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A new species of *Amolops* (Anura: Ranidae) from Vietnam

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Abstract. A new species of *Amolops* is described from northwestern Vietnam based on morphological differences and molecular divergence. Morphologically, *Amolops ottorum*, new species, is distinguishable from its congeners on the basis of a combination of the following diagnostic characters: size small (SVL 47.5–48.2 mm in females); head longer than wide; vomerine teeth absent; snout short (SE/SVL 0.14–0.15); tympanum dark brown, small (TD/ED 0.36–0.37 in females); skin smooth; supratympanic fold absent; dorsolateral fold absent; webbing formula I 0—1/3 II 0—1 III 0—1 IV 2—0 V; in life, dorsum green with some dark brown spots; flanks with irregular dark markings; head and body with irregular dorsolateral cream stripe; dorsal surface of fore and hind limbs green with dark crossbars; throat, chest, anterior part of belly light-cream with brown dots; and posterior part of belly cream. In phylogenetic analyses, the new species is weakly supported as a sister taxon of *Amolops tuberodepressus*, and approximately 5.6% divergent from it based on a fragment of the cytochrome *b* gene.

Key words. *Amolops*, molecular phylogeny, Muong La, new species, Son La Province, taxonomy

INTRODUCTION

The genus *Amolops* Cope, 1865 contains 58 recognised species with a wide distribution from Nepal and northern India eastwards to China and southwards to Malaysia (Frost, 2019). In Vietnam, Frost (2019) listed eleven species of *Amolops,* namely *A. compotrix* (Bain, Stuart & Orlov), *A. cremnobatus* Inger & Kottelat, *A. cucae* (Bain, Stuart & Orlov), *A. iriodes* (Bain & Nguyen), *A. mengyangensis* Wu & Tian, *A. minutus* Orlov & Ho, *A. ricketti* Boulenger, *A. spinapectoralis* Inger, Orlov & Darevsky, *A. splendissimus* Orlov & Ho, *A. viridimaculatus* Jiang, and *A. vitreus* (Bain, Stuart & Orlov). In Son La Province, Nguyen et al. (2009) reported only *A. ricketti*. Le et al. (2015) subsequently recorded *A. vitreus* for the first time from Vietnam on the basis of specimens collected from Son La and Dien Bien provinces. Pham (2016) recently provided a list of three species from Son La Province, namely *A. compotrix*, *A. ricketti*, and *A. vitreus*.

During our recent field work in Son La Province, Vietnam, two specimens of *Amolops* were collected in the evergreen forest of Muong La District. These specimens were also identified as a member of the *Amolops mantzorum* species group (sensu Fei et al., 2005) based on molecular data. Morphologically, these specimens could be assigned to the *A. mantzorum* group on the basis of the following characters: the absence of dorsolateral folds and the absence of circummarginal groove on the disc of the first finger (Fei et al., 2005, 2009). Closer morphological examination showed that the specimens from Son La Province are clearly distinguishable from other known species of the *A. mantzorum* species group by a combination of morphological features. Therefore, we herein describe it as a new species.

MATERIAL AND METHODS

Sampling. Field surveys were conducted in October and November 2016 in Ngoc Chien Commune, Muong La District, Son La Province, northwestern Vietnam (Fig. 1). After photographing individuals in-life, specimens were euthanised in a closed vessel with a piece of cotton wool containing ethyl acetate (Simmons, 2002), fixed in 80% ethanol for eight hours, and then later transferred to 70% ethanol for permanent storage. Tissue samples were preserved separately in 95% ethanol prior to fixation. Specimens referred to in this paper are deposited in the collections of

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Fig. 1. Map of sampling site in Son La Province, Vietnam: Muong La District (black square), the type locality of *Amolops ottorum,* new species.

Table 1. Samples used in molecular analyses.

Species	GenBank No.	Locality	Voucher
Amolops chunganensis	KJ008460	Dayi, Chadiping, Quangdong, China	–
Amolops granulosus	KJ008439	Anxian, Sinchuan, China	–
Amolops granulosus	KJ008444	Anxian, Sinchuan, China	–
Amolops jinjangensis	KJ008372	Zhongdian, Yunnan, China	–
Amolops jinjangensis	KJ008372	Zhongdian, Yunnan, China	–
Amolops lifanensis	KJ008447	Maoxian, Sichuan, China	–
Amolops lifanensis	KJ008456	Lixian, Sichuan, China	–
Amolops loloensis	KJ008427	Qiliba, Zhaojue, Sichuan, China	–
Amolops loloensis	KJ008430	Huanyuan, Sichuan, China	–
Amolops mantzorum	KJ008277	Wanba, Jiulong, Sichuan, China	–
Amolops mantzorum	KJ008297	Wanba, Jiulong, Sichuan, China	–
Amolops mantzorum	KJ008339	Wenxian, Gansu, China	–
Amolops mantzorum	KJ008360	Maoxian, Sichuan, China	–
***Amolops ottorum*, new species**	MK941135	Muong La, Son La, Vietnam	IEBR 4342
***Amolops ottorum*, new species**	MK941136	Muong La, Son La, Vietnam	TBU 06
Amolops ricketti	KJ008461	Zhangjiajie, Hunan, China	–
Amolops tuberodepressus	KJ008426	Mt. Wuliang, Jingdong, Yunnan, China	–
Amolops viridimaculatus	KJ008459	Tengchong, Yunnan, China	–
Amolops xinduqiao	KJ008410	Xinduqian, Sichuan, China	–
Amolops xinduqiao	KJ008423	Xinduqian, Sichuan, China	–

the Institute of Ecology and Biological Resources (IEBR), Hanoi, Vietnam and Tay Bac University, Son La Province, Vietnam (TBU).

