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Recent research, aspects and conservation strategy towards amphibians of Bangladesh

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Abstract

The present review described the research trends and conservation issues on amphibians of Bangladesh based on recent published research works. We found twenty amphibian species (11 dicroglossids, 5 microhylids, 2 ranids, 1 rhacophorid and 1 bufonid) from Bangladesh have morphometric data. These researches involved taxonomy, reproduction biology, cryptic diversity and other natural history gives superficial scenario in amphibian conservation. Most research has been conducted in southeastern and northeastern Bangladesh describe ecological implications and threat due to anthropogenic activities and habitats destructions. Morphological and molecular investigations have resulted in the description of six new species i.e., *Minervarya asmati, Microhyla mukhlesuri, Microhyla mymensighensis, Minervarya dhaka, Euphlyctis kalasgramensis, Microhyla nilphamariensis* recently. Here genus *Zakerana* was erected for several South Asian species that previously assigned to *Fejervarya*, but later into the *Minervarya*. Bio-acoustic analyses are largely wanting but some cross-breeding experiments exist for *Hoplobatrachus* spp. A large number of amphibian species have been recognized by some morphometric assessments. Amphibian deformity has been reported from Bangladesh, and this serves as a warning and new challenge for survival in the near future. Relative to other countries, Bangladesh has received little attention on amphibians. Accordingly, many important species may be lost before their discovery. In this paper we proposed the diverse amphibian fauna that occupies habitats ranging from the northern and eastern hills to mangrove Sundarbans forests in the southwest and to the southern Bay of Bengal need proper survey and conservation.

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Introduction

Amphibians are most vulnerable vertebrate group (Daszak *et al.*, 2003; Stuart *et al.*, 2004) and in contrary, the rate of new and cryptic species discoveries indicates to an underestimation of species richness (Vieites *et al.*, 2009; Yan *et al.*, 2016). Traditional morphology-based taxonomic methods for species identification requires ample of time which may lead to the extinction of a species before its discovery (Murphy *et al.*, 2011; Spinks *et al.*, 2012). DNA barcoding has eased the demarcation and discovery of amphibians (Vieites *et al.*, 2009; Yan *et al.*, 2016) and could be a principal tool to help efficiently identify species and set their conservation priorities (Murphy *et al.*, 2013; Chambers and Hebert 2016). In Bangladesh, genetic analyses focused mainly on the families Dicroglossidae (Alam *et al.*, 2008; Islam *et al.*, 2008a, b; Howlader *et al.*, 2015a, 2016) and Microhylidae (Hasan *et al.*, 2012a and 2014a; Howlader *et al.*, 2015b), others remained untouched.

Despite many species have been reported from Bangladesh (e.g., Howlader 2011a; Hasan *et al.*, 2012b; Hasan *et al.*, 2014a), the taxonomic record remains unsatisfactory. In many cases, authorities have overlooked many authenticated records (Asmat, 2005). This points to an urgent need of quality research on amphibian diversity and including conservation assessments.

The recent description of a new species from a highly populated urban area (Howlader *et al.*, 2016) raises hope of progress and yet the first report of organ deformity (Jaman *et al.*, 2017) signals a warning of things to come.

As a part of the global biodiversity hotspot in tropical Asia, Bangladesh contains a unique and highly threatened biota (Kabir *et al.*, 2009). Unfortunately, in contrast to countries like India and Sri Lanka, few attempts have been made to document its biodiversity and little effort has been devoted to resolve the species' evolutionary affinities (Molur, 2008). The problem is pervasive to the extent that the total number of amphibian is a matter of debate: Khan (1982) lists 19; IUCN (2000) 22; Asmat (2007) 37; Khan (2008) 53; Kabir *et al.*, (2009) 34; Khan (2010) 42; Reza (2014) 57; Hasan *et al.*, (2014b) 49; IUCN (2015) 49; Khan (2015) 64; AmphibiaWeb (2019) 37 and Frost (2019) 53 species.

Several reports documented massive amphibian declines worldwide (Bosch *et al.*, 2001; Hero and Shoo 2003) and the scientists are seeking causes of this (Sparling *et al.*, 2000; Linder *et al.*, 2003). However, researchers are neglecting these issues in Bangladesh and if this continues many species may face extinction before knowing why.

Bangladesh has few batrachologists and, hence, a scarcity of research. Most research has not been published in peer reviewed, accessible journals (Reza, 2014). Thus, it's a huge challenge to the critical need for a summary of the research trends, conservation issues and future directions for the amphibians of Bangladesh. Here, we try to make it available for forthcoming researchers regarding amphibian's research strategy and conservation policy. Thus, our review may serve as a guide for amphibian imminent investigations.

Salient research aspects on amphibians in Bangladesh

Taxonomic study

Taxonomy is the root of conservation and management (Kohler *et al.*, 2005). Advances in molecular phylogenetics have enhanced taxonomic studies in many regions (e.g., Islam *et al.*, 2008a, b; Hasan *et al.*, 2012a, b; Howlader *et al.*, 2015a, b). However, herpetological research in Bangladesh still mainly involves morphometric analyses alone (Howlader 2011a; Rahman *et al.*, 2011, 2012; Rahman and Mortuza 2015). Sometimes acoustic data have been analyzed (Howlader 2011a; Hasan *et al.*, 2015; Howlader *et al.*, 2016), but many authors have only reported amphibian diversity without additional analysis (Hasan and Feeroz 2014; Reza and Perry 2015). Existing studies fall into the following four topics.

Diversity study

Bangladesh is a bio-ecologically diverse country (Nishat *et al.*, 2002). We considered six regions, following Khan 2008 and Hasan *et al.*, 2014, to predict the species distribution and research frequencies in different parts of the country (Fig. 1).

