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A new *Calamiana* species (Teleostei: Gobiidae) from brackish waters of northern Taiwan

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Abstract

A new species of brackish water goby, *Calamiana taiwanensis* **sp. nov.**, from northern Taiwan is described in this paper. This new species is characterized by the following unique combinations of features: (1) second dorsal fin rays I/7–8, anal fin rays I/7–8; (2) longitudinal scale rows 34–36; (3) first dorsal fin triangular, second to third spines filamentous in adult males; and (4) specific head pore system: anterior termination with a pair of head pores σ and *λ*, median interorbital region with a pair of pores *κ1* and *κ*, postorbital region with a pair of pores *ω*, lateral termination with a pair of pores *α*, upper margin of preopercular region with a pair of pores *β* and *ρ*. The present study revealed that the head pore pattern is varied among the species of genus *Calamiana*, therefore this feature can be regarded as an important character for the species identification within *Calamiana*.

Key words: *Calamiana*, goby, new species, taxonomy, brackish water

Introduction

The gobiid fishes comprise the most diverse group among teleosts (Miller 1988). The genus *Calamiana* Herre, 1945b is a group of small gobies widely distributed in brackish water habitats of the Indo-West Pacific, including Australia, Thailand, Indonesia, Singapore and Philippines (Larson 1999, 2001). Combinations of multiple characters were proposed to define *Calamiana* (Larson, 1999) with 16 segmented caudal rays in 9/7 pattern; jaws usually not enlarged in males; snout short; vertebral counts 26 (10+16); pterygiophore formula 3-12210 in anterior vertebrate pattern; two epurals; always having typical longitudinal papillae pattern; and with two to three rows of papillae rows on snout. This genus belongs to a member under the *Mugilogobius* group (Larson 2001; Huang *et al.* 2016a).

Three species of *Calamiana* were considered as valid genus (Larson, 1999) comprising *C. mindora* (Herre, 1945a), *C. illota* Larson, 1999 and *C. variegata* (Peters, 1868). This genus was later considered as a junior synonym of the genus *Eugnathogobius* Smith, 1931 based on morphological analysis (Larson 2009). However, Huang *et al.* (2013b) proposed that the genus *Calamiana* can be well distinguished from the genus *Eugnathogobius*, and therefore the genus *Calamiana* was suggested as valid (Huang *et al.* 2013b).

Previously, several taxonomic studies of the *Mugilogobius* group have been reported and several new species have been described from the Southeast Asia, China and Taiwan (Chen *et al.* 2013; Huang *et al.* 2013a, b) such as *Pseudogobius fulvicaudus* Huang, Shao & Chen, 2013, and *Pseudogobius taijiangensis* Chen, Huang & Huang, 2013. Moreover, Huang *et al.* (2013a) proposed that the mangrove goby *Hemigobius crassa* (Herre 1945c) is valid and can be well distinguished from its congener —*Hemigobius hoevenii* (Bleeker, 1851) based on both morphological and molecular evidence. All these taxonomic studies promote our understanding of the brackish water gobies around Indo-West Pacific region.

In recent years, an undescribed species of *Calamiana* was discovered during our surveys to explore brackish

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water fish fauna in northern Taiwan. The osteological features of this undescribed species as well as a diagnostic key to all valid species of *Calamiana* are provided in this study.

Materials and Methods

Sample collection. All specimens were collected by hand net. Specimens were fixed in 10% formalin solution for three days, followed by 70% ethanol for long-term preservation.

Morphological studies. The morphological measurements followed Miller (1988) and meristic counts followed Chen and Shao (1996), and Chen and Kottelat (2003). The terminology of cephalic sensory canals and free neuromast organ (sensory papillae) followed Miller (1988), Chen and Shao (1998), and based on Sanzo (1911). The osteological terminology followed Murdy (1985) and Birdsong *et al.* (1988).

Meristic abbreviations are as follows: A, anal fin; C, caudal fin; D1 and D2, first and second dorsal fins, respectively; LR, longitudinal scale series; P, pectoral fin; PreD, predorsal scales; SDP, scale series from origin of first dorsal fin to upper pectoral origin; TR, transverse scale series from second dorsal to anal fin; VC, vertebral count. Standard length (SL) was used for measurement of specimens. Number of vertebrae was counted based on X-ray photographs. Sampling localities of this new species are shown in Fig. 1. All examined materials were deposited at the Institute of Marine Biology, National Taiwan Ocean University, Keelung, Taiwan (NTOUP), and the Biodiversity Research Museum, Biodiversity Research Center, Academia Sinica, Taipei, Taiwan (ASIZP).

