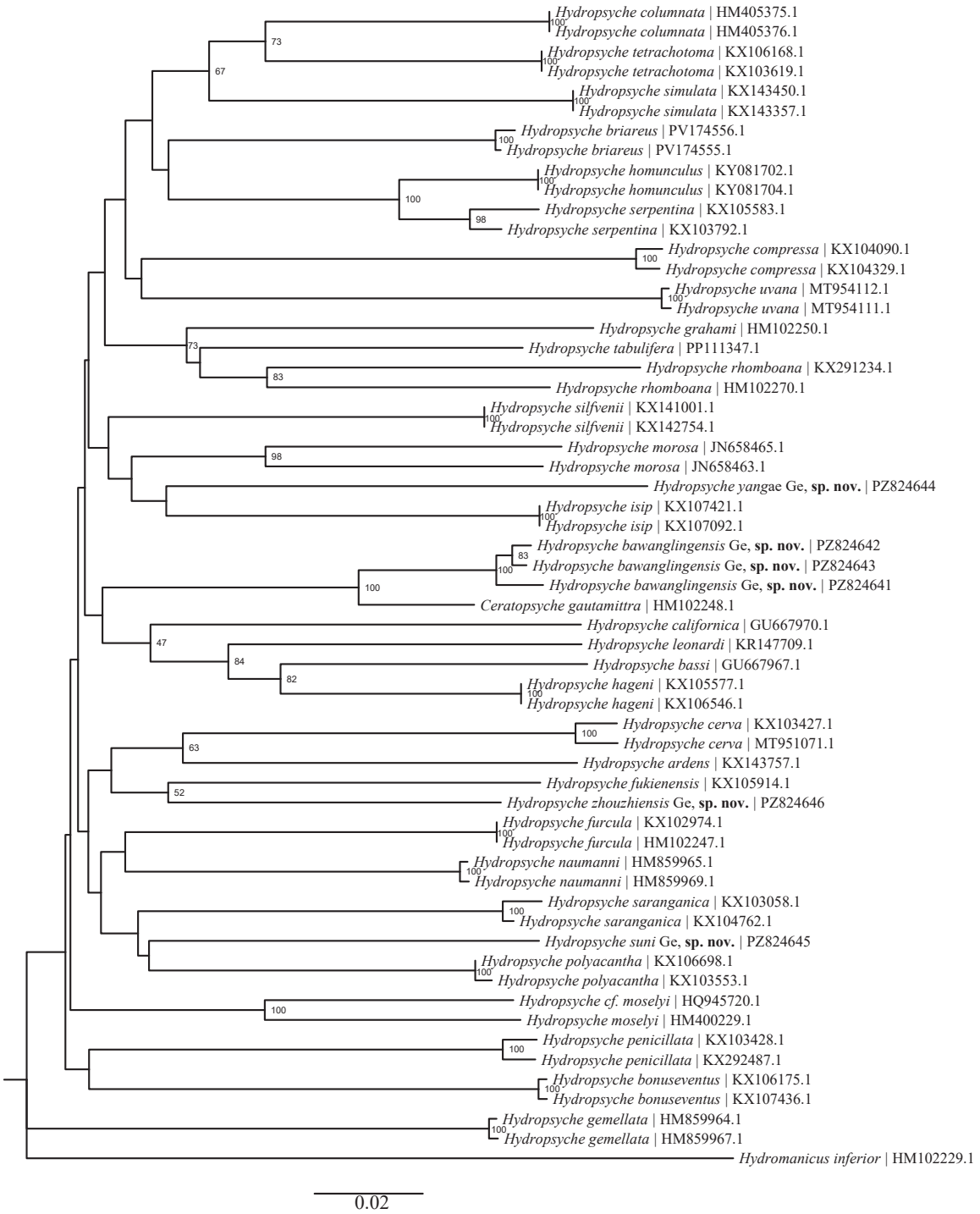

Figure 5. NJ tree, based on *mtCOI* datasets, with bootstrap support values shown at nodes.

