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CHAPTER 13

Status, Distribution and Conservation of the Amphibians of Bangladesh

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Abbreviations cited in the text and references: AD = Asian Development Bank; BHC = Benzene Hexa Chlorine; asl = above sea level; CITES = Convention on International Trade in Endangered Species of Wild Fauna and Flora; DDT = Dichloro Diphenyl Trichloroethane; FAO = Food and Agriculture Organization of the United Nations; IUCN = International Union for the Conservation of Nature; MOEF = Ministry of Environment and Forests; MOP = Muriate Of Potash; NPK = Nitrogen Phosphorus and Potassium; SDNP = Sustainable Development Networking Programme; SSP=Single Super Phosphate; TSP = Triple Super Phosphate; UNDP = United Nations Development Programme; WHO = World Health Organization.

I. INTRODUCTION

Bangladesh boasts of richness in history, vegetation, and wildlife. Spread over 147,570 sq km, this subtropical country is almost entirely surrounded by India from the west, north and east; it shares its southeastern border with Myanmar, and the Bay of Bengal laps the entire south of the country (Anonymous 2004). The country is located between 20°34" and 26°38" north latitude and 88°01" and 92°41" east longitude. Situated in the Oriental Region, Bangladesh has a number of diverse ecosystems and associated richness of plant and animal life (Nishat *et al*. 2002).

Following independence from British rule in 1947, Bangladesh was plagued by war, civil revolutions, and political instability, which led to a hiatus in natural history studies. Between 1947 and 1971, Bangladesh was known as 'East Pakistan' and ruled by the federal government of present-day Pakistan. Dissatisfaction by the people of East Pakistan ultimately led to a nine-month civil war with Pakistan, culminating in the independence of a new country that was named Bangladesh in 1971. Approximately 3 million human lives were lost during this conflict. Independence was marked by severe socio-economic problems, such as a food crisis that led to mass epidemics and mortality. In 1973, the country fell under the control of a series of military dictators. Present-day democracy in Bangladesh began in the early 1990s.

Bangladesh occupies one of the most fertile regions of the world: the Gangetic delta. The seventh most populous country in the world (UN 2005), it is exceptionally sensitive to climatic change because of its distinct hydro-geographical setting with one of the world's highest densities of humans (Cruz *et al*. 2007). It provides an outlet for some of Asia's largest river systems, formed by the Ganga, the Brahmaputra, and the Meghna rivers along with their network of tributaries and distributaries. The total area of the Ganga-Brahmaputra-Meghna drainage basin is about 1.5 million sq. miles and the flow of the combined system is second only to the Amazon River system in South America (IUCN Bangladesh 2000). One of the world's largest estuarine delta systems, Bangladesh experiences periodic inundation of the floodplains because of the large number of rivers in this relatively small country.

Biogeographically, Bangladesh lies at the crossroads of India and southeastern Asia, and harbours a diverse amphibian and reptilian fauna (Reza 2010). The amphibian fauna of Bangladesh is poorly known. During the colonial period, British natural history collectors mostly confined their expeditions to the existing road network or to human settlements; as a result most remote areas, especially upland forested regions, remained unexplored. Roughly 70% of the amphibians of Bangladesh are facing conservation threats of various kinds (IUCN Bangladesh 2000). This is obviously an underestimate since the result is not updated and mostly is based on surveys conducted over a century ago.

Bangladesh has a diverse amphibian fauna that occupies habitats ranging from the northern and eastern hills to mangrove forests in the southwest and to the southern Bay of Bengal. Large-scale deforestation for agriculture and human settlements has destroyed much of Bangladesh's natural habitat, in turn causing the decline of many vertebrate species. There is some sporadic historical information about Bangladesh's major 'megafauna', but virtually no data on small vertebrates like amphibians. With this lack of historic data, it is very difficult to definitively track previous population trends. It is clear, however, that amphibians are particularly vulnerable to recent changes in the environment — their moist skins help them breathe on land but gives them little defense against pathogens and chemical poisons, either natural or man-made (Reza 2009).

II. PHYSIOGRAPHIC REGIONS

Bangladesh occupies a unique geographic location — spanning a relatively short stretch of land between the Himalayan mountain chain and the Bay of Bengal. The country is located at the lower reaches of three gigantic river systems: the Ganga-Padma, the Brahmaputra-Jamuna, and the Surma-Meghna. Based on bio-physical parameters, Bangladesh is divided into 12 bio-ecological zones, some of which were then further divided into sub-zones (Nishat *et al*. 2002). Three broad physiographic regions are discernible in Bangladesh — floodplains occupy about 80% of the total land area, terraces (slightly uplifted fault blocks) about 8%, and hills about 12%. The following description is a simplified version of the physiographic regions of the country:

A. The Northwest

This region is bounded by the Ganga River in the south and the Jamuna River in the east. The piedmont plains and floodplains occupy a major portion of the northwest. The Himalayan piedmont plain extends into the country from the northwest. The land area is characterized by piedmont sands and gravel as well as alluvial sediments deposited by the Mahananda and Karatoya rivers. Reeds and grasslands are characteristic vegetation and small strips of Sal (*Shorea robusta*) forests also occur (Nishat *et al*. 2002). The Tista floodplain stretches between the old Himalayan piedmont plain in the northwest to the Brahmaputra River that runs from north to south. This floodplain extends over several different landscapes.

Towards the centre of the region is the Barind tract, known locally as *Borendro Bhumi*. It is an ecologically fragile region with little vegetative cover. It is the largest of the three Pleistocene upland blocks, and at a slightly higher elevation than the surrounding floodplains. Field crops, such as sugarcane, black gram, potato, and mustard are grown. To the southeast of the Barind tract is the Bhar basin, the centre of which is a large marshy area called the Chalan *Beel* that consists of a series of connected *beels* forming a single continuous body of water during the rainy season. However, they dry up during the winter, to form water-holes.

B. The East and the Northeast

Sal forests (referred to as moist deciduous forests) occupy an area of about 121,000 ha and are widely distributed in the central and northern parts of the country. They are distributed in Gazipur, Tangail, Mymensingh, Jamalpur, Comilla, Dinajpur, Thakurgaon, Rangpur, and Rajshahi districts. The major sal forests, however, occur in the regions of Mymensingh and Tangail districts in central Bangladesh. This belt is popularly known as the *Madhupur Garh*, a region of characteristic red soil and blessed with immense floral diversity. These forests have been victims of large-scale degradation and encroachment.

The old Brahmaputra floodplains and the relatively recently formed Jamuna floodplains together comprise the Brahmaputra-Jamuna floodplains. The Brahmaputra shifted from a course around the eastern edge to the western side of the Madhupur Tract and the new portion of the Brahmaputra is known as the Jamuna (Rashid 1991). The Surma-Kushiyara floodplain is formed from rivers draining from the eastern border towards the Sylhet Basin. It has numerous *beels* and canals. Secondary rivers, seasonally inundated lands, and degraded swamp forests characterize this floodplain.

The *Haor* is a saucer-shaped natural depression and is an internationally important wetland ecosystem situated in the northeast. This zone has about 400 *haors* and *beels* and extends between the old Brahmaputra floodplain in the west, the Meghalaya plateau's foothills in the north, Sylhet high plain in the east, and old Meghna estuarine floodplain in the south (Nishat *et al*. 2002).

The Sylhet hills are remnants of Pleistocene terraces and are constituted by six ranges of the Tripura Hills of India that project into the Sylhet district of Bangladesh. The highest peak in the Sylhet area is the Harargaj, which has an elevation of 336 m above mean sea level (Brammer 1996). These hills are marked by lush tropical evergreen forests and a rich floral and faunal diversity, especially in the valley.

C. The South and Southwest

The active floodplain of the Ganga River together with the adjacent floodplains comprises the Ganga river floodplain. This area has a large number of bodies of water, degraded swamp forests, channels, rivers, and tributaries and these support a rich biodiversity. The Ganga tidal floodplain, with its low ridge and basin relief, is characterized by innumerable tidal rivers and creeks. The sediments that occur there are mostly non-calcareous clays, but they are silty and slightly calcareous on the riverbanks.

To the south and the southwest of the Ganga tidal floodplain lies the Sundarbans mangrove forest. It extends from the international boundary with India along the Harinbhaga-Raimangal-Kalindi river system in the west and the Baleswar River in the east. Bangladesh Sundarbans covers an area of about 5770 sq km of which 4016 sq km is land and the remaining 1761 sq km is covered by water (Hussain and Karim 1994). These forests play a vital role in protecting millions of people from cyclonic storms and tidal waves that originate from the Bay of Bengal (Reza *et al*. 2004). These mangroves are rich in biodiversity and form the refuge of the Bengal Tiger (*Panthera tigris*).

The Meghna floodplain in the southeast is comprised of a river floodplain and an estuarine floodplain. Palms are a dominant feature of the vegetation. The districts of Noakhali and Lakshmipur have a newly accredited mudflat, which is the main physiographic feature of the Meghna estuarine floodplain. These mudflats play an important role in hosting migratory waterfowl.

D. The Hills of the Southeast

Tropical evergreen and semi-evergreen forests cover most of the southeastern hills. These hills consist of the Chittagong hills, the Chittagong Hill Tracts, and the Lamai Tipperah hills. The evergreen and semi-evergreen forests are generally intermingled with the lower canopy of mainly evergreen species, while the species that occupy the upper canopy of the forest are deciduous. While the hills are not high — generally about 600 m — they are rugged and often steep (Nishat *et al*. 2002). The valleys in the zone support tropical evergreen forests.

