

Amphibians of Sikkim Himalaya: An evaluation of diversity, distribution pattern and threats along the elevation gradient

Abstract

Amphibians constitute an important component of ecosystem linking minor vertebrates with major and aquatic life with terrestrial. Unlike birds and mammals, the study of amphibians is mostly limited to taxonomy. Understanding the diversity and distribution of species along the geographical gradient will aid in conservation and management of biodiversity. With the projected impact of climate change in the Himalayas, the study of distribution pattern along the elevation gradient is very important. Sikkim, part of the Eastern Himalayan Biodiversity Hotspots, exhibits immense gradient of altitude and climate resulting in great variation of life forms. Amphibians were studied along the elevation gradient of Sikkim Himalaya. A total of 28 species was recorded during the study period with maximum richness between 1000-2000m elevations. Most amphibian species of Sikkim Himalaya were confined to narrow elevational width. Hence conservation of entire gradient of habitat is essential for the conservation of amphibians. During our study, we found extraction of frogs by locals for meat and medicine. With the rapid land use change, climate change and unsustainable harvesting, the amphibian of the Himalaya poses great challenge for future survival.

Introduction

Amphibians play an important role in energy flow and nutrient cycling in the ecosystem and serve as the bio-indicators of ecosystem health because of the sensitive permeable skin and dual mode of life (Beebee and Griffiths, 2005). Amphibian populations are declining and disappearing globally at a fast rate even from protected areas (Blaustein and Wake, 1990; Stuart et al. 2004). However, new species are continuously being discovered at the high rate (25% in the last 11 years). Many new species are being continuously described from North East India (Kamei et al. 2009; Biju et al. 2010; Mahony et al. 2013; Subba et al. 2015; Biju, 2016).

Rodgers and Panwar (1988) included Sikkim as part of Trans Himalaya and Central Himalayas. However, other literatures considered the state as part of the Eastern Himalayan region (Ali, 1962; Mani, 1974). Sikkim is now a part of two biodiversity

hotspots, Indo-Burma hotspots and Himalaya hotspots (Mittermeier et al. 2004). Although Sikkim is only one twentieth of the Western Ghats in geographical area, diversity of flora with 4,458 species of flowering plants including 525 species of orchids, 58 primulas and 36 rhododendrons is spectacular. Fauna also displays rich diversity with 169 species of mammals, 574 birds, 88 reptiles (71 snakes and 17 lizards), 50 amphibians, 50 fishes and 689 species of butterflies (Acharya and Sharma, 2013). This high diversity is attributed to its geographical location on the confluence

Key words:

*Amphibian,
Conservation,
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Nasutixalus jerdonii.
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Basundhara Chettri

Department of Zoology, Sikkim University
Barad Sadan, 5th Mile, Tadong - 737102, Gangtok, Sikkim.

Corresponding author e-mail: bchettri01@cus.ac.in

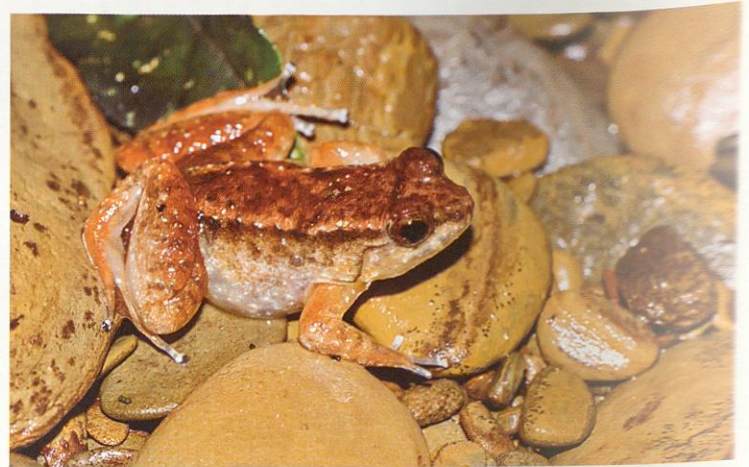


between Oriental and Palearctic zoogeographical realms, an elevation range extending from 300 m to over 8598 m and climatic regime from tropical to cold desert. Despite high diversity, Northeast India is far less explored as compared to Western Ghats and much of the diversity awaits scientific discovery (Biju et al. 2016).

Diversity and distribution of life forms along the geographical gradients such as latitude and elevation has fascinated biogeographers since past many years. Why species declines from tropics towards the poles? Similarly, why some species are restricted to sea level while others at the mountain tops? Many studies around the globe have attempted to understand these uneven patterns of distribution, yet the generality of such trend is unknown. The study of species distribution pattern along the different elevational gradient will help in prioritization of areas for conservation of biodiversity (Gaston, 2000; Hu et al. 2011; Aynekulu et al. 2012). Apart from biodiversity conservation, such studies are crucial for evaluating the impact of climate change under which contraction or expansion of species range size are expected (Ah-Peng et al. 2012).

The people in the Himalayan region, including Sikkim live in close association with nature. The livelihood of Himalayan people revolves around the natural resources but with current rate of population increase and anthropogenic activities taking place, biodiversity of this region is in serious threat (Schleich & Kästle, 2002). We noticed that local and migrant communities exploit various species of amphibians for meat and medicine endangering the species pool in the region. While the local communities of Sikkim Himalaya especially aboriginal tribe "Lepcha" have profound indigenous knowledge on biodiversity which can be utilized for the conservation of rich biodiversity of the region (Acharya et al. 2009).

Here, I compiled and updated the checklist of amphibians of Sikkim based on extensive research and available literatures. The elevational range of the amphibian species are obtained from both primary and secondary data. The diversity and distribution pattern of amphibians along the



Ingerana borealis.
Photo Credit: Abhijit Das

elevation gradient are evaluated to identify diverse areas of conservation importance. In addition, threats to amphibians with reference to extraction by humans were also evaluated. Certain conservation measures have been recommended.

