

Anuran diversity distribution patterns in Lower Dibang Valley of Arunachal Pradesh, India

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Abstract. The present study was conducted to estimate the anuran species diversity distribution patterns at Lower Dibang Valley with respect to secondary habitat conservation. Time-constrained Visual Encounter Surveys (VES) were conducted for amphibians followed with opportunistic observations during the study period. We compared the species diversity from three land use/land cover types that explained the available habitats and the importance of secondary forest in recolonizing anuran species during the course of study. Interestingly, anuran diversity measured from secondary/abandoned jhum and primary forest areas were found to be relatively equal (Shannon index; H: 2.77 and 2.76). The highest percentage of unique species was recorded from primary forest followed by secondary/abundant jhum and agriculture/settlement areas. However, secondary/abandoned jhum areas provided refuge for most anuran species normally inhabiting primary forest. We found beneficial human interaction along with secondary succession for creating habitat heterogeneity in secondary/abundant forest; and thus supports maximum anuran breeding habitats and species diversity in secondary/abundant jhum areas. Hence, secondary/abundant habitats were also important for anuran habitat conservation along with primary forest. We reported four new distribution records from Arunachal Pradesh: *Nanorana chayuensis*, *Hydrophylax leptoglossa*, *Odorrana chloronota* and *Theloderma moloch*.

Keywords. Arunachal Pradesh, anuran diversity, habitat heterogeneity, land use/land cover, Lower Dibang Valley

Introduction

Understanding amphibian diversity distribution patterns across different land use/land cover types are important for their conservation. The change in land use characteristics (Collins et al., 2003; Gibbs et al., 2005) due to human intervention following habitat fragmentation and habitat loss (Pawar and Birand, 2001; Stuart et al., 2004; Hayes et al., 2010) has an impact on the decline of amphibian populations globally. However, habitat heterogeneity created due to different agricultural practices such as jhum cultivation (traditional slash and burn agriculture or shifting cultivation; Pawar et al., 2004) at different scales enhance most amphibian species richness (Pawar et al., 2004; Loehle et al., 2005; Funk

et al., 2005), followed by vegetation cover and local microclimate (Rios-Lopez and Aide, 2007). However, elevation and terrain types influence amphibian habitat characteristics, followed by human disturbances (Tocher et al., 1997; Pawar and Birand, 2001). The present study area, Lower Dibang Valley situated at the base of the eastern Himalayas, has land ownership classified in three broad categories: (1) community ownership (2) clan/individual ownership and (3) government ownership. Our study was carried out across community reserve forest areas of Idu Mishmi. The habitat is mountainous (250–3500 m a.s.l.) and is represented by tropical moist evergreen forest, evergreen forest and grassland. Being part of the Eastern Himalayas, the district is home to numerous wildlife species including several endemic, vulnerable and threatened species (Choudhury, 1995; Choudhury, 2003; IBCN, 2015). However, studies on amphibians from the region are very limited, with only two amphibian inventories reported during the Abor Hill expedition (Annandale, 1912), which documented 25 species, followed by 30 species reported from Dehang Dibang Biosphere Reserve by Bordoloi et al. (2002). Our study along the Dibang river basin aimed to measure anuran diversity at three different land use/

