Tropical Natural History 13(2): 87-95, October 2013

Taxonomic Status and Distribution of *Leptobrachium smithi* Matsui, Nabhitabhata & Panha, 1999 (Anura: Megophryidae) in India with New Locality Records

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Received: 21 June 2013; Accepted: 16 August 2013

Abstract.– The Megophrid genus *Leptobrachium* Tschudi, 1838 represents a group of megophryid frogs characterized by a stocky body with wide head, slender, long forelimbs, and short hindlimbs. Currently the genus is represented by 32 species, of which two have been reported from India. Recently, in describing *L. rakhinensis* from Rakhini State of Myanmar, Wogan (2012) suggested the presence of the species also in India because the Rakhini Hills are biogeographically contiguous to Assam Hills of Northeast India. Comparing the detailed morphometry and colour pattern of *L. rakhinensis* and *L. smithi* with the Northeast India populations of *Leptobrachium*, we conclude that the Northeast Indian populations closely resemble *L. smithi* in all aspects, and we recommend to apply the nomen *L. smithi* for those populations.

KEY WORDS: Taxonomy; *Leptobrachium smithi*; distribution; Northeast India

INTRODUCTION

The megophryidae frogs of the genus *Leptobrachium* Tschudi, 1838 are characterized by a stocky body with wide head, slender, long forelimbs, and relatively short hind limbs (Dubois and Ohler, 1998; Inger and Stuebing, 1997). They occur from southern China and India to the islands of the Sunda Shelf and the Philippines (Frost, 2013). This genus is currently represented by 32 species, of which two species (*Leptobrachium smithi* and *L. bompu*) have been reported from India (Sondhi and Ohler, 2011).

Leptobrachium smithi was formerly confused with *L. hasseltii* from Java, but was split from it as a distinct species on the basis of specimens from Ton Nam Plu Waterfall, Khao Chong, Trang Province, peninsular Thailand (Matsui *et al*., 1999). Sengupta *et al.* (2001) and Das and Chanda (2004) recognised Indian and Myanmar populations of *Leptobrachium* as *L. smithi*. In India, this species has been reported from Assam State (Sengupta *et al.,* 2010), Meghalaya State (Chanda, 1994; Mathew and Sen, 2010) and Mizoram State (Lalremsanga *et al.*, 2007). However, Wogan (2012) identified the Indian population of *L. smithi* as *L. rakhinensis* because of biogeographical similarity of Rakhini Hills of Myanmar and northeast Indian Hills. In order to determine taxonomic status of Indian populations, we here compare morphological characters of populations allied to *L. smithi*. Further, details of the distribution of the Indian population are provided on the basis of results obtained.

MATERIALS AND METHODS

Population sampling was made at localities across Northeast India employing active search method (Sarkar *et al.*, 1992) and Pitfall trapping (Heyer *et al.*, 1994) from September 2009 to September 2012. Further, preserved specimens were also studied at Zoological Survey of India Kolkata (ZSIC) and Zoological Survey of India, Eastern regional Station Shillong (ZSIS). Morphometric examination of the specimens (see Appendix I) was carried out following the protocol of Sengupta et al. (2008). The colour code of Smithe (1975) was followed to describe colouration of live specimens. The advertising call was recorded by a digital recorder (Sony ICD-UX533F/B) in the field in the late evening (1830 hours to 2000 hours); the range of the air-temperature and humidity, recorded with a thermo-hygrometer (VICTOR-VC230A), was 28^0C-29^0C and 78%-94%, respectively. Oseen and Wassersug (2002) reported that calling of *R. clamitans* in early season, was sensitive to relative humidity. To avoid any disturbance that may arise due to air interference, the recorder was mounted on a long stick, and was placed as close to the source as possible (< 30 cm). The interferences were cleared using Audacity-2.0.3 and analyzed in Sound Ruler-0.9.6.0 at FFT 256 points 50% overlap and hamming window.

A Garmin™ GPSMAP76 GPS was used to obtain geographic coordinates. Based on all these data, a Gazetteer list mentioning locality of distribution with State, District, GPS coordinates, and altitudes concerning *Leptobrachium* species affiliated to *L. smithi* of Northeast India was prepared along with a distribution map.

