ORIGINAL ARTICLE

Asian Herpetological Research 2023, 14(1): 41–53
DOI: 10.16373/j.cnki.ahr.220059

Two New Species of Fire-Bellied Newts (Caudata, Salamandridae, *Cynops*) from Southeastern China

Zhitong LYU[1*], Shuo QI[1], Siyu ZHANG[1], Keyuan DAI[2] and Yingyong WANG[1*]

[1] *State Key Laboratory of Biocontrol/ The Museum of Biology, School of Life Sciences/ School of Ecology, Sun Yat-sen University, Guangzhou 510275, Guangdong, China*
[2] *Guangdong Shimentai National Nature Reserve, Qingyuan 513000, Guangdong, China*

Abstract The fire-bellied newt genus *Cynops* contains ten known species distributed in China and Japan in East Asia. In this work, two new *Cynops* species are described, namely *Cynops jiaoren* **sp. nov.** distributed in northern Guangdong and *Cynops maguae* **sp. nov.** distributed in eastern Jiangxi. The two new species can be distinctly distinguished from their congeners by the independent phylogenetic placements and a combination of morphological characteristics. The discovery of these two new species in the Southeast Chinese Hilly Area, where half of congeners occur, increases the known diversity of *Cynops*, and indicates unresolved relationships among the species in southeastern China. Further discussions on the taxonomic status of *Cynops cyanurus* are also provided.

Keywords *Cynops jiaoren* **sp. nov.**, *Cynops maguae* **sp. nov.**, *Cynops yunnanensis* **comb. nov.**, Southeast Chinese Hilly Area, taxonomy

1. Introduction

The fire-bellied newts contain ten known species distributed in China and Japan in East Asia (Frost, 2022). The generic classification of these newts has been in controversy for decades and has not been settled (Chang, 1935, 1955; Dubois and Raffaëlli, 2011; Fei and Ye, 2016; Tschudi, 1838; Wolterstorff, 1934; Zhao and Hu, 1984; Zhao *et al.*, 1988). A provisional arrangement that is adopted by most public databases and non-taxonomic literature treats all species of fire-bellied newts collectively in the genus *Cynops* Tschudi, 1838 (e.g., AmphibiaChina, 2022; AmphibiaWeb, 2022; Frost, 2022). These newts are mainly distributed in three different geographic regions that are isolated from each other: (1) *C. pyrrhogaster* (Boie, 1826) and *C. ensicauda* (Hallowell, 1861) are endemic to the Japanese Archipelago; (2) *C. wolterstorffi* (Boulenger, 1905), *C. cyanurus* Liu, Hu and Yang, 1962, *C. chenggongensis* Kou and Xing, 1983, and *C. puerensis* Rao, Zeng, Zhu and Ma, 2022 occur in the Yunnan-Guizhou Plateau in southwestern China; (3) *C. orientalis* (David, 1873), *C. orphicus* Risch, 1983, *C. fudingensis* Wu, Wang, Jiang and Hanken, 2010, and *C. glaucus* Yuan, Jiang, Ding, Zhang and Che, 2013 inhabit the Southeast Chinese Hilly Area. These three geographical clusters also correspond to the recognitions of the *C. pyrrhogaster* group, the *C. wolterstorffi* group (or alternatively *C. cyanurus* group), and the *C. orientalis* group based on morphological characters (Fei and Ye, 2016; Zhao and Hu, 1984; Zhao *et al.*, 1988).

During our herpetological surveys in southeastern China, we collected a series of *Cynops* specimens from northern Guangdong and eastern Jiangxi, respectively. Morphological examinations and phylogenetic analyses both suggest these specimens belong to two independent unnamed species, which are described in this work. We further present discussions on the taxonomic status of *Cynops cyanurus*.

2. Materials and methods

2.1. Specimens and morphological measurements Six unnamed *Cynops* specimens were collected from Shimentai Nature Reserve, Yingde City, Qingyuan City, Guangdong, and two unnamed *Cynops* specimens were collected from Mt

* Corresponding author: Dr. Zhitong LYU, from Sun Yat-sen University, Guangzhou, Guangdong, China, with his researches focusing on the taxonomy and phylogeny of Chinese Herpetology; Prof. Yingyong WANG, from Sun Yat-sen University, Guangzhou, Guangdong, China, with his researches focusing on the taxonomy and phylogeny of Chinese Herpetology.
E-mail: lvzht@foxmail.com (Zhitong LYU); wangyy@mail.sysu.edu.cn (Yingyong WANG)
Received: 11 October 2022 Accepted: 26 December 2022

Magu, Nancheng County, Fuzhou City, Jiangxi. All specimens were fixed in 10% buffered formalin, later transferred to 70% ethanol, and deposited in the Museum of Biology, Sun Yat-sen University (**SYS**) and Chengdu Institute of Biology, Chinese Academy of Sciences (**CIB**), PR China.

External measurements were made for the unnamed specimens with digital calipers (Neiko 01407A Stainless Steel 6-Inch Digital Caliper) to the nearest 0.1 mm. Only adult specimens were measured. These measurements are as follows: total length (**TOL**) from tip of snout to tip of tail; snout–vent length (**SVL**) from tip of snout to posterior edge of vent; tail length (**TAL**) from posterior edge of vent to tip of tail; maximum tail depth (**TAD**); head length (**HL**) from tip of snout to the posterior edge of the parotoid gland; maximum head width (**HW**); snout length (**SL**) from tip of snout to the anterior corner of eye; eye diameter (**ED**) from the anterior corner to the posterior corner of the eye; interorbital distance (**IOD**) between the anterior corner of each eye; eye–nostril length (**EN**) from the anterior corner of the eye to the nostril; internasal distance (**IND**) between the external nares; axilla–groin length (**AG**) between the axilla and the groin along the body; forelimb length (**FLL**) from elbow to tip of finger III; and hindlimb length (**HLL**) from knee to tip of toe III. Statistical analyses on the morphometric measurements were performed in R version 4.0.0, following Lyu *et al.* (2020). Males and females were analyzed separately, due to obvious sexual size dimorphism (Fei *et al.*, 2006). All measurements were ln-transformed to normalize and reduce the variance. One-way analysis of variance (ANOVA) was conducted with statistically similar variances (P values > 0.05 in the Levene's test) using *car* R package. Principal component analysis (PCA) was performed to reduce the dimensionality of variation in the data to find whether morphological variation form the basis of detectable group structure, using *prcomp* function and *ggplot2* package.

Morphological characters of all *Cynops* congeners were obtained from examined museum specimens listed in the Appendix and from the literature of the original and subsequently supplemental descriptions (Boie, 1826; Boulenger, 1905; David, 1873; Fei and Ye, 1983, 2016; Fei *et al.*, 2006; Hallowell, 1861; Liu *et al.*, 1962; Kou and Xing, 1983; Rao, 2022; Risch, 1983; Wu *et al.*, 2010; Yang, 1983; Yuan *et al.*, 2013).

2.2. Phylogenetic sampling and analyses A total of 12 liver samples of the genus *Cynops* were used in this study, including six samples of the unnamed specimens from Guangdong, two samples of the unnamed specimens from Jiangxi, one sample of *C. cyanurus*, one sample of *C. orientalis*, and two samples of *C. fudingensis*. All samples were obtained from previously anesthetized and subsequently euthanized specimens and then preserved in 95% ethanol and stored at –40 °C.

Genomic DNA was extracted, using a DNA extraction kit from Tiangen Biotech (Beijing) Co., Ltd. One mitochondrion gene, namely NADH dehydrogenase subunit 2 (*ND2*), was amplified using the primers *ND2*-4F (5′-TATGAGTACGAGCATCATACCC-3′) and *ND2*-4R (5′-CTTCTGCTTAAGACTTTGAAGGTC-3′) (Lyu *et al.*, 2021). PCR amplifications were processed with the following cycling conditions: denaturing at 95 °C for 4 min, 35 cycles of denaturing at 95 °C for 40 s, annealing at 53 °C for 34 s and extending at 72 °C for 60 s, and a final extending step at 72 °C for 10 min. PCR products were purified with spin columns and then sequenced with both forward and reverse primers using BigDye Terminator Cycle Sequencing Kit from Applied Biosystems, on an ABI Prism 3730 automated DNA sequencer by Wuhan Tianyi Huiyuan Bioscience and Technology Inc. All sequences have been deposited in GenBank (Table 1).

