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A new species of freshwater crab of the genus *Tiwaripotamon* Bott, 1970 (Crustacea, Brachyura, Potamidae) from northern Vietnam and southern China

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Abstract. A new freshwater crab species of the family Potamidae is described from the boundaries of northern Vietnam and southern China. *Tiwaripotamon pluviosum* sp. nov. can be distinguished from other species by a suite of morphological characters, including a relatively flat carapace, relatively less slender legs, and distinct dorsal flaps on the male first gonopods. Molecular data using the mitochondrial cytochrome oxidase subunit I (COI) also supports this species as being new.

Key words. *Tiwaripotamon pluviosum*, taxonomy, mitochondrial DNA, cytochrome oxidase subunit I, COI

INTRODUCTION

Seven species of the freshwater crab genus *Tiwaripotamon* Bott, 1970, have been reported, with the distribution being around southwestern China and northern Vietnam; *T. annamense* (Balss, 1914), *T. araneum* (Rathbun, 1905), *T. edostilus* Ng & Yeo, 2001, *T. pingguoense* Dai & Naiyanetr, 1994, *T. vietnamicum* (Dang & Ho, 2002), *T. vixuyenense* Shih & Do, 2014, *T. xiurenense* Dai & Naiyanetr, 1994, with the exception of *Telphusa austeniana* Wood-Mason, 1871 which should be excluded from this genus (Ng & Yeo, 2001). *Tiwaripotamon* are generally known from limestone environments and are sometimes found in caves. Apart from the long legs, there is no apparent morphological adaptation for the habit of cave dwelling, and its behavior and ecology are largely unknown due to its cryptic (especially nocturnal) habits (Ng & Yeo, 2001). Based on unpublished genetic data, Shih & Do (2014) have mentioned this genus to be closely related with taxa within the "China-East Asian islands Group" (including the genera from Hainan Island, East Asian island Arc, and the coastal provinces of China) (Shih et al., 2009).

In recent surveys around the borders of Vietnam and China, we obtained some specimens of *Tiwaripotamon*, which were examined and compared with other species from around the vicinity. We confirm this species as being new to science with a suite of morphological characters, supported by a genetic study using the mitochondrial cytochrome oxidase subunit I (COI). Our study brings the total number of species of this genus to eight.

MATERIAL AND METHODS

Specimens of *Tiwaripotamon* collected from northern Vietnam and southern China (see material examined and Table 1) were preserved in 70–95% ethanol after collection and illustrated with the help of a drawing tube attached to a stereomicroscope. Material examined are deposited in the Institute of Ecology and Biological Resources (IEBR-FC); the Zoological Collections of the Department of Life Science, National Chung Hsing University, Taichung, Taiwan (NCHUZOOL); Sun Yat-Sen Museum of Biology, Sun Yat-Sen University, Guangzhou, China (SYSU); and the Zoological Reference Collection of the Lee Kong Chian Museum of Natural History, National University of Singapore, Singapore (ZRC).

The abbreviations G1 and G2 are used for the male first and second gonopods, respectively. Measurements, in millimeters (mm), are of the carapace width (CW), carapace length (CL), as well as the ratio of length/width of the fourth ambulatory leg. The terminology used essentially follows that of Ng & Yeo (2001).

Sequences of COI were obtained following the method described by Shih & Do (2014), by using the primers LCO1490, HCO2198 (Folmer et al., 1994), COL14 (Roman & Palumbi, 2004) and COH6 (Schubart & Huber, 2006), and aligned with MUSCLE (Edgar, 2004) under default settings, as implemented in MEGA v. 5.2.2 (Tamura et al., 2011), after verification with the complimentary strand. Sequences of the different haplotypes have been deposited in the DNA

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Table 1. COI gene haplotypes for six species of *Tiwaripotamon* from Vietnam and China. For institutional abbreviations, see material and methods.

