

On the *Liurana* (Anura: Ceratobatrachidae) of India with the description of three new species from Talley Valley Wildlife Sanctuary in Arunachal Pradesh, Eastern Himalayas

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Abstract

The moss and leaf litter dwelling small frog group under genus *Liurana* are represented by only 4 species, all described from China; of which *L. medogensis* is known to occur in India. In recent years, surveys into Talley Valley Wildlife Sanctuary of Arunachal Pradesh have revealed the occurrence of *L. medogensis* along with 3 hitherto unknown species of this genus from the protected area. Herein, we are describing 3 new species of *Liurana* and have provided a taxonomic key to the species of the genus.

Keywords: *Liurana himalayana* sp. nov., *L. indica* sp. nov., *L. minuta* sp. nov., Lower Subansiri, Northeast India, Pange

Introduction

The genus *Liurana* is represented by 4 species, *L. alpina*, *L. medogensis*, *L. valleculella* and *L. xizangensis*, all of which are found in southern China bordering with Arunachal Pradesh of India (Fei and Ye, 2016; Jiang *et al.*, 2019). Borah *et al.*, (2013) reported *L. medogensis* from Arunachal Pradesh [Pange in Lower Subansiri and Basar in Lepa-Rada] making it the only known *Liurana* species in India. Recently, Roy *et al.*, (2018) reported *L. medogensis* from another location of the State [Dibang River basin], along with another unnamed *Liurana* species.

During the faunistic surveys to Talley Valley Wildlife Sanctuary (Figure 1), located in central Arunachal Pradesh (2015-18), a number of amphibians have been collected by one of the authors (BJS) along with 5 specimens of small sized moss and leaf litter dwelling frogs belonging to the genus *Liurana*, identified due to their small size, absence of toe webbings, slightly enlarged toe pads but no disks and grooves on finger and toe tips

not clearly differentiated, and presence of lingual papilla (Dubois, 1987; Borah *et al.*, 2013; Yan *et al.*, 2016; Jiang *et al.*, 2019). Out of the 5 specimens, only 1 specimen could be attributed to a known species of *Liurana* as *L. medogensis*, while the rest of the 4 specimens could not be assigned to any of the known species (as per Hu, 1977; Huang and Ye, 1997; Fei *et al.*, 1997; Fei *et al.*, 2012; Yan *et al.*, 2016; Fei and Ye, 2016; Jiang *et al.*, 2019). A thorough morphological study of these specimen leads to them being identified as un-described species of *Liurana*. Herein, we are describing 3 new species of *Liurana* based on morphological differences and characters.

Material and Methods

All the specimens were collected during 2015-16 period from various locations of Talley Valley Wildlife Sanctuary, located in central Arunachal Pradesh, India, between altitudes of 1798-2457 meters above sea level. After photography of the live animals, the specimens

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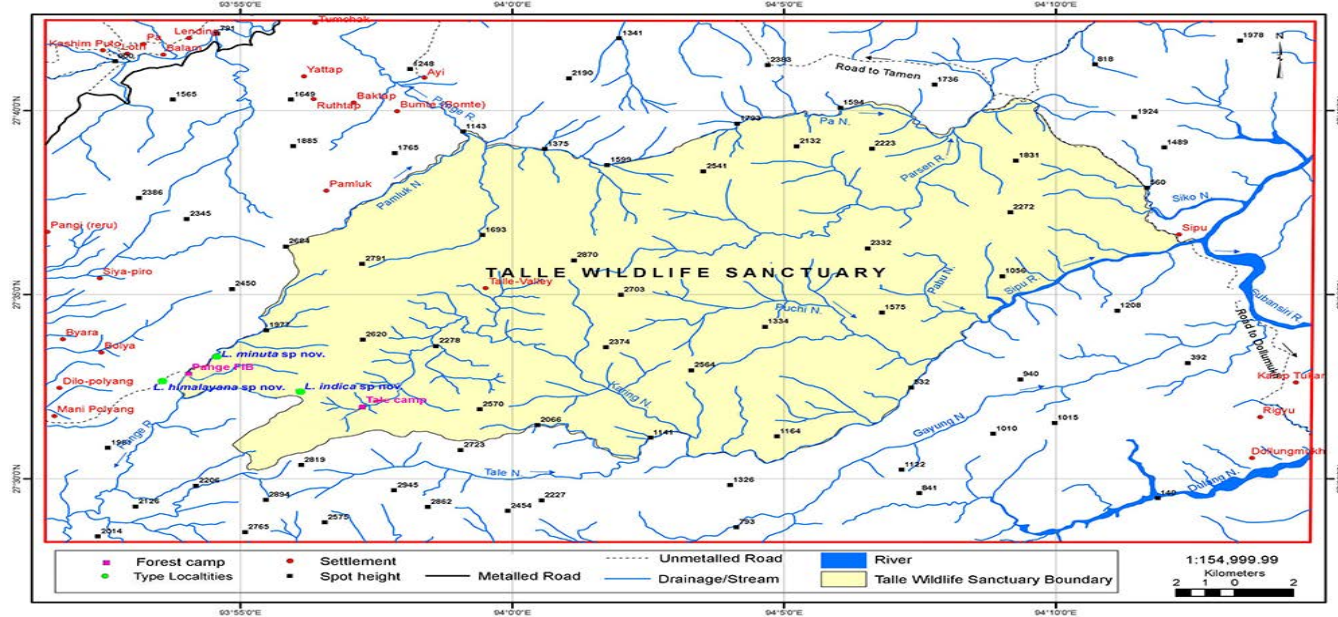