For the phylogenetic analyses, 33 sequences from additional Chinese *Cynops* congeners and 2 sequences of out-group species of the genera *Pachytriton* Boulenger, 1878 and *Paramesotriton* Chang, 1935, were obtained from GenBank and incorporated into our dataset. Detailed information is provided in Table 1. DNA sequences were aligned by the Clustal W algorithm with default parameters (Thompson *et al.*, 1997). PartitionFinder2 was used to test the best partitioning scheme and jModelTest v2.1.2 was used to test the best fitting nucleotide substitution model. Sequenced data were analyzed using Bayesian inference (BI) in MrBayes 3.2.4 (Ronquist *et al.*, 2012), and maximum likelihood (ML) in RaxmlGUI 1.3 (Silvestro and Michalak 2012). Two independent runs were conducted in a BI analysis, each of which was performed for 10,000,000 generations and sampled every 1000 generations with the first 25% samples discarded as burn-in, resulting in a potential scale reduction factor (PSRF) of <0.005. In the ML analysis, the bootstrap consensus tree inferred from 1000 replicates was used to represent the evolutionary history of the taxa analyzed. Mean genetic distances between and within species were calculated in MEGA 6 using the uncorrected *P*-distance model.

3. Results

The BI and ML analyses resulted in identical topologies (Figure 1). The *P*-distances based on the *ND2* gene among species are presented in Table 2. As shown in the tree, three clades (BPP 1.00, BS 100, respectively) were revealed for the samples of *Cynops*, while the relationship among these clades are not resolved. The first clade is composed of samples of *C. cyanurus* but can be further divided into two distinct lineages corresponding to the Guizhou and Yunnan populations (BPP 1.00, BS > 99, respectively). The second clade consists of *C. glaucus* from eastern Guangdong (BPP 1.00, BS 100) and an unnamed lineage from northern Guangdong (BPP 1.00, BS 100). Within

Table 1 Localities, voucher information, and GenBank accession numbers for all samples used in this study.

ID	Species	Localities	Voucher	*ND2*
1	*Cynops jiaoren* **sp. nov.**	China: Guangdong: Qingyuan: Yingde	SYS a008786	OQ116679
2	*Cynops jiaoren* **sp. nov.**	China: Guangdong: Qingyuan: Yingde	SYS a008787	OQ116680
3	*Cynops jiaoren* **sp. nov.**	China: Guangdong: Qingyuan: Yingde	SYS a008788	OQ116681
4	*Cynops jiaoren* **sp. nov.**	China: Guangdong: Qingyuan: Yingde	SYS a008789	OQ116682
5	*Cynops jiaoren* **sp. nov.**	China: Guangdong: Qingyuan: Yingde	CIB 118534	OQ116683
6	*Cynops jiaoren* **sp. nov.**	China: Guangdong: Qingyuan: Yingde	SYS a008791	OQ116684
7	*Cynops maguae* **sp. nov.**	China: Jiangxi: Fuzhou: Mt Magu	CIB 118535	OQ116685
8	*Cynops maguae* **sp. nov.**	China: Jiangxi: Fuzhou: Mt Magu	SYS a007032	OQ116686
9	*Cynops cyanurus* (Guizhou)	China: Guizhou: Liupanshui: Shuicheng	CIB 95897	GU301784
10	*Cynops cyanurus* (Guizhou)	China: Guizhou: Liupanshui: Shuicheng	GZNU 20050727002	FJ415604
11	*Cynops cyanurus* (Guizhou)	China: Guizhou: Liupanshui: Shuicheng	KIZ 02331	ON793754
12	*Cynops cyanurus* (Guizhou)	China: Guizhou: Liupanshui: Shuicheng	KIZ 02332	ON793755
13	*Cynops cyanurus* (Yunnan)	China: Yunnan: Chuxiong	TP-MVZ 02	EU880309
14	*Cynops cyanurus* (Yunnan)	China: Yunnan: Chuxiong: Zijing	KIZ 021922	ON793749
15	*Cynops cyanurus* (Yunnan)	China: Yunnan: Chuxiong: Zijing	KIZ 021923	ON793750
16	*Cynops cyanurus* (Yunnan)	China: Yunnan: Honghe: Shiping	SYS a007780	OQ116687
17	*Cynops cyanurus* (Yunnan)	China: Yunnan: Kunming: Gulu	KIZ 022160	ON793752
18	*Cynops cyanurus* (Yunnan)	China: Yunnan: Kunming: Huahongdong	KIZ 022157	ON793751
19	*Cynops cyanurus* (Yunnan)	China: Yunnan: Pu'er: Ning'er	KIZ 01445	ON793756
20	*Cynops cyanurus* (Yunnan)	China: Yunnan: Pu'er: Ning'er	KIZ 03900	ON793747
21	*Cynops cyanurus* (Yunnan)	China: Yunnan: Pu'er: Ning'er	KIZ 03901	ON793748
22	*Cynops fudingensis*	China: Fujian: Ningde: Mt Taimu	CIB 97874	GU301785
23	*Cynops fudingensis*	China: Fujian: Ningde: Jiulongjing	SYS a008487	OQ116688
24	*Cynops fudingensis*	China: Fujian: Ningde: Jiulongjing	SYS a008488	OQ116689
25	*Cynops fudingensis*	China: Fujian: Ningde: Qingyu	KIZ 012214	ON793743
26	*Cynops glaucus*	China: Guangdong: Meizhou: Mianyang	KIZ 09793	ON793715
27	*Cynops glaucus*	China: Guangdong: Meizhou: Mianyang	KIZ 09799	ON793716
28	*Cynops glaucus*	China: Guangdong: Meizhou: Mianyang	KIZ 09800	ON793717
29	*Cynops orientalis*	China: Anhui: Huangshan: Furonggu	SYS a002711	OQ116690
30	*Cynops orientalis*	China: Anhui: Huoshan: Shangtushi	KIZ 021844	ON793742
31	*Cynops orientalis*	China: Anhui: Xiuning: Dafu	KIZ 021962	ON793737
32	*Cynops orientalis*	China: Henan: Xinyang: Mt Jigong	KIZ 013021	ON793736
33	*Cynops orientalis*	China: Jiangxi: Jiujiang	KIZ 020539	ON793739
34	*Cynops orientalis*	China: Jiangxi: Shangrao: Wannian	CIB 97867	GU301788
35	*Cynops orientalis*	China: Jiangxi: Shangrao: Wuyuan	KIZ YPX25002	ON793740
36	*Cynops orientalis*	China: Zhejiang: Hangzhou	MVZ 230345	EU880311
37	*Cynops orientalis*	China: Zhejiang: Jinhua	KIZ 06358	ON793718
38	*Cynops orientalis*	China: Zhejiang: Quzhou	CIB 97919	GU301790
39	*Cynops orientalis*	China: Zhejiang: Taizhou: Tiantai	KIZ 012941	ON793732
40	*Cynops orphicus*	China: Fujian: Fuzhou: Yongtai	KIZ 09905	ON793728
41	*Cynops orphicus*	China: Fujian: Quanzhou: Dehua	MVZ 231158	DQ517771
42	*Cynops orphicus*	China: Fujian: Quanzhou: Mt Daiyun	KIZ 09839	ON793723
43	*Cynops orphicus*	China: Guangdong: Chaozou: Mt Fenghuang	KIZ 09816	ON793719
44	*Cynops orphicus*	China: Guangdong: Chaozou: Chao'an	MVZ 241427	DQ517772
45	*Cynops orphicus*	China: Guangdong: Chaozou: Chao'an	MVZ 241428	EU880312
46	*Pachytriton moi*	China: Guangxi: Guilin: Mt Maoer	KIZ 07768	KU375033
47	*Paramesotriton caudopunctatus*	China: Guizhou: Qiandongnan: Mt Leigong	MVZ 236250	DQ517799