Species	Locality	Catalogue no.	Access. no. of COI
T. edostilus	Vietnam: Cat Ba, Haiphong	NCHUZOOL 13613	AB896762
		ZRC 2000.0096 (holotype)	AB896763
T. pingguoense	China: Pingguo County, Baise City, Guangxi	SYSU 001166	LC145315
T. pluviosum sp. nov.	Vietnam: Coong Village, Ha Lang District, Cao Bang	IEBR-FC TTx01 (holotype); IEBR-FC TTx04	LC145316; LC145317
		NCHUZOOL 14786	LC145318; LC145319
		ZRC 2015.0482	LC145320; LC145321
	China: Longzhou County, Chongzuo City, Guangxi	SYSU 001205	LC145322; LC145323; LC145324
T. vietnamicum	Vietnam: Cuc Phuong, Ninh Binh	NCHUZOOL 13612	AB896760
		NCHUZOOL 13612	AB896761
T. vixuyenense	Vietnam: Vi Xuyen, Ha Giang	NCHUZOOL 13611	AB896758
		IEBR-FC TVx01 (holotype)	AB896759
T. xiurenense	China: Lipu, Guangxi	NCHUZOOL 13610	AB896764

Data Bank of Japan (DDBJ) (accession numbers in Table 1), with other sequences which published in earlier papers of HTS (Table 1). The pairwise estimates of Kimura 2-parameter (K2P) distances (Kimura, 1980) between haplotypes of this genus (with pairwise deletion) were calculated using MEGA.

TAXONOMY

Family Potamidae Ortmann, 1896

Subfamily Potamiscinae Ortmann, 1896 (sensu Yeo & Ng, 2003)

Genus *Tiwaripotamon* Bott, 1970

Type species: *Geothelphusa annamensis* Balss, 1914, by original designation.

Tiwaripotamon pluviosum sp. nov.

(Figs. 1–6)

Material examined. **Holotype**: male (32.2 × 23.2 mm) (IEBR-FC TPx01), 22°43'466"N 106°39'051"E, Coong Village, Duc Quang Commune, Ha Lang District, Cao Bang Province, Vietnam, 572 m, coll. T.C. Pham, 7 June 2014. **Paratypes**: 1 male (23.3 × 18.8 mm) (IEBR-FC TPx02), 2 females (29.7 × 22.1, 16.9 × 13.5 mm) (IEBR-FC TPx03, IEBR-FC TPx04); 1 male (21.7 × 17.1 mm), 1 female (32.7 × 25.3 mm) (NCHUZOOL 14786); 1 male (21.0 × 16.3 mm), 1 female (16.7 × 13.1 mm) (ZRC 2015.0482), same data as holotype. **Other material**: male (39.8 × 28.8 mm) (SYSU 001205), Nonggang Natural Reserve, Longzhou County, Chongzuo City, Guangxi Province, China, coll. local collector, August 2013.

Comparative material. ***Tiwaripotamon edostilus*** Ng & Yeo, 2001: 1 male (26.1 × 21.4 mm), (IEBR-FC TE01), Cat Ba Island, Hai Phong City, Vietnam, 15–170 m, coll. V.T. Do, 18–19 March 2013. ***T. pingguoense*** Dai & Naiyanetr, 1994: female (42.2 × 32.6 mm) (SYSU 001166), Pingguo County, Baise City, Guangxi Province, China, coll. local collector, September 2013. ***T. vietnamicum*** (Dang & Ho, 2002): 2 males (44.5×32.8 mm, 41.3×31.2 mm), (IEBR-FC TVn01, NCHUZOOL 13612), Cuc Phuong National Park, Ninh Binh Province, Vietnam, 500 m, coll. V.T. Do, 14 May 2013. ***T. vixuyenense*** Shih & Do, 2014: 1 male (26.4 × 20.5 mm) (IEBR-FC TVx01), Tung Ba Commune, Vi Xuyen District, Ha Giang Province, Vietnam, 758 m, coll. N.L. Doan & X.N. Nguyen, 2 July 2013. ***T. xiurenense*** Dai & Naiyanetr, 1994: 1 male (39.6 × 29.7 mm) (NCHUZOOL 13610), Lipu, Guangxi, China, coll. local collector, 18 May 2009.

Diagnosis. Carapace about 1.3 times broader than long; transverse, low; dorsal surface relatively flat; glabrous; regions poorly defined, cervical groves shallow; H-shaped depression shallow but distinct. Epigastric cristae distinct; postorbital cristae rounded, confluent with epibranchial tooth. External orbital angle triangular, outer margin gently convex; epibranchial tooth small, broadly triangular, separated from external orbital angle by distinct, broadly triangular cleft. Ambulatory legs less slender; fourth pair with length of merus about 4.7 times width. G1 terminal segment distinctly upcurved, with distinct dorsal flap in proximal part.