Figure 1. Map showing type localities of the new species of *Liurana* in and around Talley Valley Wildlife Sanctuary, Arunachal Pradesh, India

were euthanized with ethyl acetate soaked in cotton followed by relaxing the specimens in 30% ethanol. Then the specimens were fixed overnight in 10% formalin and finally preserved in 70% ethanol after washing thoroughly under running tap water. All measurements (in millimetres) were done with a Mitutoyo™ digital caliper. The measurements taken are SVL (Snout Vent Length), HL (Head Length), HW (Head Width), MN (Mandible Nostril distance), MFE (Distance of Mandible to the Front of Eye), MBE (Distance of Mandible to the Back of Eye), IFE (Distance between the Front of Eyes), IBE (Distance between the Back of Eyes), IN (Inter-Narial distance), EN (Distance from Eye to Nostril), SN (Distance from Snout tip to Nostril), EL (Eye Length), SL (Snout Length), TYD (Greatest Tympanum Diameter), IUE (Minimum distance between the Upper Eyelids), UEW (maximum width of the Upper Eyelid), HAL (Hand length from the base of inner metacarpal tubercle to the tip of third finger), FLL (Forearm Length from the elbow joint to base of the inner metacarpal tubercle), TFL (Third Finger Length from the first subarticular tubercle to tip of the finger), FL (Femur Length), TL (Tibia Length), TFO (Length of Tarsus and Foot), FOL (Foot Length, from inner metatarsal tubercle to the tip of fourth toe), FTL (Fourth Toe Length, from first subarticular tubercle to the tip), IMT (Inner Meta-tarsal Tubercle), TTA (Tibio-Tarsal Articulation). Dissection of the specimens was

carried out to ascertain their sexes. GPS coordinates were recorded using GARMIN Oregon 550. The amphibians were collected during 17:00 to 20:00hrs. All the specimens are registered and deposited in the collection of the Zoological Survey of India, Shillong (ZSIS).

The following literatures were consulted for comparative data of all the known congeners of the genus: Hu (1977); Huang and Ye (1997); Fei *et al.*, (1997); Borah *et al.*, (2013), Fei *et al.*, (2012), Yan *et al.*, (2016), Roy *et al.*, (2018) and Jiang *et al.*, 2019.

Results

Species Description: *Liurana himalayana* sp. nov.

Holotype: V/A/NERC/ZSI/1438 (male; Figure 2B-E) collected between Pangge & Maniployang (Figure 2A), Talley Valley WLS, Lower Subansiri District, Arunachal Pradesh, INDIA, on 21 September, 2016 by Bikramjit Sinha, Lat. 27.5477 N, Long. 93.8978 E, Alt. 1798 m above mean sea level.

Paratype: V/A/NERC/ZSI/1439 (male) collected from Talley Camp, Talley Valley WLS, Lower Subansiri District, Arunachal Pradesh, INDIA, on 11 November, 2015 by Bikramjit Sinha, Lat. 27.5341 N, Long. 93.9515 E, Alt. 2372 m above mean sea level.

Diagnosis: *Liurana himalayana* sp. nov. is assigned to the genus *Liurana* on the following morphological

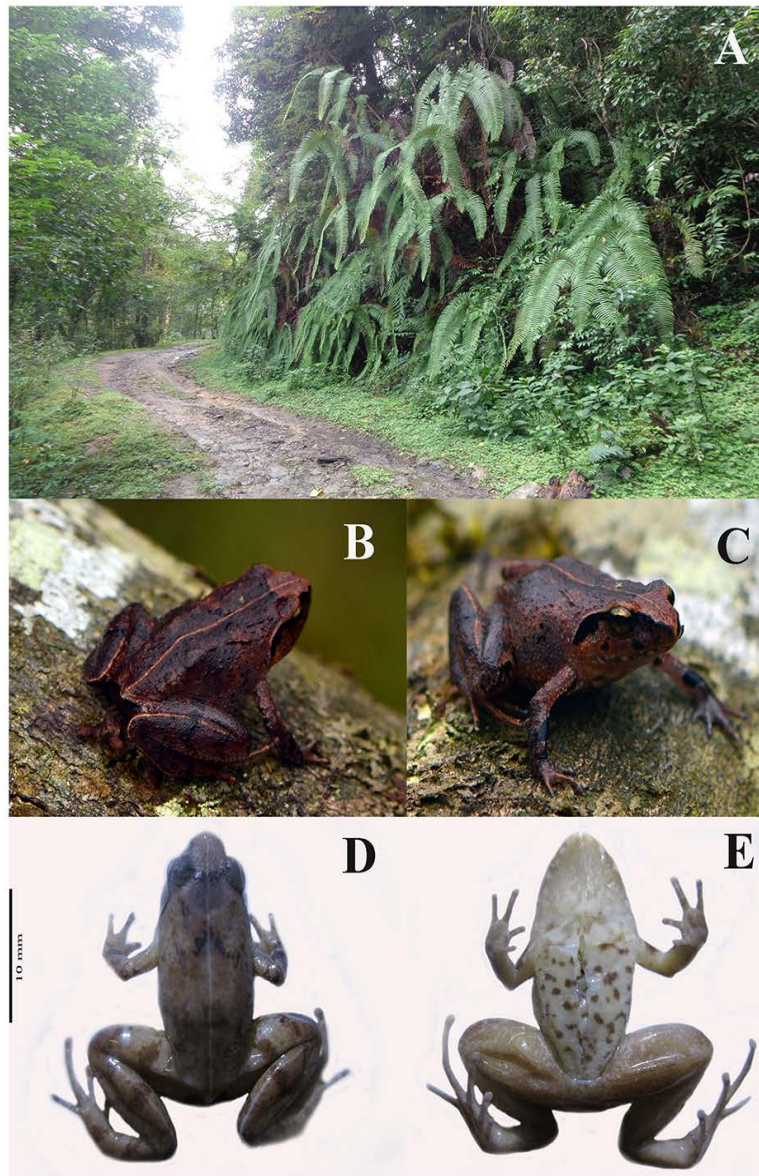


Figure 2. *Liurana himalayana* sp. nov. showing the type locality; holotype in live and preserved conditions. Scale is for the preserved specimen photographs only.

characters: (1) body size small (SVL 13.52-20.10 mm, $n=2$), (2) Finger and toe tips not expanded, (3) grooves not clearly differentiated into circum-marginal groove, (4) digits without webbing, (5) no tarsal fold, (6) vocal sac and its opening not present.