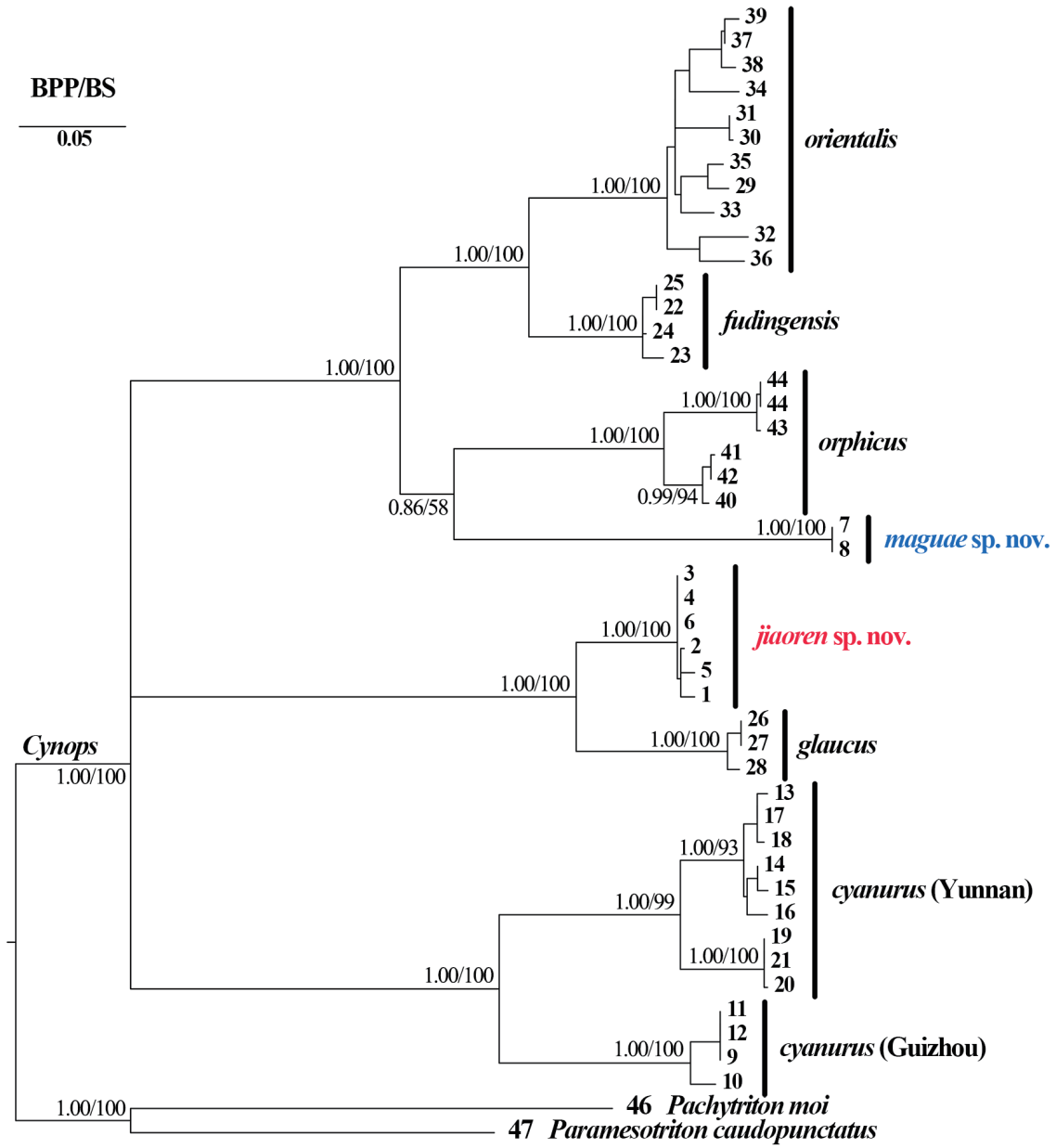


Figure 1 Bayesian inference and maximum-likelihood phylogenies based on mitochondrial *ND2* gene. Bayesian posterior probabilities (BPP) and the bootstrap supports (BS) are all shown. Number at the ends of the lineages correspond to the IDs in Table 1.

Table 2 Mean *P*-distance based on the *ND2* gene among *Cynops* species (in 0.1%).

ID	Species	1	2	3	4	5	6	7	8
1	*Cynops jiaoren* **sp. nov.**	0.4							
2	*Cynops maguae* **sp. nov.**	17.3	0						
3	*Cynops glaucus*	7.0	18.0	0.4					
4	*Cynops orphicus*	16.3	11.8	16.5	2.2				
5	*Cynops orientalis*	16.3	12.2	16.2	12.5	2.8			
6	*Cynops fudingensis*	15.2	11.8	15.7	11.2	7.4	0.6		
7	*Cynops cyanurus* (Guizhou)	16.1	18.6	17.1	17.3	17.3	16.7	0.8	
8	*Cynops cyanurus* (Yunnan)	17.2	18.4	17.2	17.2	16.9	16.6	10.6	2.6

the third clade, unnamed samples from eastern Jiangxi form a distinct lineage (BPP 1.00, BS 100) relatively close to *C. orphicus* but with relatively weak support values (BPP 0.86, BS 58).

Morphologically, the *Cynops* specimens from these two unnamed lineages can be distinguished from all known congeners reliably (details in the Taxonomic account below). Statistical analyses on the morphometric measurements were performed on the unnamed *Cynops* population from northern Guangdong and its sister taxon *C. glaucus* from eastern Guangdong (Table 3; Figure 2). The results of ANOVA on morphometrics showed that individuals of the northern Guangdong population and *C. glaucus* are significantly different, in TAD, HL, ED, IOD, and IND for males (*P*-values < 0.05), and in TOL, TAL, TAD, SL, ED, IOD, IND, and AG for females (*P*-values < 0.05). For the PCA result of males, the first two principal components (PCs) account for 86.7% and 7.4% of the variance, respectively (in total > 90.0% of the variance). For females, the first two PCs account for 81.9% and 9.6% of

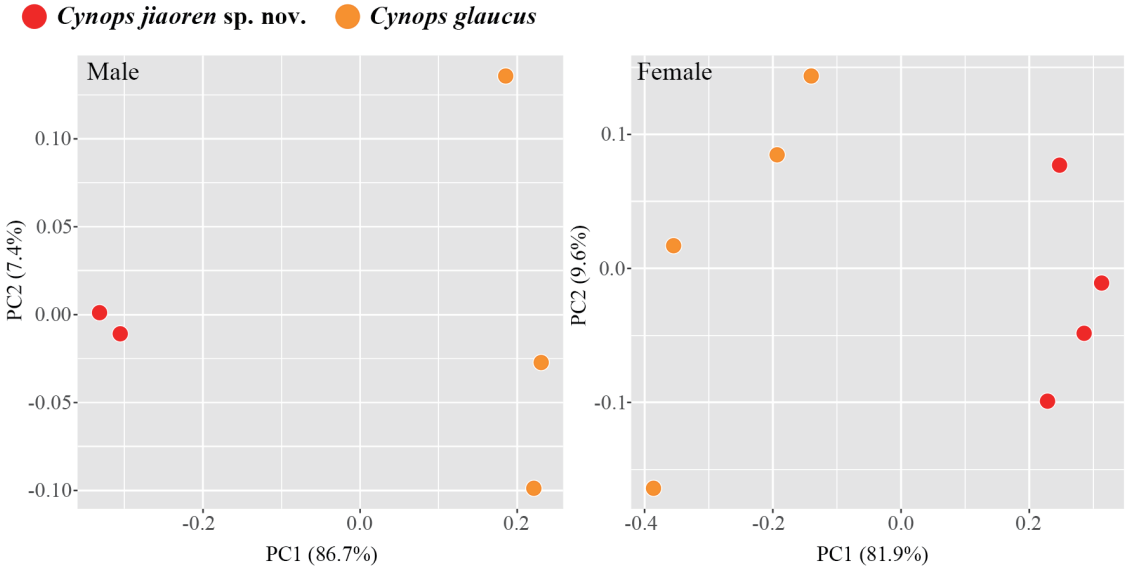


Figure 2 Scatter plot of PC1 and PC2 of Principal Component Analysis based on the morphometric measurements, distinguishing *Cynops jiaoren* **sp. nov.** and *C. glaucus*.