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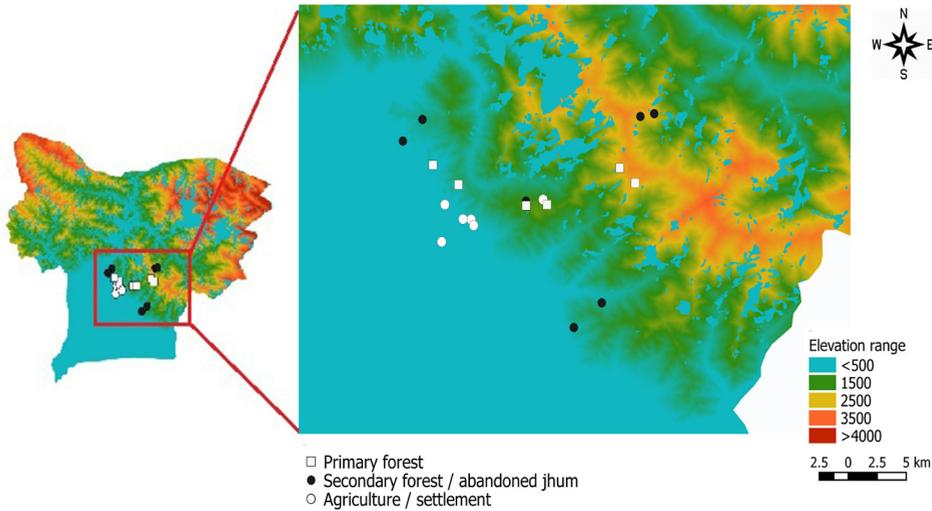


Figure 1. Study area map, showing sampling points from three land use/land cover types at Lower Dibang Valley, Arunachal Pradesh, India.

land cover types in relation to the degree of human disturbances at a local scale. This study is necessary, since the community reserve forests in Lower Dibang Valley is currently under constant human pressure and poorly protected.

Materials and Methods

The present study was conducted in Lower Dibang Valley of Arunachal Pradesh situated at the base of the eastern Himalayas between 27.133° to 28.583° N and 94.100° to 95.400° E along the Dibang river basin (Fig. 1). We surveyed the area from May to August 2015 at 19 sites categorized into three land use/land cover types i) agriculture/settlement ($n=6$); ii) secondary/abandoned jhum ($n=7$) and iii) primary forest areas ($n=6$) (Fig. 1). The amphibian survey was conducted by using Visual Encounter Surveys (VES; Crump and Scott, 1994) between 18:30–20:30 h and acoustic searches (Rödel and Ernst, 2004) along different streams and forest trails, shallow water bodies, agricultural lands were surveyed covering altitude from 250–2655 m. Shannon-Wiener Index (H) of species diversity (H) was estimated by using ‘vegan’ package in R 2.14 statistical tool for analysis (Oksanen *et al.*, 2015) to compare species composition and habitat characteristics from three land use/land cover types. Pairwise Sørensen index of similarity was tested to compare the species composition among three land use/land cover types

(Baselga, 2012). We did a pairwise Mann-Whitney U test to compare the number of individuals encountered from three land use/land cover types. To measure the effect of human disturbances on anuran distribution, we grouped disturbance variables into six categories: tree cutting, lopping, grass/bamboo/cane cutting, human/domestic animal trail, number of people seen and other grazing livestock seen during the survey time period. The data for all disturbance variables were recorded in standard data sheet (Jhala *et al.*, 2009). We did a Pearson correlation analysis between the anuran relative abundance with all disturbance variables to assess the influence of human intervention at three land use/land cover types.

Results

A total 31 anuran species representing five families and sixteen genera were recorded from Lower Dibang Valley of Arunachal Pradesh (Table 1). It included four new distribution records from Arunachal Pradesh: *Nanorana chayuensis*, *Hydrophylax (Hylarana) leptoglossa*, *Odorrana chloronota*, and *Theloderma moloch* (Fig. 2: A, B, C and D). Brief natural history notes on four anuran species were included in appendix 1. The highest anuran species richness was recorded from secondary/abandoned jhum areas ($n=20$), followed by primary forest areas ($n=19$). Species richness was lowest in areas under agriculture/settlement ($n=13$).

Table 1. List of anuran species encountered from three landuse/land cover types, Lower Dibang Valley of Arunachal Pradesh during 2015.

