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Amphibian species assemblages in a tropical forest of Bangladesh

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Tropical forests are considered one of the most important biogeographic zones for amphibian species diversity. As a tropical country in Asia, Bangladesh implements different types of forest management practices in its forests, which might affect prevailing forest quality in the existing forest types. The current state of information on the impact of habitat alteration on amphibian species assemblages in Bangladesh is inadequate. To evaluate this, we conducted a study in Khadimnagar National Park (KNP) in north-eastern Bangladesh. We used a combination of several common amphibian study techniques in 15 pre-marked transects covering three major habitat types in KNP: forest edge, forest interior and swamp area. Twelve anuran species belonging to eleven genera and six families were recorded during the study period. *Euphlyctis cyanophlyctis* was the most abundant species, representing 51.7% of the recorded individuals, followed by *Fejervarya* spp. (18.9%); the remaining 10 species altogether recorded less than 30% of the total abundance. *Duttaphrynus melanostictus*, *Kaloula pulchra* and *Raorchestes parvulus* in particular occurred with very low abundance. Species richness, Shannon-Wiener diversity index, and evenness index value indicated that the amphibian species assemblage in the forest interior is more diverse than the forest edge and swamp area.

Key words: Amphibian, species assemblages, abundance, diversity, habitat types, tropical forest

INTRODUCTION

Amphibians are among the planet's most threatened taxa, yet the most abundant vertebrate group in the tropical forest ecosystems, where they have essential roles in trophic dynamics (Hairston, 1987; Welsh & Droege, 2001). For example, they are an essential invertebrate predator in the ecosystem, and also an important part of the food web as prey species (Stebbins & Cohen, 1995). Amphibians are also highly efficient in converting energy into biomass in the entire food web (Stebbins & Cohen, 1995). However, tropical amphibian populations have undergone drastic population declines and extinctions in the recent decades. Nearly one-third of the world's 6,187 species of amphibians are threatened with extinction (Stuart et al., 2004). Declines and extinctions of amphibians have been more severe in the tropics than in other biogeographic regions. Population declines in recent decades have been especially severe, with up to five species going extinct each year (Stuart et al., 2004).

Causes of amphibian species decline are increasingly linked to human activities, and both the number and magnitude of threats has increased dramatically in modern times. Current threats to biodiversity include habitat loss (Young et al., 2001; Stuart et al., 2004), emerging infectious diseases (Daszak et al., 2003), invasive species (Vredenburg, 2004), increased UV-B radiation and chemical contaminants (Hayes et al., 2002; Blaustein et al., 2003; Davidson et al., 2001), and global climate change (Pounds, 2001; Thomas et al., 2004). In most cases, multiple factors are working synergistically to cause amphibian mortality and extinction (Mittermeier et al., 1998; Kiesecker et al., 2001).

Unless rapid and effective actions are implemented to halt the current wave of extinctions, it is likely that we will lose a significant proportion of amphibian diversity by the end of the century. Resolving this environmental crisis requires a combination of ecological, economic and socio-political solutions, which should be initiated on a local scale. Amphibian species diversity and relative abundance at the local scale is vital to monitoring community composition and providing fundamental information for conservation initiatives (Reza & Perry, 2015). Here, this study aims to investigate the amphibian assemblage structure across different habitat types in a tropical forest of Bangladesh in south-eastern Asia. This

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work is specifically significant as no such study currently exists for Khadimnagar National Park in north-eastern Bangladesh.

MATERIALS AND METHODS

Study Site - The study was conducted in Khadimnagar National Park (24°56´-24°58´N latitude, 91°55´- 91°59´E longitude), located in the north-east region of Bangladesh (Fig. 1). Khadimnagar National Park (KNP) is located within the Indo-Burma Biodiversity Hotspot, and harbours some of the richest biota on earth (Mittermeier et al., 1998; Nishat et al., 2002). The Park was established as a Reserved Forest in 1957 and declared as a National Park in 2006 following the Bangladesh Wildlife (Preservation) Amendment Act, 1974 (currently known as Wildlife Conservation and Security Act, 2012). Prior to becoming a protected area of about 7 sq. kilometres, KNP suffered huge habitat alteration through logging and plantation. There was an attempt to recover the forest through mixed and monoculture plantation at the peripheries and along the main brook prior to its adoption as a national park. However, KNP is considered one of the important protected areas in Bangladesh due to its diverse flora and fauna (Sobuj & Rahman, 2011).