L. himalayana sp. nov. can be distinguished from the known congeners on the basis of the following morphological features: (1) Head wider than long, (2)

tympanum small and hidden, (3) snout appeared like an arrow-head when viewed dorsally, (4) strikingly distinct chocolate coloured dorsum, (5) presence of mid-dorsal line from snout to vent, (6) tarsal line present on the dorsal side (7) dark inter-orbital marking (8) dorsum smooth with 2 pairs of tubercles behind eyes, (9) light coloured ventrum with distinctly marbled markings, (10) finger I half of finger II, and (11) TTA reaching nostril.

Description of the Holotype: A small sized (male) frog (SVL-20.10mm); head wider than long, canthus rostralis prominent. Nostril is almost equidistant. Snout appears like an arrow head when viewed dorsally. Tongue crown shapes, vomerine teeth absent. Eyes rounded; pupil horizontal. Upper eyelid width is equal to inter-orbital space. Tympanum small and indistinct, not nearer to eye. Supratympanic fold prominent. Dorsum occiput with 2 pairs of tubercles, located near the mid-dorsal line at an angle to it. Hand length almost equal forearm length. Fingers free without webbings, a pair of metacarpal tubercles present; tips of fingers ending enlarged without groove. Relative finger length is I<II<IV<III, with Finger I almost half the size of finger II. Hindlimbs long, femur (10.85mm) slightly

longer than tibia (10.71mm); each slightly longer than half of SVL. TTA reaches nostril when the leg is folded along the body. Both inner and outer metatarsal tubercles present; inner elongated, outer rounded. Webbing in the toes absent; toe tips rounded and with grooves not clearly differentiated. Fourth toe (6.5 mm) relatively longer, about one-third of SVL (Table 1).

Colour in life: Dorsum is chocolate coloured and smooth (Figure 2B&C) with scattered dark small blotches. A dark inter-orbital mark present. Snout of lighter shade than the dorsum colour. A dark band from the snout tip to the back of the tympanum, interrupted by the eye socket. Upper jaw with 2 black spots beneath the eye. Iris golden

Table 1. Morphometrics of the *Liurana* species of Talley Valley WLS, Arunachal Pradesh

Sl. No	Characters	<i>L. himalayana</i>	<i>L. himalayana</i>	<i>L. indica</i>	<i>L. medogensis</i>	<i>L. minuta</i>
Reg. No		V/A/NERC/1438	V/A/NERC/1439	V/A/NERC/1440	V/A/NERC/1442	V/A/NERC/1441
Sex		Male	Male	Female	Female	Male
1	SVL	20.10	13.52	18.02	15.75	14.26
2	HL	5.83	4.31	5.48	4.92	4.55
3	HW	6.96	5.15	6.77	6.09	5.25
4	MN	4.17	3.12	4.43	3.74	3.16
5	MFE	3.42	2.35	3.63	2.73	3.00
6	MBE	1.88	1.67	1.76	1.90	1.40
7	IFE	3.91	3.02	3.75	3.13	3.00
8	IBE	5.90	4.48	5.80	5.20	4.68
9	IN	2.46	2.10	2.45	2.37	2.25
10	EN	1.47	1.28	1.10	1.36	1.16
11	EL	2.45	1.95	2.42	2.10	1.72
12	SN	1.50	1.28	1.52	1.36	1.16
13	SL	3.43	2.47	3.00	2.63	2.41
14	TYD	1.08	1.45	1.58	0.94	1.37
15	IUE	1.58	1.37	1.84	1.70	1.61
16	UEW	1.60	1.36	1.64	1.30	1.26
17	HAL	4.73	3.10	4.72	3.55	3.75
18	FLL	4.56	2.45	3.58	3.00	3.20
19	TFL	2.35	1.48	2.60	1.65	1.75
20	FL	10.85	7.66	8.24	8.72	8.44
21	TL	10.71	8.01	8.94	8.72	8.44
22	TFOL	15.57	11.08	15.15	13.03	12.60
23	FOL	10.69	6.95	10.42	4.45	8.42
24	FTL	6.20	3.97	6.22	4.56	4.92
25	IMT	1.21	negligible	0.92	0.86	0.79

yellow. A mid-dorsal line of brown shade from snout tip to vent; another line of same shade present over the tarsi. A dark inverted V shaped marking on the dorsal occiput between the 2 pairs of tubercles and interrupted by the mid-dorsal line. Vent with a dark blotch. Forearm and hindlimbs with bands. Ventrums white with dark patches made up of fine dots. Similar dots scattered around the throat region. Lower jaw banded with dark and light spots. Forelimbs and hindlimbs darker.

Colour in preservative: The specimen loses its colours (Figure 2D&E) and appears light brown while the darker markings on the dorsum persist. Ventrums remains white, except the darker blotches and dots.

Variations: The paratype matches with the holotype except the mid-dorsal line starts from behind the inter-orbital band. Tympanum is distinct and relatively larger in the paratype. Another variation is the relatively lesser blotches on the ventrum. The IMT in the paratype is not distinct.

Etymology: The species name is a toponym as the type locality is located in the southern slope of the Eastern Himalayas. The suggested common English name for this species is **Himalayan papilla-tongued frog**.

Distribution: *L. himalayana* sp. nov. is currently known only from Talley Valley WLS and around, Lower Subansiri District, Arunachal Pradesh, India (Figure 1) from an altitudinal range of 1798-2372 m asl.

Natural History: The holotype was collected from a moist tropical mixed evergreen forest interspersed with some pine and large ferns, while the paratype was collected from decomposing leaf litter in an area primarily of open pine forest having thick growth of grass. The temperature in the paratype locality was well below freezing point and the morning witnessed thick frost.

Comparisons: *Liurana himalayana* sp. nov. is compared with all the known congeners and the newly described ones (Table 2).

L. himalayana sp. nov. superficially resembles *Liurana alpina* in having overlapping SVL range and hidden tympanum, but differs in the following morphological parameters (*L. alpina*; in parenthesis): snout shape appears like an arrow head (vs. none), dorsum with 2 pairs of tubercles on the occiput (vs. none), mid-dorsal line from snout tip to vent (vs. absent), tarsal line present (vs. absent); finger I half the size of finger II (vs. finger

I shorter, but not half of finger II), dorsum colouration chocolate (vs. brown), belly ground colour white, with marbled markings (vs. none).