Molecular data and phylogenetic analyses. We used Le et al.'s (2006) protocols for extraction, amplification, and DNA sequencing. A fragment of the mitochondrial gene, cytochrome *b*, was amplified using a primer pair, F1 and R3 (Lu et al., 2014). We compiled all cytochrome *b* sequences available from GenBank of species within the *Amolops mantzorum* species group from Lu et al. (2014) and added data from two samples from the population in Son La Province (Table 1). Sequences of *A. kangtingensis* were renamed to *A. xinduqiao* based on the taxonomic revision of Fei et al. (2017). Two species, *A. chungaensis* and *A. ricketti*, were used to provide outgroup polarity (Lu et al., 2014). In total, 18 sequences of 10 species were retrieved from GenBank (Table 1).

Obtained sequences were edited in Geneious v.11 (Kearse et al., 2012). The sequences were then aligned in ClustalX v2 (Thompson et al., 1997) with default settings. Data were analyzed using maximum parsimony (MP) as implemented in PAUP 4.0b10 (Swofford, 2001), and maximum likelihood (ML) in IQ-TREE (Nguyen et al., 2015), and Bayesian analysis (BA) in MrBayes 3.2 (Ronquist et al., 2012). For MP analysis, heuristic analysis was conducted with 100 random taxon addition replicates using tree-bisection and reconnection (TBR) branch swapping algorithm, with no upper limit set for the maximum number of trees saved. Bootstrap support (BP) (Felsenstein, 1985) was calculated using 1,000 pseudo-replicates and 100 random taxon addition replicates. All characters were equally weighted and unordered. For combined and partitioned ML analyses, we used TIM+I+G and TVMef +G, HKY+I, and TrN+G (for three codon positions – first, second, and third) as the optimal evolution models, respectively, as selected by ModelTest v3.7 (Posada & Crandall, 1998). To estimate ultrafast BP in the ML analysis, we used the function -bb in IQ-TREE with 10,000 replications. We assumed MP and ML bootstrap values of ≥ 70 % and 95% to represent strong support and values of < 70 % and <95% as weak support, respectively (Hillis & Bull, 1993; Bui et al., 2013).

For Bayesian analyses, we used the optimal model determined by Modeltest with parameters, e.g., stationary state frequencies and substitution rates, estimated by MrBayes 3.2.1. Two independent and simultaneous analyses with four Markov chains (one cold and three heated) were run for 10 million generations with a random starting tree and sampled

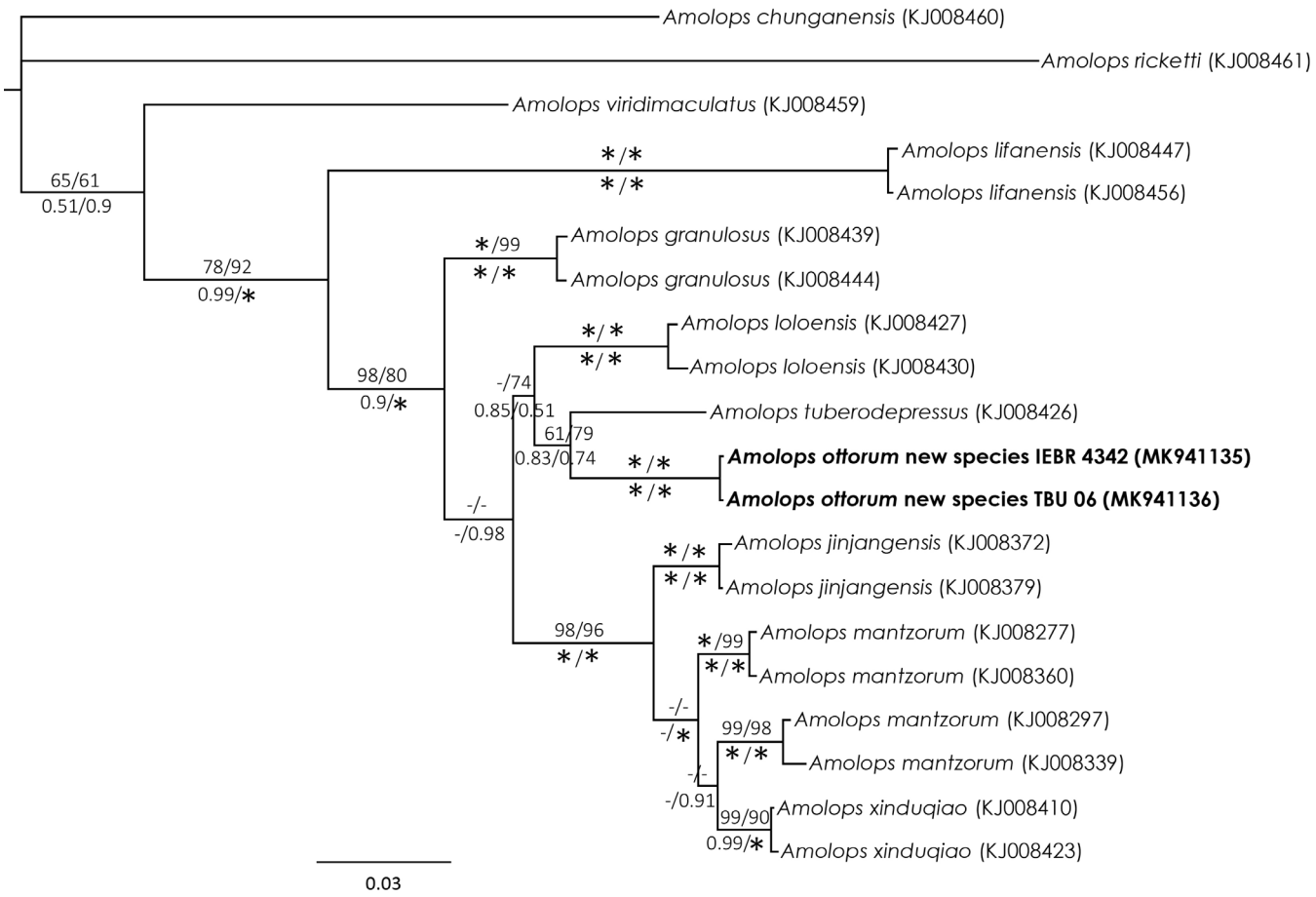

Fig. 2. Phylogram based on the partitioned Bayesian analysis. Number above and below branches are MP/ML bootstrap values and combined Bayesian/partitioned Bayesian posterior probabilities (>50% or 0.5), respectively. Asterisk and dash represent 100% (1.0) and <50 % (0.5) values, respectively. The results from the partitioned ML analysis were very similar to those from the combined ML analysis and not presented (see Supplementary Material).