Table 3 Morphometric comparisons based on the morphometric measurements (in mm) of *Cynops jiaoren* **sp. nov.** and *C. glaucus*. * *P*-values < 0.05, ** *P* -values < 0.01, *** *P* -values < 0.001.

	C. jiaoren **sp. nov.**		*C. glaucus*		*P*-values	
	Male (*n* = 2)	Female (*n* = 4)	Male (*n* = 3)	Female (*n* = 4)	Male	Female
TOL	70.7–70.8	77.8–90.3 (82.3 ± 5.9)	70.7–79.8 (74.7 ± 4.7)	87.5–99.7 (91.5 ± 5.6)	0.9754	0.0016**
SVL	42.7–43.4	45.1–53.2 (48.3 ± 3.8)	43.4–49.9 (45.6 ± 3.7)	49.6–55.6 (51.5 ± 2.8)	0.4229	0.2061
TAL	27.4–28.0	32.2–37.1 (34.0 ± 2.2)	27.3–30.0 (29.1 ± 1.5)	37.3–44.1 (40.0 ± 2.9)	0.9825	0.0014**
TAD	5.1–5.2	4.9–5.5 (5.2 ± 0.3)	6.4–6.8 (6.7 ± 0.2)	5.7–7.5 (6.5 ± 0.8)	0.0034**	0.0190*
HL	13.6–13.8	13.0–15.2 (14.1 ± 0.9)	12.2–12.5 (12.3 ± 0.2)	13.7–14.8 (14.1 ± 0.5)	0.0410*	0.0743
HW	8.6–8.6	8.7–10.6 (9.6 ± 0.8)	9.2–10.4 (9.9 ± 0.6)	10.1–11.6 (10.9 ± 0.7)	0.0795	0.057
SL	4.0–4.2	3.9–4.3 (4.2 ± 0.2)	4.7–4.8 (4.7 ± 0.1)	4.5–5.8 (5.0 ± 0.6)	0.0761	0.0148*
ED	2.7–2.7	2.5–2.9 (2.8 ± 0.2)	2.4–2.5 (2.5 ± 0.1)	2.5–2.7 (2.6 ± 0.1)	0.0083**	0.0246*
IOD	5.0–5.1	4.9–5.7 (5.3 ± 0.4)	5.6–6.1 (5.8 ± 0.3)	5.8–6.6 (6.2 ± 0.4)	0.0093**	0.0065**
EN	2.7–2.9	2.7–3.1 (2.9 ± 0.2)	2.9–3.0 (2.9 ± 0.1)	2.8–3.8 (3.2 ± 0.4)	0.7586	0.6825
IND	2.2–2.3	2.3–2.4 (2.3 ± 0.1)	3.2–3.6 (3.4 ± 0.2)	3.4–3.9 (3.6 ± 0.2)	0.0006***	0.0000***
AG	19.7–20.1	23.3–27.7 (25.7 ± 2.0)	18.6–19.8 (19.3 ± 0.6)	21.4–25.3 (23.5 ± 1.6)	0.0988	0.0030**
FLL	9.5–9.7	10.0–10.8 (10.3 ± 0.4)	8.6–10.4 (9.4 ± 0.9)	10.2–11.7 (10.7 ± 0.7)	0.077	0.2748
HLL	10.5–10.6	10.5–11.1 (10.9 ± 0.3)	8.8–10.6 (9.8 ± 0.9)	10.6–11.9 (11.2 ± 0.5)	0.1168	0.4522

the variance, respectively (in total > 90.0% of the variance). As illustrated in the scatter plots (Figure 2), individuals of the northern Guangdong population and *C. glaucus* formed respective clusters that distinctly separated from each other in both males and females. Since only two specimens of the eastern Jiangxi population were collected and the obvious divergence of this population in phylogeny (Figure 1), related morphometric analyses were not carried out.

Combining the results of the morphological examination presented below, the morphometric statistical analyses, and the phylogenetic analyses, these two *Cynops* populations from northern Guangdong and eastern Jiangxi respectively are regarded as belonging to two new species that are described herein.

4. Taxonomic accounts

4.1. *Cynops jiaoren* sp. nov. Lyu, Qi and Wang

Holotype SYS a008791, adult male, collected by Zhao-Chi Zeng and Hong-Hui Chen on 25 April 2021 from Bainiaotang (24.4302°N, 113.1382°E; ca 960 m a.s.l.), Shimentai Nature Reserve, Yingde City, Qingyuan City, Guangdong, China.

Paratypes CIB 118534 (formerly SYS a008790), adult male, and SYS a008786–8789, adult females, same collection data as the holotype.

Etymology The specific name *jiaoren* is used as a noun in apposition and refers to Jiaoren (鲛 人), a mythical merfolk living in southern China whose tears turn into pearls in Chinese folklore. This new species is distributed in the Beijiang River Basin, which is a northern tributary of the Pearl River that is named after pearls. We suggest its English common name as "Beijiang Fire-bellied Newt" and Chinese common name " 北江蝾螈 (běi jiāng róng yuán)", both according to its distribution in the Beijiang River Basin.

Diagnosis (1) small body size, TOL 70.7–70.8 mm in adult males, TOL 77.8–90.3 mm in adult females; (2) parotoid gland inconspicuous; (3) postocular orange spot absent; (4) surface smooth, gular fold absent; (5) fingers and toes overlapping when forelimb and hindlimb adpressed towards each other along body; (6) dorsum, flanks, limbs, and upper side of tail usually uniformly dark brown, several individuals with irregular obscure greyish blue patches on flanks, dorsal limbs, and lateral tail; (7) vertebral ridge weak and inconspicuous, uniformly dark brown as dorsal surface; (8) ground color of venter dark brown, with irregular bright orange patches on chin, chest, and belly.

Description of the holotype SYS a008791 (Figure 3), adult male with a slender and small-sized body (TOL 70.8 mm, SVL 43.4 mm, TAL 27.4 mm). Head oval in dorsal view; snout truncate, projecting slightly beyond mandible; nostril small but conspicuous; labial fold developed on posterior part of upper jaw; tongue elongate, enlarged anteriorly, with free lateral margin; vomerine tooth patch "^"-shaped; parotoid gland conspicuous, gill remnants absent; gular fold absent; Surface smooth, with tiny granules on dorsum, flanks, venter, limbs, and tail; vertebral ridge weak and inconspicuous; cloacal opening oval, slightly protruding. Limbs slender, fingers and toes overlapping when forelimb and hindlimb adpressed towards each other along body; four fingers and five toes, slender and elongated, lack webbing; relative length of fingers I < IV < II < III; relative length of toes I < V < II < IV < III. Tail laterally compressed, tapers posteriorly; caudal fin distinct; tail tip bluntly pointed.

Coloration of the holotype In life, dorsum, flanks, limbs, and upper side of tail uniformly dark brown; vertebral ridge uniformly dark brown as dorsal surface; ground color of venter dark brown, with irregular bright orange patches on chin, chest, and belly; axilla, cloacal opening, and underside of tail bright orange; tips of digits orange. In preservative (Figure 3), dorsum, flanks, and limbs uniformly dark. All orange coloration on venter and tips of digits fades to creamy white.

Variations Measurements of the type series are given in Table 4. Females (TOL 77.8–90.3 mm, n = 4) distinctly larger than males (TOL 70.7–70.8 mm, n = 2). All paratypes resemble the holotype except: the cloaca is wider and more swollen in males than in females; irregular bright orange patches on ventral surface vary among individuals; two individuals (SYS a008788–8789) possess irregular obscure greyish blue patches on flanks, dorsal limbs, and lateral part of tail (Figure 4E).