Sl. No.	Scientific Name	Family	Landuse/Land cover type		
			Agriculture/ settlement	Secondary/ abandoned jhum	Primary forest
1	<i>Duttaphrynus melanostictus</i>	Bufonidae	✓	✓	–
2	<i>Duttaphrynus stuarti</i>		–	✓	✓
3	<i>Nanorana chayuensis</i>	Dicroglossidae	–	✓	✓
4	<i>Euphlyctis cyanophlyctis</i>		✓	✓	✓
5	<i>Fejervarya pieri</i>		✓	–	–
6	<i>Fejervarya syhadransis</i>		✓	–	–
7	<i>Fejervarya nepalensis</i>		–	✓	–
8	<i>Fejervarya teraiensis</i>		✓	✓	–
9	<i>Hoplobatrachus crassus</i>		✓	–	–
10	<i>Hoplobatrachus tigerinus</i>		✓	✓	–
11	<i>Liurana medogensis</i>		–	✓	✓
12	<i>Xenophrys robusta</i>	Megophryidae	✓	✓	✓
13	<i>Xenophrys</i> sp1		–	–	✓
14	<i>Xenophrys</i> sp2		–	✓	✓
15	<i>Amolops marmoratus</i>	Ranidae	✓	✓	✓
16	<i>Amolops viridimaculatus</i>		–	–	✓
17	<i>Humerana humeralis</i>		✓	✓	✓
18	<i>Odorrana chloronota</i>		–	–	✓
19	<i>Hydrophylax leptoglossa</i>		–	✓	–
20	<i>Polypedates himalayensis</i>	Rhacophoridae	✓	✓	–
21	<i>Rhacophorus maximus</i>		✓	✓	✓
22	<i>Rhacophorus bipunctatus</i>		–	–	✓
23	<i>Rhacophorus tuberculatus</i>		–	–	✓
24	<i>Rhacophorus translineatus</i>		–	✓	✓
25	<i>Theلودerma asperum</i>		–	✓	–
26	<i>Theلودerma moloch</i>		–	–	✓
27	<i>Kurixalus naso</i>		–	✓	✓
28	<i>Kurixalus</i> sp		–	–	✓
29	<i>Philautus</i> sp1		✓	✓	–
30	<i>Philautus</i> sp2		–	✓	–
31	<i>Philautus</i> sp3		–	–	✓

✓ Species recorded during the survey
– Species not recorded during the survey

Similarity in species composition (Sørensen similarity index: S_s) was found higher between agriculture/settlement and secondary/abandoned jhum ($S_s=0.61$), followed by primary and secondary/abandoned forest, and agriculture/settlement and primary forest ($S_s=0.31$). We found all three land use/land cover types to have specific habitat features important for anuran

distribution in the area. Among the 31 recorded anuran species, *Xenophrys* sp. 1, *Amolops viridimaculatus*, *Odorrana chloronota*, *Kurixalus* sp., *Philautus* sp. 3, *Rhacophorus bipunctatus*, *Rhacophorus tuberculatus*, and *Theلودerma moloch*, were found only in primary forest areas ($n=8, 25.81\%$). On the other hand, *Fejervarya pieri*, *Fejervarya syhadransis*, and *Hoplobatrachus*