The coastal plains are situated in the south and are underlain by heavy marine or tidal clays coming from the Bay of Bengal. Near the foot of the hills these plains are buried under sandy or silty deposits along the courses of rivers and streams. The eastern coastline, extends from the mouth of the Feni River to the southern tip of the mainland near Chittagong; it is regular and unbroken and protected from the sea by mudflats and submerged sands (Nishat *et al*. 2002).

The Chittagong Hill Tracts are situated in the extreme southeast, and is the only true mountainous region of the country. These mountains run in a north to south direction forming parallel ridges with deep narrow valleys. This range continues north to form the hill ranges of Tripura and extends south to the coast in the western Rakhine District of Myanmar. In the east, it is connected to the Mizo Hills of Mizoram, India, and the Chin Hills of Myanmar. The highest elevation in Bangladesh occurs in the Chittagong Hill Tracts: Tahjindong at 1003 m asl (Mahony and Reza 2008). The habitat of this area, until recently, consisted of mixed semi-evergreen and bamboo forests.

III. THE AMPHIBIAN FAUNA

Bangladesh is currently experiencing an 'age of discovery' in terms of amphibian research. Roughly 70% of the amphibian species were first reported from the country only within the past decade. IUCN Bangladesh reported 22 amphibian species in 2000 (IUCN Bangladesh 2000), whereas at least 57 species are currently known from the country (Table 1).

The number of amphibian species currently recorded within the political boundary of Bangladesh is surely an underestimate and putting together an up-to-date list is a challenge. Since Bangladesh does not have a natural history museum and specimens are not kept in a common place, taxonomic identities of many species remain uncertain. Information on geographic distributions and natural history of most of the species is limited and inadequate. Moreover, local researchers are reluctant to publish their findings in peer-reviewed journals. In general, the amphibian fauna of Bangladesh has not received the attention it deserves, because there is little local interest, and trained manpower, long-term research projects, and funding for conservation are lacking. Representative species are portrayed in Figure 1.

More new species await discovery and description. Few molecular studies have been conducted to clarify the many taxonomic problems, define species complexes and identify cryptic taxa. A more rigorous, intensive, and long-term survey effort with contemporary technology is the prime requirement for the country to assess the true diversity of amphibians in Bangladesh. Potential collaboration for funding research into amphibian conservation deserves immediate attention. Several young researchers are currently becoming interested in amphibians and would shine light on this poorly studied group of vertebrates in Bangladesh.

A. Regional distributions

Of the 57 currently reported amphibian species from Bangladesh, at least 12 are widely distributed throughout almost all types of habitats. The current distributional ranges of more than 17 species are inadequately known. About 26 amphibian species are habitat specialists, and are mostly restricted to forests. Roughly 18 species have

Table 1. Checklist of the amphibians of Bangladesh, current as of 10 December 2012.

TAXON	REFERENCE	COMMENTS
ORDER ANURA: Family Bufonidae		
Duttaphrynus "*Bufo*" *stomaticus* (Lütken, 1864)	Reza (2010)	Based on a male sample from central Bangladesh. Confirmed records from northwest.
Duttaphrynus himalayanus (Günther 1864)	Khan (2008)	Further confirmation needed. No record from Bangladesh yet.
Duttaphrynus melanostictus (Schneider 1799)	Khan (1982)	Widely distributed in Bangladesh.
Pedostibes kempi (Boulenger 1919)	Khan (2008)	Further confirmation needed. No record from Bangladesh yet.
Family Dicroglossidae		
Euphlyctis cyanophlyctis (Schneider 1799)	Khan (1982)	Widely distributed in Bangladesh.
Euphlyctis hexadactylus (Lesson 1834)	Reza (2010); Reza *et al*. (2000)	Based on several samples from southwestern and central Bangladesh. Confirmed records from the northwest.
Fejervarya asmati* (Howlader, 2011)	Howlader (2011); Sarker & Howlader (2011a); Sarker *et al*. (2012)	Species description was based on several samples from the southeast. Records from the northwest and from the mega-city, Dhaka, of central Bangladesh.
Fejervarya cancrivora* (Gravenhorst 1829)	Reza (2010)	Samples from the southwest and southeastern coastal islands. Detailed study is currently underway.
Fejervarya limnocharis* (Gravenhorst 1829)	Khan (1982)	Species complex. Believed to be widely distributed. Detailed study is currently underway.
Fejervarya moodiei* (Taylor 1920)	Hasan *et al*. (2012b)	Species complex. Samples from the southeast and southwest. Detailed study is currently underway.
*Fejervarya** nepalensis (Dubois 1975)	Rasel *et al*. (2007)	Further confirmation needed. No confirmed records from Bangladesh yet.
*Fejervarya** pierrie (Dubois 1975)	Sarker and Howlader (2011b)	Few samples from the northwest. Detailed study is currently underway.
Fejervarya syhadrensis* (Annandale 1919)	Rasel *et al*. (2007)	Further confirmation needed. Detailed study is currently underway.
Fejervarya teraiensis* (Dubois 1984)	Rahman and Howlader (2011b); Sarker (2012)	Based on several samples from southeastern and central Bangladesh. Detailed study is currently underway.
Hoplobatrachus crassus (Jerdon 1854)	Khan (1982)	Widely distributed in Bangladesh.

TAXON	REFERENCE	COMMENTS
Hoplobatrachus litoralis (Hasan, Kuramoto, Islam, Alam, Khan, and Sumida 2012)	Hasan *et al*. (2012a)	Species description was based on several samples from southeastern Cox's Bazar District.
Hoplobatrachus tigerinus (Daudin 1802)	Khan (1982)	Widely distributed in Bangladesh. Harvested for food among tribal communities.
Ingerana borealis (Annandale 1912)	Reza (2008a)	Based on several samples from the southeastern hilly forest.
Limnonectes khasianus (Anderson 1871)	Khan (2008)	Further confirmation needed. No record from Bangladesh yet.
Limnonectes laticeps (Boulenger 1882)	Reza (2010)	Based on several samples from southeastern Bangladesh.
Occidozyga lima (Gravenhorst 1829)	Reza (2010) Khan (2001)	Based on several samples from the south-eastern forests.
Occidozyga sumatrana (Peters 1877)	Frost (2011)	Further confirmation needed. No record from Bangladesh yet.
Sphaerotheca breviceps (Schneider 1799)	Khan (2008)	Further confirmation needed. No record from Bangladesh yet.
Family Megophryidae		
Leptobrachium smithi (Matsui, Nabhitabhata and Panha 1999)	Reza (2009a)	Based on several samples from northern and southeastern Bangladesh.
Xenophrys parva (Boulenger 1893)	Mahony and Reza (2008)	Based on several samples from the southeast.
Family Microhylidae		
Kalophrynus interlineatus (Blyth 1855)	Mahony and Reza (2007a)	Based on a few adult specimens from central Bangladesh.
Kaloula assamensis (Das, Sengupta, Ahmed and Dutta 2005)	Frost (2011)	Further confirmation needed. No record from Bangladesh yet.
Kaloula pulchra (Gray 1831)	Khan (1982)	Widely distributed in Bangladesh.
Kaloula taprobanica (Parker 1934)	Reza and Mahony (2007)	Based on samples from central Bangladesh. Confirmed record from southwest.
Microhyla berdmorei (Blyth 1856)	Mahony and Reza (2008)	Based on several samples from different forests in the northeast, southeast and central Bangladesh.
Microhyla ornate (Duméril and Bibron 1841)	Hasan *et al*. (2012b)	Cryptic species. Believed to be widely distributed in Bangladesh.
Microhyla rubra (Jerdon 1854)	Khan (1982)	Widely distributed in the forests of Bangladesh.
Uperodon globulosus (Günther 1864)	Khan (1982)	Widely distributed in Bangladesh.
Uperodon systoma (Schneider 1799)	Khan (1982)	Further confirmation needed. No recent record from Bangladesh.

TAXON	REFERENCE	COMMENTS
Micryletta sp.	Reza (2010)	Based on an adult sample from the northeast. More information and research needed.
Family Ranidae		
Amolops formosus (Günther 1876)	Frost (2011)	Further confirmation needed. No record from Bangladesh yet.
Amolops marmoratus (Blyth 1855)	Kabir *et al*. (2009)	Confirmed records from southeastern Bangladesh.
Clinotarsus alticola (Boulenger 1882)	Reza 2008b	Based on several samples from the northeast and southeast.
Humerana humeralis (Boulenger 1887)	Kabir *et al*. (2009)	Based on several photographs from northern and southeastern Bangladesh.
Hylarana erythraea (Schlegel 1837)	Kabir *et al*. (2009)	Further confirmation needed. No recent record from Bangladesh.
Hylarana leptoglossa (Cope 1868)	Mahony and Reza (2007b)	Based on several samples, widely distributed in and adjacent to the forests.
Hylarana nigrovittata (Blyth 1856)	Kabir *et al*. (2009)	Based on several photographs from southeastern Bangladesh.
Hylarana taipehensis (Van Denburgh 1909)	Hasan *et al*. (2012b); Kabir *et al*. (2009)	Cryptic species. Based on samples form central and southern Bangladesh.
Hylarana tytleri (Theobald 1868)	Sarker and Howlader (2012)	Based on several samples from northwestern Bangladesh.
*Pterorana khare (*Kiyasetuo and Khare 1986)	Not published yet	Based on several photographs from southeastern Bangladesh. M. Khan (pers. comm. Oct 2012). Needs further confirmation.
Family Rhacophoridae		
Chiromantis doriae (Boulenger 1893)	Hasan *et al*. (2010)	Based on several samples from northeastern Bangladesh.
Chiromantis simus (Annandale 1915)	Rahman and Howlader (2011a)	Based on several specimens from southeast.
Chiromantis vittatus (Boulenger 1887)	Khan (2008)	Based on several specimens from southeast. Confirmed records from central Bangladesh.
Polypedates leucomystax (Gravenhorst 1829)	Khan (1982)	Widely distributed in Bangladesh.
Polypedates maculatus (Gray 1830)	Khan (1982)	Further confirmation needed. No record from Bangladesh yet.
Polypedates taeniatus (Boulenger 1906)	Frost (2011)	Further confirmation needed. No record from Bangladesh yet.
Raorchestes parvulus (Boulenger 1893)	Ghose and Bhuiyan (2012)	Based on several samples from northeastern forests.