TABLE 1. Comparison of morphological characters of *L. rakhinensis, L. smithi* and *Leptobrachium* populations from Northeast India.

L. rakhinensis	***L. smithi***	**Northeast Indian population of *Leptobrachium* cf. *smithi***
Head with distinct inverted Y shaped mark extending from beneath eye to snout	Head with irregular dark mark	Head with irregular dark blotches
Two strings of dark blotches stretch dorsolaterally and laterally sometimes forming dark irregular lines.	Sides with smaller dark spots than dorsal blotches.	Small dark blotches present dorso-laterally.
Dorsal blotches are outlined in white.	Blotches are not outlined in white.	Blotches are not outlined in white.
A second middorsal "Y" shaped spot begins just posterior to the eyes and broadens between the shoulders, also faintly outlined in white	Dark grey spots dorsally on head and body, with an irregular dark mark commencing discretely in frontal region and fading to half length of back.	Dorsal irregular blotches present.
Ventrum light (*sensu stricto* Wagon, 2012) in colour (not white), without splotches.	Ventrum white with varying amounts of darker infusion, especially on throat and posterior half of abdomen.	Ventrum creamy to white with varying amount of dark infusion.
Size dimorphic range small.	Size dimorphic range large.	Size dimorphic range large.
Eggs are unicoloured cream	Eggs bicoloured.	Eggs bicoloured (Plate-1: D)

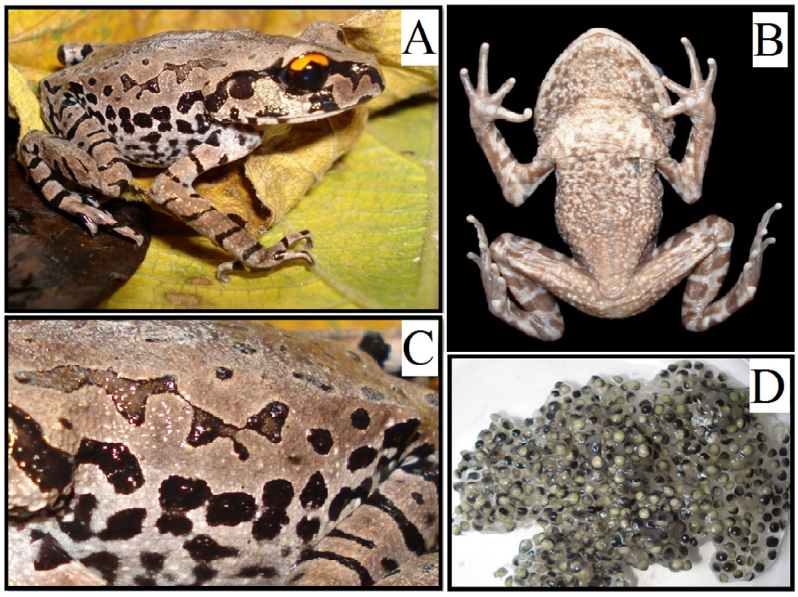

FIGURE 1. A: Life picture; B: Ventral pattern; C: Blotch pattern; D: Unfertilized bicoloured eggs of *Leptobrachium smithi.*