Study Area

Sikkim, one of the smallest states of India (27° 5' - 28° 10' N and 87° 4' - 88° 58' E) is situated at the western most boundary of eastern Himalayas and encompasses geographical area of 7096 km². Entire Sikkim is considered as the catchment of River Teesta. Sikkim has 180 perennial lakes among them Khechopelri, Guru Dongmar, Chho-Lhamu, Tsomgo and Menen Tso are a few high altitude lakes to mention, which are not only of scenic and religious importance, but have immense ecological value (Acharya and Sharma, 2013). The catchment area along the course of the river is wet and humid, conducive for the amphibians. Besides, the swift tributaries of Teesta shelter many torrent frogs, which are either unknown or poorly known.

Within a very small geographical span (linear distance of ~150 km), climate changes from hot tropical to temperate condition, vegetation from tropical semi-deciduous in the lower elevations through temperate broad-leaved forest at the mid and coniferous to sub-alpine and alpine vegetation at the higher altitude. The other abiotic factors such as humidity, rainfall, temperature and atmospheric pressure also changes accordingly. Lower valleys are hot and humid and receive heavy rainfall, sometimes exceeding 3500mm per annum (Chettri et al. 2010). The high elevation

regions are drier and colder with relatively less annual precipitation. Precipitation in the sub-alpine and alpine region occurs in the form of snow.

In addition to literature survey, an extensive field research on amphibians was carried out in the Teesta valley and Maenam Wildlife Sanctuary in Sikkim during 2009-2010. Teesta originates at snow fed Chollamu Lake, at 4800m above mean sea level and flows in north-south direction till it

enters into the West Bengal near Melli at 300m. Survey locations for amphibians are shown in Figure 1. For data collection, study area was categorized into seven zones based on elevation (500m interval; Table 1). Apart from extensive study in Teesta valley, surveys were carried out in Maenam Wildlife Sanctuary, located on the Tendong-Maenam ridge within the southern district of Sikkim and spreads over a geographical area of 36 sq km (Fig. 1).

Table 1: Categorization of the study area based on altitude (500m interval) in Sikkim

Elevational zone	Elevation (m)	Forest type
Zone I	< 500	Tropical Semi Deciduous Forest (TrSDF)
Zone II	500-1000	Tropical Semi Deciduous Forest (TrSDF)
Zone III	1000-1500	Tropical Broad Leaved Forest (TrBLF)
Zone IV	1500-2000	Tropical + Temperate Broad-Leaved Forest (TrBLF + TmBLF)
Zone V	2000-2500	Temperate Broad-Leaved Forest (TmBLF)
Zone VI	2500-3000	Temperate Broad-Leaved + Coniferous Forest (TmBLF + CnF)
Zone VII	>3000	Coniferous Forest + Sub-alpine + Alpine (CnF + SA1 + A1)

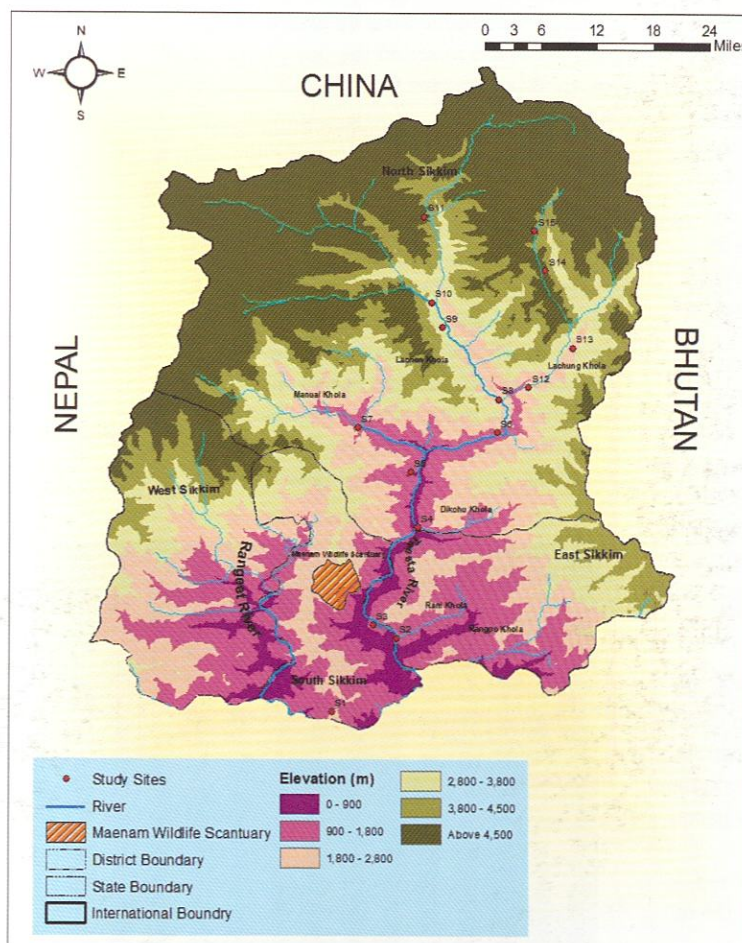


Figure 1: Map showing the sampling locations in Teesta valley (red dots) and Maenam Wildlife Sanctuary in Sikkim. (S1 - Melli; S2 - Singtam; S3 - Reshap Dalep; S4 - Dikchu; S5 - Sangkalang Dzongu; S6 - Toong; S7 - Muyong; S8 - Chungthang; S9 - Lachen; S10 - Zema; S11 - Thangu; S12 - Khedum; S13 - Lachung; S14 - Yumgthang; S15 - Yumesamdong (South).

MATERIALS AND METHODS

Compilation

Thorough literature review dealing with herpetofauna of Sikkim and neighbouring areas of Darjeeling Hills was undertaken to generate information on species occurrence in the state. Data on elevational range were also obtained from literature supported by the field observations.