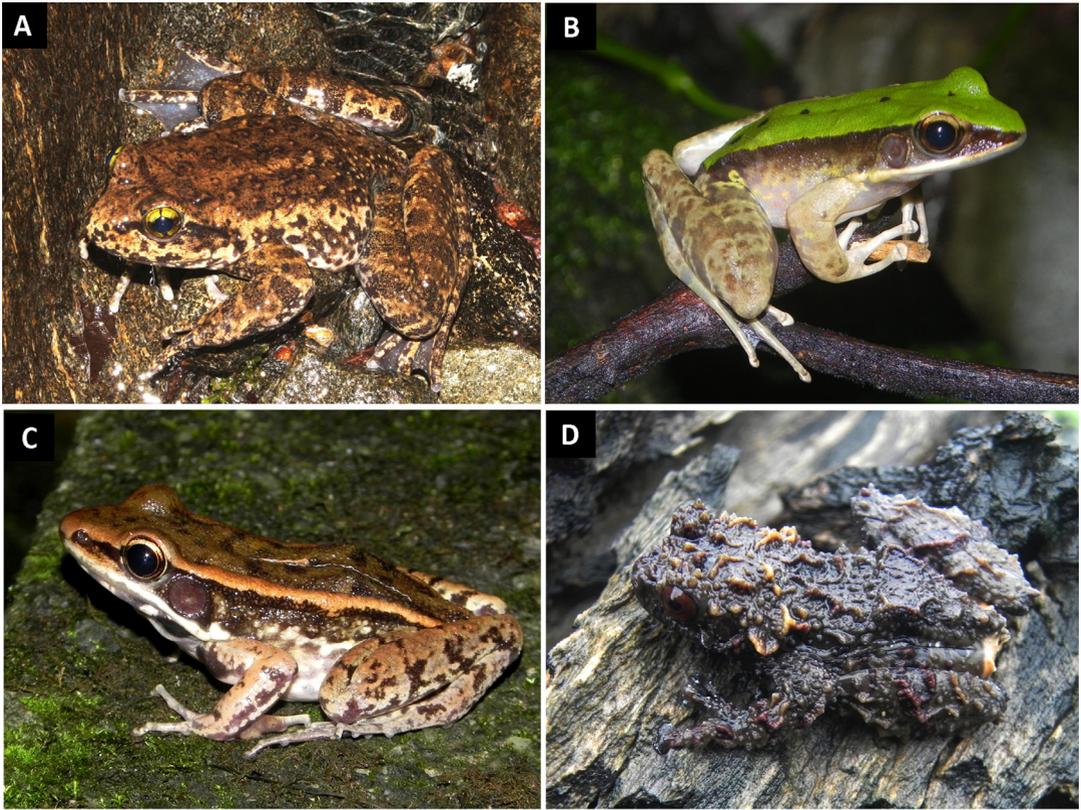


Figure 2. New distribution records of four anuran species from Arunachal Pradesh, India: A - *Nanorana chayuensis*; B - *Odorrana chloronota*; C - *Hydrophylax leptoglossa*; D - *Theloderma moloch*.

crassus were found only in agricultural/settlement areas ($n=3$, 9.68%); *Fejervarya nepalensis*, *Hydrophylax leptoglossa*, *Philautus* sp. 2, and *Theloderma asperum* were found only in secondary/abandoned jhum areas ($n=4$, 12.9%) (Fig. 3). The Shannon-Wiener Index (H) of species diversity was found to be relatively equal for both primary forest and secondary/abandoned jhum areas (2.77 and 2.76) compared to agriculture/settlement areas (2.36). We found a significantly higher number of individuals from agriculture/settlement than primary forest areas (Mann-Whitney U test; $U=57.5$, $n_1=13$, $n_2=19$, $p<0.05$). However, we did not find significant differences in the number of individuals encountered in agriculture/settlement and secondary/abandoned jhum areas ($U=96$, $n_1=13$, $n_2=21$), or secondary/abandoned jhum and primary forest areas ($U=142.5$, $n_1=21$, $n_2=13$). However, from the mode of habitat requirements, we found differences in the proportion of anuran species occurrence at three land use/land cover types (Fig. 4).

The proportion of arboreal anurans was significantly affected at all three land use/land cover types ($\chi^2=12.96$), followed by shallow water body ($\chi^2=19.39$), stream dwelling ($\chi^2=22.49$), and terrestrial anurans ($\chi^2=28.57$), with degrees of freedom (df) 2 and significant level (p) at <0.01 for all the cases.

From the disturbance variable estimation, we did not find significant relationship between anuran relative abundance and all disturbance variables (Fig. 5). However, the number of people seen and number of grazing livestock seen had a negative impact with the anuran relative abundance estimated from three land use/land cover types followed by tree cutting and grass/bamboo/cane cutting (Fig. 5). We found the presence of human/domestic animal trails had a positive relationship with the anuran relative abundance estimated from three land use/land cover types followed by looping (Fig. 5).