L. himalayana sp. nov. superficially resembles *Liurana medogensis* in having overlapping SVL range and marbled ventrum, but differs in the following morphological parameters (*L. medogensis*, in parenthesis): tympanum small and hidden (vs. large and distinct), with inter-orbital band (vs. absent or faded), snout shape appears like an arrow head (vs. none), dorsum with 2 pairs of tubercles on the occiput (vs. none), mid-dorsal line from snout tip to vent (vs. absent), tarsal line present (vs. absent); finger I half the size of finger II (vs. finger I much shorter, but not half of finger II), belly ground colour white (vs. light yellow or purple), TTA reaching nostril (vs. between eye and nostril), dorsum colouration chocolate (vs. yellow).

L. himalayana sp. nov. superficially resembles *Liurana valleculella* in having similar SVL range but differs in the following morphological parameters (*L. valleculella*, in parenthesis): tympanum hidden, small (vs. large, distinct), snout arrow shaped (vs. rounded), smooth dorsum with 2 pairs of flat tubercles (vs. random tubercles), mid-dorsal line present (vs. absent), tarsal line present (vs. absent), tarsi lightly banded (vs. distinctly banded), belly smooth (vs. with flat tubercles), tongue crown shaped (vs. elongated, deeply notched), toe tips without a clearly differentiated grooves (vs. absent), TTA up to nostril (vs. beyond snout).

L. himalayana sp. nov. superficially resembles *Liurana xizangensis* in having similar SVL range and inter-orbital band, but differs in the following morphological parameters (*L. xizangensis*, in parenthesis): tympanum small and hidden (vs. large and distinct), snout shape appears like an arrow head (vs. none), dorsum with 2 pairs of tubercles on the occiput (vs. none), mid-dorsal line from snout tip to vent (vs. absent), tarsal line present (vs. absent); finger I half the size of finger II (vs. almost same length), belly ground colour white, with marbled markings (vs. light yellow), dorsum colouration chocolate (vs. light yellow-brown).

L. himalayana sp. nov. superficially resembles *Liurana indica* sp. nov. in having overlapping SVL range and mid-dorsal line, but differs in the following morphological parameters (*L. indica* sp. nov., in parenthesis): dorsum mostly smooth (vs. minutely warty), tympanum small and hidden; little away from the eye (vs. large and distinct; near to eye), snout shape appears like an arrow head (vs. none),

Table 2. Comparative data of morphological characters for *L. alpina*, *L. medogensis*, *L. valleculea* and *L. xizangensis* based on Hu (1977), Hunag & Ye (1997), Fei *et al.*, (1997), Borah *et al.*, (2013), Fei *et al.*, (2012) and Fei and Ye (2016), Jiang *et al.*, (2019).

Characters	<i>L. alpina</i>	<i>L. medogensis</i>	<i>L. valleculea</i>	<i>L. xizangensis</i>	<i>L. himalayana</i> sp.nov.	<i>L. indica</i> sp. nov.	<i>L. minuta</i> sp. nov.
Size	M 16.6-20.2	M 17.5; F 21.0	M 14.6; F 20.4	M 21.3	20.10	18.02	14.26
Tympanum	Hidden	Large, distinct	Large, distinct	Large, distinct	Small; hidden	Large, distinct	Large, distinct
Snout	-	Rounded	Rounded	-	Lighter color than the dorsum; like an arrow head	Pointed	Lighter color than the dorsum; like an arrow head
Dorsal colour & markings	-	Variable; light yellow with dark blotches or dirty yellow band from snout to vent, laterally dark mottlings	Reddish brown, dark brown streaks & marbled patterns on dorsal skin; X shaped mark on pectoral region.	-	Chocolate-brown A dark inverted V shaped marking on the dorsal occiput	Peach coloured	Dark dorsum, with bright brown-red towards the vent and lateral sides Occiput region dark that faintly bifurcates into two bars towards the groin.
Dorsum skin	Smooth with flat tubercles	Smooth with folds	Random tubercles on dorsum; discontinuous folds dorso-laterally.	Smooth, scattered with small tubercles	Smooth with 2 pairs of flat tubercles & minute warts	Not smooth, with tubercles forming incomplete dorsolateral folds	Smooth with scattered flat tubercles & minute warts
Inter-orbital markings	-	-	Dark marking	-	Dark marking	Light marking	Dark marking
Mid-dorsal line	Absent	Absent	Absent	Absent	Present	Present	Absent
Vent blotch marking	-	Present	-	-	Present	Absent	Present
Line on Hindlimbs	Absent	Absent	Absent (transverse streaks)	Absent	Present	Present	Absent
Belly skin	Smooth	Smooth	With flat tubercles	Granular	Smooth, white with black blotches	Smooth, dirt white speckled with dark dots	Smooth
Skin on thigh & tibia	Small tubercles on dorsal side	Smooth	Distinct transverse bands (4 bands on thigh, 3 on tibia)	Smooth	Banded	Same as dorsum	Smooth

Vomerine teeth	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Tongue	-	Rounded	Elongated; deeply notched	-	Crown	Notched	Bifid
Finger I to II	I<II	I much shorter than II	I<II	Almost the same length	I half of II	I<II	I<II
Metacarpal tubercles	NA	inner and outer present	Present; 3 numbers.	NA	inner and outer present	inner and outer present	inner and outer present
Toe tips	Not swollen	Slightly swollen, distinctly enlarged, but no transversal grooves	Slightly expanded, without grooves	Not dilated but with indistinct transverse grooves	without a clearly differentiated grooves	without a clearly differentiated grooves	without a clearly differentiated grooves
Metatarsal tubercles	NA	Both present	Inner oval; outer indistinct	NA	Both present	Both present	Both present
Webbing	Absent	Absent or rudimentary	Absent	Absent	Absent	Absent	Absent
Belly colouration	Pale red reticulation or markings	Light purple with distinctly marbled markings	Grayish brown with white marble patterns	Pale yellow with black reticulated markings	Light coloured with distinctly marbled markings	Dirty off white with scattered dots	Light coloured with scattered dark dots
TTA	-	Between eye & nostril	Beyond snout	-	Nostril	Between eye & nostril	Beyond nostril

snout colour lighter than dorsum (vs. concolorous), inter-orbital band dark (vs. lighter), dorsum with 2 pairs of tubercles on the occiput (vs. tubercles forming incomplete dorso-lateral folds), tarsal line present (vs. line from vent to the outer metatarsal tubercle); finger I half the size of finger II (vs. finger I much shorter, but not half of finger II), FL>TL (vs. (FL<TL), both FL & TL more than half of SVL (vs. less than half of SVL), black blotch on vent (vs. lighter blotch), belly with marbled markings (vs. none), fourth toe less than one-third of SVL (vs. more than one third of SVL), TTA reaching nostril (vs. between eye and nostril), dorsum colouration chocolate (vs. brown).