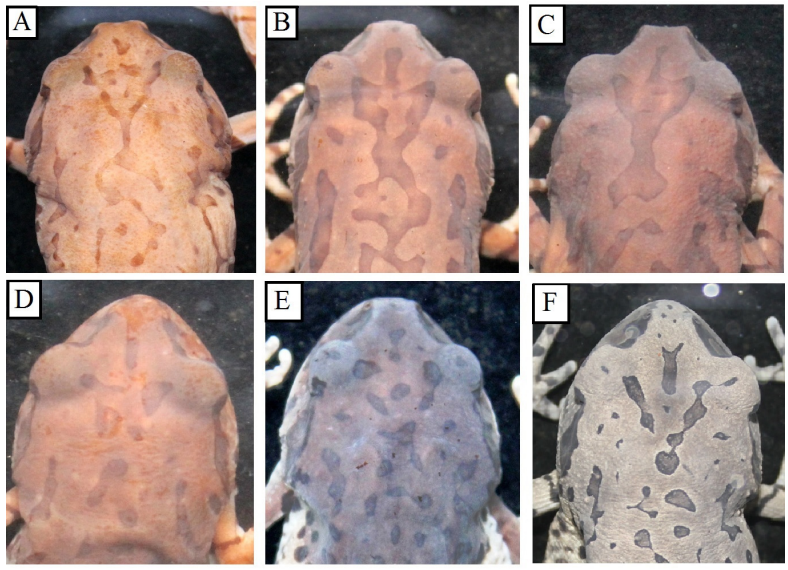

FIGURE 2. A-F: Dorsal head region showing all different, irregular blotch pattern in *Leptobrachium smithi* population of India.

RESULTS AND DISCUSSION

Leptobrachium cf. *smithi* of Northeast India is a midium-sized frog [SVL range: 36.6 – 56.7 (males=M); 39.2-70.7 (females=F) mm] with robust body and smooth skin (Table 1). The species has a diagnostic eye

TABLE 2. Comparison of morphometric data (measurements in mm) between *Leptobrachium smithi* (Holotype), *L. rakhinensis* and Northeast Indian population of *Leptobrachium* cf. *smithi*. For abbreviations, see Appendix II.

***L. smithi* (Holotype)**	***L. rakhinensis***		**Northeast Indian population of *Leptobrachium* cf. *smithi***	
Male	**Male**	**Female**	**Male**	**Female**
SVL	41.2	52.7 (48.3-57.1)	60.9 (57.8-65.7)	47.4 (36.6-56.7)	53.4 (39.1-70.8)
HL	18	23.1 (22.2-24.8)	25.8 (25.3-26.4)	19. 9 (12.1-23.9)	21.3 (14.6-27.9)
EN	3.9	4.8 (4.8-4.9)	6.7 (6.3-7.3)	4.4 (3.1-5.5)	4.9 (3.3-6.5)
SL	7.2	NA*	NA*	8.4 (7.0-10.2)	9.3 (7.3-11.3)
ED	5.9	NA*	NA*	6.3 (5.3-8.1)	6.6 (4.9-8.0)
TE	2.1	11.5 (10.9-12.6)	12.7 (11.5-13.8)	2.8 (1.9-3.7)	3.2 (1.8-4.6)
HTYD	3.4	3.8 (3.0-4.3)	4.5 (4.2-4.9)	3.2 (1.7-6.3)	3.3 (2.0-5.9)
HW	18.2	19.4 (18.5-21.3)	25.6 (24.4-26.3)	19.4 (12.5-24.3)	22.0 (15.6-27.9)
INS	3.5	4.6 (4.32-4.97)	5.1 (4.9-5.2)	3.6 (2.8-4.6)	4.1 (3.1-5.3)
IOS	5.8	NA*	NA*	6.5 (2.7-9.4)	7.6 (5.7-10.4)
UE	4.5	NA*	NA*	5.0 (4.0-6.4)	5.4 (3.9-6.9)
HLL	50.1	NA*	NA*	49.4 (41.2-67.8)	53.9 (40.0-70.6)
TBL	14.6	17.9 (16.9-19.8)	20.6 (20.5-20.7)	16.9 (11.2-20.9)	19.7 (15.0-23.9)
IMT	1.2	2.7 (2.5-3.1)	2.5 (2.3-2.7)	1.5 (1.1-2.1)	1.7 (1.3-2.5)
MN	NA*	19.4 (18.5-21.3)	21.7 (21.4-22.3)	16.8 (9.4-21.6)	18.9 (7.4-25.9)
MPE	NA*	8.8 (7.6-9.9)	9.5 (7.0-11.1)	9.6 (7.1-19.6)	10.1 (6.8-13.2)
MAE	NA*	15.0 (13.8-16.9)	16.0 (14.3-17.8)	13.9 (9.2-17.3)	14.3 (10.3-20.1)
IFE	NA*	9.2 (8.5-10.8)	10.2 (9.3-10.8)	9.3 (7.2-11.4)	10.1 (8.0-13.2)
IBE	NA*	16.4 (15.5-18.4)	18.0 (17.0-18.3)	15.2 (11.5-18.6)	16.7 (13.4-20.4)

NA*: Data not provided in original paper; Measurements for holotype of *L. smithi* were taken from Matsui *et al.* (1999) and for *L. rakhinensis* were taken from Wogan 2012.