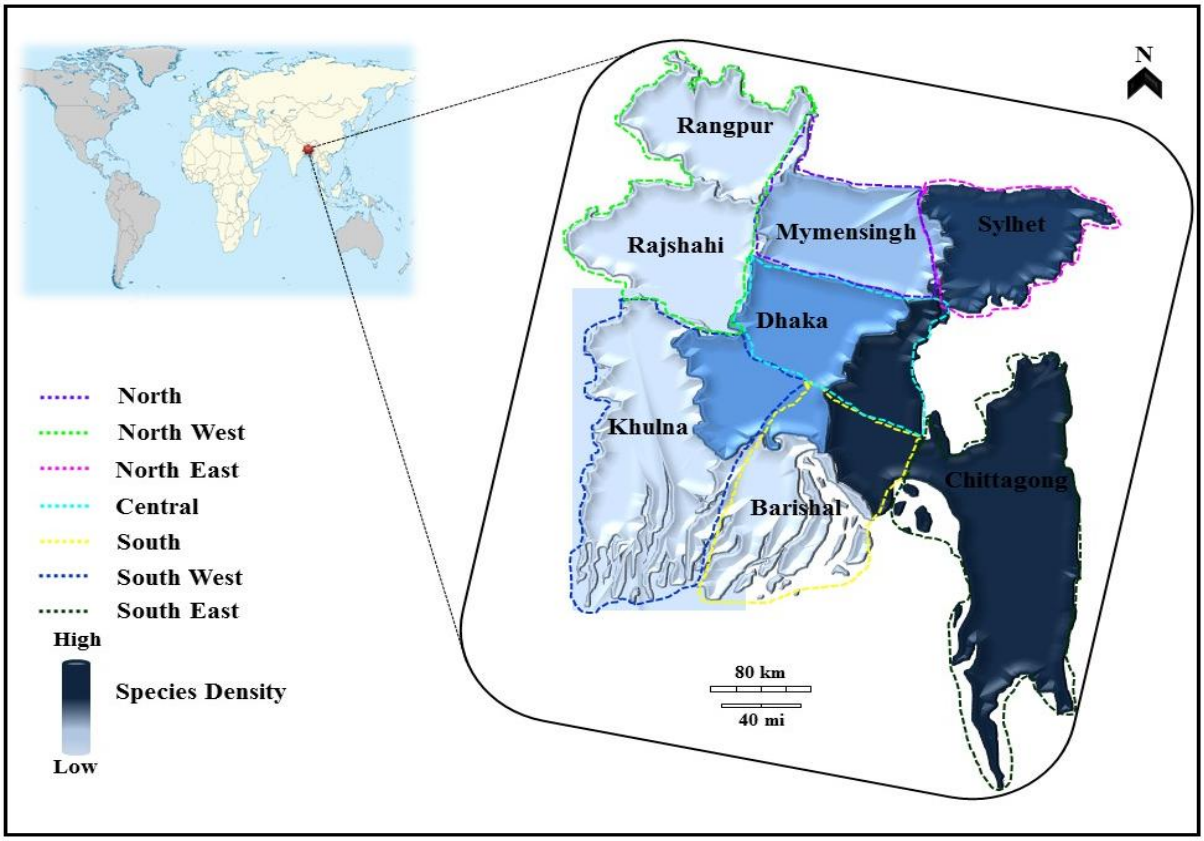

Fig. 1. Map of Bangladesh showing different regions and divisions with species richness. Species richness arranged division-wise not regions.

Most research on Bangladeshi amphibians' centers on diversity of a few regions (Fig. 2.A). We discussed the regions based on the importance and research frequencies below.

Hill tracts and tropical forests, southeastern and northeastern Bangladesh

This region covers mainly the hill tracts of Chittagong and Sylhet Division (Nishat *et al.*, 2002). It belongs to the Indo-Burma Biodiversity Hotspot (Myers *et al.*, 2000; Mittermeier 2004) and most research on amphibian diversity focuses here. Three new species have described from this region: *Minervarya asmati* (Howlader 2011a), *Hoplobatrachus litoralis* (Hasan *et al.*, 2012b) and *Microhyla mukhlesuri* (Hasan *et al.*, 2014a). Rahman and Motuza (2015) found *Duttaphrynus melanostictus* on the small St. Martyn's Island in the Bay of Bengal, while the Bay of Bengal Large Marine Ecosystem (BOBLME) Project (2015) reported six species from there. Rasel *et al.*, (2007) recorded *Minervaria nepalensis*, *M. pierrei*, *M. syhadrensis* and *M. teraiensis* for the first time in Bangladesh from this area.This region appears to harbor most Bangladeshi amphibian species (Hasan and Feeroz 2014; Reza and Perry 2015). Hasan and Feeroz (2014) counted 32 species from the six protected areas including Chittagong. However, Mahony and Reza (2008) found only 11 and Ghose *et al.*, (2017) found 12 amphibians in Khadimnagar National Park, a protected area in Sylhet Division. Moreover, IUCN (2015) documented 44 species in this region.

Sal forest basin, central Bangladesh

This region, which includes the areas in Dhaka and Mymensingh Division (Nishat *et al.*, 2002), contains

some unique species (Reza and Perry 2015) and has the second highest number of amphibians with 23 species (IUCN 2015). However, the area remains to be explored thoroughly.

Rahman *et al.*, (2013) recorded eight species from the small area of Bangladesh Livestock Research Institute campus, Dhaka, while Reza and Perry (2015) reported 11 species from Jahangirnagar University campus and 13 from Madhupur National Park. However, *Microhyla mymensighensis* (Hasan *et al.*, 2014a) and *Minervarya dhaka* (Howlader *et al.*, 2016) have also been discovered in this region.

Poorly explored regions

Although the other regions cover almost 60% of the country, only few surveys have been conducted here, and these assessments constituted short-term locality-specific expeditions. Both *Euphlyctis kalasgramensis* (Howlader *et al.*, 2015a) and *Microhyla nilphamariensis* (Howlader *et al.*, 2015b) were described from these regions. However, according to the IUCN (2015), this region is home of 20 species.

In comparison, while Howlader (2010) reported 14 amphibians from Barisal, Reza and Perry (2015) 12 from Sundarbans Reserve Forest and Rahman *et al.*, (2014) reported six from Jamuna Bridge and adjacent areas. Ahmad and Alam (2014) testified five species of *Fejervarya* (4 from *Minervarya* and 1 from *Fejervarya*) from Naogaon and Al-Razi *et al.*, (2014) found *Humerana humeralis* in Rangpur.

Bioinformatics

Molecular studies have just started and presently less than 40% of Bangladeshi amphibian species have DNA barcodes. These analyses indicate the existence of several cryptic species. Hasan *et al.*, (2012a) found eight potential cryptic species involving *Hoplobatrachus*, *Fejervarya* (*Minervarya*), *Hylarana* and *Microhyla*.

Their barcodes based on mitochondrial 16s rRNA revealed very divergent conspecific differences, even as much as 15.8%. Sultana *et al.*, (2016) reported mitochondrial *Cytb* and variation in 21 microsatellite loci from *Hoplobatrachus tigerinus*. Divergence existed between western and eastern populations of Bangladesh that associated with major rivers. Hasan *et al.*, (2008), Khan *et al.*, (2002) and Islam and Hossain (2012) reported similar results.

Alam *et al.*, (2008) did not find any substantial difference between the *Hoplobatrachus tigerinus* of Bangladesh and India (< 2.0% difference in sequences) but divergence exceeded 3.5% in *Euphlyctis hexadactylus* and 4.0% in *E. cyanophlyctis*. *Euphlyctis cyanophlyctis* of Bangladesh differed by 3.4% from Sri Lanka, but populations within Bangladesh did not differ substantially. Khan *et al.*, (2002) also found the similar result. Islam *et al.*, (2008a) reported three major groups of *Fejervarya* (*Minervarya*) from Bangladesh through evaluating *Cytb* and 12s and 16s rRNA sequences: a mangrove type, a large type, and others. The last group further divided into medium and small types. Islam *et al.*, (2008b) also mentioned the three major groups.