Mean annual temperatures of KNP varies between 18.9°C and 30.7°C. The average annual precipitation is 3,400mm, most of which occurs between June and September (BBS/UNDP, 2005). The topography of the site is undulating with slopes and hillocks, ranging from 10 to 50 m asl (Sobuj & Rahman, 2011; Ghose & Bhuiyan, 2012). KNP is surrounded by seven tea gardens and the anthropogenic disturbances resulting from the tea production activities might have some influence on the amphibian population of the national park.

Field Survey – We conducted fieldwork between April 2012 and March 2013, when a total of ~32 days were spent in the field covering all major seasons of Bangladesh: summer (hot and humid weather coincides with south-western wind from March to June), monsoon (mostly comfortable, rainy monsoon from July to October), and winter (cool, but very comfortable temperature with low precipitation from November to February). To maximise the data collection success, we used a combination of common amphibian population sampling techniques. We primarily used Visual Encounter Surveys (Crump & Scott, 1994; Doan, 2003) (total ~480 man-hours), supplemented by amphibian auditory or call surveys (Pierce & Gutzwiller, 2004), some trapping efforts (PVC pipes as artificial refuge and bucket traps), and opportunistic collection of specimens from local community members.

We categorised the study site into three major habitat types: i) Forest interior: the core area of the national park with heterogenic habitat types where plantation was initiated in late 1950s in a hilly landscape; ii) Forest edge: the dry peripheral land of national park that continued with tea plantation; iii) Swamp area: habitat composed of streams, seasonal perennial water bodies and adjacent fallen land. Streams in KNP have either north-south or east-west direction and the major source of household water for tea garden inhabitants.

