TWO NEW RHACOPHORID FROGS FROM CAT BA ISLAND, GULF OF TONKIN, VIETNAM

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Two new species of microsized rhacophorid frogs of the genera *Liuixalus* and *Philautus* are described from Cat Ba island, Gulf of Tonkin, Hai Phong Province, Vietnam, based on field work done in 2008 – 2011. A diagnosis of the genus *Liuixalus* is given, with discussion on estimated distribution of this genus. Both new species are potential endemics so far known only for Cat Ba island.

Keywords: *Liuixalus*; *Philautus*; new species; Rhacophoridae; Cat Ba; Hai Phong; Vietnam.

INTRODUCTION

Cat Ba island is located in Ha Long Bay, Gulf of Tonkin, Vietnam. This largest island of the Cat Ba Archipelago consisting of 366 small islands and islets is approximately 285 km^2 and is covered mainly by moist tropical forest on karstic rocks (Nadler and Ha, 2000; Furey et al., 2002; Nadler et al., 2002). Together with the islands of the Bai Tu Long Archipelago the Cat Ba Archipelago consist one of the largest karst areas in the world. This island is characterized by high levels of endemism in vertebrate fauna, including a recently described endemic species of eublepharid lizard *Goniurosaurus catbaensis* (Ziegler et al., 2008), and a skink *Sphenomorphus tonkinensis*, restricted to several karstic islands of the Gulf of Tonkin and the Hainan Island of China (Nguyen, Schmitz et al., 2011). As a result of previous herpetological surveys, about 17 species of amphibians and 40 species of reptiles were reported for the Cat Ba Island (Darevsky, 1990, 1999; Bobrov, 1993; Nguyen and Schim, 1997; Nguyen et al., 2009; Nguyen et al., 2011b).

Our investigations contributed towards the enrichment of Cat Ba herpetofauna by the discovery of two new species of rhacophorid frogs which we assume are endemic to the island. During field work in Cat Ba National Park in 2008 and 2011, several specimens of two previously unknown species of small-sized rhacophorid frogs were collected. The first species of small rhacophorid frogs was assigned to the genus *Philautus* (*sensu* Bossuyt and Dubois, 2001). These frogs strongly differ in morphology from other Vietnamese *Philautus* in a number of diagnostic characters and should be considered as a new species.

The frogs of the second species were assigned to the genus *Liuixalus*, which makes it the first record of this genus in Vietnam. This generic name was proposed in 2008 (Li et al., 2008) on the basis of phylogenetic position of *Chiromantis romeri*, which was recovered as a sister clade in respect to all other members of the subfamily Rhacophorinae. This basal phylogenetic position was subsequently supported by combined analysis of both mtDNA and nuclear DNA gene sequences (Li et al., 2008, 2009, 2013). However, the authors gave no morphological diagnosis or short description of the new genus and just indicate *Chiromantis romeri* (Smith, 1953) as the type species of the new genus *Liuixalus*. According to molecular genetic data, this new genus provisionally contains two species: *C. romeri* and one unidentified species (Li et al., 2008). Recently, two subsequent species from the Hainan Island, *Philautus haina-*

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Fig. 1. *Liuixalus romeri* (courtesy of Fei Liang).

nus and *Philautus ocellatus*, were also included in the genus *Liuixalus* (Li et al., 2009).

More recently, Hertwig et al. (2011) erroneously placed *Philautus albopunctatus* as a fourth species of this genus. Apparently authors associated tissue sample of the unidentified species or subspecies of *Liuixalus* with this invalid name. Identity of *Philautus albopunctatus* (Liu et Hu, 1962) and *Theloderma asperum* (Boulenger, 1886) was convincingly established by Yu et al. (2008). Hereby we consider *Philautus albopunctatus* as a subjective junior synonym of *Theloderma asperum* and remove this species from the genus *Liuixalus*.

Taxonomic status of several frog populations found in the Guangxi province of China (see Mo et al., 2007; Li et al., 2013) is unclear and requires further study. New discoveries of *Liuixalus* in karstic areas of southern China and northern Vietnam are anticipated. Morphological diagnosis and additional data on this yet practically "undescribed" rhacophorid genus *Liuixalus* with a description of the new species as well as a new species of the genus *Philautus* are given below.

MATERIAL AND METHODS

The authors conducted field work at Cat Ba National Park, Hai Phong province, Vietnam in 2008 and 2011 during the spring (April – May) and autumn (October – November) seasons. Specimens were fixed in 80% ethanol and later preserved in 70% ethanol. For preserved specimens, we took next body measurements (Tables 1 and 2): SVL, snout-vent length; A-G, axilla to groin, distance from posterior base of forelimb at its emergence from body to anterior base of hind limb at its emergence from body; HW, head width at the greatest cranial width; HL, head length from the rear of the lower jaw to the tip of the snout; HD, head depth, greatest transverse depth of head, taken beyond interorbital region; UEW, upper eyelid width: greatest width of upper eyelids; IOD, interorbital distance; ED, horizontal diameter of eye; TD, horizontal diameter of tympanum; ESL, tip of snout-eye distance; TED, tympanum-eye distance from anterior edge of tympanum to posterior corner of the eye; IND, internarial distance: distance between nostrils; END, eye to nostril distance: distance from anterior corner of eye to nostril; FLL, length of forelimb from tip of disk of finger III to axilla; FFL, first finger length; TFL, third finger length; FTD, maximal diameter of disc of finger III; NPL, nuptial pad length; MKT, length of metacarpal tubercles (MKTi, length of inner metacarpal tubercles; MKTe, length of exterior metacarpal tubercles). Formula of webbing by Glaw and Vences (1994); Orlov et al. (2006), where: i, inner side; e, exterior side of phalanges. We used dial calipers with accuracy 0.1 mm and binocular dissecting microscope for measurements taken. All recordings of *Liuixalus* sp. vocalization were made in Cat Ba National Park during 29 – 30 April 2011, around 23 h at temperature of 25°C. To record calls, we used camera Olympus SP800UZ in video mode. Calls parameters were analyzed in Adobe Audition CS6 program (version 5.0) and Avisoft SASLab Pro software v. 5.2.05 (Avisoft Bioacoustics, Berlin, Germany) with a 22.05 kHz sampling frequency and 16-bit precision. The general problem of these recordings is insignificant ratio of signal/noise. In spite of this, quality of some of calls allows to measure the main frequency and structural parameters.