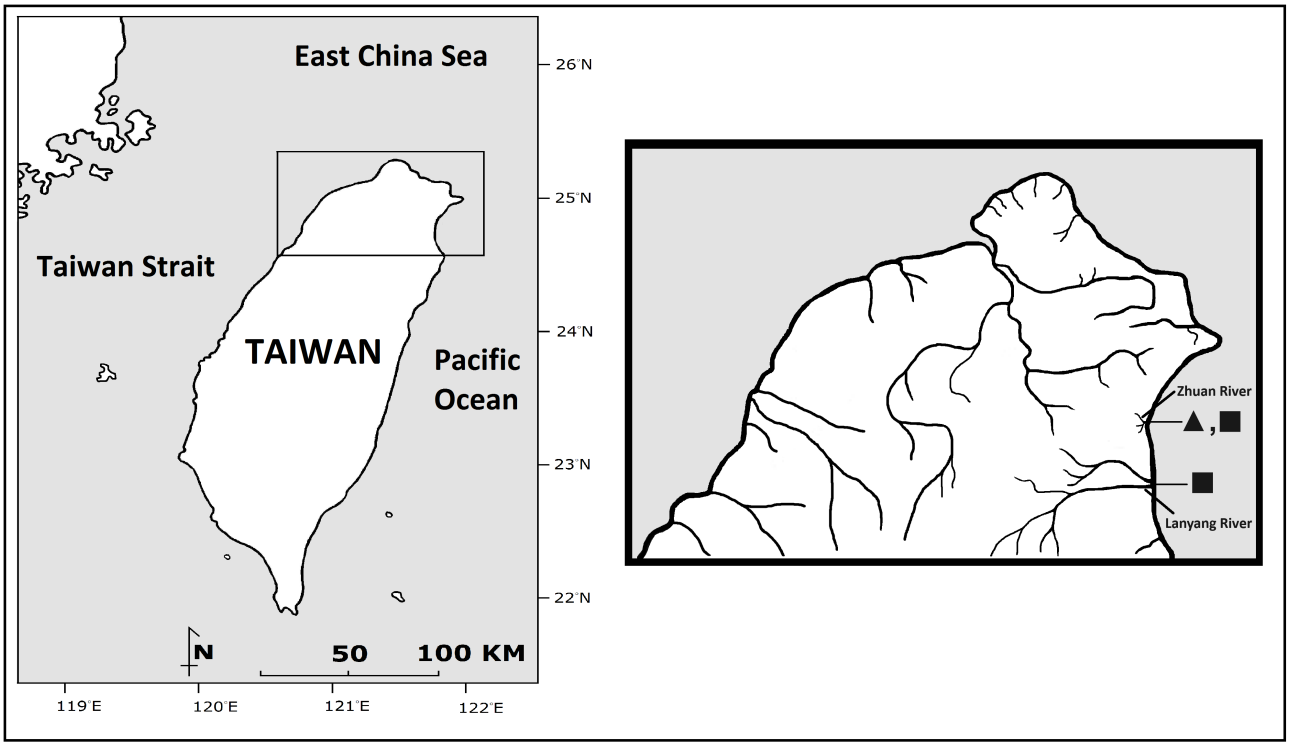

FIGURE 1. The sampling localities of *Calamiana taiwanensis* **sp. nov.** in northern Taiwan. ▲, type locality of holotype; ■, sampling sites of paratypes.

Among three valid species of *Calamiana*, all morphological characters of *C. illota* and *C. variegata* were counted and measured in this study. All meristic features and descriptions of *C. mindora* used for comparison in this study relied on Larson's description in 1999. The original head pore and papillae patterns, and specimen photos of *C. mindora* were shown in Figs. 3, 7 and 9 in Larson (1999).

Taxonomy

***Calamiana taiwanensis* sp. nov.**
(臺灣克利米鰕虎)
(Figs. 2–5)

Material examined

Holotype.—NTOUP 2012-04-135, 28.5 mm SL, male, estuary of the Zhuan River, Yilan, Taiwan, coll. Shih-Pin Huang, 15 January 2010.

Paratypes.—ASIZP0081789, 1 specimen, 27.9 mm SL, female, estuary of the Lanyang River, Yilan, Taiwan, coll. S.-P. Huang, 15 February 2012. NTOUP 2012-04-136, 1 specimen, 28.1 mm SL, estuary of the Zhuan River, Yilan, Taiwan, coll. S.-P. Huang, 15 January 2009. NTOUP 2012-04-137, 3 specimens, 21.3–30.8 mm SL, estuary of the Zhuan River, Yilan, Taiwan, coll. S.-P. Huang and H.-M. Huang, 1 February 2013. NTOUP 2012-04-139, 1 specimen, 32.8 mm SL, estuary of the Zhuan River, Yilan, Taiwan, coll. S.-P. Huang, 15 July 2010.

Non-types: NTOUP 2012-04-138, 4 specimens, 13.7–19.2 mm SL, collected with NTOUP 2012-04-137. NTOUP 2012-04-134, 1 specimen, 32.5 mm SL, estuary of the Zhuan River, Yilan, Taiwan, coll. S.-P. Huang and H.-M. Huang, 15 July 2010.

Diagnosis. *Calamiana taiwanensis* **sp. nov.** can be distinguished from congeners by the combination of features: (1) fin rays: D2 I/7–8 (modally 8), A I/7–8 (modally 8), P 16–18, and first dorsal fin triangular, second to third spines filamentous in adult males; (2) squamation: longitudinal scales 34–36 (modally 35), predorsal scales 16–18 (modally 17); (3) specific coloration: four distinct stripes on the cheek and preopercular regions, caudal fin base with two black spots, caudal fin membrane with 5–11 vertically-aligned lines; and (4) specific head pore pattern: anterior termination with a pair of pores σ and λ, median interorbital region with a pair of pores κ1 and κ, postorbital region with a pair of pores ω, lateral termination with a pair of pores α, upper margin of preopercular region with a pair of pores β and ρ.