every 1,000 generations. Log-likelihood scores of sample points were plotted against generation time to determine stationarity of Markov chains. Trees generated before log-likelihood scores reached stationarity were discarded from the final analyses using the burn-in function. Two independent analyses were run simultaneously. The posterior probability (PP) values for all clades in the final majority rule consensus tree were provided. We ran analyses using both combined and partitioned datasets to examine the robustness of the tree topology (Nylander et al., 2004; Brandley et al., 2005). In the Bayesian partitioned analysis, we used three models as selected by Modeltest for three codon positions, and then assigned to these partitions in MrBayes 3.2 using the command APPLYTO. Model parameters were inferred independently for each data partition using the UNLINK command.

Morphological characters. Measurements were taken with a digital caliper to the nearest 0.1 mm. The following abbreviations were used: SVL: snout-vent length (from tip of snout to cloacal); AG: axilla to groin (from posterior edge of fore limb insertion to anterior edge of hind limb insertion); HL: head length (from the back of mandible to tip of snout); HW: maximum head width (across angles of jaws); HD: maximum head height (from occiput to underside of jaw); SE: distance from tip of snout to anterior corner of eye; SND: distance from nostril to the tip of snout; END: eye to nostril distance (from anterior corner of eye to the nostril); IND: internarial distance (distance between nostrils); UEW: maximum width of upper eyelid; IOD: interorbital distance (minimum distance between upper eyelids); ED: horizontal eye diameter (from the anterior corner to the posterior corner of the eye); TD: maximum tympanum diameter; TED: tympanum-eye distance (from anterior margin of tympanum to posterior corner of the eye); UAL: Upper arm length (from axilla to elbow); FAL: Forearm length (from the elbow to the tip of third finger); FLL: forelimb length (UAL+FAL); FFL: first finger length (from the base to the tip of the first finger); TFL: third finger length (from the base to the tip of the third finger); FTD: maximum width of disc of finger III; HLL: hindlimb length (FL+TL+FOT); FL: femur length (from vent to knee); TL: tibia length (from knee to tarsus); FOT: length of hind limb (from tarsus to the tip of fourth toe); FTL: first toe length (from the base to the tip of the first toe); FFTL: fourth toe length (from the base to the tip of the fourth toe); HTD: maximum width of disc of fourth toe; MTTi: inner metatarsal tubercle length. For webbing formula, we followed Glaw & Vences (2007). Sex was determined by gonadal inspection.

Table 2. Uncorrected ("p") distance matrix showing percentage pairwise genetic divergence (cytochrome b) between the new and other species in the *Amolops mantzorum* species group.

Species Name	1	2	3	4	5
1. *A. granulosus*					
2. *A. jinjangensis*	7.1–7.4				
3. *A. lifanensis*	13.2–13.4	14.8–14.9			
4. *A. loloensis*	6.0–6.4	7.0–7.2	14.1–14.4		
5. *A. mantzorum*	6.7–7.1	3.1–3.6	13.7–14.5	6.8–7.3	
6. *A. mantzorum*	6.8–7.1	3.1–3.4	13.5–14.5	6.7–7.1	2.9–3.2
7. *A. ottorum*, new species	**6.7**	**6.9–7.2**	**14.3–14.7**	**5.7–6.0**	**6.9–7.2**
8. *A. tuberodepressus*	7.1–7.2	6.9–7.1	14.6–14.7	6.3–6.7	7.0–7.1
9. *A. viridimaculatus*	12.0–12.1	12.0–12.3	16.6–16.7	12.3–12.6	11.9
10. *A. xinduqiao*	7.0	3.4–3.6	14.1–14.2	5.6–6.0	2.3–2.6

Species Name	6	7	8	9	10
1. *A. granulosus*					
2. *A. jinjangensis*					
3. *A. lifanensis*					
4. *A. loloensis*					
5. *A. mantzorum*					
6. *A. mantzorum*					
7. *A. ottorum*, new species	**7.7–7.8**				
8. *A. tuberodepressus*	7.1–7.2	5.6			
9. *A. viridimaculatus*	11.5–11.7	11.9–12.2	13.9		
10. *A. xinduqiao*	2.4–2.8	6.4–6.5	6.9–7.0	11.4	

SYSTEMATICS

Phylogenetic analyses. The combined matrix contained 998 aligned characters and 20 sequences. Of those, 240 were parsimony informative. MP analysis of the dataset recovered 3 most parsimonious trees with 645 steps (CI = 0.68; RI = 0.72). In the BA, -lnL scores reached stationarity after 21,000 and 20,000 generations in both runs in combined and partitioned analyses, respectively. Our phylogenetic results were in general agreement with those generated by Lu et al. (2014), although there were changes in the placements of *Amolops granulosus* and *A. jinjangensis* with low statistical support values. Without the new species, our combined Bayesian and both maximum likelihood topologies are identical to that of Lu et al. (2014) (Fig. 2 in the paper) (see Supplementary Material). The new species was weakly supported as a sister taxon of *A. tuberodepressus* (BP < 70, PP < 95) (Fig. 2). In terms of genetic distance, the new species is also most closely related to *A. tuberodepressus* with approximately 5.6% divergence between the two taxa based on the cytochrome *b* data (Table 2. The level of genetic divergence is higher than or comparable to those between other species in the group, except for *A. lifanensis* and *A. viridimaculatus* (Table 2).