SYSTEMATICS

Liuixalus Li, Che, Bain, Zhao et Zhang, 2008
Type species: *Philautus romeri* Smith, 1953

Diagnosis. Microsized rhacophorid frogs with free-swimming aquatic tadpole. Webbings strongly reduced in the forelimbs, toes one-third webbed. Hindlimbs long, tibio-tarsal articulation reaches between nostril and over tip of snout. Vomerine teeth absent, tongue notched, tympanum distinct. Discs on the digits well developed, discs of toes a little smaller than fingers ones. Skin on the dorsum verrucosed and marked by X-shape figure on the shoulders.

Included species. *Liuixalus romeri* (Smith, 1953); *Liuixalus ocellatus* (Liu et Hu, 1973); *Liuixalus hainanus* (Liu et Wu, 2004), Figs. 1 – 4; *Liuixalus* sp. nov. Taxonomic status of two *Liuixalus* populations reported from Guangxi Province (Li et al., 2008, 2009, 2013) requires further confirmation.

Distribution. China: Hongkong and adjacent small offshore islands, Hainan island, possibly also in the mainland (confirmed for Guangxi Province, also may be

TABLE 1. Measurements of *Liuixalus calcarius* sp. nov. (in mm)

	ZISP 10522 male	ZISP 10523 male	ZISP 10524 male	ZISP 10525 male	ZISP 10526 male	ZISP 10527 male	ZISP 10528 female	ZISP 10667 female	ZMMU A-4940-1 male	ZMMU A-4940-2 male	ZMMU A-4940-3 male	ZMMU A-4940-4 female
SVL	17.7	16.1	18.0	16.5	15.8	16.4	20.6	20.8	15.3	16.3	16.4	22.0
A-G	7.6	7.3	7.5	7.2	7.0	7.0	9.3	9.5	5.9	7.1	6.2	9.5
HL	6.9	6.0	6.0	5.8	5.7	5.4	6.7	7.1	5.4	5.4	5.6	7.3
HW	6.8	6.4	6.7	6.5	6.2	5.4	6.7	7.5	5.9	6.0	5.9	7.5
HD	3.4	3.3	3.5	3.3	3.1	3.3	4.1	4.2	3.5	3.5	3.6	4.6
UEW	2.4	2.3	2.6	2.2	2.2	2.3	2.9	2.9	2.2	2.1	2.3	3.0
IOD	3.8	3.1	3.5	3.5	3.2	3.2	3.7	4.1	3.4	3.2	3.3	4.2
ED	2.1	2.0	2.2	2.0	1.9	1.9	2.1	2.3	2.0	2.0	2.0	2.7
TD	1.2	1.6	1.2	1.2	0.9	1.0	1.4	1.3	0.9	1.0	1.0	1.5
ESL	3.0	2.4	3.0	2.8	2.7	2.8	3.4	3.4	2.6	2.7	2.7	3.6
TED	0.8	0.5	0.6	0.5	0.5	0.8	0.8	0.9	0.8	0.8	0.8	1.1
IND	2.0	1.9	1.9	2.0	1.8	1.8	2.2	2.2	1.9	2.0	1.9	2.4
END	1.5	1.3	1.5	1.4	1.3	1.3	1.9	1.7	1.3	1.3	1.3	1.7
FLL	10.1	9.6	9.8	9.9	9.5	9.7	11.5	12.1	10.0	10.1	10.1	13.4
FFL	1.2	1.1	1.3	1.2	1.3	1.2	1.3	1.4	1.2	1.2	1.1	1.9
TFL	3.0	2.0	2.6	2.5	2.2	2.3	2.8	3.0	2.5	2.2	2.2	3.1
FTD	0.7	0.6	0.8	0.8	0.6	0.6	0.9	0.9	0.7	0.7	0.6	1.0
NPL	1.5	1.4	1.6	1.6	1.4	1.4	No	No	1.2	1.5	1.1	No
MKTi	0.2	0.1	No	No	0.2	No	No	No	No	No	No	0.5
MKTe	0.3	0.3	No	No	0.3	No	No	No	0.2	No	No	No
Relative length of fingers	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3
Subarticular tubercles formula	1, 1, 2, 2	1, 1, 2, 2	1, 1, 2, 2	1, 1, 2, 2	1, 1, 2, 2	1, 1, 2, 2	1, 1, 2, 2	1, 1, 2, 2	1, 1, 2, 2	1, 1, 2, 2	1, 1, 2, 2	1, 1, 2, 2
HLL	27.3	26.8	28.7	27.3	26.3	27.4	32.6	33.2	27.2	27.7	27.2	34.7
FL	8.2	8.0	8.3	8.0	7.1	7.1	9.6	10.0	8.1	8.2	8.5	10.5
TL	8.8	8.4	8.5	8.5	8.4	8.4	10.0	10.9	8.9	9.1	9.1	11.3
FOT	11.4	11.0	12.0	11.8	11.5	12.2	14.0	14.5	11.9	12.0	11.7	15.8
FTL	1.6	1.2	1.6	1.5	1.5	1.4	2.0	2.0	1.4	1.4	1.3	2.3
FFTL	3.8	3.8	4.0	4.0	4.0	4.0	4.8	4.9	3.9	4.0	4.0	5.5
HTD	0.8	0.5	0.7	0.7	0.6	0.6	0.7	0.7	0.7	0.6	0.6	0.9
Relative toes length	1 < 2 < 3 = = 5 < 4	1 < 2 < 3 = = 5 < 4	1 < 2 < 3 = = 5 < 4	1 < 2 < 3 = = 5 < 4	1 < 2 < 3 = = 5 < 4	1 < 2 < 3 = = 5 < 4	1 < 2 < 3 = = 5 < 4	1 < 2 < 3 = = 5 < 4	1 < 2 < 3 = = 5 < 4	1 < 2 < 3 = = 5 < 4	1 < 2 < 3 = = 5 < 4	1 < 2 < 3 = = 5 < 4
Subarticul. tubercl. formula	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2
Webbing formula	I(1.5) IIi(1.5)e(1) IIIi(2.5)e(1.5) IVi(3)e(2.5) V(1)	I(1) IIi(1.5)e(1.5) IIIi(2.5)e(2) IVi(3)e(2.5) V(1.5)	I(1) IIi(1.5)e(1) IIIi(2.5)e(1.5) IVi(3)e(2.5) V(1)	I(1.5) IIi(1.5)e(1) IIIi(2.5)e(2) IVi(3)e(2.5) V(1)	I(1) IIi(1.5)e(1) IIIi(2.5)e(2) IVi(3)e(2.5) V(1)	I(1) IIi(2)e(1) IIIi(3)e(2) IVi(3.5)e(3) V(1.5)	I(1) IIi(2)e(1) IIIi(2.5)e(1.5) IVi(3)e(2.5) V(1)	I(1.5) IIi(2)e(1) IIIi(2.5)e(1.5) IVi(3)e(2.5) V(1.5)	I(1.5) IIi(1.5)e(1) IIIi(2.5)e(2) IVi(3)e(2.5) V(1)	I(1.5) IIi(2)e(1) IIIi(2.5)e(1.5) IVi(3)e(2.5) V(1)	I(1.5) IIi(2)e(1) IIIi(2.5)e(1.5) IVi(3)e(2.5) V(1)	I(1) IIi(2)e(1) IIIi(2.5)e(1.5) IVi(3)e(2.5) V(1)
MTTi	0.7	0.6	0.7	0.6	0.6	0.6	0.7	0.8	0.4	0.6	0.5	0.7
MTTe	0.3	0.3	0.3	No	No	No	0.3	0.3	No	No	No	0.4