During VES, we used a time-constrained active

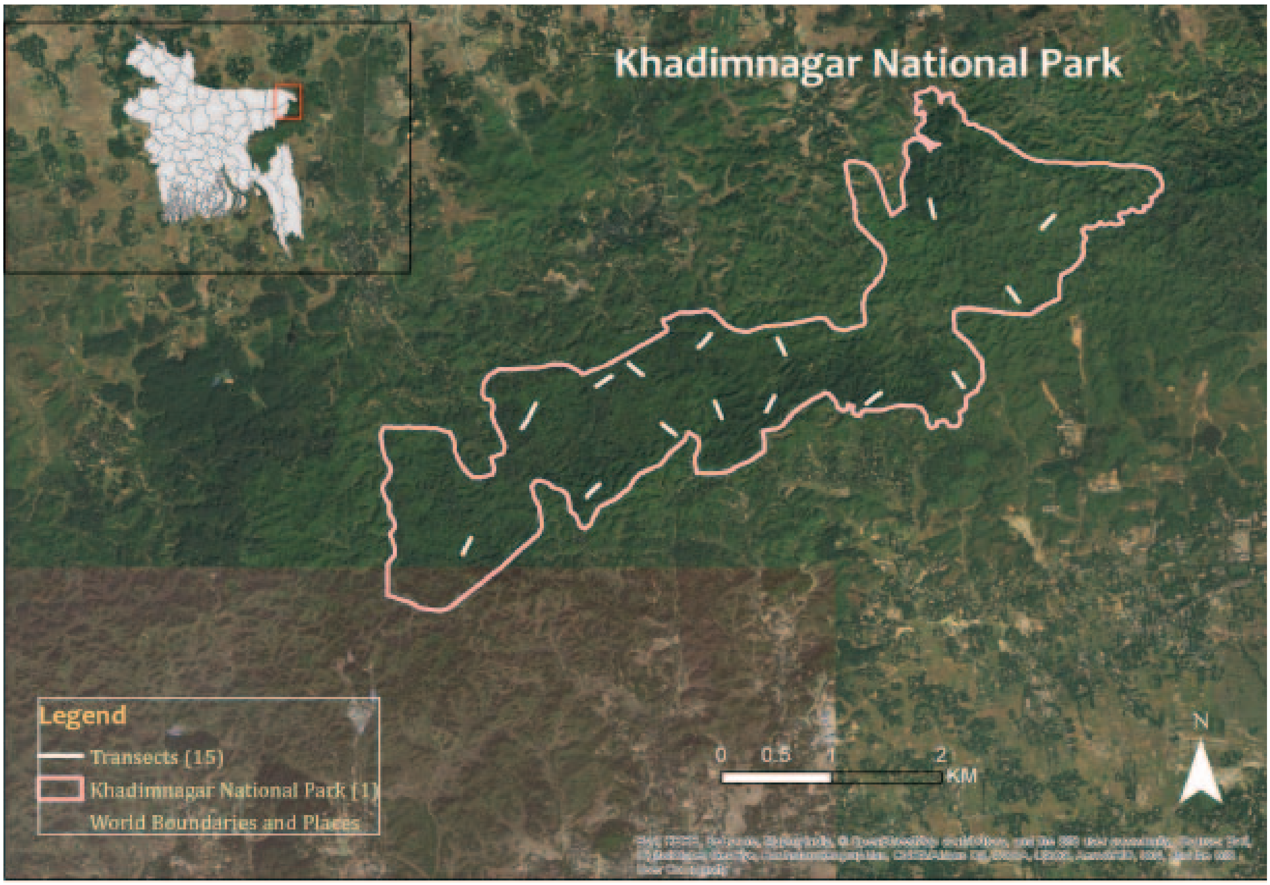

Figure 1. Map of the study area, Khadimnagar National Park in Bangladesh.

search for amphibians in fifteen pre-marked transects throughout the three major habitat types: six transects in the forest interior, four transects in forest edge, and five transects in swamp area. The routes were selected based on the available habitat types proportionately with roughly 150 m length and were surveyed with a team of three members, which covered both day and night time searches.

We checked the PVC pipes as artificial refuge placed in different parts of the forest on a weekly basis and amphibians captured in the pipes were identified, recorded and released in the same location. For call survey, we positioned ourselves in a quiet spot in our study site at least half an hour after sunset and used a smartphone to record all the calls for 10 to 15 minutes at a time. We repeated the process up to three times depending on the amphibian activities of the night and used the recorded files later for species identification in the laboratory. When performing amphibian auditory or call surveys, in most cases, we were able to identify frog calls during their breeding season using some of the techniques discussed in Roy and Elepfandt (1993). We photographed each recorded species during our study and also the available captured ones during call surveys.

Data analysis - We calculated the average Shannon-Wiener diversity index (Magurran, 1988), evenness (the variation in the abundance of individuals per species within a community) and dominance (proportional importance of the most abundant species) (Magurran, 1988) for each habitat type by using PAST software (Hammer et al., 2001). We used the 'BiodiversityR' package of R software (Kindt & Coe, 2005) to extract rank abundance curves and species rarefaction curves. Kruskal-Wallis test (Spurrier, 2003), which is free of assumptions of normality, was used to determine if there were significant differences in abundance between habitat types using a significance level of $p=0.05$. Microsoft Excel®2007 software was used to calculate and compare the percentage of occurrence of each species in the three major habitat types by dividing the number of plots where a particular species was present by the total number of plots.

RESULTS

We encountered a total of 497 individuals– all anurans – belonging to 6 families, 11 genera, and 12 species, (Table 1, Fig. 2). The families Dicroglossidae and Microhylidae (6 species) were the most abundant, followed by Megophryidae (2 species), Rhacophoridae (2 species) Bufonidae (1 species), and Ranidae (1 species). We noticed that the number of species recorded during our fieldwork is lower than the recorded species from other studies like Hasan and Feeroz (2014). No caecilian and salamander species were recorded from the study area during our fieldwork. The species rarefaction curves suggest a larger sample size would not have added many more species to our findings (Fig. 3).