Other than *Fejervarya frithii* (Theobald 1868), later considered to be an invalid species (Matsui *et al.*, 2007), and *Minervarya asmati* (Howlader 2011a), all newly described Bangladeshi amphibian species have been based mainly on genetic analyses (Table 1).

In 16s RNA sequences, new *Hoplobatrachus litoralis* differs by 3.2% from *H. tigerinus* (Hasan *et al.*, 2012b), *Euphlyctis kalasgramensis* by 5.5–17.8% from its closely related species (Howlader *et al.*, 2015a), and *Minervarya Dhaka* by 3.1–20.1% from other congeners (Howlader *et al.*, 2016). Further, *Microhyla mukhlesuri* differs from *M. fissipes* by 3.6% (Hasan *et al.*, 2014a), *M. mymensinghensis* from *M. fissipes* by 4.2% (Hasan *et al.*, 2014a), and *Microhyla nilphamariensis* from its other congeners by 5.7–13.2% (Howlader *et al.*, 2015b), although later Hasan *et al.*, (2015) found only meager 3.2% divergence between *M. nilphamariensis* and *M. ornata*.

Table 1. Trends of using taxonomic means in describing new species.

Species	Taxonomic means	Published Year
Fejervarya frithii	Morphology	1868 (invalid according to Matsui *et. al.,* 2007)
Fejervarya asmati	Morphology	2011
Hoplobatrachus litoralis	Morphology and Genetics	2012
Microhyla mukhlesuri	Morphology and Genetics	2014
Microhyla mymensinghensis	Morphology and Genetics	2014
Euphlyctis kalasgramensis	Morphology and Genetics	2015
Microhyla nilphamariensis	Morphology and Genetics	2015
Fejervarya dhaka	Morphology and Genetics	2016

Study of morphology

Morphometry has been using as the principal means of studying amphibian taxonomy in Bangladesh. Morphometric data used in literatures on taxonomy of amphibians of Bangladesh (Khan *et al.*, 2002; Islam *et al.*, 2008a; Howlader 2011a; Rahman *et al.*, 2011; 2012; Alam *et al.*, 2012; Al-Razi *et al.*, 2014; Hasan *et al.*, 2008; 2012b; 2014a; 2015; Rahman and Mortuza 2015; Howlader *et al.*, 2015a, b; 2016) can be divisible into three sections; i. species that have adequate morphometric data (Appendix 1); ii, species with few morphometric data (Appendix 2); and iii, the species having sufficient information on ratios of morphometric data (Appendix 3). Twenty amphibian species (11 dicroglossids, 5 microhylids, 2 ranids, 1 rhacophorid and 1 bufonid) from Bangladesh have morphometric data (Fig. 3A). Among these species, 13 (Appendix 1) have more or less adequate data for comparisons, while seven (Appendix 2) did not. Only 3 species have adequate data and all seven species with inadequate data combine information for males and females. Sixteen species (Appendix 3), 11 from Dicroglossidae and five from Microhylidae, have information on ratios of morphometric data.

The ratios were formulated from average measurements without treating males and females separately. Beside citing comparison through morphological measurements many authors depicted pictorial presentation of morphological variations, eg., different species of *Microhyla* (Howlader *et al.*, 2015b), *Minervarya* (Howlader *et al.*, 2016) etc.

Bioacoustics

Advertisement calls are a unique feature of frogs and they are often species-specific. Accordingly, bioacoustic analysis also can serve as an important taxonomic identifier (Purkayastha and Matsui, 2012; Wijayathilaka and Meegaskumbura, 2016).

Howlader (2011a) reported three types of very fast trills in the call of *F. asmati*. Type 1 consisted of a group of similar pulsed trains of 92–134ms interposed by short single notes. The second and third types were both of 775ms. The pulses of type one had a melodious modulation with five identifiable bands.

The dominant frequency was around 0.2–1.0 kHz, followed by a second band at 1.4–2.2 kHz, then a formant band at 2.6–3.4 kHz followed by some additional bands at 3.8–4.6 kH *F* and 5.0–5.8 kH*F*. In contrast, the calls of *F. dhaka* were comprised of short cheeping notes of inconstant duration lasting from 61 to 144ms, and the number of pulses per note varied from 8 to 20. Frequency ranged from 2.5 to 4.7 kHz with a dominant frequency lying between 2.6 and 3.8 kHz (Howlader *et al.*, 2016). Hasan *et al.*, (2015) described the acoustic parameters of the advertisement call of *M. nilphariensis* and compared it with other congeners. They found that the notes of *M. nilphamariensis* had more pulses and longer durations than those of *M. ornate* and *M. fissipes*. Though the pattern of pulse repetition in *M. nilphamariensis* was similar to *M. fissipes*, it differed from *M. ornata*. *Microhyla nilphamariensis* had two discrete principal frequency bands (1.65 & 3.62 kHz), which were higher than those of *M. fissipes* (1.36 & 2.86 kHz) and *M. ornata* (1.25 & 2.62 kHz). Moreover, Hasan *et al.*, (2012b) gave a sound

spectrogram of *Hoplobatrachus litoralis* but without description or comparison.

Breeding biology

Breeding behavior may be species-specific and, thus, serve to maintain species by reproductive isolation (Mayr, 1942). However, no observations of amphibian breeding in nature have been reported for Bangladesh, although some laboratory experiments exist. Islam *et al.*, (2008a) experimented on large, medium, small and mangrove types of *Fejervarya* (*Minervarya*) from Bangladesh and reported three different modes of reproductive isolation. Gametic isolation occurred between large and mangrove types. Hybrid in viability was found between large type with medium and small types, i.e., fertilization occurred but offspring died at their embryonic stage. Further, hybrid sterility occurred between small and medium types. They also investigated cross breeding between *Fejervarya* (*Minervarya*) of Bangladesh and other Asian countries and found more or less similar results as Djong *et al.*, (2007) reported.