Description. Body elongated, sub-cylindrical anteriorly and compressed posteriorly. Head large. Upper lip more prominent than lower lip when closed. Eyes moderately large and placed dorsolaterally on head. Mouth maxillary extending to the vertical of anterior margin of pupil in adult males, and only reaching anterior margin of orbit in females. Anterior nares as short tube, posterior nares as round hole. Gill slit restricted, extending ventrally slightly beyond the middle vertical line of operculum. Vertebral counts 26 (10+16) (in 8 individuals) (Table 1).

Teeth in males slightly longer than in females. Upper jaw with two rows of stout small teeth, anterior teeth obviously longer than the laterals; lateral teeth nearly even in size. Anterior region of lower jaw with three rows of teeth; two rows of teeth laterally; outermost teeth slightly curved and larger.

Fins. D1 VI; D2 I/7–8 (modally 8); A I/7–8 (modally 8); P 16–18 (Table 2). First dorsal fin triangular, second to third spines usually filamentous in adult males, but rounded and lacking any filamentous rays in females. Anal fin inserted below first branched rays of second dorsal fin. Pelvic fin rounded. Caudal fin oval-shaped and rear margin rounded.

Scales. LR 34–36 (modally 35); TR 12–13 (modally 12); PreD 16–18 (modally 17); SDP 11–12 (modally 11) (Table 2). Body covered with moderate-sized ctenoid scales. Predorsal region and belly covered with moderate-sized cycloid scales. Opercular region covered with small cycloid scales. Cheek naked.

Head lateral-line system: head canals. Anterior oculoscapular canal present, interior termination with a pair of pores σ and λ, median interorbital region with a pair of pores κ1 and κ, postorbital region with a pair of pores ω, lateral termination with a pair of pores α, upper margin of preopercular region with a pair of pores β and ρ.

Head lateral-line system: sensory papillae. Row *a* short, about two-thirds of orbit diameter. Row *b* short, with densely-set papillae, starting from vertical of rear margin of pupil. Single *c* papilla. Row *cp* short, extending to posterior region of orbit. Row *d* long and with densely-set papillae. Opercular region with rows *os*, *oi* and *ot*. Rows *oi* and *ot* slightly separated. Row *f* consists of a pair of papillae.

TABLE 1. Morphometric measurements of *Calamiana taiwanensis* **sp. nov.**

	Calamiana taiwanensis **sp. nov.**							
Characters	Male				Female			
n	3				6			
Percent standard length (%)								
Head length	26.8	–	28.6	(27.5)	26.4	–	26.9	(26.7)
Predorsal length	36.8	–	37.8	(37.2)	36.9	–	37.6	(37.2)
Snout to 2nd dorsal origin	54.5	–	57.6	(55.6)	56.0	–	57.4	(56.7)
Snout to anus	50.3	–	51.9	(50.9)	52.3	–	54.1	(53.3)
Snout to anal fin origin	56.2	–	59.6	(57.8)	57.3	–	59.2	(58.3)
Prepelvic length	26.7	–	30.7	(28.0)	28.6	–	31.0	(29.7)
Caudal peduncle length	26.4	–	27.9	(27.0)	26.6	–	27.3	(27.0)
Caudal peduncle depth	11.3	–	12.4	(12.0)	12.9	–	14.1	(13.3)
1st dorsal fin base	12.0	–	13.9	(12.7)	11.7	–	13.1	(12.6)
2nd dorsal fin base	20.5	–	22.0	(21.1)	19.0	–	21.7	(20.2)
Anal fin base	17.0	–	19.3	(18.1)	17.3	–	18.5	(17.9)
Caudal fin length	28.3	–	32.0	(29.9)	26.6	–	27.9	(27.5)
Pectoral fin length	21.8	–	24.6	(23.2)	21.7	–	24.6	(23.2)
Pelvic fin length	19.2	–	21.8	(20.1)	17.1	–	18.6	(18.1)
Body depth at pelvic fin origin	15.9	–	16.4	(16.1)	17.5	–	18.7	(18.0)
Body depth at anal fin origin	15.2	–	16.3	(15.7)	17.1	–	17.8	(17.4)
Body width at anal fin origin	9.1	–	11.8	(10.2)	11.5	–	13.4	(12.3)
Pelvic fin origin to anus	20.7	–	22.9	(22.2)	23.8	–	24.9	(24.5)
Percent head length (%)								
Snout length	26.2	–	26.8	(26.5)	25.1	–	26.4	(25.7)
Eye diameter	25.2	–	25.9	(25.6)	25.2	–	26.7	(25.8)
Cheek depth	30.5	–	35.3	(32.5)	29.0	–	31.4	(30.5)
Postorbital length	50.5	–	52.3	(51.5)	52.4	–	55.6	(54.1)
Head width in maximum	71.1	–	78.3	(73.6)	71.7	–	76.2	(74.6)
Head width in upper gill	49.9	–	52.0	(50.7)	51.0	–	53.8	(52.6)
Bony interorbital width	12.0	–	12.9	(12.5)	12.2	–	13.1	(12.6)
Fleshy interorbital width	31.0	–	33.5	(31.9)	29.5	–	31.1	(30.4)
Lower jaw length	43.9	–	49.8	(46.4)	42.2	–	43.5	(42.8)

*the number in parenthesis is the average of anterior different value.