Euphlyctis cyanophlyctis was the most abundant anuran species, representing 51.7% of the total abundance, followed by *Fejervarya* spp. (18.9%) (Fig. 4).

Figure 2. Some of the anuran species encountered in the Khadimnagar National Park: A) *E. cyanophlyctis*; B) *Fejervaya* spp.; C) *H. tigerinus*; D) *K. pulchra*; E) *H. leptoglossa*; F) *R. parvulus*; G) *M. ornata* and H) *L. smithi*.

Table 1. Amphibian species encountered in the different habitats of Khadimnagar National Park during the study [x = species recorded]

Family	Species	Habitat type: Forest edge	Forest interior	Swamp area
Bufonidae	*Duttaphrynus melanostictus*		x	x
Dicroglossidae	*Euphlyctis cyanophlyctis*	x	x	x
	Fejervarya spp.	x	x	x
	Hoplobatrachus tigerinus	x	x	
Megophyridae	*Leptobrachium smithi*	x	x	x
	Xenophrys parva	x	x	x
Microhylidae	*Kaloula pulchra*		x	
	Microhyla ornata	x	x	x
	M. rubra	x	x	
Ranidae	*Hylarana leptoglossa*	x	x	x
Rhacophoridae	*Polypedates leucomystax*	x	x	x
	Raorchestes parvulus		x	

There has been mounting evidence of this across Asia, and Islam et al. (2008) suggests that there could be four groups within a *Fejervarya* complex in Bangladesh.

However, we still used the traditional classification due to the difficulties of their identification in the field. The remaining species represented less than 30% of the total abundance, ranging from 2 to 29 individuals per species. *Duttaphrynus melanostictus*, *Kaloula pulchra*