TABLE 2. Measurements of *Philautus catbaensis* sp. nov.

	ZISP 10668 female	ZISP 10669 male	ZISP 10670 male	ZISP 10671 female	ZISP 10672 male	ZISP 10673 male	ZISP 10674 male	ZISP 10675 male	ZMMU A-4941 male
SVL	22.7	20.9	20.8	19.4	19.8	19.1	18.8	18.8	18.6
A-G	11.7	11.0	9.0	9.5	10.3	10.1	9.4	10.4	9.4
HL	8.3	6.7	7.2	6.9	7.0	6.8	6.7	6.8	6.4
HW	8.6	7.4	7.9	7.4	7.2	6.8	6.9	6.5	6.7
HD	4.6	3.9	3.5	3.5	3.6	3.5	3.5	3.5	3.0
UEW	3.3	2.3	3.0	3.0	2.8	3.0	2.7	2.7	2.6
IOD	5.1	4.2	4.2	4.1	4.2	4.1	4.0	4.1	3.9
ED	3.0	2.1	2.4	2.4	2.1	2.3	2.2	2.3	2.0
TD	1.2	1.1	1.1	1.1	1.1	1.1	0.9	1.1	1.0
ESL	4.0	3.5	3.6	3.6	3.6	3.4	3.4	3.5	3.1
TED	0.9	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.6
IND	2.6	2.3	2.3	2.1	2.1	2.2	1.8	2.1	2.0
END	2.1	1.7	1.8	1.7	1.9	1.6	1.8	1.7	1.6
FLL	13.7	13.0	12.5	12.4	12.5	11.7	11.5	11.6	10.9
FFL	2.0	1.8	1.5	1.7	1.5	1.6	1.4	1.5	1.3
TFL	3.7	3.3	3.2	3.1	3.2	3.0	2.7	2.9	2.7
FTD	1.0	1.0	1.1	0.9	1.0	1.0	0.9	1.0	1.0
NPL	No	No	No	No	1.3	1.3	No	No	No
MKTi	0.9	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.6
MKTe	0.7	0.6	0.5	0.6	0.4	0.5	0.6	0.6	0.5
Relat. length of fingers	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3	1 < 2 < 4 < 3
Subarticular tubercles formula	1, 1, 2, 1	1, 1, 2, 1	1, 1, 2, 1	1, 1, 2, 1	1, 1, 2, 1	1, 1, 2, 1	1, 1, 2, 1	1, 1, 2, 1	1, 1, 2, 1
HLL	33.2	31.7	31.2	29.6	29.7	29.0	28.5	28.6	28.4
FL	9.6	9.6	9.2	8.9	9.0	8.4	8.3	8.6	8.4
TL	11.0	11.0	9.5	9.6	9.5	8.9	8.9	9.2	9.0
FOT	14.2	13.0	13.1	12.5	12.5	11.8	11.9	12.0	11.9
FTL	2.0	1.7	1.8	1.7	1.6	1.6	1.7	1.6	1.6
FFTL	4.5	3.1	4.1	4.0	4.1	3.9	3.7	3.8	3.7
HTD	1.0	1.0	0.8	0.9	0.9	0.8	0.9	0.9	0.8
Relative toes length	1 < 2 < 3 < 5 < 4	1 < 2 < 3 < 5 < 4	1 < 2 < 3 < 5 < 4	1 < 2 < 3 < 5 < 4	1 < 2 < 3 < 5 < 4	1 < 2 < 3 < 5 < 4	1 < 2 < 3 < 5 < 4	1 < 2 < 3 < 5 < 4	1 < 2 < 3 < 5 < 4
Subarticul. tubercl. formula	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2	1, 1, 2, 3, 2
webbing formula	I(0) IIi(1)e(0) IIIi(1.5)e(0) IVi(1)e(0.5) V(0)	I(1) IIi(1)e(0) IIIi(1)e(0) IVi(1)e(1) V(0.5)	I(1) IIi(2)e(0) IIIi(1)e(0) IVi(1.5)e(1) V(0.5)	I(1) IIi(1)e(0.5) IIIi(1)e(0.5) IVi(1.5)e(1) V(0.5)	I(1) IIi(1)e(0.5) IIIi(1)e(0) IVi(1.5)e(1) V(0.5)	I(0.5) IIi(1)e(0.5) IIIi(1)e(0.5) IVi(1)e(1) V(0)	I(0.5) IIi(1)e(0) IIIi(1)e(0.5) IVi(1)e(1) V(0.5)	I(1) IIi(1.5)e(0) IIIi(1)e(0.5) IVi(1.5)e(1) V(0.5)	I(0.5) IIi(1)e(0) IIIi(1.5)e(0.5) IVi(1.5)e(1) V(0.5)
MTTi	1.0	0.7	0.9	0.9	0.9	0.7	0.7	0.7	0.7
MTTe	No	No	No	No	No	No	No	No	No

Fig. 2. *Liuixalus ocellatus*, male, Hainan, 2005.

Fig. 3. *Liuixalus ocellatus*, female, Hainan, 2005.

found in Guangdong Province); Vietnam: Hai Phong province: Cat Ba island. For distribution of known records of *Liuixalus* see Fig. 5.

Liuixalus calcarius **sp. nov.**
(Figs. 6 – 11)

Holotype. ZISP 10522, an adult male, collected near Viet Hai village, Cat Ba island, Hai Phong province, Vietnam, 29 – 30 April 2011 by Nikolai L. Orlov, Konstantin D. Milto, and Roman A. Nazarov.