TAXON	REFERENCE	COMMENTS
Rhacophorus bipunctatus (Ahl 1927)	Reza and Mukul (2009)	Based on several samples from northeast and southeastern forests.
Rhacophorus maximus (Günther 1858)	Kabir *et al*. (2009)	Based on several photographs from southeastern forests. More information needed.
Theloderma asperum (Boulenger 1886)	Not published yet	Based on several photographs from southeastern Bangladesh. T. Khan and M. Ahmed (pers. comm. Oct 2012). Further confirmation needed.
ORDER GYMNOPHIONA: Family Caeciliidae		
Chikila sp.	Published in local newspaper (Prothom Alo, 02 Oct 2012)	Based on a dead specimen from southeastern forest. T. Khan and M. Ahmed (pers. comm. Oct 2012). Doubtful species identification, more information needed.
Family Ichthyophiidae		
Ichthyophis sp.	Not published yet	Based on specimens from southeastern forest. S.C. Rahman (pers. comm. Nov 2012). More information needed.

* A molecular study on *Fejervarya* is currently underway and reports on this Asian clade will be available soon (Howlader, pers. comm. Nov 2012).

been reported from evergreen and semi-evergreen forests of the southeastern hills. More than nine species are found mostly in the northeastern evergreen forests. Deciduous forests and nearby areas in central Bangladesh support at least five unique species. At least two amphibian species are mostly restricted to the southern saline, brackish, or tidal habitats.

Roughly 13 currently known amphibian species are recorded only as a single occurrence or from one isolated population at one site. For example, *Hoplobatrachus litoralis* is a recently recorded species reported only from Cox's Bazar District in southeastern Bangladesh (Hasan *et al*. 2012b). *Kalophrynus interlineatus* is only reported from Madhupur National Park in central Bangladesh (Mahony and Reza 2007a). Other single-occurrence reports are: *Philautus* sp. (Mahony *et al*. 2009), *Limnonectes laticeps* (Reza 2010), *Chiromantis doriae* (Hasan *et al*. 2010), *Micryletta* sp. (Reza 2010), *Pterorana khare* (M. Khan, personal communication, Oct. 2012), *Theloderma asperum* and *Chikila* sp. (T. Khan and M. Ahmed, personal communication, Oct. 2012), *Ichthyophis* sp. (S. Rahman, personal communication, Nov. 2012). On the other hand, *Fejervarya asmati*, another newly reported species from Chittagong University Campus (Howlader 2011), was later found in several places in the country (Sarker and Howlader 2011a; Sarker *et al*. 2012), making it a candidate for a widely distributed species.

Based on the currently available data on speciess distributions, amphibian diversity is highest in the southeastern mountainous areas (Chittagong Hill Tracts) and a part of the northeastern hilly evergreen forest (the greater Sylhet region). The Chittagong Hills Tract is the largest continuous chunk of land and it harbours the highest number of amphibian species. Chittagong Hills Tract also has the lowest population density of humans in Bangladesh and apparently has the lowest risk of natural hazards (e.g. flash floods and/or seasonal floods, tropical storms) (MOEF 2008). Finally, considering its species richness and uniqueness, the Chittagong Hills Tracks arguably constitute the best location in Bangladesh for initiating further research on amphibians and establishing conservation practices.

Fig. 1. Representative Bangladeshi amphibians. **A.** *Duttaphrynus* "*Bufo*" *stomaticus*; **B.** *Fejervarya asmati*; **C.** *Fejervarya cancrivora*; **D.** *Ingerana borealis*; **E.** *Limnonectes laticeps*; **F.** *Occidozyga lima*; **G.** *Leptobrachium smithii*; **H.** *Xenophrys parva*.

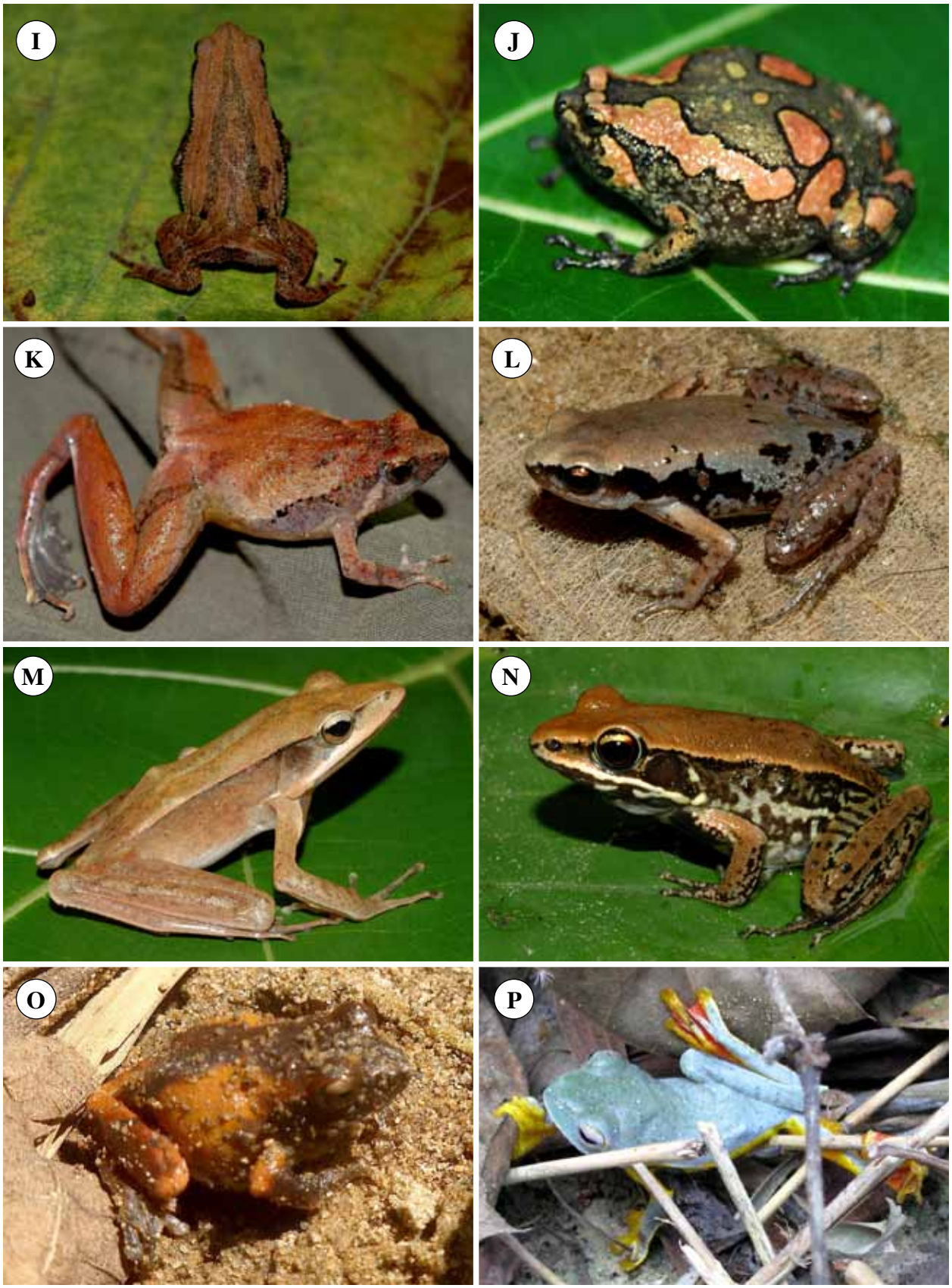

Fig. 1. Representative Bangladeshi amphibians (Continued). **I.** *Kalophrynus interlineatus*. **J.** *Kaloula taprobanica*; **K.** *Microhyla rubra*; **L.** *Micryletta* sp.; **M.** *Clinotarsus alticola*; **N.** *Hylarana leptoglossa*; **O.** *Raorchestes parvulus*; **P.** *Rhacophorus bipunctatus*; (opposite) **Q.** *Theloderma asperum*; and **R.** *Ichthyophis* sp.

The greater Sylhet region should also be taken into consideration for management practices. In addition, attention should be focused on the central part of the country (Madhupur Sal Tract) as this area harbours several unique amphibian species (e.g. *Kalophrynus interlineatus*, *Kaloula taprobanica*). Last, but not least, the Sundarbans Reserve Forest is the only mangrove forest in Bangladesh and the largest single tract of productive mangrove forest in the world. Mangrove forests normally do not support high amphibian diversity due to high salinity, but the Sundarbans are home to several amphibians (*Fejervarya cancrivora*, *Euphlyctis hexadactylus*) who are unique to the Subcontinent, or otherwise ecologically interesting, and their conservation should be given due attention.

The total land area of Bangladesh is relatively small, compared most other Asian countries, and habitat heterogeneity is rather low, as *ca*. 80% of the total land area comprises floodplains. Moreover, the current data on distributions are incomplete and, therefore, generalizations about regional distributional pattern may be premature. However, the south and northeastern hilly evergreen forests are currently known hotspots for amphibian species diversity within Bangladesh.

