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Chapter

The Role of Community Reserved Forests in the Conservation of Anuran Amphibians in Meghalaya, North-East India

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Abstract

The state of Meghalaya is situated in the north-eastern India and it comprises three major regions, namely, the Khasi Hills, the Jaintia Hills and the Garo Hills inhabited by three main tribal groups, the Khasis, the Jaintias and the Garos respectively. The tribal communities of Meghalaya protect and nurture the forests located close to their habitation and consider them as sacred. These Community reserved forests are managed by the community for their benefits and they comprise almost about 90% of the total forest cover in Meghalaya. With the recent trends of development and construction in the state many habitats are getting destroyed at an alarming rate. These community reserve forests have been seen to provide the maximum number of existing and stable habitats for many amphibian (anuran) species. In addition, they served as suitable sites for the breeding activities and oviposition by anurans. Discovery of many new anuran species have also been reported from such reserved forests.

Keywords: Anurans, Amphibians, Conservation, Community reserved forests, Meghalaya, India

1. Introduction: Meghalaya- the people, the forests and conservation

Meghalaya (in sanskrit, Meghalaya meaning “abode of clouds”) is one of the seven states that are popularly known as the seven-sisters, located in the North Eastern part of India. Lying between 25° 47' and 26° 10' N latitude, and 89° 45' and 92° 47' E longitude the state of Meghalaya is represented by an irregular terrain in the western and northern regions, and steep slopes to the south and west sharing a 496 km long international border with Bangladesh (**Figure 1**). It has a wide range of altitudinal variation ranging from about 50–1950 m [1], with Shillong peak as the highest peak. With a geographical area of 22 429 square km. [2], the diverse topography of the state provides for a variety of unique vegetation types at different levels of altitude accompanied by varied climatic conditions and edaphic composition. In general, the forests types in Meghalaya can be broadly classified into temperate and tropical mainly based on the rainfall, altitude and composition of dominant species [3].

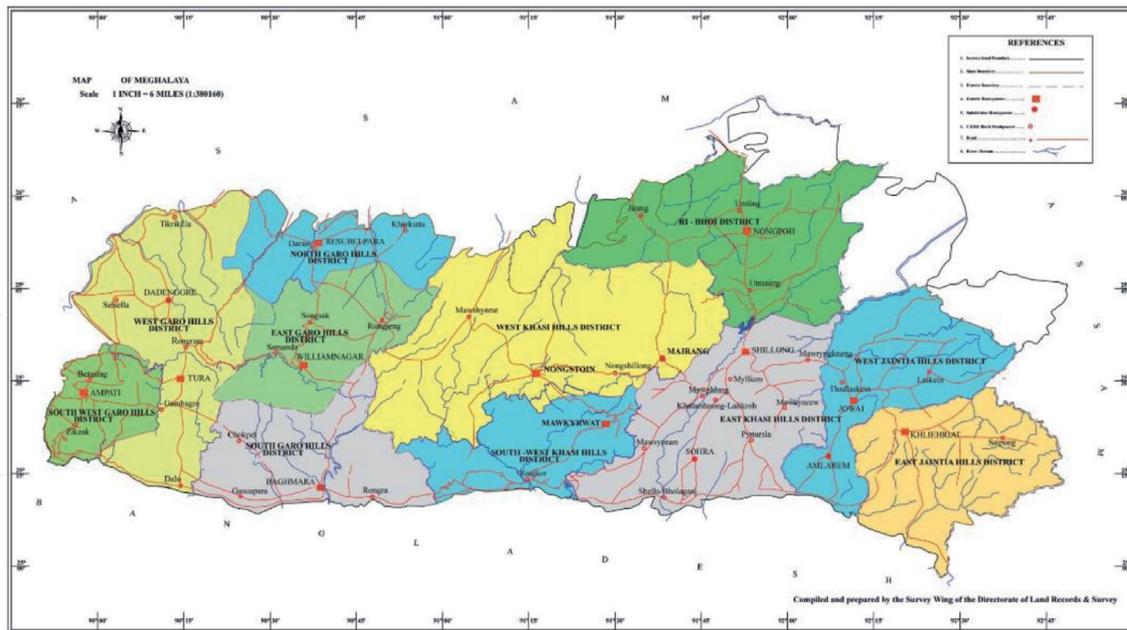


Figure 1.
Map of Meghalaya [source: <http://megipr.gov.in>].

The variation in elevation and physical relief affects the climate of Meghalaya. The geographical area of Meghalaya is divided into three major regions, namely, the Khasi Hills, the Jaintia Hills and the Garo Hills. Garo Hills is relatively lower in elevation as compared to Khasi and Jaintia Hills and therefore experiences higher temperature conditions and humidity. The Khasi and Jaintia Hills experience a moderate climate because of higher elevation. Rainfall in the state is also influenced by the difference in elevation and topography. The average annual rainfall varies from place to place, about 2600 mm in western Meghalaya, between 2500 and 3000 mm over the northern parts and about 4000 mm over south-eastern Meghalaya [4]. The southern parts of the Meghalaya plateau have the Cherrapunji -Mawsynram region which receives the heaviest rainfall, an annual average of 14,000 mm. In fact, the two places Mawsynram and Cherrapunjee (also Sohra) in Meghalaya are famous for receiving the highest rainfall in the World. A combination of all these factors results in a variety of unique habitats [5, 6].

