REPTILES & AMPHIBIANS

A Rapid Survey of Herpetofaunal Diversity in Nijhum Dwip National Park, Bangladesh

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Abstract.—The ecological effects of habitat use by herpetofaunal species vary widely and recognizing relative habitat value will help to improve conservation theory and practice in a particular landscape. To understand how different habitat uses influence diversity in riparian landscapes, we studied reptilian and amphibian assemblages across major habitats (agricultural land, forest, human habitation, and bodies of water) in Nijhum Dwip National Park, Bangladesh. We recorded 35 herpetofaunal species, 17 were encountered during surveys and 18 reported by local residents. Among observed species, the Asian Common Toad (*Duttaphrynus melanostictus*) was the most frequently seen (relative abundance 0.32). We found the greatest diversity in forest habitat, followed by agricultural land, human habitation, and bodies of water. Eight species occupied only a single habitat, whereas nine species occurred in two or more habitats. Our results show that different habitats support different species assemblages in Nijhum Dwip National Park, signifying the importance of maintaining diverse habitats.

Because herpetofauna are particularly sensitive to environmental changes (Stuart et al. 2004), documentation of community structure, function, and conservation are important. Amphibians and reptiles are found in all terrestrial habitats except those in the high Arctic and Antarctica and both groups face serious worldwide declines (Lesbarrères et al. 2014). Habitat loss, fragmentation, and alterations due to anthropogenic disturbances are major causes of herpetofaunal mortality (Van Rooy and Stumpel 1995). Only a few generalist species can adapt to those conditions whereas a majority of species are responsive to habitat quality (Ahmed et al. 2009). However, some research suggests that herpetofauna can use fragmented habitats that share some similarities with natural forested habitat (e.g., Pineda et al. 2005; Bell and Donnelly 2006; Urbina-Cardona et al. 2006), but few publications (e.g., Vallan 2002; Kanowski et al. 2006) have assessed the relative value of diverse habitats for maintaining herpetofaunal assemblages.

Protected areas (PAs) are established to conserve habitats and ecosystems and thus protect sensitive species; however, studies in southern Asia suggest that habitat loss has not been reduced by establishing protected areas (Clark et al. 2013) despite PAs harboring more species than other habitat matrices (Toral et al. 2002; Faria et al. 2007; Gardner et al. 2007a, 2007b). Land use in buffer zones of PAs influences habitat loss and fragmentation by changing patch sizes, edge effects, and altering movements of wildlife, all of which affect habitat-specific species negatively, whereas generalists might gain an advantage (Ricketts 2001; Rothermel and Semlitsch 2002; Bender and Fahrig 2005; Mazerolle and Desrochers 2005; Watling et al. 2011).

PAs in the southern coastal region of Bangladesh include national parks, sanctuaries, and game reserves (Mukul et al. 2008). Of these, Nijhum Dwip National Park is unique in terms of climatic conditions, landscape types, and location at the estuary of the Meghna Channel in the mouth of the Bay of Bengal (SRCWP 2014). Nevertheless, during the last few decades, 29% of forest loss was due to encroachment of agriculture and residences for the local population, with the expansion of cultivated areas exerting immense pressure on wildlife (SRCWP 2014). As a riparian strip, Nijhum Dwip can reduce bank erosion and maintain water quality by filtering fertilizers, pesticides, and sediments (Gilliam 1994; Vought et al. 1995). In part because the park serves as an important wintering ground for migratory birds (Nishorgo 2018), previous studies focused mainly on birds (Rabbi 2009; SRCWP 2014; Feeroz and Uddin 2015; Chowdhury et al. 2020), and herpetofaunal species were largely ignored. Herein we present the results of a rapid survey of species assemblages and how they differ in richness and diversity in various habitats.

Methods

Study area.—Nijhum Dwip National Park covers 16,352.23 ha on the Bay of Bengal in Noakhali District (Forest

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Department 2020). Its diverse habitats include forests, agricultural land, human settlements, and coastal waters (Nishorgo 2018).