Osteological features. Top of cranium always smooth and flat, lacking elevated ridge (Fig. 6A). Pterygiophore formula is 3-12210 (Fig. 6B). Caudal skeleton with hypurals 1 and 2, hypurals 3 and 4, hypural 5, a pair of epurals and single parhypural (Fig. 6C); the hypurals 1 and 2, and hypurals 3 and 4 fused together, respectively. Anterior epural bar-shaped, the posterior epural triangular, the parhypural needle-like. Jaws and suspensorium (Fig. 6D); maxilla stout and short; ectopterygoid stout, short and triangular. Upper jaw with two rows of teeth. Anterior process of premaxilla tall, and posterior portion distinctly prominent. Palatine slightly stout, and lower margin not in touch with quadrate. Metapterygoid rectangular. Posterior portion of dentary tall, with a square tip. Anguloarticular at upper tip longer than the lower. Quadrate joining anguloarticular and ectopterygoid along anterior margin, joining symplectic at posterior margin, joining metapterygoid at upper margin, and preopercle at lower margin. Hyomandibula joining metapterygoid at anterior margin, and joining preopercle at posterior margin. Preopercle L-shaped, anterior tip elongated and sharp. Interopercle elongate and anterior tip pointed.

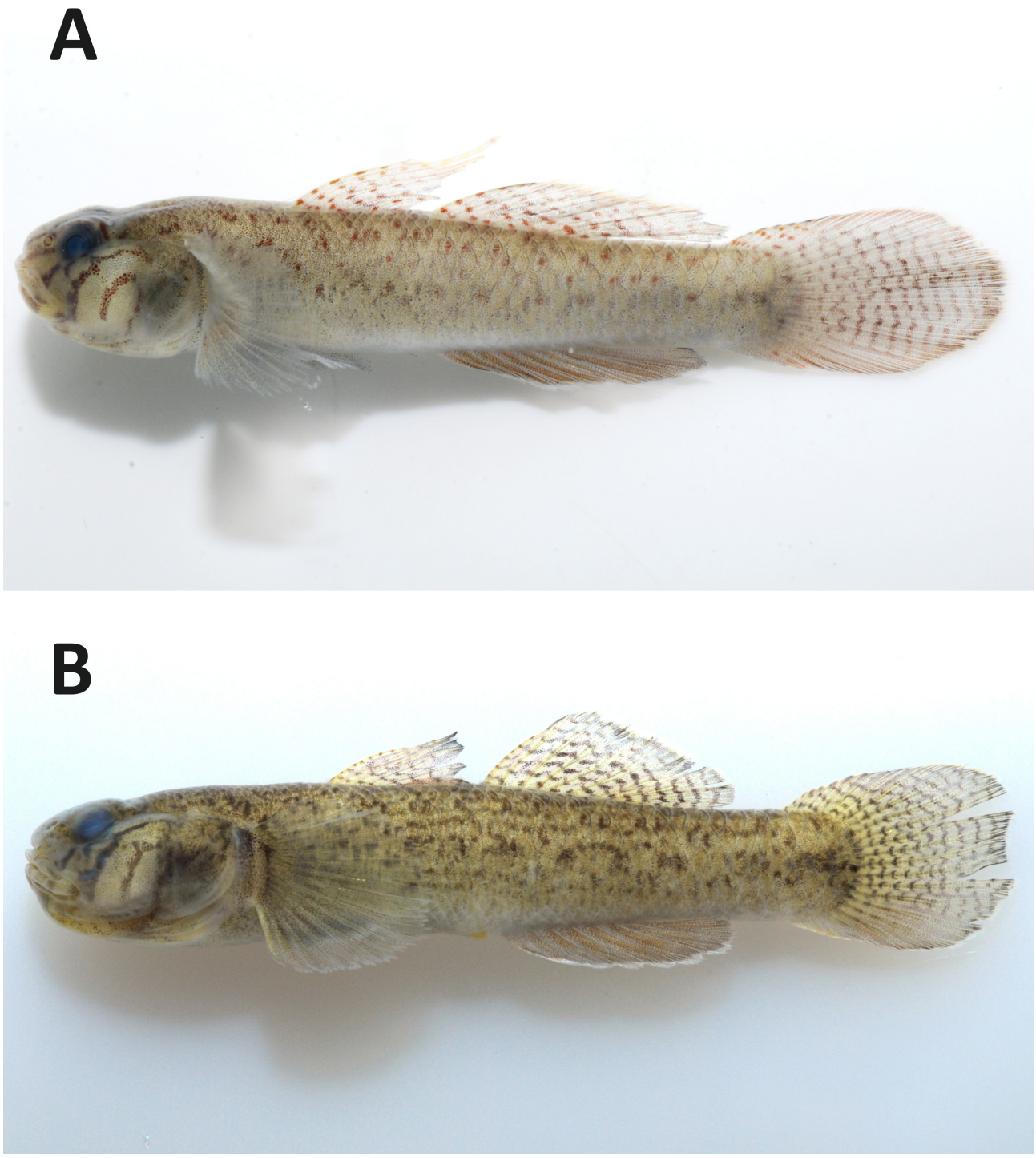

FIGURE 2. Specimen photographs of (A) *Calamiana taiwanensis* **sp. nov.**, NTOUP 2012-04-135, holotype, male, 28.5 mm SL; (B) *C. taiwanensis* **sp. nov.**, ASIZP0081789, paratype, female, 36.4 mm SL.