Most tribal populations in India have a close interaction with nature and especially with the forests. They live close to the forests and depend on them for obtaining various resources for their needs. Meghalaya is a very diverse state having a sizeable number of indigenous groups that includes the Khasis, the Garos and Jaintias (in higher numbers); and other groups like the Karbis, Mikirs, Hajongs, Kochs and Rabhas in smaller numbers [7, 8]. The three major regions, namely, the Khasi Hills, the Jaintia Hills and the Garo Hills are inhabited by three main indigenous communities, the Khasi tribe, the Jaintias and the Garos respectively. The tribal people of Meghalaya nurture tracts of forests that are located close to their settlement as reserved forests as part of their culture, or religious belief or for different community benefits like water sources, forest resources, etc. The Khasi and Jaintia hills are home to a large number of forests that are held as sacred by the indigenous people and remain undisturbed by any human activity. The forests are believed to be the dwelling place of the deities and hence considered as spiritual places similar to a place of worship as in any religion. It is therefore forbidden to collect or gather anything that belongs to the forest, even as small as leaves, wood, water, etc. without the knowledge of the elders of the community or the local people in charge of the forest or care takers of these forests. These practices are

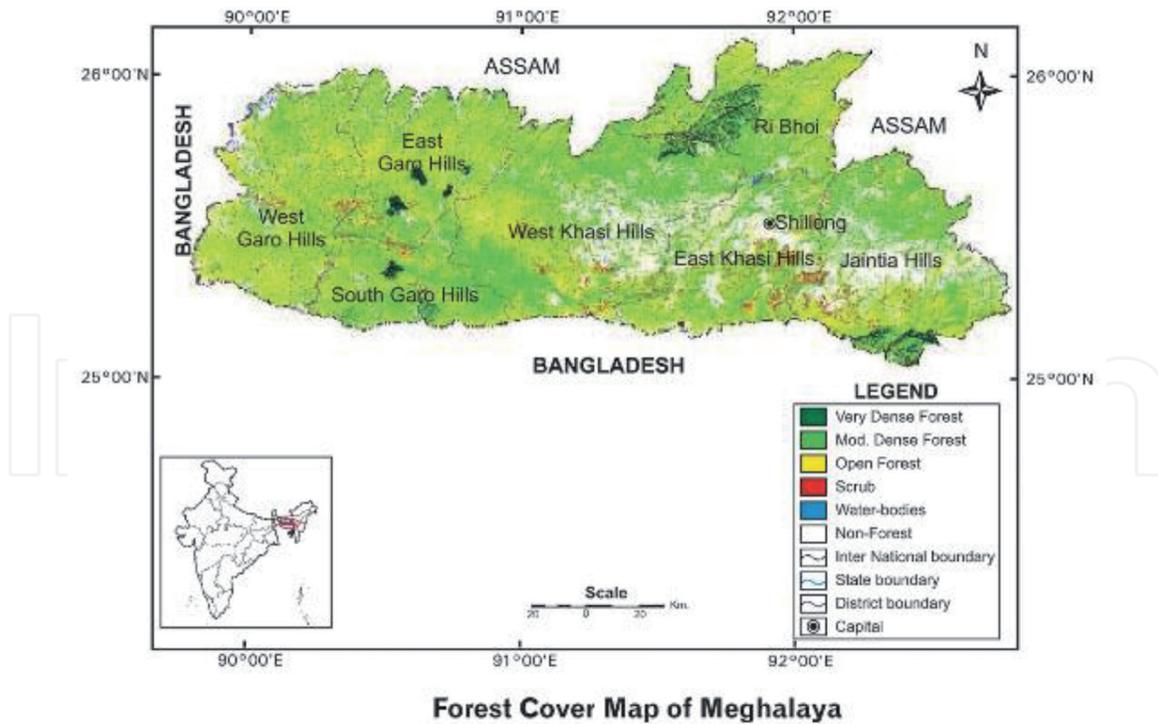


Figure 2.
Map of Meghalaya showing forest cover [source: <https://megbiodiversity.nic.in/>].

passed on from one generation to another like some traditional or customary law. Such practices of the tribal communities have been seen to promote conservation by their cultural beliefs, religious beliefs and even their customary laws [9–11].

The pattern of land ownership plays an important role in determining the type of land use in Meghalaya and thus, the amount of forest cover. In the three regions of Meghalaya the land ownership and land tenure system vary according to administration and religious beliefs of the people. According to the 6th schedule of Indian constitution, land ownership systems in Meghalaya and other parts of North Eastern India are imparted with a special status. Tiwari and Shahi broadly classify the land ownership system in Meghalaya into two types, i.e. riotwary and customary land system [12]. In the riotwary system the government deals directly with the land owners without interference of intermediaries.

The State Forest Department has classified the forests of Meghalaya (**Figure 2**) into the following six categories, see in [13].

- i. Reserved forests (including government forests, national parks and sanctuaries) cover 993.0 sq. km and are owned and controlled by the State Forest Department. Local communities have very few rights over these forests.
- ii. Unclassified forests, which cover 7146.5 sq. km, are forests where local communities have all the rights and de facto control. Most of these forests are used for shifting cultivation.
- iii. Private forests cover 384.0 sq. km and belong to individuals, who use them primarily for personal consumption.
- iv. Protected forests cover 129.0 sq. km and are used by local communities, primarily for personal consumption. Local communities have rights to these forests, but they are controlled by the State Forest Department, which

considers the status of protected forest as an interim measure; the department intends to convert these forests into reserved forests.

v. Village forests, which cover 25.9 sq. km, were demarcated and registered by the village community under the United Khasi–Jaintia Management of Forests Act 1958. Most of these forests are used for subsistence purposes.

vi. Community (Raid) forests, which cover 768.0 sq. km, are large community forests (Raid means commune) that are managed by the Raid or commune head under the local administrative head.

This type of forest management according to traditions and rituals in Meghalaya existed before British occupation. And although they cannot be considered to be scientific in approach but were seen to be very effective in protection and conservation of forests. According to the tribal customary laws of Meghalaya, the forests can be further divided into different types according to their intended use. These include- sacred forests (Law Kyntang), village forests (Law Shnong), village restricted forests (Law Adong), forests belonging to a group of villages (Law Raid), private forest or community land (Law Ri-Sumar), private forests or private land (Law Ri-Kynti), clan forest (Law Kur) and cemetery forests (Law Lum Jingtep). These forests are currently called community reserved forests or community conserved areas and they serve a number of ecosystem services to the communities including serving as catchment areas for water sources, conservation of flora and faunal biodiversity, and sanctuary to a variety of medicinal plants [14].