TABLE 3. Morphometric comparison between *Leptobrachium smithi* and Northeast Indian population of *Leptobrachium* cf. *smithi* (R=ratio to SVL, expressed in percentage).

Parameters	***L. smithi***	**Northeast Indian population of *Leptobrachium* cf. *smithi***	
	Male (holotype)	**Male**	**Female**
RHL	43.7	41.9 (33.0-42.1)	39.4 (37.3-39.8)
REN	9.5	9.2 (8.4-9.7)	9.1 (8.4-9.1)
RSL	17.5	17.7 (17.9-19.1)	17.4 (15.9-18.6)
RED	14.3	14.2 (13.3-14.4)	12.3 (11.3-12.5)
RTE	5.1	5.9 (5.2-6.5)	6.0 (4.6-6.5)
RHTYD	8.3	6.7 (4.6-11.1)	6.1 (5.1-8.3)
RHW	44.2	40.9 (34.1-42.8)	39.9 (39.4-41.1)
RINS	8.5	7.6 (7.6-8.1)	7.7 (7.5-7.9)
RIOS	14.1	13.7 (7.3-16.6)	14.6 (14.2-14.7)
RUE	10.9	10.9 (10.5-11.3)	9.9 (9.7-10.1)
RHLL	121.6	112.5 (104.2-119.6)	100.9 (99.7-102.3)
RTBL	35.4	35.6 (30.6-36.8)	36.9 (33.7-38.4)
RIMT	2.9	3.1 (2.3-3.7)	3.3 (3.2-3.5)

coloration with bicoloured iris, upper half orange yellow (#18) (Smithe, 1975) and lower half black, and smalt blue (#170) pupil. Northeast Indian populations show dorsal skin colouration ranging from medium neutral grey (#84) to light brown

(Fig. 1A). Dorsal and dorsolateral parts of body have blotches of irregular shape and size; dorsal blotches are slightly darker than the ground colour at core, with a dark brown to black coloured rim; dorsolateral blotches are evenly dark brown (Fig. 1C).

Wogan (2012) found that specimens of *L. rakhinensis* have dorsal blotches distinctly outlined white and a Y-shaped mark on the head. However, the dorsal spots and/or blotches present in Northeast Indian populations showed individual variation (Fig. 2A-F). Among the specimens examined (n=53), 15.6% has a distinct Y-shaped mark on the forehead and 31.5% showed a broken Y-shaped mark, but 52.8% lacked particular Y-shaped mark. The dorsal Y-shaped blotches are outlined with a broad, dark brown rim (Fig. 1A, 1C). In *L. rakhinensis* ventral side of body is light coloured (*sensu stricto* Wogan, 2012) with small white speckles, and throat is dark brown with small white spots (Wogan, 2012). However, ventrum of all the Indian

TABLE 4. Comparison of acoustic data of *Leptobrachium smithi* (from the original description) and the Northeast Indian population of *Leptobrachium* cf. *smithi.*

***Leptobrachium smithi* (original description)**	**Northeast Indian population of *Leptobrachium* cf. *smithi***
1–7 notes (usually 1) lasting 2.1 sec A note with many unclear pulses, lasting 0.109 – 0.230 sec	4 – 6 notes lasting 0.8-1.2 sec A note with 22 pulses, lasting 0.13 – 3.3 sec with interval of 0.4 sec
Call with 2 or more notes.	Call with 2 or more notes
Dominant frequency 750 – 1600 Hz range	Dominant frequency 1370 (1280 – 1420) Hz