IV. THREATS TO AMPHIBIANS

Amphibian declines have not been well documented in most Asian countries. Tropical Asian amphibians are threatened by habitat destruction, disease, climatic change, and harvesting for food and the international pet trade (Sodhi *et al*. 2008; Rowley *et al*. 2010). There is a lack of information about populations for most taxa, owing to lack of long-term monitoring, and 16 species are listed as Data Deficient (IUCN 2012). Nevertheless, populations of at least 12 species of amphibians that occur in Bangladesh are believed to be declining across their ranges.

B. Destruction and Fragmentation of Habitats

Once blanketed with dense forests, Bangladesh has now lost much of its forest cover as a result of logging; this represents an overt loss of habitat for amphibians. Rampant logging, as well as extracting firewood by chopping down smaller plants, have denuded large tracts of Bangladesh's once vibrant forests. The resultant higher temperature of bodies of water presumably stress eggs, tadpoles, and juveniles, while higher land temperatures contribute to reduced moisture and desiccation. Fragmented forests isolate amphibian populations, by removing corridors between populations.

'Protected' areas are the only habitats managed by the government and are last strongholds for most habitat specialists (Reza 2010). Unfortunately, most protected areas are shrinking or suffering further fragmentation for various reasons. Many of the important forest habitats are now confined to fragmented pockets because of such anthropogenic activities as legal and illegal commercial logging and *jhum* (slash and burn) farming (Mahony and Reza 2008). Mangroves generally thrive in regions that receive an influx of water influx or flushing by tidal water. In the past 100 years, nearly 150,000 ha of mangrove forests were destroyed to make way for agriculture.

The Sundarbans mangrove forest alone provides livelihood and employment for an estimated 112,000 people (Reza 2004).

Bangladesh is a country of rivers, which traverse about 24,000 km (roughly 7% of the country) and is rich in aquatic biodiversity (NFA 2007). One million people are full-time fisherfolk and 11 million have taken to part-time fishing. The fishery sector contributes *ca*. 3.3% of the total export revenue and employs 5% of the country's total workforce (Parveen and Faisal 2003). However, unplanned and unmanaged extraction of resources make the habitats unsustainable for biodiversity.

Forest cover in Bangladesh has been shrinking rapidly (Fig. 2) despite the presence of a large government agency dedicated to the protection and management of forests (Salam *et al*. 1999). The overall quality and area of forests in Bangladesh have been subjected to rapid depletion for decades. Between 1990 and 2005, Bangladesh lost over 1.3% of its natural forest, which adds up to 11,000 ha of tropical forests. The earlier records were even more catastrophic; the loss of natural forest was 2.1% annually over the 20-year period ending in the early 1980s and at a rate of 2.7% in the period between 1984 and 1990 (FMP 1992).

The Bangladesh Forest Department indicated that 14.6% (2.2 million ha) of the total land area of the country is under forest cover (Anonymous 1994). A more recent estimate accounts for only 9.8% of the area as forested (NFA 2007). In reality, only *ca*. 6% merits the term, 'forest' (Collins *et al*. 1991; Giri *et al*. 1996).

Fig. 2. A brickfield (using wood for fuel) at the edge of Teknaf Reserve Forest (December 2008). Brickfields constitute a major cause of forest destruction in Bangladesh.

C. Exploitation

Froglegs are a gastronomic delicacy in many parts of the world. In addition to being harvested seasonally for local consumption (Fig. 3), the frog trade has found a perennial international market. As more and more people acquire the taste for this gourmet food, the likes of which have been compared to chicken, the demand for frogs has risen drastically over the past fifty years. Froglegs from a few species supply the international trade, featuring mainly the Indian Bullfrog (*Hoplobatrachus tigerinus*), the Green Pond Frog (*Euphlyctis hexadactylus*) and

the American Bullfrog (*Lithobates catesbeianus*). Of these, *Euphlyctis hexadactylus* was chiefly harvested from India, while *Hoplobatrachus tigerinus* used to be harvested from both India and Bangladesh. Other Asian countries also conduct brisk local and export trades in amphibians (Kusrini, 2012; Kusrini *et al*. 2012).

Fig. 3. Frogs collected for local consumption by Murong tribal people in the Chittagong Hill Tracks (June 2008).

Overexploitation has lead to large-scale declines in populations of edible frogs in Europe and USA. To satisfy this enormous demand, Asian countries, such as Indonesia, Bangladesh, India, and a few others started harvesting froglegs. The major importers of frogs are France, USA, Belgium, and Luxembourg (Warkentin *et al*. 2009). In the 1950s, India and Bangladesh emerged as the largest exporters of frogs. In 1983, Bangladesh, India, and Indonesia exported about 10 million kg of froglegs (about 200 million frogs). Between 1977 and 1983, exports from Bangladesh ranged between 400 and 1200 tons. In 1983, the country reached an all time high of 3000 tons, and became one of the largest exporters of froglegs to the international markets. India and Bangladesh formed the largest exporters, together supplying more than 4000 tons of frogs. The actual numbers harvested far exceed the export numbers because of the large number of frogs being discarded for lack of export quality (Niekisch 1986).

Fugler (1985) documented serious declines in the *Hoplobatrachus tigerinus* population density as a result of overexploitation in Bangladesh. This alarming decline in frog populations has lead to other problems. Large-scale harvesting of *H. tigerinus* from paddy fields and wetlands caused an increase in agriculturally destructive pests. Farmers soon began resorting to importing pesticides as a substitute. Frogs are known for consuming their own weights in insects during the spawning season, and they form constitute natural biological pest control in agricultural lands.

Frogs are predators on insect vectors of disease. Accordingly, reduction of frog population densities caused an increase in the spread of diseases such as malaria and encephalitis (Whiting 1984). The rapid increase in use of pesticides polluted the spawning areas of frogs, further accelerating the process of their decline. Between 1977 and 1989, importation of pesticides cost Bangladesh about US$ 89 million (Barnes 1996). Thus, the profits gained from the export of froglegs proved to be less than the amount spent in importing pesticides. About US$ 30 million were being spent annually to gain US$ 10 million from the trade in froglegs.

In 1985, *Euphlyctis hexadactylus* and *H. tigerinus* were included in Appendix II of CITES (Oza 1990; Warkentin 2009). Due to concerns over the escalating imports of pesticides, as well as the cruel methods of killing frogs, a ban was imposed on the exportation of froglegs from Bangladesh in 1989. As a result, imports of pesticides declined greatly. Although the export of froglegs from Bangladesh was reduced as a result of the ban, illegal harvesting and poaching continues as a consequence of the huge demand for froglegs.

D. Chemical Pollution

Application of pesticides in Bangladesh has risen from about 7350 metric tons in 1992 to 16,200 metric tons in 2001 (Dasgupta *et al*. 2004). Amphibians have a permeable moist skin and unprotected eggs are thus are vulnerable to changes in water quality. Acidification of bodies of water and use of fertilizers, pesticides, and other chemicals adversely effects or kills amphibians (Boyer and Grue 1995; Boone *et al*. 2009; Marco and Ortiz-Santaliestra 2009; Räsänen and Green 2009). Beginning in 1957, DDT and BHC were widely used as agricultural pesticides and were distributed free of cost to Bangladeshi farmers. Because of their efficiency

in alleviating pests at low costs, they became extremely popular. About 70% of the total pesticides used in Bangladesh in connection with cultivation of rice.

The pesticides most commonly used now in Bangladesh are carbofuran, diazinon, bashudin, sumithion, and phosphamidon (Parveen and Nakagoshi 2001). Most of the pesticides used in Bangladesh have been classified as 1A, 1B, or 11 by the WHO, which means they are extremely, highly, or moderately hazardous (Pagiola 1995). Incorrect labeling and farmer's ignorance has led to the use of large quantities of dangerous pesticides. Larvae exposed to basudin and diazinon show abdominal and head oedemas and blistering, stunting, flexure of the tail, underdevelopment of gills, and skeletal deformities (Harris *et al*. 1998).

The major fertilizers used in Bangladesh are mainly urea, triple super phosphate (TSP) and muriate of potash (MOP), diammonium phosphate (DAP), single super phosphate (SSP) and mixed fertilizers (NPK) (Shah *et al*. 2008). NPK fertilizer nutrient consumption in Bangladesh is rising at an exponential growth rate of 7.8% per annum (Mustafi and Islam 2008). Higher levels of nitrate and nitrite in agricultural run-off cause amphibian larvae to show disequilibrium, paralysis, deformities, oedemas, and death (Marco *et al*. 1999).

Studies have also shown a relationship between trematode infection and toxic chemical accumulation in amphibians (He 2000; Rohr *et al*. 2009). Trematode infection is in places with agricultural run-off. The occurrencse of limb deformities in developing amphibians is directly related to infection by trematodes (Kiesecker 2002). The stress was invariably due to the irritating and neurotoxic effects of the pesticides. The rate is accelerated in the presence of pesticides and other toxic compounds; this probably also applies to Bangladeshi amphibians.

E. Other Threats

A recent fatal fungal disease has been implicated for mass mortalities of amphibians all over the world. Mass epidemics have been reported both in wild and domestic populations of amphibians in North America, Central America, South America, Australia, Caribbean islands, Europe, and parts and Asia (Berger *et al*. 2009; Heatwole 2013). The causal organism, *Batrachochytrium dendrobatidis*, a chytridomycete fungus, occurs primarily in the soil and water (Berger *et al*. 1998). Post-metamorphic amphibians show widespread infection of the skin, leading to hyperkeratosis, sloughing and erosion of the epidermis, and occasional ulceration (Berger *et al*. 1999).