The present study aims to highlight the impact of community reserved forests on the conservation of anuran amphibian biodiversity in the state of Meghalaya. Our study is based on review of an extensive survey of literature. In addition, our aim is to establish the importance of the reserved forests in preservation of pristine habitats for both floral and faunal diversity in the state.

2. Conservation of Amphibian biodiversity by community reserved forests of Meghalaya

The state of Meghalaya is blessed with a rich assemblage of diverse flora and fauna. Being part of the North east India, which falls under the Eastern Himalayas as well as Indo-Myanmar Biodiversity Hotspots, the state supports some of the rich and endemic species of both flora and fauna. Further, owing to its unique biogeographic position, Meghalaya serves as a corridor zone for the occurrence of flora and fauna of both Southeast Asia and Peninsular India. Some of the unique animals found in the forests of Meghalaya include the endangered Western Hoolock Gibbon (*Hoolock hoolock*) whose distribution is restricted to the closed-canopy rainforests of North East India, Bangladesh and Myanmar. In addition, the Capped Langur (*Trachypithecus pileatus*), Macaques (Rhesus *Macaca mulatta*, Assamese *Macaca assamensis*, Northern Pig-tailed *Macaca leonina* and Stumped-tailed *Macaca arctoides*) are also found in the forest canopies of Meghalaya. Among the carnivores, the Clouded Leopard (*Neofelis nebulosa*) is Meghalaya's state animal and other big cats such as Tiger (*Panthera tigris*) and Leopard (*Panthera pardus*) are found in the deep jungles of Meghalaya. Threatened and rare ungulates include the Himalayan Serow (*Capricornis thar*), Hog Deer (*Hyelaphus porcinus*), Sambar Deer (*Rusa unicolour*) and the globally endangered Indian Wild Water Buffalo (*Babalus arnee*). The endangered Chinese Pangolin (*Manis pentadactyla*) is also found in forest covers of Meghalaya. Adding to the list of wild animals is the endangered

Asian Elephant (*Elephas maximus*) which inhabit the wild forests of Meghalaya. In terms of the herpetofauna, the state of Meghalaya is a home to a diverse group of animals ranging from venomous snakes such as the King Cobra (*Ophiophagus Hannah*), MacClelland's Coral Snake (*Sinomicrurus macclellandi*), the White-lipped Pit Viper (*Cryptelytrops albolabris*) to the less venomous and non-venomous ones such as the Khasi Earth Snake (*Stoliczkaia khasiensis*) and the Khasi Keelback (*Amphiesma khasiensis*). In addition to snakes, the state also has records of lizards such as the Khasi Hills Bent-toed Gecko (*Cryptodactylus khasiensis*), the Tokay Gecko (*Gekko gekko*) and some of the recently discovered Karst-dwelling bent-toed geckos (*Cyrtodactylus jaintiaensis*, *Cyrtodactylus karsticola* and *Cyrtodactylus agarwali*) [15] including a skink *Spenomorphus apalpebratus* [16] from Mawphlang Sacred Grove. Apart from the wild animals, Meghalaya is also a home to wide variety of invertebrates such as spiders, colourful butterflies, moths, leeches, ants, giant earthworms, millipedes, centipedes, beetles as well as crickets and praying mantis.

2.1 Amphibian records from Meghalaya (old records to new discoveries)

Meghalaya, North East India is evident to have the richest expression of amphibians in North East India. The hilly terrain of the state with its numerous hills, valleys, streams, rivers, drainages along with cascading waterfalls, rainfed pools and grasslands all of which serve as congenial or compatible habitats that harbor a wide variety of amphibians with high level of endemism. The amphibians include anurans (tailless amphibians such as frogs and toads), salamanders (tailed amphibians) and caecilians (limbless amphibians). Among amphibians, anurans are the major and diverse component of many terrestrial and freshwater ecosystems. The pioneering studies relevant to diversity of amphibians in Meghalaya, North East India is evident from the accounts made by some workers such as Boulenger [17, 18], Yazdani and Chanda [19], Pillai and Yazdani [20], Pillai and Chanda [21–24], Sahu and Khare [25] and Hooroo [26]. Earlier records on the amphibian species of Meghalaya include descriptions contributed by Boulenger [18] who described a new frog *Rana garoensis* from Garo Hills while Roonwal and Kripalani [27] described *Philautus cherrapunjiae* from Cherrapunjee. Further, Yazdani and Chanda [19] described the Khasi Hills Rock Toad, *Ansonia meghalayana* from Mawblang near Cherrapunjee and this species was later reallocated to the genus *Bufoides* by Pillai and Yazdani [20]. This endemic Rock Toad (*Bufoides meghalayana*) (**Figure 3**) which was thought to be extinct from the wild was rediscovered again after 30 years from the same locality by Das *et al.* [28]. Pillai and Chanda [29] reported and described a new species of *Philautus* (*Raorchestes*) from Shillong, viz. *Raorchestes shillongensis* (**Figure 4**). Pillai and Chanda [22] also described two new frogs from



Figure 3.
Bufoides meghalayana.



Figure 4.
Raorchestes shillongensis.



Figure 5.
Hylarana danielli.

Mawphlang, Meghalaya viz. *Rana danieli* (**Figure 5**) and *Rana mawphlangensis*. In addition, Chanda [30] described a new frog *Rana mawlyndipi* (Ranidae) from Khasi hills, Meghalaya, India. The limbless amphibian, *Ichthyophis garoensis* was described as a new species by Pillai and Ravichandran [31] from Garo Hills.

Amphibians currently include 8352 recognized species with representatives found virtually in all temperate and tropical lands except for Arctic and Antarctic latitudes and in many oceanic islands. At present, 445 species of amphibians (composed of three orders- Anura, Gymnophiona and Caudata) are known from India. Of these, 404 species belong to Anura, 39 species belong to Gymnophiona and 2 species belongs to Caudata [32]. The seven sister states of North-Eastern India that comprised of Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram, Tripura, Meghalaya and Sikkim harbours 146 species of amphibian assemblages out of which 53 are endemic [33].