Although we could only include two samples in phylogenetic analyses, the results show that they are reciprocally monophyletic. Moreover, the level of genetic divergence is similar or higher than most species within this complex. In our analyses, the phylogenetic placement of the new taxon is still unclear, possibly due to incomplete taxon sampling (more unknown species to be discovered) or insufficient data to resolve the nodes. Nonetheless, according to both lines of evidence, i.e., application of the integrative taxonomy approach (Dayrat, 2005; Padial et al., 2010; Schlick-Steiner et al., 2010), it can be concluded that the new taxon needs to be considered as a distinct species.

Family Ranidae Batsch, 1796

Genus *Amolops* Cope, 1865

***Amolops ottorum*, new species**
(Figs. 3–5)

Holotype. IEBR 4342 (Field No. SL 2016.301), adult female, collected by NB Song and TV Dau on 28 October 2016 in the forest near Nam Nghiep Village (21°34.956′N, 104°17.160′E, at an elevation of 2.125 m), Ngoc Chien Commune, Muong La District, Son La Province, Vietnam.

Paratype. TBU 06 (Field No. SL 2016.514), adult female, collected on 10 November 2016 (the same data as the holotype).

Diagnosis. The new *Amolops* species from Son La Province is assigned to the *A. mantzorum* species group on the basis of the following characters: the absence of a dorsolateral fold and the absence of circummarginal groove on the disc of the first finger (Fei et al., 2009, 2017). The new species is also supported as a member of the *A. mantzorum* species group based on the molecular analyses (Fig. 2). *Amolops ottorum,* new species is distinguishable from its congeners by a combination of the following morphological characters: (1) size small (SVL 47.5–48.2 mm in females); (2) head longer than wide; (3) vomerine teeth absent; (4) snout short (SE/SVL 0.14–0.15); (5) tympanum dark brown, small (TD/ED 0.36–0.37 in females); (6) skin smooth; (7) supratympanic fold absent; (8) dorsolateral fold absent; (9) webbing formula I 0–1/3 II 0–1 III 0–1 IV 2–0 V; (10) in life, dorsum green with some dark brown spots; (11) flanks with irregular dark markings; (12) head and body with irregular dorsolateral cream stripe; (13) dorsal surface of fore and hind limbs green with dark crossbars; (14) throat, chest and anterior part of belly light-cream with brown dots, posterior part of belly cream.

Description of holotype. Adult female; SVL 48.2 mm; body long (AG/SVL 0.55); head broad and flat (HL/VL 0.33, HW/SVL 0.31, HD/SVL 0.15), longer than wide (HL 16.0 mm, HW 14.9 mm); snout round anteriorly in dorsal view (SE/SVL 0.14), projecting beyond lower jaw; nostril lateral, closer to the eye than to tip of snout (SND 3.1 mm, END 3.3 mm); canthus rostralis distinct; loreal region slightly concave; snout length greater than eye diameter (SE 6.8 mm, ED 5.8 mm); eyes very large (ED/HL 0.36, ED/SE 0.85 mm); pupil horizontally oval; internarial distance wider than interorbital distance and upper eyelid (IND 4.9 mm, IOD 4.8 mm, UEW 3.2 mm); tympanum slightly distinct, round (TD/ED 0.36); vomerine teeth absent; tongue cordiform, notched posteriorly.

Fore limbs robust, FLL/SVL 0.67; relative finger lengths: I<II<IV<III; fingers without webbing; tips of fingers expanded into discs, second to fourth with circummarginal grooves; tip of first finger smaller, without circummarginal groove; width of disc of finger III greater than the diameter of tympanum (TD 2.1 mm, FTD 2.7 mm); subarticular tubercles round, formula 1, 1, 2, 2; inner metatarsal tubercle oval, elongate; outer metatarsal tubercle absent.

Fig. 3. Dorsolateral view (A) and ventral view (B) of the female holotype (IEBR 4243) of *Amolops ottorum,* new species, in life. Photo = A. V. Pham.

Hind limbs long, HLL/SVL 1.71; tibia longer than thigh (FL 23.5 mm, TL 27.8 mm); relative toe length I<II<III<V<IV; tips of toes expanded into discs; width of disc of toe IV narrower than that of finger III; webbing formula I 0 – 1/3 II 0 – 1 III 0 – 1 IV 2 – 0 V; subarticular tubercles oval, formula 1, 1, 2, 3, 2; inner metatarsal tubercle elongate; outer metatarsal tubercle absent.

Skin texture in life: Dorsal surface of head, body and limbs smooth; supratympanic fold absent; dorsolateral fold absent; throat, chest, belly and ventral surface of thigh smooth.

Colouration in life: Dorsal surface of head and back green with some dark brown spots; head and body with a discontinuous dorsolateral cream stripe; side of head and flank green with some dark brown spots on upper part; upper lip green with a thin dark brown longitudinal stripe, the tip of snout cream; iris black, edged in white; tympanum dark brown; dorsal surface of fore and hind limbs green with dark crossbars; throat, chest and anterior part of belly light cream with brown dots; posterior part of belly cream;