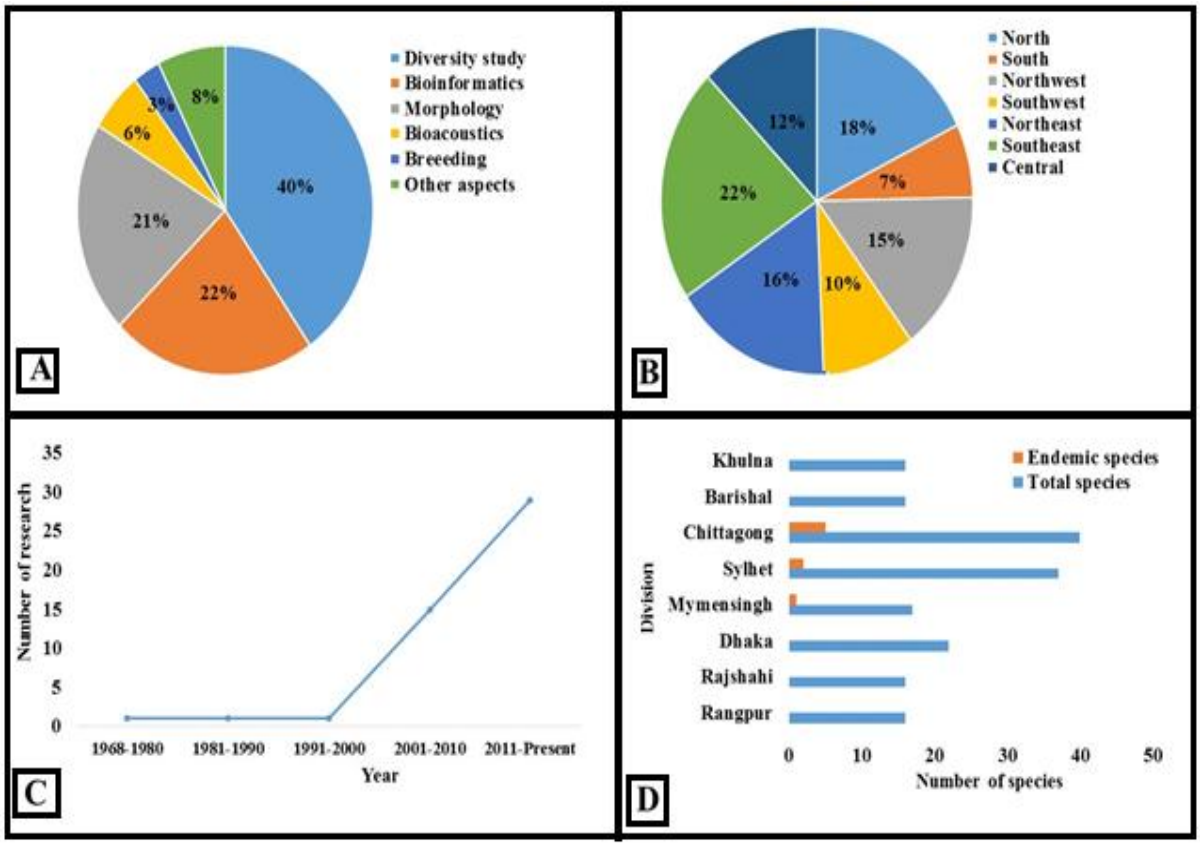

Fig. 2. A. Research aspects on amphibians conducted in Bangladesh. B. Researches on amphibians in different regions of Bangladesh. C. Trends of amphibian research (research frequency) in Bangladesh. D. Recorded amphibian species in different divisions of Bangladesh (endemic species means that is not yet reported from other division of Bangladesh).

Alam *et al.*, (2012) tested for inter- and intrageneric hybridization. They found complete gametic isolation between male *Fejervarya* (*Minervarya*) and females of *E. cyanophlyctis* and *H. tigerinus* and complete hybrid in viability between female *E. cyanophlyctis* and male *H. tigerinus* and *H. chinensis*. A few mature allotriploid (maternal-2n+paternal-n) hybrids occurred between female *H. tigerinus* and male *H. chinensis*. Earlier, Djong *et al.*, (2007) reported the same results.

Cryptic species aspects and ecological implications

The researchers also investigated some new cryptic aspects on amphibians of Bangladesh as described below.

Erection of genus Zakerana

Howlader (2011b) split *Fejervarya* into South Asian and Southeast Asian groups. He summarized comparisons and restricted Southeast Asian forms to *Fejervarya* and erected the new genus *Zakerana* for South Asian forms. Further, he hypothesized that *Minervarya* and *Zakerana* were sister-taxa because they occurred together, shared habitats and both had small body sizes along with undeveloped webbing on their feet. *Zakerana* differed from *Minervarya* by having more tubercles and lacking a rictal gland. Later, *Zakerana* was eventually synonymized with *Fejervarya* (Dinesh *et al.,* 2015) and finally with *Minervarya* (Sanchez *et al.*, 2018).

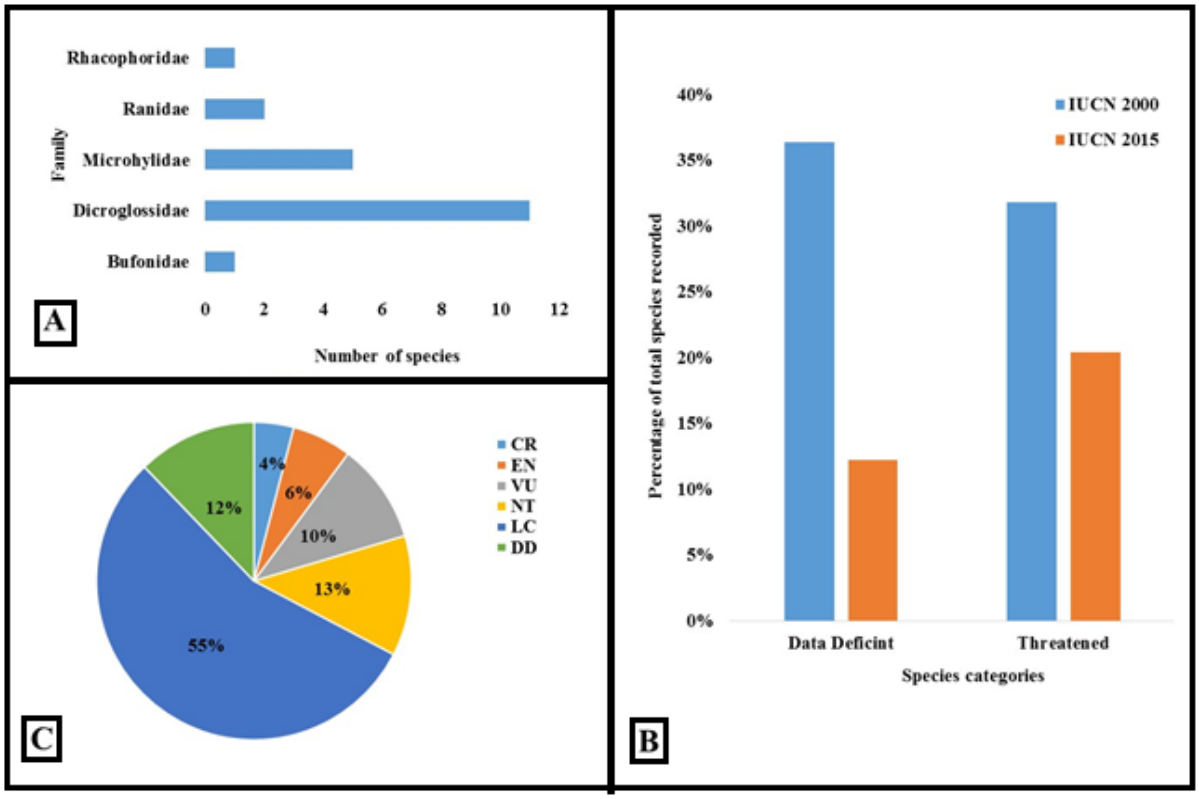

Fig. 3. A. Number of species belong to amphibian families of Bangladesh having available morphometric measurements. B. Proportion of Data Deficient and Threatened amphibians of Bangladesh, assessed in 2000 and 2015. C. Percentages of amphibians of Bangladesh in different categories assessed by IUCN in 2015.