In Meghalaya, no comprehensive studies have been made on the endemic amphibian fauna and their distribution. However, Hooroo *et al.* [26] reported for the first time the Painted Balloon Frog, *Kaloula pulchra* from Cherrapunjee, East Khasi Hills district, Meghalaya. Sen [34], reported that there are 49 species of amphibians in the state of Meghalaya. Mahony [35] redescribed *R. mawphlangensis* and re-located the generic name and placed it in the genus *Odorrana* (**Figure 6**) based on morphological characters of the holotype. Since then, some more reports have been made on the documentation of new amphibian fauna in the state of Meghalaya. Mathew and Sen [36] described three new species of caecilians, *Ichthyophis nokrekensis*, *Ichthyophis alfredi* and *Ichthyophis daribokensis* from Nokrek Biosphere Reserve. *Pterorana khare* (Ranidae) was also reported as a new state record form Meghalaya



Figure 6.
Odorrana mawphlangensis.



Figure 7.
Leptolalax khasiorum.

by Rangad *et al.* [37]. A new species of megophryid frog of the genus *Leptolalax*, viz. *Leptolalax khasiorum* (**Figure 7**) was described by Das *et al.* [38] from the sacred groves of Mawphlang, East Khasi Hills, North-eastern India. Another new species of *Leptolalax* was discovered from Nokrek Biosphere Reserve viz. *Leptolalax nokrekensis* by Mathew and Sen [39]. In addition, a new Dicroglossid species was described from the same forest (Mawphlang Sacred Grove), Meghalaya by Purkayastha and Matsui [40] viz. *Fejerverya sengupti*. The discovery of a new genus of the limbless amphibian from Tura, Garo Hills namely *Chikila gaiduwani* by Kamei *et al.* [41] is also noteworthy to mention. Adding to the new discoveries of amphibian species are the new species records of four megophryid frogs namely *Xenophrys megacephala* [42] from Ri Bhoi district, *Xenophrys oropedion* [43] (**Figure 8**) from Malki forest (Riat Laban Reserved Forest) Shillong, *Xenophrys falvipunctata* [44] from Mawphlang Sacred Grove and *Xenophrys oreocrypta* [44] from Tura, Garo Hills. Hence till date there are 61 species of amphibians in the state of Meghalaya. Further, the list of amphibian species belonging from different families that have been recorded throughout our surveys (2015 till date) from the diversified habitats of different forest areas of Meghalaya (sacred groves, reserved and protected forests) have been listed in **Table 1**.

Endemic species have a generally restricted distribution and potential threats to these species can carry more risk of extinction than for broadly distributed species. Since, these species are highly adapted to their home range, any alterations



Figure 8.
Xenophrys oropedion.

in the prevailing environmental factors caused due to anthropogenic or natural causes within their range, their adaptations can function as a source of competitive strength or weakness.

Thus, endemic species are a focus for the conservation of biological diversity, or biodiversity. The first comprehensive attempt to document the endemic species of amphibians in the state of Meghalaya was made by Saikia and Kharkongor [45], who reported in their checklist that there are 19 amphibian species which are considered endemic to the state of Meghalaya (**Table 2**).

Amphibians are a group of organisms that are highly selective about their breeding habitat and choice of suitable oviposition sites. Therefore, they are highly sensitive to changes of the variables that govern an amphibian habitat. Relatively low vagility [46, 47] and narrow habitat tolerance [48–50] seems to amplify the effect of habitat degradation, fragmentation and habitat loss on amphibians. Amphibians are among the planet's most threatened taxa and about one-third of the world's species are threatened with extinction [51]. Habitat loss and fragmentation appear to contribute directly to most of these threats [50, 52, 53]. Anthropogenic activities have brought about different degree of threats towards amphibian community [54]. Amphibian habitats in these forested areas are becoming smaller day by day. Water and moisture conservation abilities are reduced due to decrease in forest coverage. Landslides and soil erosion are covering forest creeks and thus, reducing the number of water sources in these forests. Such threats eventually hamper the breeding and breeding sites of many amphibian species. However, in the state of Meghalaya, these protected areas serve as important ground not only for amphibian diversity and abundance but also for their breeding and development. The protected forest areas seem to harbour a large number of microhabitats to many amphibian species. This is evident from the recent works by various scholars. For instance, *L. khasiorum* is reported to be one of the earliest breeders of amphibians in the forest stream of Mawphlang sacred groove [55]. Other amphibian species occurring in sympatry at this sacred groove include: *X. oropedion*, *Sylvirana danieli*, *Hylarana leptoglossa*, *Philautus sp.*, *Polypedates himalayensis*, *Rhacophorus bipunctatus*, *Euphlyctis cyanophlyctis*, *Duttaphrynus melanostictus* (**Figure 9**), *Amolops gerbillus*, *Amolops formosus*, and *Fejervarya sengupti* [35, 38, 40, 43]. Similarly, Khongwir *et al.*, [56] studied the breeding and nesting behavior of *Rhacophorus maximus* (**Figure 10**) in a Mawsynram and Sohra, the regions which lie in the southern slopes of the State and receive exceptionally high levels of rainfall. Multiple amplexing pairs are seen in the temporary rainfed pond at under the forested cover which appeared to be a congenial breeding habitat during the peak of the breeding period. Further,