The extent of the disease in Asia is relatively unknown. Until recently, little effort was exerted to detect or monitor *B. dendrobatidis* in Asia. The fungus has been detected in Japan (Une *et al*. 2008), South Korea (Yang *et al*. 2009), China (Bai *et al*. 2010), and Indonesia (Kusrini *et al*. 2008), but not in Thailand (McLeod *et al*. 2008) or Hong Kong (Rowley *et al*. 2007). To date, no field sampling for amphibian chytrid fungus has been conducted in Bangladesh and its occurrence there is unknown, but cannot be ruled out.

Amphibian survival is also affected by the introduction of alien invasive species. Fisheries and aquaculture are a major source of employment, foreign currency, and food for Bangladesh. Due to environmental degradation, and over-harvesting of fish for food as a consequence of the rapidly expanding human population, a significant decline in wild fish populations was inevitable. As a result, fish began to be cultured in enclosed waters to satisfy the protein demands of the people.

Roughly 15 alien species of carp were introduced into Bangladesh, the most prominent of which are the African catfish (*Clarias gariepinus*), Pangas (*Pangasius sutchi*), Giant Pangas (*Pangasius giganticus*) (Barua *et al*. 1999; Islam *et al*. 2003). The African catfish and the *Pangasius* species are voracious feeders. Alhough there is no documented evidence of amphibian declines as a result of aquacultural practices, it is fair to assume that the combined effect of loss of habitat to urbanization, aquaculture, invasive species, and pesticides and other toxic chemicals has a deleterious impact on amphibian populations in Bangladesh.

V. CONSERVATION AND MANAGEMENT

A. Taxonomic Challenges

Efforts to describe species-level diversity of Bangladeshi amphibians face a number of significant challenges, both sociological and biological. The paucity of in-country systematic herpetologists and lack of funding for research are major hindrances to the taxonomic study of amphibians. Concomitant with the dearth and funding

for systematic herpetologists is the lack of well-developed natural history collections in the country. Bangladesh currently does not have a national natural history museum.

Recent investigations have shown that numerous widespread 'species' of tropical Asian amphibians actually represent complexes of morphologically cryptic species. Cryptic species are found both in forest-dwelling taxa and in those from open areas, and in some cases, cryptic species occur in sympatry (Bickford *et al*. 2006; Stuart *et al*. 2006). Cryptic species diversity in tropical Asia has been identified in such phylogenetically disparate taxa as *Polypedates* (Inger *et al*. 1999), *Odorrana* (Bain *et al*. 2003; Stuart *et al*. 2006), *Euphlyctis* (Alam *et al*. 2008), *Fejervarya* (Islam *et al*. 2008), and *Microhyla* (Hasan *et al*. 2012b). These findings suggest that amphibian species diversity in Bangladesh is may be significantly underestimated. For example, only two species of frogs in the genus *Fejervarya* have been reported from Bangladesh (Kabir *et al*. 2009), but at least five distinct genetic lineages have been identified in the country, based on mtDNA gene sequence data (Islam *et al*. 2008). More recently, a new species of *Fejervarya* has been described species from the Chittagong area (Howlader 2011) and several other species are in the process of being described (Howlader, personal communication, Nov. 2012). Hasan *et al*. (2012b) assumed the existence of *Microhyla fissipes* (which needs further taxonomic study) based on a recent mitochondrial 16S rRNA study. This indicates that a variety of approaches, including the use of molecular and bioacoustic tools, will be required to more accurately define the species diversity of amphibians in Bangladesh.

B. Identifying Research Needs

Human actions are causing a biodiversity crisis, with species extinction rates up to 1000 times higher now than in earlier times (Pimm *et al*. 1995). Moreover, the processes driving extinction are eroding the environmental services on which humanity depends (Brooks *et al*. 2006). As such, we need to quickly prioritizing conservation needs. For a country like Bangladesh, where species lists are incomplete for many taxa, it is important to construct a clear and specific plan for generating baseline information and to conduct action-specific research.

Tropical Asian amphibians are threatened by disease, climaic change, and overharvesting (Sodhi *et al*. 2008; Rowley *et al*. 2010). The amphibian chytrid fungus *Batrachochytrium dendrobatidis* causes the disease chytridiomycosis that has been causally linked to population declines and species extinctions of amphibians (Berger *et al*. 1998, 2009). In recent decades, large areas of natural habitats have been converted to agricultural lands and urban environments to support human populations and promote economic growth. There is a pressing need for conducting conservation research on amphibians while there are still opportunities for mitigating loss of biodiversity through establishingt, reassessingt, and improving protected areas in Bangladesh.

C. Past and Present Laws and Regulations

A comprehensive Forest Act for the Indian subcontinent was enacted in 1927 by modifying the first Forest Act of 1865. A separate forest department was created for Bengal in 1876. The Chittagong Forest Division was the first division created in Bangladesh by the British in 1872 and the Sundarbans Forest Division was created in 1879 (FD 2011). At that time, forests were managed primarily for the collection of revenue under the control of the Revenue Department. The primary objective of forest management during this period was production of wood, mainly to generate revenue. This management strategy was not supportive of conserving biodiversity.

The only government agency for managing wildlife and protecting natural areas is the Bangladesh Forest Department, under the Ministry of Environment and Forests. The Bangladesh Wildlife (Preservation) (Amendment) Act of 1974 is the only national law that provides guidelines for wildlife management in Bangladesh, and it is not explicit. The present management practices and wildlife laws of Bangladesh only allow conservation management of wildlife in protected areas. The Bangladesh Government, on the other hand, has limited involvement in managing wildlife outside of governmental lands.

The Bangladesh Forest Department is not equipped with modern research and management tools. It also faces problems with funding and the training of manpower (Olivier 1979; Gittins and Akonda 1982). These problems should be solved and cooperation, as well as working relations, should be established between different governmental agencies, academic institutions, and non-government entities.

D. Management of Protected Areas

As mentioned above, the forest management strategies in Bangladesh since the British period was not supportive of conservation. Successful conservation of biodiversity and forest management depend on a specific long-term strategic plan. Recent forest management has been primarily guided by the Forestry Master Plan completed in 1992 with assistance from several donor agencies (e.g. ADB, UNDP and FAO) to the Bangladesh Government (FMP 1992).

Most protected areas around the world are managed for multiple, yet compatible, uses. At present, Bangladesh has 19 protected areas of various status: eight wildlife sanctuaries, ten national parks and one game reserve (Fig. 4). There are six eco parks and one safari park, established mainly for recreational purposes. Protected areas, the only government-managed habitats in the country, cover 243,677 ha, which accounts for only 2% of the total area of the country (FD 2011).

The existing system of protected areas was reviewed in the 1980s (Green 1989). It is not comprehensive, having been established with little regard to ecological and other criteria and falls well below the target of 5% recommended by the Ministry of Agriculture Task Force (SDNP 2011). Some effort was made to include representative samples of the major habitats but, for example, marine and freshwater areas were largely neglected (Khan 1985; Rahman and Akonda 1987).

E. Recommendations

Bangladesh needs a detailed and effective long-term (30 to 50 years) national biodiversity management plan for conservation. This should be prepared by the Government of Bangladesh in collaboration with other relevant stakeholders involving research and development agencies. The proposed document presenting the long-term policy should be strictly implemented, no matter what Government is in power. A few major highlights of the directions conservation should take include:

- **Institution:** Establish an independent biodiversity conservation institute for managing sustainable biodiversity in the country.
- **Funding:** Outline a detailed plan for long-term budgeting and identify major funding sources for the conservation management programs.
- **Research:** Produce a detailed plan and conduct action-oriented, multi-dimensional biodiversity research in Bangladesh.
- **Implementation:** Implement the long-term national conservation management plan with immediate (5 to 10 years) conservation goals.
- **Monitoring:** Establish a sustainable and independent biodiversity monitoring system for Bangladesh.

In 1976, a ‘Wildlife Circle’ was established within the Forest Department, with specific responsibility for wildlife matters under the charge of a Conservator of Forests responsible directly to the Chief Conservator of Forests. The Circle was subsequently abolished in 1983, allegedly in the interests of economy and following the recommendations of several internal Government agencies (SDNP 2011). The post of Conservator of Forests (General Administration and Wildlife) remains, but the incumbent has many other administrative duties unrelated to wildlife management.

Following its general downgrading within the Forest Department, wildlife conservation has become the theoretical responsibility of the various divisional forest officers (Blower 1985; Husain 1986). The Bangladesh Wildlife (Preservation) (Amendment) Act of 1974 provides for the establishment of a ‘Wildlife Advisory Board’, which was set up in 1976 under the chairmanship of the Minister of Agriculture. The Board is supposed to approve important wildlife management decisions (Olivier 1979). Although it exists, the Board does not appear to be a dynamic force (Blower 1985; Anonymous 1987).