Data collection

Field study was carried during April 2009-July 2010 with intensive sampling during May to August when species are breeding and, therefore, activity is at its highest. Time constraint visual encounter survey (VES) method (Heyer et al. 1994) was followed for sampling amphibians. Search was conducted during day hours (09:00 to 14:00 Hrs) and microhabitats such as boulders, logs and mosses were thoroughly examined searching for the animals. Since most amphibians are crepuscular or nocturnal, VES was supplemented by night stream surveys (19:00 to 20:30 Hrs) in various locations. Data on type and extent of any kind of disturbance(s) were noted to assess the threat on amphibians. Total number of people involved in extraction, community type (such as Lepcha, Bhutia, Rai, Limboo, Tamang, etc.), location and elevation, species and number of individuals caught were collected. The persons involved in such activities were casually interviewed to verify the data and to gather more information.

Data analysis

The data generated during the study were analyzed using different computer packages and statistical software such as SPSS and Microsoft excel. Species richness, diversity, evenness and abundance were calculated for total and each elevation zone separately. Species richness was obtained as cumulative number of species and abundance as total number of individuals observed during the study. Based on these data, we estimated distribution pattern along the elevation gradient. Anthropogenic threat on amphibians was analyzed based on extraction to figure out the total amphibian extraction per site, preferred species, purpose of extraction and time of collection.

Results

Species richness and composition

Number of species reported from Sikkim by different researchers varied from 15 to 30. Boulenger (1890) and Gammie (1928) reported 17 and 16 species of amphibians respectively from Sikkim. Inger and Dutta (1986) summarized amphibian distribution based on the literature and reported 56 species from Northeast India, 15 specific to Sikkim. Waltner (1973) documented 53 species of amphibians from the entire range of Himalayas including 30 from Sikkim. Swan (1993) found 41 amphibian species from plains and mountains of both Sikkim and Darjeeling area, but reduced the species confined to hills as 32. Chanda (2002) documented Indian amphibians, which included 21 species found in Sikkim. Jha and Thapa (2002) reported 26 species of amphibians from Sikkim Himalayas of which 20 are specific to Sikkim. Most of the above reports are based on museum records and compilation from published literature except the recent work by Subba et al. (2016) which reported the occurrence of 23 amphibian species from Sikkim Himalaya.

Based on various published literatures (Boulenger, 1890; Chanda, 1986; Schleich & Kastle, 2002, Jha and Thapa 2002; (Subba *et al.* 2016) and the field study conducted in Teesta valley and Maenam Wildlife Sanctuary we found occurrence of 37 amphibian species (Table 2). Of the total 37 species, 35 species belong to five families under order anura and the remaining two species are represented by each order urodela and gymnophiona. Out of total 37 species, nine are not evaluated (NE) and

Nanorana cf. annandalii.
Photo Credit: Abhijit Das



two are data deficient (DD) hence their population status in the wild is not known.

Field study in Teesta valley and Maenam Wildlife Sanctuary yielded 25 amphibian species. These species belonged to seven families and two amphibian orders (Table 2). Order Apoda was represented by single

family and species, whereas order Anura comprised of six families and 24 species. According to IUCN red list one species is under vulnerable (VU) category (*Ingerana borealis*) and two under near threatened (NT) category (*Nanorana gammii*, *Nanorana annandali*, *Nanorana ercepeae* and *Rhacophorus reinwardtii*).

Amphibia Family	Species	Elevation range(m)	IUCN Red list categories
Order - Anura			
Family			
Bufonidae	<i>Duttaphrynus himalayanus</i> *	1000-3500	LC
	<i>Duttaphrynus melanostictus</i> *	300-1800	LC
	<i>Duttaphrynus stuarti</i> ⁵	500-650	NE
	<i>Duttaphrynus stomaticus</i> ³	300-1800	NE
Megophryidae	<i>Megophrys major</i> ¹	300-2500	NE
	<i>Megophrys parva</i> *	1500-2300	NE
	<i>Megophrys robusta</i> *	800-2300	NE
	<i>Scutigera boulengeri</i> *	4005-5270	LC
	<i>Scutigera sikkimensis</i> *	2619-4395	LC
Dicroglossidae	<i>Fejervarya nepalensis</i> *	1350-1580	LC
	<i>Fejervarya teraiensis</i> *	300-700	LC
	<i>Hoplobatrachus tigrinus</i> *	300-500	LC
	<i>Nanorana annandalii</i> *	1500-2650	NT
	<i>Nanorana blanfordii</i> *	1400-2000	LC
	<i>Nanorana ercepeae</i> *	2200-2600	NT
	<i>Nanorana gammii</i> *	1000-2000	NT
	<i>Nanorana liebighii</i> *	1220-3000	LC
	<i>Nanorana polunini</i> *	2300-3390	LC
	<i>Ingerana borealis</i> *	400-1000	VU
<i>Ombrana sikkimensis</i> ⁴	1200-2500	LC	
Ranidae	<i>Amolops marmoratus</i> *	1000-2165	LC
	<i>Amolops monticola</i> *	1060-2350	LC
	<i>Amolops formosus</i> *	1190-2480	LC
	<i>Amolops gerbillus</i> ⁴	300-1700	LC
	<i>Amolops himalayanus</i> *	1700-2300	LC
	<i>Clinotarsus alticola</i> ⁴	900	LC
	<i>Odorana livida</i> ⁴	300-1000	NE
Rhacophoridae	<i>Polypedates leucomystax</i> *	300-1500	LC
	<i>Polypedates maculates</i> *	300-2400	NE
	<i>Polypedates megacephalus</i> *	300-1500	LC
	<i>Raorchestes annandalii</i> *	900-2700	LC
	<i>Philautus dubius</i> ²	1000-1500	DD
	<i>Nasutixalus jerdonii</i> ²	1500-2000	NE
	<i>Rhacophorus maximus</i> ⁵	500-2000	LC
	<i>Rhacophorus reinwardtii</i> ¹	900-1800	NT
Order- Gymnophiona			
Ichthyophidae	<i>Ichthyophis sikkimensis</i> *	1550-2000	DD
Order - Urodela			
Salamandridae	<i>Tylotriton verrucosus</i> ¹	1200-3350	LC

LC: Least concern; NE: Not evaluated; NT: Near threatened; VU: Vulnerable; DD: Data deficient.