Forests	Families	Species	Total no. of Families & Species
1. Riat Laban Reserve Forest	i. Bufonidae	<i>Duttaphrynus melanostictus</i>	5 Families 16 Species
	ii. Dicroglossidae	<i>Fejervarya nepalensis, Fejervarya pierrae, Fejervarya syhadrensis, Fejervarya teraiensis.</i>	
	iii. Ranidae	<i>Pterorana khare, Odorrana livida, Odorrana mauphlangensis, Hylarana nicobariensis, Sylvirana danieli.</i>	
	iv. Rhacophoridae	<i>Philautus andersoni, Raorchestes shillongensis, Polypedates himalayensis, Polypedates teraiensis, Rhacophorus bipunctatus.</i>	
	v. Megophryidae	<i>Xenophrys oropedion</i>	
2. Upper Shillong Protected Forest	i. Bufonidae	<i>D. melanostictus.</i>	5 Families 17 species
	ii. Dicroglossidae	<i>F. nepalensis, Fejervarya pierrae, F. syhadrensis, F. teraiensis.</i>	
	iii. Ranidae	<i>Amolops gerbillus, Clinotarsus alticola, Odorrana chloronota, O. livida, Hylarana nicobariensis, S. danieli.</i>	
	iv. Rhacophoridae	<i>P. andersoni, Raorchestes shillongensis, Polypedates himalayensis, P. teraiensis, R. bipunctatus.</i>	
	v. Ichthyophiidae	<i>Ichthyophis garoensis.</i>	
3. Laitkor Protected Forest	i. Bufonidae	<i>D. melanostictus.</i>	4 families 12 species
	ii. Dicroglossidae	<i>F. nepalensis, Fejervarya pierrae, F. syhadrensis, F. teraiensis.</i>	
	iii. Ranidae	<i>O. livida, S. danieli.</i>	
	iv. Rhacophoridae	<i>P. andersoni, R. shillongensis, Polypedates himalayensis, P. teraiensis, R. bipunctatus.</i>	
4. Myllem Community Forest	i. Bufonidae	<i>D. melanostictus.</i>	4 Families 11 species
	ii. Dicroglossidae	<i>Euphlyctis cyanophlyctis, F. nepalensis, Fejervarya pierrae, F. syhadrensis, F. teraiensis.</i>	
	iii. Hylidae	<i>Hyla annectans.</i>	
	iv. Rhacophoridae	<i>R. shillongensis, Polypedates himalayensis, P. teraiensis, R. bipunctatus.</i>	

Forests	Families	Species	Total no. of Families & Species
5. Laitkroh Community Forest	i. Bufonidae	<i>D. melanostictus</i> .	4 Families 9 species
	ii. Dicroglossidae	<i>E. cyanophlyctis</i> , <i>F. nepalensis</i> , <i>Fejervarya pierrae</i> , <i>F. syhadrensis</i> , <i>F. teraiensis</i> .	
	iii. Hylidae	<i>H. annectans</i> .	
	iv. Rhacophoridae	<i>P. teraiensis</i> , <i>R. bipunctatus</i> .	
6. Cherrapunjee (Community Forest & Sacred grove)	i. Bufonidae	<i>Bufoides meghalayana</i> , <i>D. melanostictus</i> .	6 Families 16 species
	ii. Dicroglossidae	<i>E. cyanophlyctis</i> , <i>Fejervarya asmati</i> , <i>F. nepalensis</i> , <i>Fejervarya pierrae</i> , <i>F. syhadrensis</i> , <i>F. teraiensis</i> .	
	iii. Hylidae	<i>H. annectans</i> .	
	iv. Microhylidae	<i>Kaloula pulchra</i> .	
	v. Ranidae	<i>A. gerbillus</i> , <i>C. alticola</i> .	
	vi. Rhacophoridae	<i>Kurixalus naso</i> , <i>P. teraiensis</i> , <i>R. bipunctatus</i> , <i>Rhacophorus maximus</i> .	
7. Laitkynsew Village Community Forest	i. Bufonidae	<i>Bufoides meghalayana</i> , <i>D. melanostictus</i> .	6 Families 16 species
	ii. Dicroglossidae	<i>E. cyanophlyctis</i> , <i>Ingerana borealis</i> , <i>F. nepalensis</i> , <i>Fejervarya pierrae</i> , <i>F. syhadrensis</i> , <i>F. teraiensis</i> .	
	iii. Megophryidae	<i>Xenophrys parva</i> .	
	iv. Microhylidae	<i>K. pulchra</i> , <i>Microhyla ornata</i> .	
	v. Ranidae	<i>C. alticola</i> .	
	vi. Rhacophoridae	<i>K. naso</i> , <i>P. teraiensis</i> , <i>R. bipunctatus</i> , <i>R. maximus</i> .	
8. Pynursla Community Forest	i. Bufonidae	<i>D. melanostictus</i> .	3 Families 9 species
	ii. Dicroglossidae	<i>E. cyanophlyctis</i> , <i>F. nepalensis</i> , <i>Fejervarya pierrae</i> , <i>F. syhadrensis</i> , <i>F. teraiensis</i> .	
	iii. Rhacophoridae	<i>P. teraiensis</i> , <i>R. bipunctatus</i> , <i>R. maximus</i> .	