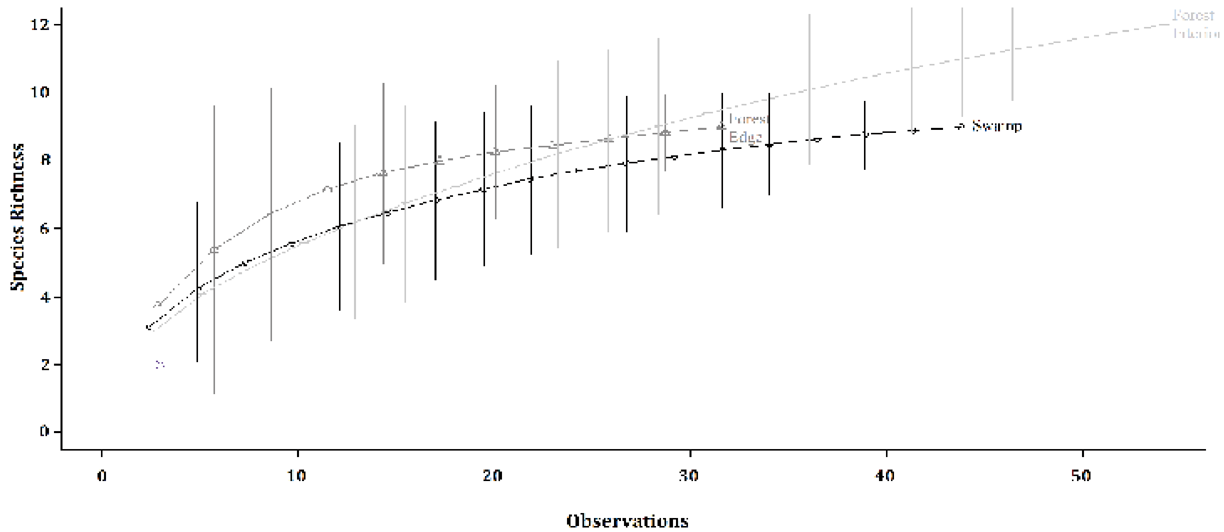

Figure 3. Species rarefaction curve for the study area

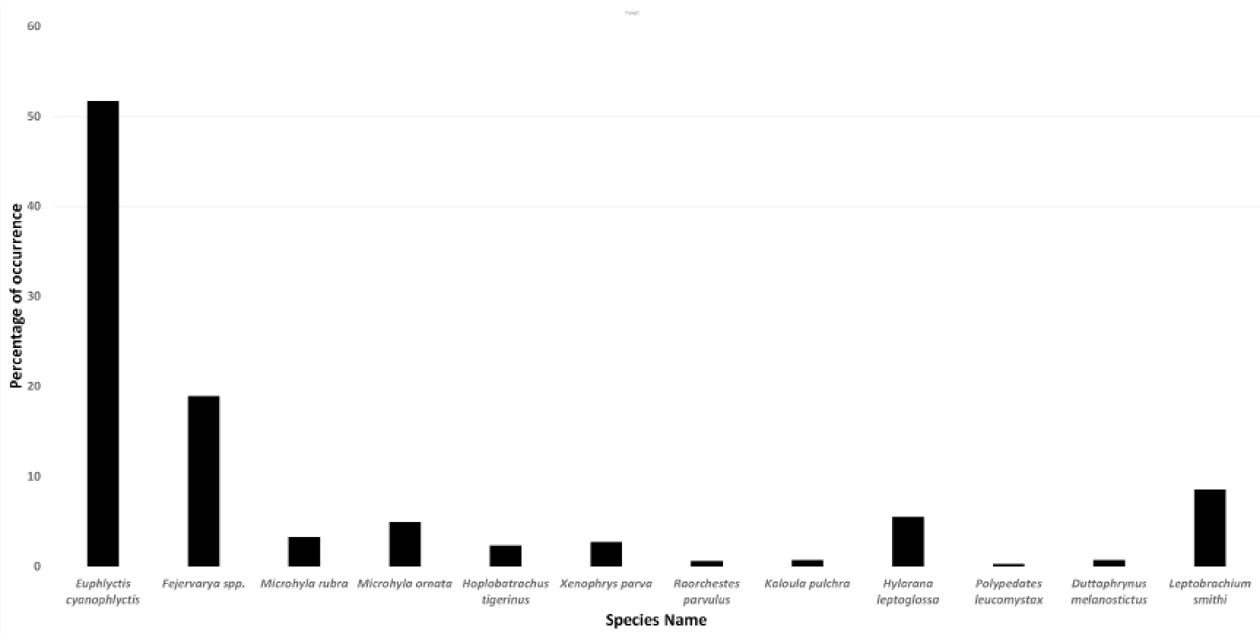

Figure 4. Percentage occurrence of amphibian species in the study plots of all the habitat types combined.

and *Raorchestes parvulus* had relatively low abundances with five, three and two records respectively during our fieldwork (Fig. 4). We found *E. cyanophlyctis* to be the most common species in the study area, recorded in 12 out of 15 transects (highest frequency of sightings, Fig. 5). *Fejervarya* spp. and *Leptobrachium smithi* were found as the second and third most commonly found species (with 83 and 35 abundance score respectively) on the transects, while we found less than 20 individuals of the remaining nine species (Fig. 5).

E. cyanophlyctis was the dominant species across all habitat types with the highest abundance and highest percentage of occurrence in each habitat type, followed by *F.* spp.; *K. pulchra* and *R. parvulus* only the forest interior (Fig. 6). All 12 amphibian species were recorded from the forest interior, whereas only seven amphibian species were found in all three habitat types (Table 1, Fig. 6). Three amphibian species (*D. melanostictus*, *K. pulchra*, and *R. parvulus*) were not recorded from forest edge, and four species (*Hopobatrachus tigerinus*, *K. pulchra*, *M. rubra*, and *R. parvulus*) were not found in the swamp area.

The evenness index showed that the highest value for the forest edge was 0.90, while for the forest interior and swamp area this was 0.82 and 0.85 respectively (Table 2). The forest edge was recorded as the lowest dominance score (0.16) as compared to those of forest interior (0.18) and swamp area (0.20; Table 2). However, the Kruskal Wallis test indicated that there was no significant differences among the three habitat types in the study area in terms of amphibian species abundance (Kruskal-Wallis χ^2 = 0.33, p-value = 0.85) (Fig. 7).