Paratypes. ZISP 10523 – 10527, five adult males; ZISP 10528, one adult female, collected near Viet Hai village, Cat Ba island, Hai Phong province, Vietnam, 29 – 30 April 2011 by Nikolai L. Orlov, Konstantin D. Milto, and Roman A. Nazarov; ZISP 10667, one adult female, collected at Cat Ba island, Hai Phong province, Vietnam, April 2008 by Nikolai L. Orlov; ZMMU A-4940-1; ZMMU A-4940-2; ZMMU A-4940-3, three males and ZMMU A-4940-4, one adult female, collected at Cat Ba island, Hai Phong province, Vietnam, 10 – 22 October 2011 by Nikolay A. Poyarkov and Eduard A. Galoyan. All specimens were found at the type locality on limestone placers in the tropical forest.

Etymology. The Latin adjective *calcarius* means "limestone," referring to the limestone karstic habitat of the new species.

Diagnosis. A *Liuixalus* with short body and obtusely pointed snout; tympanum well distinct and two times lesser than eye; dark colored X-shape fringes on the back in both sexes and with large black blotches on the sides in

Fig. 4. *Liuixalus hainanus*, male, Hainan (courtesy of Che Jing).

females. *Liuixalus calcarius* sp. nov. is characterized by a combination of the following characteristics: body compact; head relatively large and broad; snout obtusely pointed; nostril round, cut in lateral direction of snout; nostril closer to tip of snout than to eye; rostral canthi rounded, deeply concave; lores concave and depressed; eye large, diameter of eye less than length of snout; interorbital wider than eyelid; tympanum visible, a little less than eye diameter; vomerine teeth absent. Discs on fingers in medium size; webbing strongly reduced; subarticular tubercles well developed. Toe discs smaller

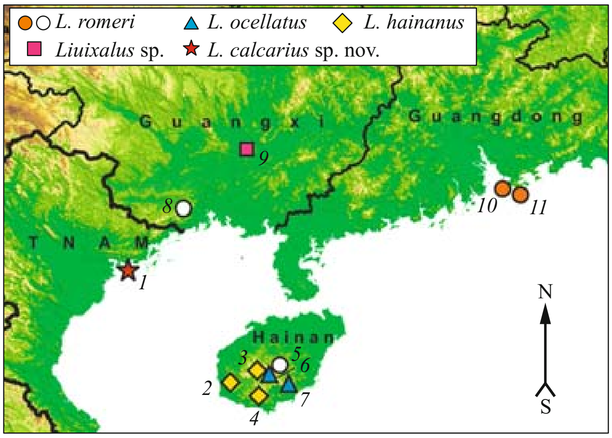

Fig. 5. Distribution of known representatives of the genus *Liuixalus*. Unconfirmed localities for *L. romeri* (*sensu* Li et al., 2013) are given in white. Localities: *1*, Cat Ba island, Hai Phong Province, Vietnam (this paper); *2*, Jiangfengling, Hainan Province, China (Fei et al., 2009; Shi et al., 2011); *3*, Yinggeling, Hainan Province, China (Fei et al., 2009; Li et al., 2013; Shi et al., 2011); *4*, Diaoluo-shan Mt., Hainan Province, China (Fei et al., 2009; Li et al., 2013; Shi et al., 2011); *5*, *6*, Wuzhi-shan Mt., Hainan Province, China (Li et al., 2013); *7*, Sifang-shan Mt., Hainan Province, China (this paper); *8*, Shiwan-shan Mt. , Guangxi Province, China (Mo et al., 2007; Li et al., 2008, 2009; indicated as *L. romeri* by Li et al., 2013); *9*, Dayao-shan Mt., Guangxi Province, China (Li et al., 2008, 2009; indicated as *L. hainanus* by Li et al., 2013); *10*, Chep Lap Kok and Lamma islands, Hongkong, China (Karsen et al., 1986; Fei et al., 2009); *11*, Lantau and Po Toi islands, Hong Kong, China (Fei et al., 2009).

Fig. 6. *Liuixalus calcarius* sp. nov., male, Cat Ba, 2011.

Fig. 7. *Liuixalus calcarius* sp. nov., male, Cat Ba, 2011.

Fig. 8. *Liuixalus calcarius* sp. nov., female, Cat Ba, 2011.

than finger discs; toes webbed only one third; two or three phalanges being free; third and fifth toes in equal size; external metatarsal tubercle not distinct; hind limbs relatively long; tibia-tarsal articulation reach over nostril; dorsal skin weekly verrucosed; X-shaped dorsal pattern weekly warted from head to near groin; ventral skin smooth; nuptial pad in males well developed and light colored; throat vocal sac dark colored; background dorsal coloration brown henna-reddish; lateral parts of head and interorbital region dark colored; dorsal dark X-shape pattern from behind eye to sacrum; white line along middle of back; humerus, sacrum, base of femur and tibia colored in henna-red; ventrum light colored with black spots; several large irregular blotches on flanks in females.

Description of holotype. Adult male, body length 17.7 mm, body compact and gentle; head big and broad, as long as broad; snout obtusely pointed (16.8% of SVL); rostral canthi deeply concaved, lores oblique and concave; eye large (ED 2.1 mm); pupil horizontal; nostril closer to tip of snout than to eye; tympanum distinct and medium sized, more than half width of eye; distant from eye by 1/3 its own diameter; interorbital wider than eyelid; vomerine teeth absent; tongue without papilla, deeply

Fig. 9. *Liuixalus calcarius* sp. nov., female, Cat Ba, 2011.