Data collection.—During March 2018, we conducted Visual Encounter Surveys (VES), investing equal effort at 24 different sites, six in each of four major habitats: Agricultural land (AL), forest (F), human habitation (HH), and various bodies of water (BW) (Fig. 1). We carried out surveys while following walking trails at 0800–1130 h, 1500–1800 h, and 1900–2330 h to account for varying activity periods. In addition to searching for exposed and/or active herpetofauna, we also searched for hidden animals and sometimes located them by hearing their calls, using flashlights and headlamps after dark (Gent and Gibson 2003). We recorded the location of

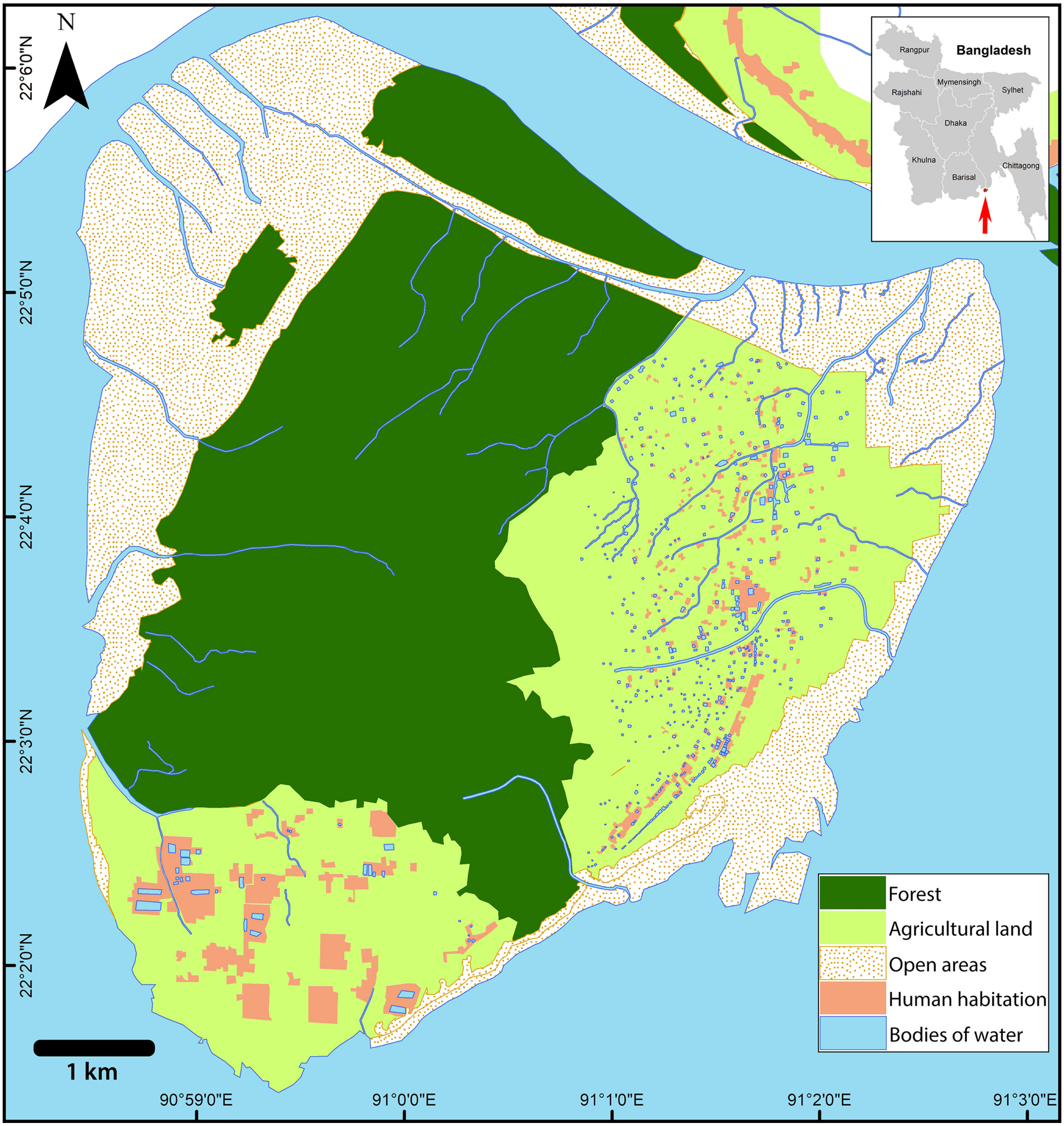

Fig. 1. Major habitats in Nijhum Dwip National Park, Bangladesh.