Forests	Families	Species	Total no. of Families & Species
9.Mawsynram Forest & Sacred Grove	i. Bufonidae	<i>D. melanostictus</i> .	5 Families 13 Species
	ii. Dicroglossidae	<i>E. cyanophlyctis</i> , <i>F. nepalensis</i> , <i>Fejervarya pierrie</i> , <i>F. syhadrensis</i> , <i>F. teraiensis</i> .	
	iii. Hylidae	<i>H. annectans</i> .	
	iv. Ranidae	<i>O. chloronota</i> , <i>O. livida</i> .	
	v. Rhacophoridae	<i>Polypedates himalayensis</i> , <i>P. teraiensis</i> , <i>R. bipunctatus</i> , <i>R. maximus</i> .	
10.SyntuKsiar, Jowai (Community Forest & Sacred grove)	i. Bufonidae	<i>D. melanostictus</i> .	4 Families 10 Species
	ii. Dicroglossidae	<i>E. cyanophlyctis</i> , <i>F. nepalensis</i> , <i>Fejervarya pierrie</i> , <i>F. syhadrensis</i> , <i>F. teraiensis</i> .	
	iii. Ranidae	<i>C. alticola</i> .	
	iv. Rhacophoridae	<i>P. teraiensis</i> , <i>R. bipunctatus</i> , <i>R. maximus</i> .	
11.Ummulong Community Forest	i. Bufonidae	<i>D. melanostictus</i> .	4 Families 11 Species
	ii. Dicroglossidae	<i>E. cyanophlyctis</i> , <i>F. nepalensis</i> , <i>Fejervarya pierrie</i> , <i>F. syhadrensis</i> , <i>F. teraiensis</i> .	
	iii. Ranidae	<i>C. alticola</i> , <i>O. chloronota</i> .	
	iv. Rhacophoridae	<i>P. teraiensis</i> , <i>R. bipunctatus</i> , <i>R. maximus</i> .	
12.Nongpoh Forest Areas	i. Bufonidae	<i>D. melanostictus</i> .	6 Families 11 Species
	ii. Dicroglossidae	<i>E. cyanophlyctis</i> , <i>F. nepalensis</i> , <i>Fejervarya pierrie</i> , <i>F. syhadrensis</i> , <i>F. teraiensis</i> .	
	iii. Megophryidae	<i>Leptobrachium smithi</i> .	
	iv. Microhylidae	<i>Microhyla berdmorei</i> .	
	v. Ranidae	<i>Hylarana leptoglossa</i> .	
	vi. Rhacophoridae	<i>P. teraiensis</i> , <i>R. bipunctatus</i> .	

Forests	Families	Species	Total no. of Families & Species
13. Mawpun Forest Area	i. Bufonidae	<i>D. melanostictus</i> .	4 Families 8 Species
	ii. Dicroglossidae	<i>E. cyanophlyctis</i> , <i>F. nepalensis</i> , <i>Fejervarya pierrie</i> , <i>F. syhadrensis</i> , <i>F. teraiensis</i> .	
	iii. Rhacophoridae	<i>P. teraiensis</i> .	
	iv. Ichthyophiidae	<i>Ichthyophis garoensis</i> .	
14. Mawphlang Sacred Grove	i. Bufonidae	<i>D. melanostictus</i> .	6 Families 15 species
	ii. Dicroglossidae	<i>E. cyanophlyctis</i> , <i>F. nepalensis</i> , <i>Fejervarya pierrie</i> , <i>F. syhadrensis</i> , <i>F. teraiensis</i> , <i>Fejervarya sengupti</i>	
	iii. Megophryidae	<i>Xenophrys falvipunctata</i>	
	iv. Microhylidae	<i>Leptotalax khasiorum</i>	
	v. Rhacophoridae	<i>P. teraiensis</i> , <i>R. bipunctatus</i> .	
	vi. Ranidae	<i>O. livida</i> , <i>S. danieli</i> , <i>O. mawphlangensis</i> , <i>Hylarana leptoglossa</i>	

Table 1.

List of amphibian species belonging to different families documented from different forest areas highlighting the diversity of anuran amphibians in community reserved forests and sacred forests of Meghalaya. Majority of the amphibian species that have been recorded were found in the diversified habitats of protected and reserved forests as well as sacred groves present in different regions of the state of Meghalaya (recorded by our team from 2015 till date).

Order	Family	Sl. No.	Species
Gymnophiona	Chikilidae	1	<i>Chikila fulleri</i> (Alcock, 1904)
		2	<i>Chikila gaiduwani</i> (Kamei, Gower, Wilkinson & Biju, 2013)
	Ichthyophiidae	3	<i>Ichthyophis alfredii</i> (Mathew & Sen, 2009)
		4	<i>Ichthyophis daribokensis</i> (Mathew & Sen, 2009)
		5	<i>Ichthyophis garoensis</i> (Mathew & Sen, 2009)
Anura	Bufonidae	6	<i>Bufoides meghalayanus</i> (Yazdani & Chanda, 1971)
		7	<i>Pedostibes kempii</i> (Boulenger, 1919)
	Dicroglossidae	8	<i>Fejervarya sengupti</i> (Purkyastha & Matsui, 2012)
	Megophryidae	9	<i>Leptolalax khasiorum</i> (Das, Tron, Rangad & Hooroo, 2010)
		10	<i>Leptolalax nokrekensis</i> (Mathew & Sen, 2009)
		11	<i>Megophrys megacephala</i> (Mahony, Sengupta, Kamei & Biju, 2011)
		12	<i>Megophrys oropedion</i> (Mahony, Teeling & Biju, 2013)
		Ranidae	13
	Rhacophoridae	14	<i>Chiromantis cherrapunjee</i> (Roonwal & Kripalani, 1966)
		15	<i>Philautus garo</i> (Boulenger, 1919)
		16	<i>Philautus kempiae</i> (Boulenger, 1919)
		17	<i>Philautus namdaphaensis</i> (Sarkar & Sanyal, 1985)
		18	<i>Polypedates assamensis</i> (Mathew & Sen, 2009)
		19	<i>Raorchestes shillongensis</i> (Pillai & Chanda, 1973)

Table 2.
 Checklist of the endemic amphibians of the state of Meghalaya.



Figure 9.
Duttaphrynus melostictus.

Shangpliang *et al.*, [57] studied and observed the unique characteristics of the breeding activity and oviposition of Annandale's high-altitude tree frog, *Kurixalus naso* (Annandale, 1912) (**Figure 11**) at a study site located under the protected area (Law Adong) Mawsynram, Meghalaya, North East India. The amplexing females lay scattered seed-like eggs inside the excavated burrows and the males, using their hind limbs, expose the eggs by pushing them to the mouth of the burrowing hole. This breeding strategy revealed by the tree frog *K. naso*, without foam formation is



Figure 10.
Rhacophorus maximus.