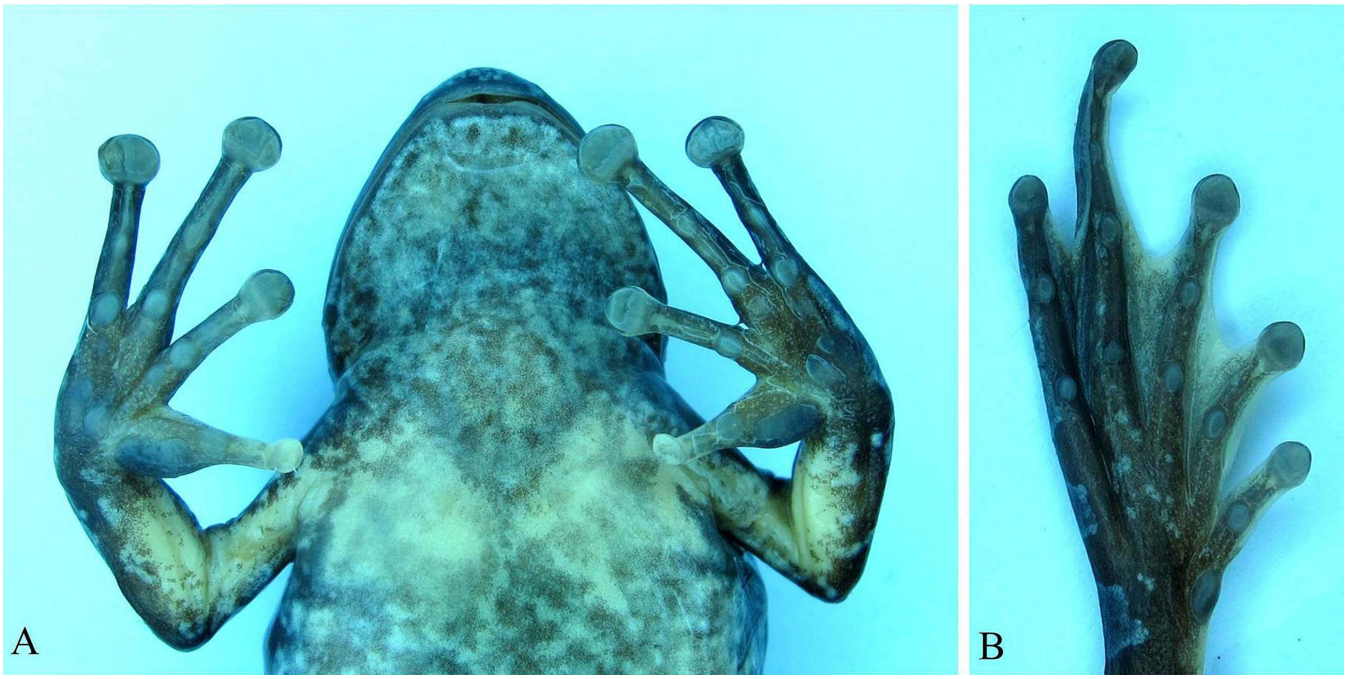

Fig. 4. Ventral side of head and chest (A) and foot (B) of the female holotype (IEBR 4243) of *Amolops ottorum,* new species, in preservative. Photo = A. V. Pham.

ventral surface of fore and hind limbs light brown with some greenish spots; toe webbing brown.

Colouration in preservative: Dorsum and flanks brown; head and body with a discontnuous light dorsolateral stripe; upper lip brown with a thin dark stripe; tympanum black; dorsal surface of fore and hind limbs brown with dark crossbars; throat, chest and anterior part of belly light grey with brown dots, posterior part white.

Variation. Measurements and morphological characters of the type series are given in Table 3.

Distribution. *Amolops ottorum,* new species is currently known only from the type locality in Muong La District, Son La Province, Vietnam (Fig. 1).

Etymology. The species name, *ottorum*, is the plural possessive form of Mrs Otti Ziegler and Mr Otto Ziegler, who facilitated herpetological research collaborations between Vietnam and Germany. For the common names we suggest Son La Sucker Frog (English) and Ếch bám đá sơn la (Vietnamese).

Ecological notes. The holotype was collected at 1905 hours on leaves, ca. 1.5 m above the ground and the paratype was collected at 500 hours on a rock nearby a stream. The surrounding habitat was secondary forest of medium and large hardwoods mixed with shrubs (Fig. 6). Air temperature was 17–22°C and relative humidity was 80–85%. Other amphibian species found at the site were *Leptobrachium* sp., *Leptobrachella* sp., *Quasipaa delacouri* (Angel), *Odorrana jingdongensis* Fei, Ye & Li, and *Kurixalus bisacculus* (Taylor).

Fig. 5. Dorsolateral view of the female paratype (TBU 06) of *Amolops ottorum,* new species, in life. Photo = A. V. Pham.

Comparisons. We compared the new species with other members of the genus *Amolops* and data obtained from the literature (Boulenger, 1899a, b, 1920; Smith, 1923, 1940; Pope, 1929; Andersson, 1939; Liu, 1950; Pope & Romer, 1951; Liu & Hu, 1961, 1975; Jiang, 1983; Wu & Zhao, 1984; Yang, 1991; Ray, 1992; Wu & Tian, 1995; Inger & Chanard, 1997; Inger & Kottelat, 1998; Inger et al., 1999; Liu & Yang, 2000; Liu et al., 2000; Bain et al., 2003, 2006; Bain & Nguyen, 2004; Zhao et al., 2005; Matsui & Nabhitabhata, 2006; Orlov & Ho, 2007; Rao & Wilkinson, 2007; Sengupta et al., 2008; Fei et al., 2009, 2010, 2017; Biju et al., 2010; Stuart et al., 2010; Dever et al., 2012; Sun et al., 2013; Sung et al., 2016; Jiang et al., 2016; Yuan et al., 2018) (Table 3).

In general appearance, *Amolops ottorum,* new species is similar to *A. granulosus* (Liu & Hu), *A. jinjiangensis* Su, Yang & Li, *A. lifanensis* Liu, *A. loloensis* Liu, *A. mantzorum*

Table 3. Measurements (in mm) and proportions of the type series of *Amolops ottorum*, new species (for other abbreviations see Material and Methods).