L. himalayana sp. nov. superficially resembles *Liurana minuta* sp. nov. in having overlapping SVL range, inter-orbital band and snout shaped like an arrow head, but differs in the following morphological parameters (*L. minuta* sp. nov., in parenthesis): tympanum small and hidden (vs. large and distinct), dorsum with 2 pairs of tubercles on the occiput (vs. scattered tubercles on the dorso-lateral sides), mid-dorsal line from snout tip to vent (vs. absent), tarsal

line present (vs. absent); finger I half the size of finger II (vs. finger I much shorter, but not half of finger II), FL>TL (FL=TL), belly colour white with marbled markings (vs. dirty light in colour with scattered dots), TTA reaching nostril (vs. beyond nostril), dorsum colouration chocolate (vs. yellow-reddish with dark markings).

Species Description: *Liurana indica* sp. nov.

Holotype: V/A/NERC/ZSI/1440 (female; Figure 3B-E) collected from Tragopan Point (Figure 3A), Talley Valley WLS, Lower Subansiri District, Arunachal Pradesh, INDIA, on 13 April, 2015 by Bikramjit Sinha, Lat. 27.5412 N, Long. 93.9299 E, Alt. 2457 m above mean sea level.

Diagnosis: *Liurana indica* sp. nov. is assigned to the genus *Liurana* on the following morphological characters: (1) body size small (SVL 18.02, $n=1$), (2) Finger and toe tips not expanded, (3) grooves not clearly differentiated into circum-marginal groove, (4) digits without webbing, (5) no tarsal fold.

L. indica sp. nov. can be distinguished from the known congeners on the basis of the following morphological features: (1) head wider than long, (2) tympanum large and distinct, (3) light brown coloured dorsum, (4) presence of mid-dorsal line from snout to vent, (5) presence of line from vent to the outer metatarsal tubercle over the hindlimbs (6) light inter-orbital marking, (7) dorsum with scattered minute tubercles forming an incomplete dorso-lateral folds, (8) ventrum smooth, dirty off white speckled with dark dots, (9) finger I shorter than finger II, (10) TTA reaching between eye and nostril.

Description of the Holotype: A small sized (female) frog (SVL-18.02 mm); head wider than long. Canthus rostralis distinct; nostril nearer to eye, placed laterally. Snout pointed. Tongue notched, vomerine teeth absent. Eyes rounded, pupil horizontal. Tympanum large and

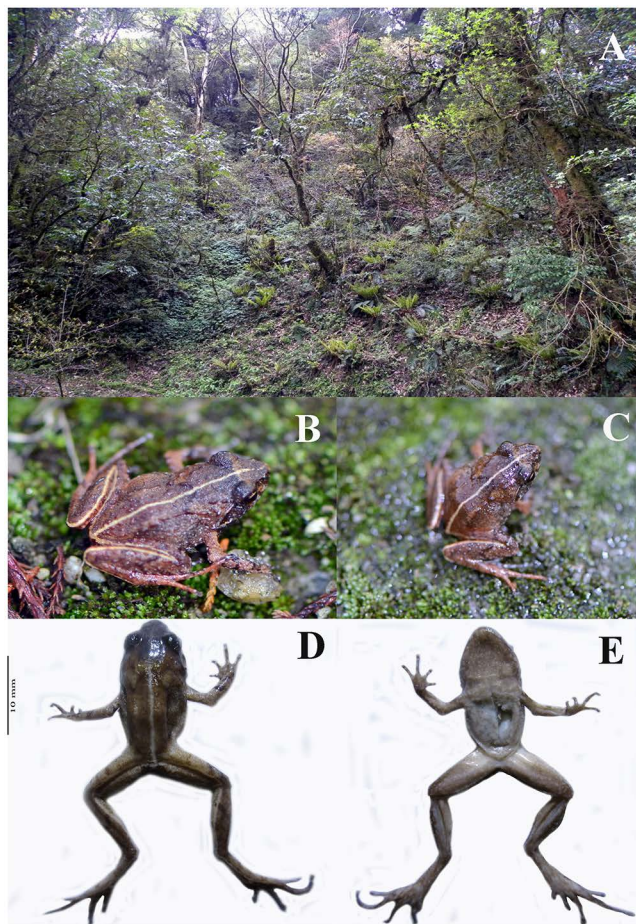


Figure 3. *Liurana indica* sp. nov. showing the type locality; holotype in live and preserved conditions. Scale is for the preserved specimen photographs only.

distinct; located very close to the eye. Supra tympanic fold prominent. Dorsum with rows of tubercles forming incomplete dorso-lateral folds. Forearm length smaller than hand length. Fingers free without webbings; a pair of metacarpal tubercles present. Relative length of finger I<II<IV<III. Femur (8.24 mm) is shorter than tibia (8.94 mm); each less than half of SVL. TTA reaches between nostril and eye, when the leg is folded along the body. Both inner and outer metatarsal tubercles present. Webbing in toes absent, toe tips rounded and with grooves not clearly differentiated. Fourth toe more than one-third of SVL (Table 1).

Colour in life: Dorsum is light brown and minutely warty (Figure 3B&C). Inter-orbital region lighter. A dark band on the sides from snout to the back of tympanum interrupted by the eye socket. Iris yellow. A creamy coloured mid-dorsal line from snout tip to vent, another line over the hindlimbs from vent to the outer metatarsal tubercle. Vent with a lighter blotch. Forearms and hindlimbs banded. Ventrums dirty white with scattered dark dots, more around the anterior region.