Table 2: Checklist of Amphibians (38 species) of Sikkim and their altitudinal distribution (Source: 1-Boulenger, 1908; 2-Waltner - 1973; 3-Schleich & Kastle, 2002; 4-Mathew and Sen, 2010; 5-Subba et al. 2016). * indicate the species recorded during the present study

Species abundance

Relative abundance of amphibian species of Sikkim Himalaya based on field study shows sparse distribution. Species abundance model showed steep decline in abundance pattern with few species dominating the amphibian community. This pattern was consistent for each zone separately as well as for the whole study area. Single species *Duttaphrynus himalayanus* represented ~600 individuals while another two species showed more than 100 individuals. Four species showed ~50 individuals while remaining 18 species had less than 50 individuals. The abundance distribution model clearly indicates that in an amphibian community a few species were common and most of them rare (Fig. 2).

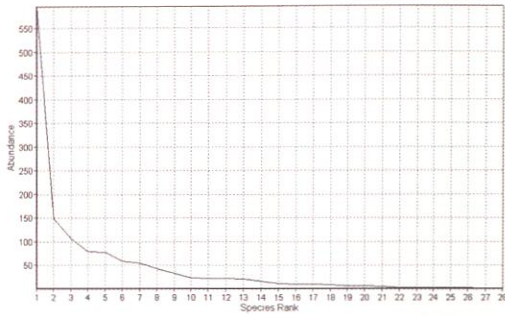


Figure 3: Species abundance model of amphibian population in Sikkim Himalaya.

The species abundance data for amphibian of Sikkim Himalaya fits to truncated log normal distribution (Fig. 3). There was no significant difference in observed and expected number of species in each abundance category ($\chi^2 = 1.43$; $p = 0.92$; $d = 5$).

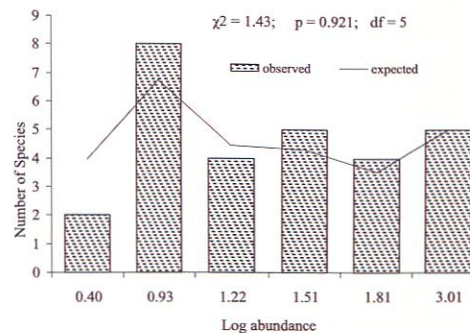
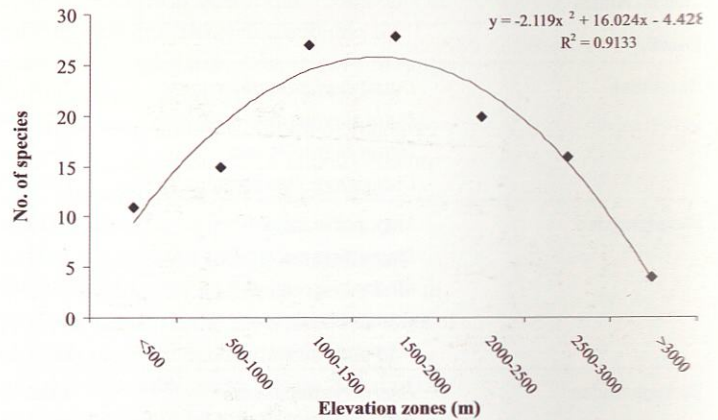


Figure 4: Species abundance data of amphibians of Sikkim Himalaya fits to truncated log normal distribution.

Elevational distribution pattern

Amphibian species richness when plotted against elevation based on compiled data (37 species) showed unimodal pattern. The species richness peaked at 1000-2000m elevations with tapering ends towards both sides though the decline was sharp towards the higher elevation (Fig. 4). Only four species were present above 3000m elevation.



Field study along the Teesta valley and Maenam Wildlife Sanctuary also revealed similar elevational distribution pattern with peak between 1000-2000m (Fig. 5; $R^2 = 0.86$; $p=0.01$). Maximum of 16 species were observed in zone IV (1500-2000m) followed by 14 species in zone III (1000-1500m). Only three species were found in highest elevation zone (>3000m) showing four-fold decline in species from mid to high elevation zone. Areas between 1000-2000m includes such as Sangkalang, Toong, Theeng, Chungthang, Lingee, Upper Payong, Maenam Wildlife Sanctuary. It is also to be noted that many developmental activities are now initiated in these areas which may degrade the probable habitat of many species which are yet to be explored. Abundance showed different pattern along the elevation gradient. The abundance peaked at 2000-2500m followed by 2500-3000m.

Figure 4: Elevational distribution pattern of amphibian species in Sikkim Himalaya (compiled data).

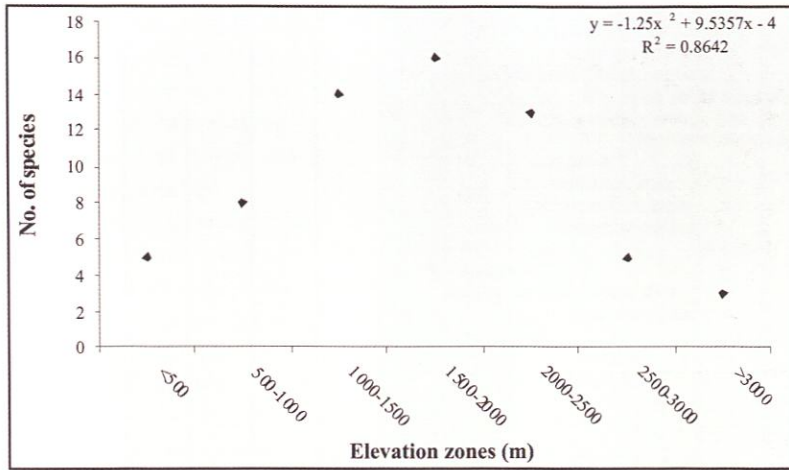


Figure 5: Elevational distribution pattern of amphibian species in Sikkim (present study).