Comparisons *Cynops jiaoren* **sp. nov.** is phylogenetically close to *C. glaucus* which is distributed in eastern Guangdong, but can be distinguished by its ventral forearms and shanks uniformly dark brown (vs ventral forearms and shanks with bright orange patches), and tail uniformly colored (vs tail with irregular black spots).

Cynops jiaoren **sp. nov.** differs from *C. orphicus* by its weak vertebral ridge (vs slightly bulged), and ventral forearms and shanks uniformly dark brown (vs ventral forearms and shanks with bright orange patches).

Cynops jiaoren **sp. nov.** differs from *C. fudingensis* by its weak vertebral ridge (vs bulged), and ground color of venter dark brown with irregular bright orange patches (vs venter almost entirely bright orange).

Cynops jiaoren **sp. nov.** differs from *C. orientalis* by its gular fold absent (vs present), and ground color of venter dark brown with irregular bright orange patches (vs ground color of venter bright orange with black spots).

The new species can be distinctly distinguished from *C. pyrrhogaster* and *C. ensicauda* by its inconspicuous parotoid gland (vs very conspicuous), weak vertebral ridge (vs distinctly bulged), and smooth skin (vs rough); and from *C. wolterstorffi*,

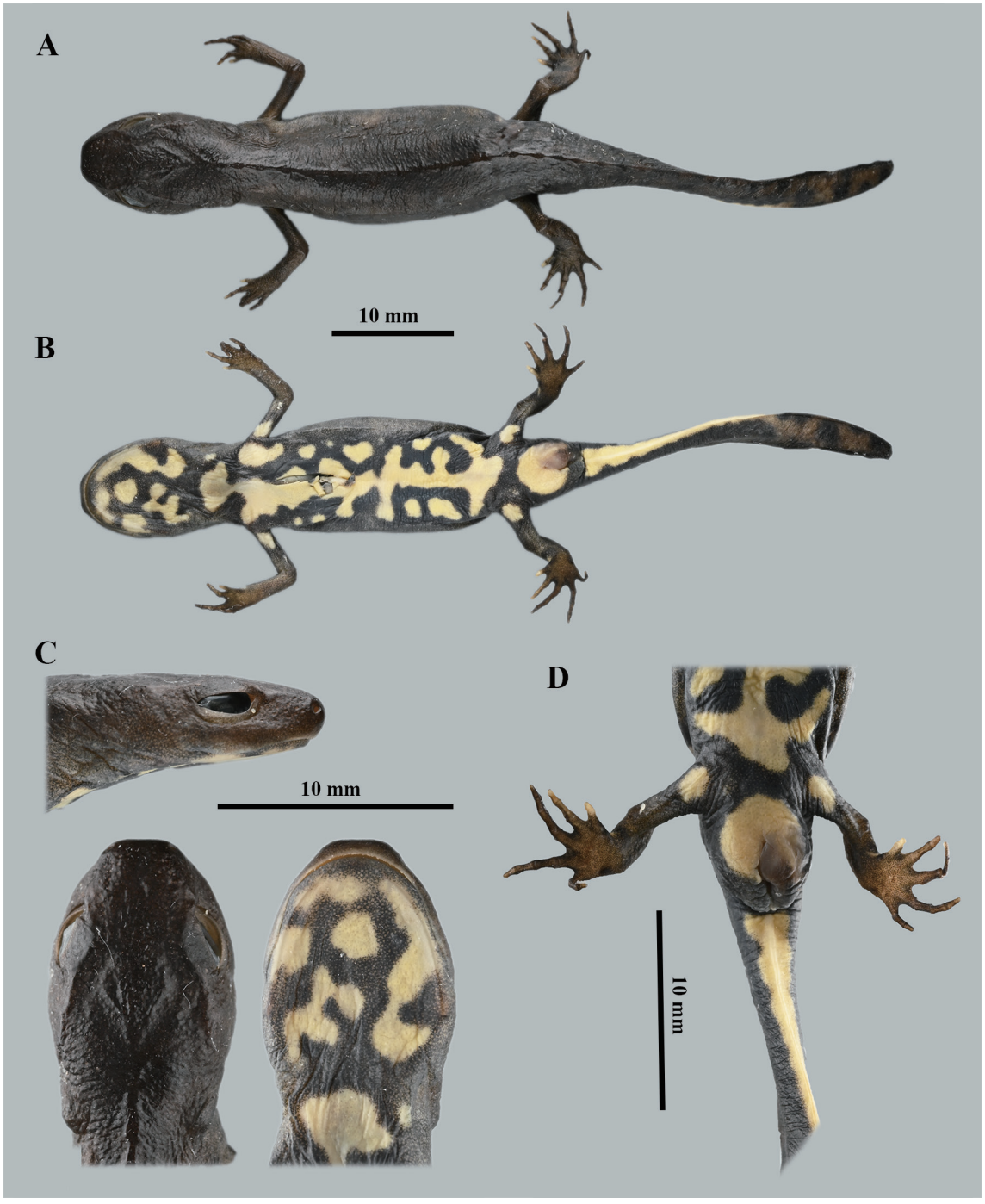


Figure 3 Holotype SYS a008791 of *Cynops jiaoren* **sp. nov.** in preservative. A: dorsolateral view. B: ventral view. C: lateral, dorsal, and ventral views of head. D: region around cloaca. Photos by Shuo QI.

C. cyanurus, *C. chenggongensis*, and *C. puerensis* by the absence of the postocular orange spot (vs present).

Distribution and habitat *Cynops jiaoren* **sp. nov.** is currently known only from its type locality in Shimentai Nature Reserve in northern Guangdong. This newt inhabits lentic environment in well-preserved montane evergreen broad-leaf forest. All individuals were observed in a small swamp on a peak at early April.

Conservation recommendation Even though the type locality of *Cynops jiaoren* **sp. nov.** is well protected by the Shimentai Nature Reserve and no major threat factors have been observed, the extent of occurrence of this species is

Table 4 Measurements (in mm) of type series of *Cynops jiaoren* **sp. nov.** and *Cynops maguae* **sp. nov.**

	C. jiaoren **sp. nov.**						*C. maguae* **sp. nov.**	
	SYS a008786	SYS a008787	SYS a008788	SYS a008789	CIB 118534	SYS a008791	CIB 118535	SYS a007032
Sex	F	F	F	F	M	M	F	M
TOL	90.3	83.1	77.8	77.9	70.7	70.8	74.6	70.9
SVL	53.2	49.2	45.6	45.1	42.7	43.4	42	39.5
TAL	37.1	33.9	32.2	32.8	28	27.4	32.6	31.4
TAD	5.5	5.4	5	4.9	5.2	5.1	4.2	5.9
HL	15.2	14.2	14.1	13	13.6	13.8	11.9	11.9
HW	10.6	9.6	9.4	8.7	8.6	8.6	8.3	8.4
SL	4.3	4.3	4.1	3.9	4	4.2	3.5	3.6
ED	2.9	2.9	2.8	2.5	2.7	2.7	2.3	2.3
IOD	5.7	5.4	4.9	5.1	5.1	5	4.8	4.8
EN	3	2.9	3.1	2.7	2.7	2.9	2.5	2.9
IND	2.3	2.3	2.4	2.3	2.2	2.3	1.9	1.9
AG	27.7	26.9	24.7	23.3	20.1	19.7	22.3	22.4
FLL	10.8	10.4	10	10	9.7	9.5	9.3	8.7
HLL	11.1	11	10.8	10.5	10.5	10.6	8.9	8.6

estimated to be less than 100 km^2, and the area of occupancy is estimated to be less than 10 km^2. We recommend *Cynops jiaoren* **sp. nov.** to be listed as Critically Endangered (CR) based on IUCN Red List criteria B1ab(iii)+2ab(iii).

4.2. *Cynops maguae* sp. nov. Lyu, Qi and Wang

Holotype SYS a007032, adult male, collected by Jian Wang and Hong-Hui Chen on 1 June 2018 from Mt Magu (27.5222°N, 116.5302°E; ca 780 m a.s.l.), Nancheng County, Fuzhou City, Jiangxi, China.

Paratypes CIB 118535 (formerly SYS a007031), adult female, same collection data as the holotype.