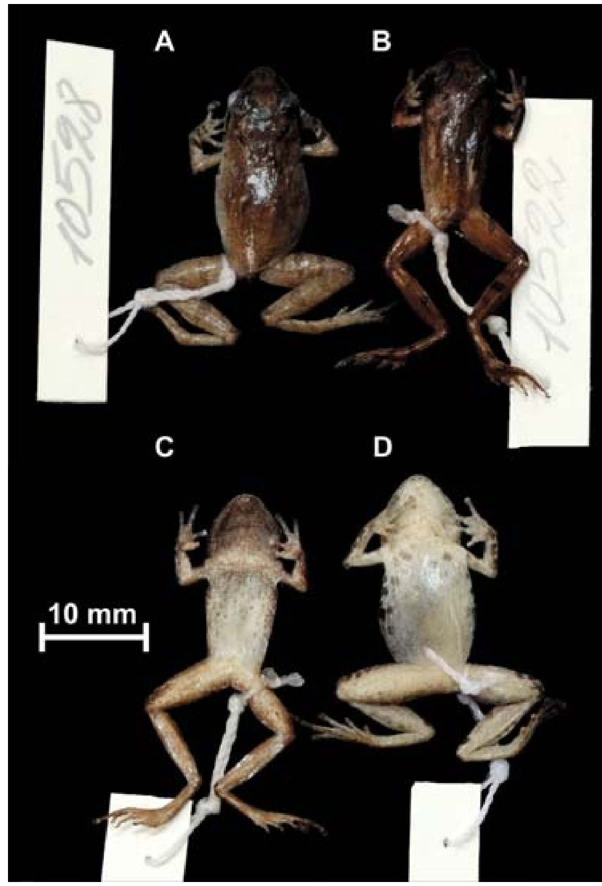

Fig. 10. **A**, **D**, paratype of *Liuixalus calcarius* sp. nov., ZISP 10528, female; **B**, **C**, holotype of *Liuixalus calcarius* sp. nov., ZISP 10522, male.

notched posteriorly; nostril round, cut in lateral direction and closer to tip of snout than to eye; skin on dorsum and limbs verrucosed, ventral skin smooth; dorsolateral fold absent, visible fold from eye to shoulder; throat smooth, dark colored; forelimb length 10.1 mm, relative length of fingers: I < II < IV < III; finger discs well developed, third finger disc wider than half of tympanum diameter; fingers without webbing; subarticular tubercles clearly visible with formula: 1, 1, 2, 2; large white nuptial pad on the first metacarpal of first finger; hindlimbs long and slender; length 27.3 mm about 2.7 times forelimb length (10.1 mm); tibia length 49.5% of SVL; first toe length 9.2% of SVL; fourth toe length 21.7% of SVL; relative toes length I < II < III = V < IV; toes with rounded discs that smaller than in fingers; webs between toes poorly developed; toes one-third webbed; three phalanges of fourth toe being free; oval inner metatarsal tubercle well developed; wart-like exterior metatarsal tubercle very small; subarticular tubercles distinct, roundish: 1, 1, 2, 3, 2; webbing formula I(1.5) IIi(1.5)e(1) IIIi(2.5)e(1.5) IVi(3)e(2.5) V(1).

Coloration in life. Dorsal coloration is brown, henna-reddish with dark X-shape pattern on the shoulders from behind the eyes to the sacrum and dark colored band in the interorbital region. Humerus, sacrum, femur base and tibia are colored in the henna-red. Several transverse dark bands on the legs: two bands on the femur, three — on the tibia and three — on the foot. Nuptial pad light colored; throat vocal sac dark colored, iris bicolored. Ventral side is light.

Coloration in alcohol. Dorsal pattern in alcohol correspond with color in life with intensity decreasing to grayish-brown color.

Measurements of holotype (in mm). Body and head: SVL 17.7; A-G 7.6; HL 6.9; HW 6.8; HD 3.4; UEW 2.4; IOD 3.8; ED 2.1; TD 1.2; ESL 3.0; TED 0.8; IND 2.0; END 1.5. Forelimbs: FLL 10.1; FFL 1.2; TFL 3.0; FTD 0.7; NPL 1.5; MKTi 0.2; MKTe 0.3. Hindlimbs: HLL 27.3; FL 8.2; TL 8.8; FOT 11.4; FTL 1.6; FFTL 3.8; HTD 0.8; MTTi 0.7; MTTe 0.3.

Variation and measurements of paratypes (in mm). Variation in all type material is given in Table 1. *Liuixalus calcarius* exhibits strong sexual dimorphism in body size and color pattern. Females are larger than males, SVL 21.1 (20.6 – 22.0, $n = 3$) in females and 16.5 (15.3 – 18.0, $n = 9$) in males; females have larger eyes, ED 2.4 (2.1 – 2.7, $n = 3$) in females and 2.0 (1.9 – 2.2, $n = 9$) in males; tympanum size also notably larger, TD 1.4 (1.3 – 1.5, $n = 3$) in females and smaller, 1.1 (0.9 – 1.6, $n = 9$) in males. Metacarpal tubercles are better expressed in mature males and not visible in females. Regarding body coloration, males are notably darker and females vary greatly from males by lighter coloration (beige to gray brown) and by the presence of large irregular dark (brown to black) blotches on the flanks.

Calls. Recordings of a specimen in 29 – 30 April 2011, 23:19, near Viet Hai village, Cat Ba National Park. Calls consisted of a series of up to 101 notes during 33 sec. During first 20 sec each two notes generate two-notes cluster. Temporal call parameters: note duration 12 – 17 and 11 – 15 msec with interval duration between clusters 11 – 15 msec, note repetition rate 3 clusters/sec. Two frequencies were recognizable, at 5100 and 2800 Hz for two types of note respectively (Fig. 12).

Comparisons. All species of genus *Liuixalus* differ from *Rhacophorus* and *Polypedates* by small body size, absence of vomerine teeth and strongly reduced webbing; they also differ from members of *Gracixalus*, *Kurixalus*, and *Raorchestes* by web reduction on the forelimbs, very short webs between toes and their small body size. They also can be distinguished from *Philautus* and *Feihyla* by verrucosed skin in life and the equal size/length of the third and fifth toes. In contrast to Asiatic species of the genus *Chiromantis*, these frogs are characterized by a relatively short body, obtusely pointed snout, not opposite first finger (not sure what this means), and X-shaped dark colored mark on the shoulders. In comparison with *Theloderma* and *Nyctixalus* species, *Liuixalus* has no skin asperities, fringes on the body and the presence of an X-shaped dark colored mark on the shoulders. *Liuixalus calcarius* is allopatrically distributed with other species of the genus. It can be distinguished from *L. romeri* by an off-white belly and verrucosed skin on the dorsal surface of the limbs (vs. dark coloration of ventral surface in *L. romeri*). *Liuixalus calcarius* differs from *Liuixalus ocellatus* by the following characteristics: tibiotarsal articulation reaches the tip of snout and over (does not reach the tip of snout in *L. ocellatus*); back is colored in henna-brown in comparison to green-brown in *L. ocellatus*. In comparison to *L. hainanus*, it differs by the absence of beige speckling (present in *L. hainanus*) on the dorsum and no yellow shade on the ventral surfaces.