Figure 11.
Kurixalus naso.

unique among frogs belonging to the family Rhacophoridae. Therefore, identification of such breeding habitats may help to understand the ecological requirements of the species and to further create more realistic conservation strategies for the long-term persistence of the amphibian community [57].

2.2 Contribution of community forests to conservation of biodiversity

Community forest have long since served as a means to protect and conserve the rich biological diversity not only because biodiversity has tangible benefits but the fact that these forests have significant religious connotations to the tribal societies and makes a significant contribution to their wellbeing and livelihood. This dependence on forests and forest resources has led the communities residing in close proximities to forest areas to understand the need for conservation and sustainable use of resources [14]. The two main factors that have contributed to the sustainable utilization of natural resources and management of forests are traditional ecological knowledge and traditional institutions prevailing in the indigenous communities worldwide [58]. The khasi communities in Meghalaya, through an age old tradition have been protecting nature and their natural resources thus reflecting great awareness for the need of conservation and management [59]. Community Forestry is successful in decreasing resource degradation and helpful in conservation of Biodiversity [60]. It has been stated that community forests have improved the overall forest conditions including biodiversity [61]. In Meghalaya, a Sixth Schedule state in NE India, over 90% of the forests are under direct or de-facto control of the communities [62]. They are managed by 'traditional institutions' (TIs), organized

at village level and recognized by the Indian Constitution [63]. The forests provide livelihood and are also culturally important for the communities [64]. The local people develop various types of traditional forest management practices which contribute to the conservation of biodiversity and addressing the livelihood needs of the rural people [14, 65, 66]. Many species such as hoolock gibbon and elephant find place in tribal stories and mythologies, and people living close to forest have a very high tolerance for these species [14].

The state harbours about 850 species of medicinal plants, of which 377 species are used by 70–80% population [67]. Similarly, there are 249 wild species of edible plants belonging to 153 genera which are still consumed by people in Meghalaya [68]. Some of the medicinally important species reported are *Acorus calamus*, *Asparagus racemosus*, *Garcinia cowa*, *Myrica esculenta*, *Panax pseudoginseng* and *Rauwolfia serpentina*, etc. [2]. Medicinal plants are a vital resource for the traditional health care systems, as well as for modern medicines. It was observed that density of Community Forests and abundance of herbal practitioners are often correlated. Tiwari *et al.* [69] found that community forests in the form of sacred groves were homes to many medicinal plants. It is found that the traditional management practices not only help in conserving the resource as evident from the presence of large patches of well protected forests (for example 700 ha village protected forest in Pynursla) and ensuring its sustainable use, but at the same time serve as a common good and ‘safety net’ for the communities as seen in the village Nongpyndeng, where a large proportion of forest is being managed by the village council for the benefit of all inhabitants of the village. Often, more than one category of forest is found within the boundary of a single village or a group of villages. Over time, these communities have evolved a system of combining forest conservation and sustainable use at a micro level [70], unlike much of national and international efforts which are aimed at meeting these requirements at national or global scales.

In 2012, the Government of India under the Ministry of Environment and Climate Change (MoEFCC) in partnership with the United Nations Development Program (UNDP), constituted the India Biodiversity Awards (IBA) to recognise and honour the outstanding role played and the success achieved by communities to protect and conserve biodiversity [71]. The Yaongyimchen Community Biodiversity Conservation Area (YCBCA) about 10sq km in area, in Longleng district of Nagaland is a community-owned forest now a safe haven for 85 species of birds, including Amur falcons, 15 species of frogs, as well as leopards, barking deers, serows and otters. This transition did not happen overnight. Credit ought to be given to the local community who halted all hunting activities; even traditional traps were completely stopped in the community-conserved area. Another example can be taken from the Land of the Rising Sun - Arunachal Pradesh where the local villagers have used traditional knowledge to protect the Bugun Liocichla in Arunachal Pradesh. The Singchung Bugun Village Community Reserve (SBVCR) in west Kameng district, Arunachal Pradesh was officially declared in 2017. The Committee was honoured with the IBA 2018 for using its “traditional knowledge to protect the bird and its habitat” threatened by activities like timber extraction, forest clearance and infrastructure development. It is to be noted that The Singchung Bugun Village Community Reserve Management Committee has members from the indigenous community as well as from the forest department.

In the year 2018, the Umru Biodiversity Management Committee in Ri-Bhoi, Meghalaya was specially recognized for their efforts in conserving the Amur Falcons. It is worth mentioning that in the same year, a Certificate of Appreciation was awarded to Ka Khloo Kongwasan Chyrmang Community Reserve in Jaintia Hills District, Meghalaya. Altogether there are 5451 BMCs in Meghalaya and each of these committees are working tirelessly to conserve the biodiversity in

their area [71]. Besides, two National Parks and four Wildlife sanctuaries the state of Meghalaya, the Govt. of Meghalaya has vide Section 36 C of the Wild Life (Protection) Act, 1972 declared 74 private and community lands/forests as Community Reserves, the maximum in the country [72]. The Forests and Environment Department in consultation with local communities have prepared management plan for scientific management and conservation of the notified community reserves. Section 36D inserted in the Wildlife (Protection) Act, 1972 in 2003 provides for preparation and implementation of management plan and to take steps to ensure protection of wildlife and its habitat in the community reserve by a Community Reserve Management Committee [73]. This will come a long way in conserving biodiversity in CFs. In Jaintia Hills, the Forests and Environment Department is taking all possible measures to persuade the communities to allow the state government to notify rich habitats of wildlife as community reserves. As we have seen, progress so far is encouraging. The department with proactive cooperation and participation of local communities is taking measures for protection, conservation and scientific management of areas which have already been notified as community reserves [74].