each sighting using a Garmin GPS unit and photographed individuals with a Canon 760D camera. We identified species by referring to Hasan et al. (2014), the most relevant field guide for the herpetofauna of Bangladesh. To supplement our surveys, we showed photographs in Hasan et al. (2014) to local residents in order to identify species that were not observed during surveys. We did not include the latter data in our analyses but did incorporate those observations in Table 1.

Table 1. Herpetofaunal species recorded in Nijhum Dwip National Park, Bangladesh, in this and previous studies. Asterisks (*) denote species recorded during the present study that were not directly observed by the authors (information collected from local residents via questionnaires). Relative abundance (RA) is listed for species directly observed during the present study. IUCN Red List status from IUCN Bangladesh (2015): CR = Critically Endangered, DD = Data Deficient, LC = Least Concern, NE = Not Evaluated, NT = Near Threatened, VU = Vulnerable.

	Species	Present study (RA)	Feeroz and Uddin 2015	SRCWP 2014	Rabbi 2009	IUCN Red List Status 2015
1	Asian Common Toad (*Duttaphrynus melanostictus*)	√ (0.32)	√	√	√	LC
2	Marbled Toad (*Duttaphrynus stomaticus*)	√ (0.01)	—	—	—	LC
3	Indian Skipper Frog (*Euphlyctis cyanophlyctis*)	√ (0.10)	√	√	—	LC
4	Kalasgram Skipper Frog (*Euphlyctis kalasgramensis*)	√ (0.02)	—	—	—	NE
5	Indian Pond Frog (*Euphlyctis hexadactylus*)	—	—	√	—	LC
6	Bangladeshi Cricket Frog (*Minervarya asmati*)	√ (0.01)	√ *Fejervarya* sp.	—	—	LC
7	Crab-eating Frog (*Fejervarya cancrivora*)	√ (0.01)	—	—	—	LC
8	Indian Bullfrog (*Hoplobatrachus tigerinus*)	√ (0.11)	√	√	√	LC
9	Treefrogs (*Polypedates* sp.)	√ *	√ *P. leucomystax*	—	√ *P. maculatus*	
10	Rice Frogs (*Microhyla* sp.)	√ *	√ *M. ornata*	—	—	
11	Common Garden Lizard (*Calotes versicolor*)	√ 0.06)	√	√	—	LC
12	Tokay Gecko (*Gekko gecko*)	√ (0.03)	√	—	—	LC
13	Spotted House Gecko (*Hemidactylus brookii*)	√ (0.10)	—	—	√	LC
14	Northern House Gecko (*Hemidactylus flaviviridis*)	√ (0.02)	√	√	√	LC
15	Common House Gecko (*Hemidactylus frenatus*)	√ (0.04)	√	√	—	LC
16	Indo-Pacific House Gecko (*Hemidactylus garnotii*)	√ (0.05)	—	—	—	LC
17	Common Skink (*Eutropis carinata*)	√ (0.08)	√	√	—	LC
18	Bowring's Supple Skink (*Subdoluseps bowringii*)	√ (0.01)	—	—	—	LC
19	Bengal Monitor (*Varanus bengalensis*)	√ (0.01)	√	√	—	NT
20	Common Water Monitor (*Varanus salvator*)	—	√	—	—	VU
21	Peacock Soft-shelled Turtle (*Nilssonia hurum*)	√ *	—	—	√	LC
22	Loggerhead Sea Turtle (*Caretta caretta*)	—	√	—	—	DD
23	Indian Roofed Turtle (*Pangshura tecta*)	√ *	√	√	—	LC
24	Indian Tent Turtle (*Pangshura tentoria*)	—	√	—	—	NT
25	Green Sea Turtle (*Chelonia mydas*)	—	√	—	—	CR
26	Olive Ridley Sea Turtle (*Lepidochelys olivacea*)	√ *	√	—	—	VU
27	Indian Flap-shelled Turtle (*Lissemys punctata*)	√ *	—	√	—	LC
28	Checkered Keelback (*Fowlea piscator*)	√ (0.04)	√	√	√	LC
29	Long-nosed Treesnake (*Ahaetulla nasuta*)	√ *	√	—	—	LC
30	Buff-striped Keelback (*Amphiesma stolatum*)	√ *	√	—	—	LC
31	Dog-faced Watersnake (*Cerberus rhynchops*)	√ *	√	√	—	LC
32	Indian Ratsnake (*Ptyas mucosa*)	√ *	√	—	√	LC
33	Smooth Watersnake (*Enhydris enhydris*)	√ *	√	—	√	LC
34	Glossy Marsh Snake (*Gerarda prevostiana*)	√ *	√	—	—	LC
35	Common Wolfsnake (*Lycodon auilcus*)	√ *	√	—	—	LC
36	Spectacled Cobra (*Naja naja*)	√ *	√	—	√	NT
37	Hook-nosed Seasnake (*Hydrophis schistosus*)	√ *	√	—	—	LC
38	Seasnake (*Hydrophis* sp.)	√ *	√ *H. cyanocinctus*	—	—	
39	Brahminy Blindsnake (*Indotyphlops braminus*)	√ *	—	—	√	LC
40	Banded Krait (*Bungarus fasciatus*)	√ *	—	—	√	LC
Total		**35**	**29**	**13**	**12**	