Colour in preservative: The specimen loses its colour (Figure 3D&E) and appears light brown, while the markings on the body persist. Ventrums appear dirty off white with light dots.

Etymology: The species name is a toponym based on the country of the type locality, India. The suggested common English name for this species is **Indian papilla-tongued frog**.

Distribution: *L. indica* sp. nov. is currently known only from Talley Valley WLS, Lower Subansiri District, Arunachal Pradesh, India (Figure 1) and from an altitudinal of 2457 m asl.

Natural History: The holotype was collected from an area displaying a transition zone between tropical evergreen forest and temperate forest.

Comparisons: *Liurana indica* sp. nov. is compared with all the known congeners and the newly described ones (Table 2).

L. indica sp. nov. superficially resembles *Liurana alpina* in having overlapping SVL range, but differs in the following morphological parameters (*L. alpina*; in parenthesis): tympanum large and distinct (vs. hidden), dorsum with rows of tubercles forming incomplete dorso-lateral folds (vs. absent), mid-dorsal line from snout tip

to vent (vs. absent), dorsal line from vent to the outer metatarsal tubercle (vs. absent), dorsum colouration light brown (vs. dark brown, yellowish-brown), belly dirty off white (vs. none).

L. indica sp. nov. superficially resembles *Liurana medogensis* in having overlapping SVL range, similar TTA and large & distinct tympanum, but differs in the following morphological parameters (*L. medogensis*, in parenthesis): snout pointed (vs. rounded), dorsum not smooth (vs. smooth with folds), finger I shorter than II (vs. I much shorter than II), tongue notched (vs. rounded), toe tips with a hint of grooves (vs. toe tips swollen but without grooves), dorsum colouration light brown (vs. yellow), snout concolorous (vs. sometimes of lighter shades than the dorsum), mid-dorsal line from snout tip to vent (vs. absent), dorsal line from vent to the outer metatarsal tubercle (vs. absent), belly dirty off white (vs. light yellow or purple).

L. indica sp. nov. superficially resembles *Liurana valleculea* in having similar SVL range large & distinct tympanum, but differs in the following morphological parameters (*L. valleculea*, in parenthesis): snout pointed (vs. rounded), tongue notched (vs. elongated, deeply notched), toe tips without a clearly differentiated grooves (vs. absent), TTA between eye and nostril (vs. beyond snout), mid-dorsal line present (vs. absent), tarsi with line (vs. tarsi with distinct bands), belly smooth with dark dots (vs. with flat tubercles with white marble patterns),.

L. indica sp. nov. superficially resembles *Liurana xizangensis* in having similar SVL range large and distinct tympanum, but differs in the following morphological parameters (*L. xizangensis*, in parenthesis): dorsum not smooth, with tubercles (vs. relatively smooth with minute tubercles), finger I<II (vs. almost same length), toe tips with a hint of grooves (vs. toe tips swollen but without grooves), dorsum colouration light brown (vs. light yellow-brown), mid-dorsal line from snout tip to vent (vs. absent), dorsal line from vent to the outer metatarsal tubercle (vs. absent), belly dirty off white (vs. light yellow).

For the differences with *L. himalayana* sp. nov., please refer to the species description account of *L. himalayana* sp. nov. above.

L. indica sp. nov. superficially resembles *Liurana minuta* sp. nov. in having large and distinct tympanum, but differs in the following morphological parameters (*L. minuta* sp. nov., in parenthesis): larger SVL (vs. smaller

SVL), nostril nearer to eye (vs. equidistant), dorsum with rows of tubercles forming incomplete dorso-lateral folds (vs. scattered tubercles on the dorso-lateral sides), mid-dorsal line from snout tip to vent (vs. absent), dorsal line from vent to the outer metatarsal tubercle present (vs. absent); belly colour white with marbled markings (vs. dirty light in colour with scattered dots), FL<TL (vs. FL=TL), TTA reaching between eye and nostril (vs. beyond nostril), dorsum colouration light brown (vs. yellow-reddish with dark markings).

Species Description: *Liurana minuta* sp. nov.

Holotype: V/A/NERC/ZSI/1441 (male; Figure 4B-E) collected from 5 km N of Pange (Figure 4A), Tale Valley WLS, Lower Subansiri District, Arunachal Pradesh, INDIA, on 06 November, 2015 by Bikramjit Sinha, Lat. 27.5595 N, Long. 93.9083 E, Alt. 1896 m above mean sea level.

Diagnosis: *Liurana minuta* sp. nov. is assigned to the genus *Liurana* on the following morphological characters: (1) body size small (SVL 14.26, $n=1$), (2) Finger and toe tips not expanded, (3) grooves not clearly differentiated into circum-marginal groove, (4) digits without webbing, (5) no tarsal fold, (6) vocal sac and its opening not present.

L. minuta sp. nov. can be distinguished from the known congeners on the basis of the following morphological features: (1) head wider than long, (2) tympanum large and distinct, (3) dark brown dorsum, with bright brown-red towards the vent and lateral sides, (4) dark inter-orbital marking, (5) dorsum smooth with scattered flat tubercles & minute warts, (6) ventrum smooth, dirty white speckled with dark dots, (7) finger I shorter than finger II, (8) TTA reaching beyond nostril.