Overall, the species richness, Shannon-Wiener diversity index, and evenness index value indicated that the amphibian assemblage in the forest interior was more diverse than the other two habitat types: forest edge and swamp area (Table 2).

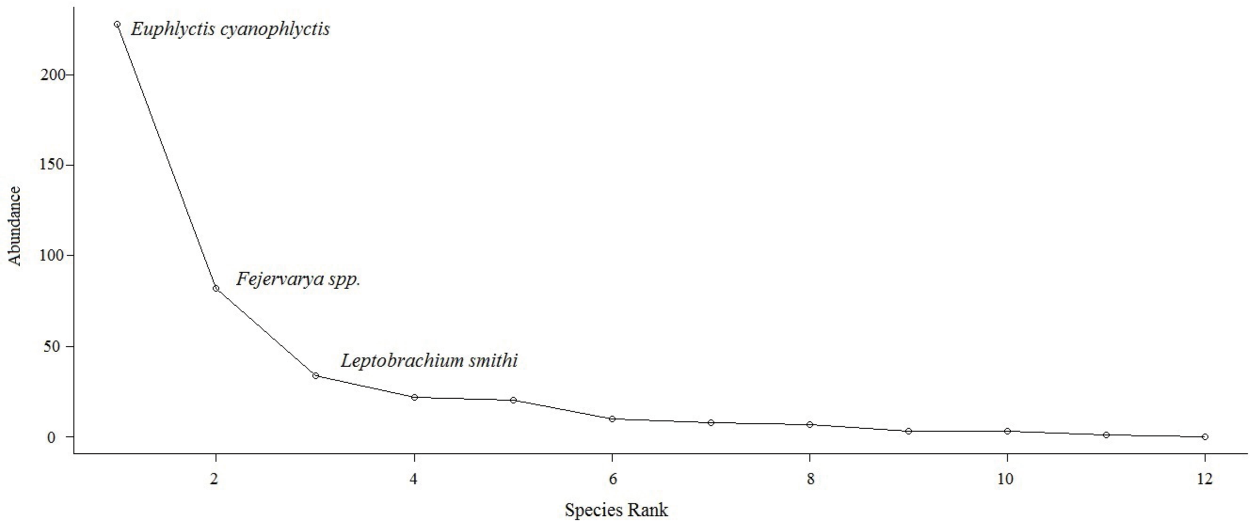

Figure 5. Rank abundance curve of amphibian species in Khadimnagar National Park, Bangladesh.

Table 2. Species diversity indices of the three habitat types of the study area.

	Forest edge	Forest interior	Swamp area
Richness	9	12	8
Individuals	40	47	41
Dominance	0.16	0.18	0.20
Shannon index	1.98	2.04	1.78
Evenness	0.90	0.82	0.86

DISCUSSION

Studies have addressed whether logging or habitat disturbance have any effect on the amphibian assemblages in different forest habitat types (Atauri & de Lucio, 2001; deMaynadier & Hunter, 1995; Dupuis & Steventon, 1999) but not many studies of this type exist for Bangladesh. As the richness of amphibians is more closely related to the abundance of certain land-use types (Atauri & de Lucio, 2001), the importance of habitat disturbances associated with logging and agriculture to the diversity, abundance, and distribution of amphibians in the KNP cannot be over-emphasised. The forest interior depicted the condition of the original forest prior to logging, while the forest edges portray the condition of adjacent agricultural land emerging from a secondary forest types. The original forest of the national park harbours all of the 12 species recorded during our study period, while the forest edge harbours 75% of them, and thus both habitat types support important richness of the amphibian species diversity. It has been suggested that many species can persist after intensive logging (Edwards et al., 2011; Gibson et al., 2011) and our current study results are consistent with this theory, and provided evidence that highly logged forests retain many of the species. It might be difficult to prove this theory in case of KNP amphibians as we do not have any reliable baseline data. The presence of *R. parvulus* and *K. pulchra* with low abundance only in the forest interior suggests that the populations might recover with better forest management practices.