Description. Carapace (Figs. 1A, 3A, 4A, 5A) about 1.3 times broader than long (n = 8). Epigastric cristae rugose, separated by narrow, shallow groove that opens up into inverted V-shape posteriorly; postorbital cristae rugose, rounded, low, confluent with epibranchial tooth; regions

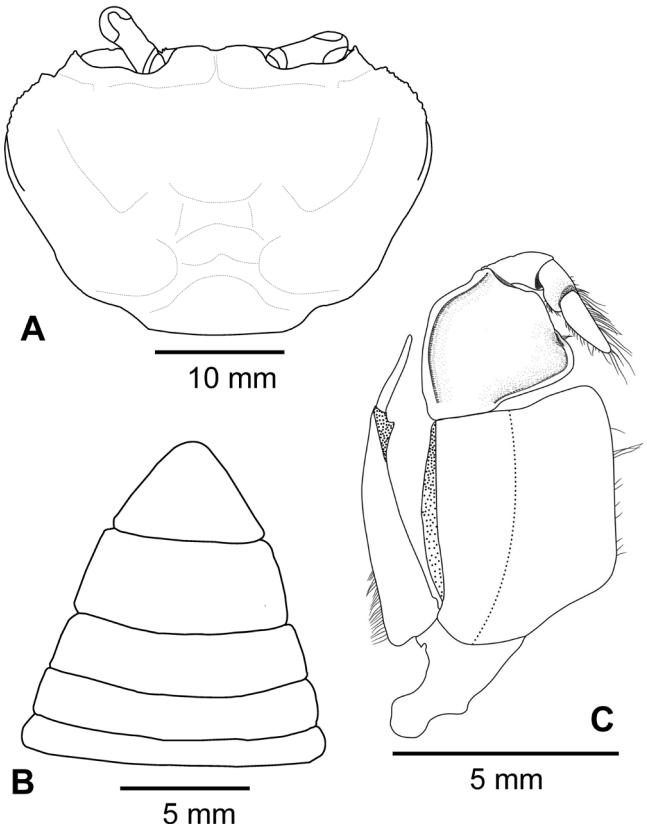

Fig. 1. *Tiwaripotamon pluviosum* sp. nov., holotype (CW 32.2 mm, IEBR-FC TTx01). A, carapace, dorsal view; B, abdominal somites 3–6 and telson; C, right third maxilliped.

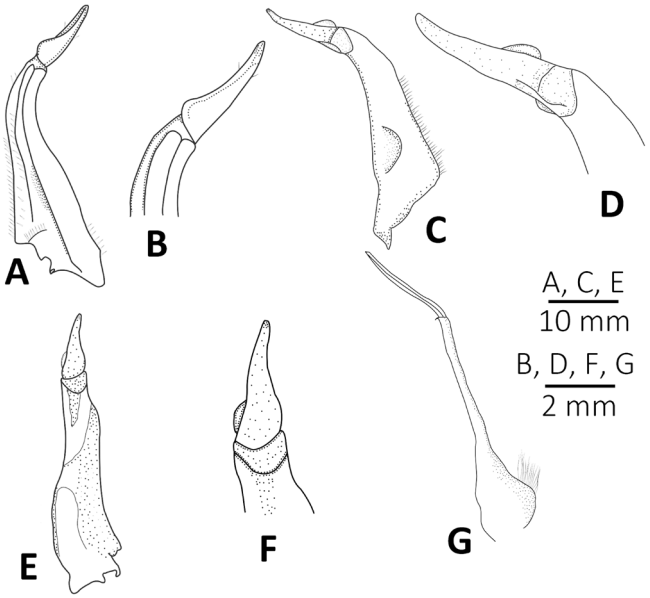

Fig. 2. *Tiwaripotamon pluviosum* sp. nov., holotype (CW 32.2 mm, IEBR-FC TTx01). A–F, left G1: A, ventral view; B, ventral view of terminal segment; C, dorsal view; D, dorsal view of terminal segment; E, mesial view; F, mesial view of terminal segment. G, right G2.