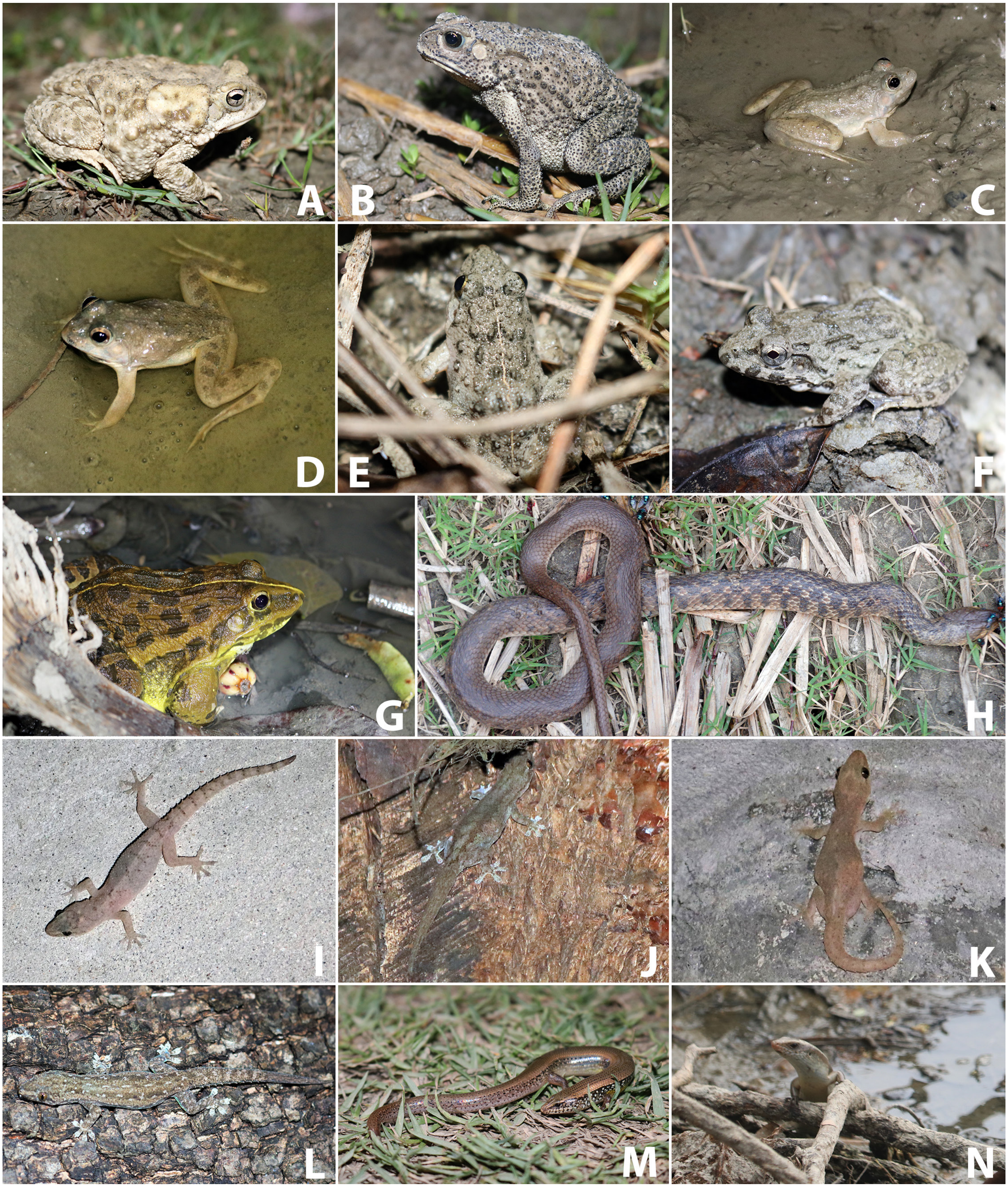

Fig. 2. Some of the herpetofaunal species observed in Nijhum Dwip National Park, Bangladesh: (A) Marbled Toad (*Duttaphrynus stomaticus*), (B) Asian Common Toad (*Duttaphrynus melanostictus*), (C) Kalasgram Skipper Frog (*Euphlyctis kalasgramensis*), (D) Indian Skipper Frog (*Euphlyctis cyanophlyctis*), (E) Bangladeshi Cricket Frog (*Minervarya asmati*), (F) Crab-eating Frog (*Fejervarya cancrivora*), (G) Indian Bullfrog (*Hoplobatrachus tigerinus*), (H) Checkered Keelback (*Fowlea piscator*), (I) Spotted House Gecko (*Hemidactylus brookii*), (J) Northern House Gecko (*Hemidactylus flaviviridis*), (K) Common House Gecko (*Hemidactylus frenatus*), (L) Indo-Pacific House Gecko (*Hemidactylus garnotii*), (M) Bowring's Supple Skink (*Subdoluseps bowringii*), (N) Common Skink (*Eutropis carinata*). Photographs by Md. Fazle Rabbe.

Data analysis.—We analyzed data obtained from the surveys to determine species richness, relative abundance, and diversity in different habitats. Species richness (S) is the number of species occurring in a particular place. Abundance of species (n) is represented as the number of individuals of a particular species. Relative abundance (hereafter RA) is calculated by dividing the number of individuals of each species by the total number of individuals of all species. We calculated the rank abundance of each species following Whittaker (1965) and diversity indices following Simpson (1949).