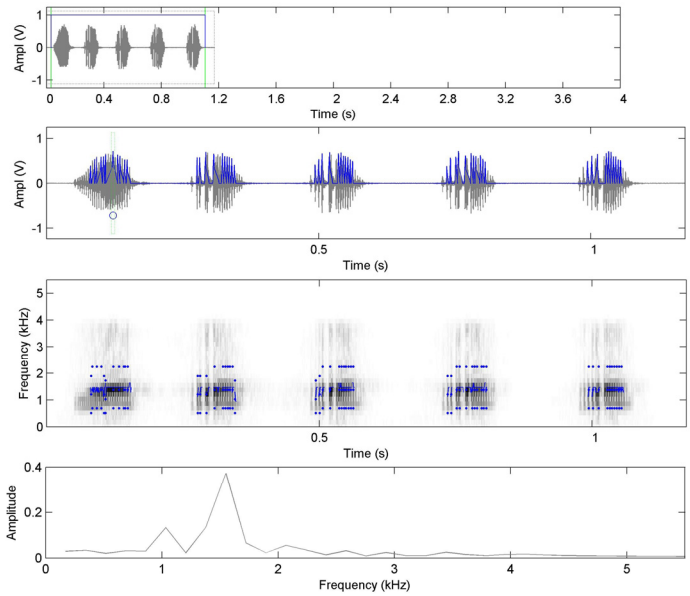

FIGURE 3. An advertisement call with five notes of *Leptobrachium smithi* of Northeast India.

TABLE 5. Gazetteer list of locality distribution with State, District, locality records, GPS coordinates, and altitudes of *Leptobrachium smithi* in India.

No.	State	District or Division	Locality Name	Latitude	Longitude	Elevation m (asl)
1	Assam	Morigaon	Rani-Gharbhanga Reserve Forest	26°3'36.518"N	91°40'22.281"E	127
2	Assam	Kamrup	Amsang Reserve Forest	26°8'28.311"N	91°53'6.233"E	147
3	Assam	Kamrup	Kulsi Reserve Forest	25°59'34.890"N	91°24'15.311"E	150
4	Assam	Kamrup	Mayang Hills and Borduar Reserve Forest	26°15'6.729"N	91°59'50.081"E	136
5	Assam	Kokrajhar	Ultapani	26°46'31.822"N	90°17'13.807"E	378
6	Assam	Darrang	Kolaghat Reserve Forest	26°6'35.955"N	92°20'11.324"E	325
7	Assam	Bongaigaon	Shankarghala	26°17'33.173"N	90°32'22.914"E	40
8	Assam	Golaghat	Nambar Wildlife Sanctuary	26°24'31.240"N	93°53'24.239"E	127
9	Assam	Golaghat	Garampani Wildlife Sanctuary	26°23'37.565"N	93°52'41.299"E	130
10	Assam	Nagaon	Panbari Reserve Forest	26°34'16.296"N	93°19'34.139"E	187
11	Assam	Cachar	Innerline Reserve Forest	24°27'26.401"N	92°53'2.979"E	126
12	Assam	Cachar	Assam University, Silchar	24°41'16.571"N	92°43'49.532"E	38
13	Assam	Cachar	Barail Wildlife Sanctuary	25°0'52.646"N	92°44'24.123"E	31
14	Assam	Karimganj	Badsahitila Reserve Forest	24°19'56.725"N	92°18'27.553"E	56
15	Assam	Karimganj	Longai Reserve Forest	24°17'3.773"N	92°15'34.601"E	57
16	Meghalaya	East Khasi Hills	Mawphlang	25°28'32.986"N	91°44'26.718"E	1751
17	Meghalaya	East Khasi Hills	Barapani	25°41'13.976"N	91°54'14.755"E	951
18	Meghalaya	Ri-Bhoi	Nongkhyllum Wildlife Sanctuary	25°53'54.965"N	91°49'3.441"E	618
19	Meghalaya	Ri-Bhoi	Burhalang near Nongpoh	25°52'45.784"N	91°53'40.165"E	751
20. A	Meghalaya	West Garo Hills	Rensangre (Nokrek Biosphere Reserve)	25°34'18.891"N	90°19'7.334"E	650
20. B	Meghalaya	East Garo Hills	Daribokgre (Nokrek Biosphere Reserve)	25°27'58.396"N	90°23'9.467"E	438
21	Meghalaya	South Garo Hills	Balpakram National Park	25°15'13.451"N	90°49'35.332"E	494
22	Mizoram	Lunglei	Nengpui National Park	22°11'57.649"N	92°54'12.160"E	552
23	Mizoram	Aizawl	Herhse	23°58'36.879"N	92°40'21.989"E	206
24	Mizoram	Aizawl	Sihhmui Picnic Spot	23°42'28.347"N	92°44'58.713"E	184
25	Mizoram	Mamit	Dampa Tiger Reserve	23°36'42.443"N	92°24'13.457"E	771
26	Manipur	Tamenglong	Jiribam	24°48'11.656"N	93°6'53.149"E	54