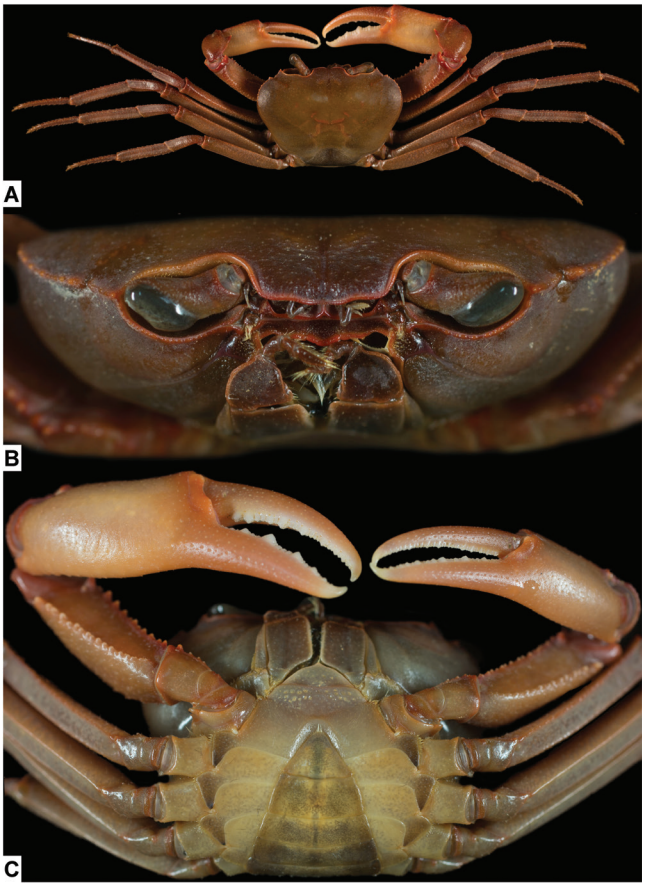

Fig. 3. *Tiwaripotamon pluviosum* sp. nov., holotype (CW 32.2 mm, IEBR-FC TTx01). A, dorsal view; B, frontal view; C, ventral view.

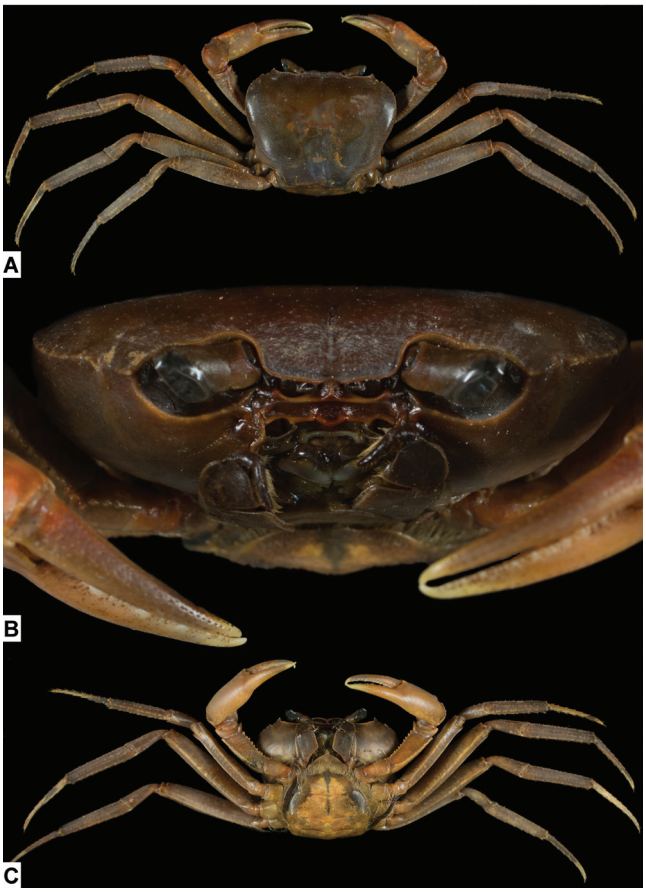

Fig. 4. *Tiwaripotamon pluviosum* sp. nov., paratype, female (CW 32.7 mm, NCHUZOOL 14786). A, dorsal view; B, frontal view; C, ventral view.