Coloration in fresh specimen. Head and body generally creamy yellow or brownish yellow, body with numerous short brownish red bars in adult males, but usually black in females. Lateral scales with blackish brown margin. Belly creamy white. Cheek and preopercular regions with four distinct oblique brownish red or black stripes. A black stripe starting from anterior region of orbit and extending forward to snout tip. First dorsal fin with 5–6 rows of longitudinally-aligned brownish red lines in adult males, and 3–4 rows of longitudinally-aligned brown lines in females. Second dorsal fin with 4–5 rows of longitudinally-aligned brownish red lines. Upper region of

pectoral fin base with a blackish brown blotch. Caudal fin base with two vertically aligned blackish brown bars. Pelvic fin grayish black in adult males, but grayish white in females. Anal fin pale orange in adult males, but grayish white in females. Caudal fin pale brownish red in adult males and grayish white in females; caudal fin membrane with 5–11 rows of vertically-aligned reddish brown or brown lines.

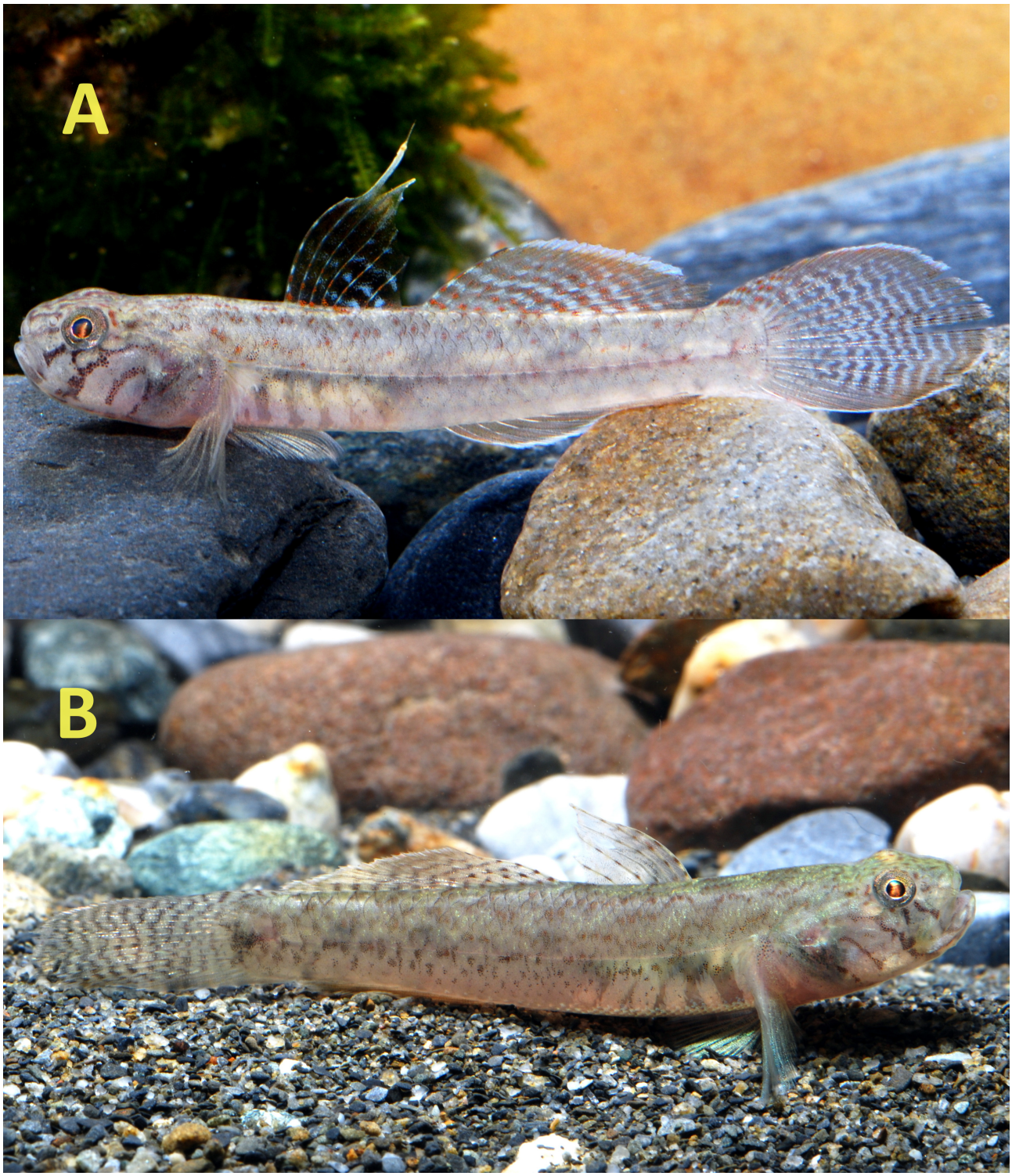

FIGURE 3. Live fish photographs of (A) *Calamiana taiwanensis* **sp. nov.**, NTOUP 2012-04-135, holotype, male, 28.5 mm SL; (B) *Calamiana taiwanensis* **sp. nov.**, NTOUP 2012-04-134, paratype, female, 32.5 mm SL.