Ribeiro et al. 2012 found a high number of species richness in the riparian zone (similar to the 'swamp area' of this study) compared to the non-riparian zone in an Amazonian forest. Our study results, on the other hand, indicated the opposite, with higher species richness in the forest interior compared with the forest edge and swamp area, possibly due to the year-round supply of water as well as damp habitat condition in the forest interior. The diversity of amphibians in the swamp area was low compared to the forest edge or forest interior. The swampy area of KNP has lost most of the original forest and has been taken over by teak plantations. However, swampy areas provide critical breeding habitat for amphibians, an important site to maintain healthy amphibian species diversity.

All 12 species of amphibians recorded during our study area are listed as 'Least Concern' by the IUCN Red List of Threatened Species (IUCN, 2017) in view of their wide distribution, tolerance of a broad range of habitats, and presumed large populations. These species are unlikely to be declining fast enough to qualify for listing in a more threatened category. While only *E. cyanophlyctis* is said to be fairly common in the study area, *D. melanostictus*, *K. pulchra* and *R. parvulus* are relatively rare in the park. *E. cyanophlyctis* is known to be very widespread in Bangladesh, and tolerates a high degree of habitat modification. There are no known threats to this species in other parts of Asia, e.g. Iran and Afghanistan (Khan et al., 2009). A complete explanation of the low abundance and low frequencies of occurrence of all other amphibian species at KNP remains uncertain.

H. tigerinus is a delicacy in Asia (Flores Nava, 2005), but the harvest data on this species is not available for KNP and it is difficult to estimate the exploitation pressure. van Dijk and Ohler (2009) described *R. parvulus* as a

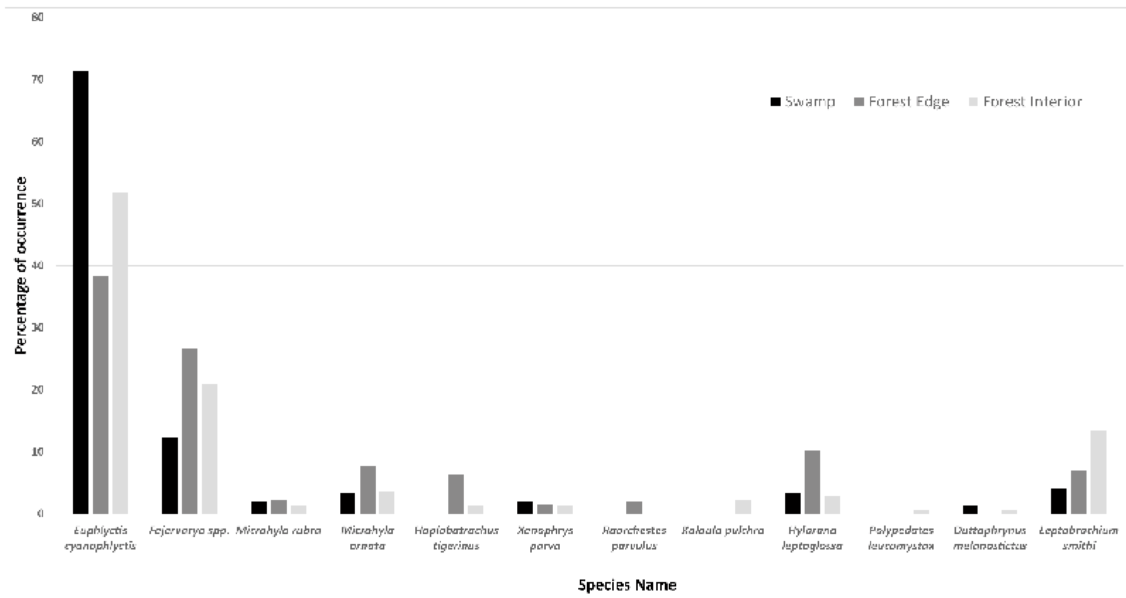

Figure 6. Percentage occurrence of amphibian species in three different habitat types in the study plots.