specimens (n=53) is heavily speckled, which is much more pronounced on the posterior half and the throat (Fig. 1B). This ventral colouration of Indian population is consistent with that of *L. smithi* (Matsui *et al.*, 1999).

Moreover, the Northeast Indian populations lack dorsal blotches outlined white, which is reported to present in *L. rakhinensis*. Further, *L. rakhinensis* seems to reach a larger body size [SVL- males: 52.7 (48.3-57.1); females: 60.87 (57.8-65.7) mm], has a relatively shorter tibia and relatively longer inner metatarsal tubercles [males: 2.7 (2.5-3.1); females: 2.5 (2.3-2.7)] than in the Northeast Indian populations (Table 2).

Wogan (2012) assumed Indian populations of *Leptobrachium* to be *L. rakhinensis* simply because of biogeographic contiguity of the Rakhine Hills and Assam Hills of Northeast India,

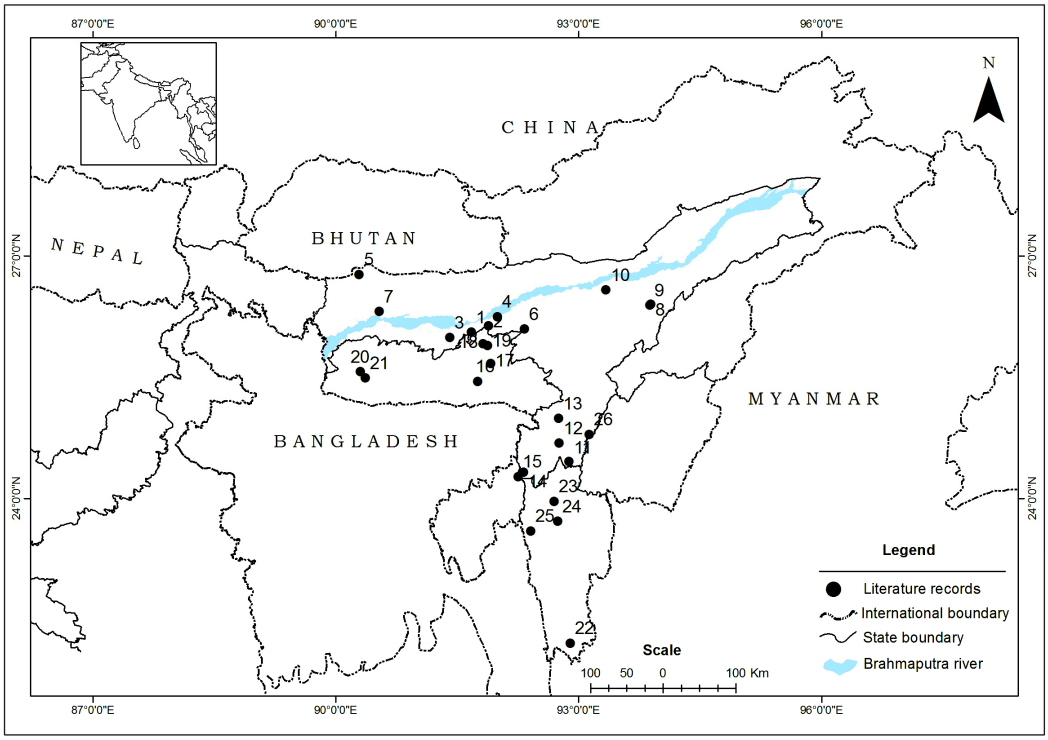

FIGURE 4. Map showing locality of *Leptobrachium smithi* in India. For locality see Table 5.

most probably without examining materials from India.