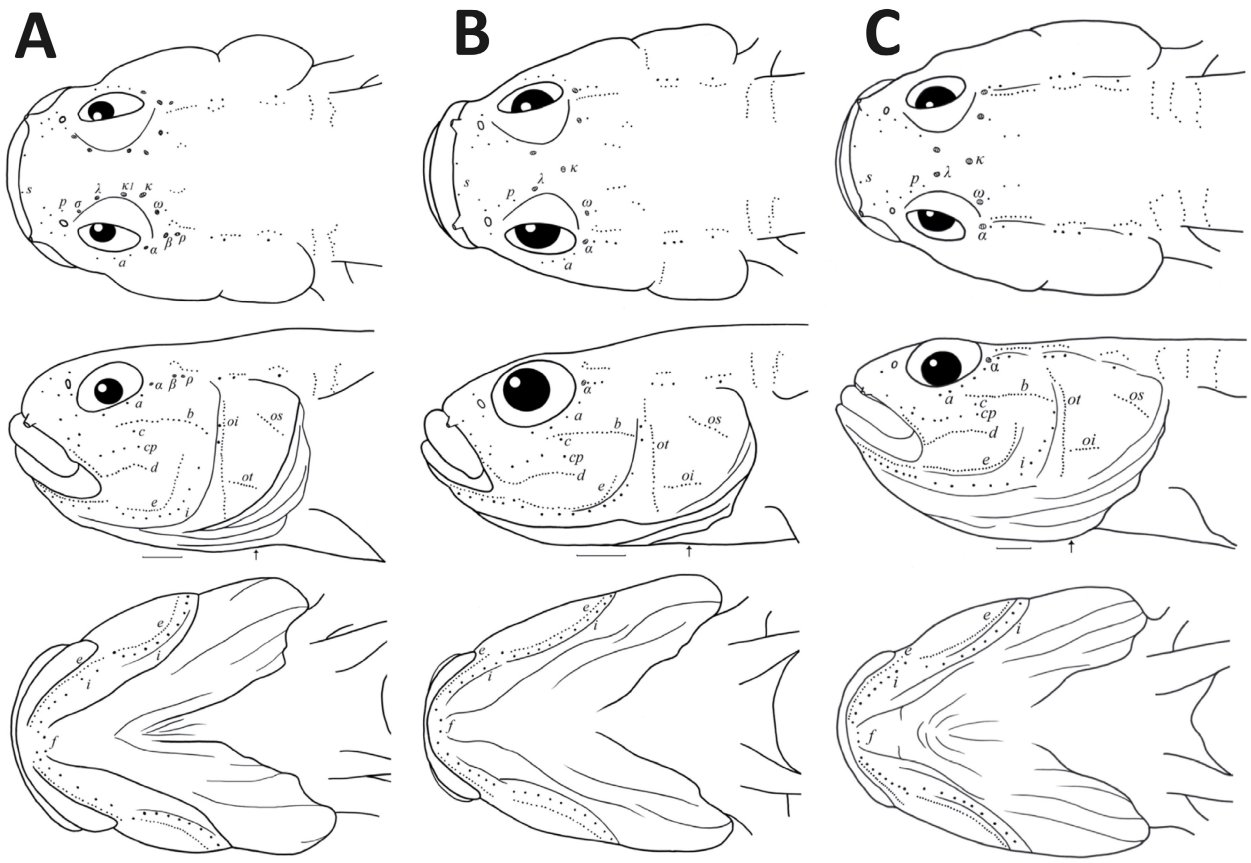

FIGURE 4. Head lateral-line system of three species of *Calamiana*. (A) *C. taiwanensis* **sp. nov.**, NTOUP 2012-04-135, holotype, male, 28.5 mm SL; (B) *C. illota*, NTOUP 2012-05-152, male, 31.2 mm SL; (C) *C. variegata*, NTOUP 2011-05-015, male, 21.9 mm SL. Arrowhead indicates position of gill-opening. Bar = 1 mm. The original head lateral-line system illustration of *C. mindora* used for comparison in this study was shown in Fig. 7 from Larson (1999).

Distribution. So far, this new species is known only from brackish water habitats of northern Taiwan (Fig. 1).

Etymology. The specific name, *taiwanensis*, refers to the locality "Taiwan" where the new species is found.