Impact of temperature on histology

Rahman (2014) reported that temperature had a significant effect on the gut structures of *F. limnocharis*. As temperature raises gut layers became more developed.

Low temperatures resulted in emaciated gut layers. Some important layers, like *mauscularis mucosa* of the esophagus, which plays a vital role, were absent. The layers thickened with raising temperatures.

Deformities

Jaman *et al.*, (2017) reported an adult male skipper frog (*E. cyanophlyctis*) with three legs and a missing left forelimb for the first time in Bangladesh.

The radiograph ensured the absence of bone formation of that limb. They assumed different pesticides and agrochemicals caused the deformity.

Habitat preference

Hasan and Feeroz (2014) reported only 16% of 32 Amphibian species from six protected areas of southeastern Bangladesh strictly occupy a single habitat. Another 34% were restricted to two habitats only and the remaining 50% were found to use more than two habitats. Species that occupied multiple habitats were most common.

Population status

Rahman *et al.*, (2013) surveyed the amphibians of the Bangladesh Livestock Research Institute (BLRI) and found 38% to be rare, 25% very common, 25% common and 12% at risk of extinction / extirpation. Likewise, Hasan and Feeroz (2014) surveyed six protected areas of Bangladesh and found that species living in single habitats were rare.

Research frequency on amphibians in Bangladesh

The research frequency on amphibians in decades and regions of Bangladesh have not been consistent (Fig. 2C). The earliest record of research on amphibians in Bangladesh was in 1968 but, until 2000 it was very scarce while there was an abrupt increase in 2001-2010 and boosted up again in later.

The total number of species recorded from the country also reflected this scenario, 22 amphibians till 2000 (IUCN 2000) which increased to 34 by 2009 (Kabir *et al.*, 2009) and again raised to 49 by 2014 (IUCN 2014; Hasan *et al.*, 2014). The research frequency in different regions also varied, Southeast region having most frequent amphibian researches followed by North and Northeast regions (Fig. 2.B).

The total number and number of endemic species of amphibians recorded from different divisions of the country also supported this finding (Fig. 2D). However, beside many challenges like, shortage of resources, superstitions among people, bureaucratic obstacles, lack of knowledge and interest to amphibian researches, it is a good sign to have recently increased research frequency, regular description of new species and new records, and thus having additional species to the list of the country. This is also an indication to the underestimation of the amphibian diversity of the country and seeking immediate action to explore total diversity.

Present conservation and recommendations of amphibians in Bangladesh

Conservation status

According to IUCN (2000) 8 species of 22 (36.37%) were threatened while more 7 species (31.82%) did not have any data. On the other hand, IUCN (2015) listed 10 of 49 (20.41%) as threatened and 6 species (12.24%) as data deficient (Fig. 3B). Data deficient species are actually threatened only need confirmation from field data (IUCN 2015). However, this scenario is indicating a slight improvement of the situation but yet far from the complete achievement for conservation of amphibians in this country.

According to the assessment of IUCN 2015 more than 20% of the amphibians of Bangladesh are threatened while 13% are near threatened and 12% data deficient (Fig. 3C). Though a large portion of the amphibian species have assessed as least concern but still they are facing a wide range of threats from habitat alteration, destruction and other man-made challenges. Formulating and implementing conservation strategies and management plans are also big issues in Bangladesh.

Hasan *et al.*, (2014b) mentioned 19 species as rare and 11 species as uncommon among 49. Most of the threatened species are distributed in southeast and northeast regions of Bangladesh which may indicate the uniqueness of these areas (IUCN 2015) or as before mentioned due to lack of knowledge from other parts.

Major threats

Bangladesh is one of the most vulnerable countries affecting from climate change. None but amphibians are animal group suffering most due to the changed environment (Carey and Alexander 2003). They are facing different new diseases (Daszak *et al.*, 2003), change in phenology (Bradshaw and Holzapfel 2006; Parmesan 2006), decrease in population sizes (Blaustein and Kiesecker 2002) etc., worldwide due to the climate change. Bangladesh is not also the exception. Being a highly populous country, the existence of amphibians is threatened more by manmade causes than natural causes in Bangladesh. Among other threats habitat alteration, loss of forests, use of pesticides, over exploitation, introduction of invasive species, pollution etc. are major threats to the amphibian conservation in Bangladesh (IUCN

2015).

Laws and legislations

Amphibians of Bangladesh are legally protected by several laws, e.g., Wildlife Act, 1974/2012, Forest Act 1927/2010, Bangladesh Environment Conservation Act, 1995 etc. The government of Bangladesh has declared 17 National Parks, 21 Wildlife Sanctuaries, 12 Ecologically Critical Areas, 6 Eco-Parks, 2 Safari Parks and 2 Botanical Gardens (Hasan *et al.*, 2014b; IUCN 2015) under the mentioned Acts. The total area of all National Parks and Wild life Sanctuaries cover almost 2% of the total area of Bangladesh (IUCN 2015).

Bangladesh has also signed a number of international conventions and treaties relevant to amphibian conservation. The mentionable Conventions and treaties are-Convention on Biological Diversity (CBD), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Convention on International Importance, especially as Waterfowl Habitat (Ramsar Convention), Convention Concerning the Protection of the World Culture and Natural Heritage (World Heritage Convention) etc. Bangladesh has declared 2 Ramsar Sites and 1 natural Heritage Site harboring a huge number of amphibians.

Apparently, Bangladesh has many strict laws to protect amphibians but, what it needs is to properly implement them. Despite having sufficient acts Bangladesh has very limited institutional capacity, education and training facilities and expert human resources to play role in the amphibian conservation (IUCN 2015).

Scope for future works

Although about 85% of land in Bangladesh consists of plains (IUCN 2015), the entire country is in need of extensive surveying. Most work has focused on southeastern and a bit of northeastern Bangladesh, which include the hill tracts and wetlands. However, Biju *et al.*, (2014) and Howlader *et al.*, (2015b) showed that the planes may also harbor rich diversity. Hence, the IUCN (2015) assumed that many new species may occur in Sylhet regions and the deciduous forests of central, northern and northwestern Bangladesh.