Character	IEBR 4243 Holotype Female	TBU 06 Paratype Female	Character	IEBR 4243 Holotype Female	TBU 06 Paratype Female
SVL	48.2	47.5	HLL	82.3	83.5
AG	26.7	25.7	FL	23.5	23.3
HL	16.0	15.1	TL	27.8	27.2
HW	14.9	14.6	FOT	37.4	38.0
HD	7.2	7.0	FTL	6.8	6.9
SE	6.8	7.0	FFTL	14.8	15.2
SND	3.3	3.2	HTD	2.1	2.2
END	3.1	3.1	MTT	2.7	2.5
IND	4.9	4.8	AG/SVL	0.55	0.54
UEW	3.2	3.3	HL/SVL	0.33	0.32
IOD	4.8	4.6	HW/SVL	0.31	0.31
ED	5.8	5.7	HD/SVL	0.15	0.15
TD	2.1	2.1	SE/SVL	0.14	0.15
TED	2.0	1.9	ED/HL	0.36	0.38
FLL	32.5	32.3	ED/SE	0.85	0.81
FFL	6.0	6.1	TD/ED	0.36	0.37
TFL	9.9	9.8	FLL/SVL	0.67	0.68
FTD	2.7	2.6	HLL/SVL	1.71	1.76

David, *A. tuberodepressus* Liu & Yang, and *A. xinduqiao* Fei, Ye, Wang & Jiang.

Amolops ottorum, new species differs from *A. granulosus* by having a tympanum visible (vs. indistinct in *A. granulosus*), the absence of vomerine teeth (vs. present in *A. granulosus*), and different dorsal colour pattern (green with some dark brown spots vs. brown with black spots in *A. granulosus*); from *A. jinjiangensis* by having a tympanum visible (vs. invisible in *A. jinjiangensis*), dorsolateral folds absent (vs. present in *A. jinjiangensis*), the absence of a pair of large tubercles on sides of cloaca (vs. present in *A. jinjiangensis*), and different dorsal colour pattern (green with some dark brown spots vs. light brown or bluish in *A. jinjiangensis*); from *A. lifanensis* by the absence of vomerine teeth (vs. present in *A. lifanensis*), having a tympanum visible (vs. invisible in *A. lifanensis*), skin smooth (vs. skin with glandular granules in *A. lifanensis*), and different dorsal colour pattern (green with some dark brown spots vs. bluish gray to olive brown stippled with black in *A. lifanensis*); from *A. loloensis* by having tympanum visible (vs. invisible in *A. loloensis*), flanks smooth (vs. small spinules on flanks in *A. loloensis*), dorsal colour pattern (green with some dark brown spots vs. dark green with many large brown spots in *A. loloensis*),

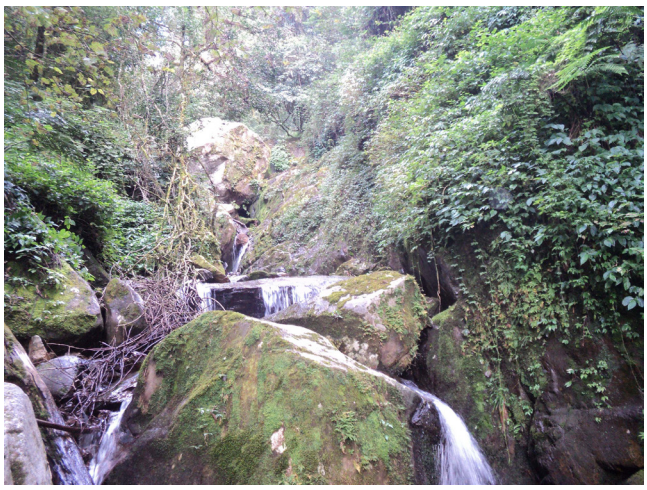

Fig. 6. Habitat of *Amolops ottorum,* new species, in Ngoc Chien Commune, Muong La District, Son La Province, Vietnam. Photo = N. B. Song.

tibiotarsal articulation reached to the nostril (vs. tibiotarsal articulation reached to the eye in *A. loloensis*), a head longer than wide (vs. wider than long or as long as wide in *A. loloensis*), and relative finger lengths: I<II<IV<III (vs. I = II<IV<III in *A. loloensis*); from *A. mantzorum* by the absence

Table 4. Morphological comparisons between *Amolops ottorum*, new species with other members of *Amolops* (morphological data obtained from the literature: Boulenger ,1899a,b, 1920; Smith 1923, 1940; Pope, 1929; Andersson,1939; Liu, 1950; Pope & Romer, 1951; Liu & Hu, 1961, 1975; Jiang, 1983; Wu & Zhao, 1984; Yang, 1991; Ray, 1992; Wu & Tian, 1995; Inger & Chanard, 1997; Inger & Kottelat, 1998; Inger et al., 1999; Liu & Yang, 2000; Liu et al., 2000; Bain et al., 2003, 2006; Bain & Nguyen, 2004; Zhao et al., 2005; Matsui & Nabhitabhata ,2006; Orlov & Ho, 2007; Rao & Wilkinson, 2007; Sengupta et al., 2008; Fei et al., 2009, 2010, 2017; Biju et al., 2010; Stuart et al., 2010; Dever et al., 2012; Sun et al., 2013; Sung et al., 2016; Jiang et al., 2016; Yuan et al., 2018). Abbreviations are as follows: ? = characters unobtainable; Y = Present; N = Absent; for other abbreviations see Material and Methods.