Habitat and natural history. All specimens of the new species were observed in the Cat Ba National Park in limestone landscape covered by primary tropical forest. Typical habitats of the species are located on the mountainous forested slopes with aggregations of big stones

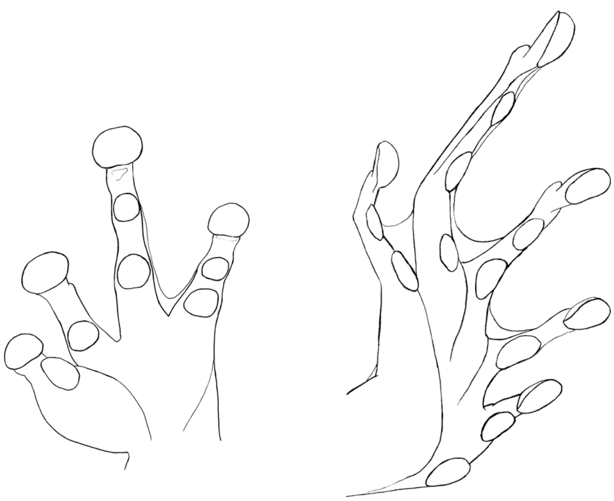

Fig. 11. Forelimb and hindlimb of *Liuixalus calcarius* sp. nov.

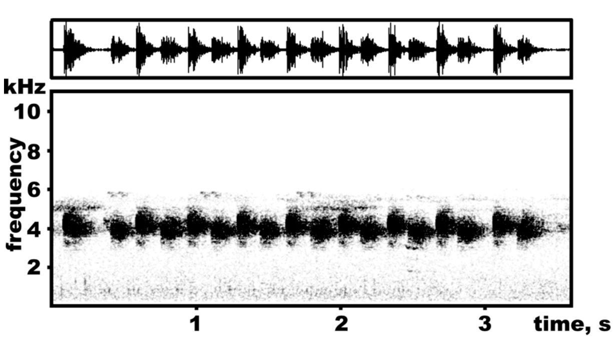

Fig. 12. Spectrogram (below) and waveform (above) of calls series of *Liuixalus calcarius* sp. nov. The recording was high-pass filtered (above 5.5 kHz) to avoid high-frequency noise. Calls for figure spectrograms were digitized with 22005 Hz sampling frequency. Figure spectrograms were created using Hamming window, FFT-length 512 points, frame 100%, and overlap 75%.

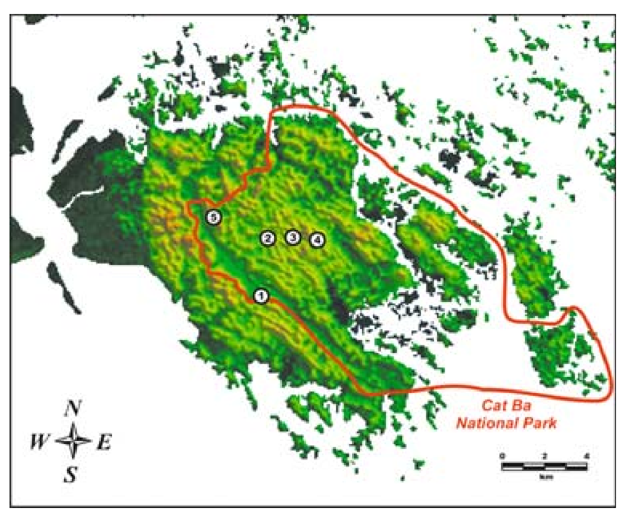

Fig. 13. Distribution of *Liuixalus calcarius* sp. nov. in the Cat Ba Island, gulf of Tonkin, Vietnam. Approximate borders of the Cat Ba National Park are shown in red. Localities: *1*, Dong Trung Trang Cave; *2*, National Park headquarters — Ao Ech trail; *3*, Ao Ech Lake; *4*, Ao Ech — Tai Lai trail (Viet Hai); *5*, Dong Nha The Cave.

and limestone rocks with numerous crevices and holes, where animals hide during day time. In April 2011, all specimens were caught at night on the surface of limestone rocks or in small caves, especially while the males vocalized. In October 2011, all males and females were recorded in extremely small depressions with water on the surface of the limestone blocks. Two males were recorded at the entrance to a large limestone cave (Trung Trang cave). It is likely that these sites are used by the frogs for breeding. During the daytime, the frogs hide in the fissures of the karst.

Distribution. Species is up to date known only from five localities within the territory of Cat Ba National Park, especially in the central part of Cat Bat island (see Figs. 13 – 15). Frogs were recorded in the following localities near temporary lake Ao Ech (Tran Chau) (loc. 3, Fig. 13) in the small mountain dale surrounded by karstic upland with primary forest; on the trail from the National Park headquarters Truong Tran — Ao Ech (loc. 2, Fig. 13) and Ao Ech — Tai Lai (Viet Hai) (loc. 4, Fig. 13) in the karstic hills covered by primary and weakly disturbed forest; in the surroundings of Viet Hai village with highly disturbed forest on the limestone. The frogs were also found near the karstic cave Dong Trung Trang (loc. 1, Fig. 13) and the cave Dong Nha The (loc. 5, Fig. 13) on the hill slope with highly disturbed forested areas.

***Philautus catbaensis* sp. nov.**
(Figs. 16 – 17)

Holotype. ZISP 10672, an adult male, collected in Cat Ba National Park, Cat Ba island, Hai Phong province, Vietnam, October 1, 2008 by Sergey A. Ryabov.

Paratypes. ZISP 10669, 10670, 10673 – 10675, five adult males; ZISP 10668, 10671, two adult females, ZMMU A-4941, one adult male; all collected in Cat Ba National Park, Cat Ba island, Hai Phong province, Vietnam, October 1, 2008 by Sergey A. Ryabov.

Fig. 14. Limestone mountain ridge near Viet Hai village.

Fig. 15. Limestone habitat in tropical forest on the Ao Ech trail.

Etymology. The specific name *catbaensis* is a toponymic adjective which refers to the type locality of the new species.