The objectives for natural resources management of the Forest Department are broad, generalized, and difficult to achieve. In addition, these objectives fail to mention recent environmental issues, e.g. the potential

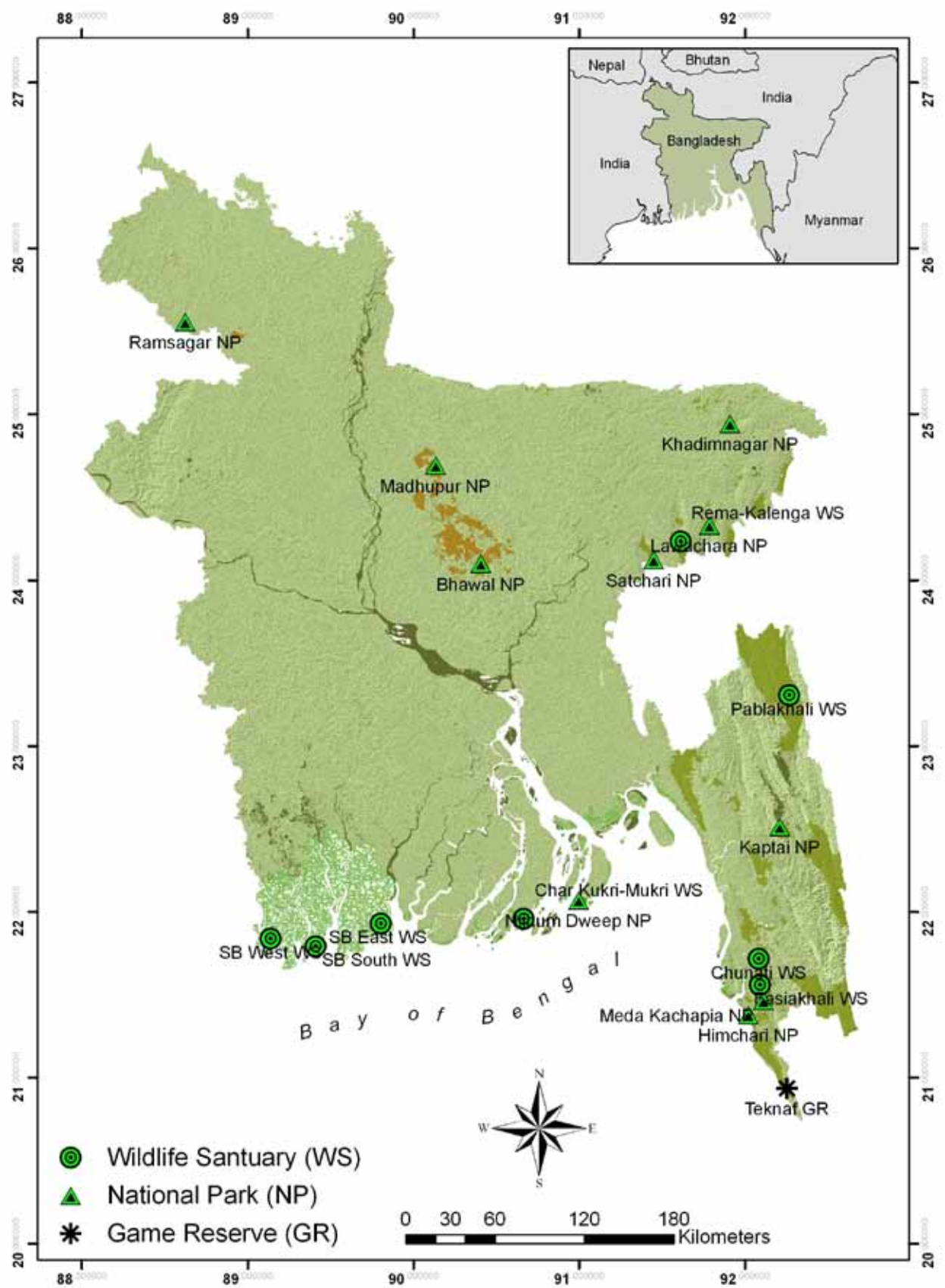

Fig. 4. Map of Bangladesh showing the locations of forest types and protected areas.

impact of climatic change is not mentioned, nor is it explained how this issue will be addressed. However, a more recent climatic-change action plan has been published (MoEF 2008), but this plan contains no suggestion as to how collaborative efforts between various governmental agencies will be achieved. A detailed monitoring system of wildlife (such as amphibians) and other natural resources is also lacking in this action plan.

A new independent 'Wildlife Institute' could be established under the Ministry of Environment and Forest, whose specific responsibility would be to initiate and manage wildlife research and conservation programs. Such an administrative unit should be separated from the Bangladesh Forest Department, whose primary objective is to raise revenues rather than to conserve biological diversity.

Funding is another major issue for conservation and management of biodiversity. Approximately 90% of the $6 billion of annual global conservation funding originates in, and is spent within, economically rich countries (James *et al*. 1999). The Bangladesh Government should focus on locating conservation funding from local sources, but at the same time pursue external financial resources for local conservation projects. A combination of effort should be taken by Government agencies and non-government entities to raise long-term funding for conservation.

Research is, by far, the most important component for a successful plan to conserve biodiversity. Bangladeshi amphibians are poorly known and the understanding of their taxonomy, natural history, biogeography, and evolution is rudimentary. Before making any decisions about conservation management or setting up of a monitoring system, knowledge about these animals should be elevated. Field research on amphibians is most important. Amphibians are sensitive to changes in climatic and environmental conditions and can serve as indicators of impacts of climate change. Bangladesh needs to produce relatively complete baseline biodiversity information as a support for further long-term research on the local fauna.

Protected areas harbour most of the amphibian species diversity in Bangladesh (Reza 2010). Despite this, their conservation has not been on the priority list of the forest management practices. Few, if any, protected areas are effectively managed and protected in Bangladesh (SDNP 2011). This has put the conservation of biodiversity in a challenging situation. In addition to improving management practices in the existing protected areas, there is a need to find suitable sites for establishing new ones.

People care most about what is close to them; hence most responses to the crisis in the conservation of biodiversity are local or national (Hunter and Hutchinson 2002). Bangladesh is largely an agricultural country that needs to focus on animals associated with agricultural landscapes. Amphibians are among those animals that live close to the people and are an important part of agricultural practices. Thus, public education on the importance of amphibians in their daily life should be highlighted. Awareness activities are important in areas of high species diversity of amphibians. Policy makers should be involved in discussing the role of amphibians in people's lives and in ecological functions (e.g., pest control). Conservation of amphibians in Bangladesh, thus, will mostly depend on the people who interact closely with animals.

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VI. REFERENCES

Alam, M.S., Igawa, T., Khan, M.M.R., Islam, M.M., Kuramoto, M., Matsui, M., Kurabayashi, A. and 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.

Anonymous, 1987. National conservation strategy for Bangladesh. Draft prospectus (Phase I). Bangladesh Agricultural Research Council/IUCN, Gland.

Anonymous, 1994. "Statistical Yearbook of Bangladesh". Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

Anonymous, 2004. "Statistical Yearbook of Bangladesh". Bangladesh Bureau of Statistics, Dhaka.

Bai, C., Garner, T.W.J., and Li, Y., 2010. First evidence of *Batrachochytrium dendrobatidis* in China. *EcoHealth* **7**: 127–134.

Bain, R.H., Lathrop, A., Murphy, R.W., Orlov, N. and Cuc, H.T., 2003. Cryptic species of a cascade frog from Southeast Asia: taxonomic revisions and descriptions of six new species. *American Museum Novitates* **3417**: 1–60.

Barnes, N., 1996. Export of frogs from Bangladesh. Pp. 217–230 *in* "Conflicts over Biodiversity, Environmental Policy in an International Context".

Barua, S.P., Khan, M.H. and Reza, A.H.M.A., 1999. The status of alien invasive species in Bangladesh and their impacts on the ecosystem. Pp. 1–5 *in* "Proceeding of a Workshop on the Alien Invasive Species". IUCN Asia Regional Biodiversity Program, Sri Lanka.

Berger, L, Speare, R. and Hyatt, A., 1999. Chytrid fungi and amphibian declines: Overview, implications and future directions. Pp.23–33 *in* "Declines and Disappearances of Australian Frogs", ed. by A. Campbell. Environment Australia, Canberra.

Berger, L, Speare, R., Daszak, P., Green, D.E. and Cunningham, A.A., 1998. Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. *Proceedings of the National Academy of Sciences* **95**: 9031–9036.

Berger, L., Longcore, J.E., Speare, R., Hyatt, A. and Skerratt, L.F., 2009. Fungal diseases of amphibians. Chapter 2 (pp. 2986–3052) *in* "Amphibian Decline: Diseases, Parasites, Maladies and Pollution", ed. by H. Heatwole and J.W. Wilkinson. Vol. 8 *in* "Amphibian Biology", ed. by H. Heawole. Surrey Beatty & Sons, Baulkham Hills.

Bickford, D., Lohman, D.J., Sodhi, N.S., Ng, P.K.L., Meier, R., Winker, K., Ingram, K.K. and Das, I., 2006. Cryptic species as a window on diversity and conservation. *Trends in Ecology and Evolution* **22**: 148–155.

Blower, J.H., 1985. "Sundarbans Forest Inventory Project, Bangladesh. Wildlife Conservation in the Sundarbans". Project Report No. 151. ODA Land Resources Development Centre, Surbiton.

Boone, M.D., Davidson, C. and Bridges-Britton, C., 2009. Evaluating the impact of pesticides in amphibian declines. Chapter 8 (pp. 3186–3207) *in* "Amphibian Decline: Diseases, Parasites, Maladies and Pollution", ed. by H. Heatwole and J.W. Wilkinson. Vol. 8 *in* "Amphibian Biology", ed. by H. Heawole. Surrey Beatty & Sons, Baulkham Hills.

Boyer, R.,and Grue, C.E., 1995. The need for water quality criteria for frogs. *Environmental Health Perspectives* **103**:352–357.

Brammer, H., 1996. "The Geography of the Soils of Bangladesh". University Press Ltd., Dhaka.

Brooks, T.M., Mittermeier, R.A., da Fonseca, G.A.B., Gerlach, J., Hoffmann, M., Lamoreux, J.F., Mittermeier, C.G., Pilgrim, J.D. and Rodrigues A.S.L., 2006. Global biodiversity conservation priorities. *Science* **313**: 58–61.

Collins, N.M., Sayer, J. and Whitemore, T. (eds.), 1991. "The Conservation Atlas of Tropical Forests in Asia and the Pacific". IUCN, Gland.