Etymology The specific name *maguae* refers to Magu (麻姑), a legendary immortal in Chinese Taoist mythology. In the mythology, Magu is the goddess of longevity and is a symbolic protector of women. The type locality of this new species, Mt Magu in Nancheng County, is also named after Magu. We suggest its English common name as "Magu's Fire-bellied Newt" according to the specific name, and Chinese common name as " 南城蝾螈 (nán chéng róng yuán)" according to the type locality in Nancheng County.

Diagnosis (1) small body size, TOL 70.9 mm in the adult male, TOL 74.6 mm in the adult female; (2) parotoid gland inconspicuous; (3) postocular orange spot absent; (4) surface rough, gular fold absent; (5) forelimb and hindlimb not meeting when adpressed towards each other along body; (6) dorsum, flanks, limbs, and upper side of tail uniformly dark brown; (7) vertebral ridge weak and inconspicuous, uniformly dark brown as dorsal surface; (8) ground color of venter bright orange with black spots on chin, chest, and belly.

Description of the holotype SYS a007032 (Figure 5), adult male with a slender and small-sized body (TOL 70.9 mm, SVL 39.5 mm, TAL 31.4 mm). Head oval in dorsal view; snout truncate, projecting slightly beyond mandible; nostril small but conspicuous; labial fold developed on posterior part of upper jaw; tongue elongate, enlarged anteriorly, with free lateral margin; vomerine tooth patch "^"-shaped; parotoid gland inconspicuous, gill remnants absent; gular fold absent; Surface rough, with dense granules and wrinkles on dorsum, flanks, venter, limbs, and tail; vertebral ridge weak and inconspicuous; cloacal opening oval, slightly protruding. Limbs slender, forelimb and hindlimb not meeting when adpressed towards each other along body; four fingers and five toes, slender and elongated, lack webbing; relative length of fingers I < IV < II < III; relative length of toes I < V < II < IV < III. Tail laterally compressed, tapers posteriorly; caudal fin distinct; tail tip bluntly pointed.

Coloration of the holotype In life, dorsum, flanks, limbs, and upper side of tail uniformly dark brown, with sparse obscure black spots; vertebral ridge uniformly dark brown as dorsal surface; ground color of venter bright orange with black spots on chin, chest, and belly; axilla, cloacal opening, and underside of tail bright orange; tips of digits light brown. In preservative (Figure 5), dorsum, flanks, and limbs uniformly dark. All orange coloration on venter and tips of digits fades to creamy white.

Variations Measurements of the type series are given in Table 4. The single female paratype (Figure 6; TOL 74.6 mm) larger than the male holotype (TOL 70.9 mm). The cloaca is wider and

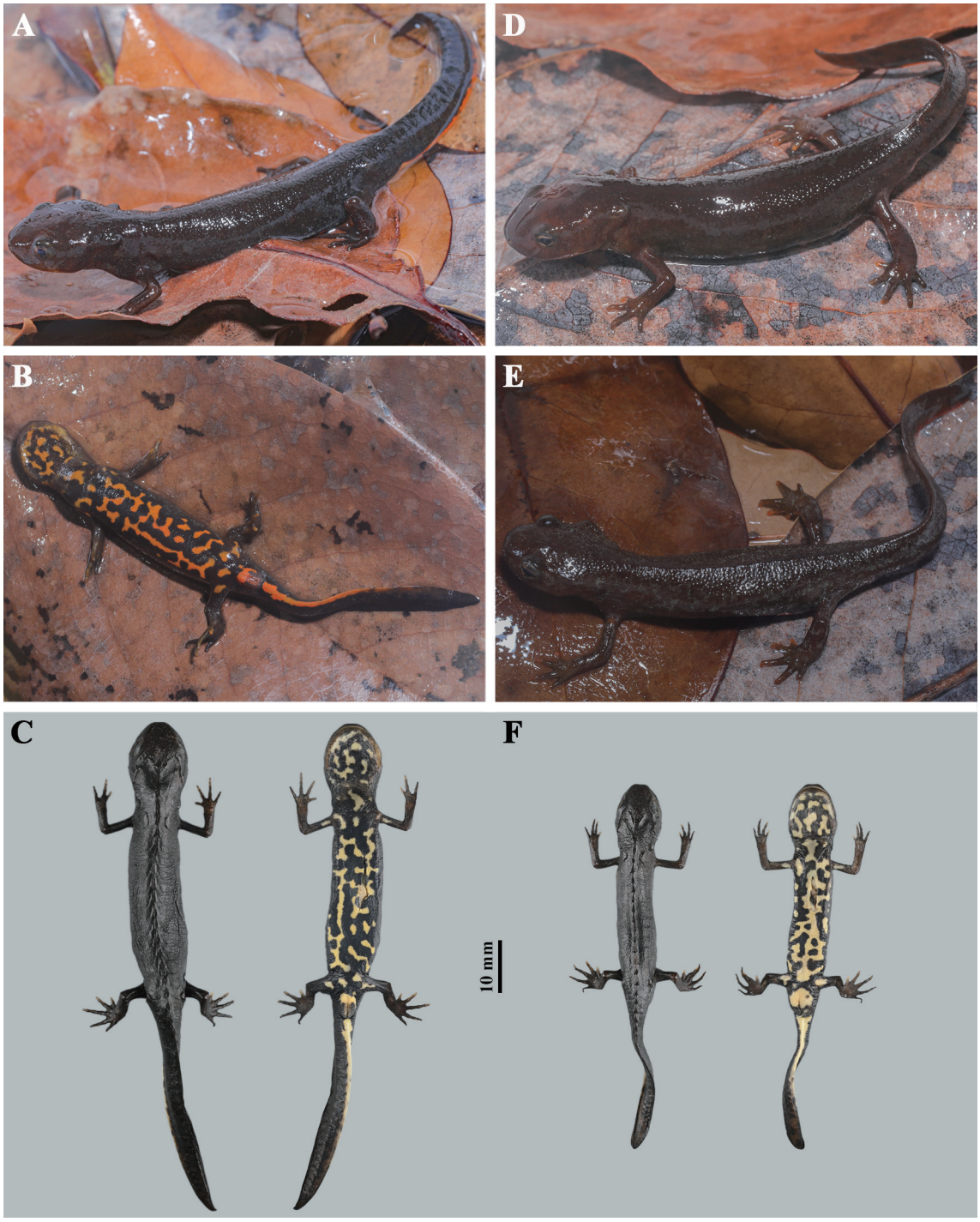


Figure 4 Paratypes of *Cynops jiaoren* **sp. nov.** A: dorsolateral view of SYS a008786 in life. B: ventral view of SYS a008786 in life. C: dorsal and ventral views of SYS a008786 in preservative. D: dorsolateral view of SYS a008787 in life. E: dorsolateral view of SYS a008789 in life. F: dorsal and ventral views of CIB 118534 in preservative. Photos by Zhaochi ZENG and Shuo QI.

more swollen in the male holotype than in the female paratype.

Comparisons *Cynops maguae* **sp. nov.** is phylogenetically close to *C. orphicus* but can be distinguished by its weak vertebral ridge (vs slightly bulged), forelimb and hindlimb not meeting when adpressed towards each other along body (vs overlapping), and ventral forearms and shanks uniformly dark brown (vs ventral forearms and shanks with bright orange patches).

