Recent research, aspects and conservation strategy towards amphibians of Bangladesh

Md. Mizanur Rahman\textsuperscript{1,2}, Saber Khederzadeh\textsuperscript{1,2}, Muhsina Yasmin\textsuperscript{3}, Zia Ur Rahman\textsuperscript{1,2}, Md. Motiur Rahman\textsuperscript{1,2}, Md. Shahinur Islam\textsuperscript{3}, Md. Golam Mostafa\textsuperscript{4}, Mosharrof Hossain\textsuperscript{5,\#}

\textsuperscript{1}State Key Laboratory of Genetic Resources and Evolution, Kunming Institute of Zoology, Chinese Academy of Sciences, Kunming 650223, Yunnan, China
\textsuperscript{2}Kunming College of Life Science, University of Chinese Academy of Sciences, Kunming 650204, China
\textsuperscript{3}IFRB, Bangladesh Atomic Energy Commission, Ganakbari, Savar, Dhaka, Bangladesh
\textsuperscript{4}Department of Zoology, Jahangirnagar University, Savar, Dhaka, Bangladesh
\textsuperscript{5}Department of Zoology, University of Rajshahi, Rajshahi-6205, Bangladesh

Key words: Amphibians, Bangladesh, Taxonomy, Genetics, Morphology, Breeding biology, Conservation.

Article published on December 18, 2019

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 Sundarban forests in the southwest and to the southern Bay of Bengal need proper survey and conservation.

\#Corresponding Author: Mosharrof Hossain \textsuperscript{5} mshzool@yahoo.com
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 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).

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

Fig. 1. Map of Bangladesh showing different regions and divisions with species richness. Species richness arranged division-wise not regions.
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 Sundarban 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 Euphyctis hexadactylus and 4.0% in E. cyanophlyctis. Euphyctis 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.
Study of morphology

Morphometry has been used 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; 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 kHz and 5.0–5.8 kHz.

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. nilphamariensis and compared it with other conegers. They found that the notes of M. nilphamariensis had more pulses and longer durations than those of M. ornata 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.

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.

---

**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).
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).

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 muscularis 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...
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 Wildlife 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.

Acknowledgements
We are grateful to Dr. Lotanna Micah Nneji of Kunming Institute of Zoology for his comments to improve the preliminary manuscript. We are also thankful to Mr Sharifuzzaman Baqui of Forest Department, Bangladesh, for sharing many relevant books and information. This works is partially supported by grant in aid No.A-1458/5/52/RU/Gibhu-17/18-19 from the Faculty of Life and Earth Science, University of Rajshahi, Bangladesh.

References


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


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


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


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

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


**Rahman MM.** 2014. Impact of temperature


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

https://doi.org/10.1371/journal.pone.0159003.