Elevational Range Size

Compilation of range size of amphibian species of Sikkim Himalaya from various sources indicates that none of the species occur along the entire gradient of elevation. Out of total 37 species, only four species had more than 2000m elevational range and 10 species had less than or equal to 500m elevation width (Fig. 6). Both the lower and higher elevation species extended their range towards middle elevation thus

increasing the species richness there.

Present study in Sikkim Himalaya indicates that most species had narrow elevational range size (Fig. 7). Out of 25 species, 7 species showed very narrow elevational width (<500m) and single species i.e. *Duttaphrynus himalayanus* had broad elevational width from 1100m to 3300m. Elevational range of most amphibian species of the present study was reduced as compared to compiled data (Fig. 6 & Fig. 7).

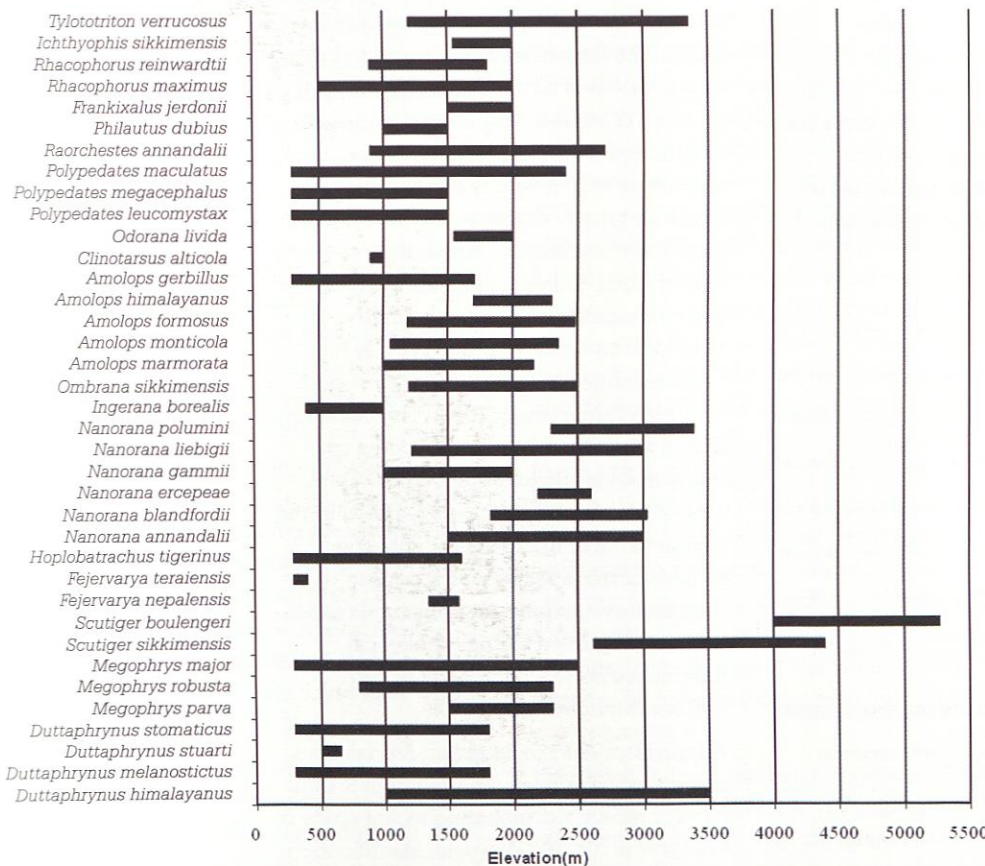


Figure 6: Elevational range profile of amphibians of Sikkim Himalaya based on compiled data.

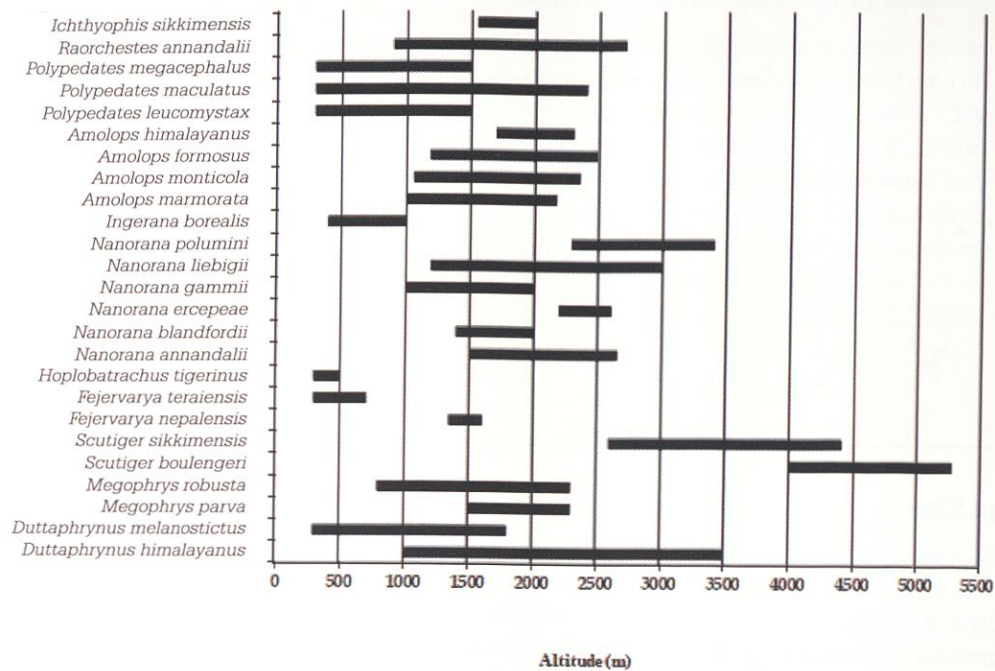


Figure 7: Elevational range profile of amphibians of Sikkim Himalaya based on present study.