Updated keys to species of the three species groups of *Hydropsyche* in China

1 Endothecal process sclerotised, digitiform or nearly digitiform ..... *H. pluvialis* species group
– Endothecal process membranous; phallotremal sclerites variously developed..... 2
2 Phallotremal sclerites fused dorsally, extended posteriorly, short or long.....*H. hamifera* species group
– Phallotremal sclerites spherical or nearly spherical, not dorsally fused and posteriorly extended .....*H. newae* species group

Key to species of the *Hydropsyche hamifera* species group

1 Sclerotised rod-like stout spine present on mid- to anterior part of the phallus before phallotremal sclerites, anteriorly connected to the phallus by membrane ..... *Hydropsyche suni* Ge, sp. nov.
– No structure present on mid- to anteriorpart of the phallus before phallotremal sclerites .....*Hydropsyche polyacantha*

Key to species of the *Hydropsyche pluvialis* species group

1 Apicoventral setose lobes present 2
– Apicoventral setose lobes absent 22
2 Apical lobes on posterolateral margins forming a right angle between margins 3
– Apical lobes on posterolateral margins forming an acute angle between margins 10
3 Harpagones short, distally bifurcate; each with inner branch broad, outer branch pointed and longer than inner branch, densely setose ..... *Hydropsyche furcula*
– Harpagones not as above 4
4 Apicoventral setose lobes long, length more than twice the width in dorsal view 5
– Apicoventral setose lobes short, length subequal to or slightly greater than width in dorsal view 7
5 The apicodorsal process of segment X continuous in a straight line with apicoventral setose lobes, median portion elevated 6
– The apicodorsal process of segment X continuous in a downward-sloping line with apicoventral setose lobes, median portion not elevated ..... *Hydropsyche futiel*
6 Segment X triangular in lateral view ..... *Hydropsyche argos*
– Segment X elongate in lateral view ..... *Hydropsyche cabarym*
7 Posterior margin of segment X U-shaped in dorsal view ..... *Hydropsyche gyantsana*
– Posterior margin of segment X V-shaped in dorsal view 8
8 Coxopodites robust, with a setose pit on apex in dorsal view ..... *Hydropsyche pungentis*
– Coxopodites robust, without such a setose pit on apex in dorsal view 9
9 Apicodorsal setose process present ..... *Hydropsyche camael*
– Apicodorsal setose process absent ..... *Hydropsyche rhomboana*
10 Endothecal process forked 11
– Endothecal process not forked 18
11 Phallic apparatus apex narrow, medially cleft 12
– Phallic apparatus apex narrow, obtusely rounded or shallowly concave 13
12 The apicodorsal process of segment X with an anterad directed, subcircular projection ..... *Hydropsyche ditalon*
– The apicodorsal process of segment X with a horizontally directed, subrectangular projection ..... *Hydropsyche binaria*
13 Phallic apparatus apex narrow, obtusely rounded ..... *Hydropsyche dolon*
– Phallic apparatus apex narrow, shallowly concave 14
14 Harpagones extremely slender apically in lateral view ..... *Hydropsyche nulanka*
– Harpagones subequal in width in lateral view 15
15 Harpagones tapering apically in ventral view ..... *Hydropsyche battos*
– Harpagones constricted subapically then expanded in ventral view ..... *Hydropsyche grahami*
16 Apicoventral setose lobes long, length more than three times width 17
– Apicoventral setose lobes short, length only slightly greater than width 18
17 Harpagones subequal in width in ventral view ..... *Hydropsyche cipus*
– Harpagones tapering apically in ventral view, width at apex one-third of base ..... *Hydropsyche stimulans*
18 Dorsal interlobular gap “V”-shaped ..... *Hydropsyche tibetana*
– Dorsal interlobular gap “U”-shaped 19
19 Coxopodites distally twice as wide as base in lateral view ..... *Hydropsyche kispupos*
– Coxopodites distally slightly wider than base width, but less than twice 20
20 Apicoventral setose lobes approximately triangular and slightly curved ..... *Hydropsyche yangae* Ge, sp. nov.
– Apicoventral setose lobes not as above ..... *Hydropsyche pallipenne*
21 Tergum X cap-shaped overall, linguiform in dorsal view ..... *Hydropsyche malformis*
– Tergum X not as above 22
22 Phallic apparatus apex broad and strongly incurved ..... *Hydropsyche retronsis*
– Phallic apparatus apex not incurved 23
23 Phallic apparatus apex widened, triangular; harpagones with subapical inner margin slightly swollen in ventral view ..... *Hydropsyche arion*
– Phallic apparatus apex not widened; harpagones normal, not swollen in ventral view ..... *Hydropsyche kaznakovi*

Key to species of the *Hydropsyche newae* species group in China

1 Phallotheca bent at base and apex forming a right or obtuse angle; apical portion long, straight or slightly curved 2
– Phallotheca bend not as above 14
2 Coxopodites with subparallel lateral margins in ventral view 3
– Coxopodites gradually widened towards apex in ventral view 6