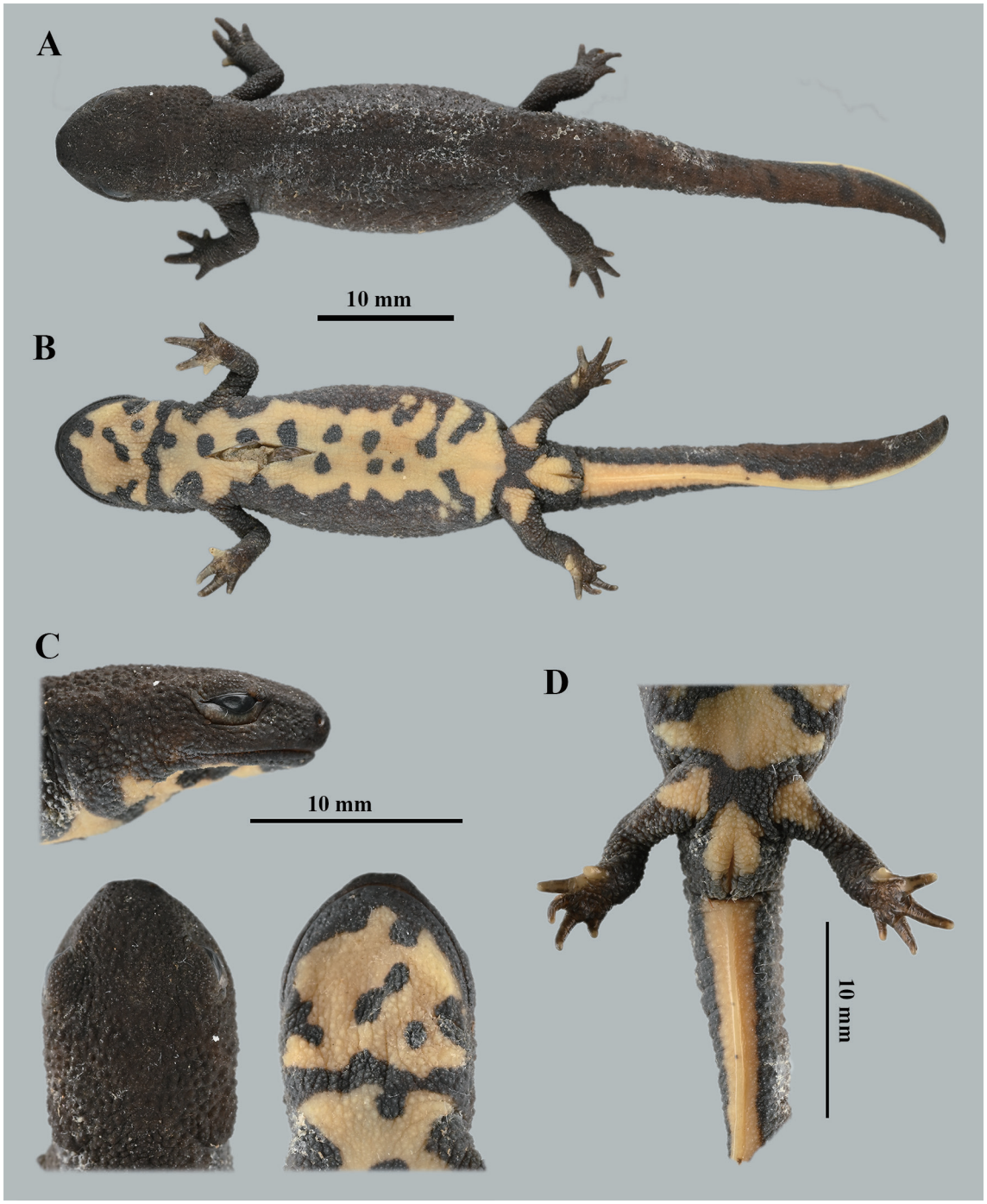


Figure 5 Holotype SYS a007032 of *Cynops maguae* **sp. nov.** in preservative. A: dorsal view. B: ventral view. C: lateral, dorsal, and ventral views of head. D: region around cloaca. Photos by Shuo QI.

Cynops maguae **sp. nov.** differs from *C. fudingensis* by its weak vertebral ridge (vs bulged), ground color of venter bright orange with black spots (vs venter almost entirely bright orange), and tail uniformly colored (vs tail with irregular black spots).

Cynops maguae **sp. nov.** differs from *C. orientalis* by its rough skin (vs smooth), absent gular fold (vs present), and forelimb and hindlimb not meeting when adpressed towards each other along body (vs overlapping).

Cynops maguae **sp. nov.** differs from *C. glaucus* by its dorsum, flanks, limbs, and upper side of tail uniformly dark brown (vs dorsum, flanks, limbs, and upper side of tail with irregular



Figure 6 Paratype CIB 118535 of *Cynops maguae* **sp. nov.** A: dorsolateral view in life. B: dorsal and ventral views in preservative. Photos by Jian WANG and Shuo QI.

obscure greyish blue patches), ventral forearms and shanks uniformly dark brown (vs ventral forearms and shanks with bright orange patches), and tail uniformly colored (vs tail with irregular black spots).

Cynops maguae **sp. nov.** differs from *C. jiaoren* **sp. nov.** by its rough skin (vs smooth), forelimb and hindlimb not meeting when adpressed towards each other along body (vs overlapping), and ground color of venter bright orange with black spots (vs ground color of venter dark brown with irregular bright orange patches).

Cynops maguae **sp. nov.** can be distinctly distinguished from *C. pyrrhogaster* and *C. ensicauda* by its inconspicuous parotoid gland (vs very conspicuous), and weak vertebral ridge (vs distinctly bulged); and from *C. wolterstorffi*, *C. cyanurus*, *C. chenggongensis*, and *C. puerensis* by its absent postocular orange spot (vs present).

Distribution and habitat *Cynops maguae* **sp. nov.** is currently known only from its type locality in Mt Magu in eastern Jiangxi. This newt inhabits lentic environment in montane evergreen broad-leaf forest. All individuals were observed at early June.

Conservation recommendation Only two individuals were found in our surveys from Mt Magu, and surveys have yet to be conducted in the neighboring areas. Thus, the exact

population status of this new species remains unknown. Mt Magu is a famous scenery spot for the culture of Magu mythology, and tourism might be a threat factor for this species. We recommend *Cynops maguae* **sp. nov.** to be listed as Data Deficient (DD) based on IUCN Red List criteria.

5. Discussion

Including the two new species described in this work, the genus *Cynops* now has 12 recognized species. Among them, six species are distributed in the Southeast Chinese Hilly Area (namely *C. jiaoren*, *C. glaucus*, *C. maguae*, *C. orphicus*, *C. fudingensis*, and *C. orientalis*), which contains half of the species diversity. Zhao and Hu (1984) and Zhao *et al.* (1988) proposed *C. orientalis* group with only *C. orientalis*, then Fei and Ye (2016) further placed *C. orphicus*, *C. fudingensis*, and *C. glaucus* into this group. The two new species *C. jiaoren* and *C. maguae* are close to these four species in morphology and biogeography which seem to belong to the *C. orientalis* group. However, in the phylogenetic analysis (Figure 1), *C. jiaoren* and *C. glaucus* form an independent clade, compared with the clade that consists of *C. maguae*, *C. orphicus*, *C. fudingensis*, and *C. orientalis*. Therefore, the relationship and species group division among these species from the Southeast Chinese Hilly Area require further studies.

The phylogenetic analysis also reveals distinct divergences within *Cynops cyanurus*. Two lineages are distinctly shown and correspond to the populations in Guizhou and Yunnan, respectively. Morphological differences have also observed between the Guizhou and Yunnan populations for long time (Fei and Ye, 1983, 2016; Kou and Xing, 1983; Yang, 1983, 1991). Therefore, the populations of *C. cyanurus* from Guizhou and Yunnan should represent two independent species based on the phylogenetic divergences and morphological differences. The topotype population from Guizhou represents the true identity of *C. cyanurus*. The Yunnan populations are more complicated. Yang (1983), Kou and Xing (1983), and Fei and Ye (1983) erected *C. cyanurus yunnanensis*, *C. chenggongensis*, and *C. cyanurus chuxiongensis*, respectively. Subsequently, Zhao *et al.* (1988) synonymized *C. cyanurus chuxiongensis* with *C. cyanurus yunnanensis*, and Yang (1991) synonymized *C. chenggongensis* with *C. cyanurus yunnanensis*, but both of these actions are not widely accepted. The description of *C. cyanurus yunnanensis* is based on specimens from Jingdong (holotype, allotype, and a portion of paratypes) and Kunming (another portion of paratypes), *C. chenggongensis* is based on specimens from Chenggong, and *C. cyanurus chuxiongensis* is based on specimens from Chuxiong. The phylogenetic analysis suggests conspecificity for Kunming and Chuxiong samples (Figure 1), while samples from Jingdong and Chenggong are currently unavailable. Thus, it is not yet clear whether *C. cyanurus yunnanensis*, *C. chenggongensis*, and *C. cyanurus chuxiongensis* belong to the same taxon. Nonetheless, *C. cyanurus yunnanensis* has nomenclatural precedence and based on our evidence we herein elevate it to species status *C. yunnanensis* **comb. nov**. Furthermore, Rao (2022) described *C. puerensis* from Pu'er, however, this species could not be distinctly distinguished from the Yunnan population of *C. cyanurus* sensu lato in morphology and is suggested to be synonymized with *C. yunnanensis* **comb. nov.** accordingly. Further studies on the *Cynops* populations from the Yunnan-Guizhou Plateau in southwestern China are definitely warranted to settle down these taxonomic confusions.