Remarks. Compared to all valid species of the genus *Calamiana*, firstly, *C. taiwanensis* **sp. nov.** can be distinguished from *C. mindora* by the following features: (1) different head pore patterns: this new species has a complex head pore pattern, including pores σ and λ, median interorbital region with a pair of pores κ1 and κ, postorbital region with a pair of pores ω, lateral termination with a pair of pores α, preopercular region with a pair of pores β and ρ. However, the holotype of *C. mindora* lacks head pores, and only Fijian specimens possess a few head pores ω, α and β, restricted to the postorbital region; (2) different osteological features: in this new species, the posterior part of the premaxilla has a distinct prominence (Fig. 6D) and the interopercle is narrow, whereas *C. mindora* has only a smooth rounded dorsal edge of the premaxilla and a wider interopercle with pointed tip; (3) cheek with four distinct curved oblique broad stripes in this new species, while 2–3 lines present on cheek and other lines broken or diffuse in *C. mindora*; and (4) this new species usually has more anal fin rays when compared to *C. mindora* (modally I/8 vs. I/7).

Additionally, this new species can be distinguished from *C. illota* by the following features: (1) first dorsal fin triangular, with second to third spines filamentous in adult males vs. first dorsal fin triangular to slightly rounded and spines occasionally filamentous; and (2) a pair of median interorbital pores κ1 and κ vs. single pore κ and pore κ1 absent. Finally, *C. taiwanensis* **n. sp.** can be separated from *C. variegata* by the following features: (1) first dorsal fin triangular, and second to third spines filamentous in adult males vs. first dorsal fin rounded and spines never filamentous; (2) a pair of median interorbital pores κ1 and κ vs. single pore κ and pore κ1 absent; (3) four stripes on the cheek and preopercular regions vs. two stripes on the cheek; and (4) more longitudinal scales, 34–36 vs. 30–32.

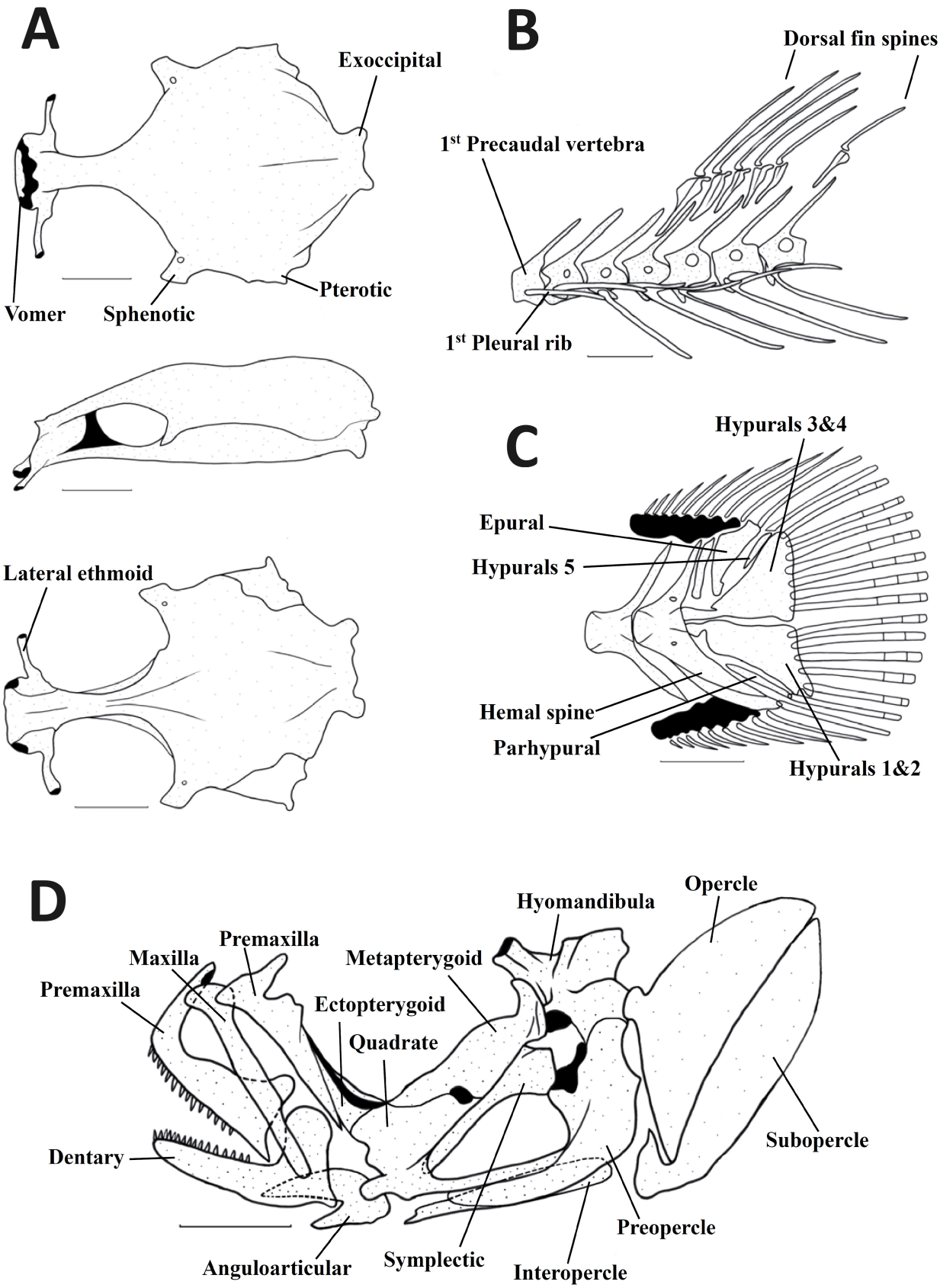

FIGURE 5. Osteological features of *Calamiana taiwanensis* **sp. nov.**, NTOUP 2012-04-134, female, 32.5 mm SL. (A) cranium; (B) anterior vertebrae and first dorsal fin; (C) caudal skeleton; (D) Lateral view of jaws and suspensorium. Blackening indicates cartilage. Bar = 1 mm.