Cruz, R.V., Harasawa, H., Lal, M., Wu, S., Anokhin, Y., Punsalmaa, B., Honda, Y., Jafari, M., Li, C. and Huu, N.N., 2007. Asia. "Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change", ed. by M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson. Cambridge University Press, Cambridge, 469–506.

Dasgupta, S., Meisner, C. and Wheeler, D., 2004. Is environmentally-friendly agriculture less profitable for farmers? Evidence on integrated pest management in Bangladesh. "World Bank Policy Research Working Paper **3417**".

FD — Forest Department, 2011. Conservation Sites: Protected Areas of Bangladesh. Bangladesh Forest Department Official Website at <bforest.gov.bd/conservation.php> (downloaded on 20 February 2011).

FMP, 1992. Forest Production. Forestry Master Plan. Project Document. ADB TA 1355–BAN UNDP/FAO BGD/88/025.

Frost, D.R., 2011. Amphibian Species of the World: an Online Reference. Version 5.5 (31 January 2011). Database at http://research.amnh.org/vz/herpetology/amphibia/American Museum of Natural History, New York, USA.

Fugler, C.M., 1985. A proposed management programme for the Indian Bullfrog, *Rana tigrina*, in Bangladesh, comments pertaining to its intensive cultivation with observations on the status of the exploited chelonians. Consultant Report to UNDP-FAO Project BGD/79/015, Fisheries Resources Survey System.

Ghose, A. and Bhuiyan, A.R. 2012. Geographic distribution. *Raorchestes parvulus* (Karin Bubble Nest Frog). *Herpetological Review* **43**: 98–99.

Giri, C. and Shrestha, S., 1996. Land cover mapping and monitoring from NOAA AVHRR data in Bangladesh. *International Journal of Remote Sensing* **17**: 2749–2759.

Gittins, S.P. and Akonda, A.W., 1982. What survives in Bangladesh? *Oryx* **16**: 275–281.

Green, M.J.B., 1989. "Bangladesh: an Overview of its Protected Areas System". UNEP World Conservation Monitoring Centre, Cambridge.

Harris, M.L., Bishop, C.A., Struger, J., Ripley, B. and Bogart, J.P., 1998. The functional integrity of northern Leopard Frog (*Rana pipiens*) and Green Frog (*Rana clamitans*) populations in orchard wetlands. Effects of pesticides and eutrophic conditions on early life stage development. *Environmental Toxicology and Chemistry* **17**: 1351–1363.

Hasan, M.K., Mahony, S. and Kabir, M.M., 2010. *Geographic distribution. Chiromantis doriae (Doria's Bush Frog). Herpetological Review* **41**: 103.

Hasan, M., Islam, M.M., Khan, M.M.R., Alam, M.S., Kurabayashi, A., Igawa, T., Kuramoto, M. and Sumida, M., 2012b. Cryptic Anuran biodiversity in Bangladesh revealed by mitochondrial 16S rRNA gene sequences. *Zoological Science* **29**: 162-172.

Hasan, M., Kuramoto, M., Islam, M.M., Alam, M.S., Khan, M.M.R. and Sumida, M. 2012a. A new species of genus *Hoplobatrachus* (Anura, Dicroglossidae) from the coastal belt of Bangladesh. *Zootaxa* **3312**: 45–58.

He, F., 2000. Neurotoxic effects of insecticides–current and future research: a review. *Neurotoxicology* **21**: 829–35.

Heatwole, H., 2013. Worldwide decline and extinction of amphibians. Chapter 18 (pp. 259–278) *in* "The Balance of Nature and Human Impact", ed by K. Rohde. Cambridge University Press, Cambridge.

Howlader, M.S.A., 2011. A new species of *Fejervarya* (Anura: Dicroglossidae) from Bangladesh. *Zootaxa* **2761**: 41–50.

Hunter, M.L. and Hutchinson, J.A., 2002. The virtues and shortcomings of parochialism: conserving species that are locally rare, but globally common. *Conservation Biology* **8:** 1163–1165.

Husain, K.Z., 1986. Wildlife study, research and conservation in Bangladesh. *Eleventh Annual Bangladesh Science Conference* **2**: 1–32.

Hussain, Z. and Karim, A., 1994. Introduction. Pp. 1–18 *in* "Mangroves of the Sundarbans". Vol. 2 "Bangladesh", ed. by Z. Hussain and G. Acharya. IUCN, Bangkok.

Inger, R.F., Orlov, N. and Darevsky, I., 1999. Frogs of Vietnam: a report on new collections.
Fieldiana Zoology, New Series **92**: 1–46.

Islam, M.M., Amin, A.S.M.R. and Sarker, S.K. 2003. "Invasive Alien Species in South-east Asia. National Reports and Directory of Resources". Global Invasive Species Programme, Cape Town, South Africa, 7–20 pp.

Islam, M.M., Kurose, N., Khan, M.M.R., Nishizawa, T., Kuramoto, M., Alam, M.S., Hasan, M., Kurniawan, N., Nishioka, M. and Sumida, M., 2008. Genetic divergence and reproductive isolation in the genus *Fejervarya* (Amphibia: Anura) from Bangladesh inferred from morphological observations, crossing experiments, and molecular analysis. *Zoological Science* **25**: 1084–1105.

IUCN Bangladesh, 2000. "Red Book of Threatened Amphibians and Reptiles of Bangladesh". IUCN-The World Conservation Union, Dhaka, Bangladesh. XII + 95 pp.

IUCN, 2012. *IUCN Red List of Threatened Species. Version 2012.2*. <www.iucnredlist.org>. Downloaded 24 November 2012.

James, A.N., Gaston, K.J. and Balmford, A., 1999. Balancing the Earth's accounts. *Nature* **401**: 323–324.

Kabir, S.M.H., Ahmad, M., Ahmed, A.T.A., Rahman, A.K.A., Ahmed, Z.U., Begum, Z.N.T., Hassan, M.A. and Khandker, M. (eds.), 2009. "Encyclopedia of Flora and Fauna of Bangladesh". Vol. 25. "Amphibians and Reptiles". Asiatic Society of Bangladesh. Dhaka.

Khan, M.A.R., 1982. "Wildlife of Bangladesh: A Checklist". The City Press, University of Dhaka, Dhaka.

Khan, M.A.R., 1985. Future conservation directions for Bangladesh. Pp. 114–122 *in* "Conserving Asia's Natural Heritage", ed. by J.W. Thorsell. IUCN, Gland.

Khan, M.A.R., 2001. A report on the Puddle Frog (*Occidozyga lima*) from the Teknaf Peninsula, Bangladesh, with notes on the presence of other vertebrates. *Zoo's Print Journal* **16**: 583–587.

Khan, M.M.H., 2008. "Protected Areas of Bangladesh — A Guide of Wildlife". Nishorgo Program, Bangladesh Forest Department, Dhaka.

Kiesecker, J.M., 2002. Synergism between trematode infection and pesticide exposure: A link to amphibian limb deformities in nature? *Proceedings of the National Academy of Sciences* **99**: 9900–9904.

Kusrini, M.D., 2012. International trade in amphibians. Chapter 8 (pp. 3494–3504) *in* "Conservation and Decline of Amphibians: Ecological Aspects, Effect of Humans, and Management", ed. by H. Heatwole and J.W. Wilkinson. Vol. 10 *in* "Amphibian Biology", ed. by H. Heatwole. Surrey Beatty & Sons, Baulkham Hills.

Kusrini, M.D., Heatwole, H. and Davenport, D., 2012. Harvesting of amphibians for food. Chapter 4 (pp. 3469–3493) *in* "Conservation and Decline of Amphibians: Ecological Aspects, Effect of Humans, and Management", ed. by H. Heatwole and J.W. Wilkinson. Vol. 10 *in* "Amphibian Biology", ed. by H. Heatwole. Surrey Beatty & Sons, Baulkham Hills.

Kusrini, M.D., Skerratt, L.F., Garland, S., Berger, L. and Endarwin, W., 2008. Chytridiomycosis in frogs of Mount Gede Pangrango, Indonesia. *Diseases of Aquatic Organisms* **82**: 187–194.

Mahony, S. and Reza, A.H.M.A., 2007a. Geographic distribution. *Kalophrynus interlineatus* (Striped Sticky Frog). *Herpetological Review* **38**: 348.

Mahony, S. and Reza, A.H.M.A., 2007b. Geographic distribution. *Sylvirana leptoglossa* (Long-tongued Frog). *Herpetological Review* **38**: 350.

Mahony, S. and Reza, A.H.M.A., 2008. A herpetofaunal collection from the Chittagong Hill Tracts, Bangladesh, with two new species records for the country. *Hamadryad* **32**: 34–45.

Mahony, S., Hasan, M.K., Kabir, M.M., Ahmed, M. and Hossain, M.K., 2009. A catalogue of amphibians and reptiles in the collection of Jahangirnagar University, Dhaka, Bangladesh. *Hamadryad* **34**: 80–94.

Marco, A., Quilchano, C. and Blaustein, A.R., 1999. Sensitivity to nitrate and nitrite in pond-dreeding amphibians from the Pacific Northwest, USA. *Environmental Toxicology and Chemistry* **18**: 2836–2839.

Marco, A. and Ortiz-Santaliestra, M., 2009. Chapter 7 (pp. 3145–3185) in "Amphibian Decline: Diseases, Parasites, Maladies and Pollution", ed. by H. Heatwole and J.W. Wilkinson. Vol. 8 *in* "Amphibian Biology", ed. by H. Heawole. Surrey Beatty & Sons, Baulkham Hills.

McLeod, D.S., Sheridan, J.A., Jiraungkoorskul, W. and Khonsue, W., 2008. A survey for chytrid fungus in Thai amphibians. *The Raffles Bulletin of Zoology* **56**: 199–204.