Species similarity among elevation zones

Species similarity among elevation zone was generally low reflecting potential of each zone in harbouring unique amphibian assemblage (Fig. 8). Among the pair of zones, maximum similarity (0.8) was observed between 2500-3000m and >3000m elevation zones. However >3000m stands distinct from the rest of the elevation zones forming separate assemblages. Species similarity index among pair of zones depicts distinct community composition in each zone.

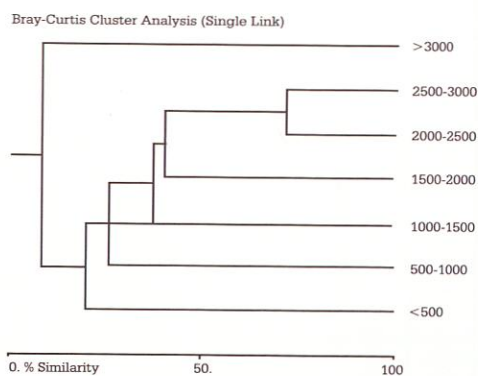


Figure 8. Dendrogram showing similarity of species composition among elevation zones in Sikkim Himalaya.

Discussion

Species richness and composition

Eastern Himalaya part of two biodiversity hotspots, the Indo-Burma and Himalaya Hotspots, possess great diversity of flora and fauna. The high diversity is attributed to its vast gradient of altitude reflecting similar gradient of climate and vegetation zones. Sikkim, part of Eastern Himalaya, represents high diversity of amphibian fauna and many new species are awaiting proper documentation. Amphibian species of this region is morphologically cryptic and remains significantly underestimated. Due to cryptic diversity, fourteen species has been described from two species in South-east Asia (Stuart et al. 2006). The taxonomy of amphibian is further complicated by many mis-identified amphibians such as *Megophrys boettgeri*. It was retained in the Indian list of amphibians because the tadpole of this species was similar to *Megalophrys kempii* of Arunachal Pradesh disregarding the clear morphological differences between the adult of both species (Mahony et al. 2013).

Polypedates leucomystax and *Polypedates maculatus* have been reported from Sikkim by various authors including recent study by Subba et al. (2016). However, identification

of the species is not clear yet. Identification keys provided by authors such as Deuti and Goswami (1995) and Subba et al. (2016) seem different for these species. Further, *Polypedates himalayanus* and *Polypedates megacephalus* possess taxonomic confusion. Similarly, *Duttaphrynus* groups are largely underestimated and wide variation occurs along the altitude gradient. Species like *Duttaphrynus stomaticus* might have been overlooked as *Duttaphrynus melanostictus*. The present study could not locate Himalayan Salamander (*Tylototriton* sp.) in Sikkim though many literatures reported its occurrence in Sikkim (Boulenger, 1890; Gammie, 1928; Mathew and Sen, 2010). Prior to Indian independence, Sikkim was a separate Kingdom including many hills and terai regions of Darjeeling known as greater Sikkim. Hence, many authors include the species in Sikkim list. However, even the recent literature supports its occurrence in Sikkim. It is probably due to the proximity and the similarity of the habitat of Sikkim with that of Darjeeling where *Tylototriton* sp is found. During a span of more than 10 years of our research work in Sikkim Himalaya we could not found it. However, it is also to be mention here that our research was focused along the Teesta basin in north and south district of Sikkim. Intensive research in probable habitat in west and east district will help to draw final conclusion on its occurrence in Sikkim Himalaya.

The number of amphibian species reported by various authors varied from 15-30. Variation in the number of species reported by different authors could be probably due to the reason that during pre-independence, Darjeeling Hills and adjacent plains were considered as part of greater Sikkim Himalayas (Gammie, 1928) and inclusion of species found in Darjeeling area might have resulted in this inconsistency. Other reasons such as taxonomic confusion and frequent changes in nomenclature in amphibian taxonomy and unequal sampling bouts/observation periods could have lead to these differences.

In 2015, one of the high elevation frog *Scutigera boulengeri* was added to the list of amphibians of Sikkim at an altitude of 5270m with the use of molecular and



Amolops formosus.
Photo Credit: Abhijit Das

morphological data (Subba et al. 2016). Recently, two new species (*Duttaphrynus stuarti* and *Fejervarya nepalensis*) was again added to the list of amphibians of Sikkim by Subba et al. (2015). More scientific studies and explorations are necessary to generate the complete list of amphibians of Sikkim.

Based on previous publication, we compiled a list of 37 amphibian species with a record of occurrence in Sikkim Himalaya. The present study along the Teesta Valley and Maenam Wildlife Sanctuary yielded 25 amphibian species. Representing such high diversity, the study area serves as potential habitat very conducive for amphibians. The high diversity in comparison to small area is attributed to high variation in altitude (300 - 5000m), climatic condition (Tropical - Arctic) and occurrence of streams and rivulets (tributaries to Teesta River) along the valley. Out of 37 species reported to occur in Sikkim, nine are not evaluated or two data deficient and hence their population trend and threat status is not known. The study on these taxa therefore should be taken up in priority to understand the distribution pattern, population trend and potential threats in order to implement any kind of conservation measures. Additionally, while planning and management of biodiversity conservation, equal justice should be given to amphibians so that protected areas and reserves includes some of these amphibian hotspot regions.