behind epigastric and postorbital cristae weakly rugose. Frontal margin broadly emarginated medially; frontal region deflexed, appearing relatively narrow from dorsal view, smooth; supra-and infraorbital margins distinctly cristate, supraorbital margins sinous, infraorbital margin arched; orbital region smooth, relative narrow; eyes normal with no adaptations to cave environments. External orbital angle sharply triangular, outer margin slightly convex; epibranchial tooth small, broadly triangular, separated from external orbital angle by distinct broadly triangular cleft; anterolateral margin convex, serrated in upper part; metabranchial regions smooth.

Ischium of third maxilliped (Fig. 1C) quadrate, about 1.2–1.5 times longer than broad, with shallow longitudinal median sulcus; exopod with short but distinct flagellum, about 1/2 of merus width (n = 4).

Chelipeds (Figs. 3A, C, 4A, C, 5A, 6) subequal, with outer surface smooth. Right cheliped large in holotype, with length of palm+pollex about 2.8 times palm height. Ambulatory legs (Figs. 3A, 4A, 5A) smooth, less slender; all dactylus and propodus with prominent spines in both upper and lower margins; second leg with dactylus about 9.1 times longer than proximal width, propodus about 5.6 times longer than broad and about 1.1 times longer than dactylus, carpus about 0.7 times length of dactylus, merus about 1.6 times longer than dactylus (n = 3); fourth leg with dactylus about 9.5 times longer than proximal width, propodus about 1.0 times length of dactylus; carpus about 0.6 times length of dactylus (n = 3), merus about 4.8 times longer than proximal width (n = 7) and about 1.3 times longer than dactylus (n = 3).

Male abdomen (Figs. 1B, 3C, 5C) broadly triangular, with proximal width of sixth segment about 2.8 times length; telson broadly triangular, tip rounded, with proximal width about 1.4 times length (n = 4).

Suture (Figs. 3C, 5C, D) between thoracic sternites 2 and 3 complete, distinct; groove between sternites 3 and 4 present; thoracic sternites 5 and 6 interrupted medially; sternites 7 and 8 medially separated by distinct longitudinal median suture (Fig. 5E, F). Male abdominal cavity reaching beyond imaginary line joining the base of the chelipeds. Tubercles of male abdominal-locking mechanism positioned in thoracic sternite 5.

G1 (Fig. 2A–F) relatively short; terminal segment distinctly upcurved, about 0.34 times length of subterminal segment, about 3.0 times longer than proximal width, with distal opening subventral in position. G2 (Fig. 2G) about 1.2 times longer than G1, distal segment well developed, about 0.5 times as long as basal segment (Fig. 3I, J). Female gonopore (Fig. 5E, F) in thoracic sternite 6, ovate, without operculum, opened posteromesially; anterioexternal margin partially covered by a raised rim; posteromesial margin surrounded by a low raised rim.

Etymology. The name "*pluviosum*" means rainy, which refers to the specimens being collected and active during the rainy season.

Live coloration. Various from reddish brown, purple to orange (Figs. 3, 4, 5A, B, 6).

Ecological notes. This species inhabits limestone mountains (Fig. 5G, H), and are most active during the rainy season (personal observation). Similar to *T. vixuyenense* (cf. Shih & Do, 2014), specimens of this species were also found crawling on the leaves and twigs, with one specimen observed being one metre above the ground at night.

Remarks. This species fits well within the character descriptions of *Tiwaripotamon* defined by Ng & Yeo (2001) due to the squarish third maxilliped ischium, short third maxilliped exopod with a short flagellum, slender legs, broadly triangular male abdomen, and an upcurved G1 terminal segment (Figs. 1–4). This new species can be separated from other congeners (see below) by the relatively flat and transverse dorsal surface of the carapace, proportionately stouter ambulatory legs and distinct dorsal flap on the G1.