We compared specimens (Annexure I) collected from whole Indian territory with the holotype of *L. smithi* (data from Matsui *et al.*, 1999) and could not observe any marked morphological difference between them (Tables 1-3) and also did not show much difference from *L. rakhinensis*.

Comparison of acoustic features of Northeast populations with *L. smithi* (data from Matsui *et al.*, 1999) showed very few differences (Table 4, Fig. 3). The difference in the duration of call might be due to difference in the variation in the number of notes coupled with environmental parameters (Oseen and Wassersug, 2002).

We studied specimens collected from different parts of Northeast India and found that they constitute a single group closely resembling *L. smithi* and thus we consider them conspecific with *L. smithi.*

The present study reconfirmed the presence of *L. smithi* in Indian states of Assam, Meghalaya, Mizoram, and Manipur (Table 5, Fig. 4). This study also provides records of its presence on the northern bank of the River Brahmaputra. Considering its distribution in Myanmar and Bangladesh, we predict its presence in Nagaland and Tripura states of India.

ACKNOWLEDGEMENTS

The authors are thankful to Forest Departments of the states of Assam, Manipur, Meghalaya and Mizoram for permission and support. We also express our

gratitude to the Director, Zoological Survey of India for permission to study voucher specimens at Kolkata and Shillong. We are thankful to K. Deuti, B.H.C.K. Murthy, N. Sen, U. Saikia, N.K. Choudhury and B. Hussain for their constant support and help. We also offer our thanks to J. K. Roy and A. Nath for lending some of their personal collections for our study. Thanks to Arup Kr. Das (Aaranyak) for preparing the map. The authors are also grateful to M. Matsui for valuable suggestions and input to the draft copy of the manuscript.

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APPENDIX I:

Specimens (n=53) studied

Arya Vidyapeeth College Museum (AVCM) - A0989, A0988, A1031, A0987, A0991, A0474, GRB6981, A0477, A0476, A0696, A0414, A0417, A0695, AD/BR 100, CND7971, CND7974, CND7976, SJN3, SJN2, SJN1, STG002, STG001, A0075, G2, A284, A0001, A1052, A1071, GRB P2, A1053, A1072, A0012, A1070, GRB P1, A1084, A1085, GRB6982, A1086, CND7977, LS 2K, LS 1RL, LS DL1, LS DR1, LS RH

Zoological Survey of India, Kolkata (ZSIC) A9102, A9135,

Zoological Survey of India Eastern Regional Station, Shillong (ZSIS) V/A/ERS/552, 553, 884, 881, 885 (3 individuals.)

APPENDIX II:

Abbreviation used

SVL, snout-vent length (from tip of snout to vent); HL, head length (distance between angle of jaws and snout-tip); EN, eye to nostril distance (distance between anterior-most point of eyes and nostrils); SL, snout length (from the anterior corner of eye to snout tip); ED, eye diameter (horizontal diameter of the eyes); TE, tympanum to eye distance(distance between anterior most part of the tympanum to the posterior most point of the eye); HTYD, horizontal tympanum diameter (distance from anterior border of tympanum to posterior border, horizontally); HW, head width (width of head at the level of jaw angle); INS, internarial space (distance between nostrils); IOS, interorbital space (least distance between upper eyelids); UE, upper eyelid width (maximum upper eyelid width); HLL, hind limb length (from groin to tip of 4th toe); TBL, tibia length (distance between surface of knee and surface of heel, with both tibia and tarsus flexed); IMT, length of inner metatarsal tubercle (greatest length of inner metatarsal tubercle); MN, mandible to nostril (distance from posterior corner of the mandible to the nostril); MPE, mandible to posterior part of eye (distance from posterior corner of the mandible to the posterior corner of the eye); MAE, mandible to anterior part of eye(distance from posterior corner of the mandible to the anterior corner of the eye); IFE, distance between anterior corner of eye; IBE, distance between posterior corner of eye; RHW, Relative Head Width; RHL, Relative Head Length; RLAL, Relative Lower arm Length; RTL, Relative Tibia Length; RFL, Relative Foot Length; RHLL, Relative Hind Limb Length; RIMTL, Relative Inner Metatarsal Tubercle Length. (Relative measurements are in comparison to SVL)