Description of the Holotype: A small sized (male) frog (SVL-14.26 mm); head wider than long, canthus rostralis prominent. Nostril equidistant. Snout appears like an arrow head dorsally. Tongue slightly bifid, vomerine teeth absent. Eyes rounded, pupil horizontal. Tympanum large and distinct, located nearer to eye. Supra-tympanic fold distinct and strong. Dorsum with scattered tubercles. Forearms slightly shorter than hand length; with a pair of metacarpal tubercles. Fingers free and without webbings. Relative finger length I<II<IV<III. Hindlimbs long, femur (8.44 mm) equals tibia (8.44 mm) length, which is more than half of the length of SVL. TTA reach beyond nostril when the leg is folded along the body. Both inner and outer metatarsal tubercles present. Webbings in toes

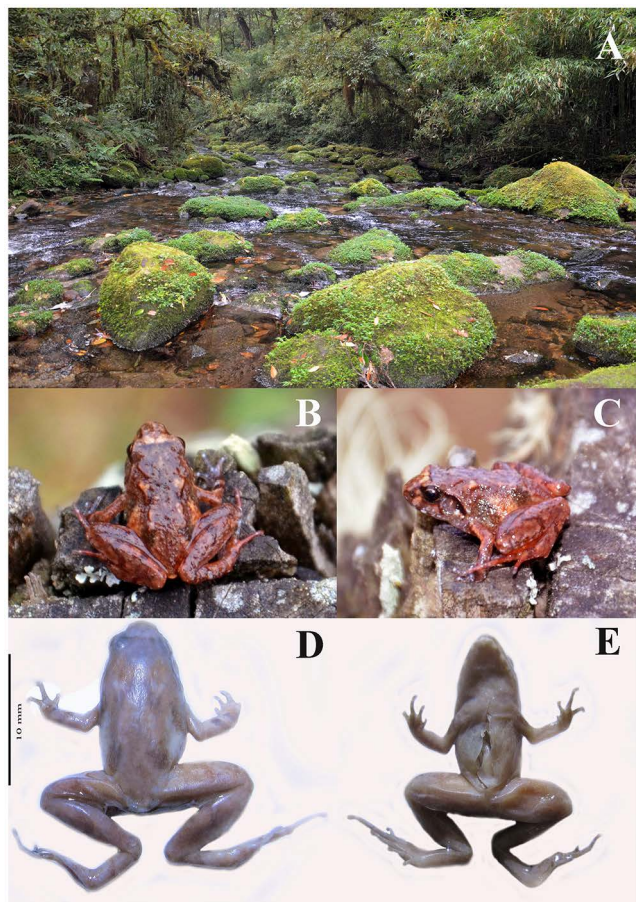


Figure 4. *Liurana minuta* sp. nov. showing the type locality; holotype in live and preserved conditions. Scale is for the preserved specimen photographs only.

absent, but toe tips with groove not clearly differentiated. Fourth toe more than one-third of the SVL.

Colour in life: Dorsum dark brown with bright brown-red towards the vent and lateral sides (Figure 4B&C). Snout is of lighter shade than the dorsum. Irish reddish-yellow. A dark band from snout to the back of tympanum. Occiput region is dark; that faintly bifurcates into two bars towards the groin. Vent with dark blotch. Forearms and hindlimbs banded. Ventrums dirty light in colour with scattered dot. Lower jaw banded with dark and light spots.

Colour in preservative: The specimen loses its colours (Figure 4D&E) and appears light brown. Upon preservation, the contrast between the snout colour with the rest of the dorsum leaves a dark inter-orbital band.

The rest of the markings appear faded. Ventrums is light dirty.

Etymology: The species name is an adjective derived from the Latin word *minuta* for minute, referring to the small size of the frog. The suggested common English name for this species is **Minute papilla-tongued frog**.

Distribution: *L. minuta* sp. nov. is currently known only from Talley Valley WLS, Lower Subansiri District, Arunachal Pradesh, India (Figure 1) and from an altitudinal of 1896 m asl.

Natural History: The holotype was collected from a river bank having rich growth of moss in tropical moist evergreen forest on the south-western fringe areas of Tale Valley Wildlife Sanctuary.

Comparisons: *Liurana minuta* sp. nov. is compared with all the known congeners and the newly described ones (Table 2).

L. minuta sp. nov. superficially resembles *Liurana alpina* but differs in the following morphological parameters (*Liurana alpina*, in parenthesis): smaller SVL (vs. larger), snout shape appears like an arrow head (vs. none), tympanum large and distinct (vs. hidden), dorsum with tubercles (vs. smooth, with flat tubercles), dorsum colouration dark brown and bright brown-red towards the vent and lateral sides (vs. brown), belly light dirty (vs. pale red reticulation/markings).

Liurana minuta sp. nov. superficially resembles *Liurana medogensis* but differs in the following morphological parameters (*L. medogensis*, in parenthesis): smaller SVL (vs. larger), snout shape appears like an arrow head (vs. none), dorsum with tubercles (vs. smooth, with folds), finger I < II (vs. finger I much shorter than II), belly light dirty (vs. light yellow or purple), TTA reaching beyond nostril (vs. between eye and nostril), dorsum colouration dark brown with bright brown-red towards the vent and lateral sides (vs. yellow or light brown).

L. minuta sp. nov. superficially resembles *Liurana valleculla* in having distinct and large tympanum, but differs in the following morphological parameters (*L. valleculla*, in parenthesis): snout appears like an arrow head (vs. rounded), dorsum smooth with flat tubercles and minute warts (vs. with random tubercles), tarsi lightly banded (vs. distinctly banded), belly smooth (vs. flat tubercles), tongue bifid (vs. elongated, deeply

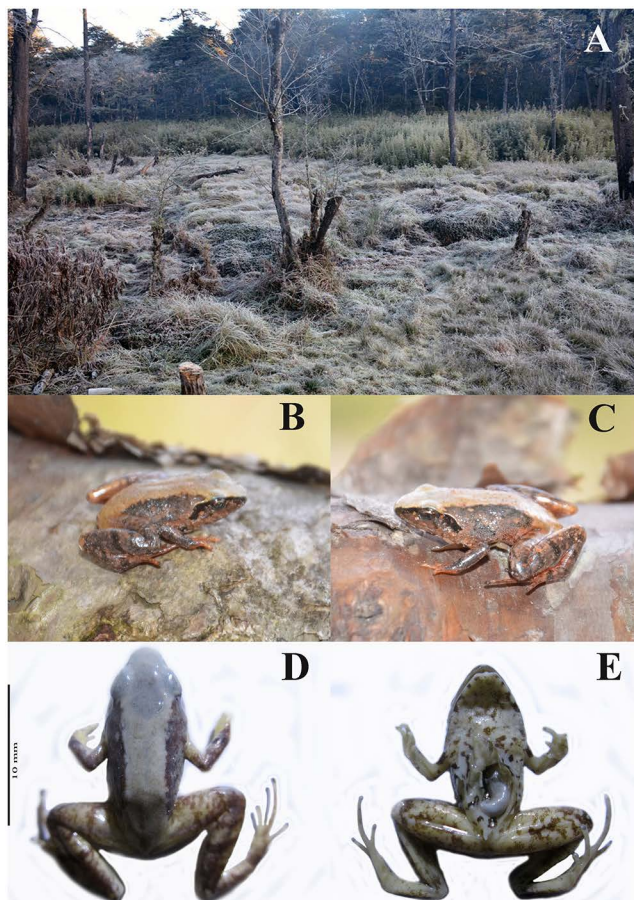


Figure 5. *Liurana medogensis* Fei, Ye, and Huang, 1997 from Talley Camp, Talley Valley Wildlife Sanctuary, Arunachal Pradesh. Scale is for the preserved specimen photographs only.

notched), TTA reaches beyond nostril (vs. beyond snout).