3 Harpagones triangular both in lateral and ventral views, apex pointed ..... *Hydropsyche kozhantschikovi*
– Harpagones not as above 4
4 Apicoventral setose lobes relatively short and stout ..... *Hydropsyche cerva*
– Apicoventral setose lobes long 5
5 A membranous projection present posterior to phallotremal sclerite ..... *Hydropsyche orientalis*
– No such membranous projection posterior to phallotremal sclerite ..... *Hydropsyche vaza*
6 Harpagones distinctly wider apically than basally in ventral view ..... *Hydropsyche carina*
– Harpagones distinctly narrower apically than basally or at most as wide as base, in ventral view 7
7 Apicoventral setose lobes only slightly arched downwards in lateral view 8
– Apicoventral setose lobes strongly bent downward, angle between base and apex nearly 90° in lateral view 12
8 Sclerotised spine at apex of endothecal process spiral ..... *Hydropsyche newae*
– Sclerotised spine at apex of endothecal process straight or slightly curved, not spiral 9
9 Ventral lobe of endotheca widened laterally near apex in ventral view ..... *Hydropsyche hackeri*
– Ventral lobe of endotheca not distinctly widened in ventral view 10
10 Apicoventral setose lobes slender and long ..... *Hydropsyche nagpupos*
– Apicoventral setose lobes short and stout 11
11 Harpagones as wide as base of coxopodites in lateral view ..... *Hydropsyche lianchiensis*
– Harpagones very slender, about 1/4 as wide as base of coxopodites in lateral view ..... *Hydropsyche keses*
12 Membranous structure at apex of ventral lobe of endotheca divided into two lobes ..... *Hydropsyche hainanensis*
– Membranous structure at apex of ventral lobe of endotheca undivided, containing several small spines 13
13 Phallus slightly widened laterally at middle in ventral view ..... *Hydropsyche nevoides*
– Phallus gradually tapered from base to apex, slightly thicker subapically in ventral view ..... *Hydropsyche trifora*
14 Phallotheca bent at base and apex forming an inverted “V”-shape; basal portion long, apical portion short 15
– Phallotheca bent at base and apex forming an inverted “U”-shape or forming a loop 21
15 Endothecal process long, membranous 16
– Endothecal process short, weakly sclerotised; or absent 18
16 Harpagones quadrangular, apex obliquely truncate ..... *Hydropsyche chengdu*
– Harpagones not quadrangular, apex slenderly pointed and rounded 17
17 Ventral lobe of endotheca bifid in ventral view ..... *Hydropsyche columnata*
– Ventral lobe of endotheca truncate apically ..... *Hydropsyche tubulosa*
18 Endothecal process absent; a pair of small spinous projections behind arched portion of phallus ..... *Hydropsyche gautamittra*
– Endothecal process present; no small spinous projections behind arched portion of phallus 19
19 Phallus apex with three membranous projections ..... *Hydropsyche fukienensis*
– Phallus apex with two membranous projections 20
20 A membranous pore present anterodorsally before phallus apex, bearing two setae ..... *Hydropsyche conoidea*
– Area anterodorsally before phallus apex slightly concave, without such setae ..... *Hydropsyche curvativa*
21 Phallotheca bent at base and apex forming an inverted U shape; apex obtuse in lateral view; basal portion long, apical portion short 22
– Phallotheca bent at base and apex forming a loop 38
22 Gonocoxites short, length less than half that of coxopodite in ventral view 23
– Gonocoxites short, length equal to or more than half of coxopodites in ventral view 33
23 Phallus apex truncate 24
– Phallus apex incised 30
24 Apical lobes on posterolateral margins foliate, angle between lateral margins about 45° 25
– Apical lobes on posterolateral margins bluntly toothed, angle between lateral margins > 45° ..... *Hydropsyche busiris*
25 Apicoventral setose lobes distinctly protruding, triangular in lateral view 26
– Apicoventral setose lobes slightly protruding, gently arched in lateral view 27
26 Harpagones uniformly thick, rod-like in lateral view ..... *Hydropsyche tagra*
– Harpagones broad basally, tapering, then widened apically in lateral view ..... *Hydropsyche uvana*
27 Harpagones gradually tapering from base to apex in ventral view 28
– Harpagones not as above in ventral view 29
28 Pair of quadrate (nearly square) structures near mid-length projecting posterad ..... *Hydropsyche bawanglingensis* Ge, sp. nov.
– No pair of quadrate (nearly square) structures near mid-length projecting posterad ..... *Hydropsyche zhouzhiensis* Ge, sp. nov.
29 Harpagones nearly uniform in width in ventral view ..... *Hydropsyche complicata*
– Harpagones wider apically than basally in ventral view ..... *Hydropsyche keska*
30 Harpagones greatly enlarged apically in ventral view ..... *Hydropsyche simulata*
– Harpagones normal, not enlarged apically in ventral view 31
31 Phallus apex incised 32
– Phallus apex not incised ..... *Hydropsyche suriel*