The G1 of this species resembles *T. edostilus* in the presence of a dorsal flap, but it is smaller in size in the latter (versus larger in this species) (Fig. 2; cf. Ng & Yeo, 2001: fig. 5). The new species can also be separated from *T. edostilus* by the flatter and more transverse carapace (ratios of CW: CL is 1.3 of this species; 1.2 of *T. edostilus*; cf. Shih & Do, 2014) and stouter ambulatory legs (see below). The carapace of the new species is similar with *T. annamense* in the morphology of the anterolateral margin. However, the two can be easily separated by the presence of a dorsal flap on the G1 in the former (Fig. 2) and the absence of such in the latter (Ng & Yeo, 2001: fig. 2D–I). The merus of the fourth ambulatory leg is about 4.8 times longer than broad for this species, which is shorter than most congeners: 6.5 for *T. vixuyenense*, 5.1 times for *T. vietnamicum*, 5.6 times for large *T. edostilus* specimens and 5.3 times for *T. xiurenense* (unpublished data; Shih & Do, 2014), but longer than *T. pingguoense* (4.3 times, unpublished data) and *T. annamense* (approximately 4.5 times, estimation derived from dactylus ratio, Ng & Yeo, 2001).

DNA results and discussion. The pairwise K2P-corrected genetic distances between species for COI are shown in Table 2. The minimum interspecific divergence between *T. pluviosum* sp. nov. and other species of *Tiwaripotamon* is 6.22%, which is large enough to support this species genetically (see below). This value is larger than the minimum interspecific K2P distances of other potamid crabs which have closely related species pairs, e.g., *Geothelphusa* (3.17% between *G. tali* Shy, Ng & Yu, 1994 and *G. minei* Shy & Ng, 1998, recalculated from Shih et al. (2011a); 2.83% between *G. candidiensis* Bott, 1967 and *G. olea* Shy, Ng & Yu, 1994, re-calculated from Shih et al. (2008)), *Nanhaipotamon* (2.17% between *N. nanriense* Dai, 1997 and *N. dongyinense* Shih, Chen & Wang, 2005, re-calculated from Shih et al. (2011b)) and *Longpotamon* (=*Sinopotamon*, see Shih et al., 2016) (1.8% between *L. shanxianense* (Dai & Chen, 1981) and *L. tongbaiense* (Dai & Chen, 1981) of the *L. yangtsekiense* (Bott, 1967) complex, Zheng et al., 2006),