Northeast India comprising of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Sikkim and Darjeeling district of West Bengal harbours

very high diversity and endemism of amphibian fauna. In the recent past many new amphibians have been described from the region (Kamei et al. 2009; Biju et al. 2010; Mahony et al. 2013; Subba et al. 2015; Biju, 2016). Occupying just 2.8% geographical area of Northeast India (about 255,168 sq km), Sikkim harbours 37% of species. The data reflects high diversity of amphibians in Sikkim relative to its small geographical extent. With more research the numbers of amphibian species are likely to increase.

Species abundance model

Amphibian abundance data showed that most of the species are rare and very few are common. This is an indicative of more diverse ecosystem, especially tropical forests (Heatwole, 1982; Magurran, 1988). Species abundance data of amphibians fits to truncated lognormal distribution which signifies the stability and equitability of the amphibian community. No significant difference between observed and expected abundance indicate that our sampling encountered most of the individual occurring in the study area.

Elevational distribution pattern

The elevational pattern of amphibians in Sikkim followed mid-elevation peak (both compiled and field based data). The pattern is consistent with birds and plants (Acharya et al. 2011a; 2011b) but slightly different from reptiles (Chettri et al. 2010) from the same study area. While few studies have reported monotonic decline of reptiles and amphibians (Heatwole, 1982; Khatiwada and Haugaasen, 2015), mid-elevation peak is the most commonly observed pattern of amphibian species richness (Fu et al. 2006; Hu et al. 2011; Araujo et al. 2015). In contrast, the anuran study along the altitude gradient of Western Ghats, South India reported increasing trend with elevation (Naniwadekar and Vasudevan, 2007). Growing evidences supports the mid-elevation peak for amphibians whereas few diversions from this pattern occurred where the sampling did not cover the entire elevation gradient available (Naniwadekar and Vasudevan, 2007; Khatiwada and Haugaasen, 2015). The variation of pattern among taxa is mainly due to the differences in their physiological requirement and micro

habitat preference. For amphibians and reptiles, temperature, precipitation and relative humidity plays significant role (Chettri, 2010; Chettri et al. 2010) whereas for birds and plants factors such as productivity and habitat heterogeneity was significant (Acharya et al. 2011a, b). Climatic condition is the most determining factor for the species distribution especially for the ectotherms (Fu et al. 2006).

Abundance showed different pattern along the elevation. High abundance towards higher elevation was due to the clumped distribution of single species *Duttaphrynus himalayanus*. Increased abundance with elevation is due to the proliferation of few species as species richness declined towards higher elevation (Heatwole, 1982).

Elevational Range Size

The narrow elevational range of most amphibian species reflects their sensitivity towards various environmental factors which changes at a faster rate along the elevation gradient. The range sizes have been used as a predictor of extinctions; narrow range species have greater risk of extinctions (Harris and Pimm, 2008; Hu et al. 2011) and are of special interest for the conservation of biodiversity (Ah-Peng et al. 2012). Most amphibians of Sikkim Himalayan had narrow elevational width with many species confined to less than 500m. Most species are restricted to single zone and unable to extend their habitat beyond certain limit. Hence, the conservation of habitats along the entire elevational gradient is necessary as many

Microhyla cf. ornata.
Photo Credit: Abhijit Das



species are restricted within narrow range. The comparison of range size between present data and compiled data showed slight variation. Since the compilation is based on various sources, species showed broader elevational range than the actual range they may occupy. Further, amphibians in Western Himalaya are found in higher elevation than in Eastern Himalaya (Schleich & Kastle, 2002). However, the amphibian in Sikkim Himalaya occupy narrow elevational range and any disturbance might lead into the decline of the population.

Species similarity among the elevation gradient

Similarity among elevation zones was low except between 2500-3000m and >3000m. Maximum similarity between 2500-3000m and >3000m elevation zones is due to the similar climatic and habitat conditions. The distinct amphibian assemblage >3000m may be due to abrupt change in climatic condition and vegetation types (broadleaved to coniferous forest) which acts as barrier for species dispersal (Gainsbury and Colli, 2003). It could be also due to isolation mechanism (Lomolino, 2001). The snow covered mountain peaks with steep slopes and circulating cold winds would have resulted in the isolation of species in the present case. The low similarity indicates that all zones contain unique assemblage of species and are distinct from other zones. Despite low richness in some zones, the conservation of representative habitats of all zones is necessary for the holistic conservation of amphibians.

Anthropogenic Threats

Extraction

We observed that local people rampantly collect amphibians from various streams. The collections are used as meat supplement as well as for some medicinal purposes after smoke dry (Fig. 9). Amphibian collection is done mostly during dusk to early night hours (19:00-21:30 hours). The people involved in extraction of amphibians during night use locally made kerosene lamp known as pultho and collect whatever they encounter. Occasionally, collections during day hours were also observed.

Based on surveys in different places along the Teesta valley such as Dzongu, Pabong, Lingee, Chungthang and Lachung and Maenam Wildlife Sanctuary, it is estimated that one individual (which most often represents one household) collects 30-35 individuals per night in an average. The collection is intense during monsoon season (June - August) with an approximate collection frequency of three times a week per household. The most preferred species are *Amolops* spp., *Nanorana* spp. and *Xenophrys* spp., although all kinds of frogs are hunted (Fig. 9). *Nanorana* species is locally known as Paa and is extensively used for medicinal purposes. Most of these species occur in the middle elevation and maximum extraction hence also occurs in mid-elevation where the maximum diversity occurs.

Besides ecological and cultural values, frogs constitute important source of protein for economically unstable communities (Gonwouo and Rodel, 2008). In Sikkim, the floating communities such as personnel working as labourers in hydro power projects and road construction activities along with few ethnic tribes are responsible for mass extraction. Further, extraction coincides the peak breeding period i.e. June to August. The unsustainable harvesting threatens the amphibian population and their habitats specially the restricted ranged species (Hu et al. 2011).

Local communities belonging to Lepcha, Bhutia, Rai and Limboo are involved in extraction mostly for medicinal purpose as well as for dietary supplement. The species preference varies among the communities. Lepcha and Bhutia communities collect almost all types of frogs, whereas other communities confined with webbed feet species locally called 'Paa' such as *Amolops* spp., *Nanorana* spp.