Bangladesh appears to have many cryptic amphibian species (Islam *et al.*, 2008a, b; Hasan *et al.*, 2012b), and this makes it very difficult to evaluate the conservation status of species. Thus, it is essential to focus on some specific genera and species complexes, such as *Fejervarya*, *Minervarya*, *Polypedates* and *Microhyla* that tend to have many cryptic species. It is also necessary to further explore threatened taxa. Such studies should make use of efficient techniques, such as DNA barcoding and molecular phylogenetic analysis (Vieites *et al.*, 2009; Murphy *et al.*, 2011) to gain insights into taxa needing traditional morphological assessments. All areas of research on Bangladeshi amphibians should also be broadened. Evolutionary affinities and other aspects such as breeding, development, plasticity, and reasons for population declines also should be considered.

Conclusion

There is an urgent need to assess the diversity and population status of amphibians in Bangladesh. The total number of amphibian species in this country will likely double that currently known (Frost 2019). Notwithstanding, amphibians are under enormous pressure due to human population explosion and other anthropogenic issues. The world is experiencing a mass amphibian extinction for several reasons, such as disease, climate change, pesticides, and habitat loss and over exploitation, and likewise Bangladesh cannot escape this cataclysm. Amphibians may be harbingers of things to come in other taxa. Thus, research on these crucial topics is urgently necessary. The importance of Bangladeshi amphibians was intensely understood in 1970s–1980s, especially as they related to agriculture, when Asian bullfrogs (*Hoplobatrachus tigerinus*) were extensively collected from the nature (IUCN 2015) for foreign currency. Although Bangladesh has laws to prevent hunting, killing or catching of wild animals, they are applied rarely. Extensive research, appropriate

execution of laws and mass awareness are, without exception, necessary to ensure the survival of amphibians. Partnerships among researchers, donors, forest department, wildlife advisory board and scientific committee, local people, should be formed. We hope that the present findings of the study provide useful information for the policy makers developing programs of amphibian conservation in Bangladesh.

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References

Ahmad F, Alam SMI. 2015. Frogs in the Genus *Fejervarya* (Anura: Dicroglossidae) of the Nazipur Area, Patnitala Upazila, Naogaon District in Northwestern Bangladesh. IRCF Reptiles and Amphibians **22,** 145-149.

Alam MS, Igawa T, Khan MMR, Islam MM, Kuramoto M, Matsui M, Kurabayashi A, Sumida M. 2008. Genetic divergence and evolutionary relationships in six species of genera *Hoplobatrachus* and *Euphlyctis* (Amphibia: Anura) from Bangladesh and other Asian countries revealed by mitochondrial gene sequences. Molecular Phylogenetics and Evolution **48,** 515-527.

Alam MS, Kurabayashi A, Hayashi Y, Sano N, Khan MMR, Fuji T, Sumida M. 2010.Complete mitochondrial genomes and novel gene rearrangements in two dicroglossid frogs, *Hoplobatrachustigerinus* and *Euphlyctishexadactylus*, from Bangladesh. Genes and Genetic Systems **85,** 219-232.

Alam MS, Islam MM, Khan MMR, Hasan M, Wanichanon R, Sumida M. 2012. Post mating isolation in six species of three genera (Hoplobatrachus, Euphlyctis and Fejervarya) from family Dicroglossidae (Anura), with special reference to spontaneous production of allotriploids. Zoological Science **29,** 743-752.

Al-Razi H, Baki MA, Alam SMI. 2014. Record of *Humerana humeralis*(Boulenger, 1887) from Rangpur District of north-western Bangladesh. Bangladesh Journal of Zoology **42,** 277-282.

Amphibia Web. 2019. University of California, Berkeley, CA, USA. Accessed 20 Jun 2019. https://amphibiaweb.org

Asmat GSM. 2005. IUCN's fun of Bangladeshi amphibians BaWNet has rejected the 2004 global amphibian assessment report. Bonnoprani **2**, 1-33 (in Bangla, English summary).

Asmat GSM. 2007. Checklist of wild animals of Bangladesh. Gazi Publishers, Dhaka, Bngladesh.

Biju SD, Garg S, Mahony S, Wijayathilaka N, Senevirathne G, Meegaskumbura M. 2014. DNA barcoding, phylogeny and systematics of Golden-backed frogs (*Hylarana*, Ranidae) of the Western Ghats-Sri Lanka biodiversity hotspot, with the description of seven new species. Contributions to Zooloogy **83,** 269-335.

Blaustein AR, Kiesecker JM. 2002. Complexity in conservation: lessons from the global decline of amphibian populations. Ecology Letters **5,** 597-608.

BOBLME. 2015. Saint Martin's biological survey report, Bangladesh. BOBLME-2015-Ecology 48.

Bosch J, Martínez–Solano I, García–París M. 2001. Evidence of a chytrid fungus infection involved in the decline of the common midwife toad (*Alytes obstetricans*) in protected areas of central Spain. Biological Conservation **97,** 331-337.

Bradshaw WE, Holzapfel CM. 2006. Climate change-Evolutionary response to rapid climate change. Science **312,** 1477-1478. https://doi.org/10.1126/science.1127000.

Carey C, Alexander MA. 2003. Climate change and amphibian declines: is there a link? Diversity and Distributions **9,** 111-121.

Chambers EA, Hebert PDN. 2016. Assessing DNA barcodes for species identification in North American reptiles and amphibians in natural history collections. PLoS ONE **11,** e0154363. https://doi.org/10.1371/journal.pone.0154363.

Daszak P, Cunningham AA, Hyatt A D. 2003. Infectious disease and amphibian population declines. Diversity and Distributions **9,** 141-150. https://doi.org/10.1046/j.1472-4642.2003.00016.x.

Dinesh KP, Vijayakumar SP, Channakeshavamurthy BH, Torsekar VR, Kulkarni NU, Shanker K. 2015. Systematic status of Fejervarya (Amphibia, Anura, Dicroglossidae) from South and SE Asia with the description of a new species from the Western Ghats Peninsular India. Zootaxa **3999,** 79-94.

Djong HT, Islam MM, Nishioka M, Matsui M, Ota H, Kuramoto M, Khan MMR, Alam MS, De Silva A, Khonsue W, Sumida M. 2007. Genetic relationship and reproductive isolation mechanism among the Fejervaryalimnocharis complex from Indonesia (Java) and other Asian countries. Zoological Science **24,** 360-375.

Frost DR. 2019. Amphibian Species of the World: an Online Reference. Version 6.0. American Museum of Natural History, New York, USA. Accessed 20th June 2019. http://research.amnh.org/herpetology/amphibia/index.html.

Ghose A, Deb JC, Dakwa K, Ray P, Jay, Reza AHMA. 2017. Amphibian species assemblages in a tropical forest of Bangladesh. Herpetological Journal **27,** 318-325.