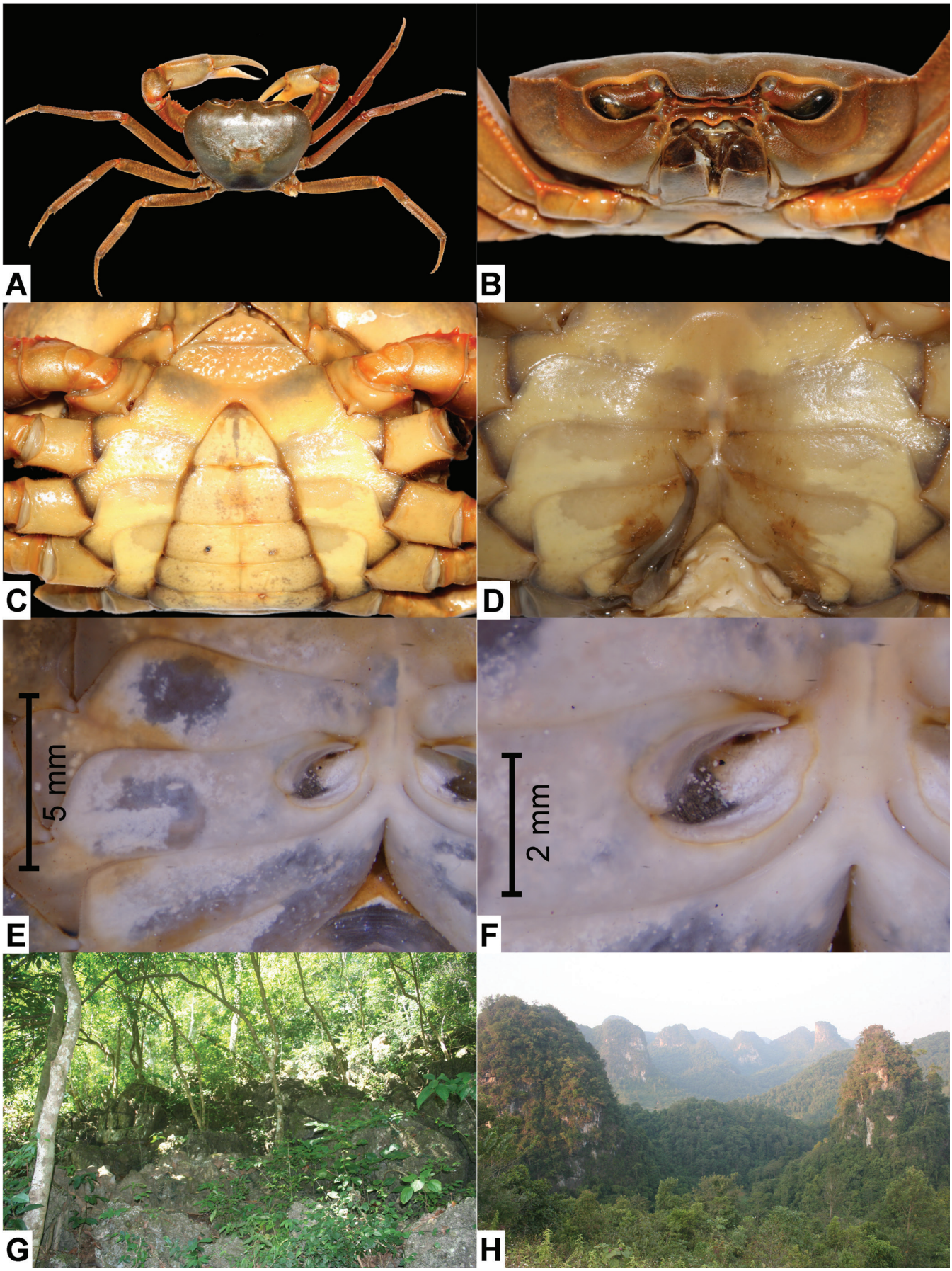

Fig. 5. *Tiwaripotamon pluviosum* sp. nov. A–D, male (CW 39.8 mm, SYSU 001205). A, dorsal view; B, frontal view; C, D, ventral view. E, F, female right gonopore (CW 32.7 mm, NCHUZOOL 14786). G, H, a habitat in Duc Quang Commune, Ha Lang District, Cao Bang Province, Vietnam.

Table 2. Mean K2P-corrected pairwise genetic distances in percent based on the COI sequences within and between six species of *Tiwaripotamon* (minimum and maximum values given in parentheses).

	Intraspecific	Interspecific				
	Nucleotide divergence	***T. pluviosum***	***T. pingguoense***	***T. xiurenense***	***T. edostilus***	***T. vietnamicum***	***T. vixuyenense***
T. pluviosum	3.18 (0.15–5.25)						
T. pingguoense	—	6.45 (6.22–6.9)					
T. xiurenense	—	7.36 (6.81–8.27)	6.11				
T. edostilus	0.30%	7.95 (7.4–8.62)	6.9 (6.73–7.07)	7.29 (7.2–7.38)			
T. vietnamicum	0.31%	11.04 (10.47–11.93)	10.48 (10.47–10.5)	9.77 (9.77–9.78)	10.87 (10.86–10.88)		
T. vixuyenense	1.86%	13.27 (12.28–14.15)	12.49 (11.75–13.23)	12.42 (11.83–13.02)	12.33 (12.15–12.51)	13.24 (12.66–13.81)	

Fig. 6. A, B, *Tiwaripotamon pluviosum* sp. nov., live coloration. Photos taken from Nonggang Natural Reserve, Longzhou County, Chongzuo City, Guangxi Province, China. Specimens not collected (courtesy of Heng-Wei He).

although it is slightly smaller than *Johora* (6.70% between *J. grallator* Ng, 1988 and *J. gua* Yeo, 2001, re-calculated from Yeo et al. (2007), excluding the possible conspecifics). In addition, although the intraspecific divergence is large from the nine specimens (mean: 3.18%; maximum: 5.25%), no further subdivision was found (phylogenetic tree not shown), which may be due to the wide distribution of *T. pluviosum* in the boundary region between Vietnam and China, with different degrees of geographical barriers.

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