TABLE 2. Frequency distribution of meristic features of *Calamiana taiwanensis* **sp. nov.** and other valid species.

	D1		D2			A			P				
	VI	x	I/7	I/8	x	I/7	I/8	x	15	16	17	18	x
C. taiwanensis **sp. nov.**	12	6.0	5	7	7.6	4	8	7.7	1	7	8	5	16.8
C. illota	10	6.0	10	-	7.0	10	-	7.0	1	9	3	-	16.2
C. mindora	1	6.0	1	-	7.0	1	-	7.0	1	-	-	-	15.0
C. variegata	10	6.0	-	10	8.0	-	10	8.0	10	9	-	-	15.5

	LR										TR				
	29	30	31	32	33	34	35	36	37	x	10	11	12	13	x
C. taiwanensis **sp. nov.**	-	-	-	-	-	1	18	5	-	35.2	-	-	9	3	12.3
C. illota	-	-	-	-	-	1	11	5	1	35.3	-	8	2	-	11.2
C. mindora	1	-	-	-	-	-	-	-	-	29.0	1	-	-	-	10.0
C. variegata	-	2	7	11	-	-	-	-	-	31.5	-	8	2	-	11.2

	PreD								SDP					VC	
	14	15	16	17	18	19	20	x	9	10	11	12	x	26	x
C. taiwanensis **sp. nov.**	-	-	4	6	2	-	-	16.8	-	-	7	5	11.4	8	26.0
C. illota	-	1	2	3	3	1	-	17.1	2	5	3	-	10.1	4	26.0
C. mindora	1	-	-	-	-	-	-	14.0	*	*	*	*	*	1	26.0
C. variegata	-	-	-	4	3	2	1	18.0	-	6	4	-	10.4	4	26.0

The meristic data of *C. midora* were based on holotype specimen, from Larson (1999).
*means lack of data in original description.

Discussion

Based on the detailed specific description by Larson (1999), there were two types of head pore patterns in *Calamiana mindora*. The first pattern has no head pores as seen in the holotype specimen. The two Fijian specimens with head pores ω, α and β, restricted to the postorbital region, belong to the other pattern.

In many brackish water gobiids, same head pore patterns can be detected within one species (Chen *et al.*, 2013; Huang *et al.*, 2013a, b). Huang *et al.* (2013b) also suggests that head pore patterns can be regarded as an important diagnostic feature for species identification in brackish water gobies. In the case mentioned in Larson (1999), those two patterns could be consider As two different species and only the holotype can represent the species. Thus, further studies to reassess the taxonomic status of *C. mindora* from Fiji would be still very necessary in the future.

Within the genus *Calamiana*, various types of head pore patterns were observed: *C. mindora* with head pores absent; *C. variegata* and *C. illota* share similar head pore patterns, restricted to interorbital region (Figs. 5B, 5C). Compared to other valid species, the new species has more head pores (Fig. 5A). These different head pore patterns can also be observed in the freshwater goby genus *Rhinogobius* (Huang *et al.*, 2016). We propose that the absence or presence of head pores as well as their different patterns can be regarded as an important diagnostic feature for species identification within the genus *Calamiana*.

A diagnostic key to all valid species of *Calamiana*

1. Head pores absent. . . . . *C. mindora*
1a. Interorbital region with head pores. 2
2a. First dorsal fin triangular, second to third spines filamentous in adult males; with pairs of head pores *α*, *β*, *λ*, *ω*, *κ1*, *κ*, σ, and *ρ* . . . . . *C. taiwanensis* **sp. nov.**
2b. First dorsal fin triangular to rounded and spines rarely filamentous; head pores σ, *κ1*, *β* and *ρ* absent 3
3a. Longitudinal scale series 30–32; second dorsal fin rays I/8; anal fin rays I/8; with compressed teeth in upper jaw like none of the others . . . . . *C. variegata*
3b. Longitudinal scale series 34–37; second dorsal fin rays I/7; anal fin rays I/7 . . . . . *C. illota*

Comparative materials

Calamiana illota
NTOUP 2012-05-152, 12 specimens, 20.3–35.8 mm SL, Sungei Buloh mangrove, Singapore, coll. I-S. Chen, July, 2001.

Calamiana variegata
NTOUP 2011-05-015, 12 specimens, 17.0–26.2 mm SL, Matang mangrove, Malaysia, coll. I-S. Chen and S. P. Huang, 21 April, 2011. NTOUP 2012-11-172, 4 specimens, 22.7–35.6 mm SL, Sungei Buloh mangrove, Singapore, coll. I-S. Chen, July, 2001.

Acknowledgements

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