Habitat destruction

Apart from extraction, amphibians of Sikkim Himalaya faced tremendous threat from habitat destruction. During monsoon, the collectors divert water from the stream to other side for fishing. In this process large number of eggs and tadpoles present there gets dehydrated and die. This activity has posed serious threat to amphibian population as well as their habitat (especially breeding) causing population

decline. Another significant threat to amphibian habitat is mining in streams. Anthropogenic disturbance to breeding habitats of amphibians is considered as the most serious threat for population decline worldwide (Mac Nally et al. 2009). Rampant

extraction of sand, gravel and boulders affect the amphibian microhabitat. Hence, regulation of such extraction is necessary for conservation of amphibian fauna and their habitat.

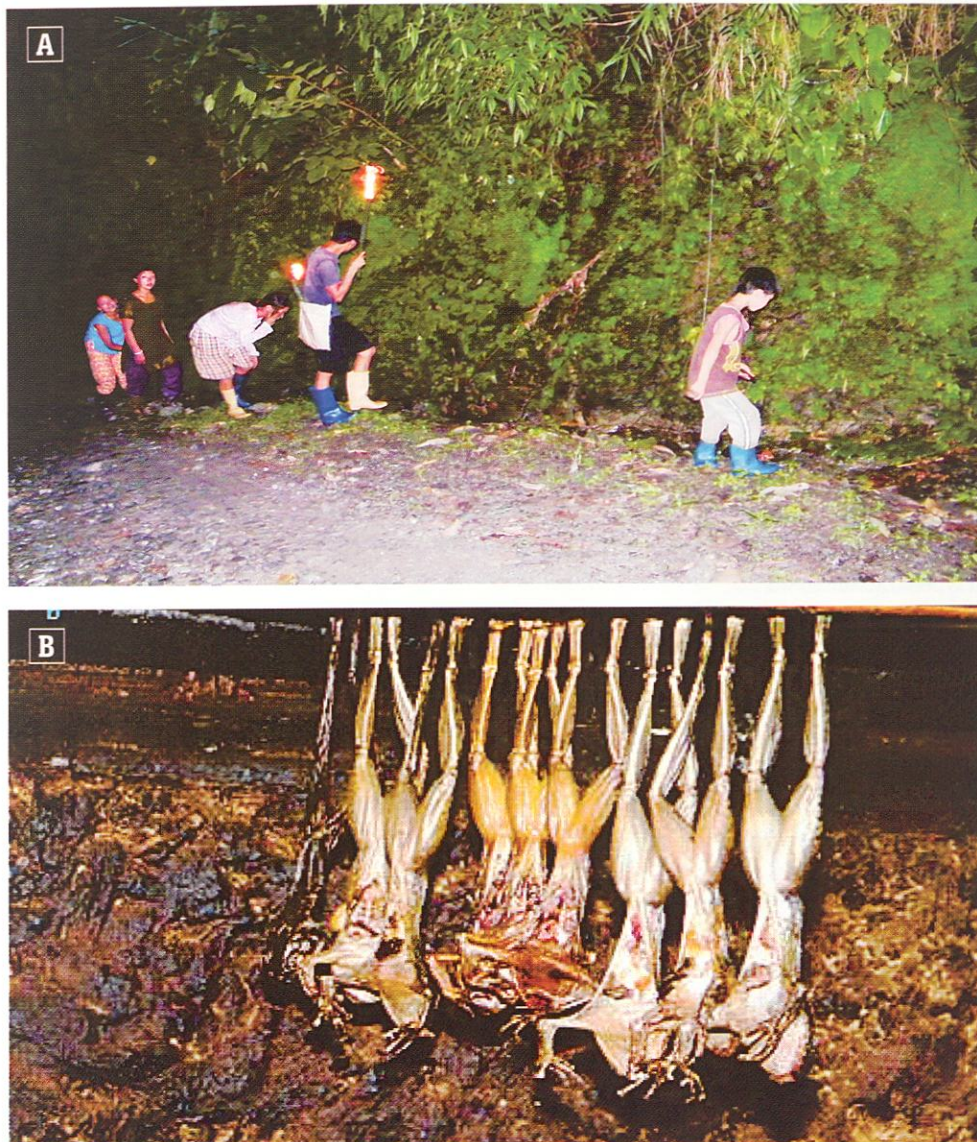


Figure 9: Frog extraction at Dzongu, North Sikkim by locals during night (A); Frogs kept for smoking above fire after collection (B). The displayed frog comprises of two most extensively hunted species - *Amolops* sp. and *Megophrys* sp.

Conclusions and Recommendations

Amphibian, and also birds and plants, shows highest diversity at mid-elevation in Sikkim Himalaya (Chettri, 2010; Acharya et al. 2011a; 2011b). Hence, priority should be given for the conservation of the areas in these elevation zones. A landscape conservation approach with community participation is highly recommended.

In Sikkim, though 34% of the geographical area is under protection, most of the protected areas lie above 2000m. Protected areas notified based on larger vertebrates may not do equal justice to minor vertebrates like reptiles and amphibians (Vasudevan et al. 2006). Multi-species study in Hong Kong also found mis-match between species richness and protected areas (Yip et al. 2004). Similar conclusion was drawn by the study of Khan et al. (1997) in Meghalaya. Hence, the present study

strongly recommends extending the protected areas towards lower elevation. Further, while planning the protected areas, minor taxa should also be taken into consideration.

Illegal harvesting of frogs and disturbance to habitats by local community was recorded in the study areas. Though extraction by native tribe for medicinal purposes can be sustainable as they used to do before also but with increasing population and developmental activities leading to habitat destruction, the extraction cannot be sustainable. More awareness about importance of these minor vertebrates in ecosystem can help in reducing this threat to great extent.

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