Hasan M, Islam MM, Khan MMR, Alam MS, Kurabayashi A, Igawa T, Kuaramoto M, Sumida M. 2012a. Cryptic anuran biodiversity in Bangladesh revealed by mitochondrial 16S rRNA gene sequences. Zoological Science **29,** 162-172.

Hasan M, Kuramoto M, Islam MM, Alam MS, Khan MMR, Sumida M. 2012b. A new species of genus *Hoplobatrachus* (Anura, Dicroglossidae) from the coastal belt of Bangladesh. Zootaxa **3312,** 4558.

Hasan M, Islam MM, Khan MMR, Igawa T, Alam MS, Djong TH, Kurniawan N, Hasan MH, Islam MM, Kuramoto M, Kurabayashi A, Sumida M. 2014a. Description of two new species of *Microhyla* (Anura: Microhylidae) from Bangladesh. Zootaxa **3755,** 401-418.

Hasan MK, Khan MMH, Feeroz MM. 2014b. Amphibians and reptiles of Bangladesh - a field guide. Arannayk Fundation, Dhaka, Bangladesh.

Hasan MK, Feeroz MM. 2014. Species diversity and habitat preference of amphibians in six protected areas of Bangladesh. Bangladesh Journal of Zoology **42,** 105-116.

Hasan M, Khan MMR, Sumida M. 2008. Morphological and genetic variation in three populations of *Hoplobatrachustigerinus* from Bangladesh. Progressive Agriculture **19,** 139-149.

Hasan M, Sarker A, Kurabayashi A, Kuramoto M, Sumida M. 2015. Genetic variation, advertisement call and morphometry of *Microhylanilphamariensis* from Bangladesh. Philippine Journal of Systematic Biology **9,** 63-80.

Hero JM, Shoo LP. 2003. Conservation of amphibians in the Old World tropics: defining unique problems associated with regional fauna. In: Amphibian conservation. 70–84 (R. D. Semlitsch,

Ed.). Smithsonian Institution Press, Washington, D. C.

Howlader MSA. 2010. Primary survey of amphibian (Anuran) fauna of Barisal, Bangladesh. Russian Journal of Herpetology **17,** 255-256.

Howlader MSA. 2011a. A new species of *Fejervarya*(Anura: Dicroglossidae) from Bangladesh. Zootaxa **2761,** 41-50.

Howlader MSA. 2011b. Cricket frog (Amphibia: Anura: Dicroglossidae): two regions of Asia are corresponding two groups. Bonnoprani- Bangladesh Wildlife Bulletin **5,** 1-7.

Howlader MSA, Nair A, Gopalan SV, Merilä J. 2015a. A new species of *Euphlyctis* (Anura: Dicroglossidae) from Barisal, Bangladesh. PLoS ONE **10,** e0116666. https://doi.org/10.1371/journal.pone.0116666.

Howlader MSA, Nair A, Gopalan SV, Merilä J. 2015b. A new species of *Microhyla* (Anura: Microhylidae) from Nilphamari, Bangladesh. PLoS ONE **10,** e0119825. https://doi.org/10.1371/journal.pone.0119825.

Howlader MSA, Nair A, Merilä J. 2016. A new species of frog (Anura: Dicroglossidae) discovered from the mega city of Dhaka. PLoS ONE **11,** e0149597. https://doi.org/10.1371/journal.pone.0149597.

Islam MM, Kurose N, Khan MMR, Nishizawa T, Kuramoto M, Alam MS, Hasan M, Kurniawan N, Nishioka M, Sumida M. 2008a. Genetic divergence and reproductive isolation in the genus *Fejervarya* (Amphibia: Anura) from Bangladesh inferred from morphometric data, crossing experiments and molecular analysis. Zoological Science **25,** 1084-1105.

Islam MM, Khan MMR, Djong TH, Alam MS, Sumida M. 2008b. Genetic differentiation of the *Fejervarya limnocharis* complex from Bangladesh and other Asian countries elucidate by allozyme analyses. Zoological Science **25,** 261-272.

Islam MR, Hossain MB. 2012. Genetic variation of three populations of Indian frog (*Hoplobatrachus tigerinus*) revealed by allozyme marker. International Journal of Zoological Research **8,**150-156.

IUCN Bangladesh 2000. Red List of Threatened Animals of Bangladesh. IUCN-the world conservation union.

IUCN 2015. Red book of threatened amphibians and reptiles of Bangladesh. IUCN, Bangladesh.

Jaman MF, Sarker MAR, Rana AS, Alam MS, Ahmed S, Shafi SM. 2017. Limb malformation in the skipper frog (*Euphlyctis cyanophlyctis*) (Amphibia: Dicroglossidae), first evidence in Bangladesh. The Herpetological Bulletin **141,** 41.

Kabir SMH, Ahmed M, Ahmed ATA, Rahman AKA, Ahmed ZU, Begum ZNT, Hassan MA, Khondker M. 2009. Encyclopedia of flora and fauna of Bangladesh. Vol. 25. Amphibians and reptiles. Asiatic Society of Bangladesh, Dhaka.

Khan MAR. 1982. Wildlife of Bangladesh- a checklist. Dhaka University, Bangladesh. Pp iv+174 with 48 black and white plates.

Khan MMH. 2008. Protected areas of Bangladesh-a guide to wildlife. Nishorgo Program, Bangladesh forest Department, Dhaka, Bangladesh.

Khan MAR. 2010. Wildlife of Bangladesh, from Amphibia to Mammalia- a checklist. Shahitya Prakash, Dhaka.

Khan MAR. 2015. Wildlife of Bangladesh: checklist and guide. M.J. Alam and Chayabithi, Dhaka, Bangladesh.

Khan MMR, Alam MS, Sarder MRI, Bhuiyan MMH, Sumida M. 2002. Genetic variation of frogs

in Bangladesh using allozyme marker. Bangladesh Journal of Fisheries **25**, 35-46.

Linder G, Krest SK, Sparling DW. 2003. Amphibian decline: an integrated analysis of multiple stressor effects. Society of Environmental Toxicology and Chemistr, Pensacola, Florida.

Lips KR, Brem F, Brenes R, Reeve JD, Alford RA, Voyles J, Carey C, Livo L, Pessier AP, Collins JP. 2006. Emerging infectious disease and the loss of biodiversity in a Neotropical amphibian community. Proceedings of the National Academy of Sciences USA **103,** 3165-3170.

Mahony S, Reza AHMA. 2008. A herpetofaunal collection from the Chittagong Hill Tracts, Bangladesh, with two new species records for the country. Hamadryad **32,** 45-56.

Matsui M, Toda M, Ota H. 2007. A new species of frog allied to Fejervaryalimnocharis from southern Ryukyuas, Japan (Amphibia: Ranidae). Current Herpetology **26,** 65-79.

Mayr E. 1942. Systematics and the origin of species, from the viewpoint of a zoologist. Cambridge. Harvard University Press. ISBN0-674-86250-3.