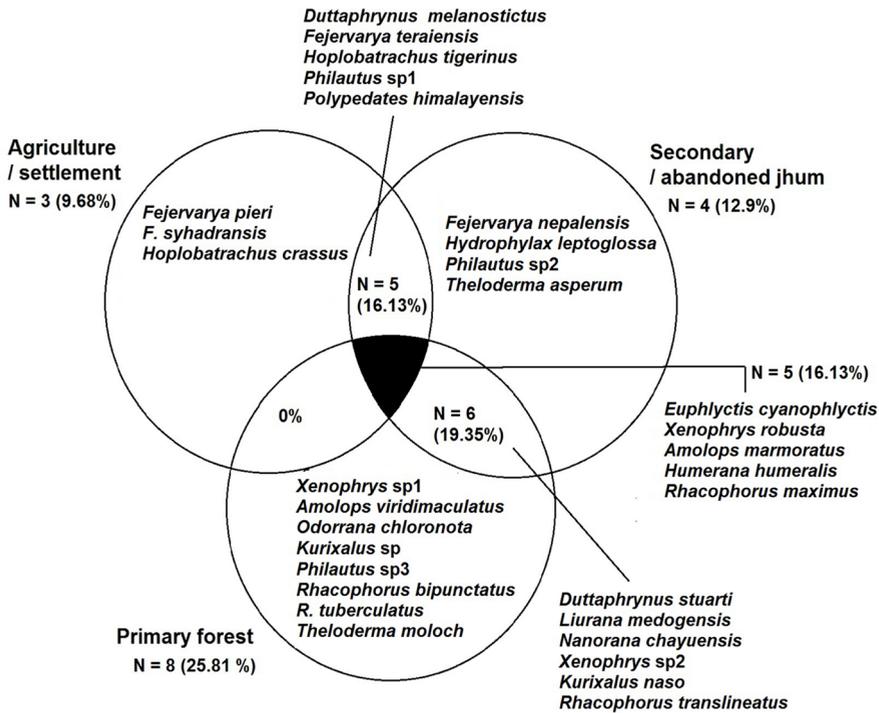


Figure 3. Distribution of unique and shared amphibian species richness among three land use/ land cover types in Lower Dibang Valley, Arunachal Pradesh, India during 2015.

Discussion

This study presented the distribution record of 31 anuran species recorded from Lower Dibang Valley district of Arunachal Pradesh. Previously Annandale (1912) and Bordoloi et al. (2002) reported amphibian diversity from Abor Hills (Siang River Basin) and Dihang-Dibang Biosphere Reserve (Siang and Dibang River Basins), respectively. The new locality recorded for *Theلودerma moloch* from the Lower Dibang Valley provided information on microhabitat and natural history of the species for further research (Roy et al., 2017). *Theلودerma moloch* is listed as Vulnerable (Dutta et al., 2004) and from Arunachal Pradesh it has been reported from Eaglenest Wildlife Sanctuary (Athreya, 2006), Abor Hills (Borah and Bordoloi, 2003) with no specific location, and from Mouling National Park (Pawar and Birand, 2001). The record of *Nanorana chayuensis* from 1484–2539 m a.s.l. considerably extends the known altitudinal distribution of this species. It was originally recorded at 1540 m (Ye, 1977) from China and later reported from Darjeeling district of West Bengal, India at 1860 m a.s.l. (Deuti and Ayyaswamy,

2008). The new locality recorded for *Hydrophylax leptoglossa* from Lower Dibang Valley district of Arunachal Pradesh. Previously this species was known to occur at low elevation in Assam, Mizoram, (Chanda, 1994; Lalremsanga et al., 2007a; Ahmed et al., 2009; Bortamuli et al., 2010).