MoEF. 2008. "Bangladesh Climate Change Strategy and Action Plan 2008". Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, Dhaka.

Mustafi, B.A.A., and Islam, M.R., 2008. Development of agricultural policies in Bangladesh. *Bangladesh Journal of Agriculture and Environment* **4**: 1–8.

NFA, 2007. "National Forest and Tree Resources Assessment 2005–2007 Bangladesh", ed. by D. Altrell, M. Saket, L. Lyckebäck, and M. Piazza. Bangladesh Forest Department, Dhaka.

Niekisch, M., 1986. The International Trade in Frogs' Legs. *Traffic Bulletin* **8**: 7–10.

Nishat, A., Huq, S.M.I., Barua, S.P., Reza, A.H.M.A. and Khan, A.S.M. (eds.), 2002. "Bio-ecological Zones of Bangladesh". IUCN — The World Conservation Union, Bangladesh Country Office, Dhaka.

Olivier, R.C. ., 1979. "Wildlife conservation and management in Bangladesh". UNDP/FAO Project No. BGD/72/005. Forest Research Institute, Chittagong.

Oza, G.M., 1990. Ecological effects of the frog's legs trade. *Environmentalist* **10**: 39–42.

Pagiola, S., 1995. "Natural Resource Degradation in Intensive Agriculture in Bangladesh". Environment Department Papers. Towards environmentally and socially sustainable development, Environmental Economics Series, The World Bank, Washington, D.C.

Parveen, S. and Faisal, I., 2003. "Open-water fisheries in Bangladesh: A critical review". Abstract submitted to the Second International Symposium on the Management of Large Rivers for Fisheries. Phnom Penh, Mekong River Commission.

Parveen, S. and Nakagoshi, N., 2001. An analysis of pesticide use for rice pest management in Bangladesh. *Journal of International Development and Cooperation* **8**: 107–126.

Pimm, S.L., Russell, G.J., Gittleman, J.L. and Brooks, T.M., 1995. The Future of Biodiversity. *Science* **269**: 347–350.

Rahman, S.A. and Akonda, A.W., 1987. "Bangladesh National Conservation Strategy: Wildlife and Protected Areas". Department of Forestry, Ministry of Agriculture and Forestry, Dhaka.

Rahman, S.C. and Howlader, M.S.A. 2011a. Geographic Distribution. *Chiromantis simus* (Assam Tree Frog). *Herpetological Review* **42**: 561–562.

Rahman, S.C. and Howlader, M.S.A. 2011b. Geographic Distribution. *Fejervarya teraiensis* (Terai Cricket Frog). *Herpetological Review* **42**: 562.

Räsänen, K. and Green, D.M., 2009. Acidification and its effects on amphibian populations. Chapter 11 (pp. 3244–3267) in "Amphibian Decline: Diseases, Parasites, Maladies and Pollution", ed. by H. Heatwole and J.W. Wilkinson. Vol. 8 *in* "Amphibian Biology", ed. by H. Heawole. Surrey Beatty & Sons, Baulkham Hills.

Rasel, M.M.R., Hannan, M.A. and Howlader, M.S.A., 2007. *Four new country records of Fejervarya Bolkay, 1915 (Amphibia: Anura: Dicroglossidae) from Bangladesh. Bonnoprani — Bangladesh Wildlife Bulletin* **4**: 1–3.

Rashid, H.E., 1991. "Geography of Bangladesh (2nd Edition)". University Press Limited. Dhaka.

Reza, A.H.M.A., 2008a. Geographic Distribution. *Occidozyga borealis* (Northern Trickle Frog). *Herpetological Review* **39**: 235.

Reza, A.H.M.A., 2008b. Geographic Distribution. *Nasirana alticola* (Annandale's Frog). *Herpetological Review* **39**: 234–235.

Reza, A.H.M.A., 2009. The Heat is On: Herpetofauna of Bangladesh. *Sanctuary Asia*. **XXIX**: 54–59.

Reza, A.H.M.A., 2009a. Natural history notes. *Leptobrachium smithii* (Smith's Litter Frog). Defense and Pigmentation. *Herpetological Review* **40**: 72.

Reza, A.H.M.A., 2010. "Diversity of Amphibians and Reptiles in Bangladesh: Impact of Climate Change, Biogeography, and Conservation Management of Herpetofauna in Bangladesh". LAP Lambert Academic Publishing GmbH & Co. KG, Saarbrücken.

Reza, A.H.M.A. and Mahony, S., 2007. Geographic distribution. *Kaloula taprobanica* (Sri Lankan Bull Frog). *Herpetological Review* **38**: 348.

Reza, A.H.M.A. and Mukul, S.A. 2009. Geographic Distribution. *Rhacophorus bipunctatus* (Twin-spotted Tree Frog). *Herpetological Review* **40**: 447.

Reza, A.H.M.A., Islam, M.A., Feeroz, M.M. and Chowdhury, M.M., 2000. A preliminary survey on amphibian fauna of Sundarbans mangrove forest, Bangladesh. *Frogleg* **4**: 1–2.

Reza, A.H.M.A., Islam, M.A., Feeroz, M.M. and Nishat, A., 2004. "Bengal Tiger in the Bangladesh Sundarbans". IUCN — The World Conservation Union, Bangladesh Country Office, Dhaka.

Rizvi, S.N.H., 1975. "Bangladesh District Gazetteers: Chittagong". Bangladesh Government Press, Dacca.

Rohr, J., Raffel, T.D. and Sessions, S.K., 2009. Digenetic trematodes and their relationship to amphibian declines and deformities. Chapter 4 (pp. 3067–3088) in "Amphibian Decline: Diseases, Parasites, Maladies and Pollution", ed. by H. Heatwole and J.W. Wilkinson. Vol. 8 *in* "Amphibian Biology", ed. by H. Heawole. Surrey Beatty & Sons, Baulkham Hills.

Rowley, J., Brown, R., Bain, R., Kusrini, M., Inger, R., Stuart, B., Wogan, G., Neang, T., Chan-ard, T., Cao, T.T., Diesmos, A., Iskandar, D.T., Lau, M., Leong, M.T., Makchai, S., Nguyen, T.Q. and Phimmachak, S., 2010. Impending conservation crisis for Southeast Asian amphibians. *Biology Letters* **6**: 336–338.

Rowley, J.J.L., Chan, S.K.F., Tang, W.S., Speare, R., Skerratt, L.F., Alford, R.A., Cheung, K.S., Ho, C.Y., and Campbell, R., 2007. Survey for the amphibian chytrid *Batrachochytrium dendrobatidis* in Hong Kong in native amphibians and in the international amphibian trade. *Diseases of Aquatic Organisms* **78**: 87–95.

Salam, M.A., Noguchi, T. and Koike, M., 1999. The causes of forest cover loss in the hill forests in Bangladesh. *GeoJournal*. **47**: 539–549.

Sarker, M.A.R., 2012. Geographic Distribution. *Fejervarya terainesis* (Terai Cricket Frog). *Herpetological Review* **43**: 440.

Sarker, M.A.R. and Howlader, M.S.A., 2011a. Geographic Distribution. *Fejervarya asmati* (Bangladesh Cricket Frog). *Herpetological Review* **42**: 562.

Sarker, M.A.R. and Howlader, M.S.A., 2011b. Geographic Distribution. *Fejervarya pierrei* (Pierre's Cricket Frog). *Herpetological Review* **42**: 562.

Sarker, M.A.R., Das, P.K. and Kundu, S., 2012. Geographic Distribution. *Fejervarya asmati* (Bangladesh Cricket Frog). *Herpetological Review* **43**: 439-440.

SDNP, 2011. Biodiversity Day 2001. Protected Areas of Bangladesh <http://www.bdix.net/sdnbd_org/world_env_day/2001/sdnpweb/sdi/international_day/biodiversity/2001/Protected Areas of Bangladesh.htm> (visited on 20 February 2011).

Shah, A.L., Rahman, M.S. and Aziz, M.A., 2008. Outlook for fertilizer consumption and food production in Bangladesh. *Bangladesh Journal of Agriculture and Environment* **4**: 9–26.

Sodhi, N.S., Bickford, D., Diesmos, A.C., Lee, T.M., Koh, L.P., Brook, B.W., Sekercioglu, C.H. and Bradshaw, C.J.A., 2008. Measuring the meltdown: drivers of global amphibian extinction and decline. *PloS One* **3**: 1–8.

Stuart, B.L., Inger, R.F. and Voris, H.K., 2006. High level of cryptic species diversity revealed by sympatric lineages of Southeast Asian forest frogs. *Biology Letters* **2**: 470–474.

UN, 2005. "World Population Prospects: The 2004 Revision (Highlights)". Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. United Nations, New York.

Une, Y., Kadekaru, S., Tamukai, K., Goka, K. and Kuroki, T., 2008. First report of spontaneous chytridiomycosis in frogs in Asia. *Diseases of Aquatic Organisms* **82**: 157–160.

Warkentin, I.G., Bickford, D., Sodhi, N.S. and Bradshaw, C.J.A., 2009. Eating frogs to extinction. *Conservation Biology* **23**: 1056–1059.

Whiting, D., 1984. Frog legs — a study in cruelty and short-sighted stupidity. *Agscene* **75**:2–4.

Yang, H., Baek, H., Speare, R., Webb, R., Park, S., Kim, T., Lasater, K.C., Shin, S., Son, S., Park, J., Min, M., Kim, Y., Na, K., Lee, H. and Park, S., 2009. First detection of the amphibian chytrid fungus *Batrachochytrium dendrobatidis* in free-ranging populations of amphibians on mainland Asia: Survey in South Korea. *Diseases of Aquatic Organisms* **86**: 9–13.