3. Measures to protect community forests of Meghalaya

Forests play a major role in the sustenance of well-being in humans as they provide services such as water purification, provision of oxygen, and spiritual and cultural benefits. Thus, forests and forest resources prove to be not only a source of income but also are an important source of food, freshwater, medicines, firewood and materials for construction. It has been reported that many indigenous communities, forest biodiversity is fundamental to their culture and identity [75]. This dependence on forests and forest resources has led the communities residing in close proximities to forest areas to understand the need for conservation and sustainable use of resources [14]. These forests known as community forests are managed and controlled either by the clans, individuals, groups or traditional institutions according to the prevailing customary laws and practices [14]. The sacred groves which is the most famous amongst the community forests has been regarded as one of the best means for ecosystem conservation. This is due to the fact that it possesses higher species diversity as compared to its surrounding areas [76]. This class of community forest houses many rare, threatened and economically important species [69]. Khiewtam and Ramakrishnan [77] stated that due to human activities much of the vegetation are disturbed and it is only in these sacred forests that thick vegetation is prevalent. Human activities comprising of agricultural activities namely clearing of native vegetation, grazing of livestock, logging and construction has led to the alteration of vast areas on earth. These activities have had intense bearings not only on biodiversity but have also affected significant ecosystem processes such as pollination and nutrient cycling, habitat loss eventually leading to habitat fragmentation [78].

The common strategies adopted by most forest management institutions are penalty which could be monetary or nonmonetary like confiscation of equipment or fines in other forms strictly governed by customary practices of the respective community. Conflicts, whether intra-village or inter-village or inter-community are resolved by institutional mechanisms. Intervention of government agencies, in particular the Forest Department is sought when matters are not settled at the community level [79]. Thus, such collective efforts have contributed to the conservation of forest resources of the country. The establishment

of Conservation and Community reserves has led the Govt. of Meghalaya vide Section 36 C of the Wild Life (Protection) Act, 1972 to declare 64 private and community lands/forests as Community Reserves. These reserves are not located within a National Park or Wildlife Sanctuary and are focused mainly on the preservation and protection of flora, fauna and traditional or cultural conservation values and practices. It is also believed that these will provide a safe habitat for the animals inhabiting such areas [80]. The concept of Conservation- and Community- reserves is although new yet it is believed to contribute to conservation of biodiversity.

The World Conservation Union in the year 1999 reported that in spite of forests being protected, yet they continue to be under the pressures of human activities and conservation is not ensured even if it involves legal designations. Further, the International Union for Conservation of Nature and Natural Resources (IUCN) reported that many protected areas lack institutional infrastructure necessary to regulate agriculture, grazing, forestry, mining, hunting, civil conflict, and tourism, financial and human resources and a reassuring legal framework [81]. The United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil, in an attempt to promote the management, conservation and sustainable development of all types of forests, introduced the non-legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of all Types of Forests, also known as the Forest Principles. By the year 2007, the United Nations General Assembly adopted the Forest Instrument which is an important step towards achieving sustainable forest management globally. The concept of sustainable forest management has influenced many new initiatives, prompted revisions to forest policies and practices and been widely accepted around the world by forestry organizations at all levels. It continues to evolve through implementation of criteria and indicators processes at the national, regional and ecoregional levels [82].

The FAO in 2000 stated that in order to meet the demands for food in a growing population, sustainable development of agriculture, fisheries as well as forests can be achieved through biotechnology [83]. The term biotechnology has been defined as the development or use of living organisms to produce, alter or improve a product or a living organism for a specified purpose. It comprises of not only conventional breeding, including domestication plant and animals, but rather, modern innovations emphasizing on biological systems [84]. Although this field has provided grounds for rapid development of new technologies, yet there is limited availability of studies on its role in forest plantation, and ecological benefits arising from genetically modified tree species. This basically arises due to the fact that trees possess the known characteristics of being sessile, having a longer lifespan, is outcrossing and can disperse pollen and seeds across very long distances, and would likely be established in environments with potential mating proximity populations of other species. These issues all of which have been overlooked [85]. However, the use of biotechnology has played a pivotal role in the processing sector, such as pulp and paper production. It also plays a significant role in various stages of the production, starting from planting to harvesting. The first ever application of biotechnology in forestry in order to increase seedling growth in tissue culture was the inoculation of seedlings with symbiotic organisms (specifically mycorrhizae). Owing to a better understanding of genetics as well as development of new techniques, forest biotechnology, now focuses on areas such as propagation, genetic transformation and genetic diversity studies which would ultimately lead to conservation of species that are not only economically but ecologically important as well [86].

4. Conclusion

Herpetofauna is currently facing a major decline on a global scale, resulting from various factors, such as climate change [87, 88], habitat loss, spread of invasive species, overcollection [89] and are therefore in an urgent need of intensive conservation effort. Natural forests are rapidly being replaced by agricultural developments and other human dominated land use types [90, 91]. The species rich tropical regions are quickly losing a large number of species presenting a big threat to global biodiversity loss. The community reserved forests now remain as the only areas that have remain untouched by drastic anthropogenic activities that destroy the breeding habitats of the anuran amphibians. Habitat destruction affects anurans drastically because of the fact that anurans are highly selective for breeding and oviposition habitats, have low vagility and narrow habitat tolerance. Measures that promote restoration of the forests cover and protection of the core habitat for amphibian diversity and abundance and preservation of their sheltered breeding and oviposition sites needs to be focused and implemented at the earliest.

Some important suggestive measures in this regard are: (i) restoration of temporary pools and different water bodies with diverse array of hydro-periods inside the forested area; (ii) minimizing the excessive use of pesticides and fertilizers in the agricultural fields adjacent to the forested area as water run-off might disturbed the survival of the herpeto-fauna; (iii) avoid utilization of the forested area as dumping site. In addition, this finding may provide platform to evaluate the relationship between diversity of amphibians and the diversity of the plant species within these forests. Further, evaluation of amphibian adaptive mechanism in these forests, comparative embryological and developmental processes and analysis of diverse reproductive strategies exhibited by the amphibians housed inside these forests may be taken into consideration for future research. This will help to establish the long-term persistence of the amphibian species and the sustainability of those populations at risk.

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Conflict of interest

“The authors declare no conflict of interests.”

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