The highest species diversity was recorded from secondary/abandoned jhum and primary forest areas, which implies a positive impact of secondary succession by providing breeding habitats for anuran species in secondary/abandoned jhum areas that were left as fallow land for several years. During the agricultural cycle, the fallow land becomes productive for amphibian recolonisation due to a mosaic of habitats created by jhum cultivation (Pawar et al., 2004). Thus, secondary habitats created in fallow land provided habitat for most anuran species to occur in secondary/abandoned jhum areas with having moderate canopy cover. The significantly higher species abundance in agriculture/settlements compared to primary forest areas is due to having generalist and widespread anuran species distribution in the agriculture/settlement areas (Barmuta et al., 2009).

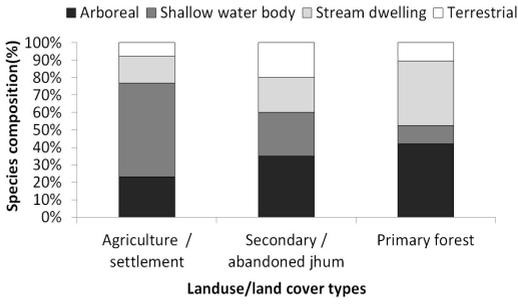


Figure 4. Proportion of amphibian species of different habitat requirements at three landuse/land cover types in Lower Dibang Valley, Arunachal Pradesh, India during 2015.

On the other hand, no significant difference in the anuran species abundance between secondary/abandoned jhum areas with agriculture/settlement and primary forest, probably because secondary/abandoned jhum acted as a transitional zone between highly disturbed agriculture/settlement areas and undisturbed primary forested habitats. A reduced proportion of arboreal species were recorded in lowland agriculture/settlement areas that were exposed to sunlight that resulted in lower humidity and higher temperatures compared to primary forest with thick canopy and high humidity. It was found that at low elevations with low humidity and high temperature arboreal species experienced physiological constraints compared to forests at high elevation with high humidity (Naniwadekar and Vasudevan, 2007). On the other hand, the highest proportion of shallow water body species in agriculture/settlement areas was due to larger habitat areas in lowland areas as opposed to smaller or temporary water bodies in primary forests. However, secondary/abandoned jhum areas had an equitable proportion of anuran species as a transitional zone between the two land use/land cover types.

Amphibian habitat loss due to deforestation, habitat modification, monoculture and other human intervention were recorded worldwide (Collins *et al.*, 2003; Stuart *et al.*, 2004; Hayes *et al.*, 2010). However, human disturbance is sometimes beneficial for anurans and other herpetofauna by creating breeding habitats at local scales following large scale habitat degradation due to continuous human intervention and deforestation. It was found that moderately disturbed and altered forests with a relatively high canopy support the most anuran species in the area and this was supported by previous studies on different herpetofauna species (Pawar *et al.*,

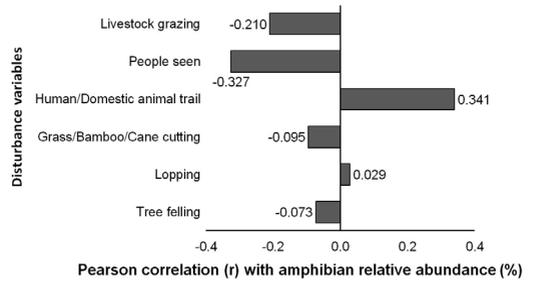


Figure 5. Correlation between amphibian relative abundance and all disturbance variables. (n=10 for all disturbance variables; not significant).