L. minuta sp. nov. superficially resembles *Liurana xizangensis* but differs in the following morphological parameters (*L. xizangensis*, in parenthesis): smaller SVL (vs. larger), tympanum large and distinct (vs. hidden), snout shape appears like an arrow head (vs. none), dorsum with tubercles (vs. smooth with scattered small tubercles), finger I < II (vs. almost same length), dorsum colouration dark brown and bright brown-red towards the vent and lateral sides (vs. light yellow-brown), belly light dirty (vs. pale yellow with black reticulated markings).

For the differences with *L. himalayana* sp. nov., and *L. indica* sp. nov., please refer to the respective

species description accounts of *L. himalayana* sp. nov. and *L. indica* sp. nov. above.

Species Account: *Liurana medogensis* Fei, Ye, and Huang, 1997

Specimen studied: V/A/NERC/ZSI/1442 (male; Figure 5B-E) collected from Talley Camp (Figure 5A), Talley Valley WLS, Lower Subansiri District, Arunachal Pradesh, INDIA, on 11 November, 2015 by Bikramjit Sinha, Lat. 27.5341 N, Long. 93.9515 E, Alt. 2372 m above mean sea level.

Diagnosis: A small sized (female) frog (SVL 15.72 mm). Head wider than long, canthus rostralis prominent. Nostril is equidistant. Eyes rounded and pupil horizontal. Tongue rounded, vomerine teeth absent. Tympanum large and distinct, nearer to the eye. Dorsum smooth, light yellow in colour; lateral sides darker. Supra-tympanic fold prominent, with a darker band beneath. Forearms shorter than hand length. Fingers free and tips with a hint of groove; a pair of metacarpal tubercles. Hindlimbs long; femur equals tibia length. Toes free.

Taxonomic Key to the species of the genus *Liurana*

1. Mid-dorsal line present2
Mid-dorsal line absent3
2. Tympanum large, distinct; tongue notched*L. indica*
Tympanum small, hidden; tongue crown shaped*L. himalayana*
3. Dorso-lateral tubercles present4
Dorso-lateral tubercles absent6
4. Dorsal skin on hindlimbs lightly banded5
Dorsal skin on hindlimbs distinctly banded*L. valleculla*
5. Finger I < II*L. medogensis*
Finger I = II*L. xizangensis*
6. Tympanum hidden*L. alpina*
Tympanum large and distinct*L. minuta*

Discussion

Roy *et al.*, (2018) reported an unnamed *Liurana* from the Dibang River basin in Arunachal Pradesh along with a locality record of *Liurana medogensis*. Although, there were hardly any details provided to ascertain about its probable specific identity, nevertheless, this report

provides an excellent clue that the southern slopes of the eastern Himalayas in the Indian state of Arunachal Pradesh harbours suitable habitats for this moss and litter dwelling small frog group. Talley Valley WLS, located in the central part of Arunachal Pradesh is home to a number of amphibians, of which a few specimens have been identified into 4 species of *Liurana*, including 3 new species.

While reporting *L. medogensis* from India, Borah *et al.*, (2013) mentioned the diagnostic characters of *Liurana* genus (then sub-genus of *Ingerana*) from *Ingerana* by the presences of grooves, enlarged toe pads, extension of webbings and presence of lingual papilla. However, contradicting Borah *et al.*, (2013), Yan *et al.*, (2016) and Jiang *et al.*, (2019) reported about the absence of grooves on the finger and toe tips and absence of interdigital webbings. The genus *Liurana* was erected by Dubois (1987) where he had highlighted the following characteristics: (1) fingertips and toe-tips not dilated, without a clearly differentiated circum-marginal groove, (2) webbing absent or reduced and (3) lingual papilla present. Given that Dubois was one of the co-authors of Borah *et al.*, (2013), we should not out-rightly agree to the conflicting generic characters mentioned in Yan *et al.*, (2016) and Jiang *et al.*, (2019). In the light of our study on the specimens of *Liurana* collected from Talley Valley, Arunachal Pradesh, we have come across that our specimens do have a semblance of groove but without clearly differentiated grooves, agreeing with Dubois (1987). Besides this observation, all the other generic characters agree with Dubois (1987) and Jiang *et al.*, (2019).

Therefore, we are expanding the generic characters of the genus *Liurana* and attributing the following morphological characters: small sized frogs; head broader

than long; tongue with papilla; tympanum visible and big, sometimes indistinct; toe tips enlarged with grooves not clearly differentiated or absent; inter digital webbings absent, maybe present but negligible and tarsal fold absent, fourth toe very long (about 1/3rd) relative to SVL and vocal sac opening absent.

With this 3 new species, the total count of species under the genus *Liurana* is revised to 7 species distributed over the Eastern Himalayas between India and China.

Zoobank Registrations

Publication LSID:

urn:lsid:zoobank.org:pub: 1ED962C6-800A-401B-A88B-AF39FF4B0ABD

Liurana himalayana LSID:

urn:lsid:zoobank.org:act:02B9CA50-EAB1-44FF-ABE0-A0469DCD4E7B

Liurana indica LSID:

urn:lsid:zoobank.org:act:C938021D-53B1-4D4E-8242-9949A1DB7CEE

Liurana minuta LSID:

urn:lsid:zoobank.org:act:B28F7525-8F33-4888-9BF0-C766BB171EE8

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