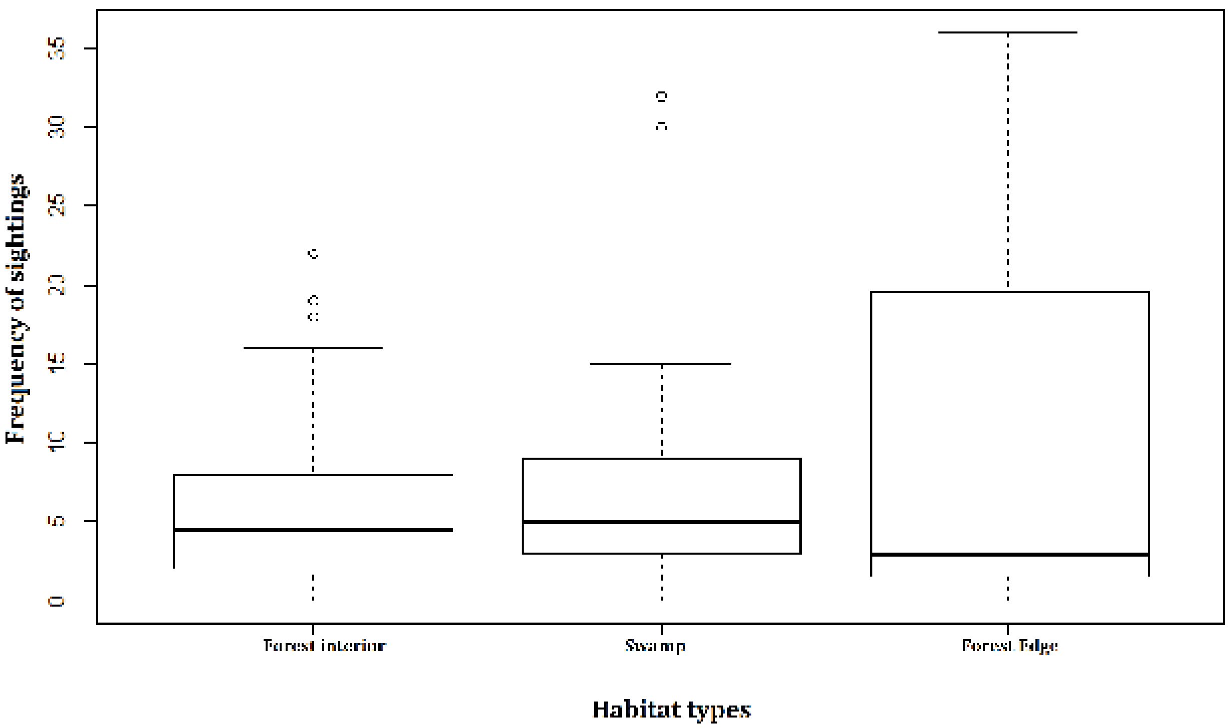

Figure 7. Amphibian species abundance among different habitat types in Khadimnagar National Park, Bangladesh.

widespread species that primarily occurs in open habitats including forest edges, however, our study suggests that the species is only found in the forest interior in KNP. *R. parvulus* is a rare species in Bangladesh with very low abundance and has been added to the country's species list very recently (Ghose & Bhuiyan, 2012).

Protected areas harbour most of the amphibian species diversity in Bangladesh (Reza 2014) even though the species diversity is generally low in KNP, one of the 19 protected areas of the country. Some potential threats to the low amphibian species diversity include, but are not limited to, anthropogenic disturbances, pollution, infectious diseases, land use conversions, and climate change. In addition, conservation management of amphibians has not been on the priority list of the forest management practices in Bangladesh. Of course, conservation decisions are not only based on a single taxonomic group, so we need to incorporate amphibians and emphasise the importance of habitat heterogeneity in any future conservation initiatives for their long-term survival in Khadimnagar National Park.

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