2004; Gillespie *et al.*, 2015; Cruz-Elizalde *et al.*, 2016). Habitats created along forest trails, artificial pools for agriculture, and fallow cultivation land provided suitable environment for anurans. Along a forest trail, the change in space and habitat characteristics results in edge effects by altering biotic and abiotic factors (Singh *et al.*, 2010). Edge effects, which vary in space and time (Laurance *et al.*, 2007), influence forest structure and species composition (Laurance, 1991; Harper *et al.*, 2005; Laurance *et al.*, 2007). In the present study, we recorded significant anuran species richness along the edge of the forest, which is due to the adaptation of specific anuran species in modified/alter habitat followed by beneficial human interactions. As it has been observed in previous studies, edge effect increased prey availability and created habitat for many anuran species (Phillip *et al.*, 1995). The anuran species abundant along the forest edge includes: *Duttaphrynus stuarti*, two species of *Kurixalus*, and all three species of *Philautus* recorded during our study period (Table 1). Hence, the secondary or degraded forest areas are of equal importance as amphibian breeding habitats compared to the primary forests in Lower Dibang Valley. Community awareness towards forest management practices for different agricultural practices is also important for amphibian habitat conservation in the area. Indigenous beliefs and religious forest management practices associated with taboos among the Idu Mishmi community peoples has significant importance to the high species richness in the study area.

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Appendix 1

Natural history notes on four anuran species records:

Nanorana chayuensis (Ye, 1977) (Fig. 2, A): We reported this species in our study area along an elevational range 1484-2539 m a.s.l. during July. Previously, it was reported from Darjeeling district of West Bengal (1860 m a.s.l.) by Deuti and Ayyaswamy (2008). *Nanorana chayuensis* is characterized by two oval patches of spines, with 33 to 56 spines on each patch on the chest of the male during the breeding season (Ohler and Dubois, 2006). All the individuals were encountered in fast flowing streams with slippery boulders and banks steep angles in first order streams. It is moderately large in size (SVL=62.11-84.11 mm, n=6).

Odorrana chloronota (Gunther, 1876) (Fig. 2, B): We recorded this species from Lower Dibang Valley (252-680 m a.s.l.) during April-July. It has wide distribution in Northeast India including Assam, Meghalaya, Nagaland, Manipur, and Mizoram (Lau et al., 2004). *Odorrana chloronota* is bright green on the dorsum, with 5-6 dark spots; fingers free, toe fully webbed, tympanum distinct and round. Individuals were encountered mostly from lowland stream areas they were present along edge of fast flowing stream with thick canopy cover (75-85 %); humid forest (80-90 %). The SVL measured for one individual of the species was 70.81 mm (n=14).

Hydrophylax leptoglossa (Cope, 1868) (Fig. 2, C): We recorded two individual of this species from the study area (488 m a.s.l.) on June near Sally Lake. Both the individuals were calling from ground covered by thick bushes near the lake. In Northeast India, *Hydrophylax leptoglossa* was reported from Assam (Ahmed et al., 2009; Bortamuli et al., 2010; Chanda 1994; Matthew and Sen 2010; Hussain et al., 2007) and Mizoram (Lalremsanga et al., 2007). *Hydrophylax leptoglossa* is characterised by cream coloured dorsolateral fold running from posterior eye to the vent; tympanum distinct and round (Ahmed et al., 2009). SVL: 49.37 and 50.34.

Theلودerma moloch (Annandale, 1912) (Fig. 2, D): We recorded this species from Lower Dibang Valley (780-910 m a.s.l.) during May-July. Annandale (1912) originally described this species from Abor Hill and it was later reported from Mouling National Park (not confirmed), Abor Hills, Eaglenest Wildlife Sanctuary and Pakke Tiger Reserve (Pawar and Birand, 2001; Borah and Bordoloi, 2003; Athreya, 2006). *Theلودerma moloch* is grayish brown in colour and characterized by a prominent, more or less serrated ridge on dorsal side of the body (Annandale, 1912; Chanda, 1994). Individuals at two sites were found calling from a tree crevice filled with rainwater. The tree was uprooted and had fallen nearly horizontal to the ground, but leaned on other tree. SVL 36.10-39.46 mm (n=4).