32 Coxopodites distinctly wider in distal half than in basal half in ventral view ..... *Hydropsyche tetrachotoma*
– Coxopodites nearly equal in width between distal and basal halves in ventral view ..... *Hydropsyche orbiculata*
33 A pair of small membranous projections present posterior to phallotremal sclerite 34
– No such small membranous projections posterior to phallotremal sclerite 35
34 Apicoventral setose lobes about four times as long as wide in dorsal view ..... *Hydropsyche penicillata*
– Apicoventral setose lobes about twice as long as wide in dorsal view ..... *Hydropsyche camillus*
35 Phallus apex obtusely rounded or only slightly concave 36
– Phallus apex with a deeper incision 37
36 Phallus apex with a pair of long membranous projections, each with a short spine at tip ..... *Hydropsyche spinata*
– Phallus apex without such membranous projections, only with two tufts of setae ..... *Hydropsyche valvata*
37 Phallus apex bearing a pair of large membranous projections, with a small membranous projection between them ..... *Hydropsyche shizongensis*
– Phallus apex without a small membranous projection between membranous projections ..... *Hydropsyche compressa*
38 Endotheca membranous, large; apical spine large, nearly as long as endotheca ..... *Hydropsyche serpentina*
– Endotheca small; apical spine also small 39
39 Phallus apex rounded in ventral view 40
– Phallus apex not as above 41
40 Phallus apex with three small projections ..... *Hydropsyche boreas*
– Phallus apex with two small projections ..... *Hydropsyche picibunk*
41 Dorsal interlobular gap "V"-shaped in dorsal view 42
– Dorsal interlobular gap "U"-shaped in dorsal view ..... *Hydropsyche laposhat*
42 Phallus apex trilobate in ventral view ..... *Hydropsyche homunculus*
– Phallus apex rounded, with a protruding, setose structure ..... *Hydropsyche briareus*

Discussion

The genus *Hydropsyche* is the most species-rich genus within Hydropsychinae and its larvae are very common in the samples used for water quality biological monitoring (Morse et al. 2007). The accurate identification of the *Hydropsyche* species can promote the application of water quality biological monitoring.

This study has reported four new species and four new records in China, thereby enriching the species diversity of *Hydropsyche* in China. Amongst them, *Hydropsyche stimulans* McLachlan, 1878 is distributed in the Palaearctic Region and the other eight species are distributed in the Oriental Region, indicating that the Oriental Region is still a biodiversity hotspot for Trichoptera. There are still numerous new record species and new species to be discovered in China, especially in Hainan and Yunnan, which have unique natural environments. We should increase the sampling frequency in the Oriental Region, especially during winter and spring.

Our results indicate that *mtCOI* barcoding can effectively distinguish these four new species from other species. Morphologically, these four new species belong to three species groups; however, none of these species groups was recovered as a monophyletic clade in the NJ tree constructed, based on barcodes and the evolutionary relationships amongst the various species groups remain unclear. This indicates that phylogenetic relationships constructed using a small number of genes may be unreliable. In the future, incorporating more taxa and additional molecular markers (mitochondrial genomes or phylogenomic) will help clarify the phylogenetic relationships within the genus *Hydropsyche*.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Artificial Intelligence (AI) use

The authors accept full responsibility for the content of the manuscript, including the disclosure of any use of AI.
No AI tools were used in the preparation of this manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

Supplementary material 1

Information on the collection of specimens and PCR primers for *mtCOI* barcoding

Authors: Xinyu Ge, Lu Chai, Na Wang, Haoran Zhang, Ni Zhang, Jingyuan Wang, Chuncai Yan
Data type: pdf
Explanation note: **fig. S1.** The photographic illustrations of genitalia of *Hydropsyche bawanglingensis* Ge, sp. nov. **fig. S2.** The photographic illustrations of genitalia of *Hydropsyche yangae* Ge**,** sp. nov. **fig. S3.** The photographic illustrations of genitalia of *Hydropsyche suni* Ge, sp. nov. **fig. S4.** The photographic illustrations of genitalia of *Hydropsyche zhouzhiensis* Ge, sp. nov. **table S1.** Information on the collection of specimens for *mtCOI* barcoding. **table S2.** PCR primers used to sequence *mtCOI* genes of *Hydropsyche* species in this study. **table S3.** Pairwise genetic distances among *Hydropsyche* species, based on *mtCOI* sequences.
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