Acknowledgements We thank Honghui CHEN, Zhaochi ZENG, Jian WANG, Yongyou ZHAO, and Nanling National Park, for their help in the fieldwork. We thank Chao HUANG from Australian Museum for polishing the manuscript. We thank the three anonymous reviewers for their valuable suggestions on this work. This work was supported by DFGP Project of Fauna of Guangdong-202115, Nanling National Park Construction Project (No. ZD22-ZC016AG), 2022 Wildlife Monitoring Projects of the Guangdong Forestry Bureau, and the National Animal Collection Resource Center, China.

References

AmphibiaChina. 2022. The database of Chinese amphibians. Kunming, China: Kunming Institute of Zoology (CAS). Available from: http://www.amphibiachina.org/ (accessed 10 October 2022)

AmphibiaWeb. 2022. AmphibiaWeb: information on amphibian biology and conservation. Berkeley, USA: University of California. Available from: http://amphibiaweb.org/ (accessed 10 October 2022)

Boie H. 1826. Merkmale einiger japonischen Lurche. Isis von Oken, 18: 203–215

Boulenger G. A. 1905. Description of a new newt from Yunnan. Proc Zool Soc London, 1905: 277

Chang M. L. Y. 1935. Note préliminaire sur la classification des salamandres d'Asie orientale. Bull Soc Zool Fr, 60: 424–427

Chang M. L. Y. 1955. Chinese Amphibians. Shanghai, China: Fudan University

David A. 1873 "1872". Quelques renseignements sur l'histoire naturelle de la Chine septentrionale et occidentale. J North China Branch R Asiat Soc. New Series 7: 205–234

Dubois A., Raffaëlli J. 2011. Subgeneric taxonomy and nomenclature of the genus *Hypselotriton* Wolterstorff, 1934 (Amphibia, Urodela). Alytes, 27: 151–153

Fei L., Hu S. Q., Ye C. Y., Huang Y. Z. 2006. Fauna Sinica. Amphibia. Volume 1. General Accounts of Gymnophiona and Urodela. Beijing, China: Science Press

Fei L., Ye C. Y. 1983. A new subspecies of *Cynops cyanurus* from Chuxiong, Yunnan (Caudata: Salamandridae). Acta Herpetol Sinica, 2: 55–58

Fei L., Ye C. Y. 2016. Amphibians of China (Vol. 1). Beijing, China: Science Press

Frost D. R. 2022. Amphibian Species of the World 6.1, an Online Reference. New York, USA: American Museum of Natural History. Available

from: https://amphibiansoftheworld.amnh.org/ (accessed 10 October 2022)

Hallowell E. 1861 "1860". Report upon the Reptilia of the North Pacific Exploring Expedition, under command of Capt. John Rogers, U.S.N. Proc Acad Nat Sci Philadelphia, 12: 480–510

Kou Z. T., Xing Y. L. 1983. A new species of *Cynops* from Yunnan. Acta Herpetol Sinica, 2: 51–54

Liu C. C., Hu S. Q., Yang F. H. 1962. Preliminary report of Amphibia from western Kweichow. Acta Zool Sinica, 14: 381–392

Lyu Z. T., Chen Y., Yang J. H., Zeng Z. C., Wang J., Zhao J., Wan H., Pang H., Wang Y. Y. 2020. A new species of *Nidirana* from the *N. pleuraden* group (Anura, Ranidae) from western Yunnan, China. Zootaxa, 4861: 43–62

Lyu Z. T., Wang J., Zeng Z. C., Zhou J. J., Qi S., Wan H., Li Y. Y., Wang Y. Y. 2021 A new species of the genus *Tylototriton* (Caudata, Salamandridae) from Guangdong, southern China, with discussion on the subgenera and species groups within the genus. Vertebr Zool, 71: 697–710

Rao D. Q. 2022 "2020". Atlas of Wildlife in Southwest China: Amphibian. Beijing, China: Beijing Publishing Group

Risch J. P. 1983. *Cynops orphicus*, a new salamander from Guangdong Province, South China (Amphibia, Caudata, Salamandridae). Alytes, 2: 45–52

Ronquist F., Teslenko M., Van Der Mark P., Ayres D. L., Darling A., Höhna S., Larget B., Liu L., Suchard M. A., Huelsenbeck J. P. 2012. MrBayes 3.2: efficient Bayesian phylogenetic inference and model choice across a large model space. Syst Biol, 61: 539–542

Silvestro D., Michalak I. 2012. RaxmlGUI: A graphical front-end for RAxML. Org Diversity Evol, 12: 335–337

Thompson J. D., Gibson T. J., Plewniak F., Jeanmougin F., Higgins D. G. 1997. The CLUSTAL_X windows interface: flexible strategies for multiple sequence alignment aided by quality analysis tools. Nucleic Acids Res, 25: 4876–4882.

Tschudi J. J. von. 1838. Classification der Batrachier mit Berücksichtigung der fossilen Thiere dieser Abtheilung der Reptilien. Neuchâtel, Switzerland: Petitpierre

Wolterstorff W. 1934. Über die Gattung Hypselotriton. Zool Anz, 108: 257–263

Wu Y. K., Wang Y. Z., Jiang K., Hanken J. 2010. A new newt of the genus *Cynops* (Caudata: Salamandridae) from Fujian Province, southeastern China. Zootaxa, 2346: 42–52

Yang D. T. 1983. A new subspecies of *Cynops cyanurus* in Yunnan (Caudata: Salamandridae). Zool Res, 4: 124

Yang D. T. 1991. The Amphibia-Fauna of Yunnan. Beijing, China: China Forestry Publishing House

Yuan Z. Y., Jiang K., Ding L., Zhang L., Che J. 2013. A new newt of the genus *Cynops* (Caudata: Salamandridae) from Guangdong, China. Asian Herpetol Res, 4: 116–123

Zhao E. M., Hu Q. X. 1984. Studies on Chinese Tailed Amphibians. Chengdu, China: Sichuan Scientific and Technical Publishing House

Zhao E. M., Hu Q. X., Jiang Y. M., Yang Y. H. 1988. Studies on Chinese Salamanders. Oxford, USA: Society for the Study of Amphibians and Reptiles

Scientific Editor: Ke JIANG

How to cite this article:

Lyu Z. T., Qi S., Zhang S. Y., Dai K. Y., Wang Y. Y. Two New Species of Fire-Bellied Newts (Caudata, Salamandridae, Cynops) from Southeastern China. Asian Herpetol Res, 2023, 14(1): 41–53. DOI: 10.16373/j.cnki.ahr.220059

Appendix

Specimens examined

Cynops cyanurus (Yunnan population) (*n* = 1): China: Yunnan: Honghe: Shiping: SYS a007780.

Cynops fudingensis (*n* = 3): China: Fujian: Ningde: Jiulongjing: SYS a008487–8489.

Cynops glaucus (*n* = 7): China: Guangdong: Jieyang: Jiexi: SYS a000729, 8511, 8601–8602; Meizhou: Fengshun: SYS a000730–0731, 4743.

Cynops orientalis (*n* = 8): China: Jiangxi: Shangrao: Wuyuan: SYS a001709–1714; Anhui: Huangshan: Furonggu: SYS a002711–2712.