	SVL (mm)		Head longer and wide	Vocal sac in males	Dorsolateral fold	Tympanum	Groove on disk of first finger	Two oblique vomerine ridges	Outer metatarsal tubercle (Forelimbs)	Dorsal colour in life
	Males	Females								
A. ottorum, new species	?	47.5–48.2	HL>HW	?	N	Visible	N	N	N	Green with some dark brown spots
A. afghanus	45.6–62.9	67.7–94.1	HL<HW	Y	N	Visible	Y	Y	N	Light reticulation on more extensive brown background
A. akhaorum	34.9–37.2	58.8–62.5	HL>HW	Y	Y	Visible	Y	Y	N	Green with distinct brown mottling
A. albispinus	36.7–42.4	43.1–51.9	HL=HW	?	N	?	Y	Y	N	Olive–brown
A. aniqiaoensis	?	52.0	?	Y	Y	Invisible	Y	Y	N	Green
A. archotaphus	38.2–42.1	58.8–62.5	HL<HW or HL>HW	Y	Weak or N	Visible	Y	Y	Y	Olive green, with irregularly distributed small brown spots
A. assamensis	52.8–61.5	82.50–94.4	HL<HW	?	N	Visible	Base Y	Y	?	Olive green with rounded or irregular brown patches
A. australis	28.7–32.7	45.8–47.0	HL>HW	Y	N	Visible	Y	Y	Y	Light–gray, interspersed with irregular dark–brown spots and blotches
A. bellulus	45.9–50.1	63.6	HL>HW	N	Y	Visible	N	Y	N	Olive green with brown spots
A. caelumnoctis	71.3–73.7	78–90.6	HL>HW	N	N	Visible	N	Y	Y	Dark purple with numerous small round light yellow spots
A. chakrataensis	?	55.0	HL<HW	?	Y	Visible	?	Y	N	Slaty brown
A. chayuensis	?	51.4	?	Y	Y	Invisible	Y	Y	N	Green
A. chunganensis	34.0–39.0	44.0–54.0	HL>HW	Y	Y	Visible	Y	Y	N	Reddish brown above but light beneath
A. compotrix	31.4–42.6	55.6–56.9	HL>HW	Y	Y	Visible	Y	Y	Y	Dark blue–green
A. cremnobatus	32.0–34.0	?	HL<HW	N	Y	Visible	Y	Y	Y or N	Yellowish brown in life
A. cucae	40.7–44.6	65.8–68.0	HL>HW	Y	Y	Visible	Y	Y	Y	Light green
A. daiyunensis	36.0–58.0	44.0–63.0	HL<HW	N	N	Invisible	Y	N	?	Yellowish brown in life

	SVL (mm)		Head longer and wide	Vocal sac in males	Dorsolateral fold	Tympanum	Groove on disk of first finger	Two oblique vomerine ridges	Outer metatarsal tubercle (Forelimbs)	Dorsal colour in life
	Males	Females								
A. formosus	53.0	53.0–75.0	HL<HW	Y	N	Invisible	N	Y	Y	Bright green above, with sharplj–defined black or blackish spots
A. gerbillus	66.0	?	HL>HW	?	Y	Invisible	?	Y	N	Dark gray
A. gerutu	34.0–37.2	45.0–58.2	HL>HW	Y	N	Visible	Y	Y	Y	Dark–brown, overlain with irregular light–gray patches
A. granulosus	36.3–41.8	51.9	HL>HW	N	N	Invisible	N	Y	N	Brown with black spots
A. hainanensis	71.2–93.1	67.8–78.2	HL<HW or HL>HW	N	N	Visible	?	N	N	Olive above, spotted with black, or black with pale olive markings
A. himalayanus	74.0–75.0	80.0–83.0	HL<HW	Y	N	Invisible	Y	Y	N	Olive or greyish
A. hongkongensis	34.0–41.0	31.0–48.0	HL=HW	Y	N	Invisible	?	N	?	Yellowish brown
A. indoburmanensis	59.0–86.0	63.0–106.0	HL>HW	Y	N	Visible	Y	Y	Y	Brown with scattering of darker brown spotting or very faint lighter reticulation or both
A. iriodes	39.0–43.0	63.0	HL>HW	Y	Y	Visible	Y	Y	N	Iridescent light green with some black spots
A. jaunsari	?	?	HL=HW or HL<HW	Y	Y	Visible	Y	Y	Y	Dark olive green, lores with obscure lighter spots
A. jinjiangensis	43.0–52.0	58.0–65.0	HL>HW	?	N	Invisible	N	?	N	Green with brown spots
A. kaulbacki	70.0–72.0	63.0	HL=HW	N	N	Slightly visible	?	Y	Y	Bluish or green
A. kohimaensis	42.8–48.6	?	HL>HW	Y	Y	Visible	Weak	Y	N	Primarily medium brown
A. larutensis	35.0–40.0	53.0–57.0	HL>HW	N	N	Visible	Y	Y	N	Dark olive above with irregular darker and lighter blotches
A. liangshanensis	?	?	?	N	Y	?	N	Y	?	?
A. lifanensis	52.0–56.0	61.0–79.0	HL=HW	N	N	Invisible	N	Y	N	Olive on back, with dark irregular marks
A. loloensis	54.5–62.0	69.5–77.5	HL>HW or HL<HW	N	N	Invisible	N	N	?	Dark green with many reddish large brown spots

	SVL (mm)		Head longer and wide	Vocal sac in males	Dorsolateral fold	Tympanum	Groove on disk of first finger	Two oblique vomerine ridges	Outer metatarsal tubercle (Forelimbs)	Dorsal colour in life
	Males	Females								
A. longimanus	?	?	HL<HW	Y	Y	Invisible	?	?	N	?
A. marmoratus	38.2–48.1	69.8–79.0	HL>HW	N	N	Invisible	Y	Y	Y	Dark mottling interspersed with light chain pattern
A. mantzorum	48.8–57	57.5 – 72.0	HL>HW	N	N	Invisible	N	Y	N	Brown, with a few large green blotches
A. medogensis	95.0	92.6	?	Y	N	Visible	?	?	?	Green with distinct brown mottling
A. mengyangensis	38.3–38.7	60.0	HL>HW	Y	Y	Visible	?	N	?	Olive–brown
A. minutus	29.7–36.4	38.5–50.2	HL>HW	?	Weak	Visible	Weak	Y	N	Marble–brown with green speckles
A. monticola	41.0	65.0–75.0	HL=HW	Y	N	Visible	Y	Y	N	Green
A. nidorbellus	76.4–82.3	85.4–98.0	HL<HW	N	N	Visible	N	Y	Y	Brown with distinct green spots
A. nyingchiensis	48.5–58.3	57.6–70.7	HL>HW	N	Y	Visible	Y	Y	N	Light brown or yellowish brown
A panhai	31.7–33.9	47.2–57.5	HL>HW	Y	N	Visible	Y	Weak	N	Light reticulation on more extensive brown background
A. ricketti	42.0–60.5	53.5–67.0	HL<HW	N	?	?	Y	Y	N	Olive–brown with large dark spots or marblings
A. spinapectoralis	41.0–53.2	52.3–66.9	HL<HW	Y	N	Visible	Y	Y	N	Olive brown network surrounding large black spots
A. splendissimus	62.6–75.6	69.3–96.8	HL=HW	?	N	Slightly visible	Y	Y	Y	Dark purple with yellow spots
A. torrentis	27.8–32.8	34.4–41.4	HL=HW	Y	N	Visible	Y	N	Y	Brown or black in life, with scattered, irregular, dark brown spots on back
A. tuberodepressus	?	61.0–70.0	?	N	N	Invisible	N	?	?	Brown with green spots
A. viridimaculatus	72.7–82.3	83.0–94.3	HL<HW	N	N	Invisible	N	Y	Y	Brown with distinct green spots
A. vitreus	37.5–43.6	?	HL>HW	Y	Y	Visible	Y	Y	Y	Green with dark brown stippling and large brown spots that concentrate near sacrum
A. wenshanensis	35.7–39.9	43.7–45.6	HL>HW	Y	Y	Visible	Y	Y	N	Green