Diagnosis. A small sized *Philautus* with a relatively large head and extensive webbing on the foot. Tympanum distinct and two times lesser than eye; large lateral red spot on posterior part of flank. *Philautus catbaensis* is characterized by a combination of the following morphological features: body relatively slender; head large and broad; snout rounded, slightly prominent at the end; nostril round, cut in lateral direction of snout; nostril closer to tip of snout than to eye; canthi distinct, rounded; lores oblique, concave; eye moderately large, diameter of eye less than length of snout; interorbital distance visible wider than eyelid; tympanum distinct, two times bigger than eye; vomerine teeth absent. Finger discs large; disc of third finger smaller than tympanum; three outer fingers with rudiment of web at base; subarticular tubercles well developed. Toe discs smaller than finger discs; web reaches between subarticular tubercle and disc; inner metatarsal tubercle low, oval; no outer metatarsal tubercle. Hind limbs relatively short, tibia-tarsal articulation reach eye. Skin smooth dorsally and ventrally; supratympanic fold weakly curved. Background dorsal coloration brownish or gray; lateral side with brown spots in females; large red lateral spot near groin in both sexes. Bifurcated dark colored bar between eye; two dark marks from behind eye to anal; irregular white spot under eye; anal region brown bordered white edge. Forelimb and hind limb light colored with brown bands. Ventrum white; pale spots on ventral surface in females.

Description of holotype. Adult male, body length 19.8, habitus gentle; head large and broad (HL 7.0, HW 7.2); snout rounded, a slightly prominence at end (18.1% of SVL); canthi rounded, sloping; lores concave; eye moderate in size (ED 2.1 mm); pupil horizontal; nostril closer to tip of snout than eye; tympanum distinct, more than half diameter of eye; distant from eye by 2/3 its own diameter; interorbital distance wider more the two times eyelid; vomerine teeth absent; tongue round without papilla, deeply notched posteriorly; nostril round, cut in lateral direction and closer to tip of snout than to eye. Skin smooth dorsally and laterally; supratympanic fold weak; dorsolateral fold absent; throat smooth, white colored. Forelimb length 12.5 mm, relative length of fin-

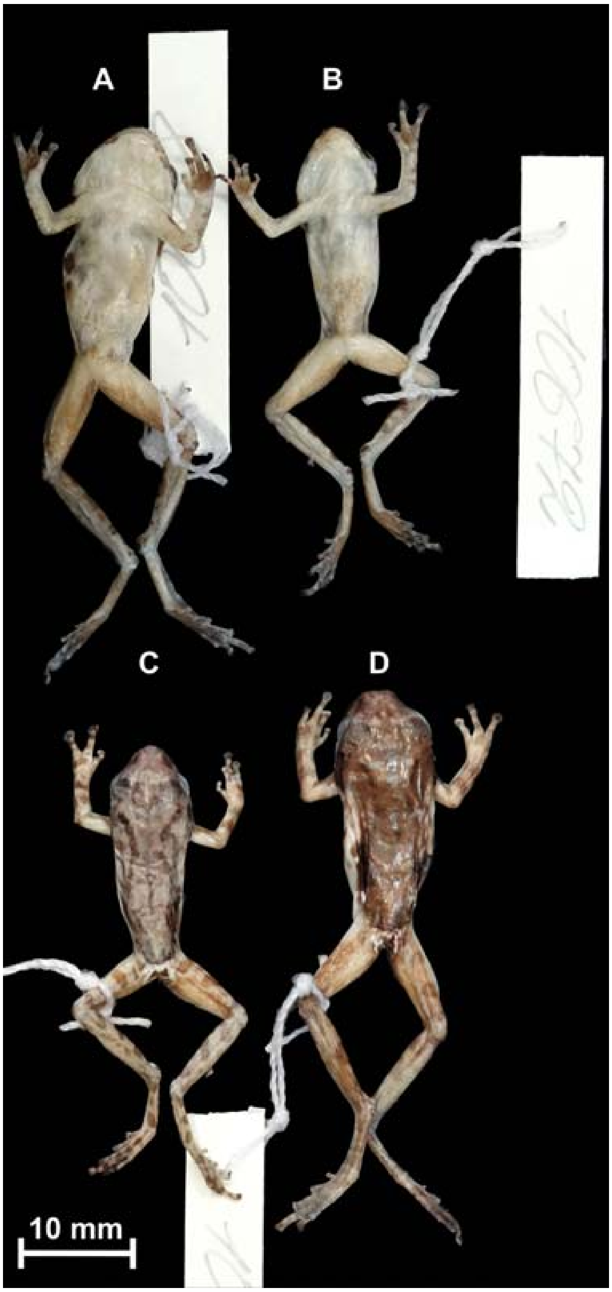

Fig. 16. **A**, **D**, paratype of *Philautus catbaensis* sp. nov., ZISP 10668, female; **B**, **C**, holotype of *Philautus catbaensis* sp. nov., ZISP 10672, male.

gers: I < II < IV < III; finger discs large, well developed; third finger disc little smaller than diameter of tympanum; three outer fingers with rudiment of web at base; subarticular tubercles conspicuous; subarticular tubercles formula: 1, 1, 2, 1; nuptial pad absent. Hindlimbs moderate in size; length 29.7 mm about 2.4 times forelimb

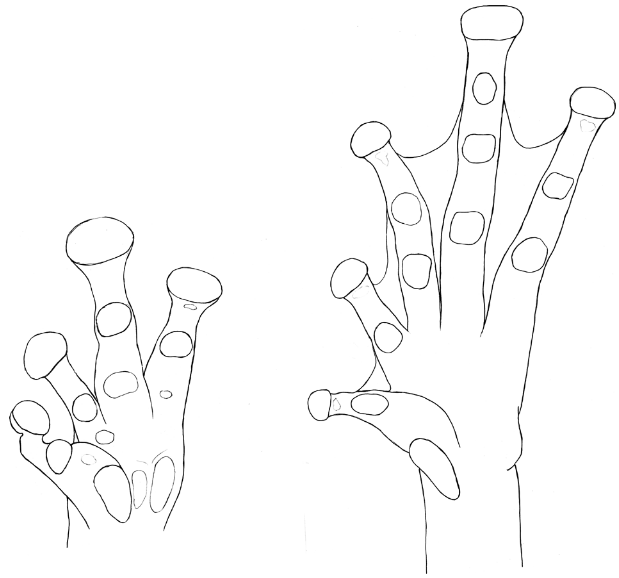

Fig. 17. Forelimb and hindlimb of *Philautus catbaensis* sp. nov.

length (12.5 mm); tibia length 48.2% of SVL; first toe length 8.1% of SVL; fourth toe length 20.6% of SVL; relative toes length I < II < III < V < IV. Discs of toes smaller than those of fingers, with rounded discs; subarticular tubercles conspicuous and rounded: 1, 1, 2, 3, 2; inner metatarsal tubercle low, oval; no exterior metatarsal tubercle; webs well developed; webbing formula I(1) IIi(1)e(0.5) IIIi(1)e(0) IVi(1.5)e(1) V(0.5).