Mittermeier RA, Robles-Gil P, Hoffmann M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, Da Fonseca GAB. 2004**.** Hotspots revisited: earth's biologically richest and most endangered terrestrial ecoregions. CEMEX, Mexico City.

Molur S. 2008. South Asian amphibians: taxonomy, diversity and conservation status. International Zoo Yearbook **42,** 143-157. https://doi.org/10.1111/j.1748-1090.2008.00050.x.

Murphy RW, Berry KH, Edwards T, Leviton AE, Lathrop A, Riedle JD. 2011. The dazed and confused identity of Agassiz's land tortoise, *Gopherusagassizii* (Testudines, Testudinidae) with the description of a new species, and its consequences for conservation. ZooKeys **71,** 39-71.

Murphy RW, Crawford AJ, Bauer AM, Che J, Donnellan SC, Fritz U, Haddad CFB, Nagy ZT, Poyarkov NA, Vences M, Wang WZ, Zhang YP. 2013. Cold Code: the global initiative to DNA barcode amphibians and nonavian reptiles. Molecular Ecology Resources **13,** 161-167.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GA, Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature **403,** 853-858.

Nagy ZT, Sonet G, Glaw F, Vences M. 2012. First large-scale DNA barcoding assessment of reptiles in the biodiversity hotspot of Madagascar, based on newly designed COI primers. PLoS ONE **7,** e34506. https://doi.org/10.1371/journal.pone.0034506.

Nishat A, Huq SMI, Barua SP, Reza AHMA, Khan AR, Moniruzzaman AS. 2002. Bio-ecological Zones of Bangladesh. IUCN Bangladesh Country Office, Bangladesh, Dhaka.

Parmesan C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology Evolution and Systematics**37,** 637-669. https://doi.org/10.1146/annurev.ecolsys.37.091305.110100.

Purkayastha J, Matsui M. 2012. A new species of *Fejervarya* (Anura: Dicroglossidae) from Mawphlang, Northeastern India. Asian Herpetological Research**3,** 31-37 https://doi.org/10.3724/SP.J.1245.2012.00031.

Rahman H, Jaman MF, Rahman MS. 2014. Ecology and diversity of wildlife in the eco-park of the Jamuna Bridge and its adjacent area, Sirajgonj, Bangladesh. Ecoprint: An International Journal of Ecology **20,** 27-36. http://dx.doi.org/10.3126/eco.v20i0.11327.

Rahman MM. 2014. Impact of temperature

fluctuations on gut histology of the Cricket frog, *Fejervarya limnocharis* (Anura: Dicroglossidae). Journal of Bio-Science**22,** 15-20.

Rahman MM, Kabir MM, Biswas JK.2011. Study on morphometry of some amphibians of Bangladesh. Bangladesh Journal of Environmental Science **21,** 67-70.

Rahman MM, Kabir MM, Biswas JK.2012. Taxonomic study of some common ranids of Bangladesh. Bangladesh Journal of Environmental Science **22,** 38-41.

Rahman MM, Kabir MM, Hassan MK.2013. Status of Herpetofauna in Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka. Jahangirnagar University Journal of Biological Sciences **2,** 9-14.

Rahman MM, Mortuza MG.2015. Confirmation of an amphibian species, Asian Common Toad (*Duttaphrynus melanostictus*), from St. Martin's Island of Bay of Bengal. Bangladesh Journal of Environmental Science **29,** 105-108.

Rasel MSR, Hannan MA, Howlader MSA. 2007. Four new country records of *Fejervarya* Bolkay, 1915 (Amphibian: Anura: Dicroglossidae) from Bangladesh. Bonnoprani–Bangladesh Wildlife Bulletin **4,** 1-3.

Reza AHMA. 2014. Status, distribution and conservation of the Amphibians of Bangladesh. In: Conservation biology of amphibians of Asia: status of conservation and decline of amphibian: Eastern Hemisphere. (Edited by Heatwole H and Das I). Natural History Publications (Borneo), Kota Kinabalu, Malaysia.

Reza AHMA, Perry G. 2015. Herpetofaunal species richness in the tropical forests of Bangladesh. Asian Journal of Conservation Biology **4,** 100-108.

Sultana N, Igawa T, Islam MM, Hasan M, Alam MS, Komaki S, Kawamura K, Khan MMR, Sumida M. 2016. Inter and intra specific genetic divergence of Asian tiger frogs (genus *Hoplobatrachus*), with special reference to the population structure of *H. tigerinus* in Bangladesh. Genes and Genetic Systems **91,** 217-227. https://doi.org/10.1266/ggs.16-00006.

Smith KG, Lips KR, Chase JM. 2009. Selecting for extinction: nonrandom disease-associated extinction homogenizes amphibian biotas. Ecology Letters **12,** 1069-1078.

Sanchez E, Biju SD, Islam MM, Hasan MK, Ohler A, Vences M, Kurabayashi A. 2018. Phylogeny and classification of fejervaryan frogs (Anura: Dicroglossidae). Salamandra **54,** 109-116.

Sparling DW, Linder G, Bishop CA. 2000. Ecotoxicology of amphibians and reptiles. Society of Environmental Toxicology and Chemistry, Pensacola, Florida.

Spinks PQ, Thomson RC, Hughes B, Moxley B, Brown R, Diesmos A, Shaffer HB. 2012. Cryptic variation and the tragedy of unrecognized taxa: the case of international trade in the spiny turtle *Heosemys spinosa* (Testudines: Geoemydidae). Zoological Journal of the Linnean Society **164,** 811-24.

Stuart SN, Chanson JS, Cox NA, Young BE, Rodrigues ASL, Fischman DL, Waller RW. 2004. Status and trends of amphibian declines and extinctions worldwide. Science **306,** 1783-1786. 10.1126/science.1103538.

Theobald W. 1868 Catalogue of reptiles in the Museum of the Asiatic Society of Bengal. Journal of the Asiatic Society of Bengal **37,** 1-88.

Vieites DR, Wollenberg KC, Andreone F, Kohler J, Glaw F, Vences M. 2009. Vast underestimation of Madagascar's biodiversity evidenced by an integrative amphibian inventory.

Proceedings of the National Academy of Sciences USA **106,** 8267-72. https://doi.org/10.1073/pnas.0810821106.

Wijayathilaka N, Meegaskumbura M. 2016. An acoustic analysis of the genus *Microhyla* (Anura: Microhylidae) of Sri Lanka. PLoS ONE **11,** e0159003. https://doi.org/10.1371/journal.pone.0159003.

Yan F, Jiang K, Wang K, Jin JQ, Suwannapoom C, Li C, Vindum JV, Brown RM, Che J. 2016. The Australasian frog family Ceratobatrachidae in China, Myanmar and Thailand: discovery of a new Himalayan forest frog clade. Zoological Research **37,** 7-14.