	SVL (mm)		Head longer and wide	Vocal sac in males	Dorsolateral fold	Tympanum	Groove on disk of first finger	Two oblique vomerine ridges	Outer metatarsal tubercle (Forelimbs)	Dorsal colour in life
	Males	Females								
A. wuyiensis	37.5–45.0	45.2–52.7	HL>HW	N	N	Invisible	Y	N	N	Brown
A. xinduqiao	41.2–47.5	48.5–56.6	HL<HW or HL=HW	N	N	Visible	N	Y	Y	Gray-brown, with indistinct gray spots
A. yunkaiensis	31.8–34.1	35.2–39.0	HL>HW	Y	N	Invisible	Y	N	N	Olive–brown or light brown

of vomerine teeth (vs. present in *A. mantzorum*), different dorsal colour pattern (green with some dark brown spots vs. brown with a few large green blotches in *A. mantzorum*), and hind limbs with dark crossbars (vs. without dark crossbars in *A. mantzorum*); from *A. tuberodepressus* by having a tympanum visible (vs. invisible in *A. tuberodepressus*), flanks smooth (vs. with flatter tubercles in *A. tuberodepressus*), and different dorsal colour pattern (green with some dark brown spots vs. brown with green spots in *A. tuberodepressus*); from *A. xinduqiao* by the absence of vomerine teeth (vs. present in *A. xinduqiao*), flanks smooth (vs. with tubercles in *A. xinduqiao*), a head longer than wide (vs. head wider than long or length equal to width in *A. xinduqiao*), and different dorsal colour pattern (green with some dark brown spots vs. gray-brown, in *A. xinduqiao*).

DISCUSSION

Our finding brings the total members of the genus *Amolops* to 12 in Vietnam (after Nguyen et al., 2009) and of the *A. mantzorum* species group to 10 (see Lu et al., 2014). This is also the first record of the group discovered in Vietnam, as all other recognised species are restricted to China (Table 2). Although some closely related species within the *A. mantzorum* clade (sensu Lu et al., 2014) have a low genetic divergence, 2.5–3.1% (Table 2), they have been demonstrated to represent separate species because there has been insignificant gene flow between populations of the species (Lu et al., 2014). The new species from Son La, Vietnam, is geographically isolated from closely related species of the *A. mantzorum* group, and unlikely to be in contact with their populations. Interestingly, many members of this groups have been recorded at high elevations: *A. jinjangenis* known from northern Yunnan and Sichuan provinces (China) at elevations between 1,020 and 2,000 m; *A. mantzorum* recorded from Gansu, Sichuan and Yunnan provinces (China) and eastern Bhutan at elevations of 900–2,900 m; *A. loloensis* known from southern Sichuan (China) at elevations of 1,840–3,700 m; *A. granulosus* recorded from eastern Sichuan to western Hubei provinces (China) at elevations from 650 to 1,750 m; *A. xinduqiao* known from Sichuan (China) at elevation of above 3,000 m (Frost, 2019); and the new species found in Son La Province (Vietnam) at elevation of above 2,100 m.

We are aware of the limitations of our study. Only two specimens of the new species were included in the analyses. Our field survey was conducted in November and the weather in northern Vietnam was cold for amphibian activities. At the moment, the phylogenetic placement of the new species is still weakly supported by all of our analyses as result of either incomplete taxon sampling or lack of informative molecular markers or both. However, it is important to note that positions of several other species in the group are not well corroborated. For the young radiation as shown by low genetic divergence, more data, from both mitochondrial and nuclear markers, need to be employed to resolve their phylogenetic relationships.

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APPENDIX

Comparative specimens examined.

Amolops compotrix (n=2): Vietnam: Son La Province: Copia Nature Reserve: TBU PAE.509, 516.

A. cremnobatus (n=6): Vietnam: Thanh Hoa Province: Pu Hu Nature Reserve: IEBR A.2013.106, 107; Thanh Hoa Province: Xuan Lien Nature Reserve: IEBR 4353–4356.

A. iriodes (n=4): Vietnam: Lao Cai Province: Bat Xat District: IEBR 4357–4360

A. ricketti (n=8): Vietnam: Cao Bang Province: Phia Oac-Phia Den National Park: IEBR 4361–4364; Vietnam: Quang Ninh Province: Hai Ha District: IEBR 4365, 4366; Vietnam: Bac Giang Province: Tay Yen Tu Nature Reserve: IEBR 4367, 4368.

A. spinapectoralis (n=5): Vietnam: Thua Thien Hue Province: A Luoi District: IEBR 4264-4266, Vietnam: Gia Lai Province: Kon Ka Kinh National Park: IEBR 4369, 4370.

A. vitreus (n=8): Vietnam: Son La Province: Copia Nature Reserve: TBU PAE.153, 154, 295, 296, 298, 361, 362, 517.