Coloration in life. No data.

Coloration in alcohol. Dorsal coloration is gray; temporal region, interorbital and dorsal pattern is brown; large reddish lateral spot near groin. Interorbital pattern forms a triangular spot; disconnected X-shaped dorsal pattern from behind eyes to anus; short line in the middle of sacrum. Irregular-shaped white spot under eye. Anal region brown in center and surrounded by white broad edging. Forelimb and hindlimb light colored with brown transverse bands along the full length including fingers and toes. Ventrum light colored; throat white; light brownish pigmentation on basal part of belly and lower surface of femur.

Measurements of holotype (in mm). Body and head: SVL 19.8; A-G 10.3; HL 7.0; HW 7.2; HD 3.6; UEW 2.8; IOD 4.2; ED 2.1; TD 1.1; ESL 3.6; TED 0.7; IND 2.1; END 1.9. Forelimbs: FLL 12.5; FFL 1.5; TFL 3.2; FTD 1.0; NPL 1.3; MKTi 0.8; MKTe 0.4. Hindlimbs: HLL 29.7; FL 9.0; TL 9.5; FOT 12.5; FTL 1.6; FFTL 4.1; HTD 0.9; MTTi 0.9.

Variation and measurements of paratypes (in mm). Variation in all type material is given in Table 2. *Philautus catbaensis* exhibits sexual dimorphism: females are slightly larger than males, SVL 19.4, 22.7 in females and 19.5 (18.6 – 20.9, n = 7) in males; females also have larger eyes, ED 2.4, 3.0 in females and 2.2 (2.0 – 2.4, n = 7) in males. Dorsal background coloration is also different in both sexes where females are brown, males are gray or gray-brown. In females, the flanks are white with several brown spots, ventrum with pale spots. Males are without clear spots and the ventrum is white.

Comparisons. *Philautus catbaensis* differs from members of *Rhacophorus* and *Polypedates* by having a smaller body size and the absence of vomerine teeth; it can be distinguished from *Kurixalus* by the smaller body size, gentle habitus, absence of web on the arm and opposite first finger. It differs from *Gracixalus* species by having well developed webbing on its hindlimbs and absence of spines, tubercles and warts on the body. In comparison with members of genera *Theloderma* and *Nyctixalus*, *Philautus catbaensis* has no skin asperities and fringes on the body and presence of X-shaped dark colored mark on the dorsum. Differs from Asiatic members of *Chiromantis* and *Feihyla* by broad head with short nose, X-shaped dorsal pattern and presence of lateral reddish spot near groin; differs from Indo-Chinese species of *Raorchestes* by gentle habitus, well developed hindlimb webbing and large tympanum. *Philautus catbaensis* differs from all Vietnamese species of *Philautus* by small body size and presence of reddish spot near groin. Also *Philautus catbaensis* differs from *Ph. petilus* by body coloration and X-shaped dorsal pattern, as well as by absence of bicolored iris; from *Ph. maosonensis* by smooth skin and large tympanum; from *Ph. abditus* by visible tympanum and disconnected X-shape pattern on the dorsum.

Habitat and natural history. All specimens of the new species were observed in limestone landscape covered by primary tropical forest. In October 2008, all males and females were collected on the vegetation in the night time on the trail from the National Park headquarters Truong Tran — Ao Ech (loc. 2, Fig. 13).

Distribution. Species is found only on Cat Bat island, Hai Phong province, Vietnam.

DISCUSSION

According to the latest review of the Vietnamese herpetofauna (Nguyen et al., 2009), the list of anurans of the Cat Ba Islands includes only four species of the family Rhacophoridae (*Chiromantis vittatus*, *Kurixalus appendiculatus*, *Polypedates leucomystax* (= *P. megacephalus*), *Polypedates mutus*). During field work on the Cat Ba Island in 2008 – 2011, we recorded nine species of rhacophorids (*Chiromantis doriae*, *Chiromantis vittatus*, *Kurixalus appendiculatus*, *Liuixalus calcarius* sp. nov., *Philautus catbaensis* sp. nov., *Polypedates megacephalus*, *Polypedates mutus*, *Theloderma asperum*, *Theloderma corticale*), indicating that the rhacophorid fauna of the island has increased more than twofold. Interestingly, the island batrachofauna is predominately composed of species that are distributed in the mountainous regions of the north-eastern Vietnam and eastern Yunnan (China), and species with wide Indochinese distribution or Pan-Asiatic species. All species of amphibians and reptiles known to be endemic to the Cat Ba Island are associated with karstic forests, these include the two rhacophorid frogs described herein and the endemic gecko species *Goniurosaurus catbaensis*.

Currently, genus *Liuixalus* has distribution in Hainan and Hong Kong off-shore islands (Smith, 1953; Liu et Hu, 1973; Liu et al., 2004; Li et al., 2008; Fei et al., 2009; Shi et al., 2011). Our record of new *Liuixalus* on the territory of Vietnam considerably expands the range of the genus and is the first record of this genus out of China. Apparently, these frogs have a broader distribution from the northern Vietnam up to Guangxi and, assumingly, Guangdong provinces of China, and Hong Kong (see Fig. 5). The most part of *Liuixalus* distribution range is located on the offshore islands, however recently two localities in the Guangxi Province of China were reported. The latter, however, have no certain taxonomic identification and their status requires clarification. In spite of the peculiar insular distribution of *Liuixalus*, new discoveries of these small frogs can be in the mountainous areas on northern Vietnam and adjacent parts of southern China (Guangxi, Guangdong and, possibly, Yunnnan provinces). The anticipated distribution of *Liuixalus* is likely associated with spacious limestone areas situated from the south of Guangxi Province to northern Vietnam. Thus the karst massifs of these territories should be examined for the presence of the new *Liuixalus* populations.

The new species, *Liuixalus calcarius* and *Philautus catbaensis* likely are endemic to the Cat Ba Island or possibly have quite limited distribution restricted to the adjacent offshore islands of the Cat Ba Archipelago. Therefore, our data indicate the certain level of endemism in Cat Ba amphibians, as well as in reptiles. The two newly described rhacophorid frogs are strongly associated with the specific environment of tropical limestone forest and thus support the hypothesis about the key role of karst forest ecosystems areas for herpetofaunal diversity in eastern and south-eastern Asia (Orlov and Ananjeva, 2007; Ziegler et al., 2007). We can assume that further studies of the taxonomic status of amphibian species found in the Cat Ba Island are needed; they may result in further enrichment of Vietnamese herpetofauna.

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