Results

Species composition.—We found 35 herpetofaunal species (17 encountered during surveys and 18 identified by local residents when questioned) in this study (details in Table 1 and Fig. 2). Of the 17 species observed, seven were amphibians and ten were reptiles. The numbers of species in agricultural land, forest, human habitation, and bodies of water were n = 8, 7, 8, and 5, respectively (Table 2).

Species diversity index.—The Simpson index indicated that forests had the highest diversity followed by agricultural land, human habitations, and bodies of water. Overall species evenness is low but species are more evenly distributed in different habitats according to the evenness index (Table 2).

Rank abundance and habitat use.—The Asian Common Toad (*Duttaphrynus melanostictus*) was the most abundant species with 50 individuals (RA = 0.32), followed by the Indian Bullfrog (*Hoplobatrachus tigerinus*) (RA = 0.11); the Marbled Toad (*Duttaphrynus stomaticus*), Bangladeshi Cricket Frog (*Minervarya asmati*), Crab-Eating Frog (*Fejervarya cancrivora*), and Bowring's Supple Skink (*Subdoluseps bowringii*) were the least abundant with only a single individual each (RA = 0.01) (Fig. 3). Some species were encountered in only a single habitat whereas others (presumably generalists) occurred in more than one habitat type (Fig. 4).

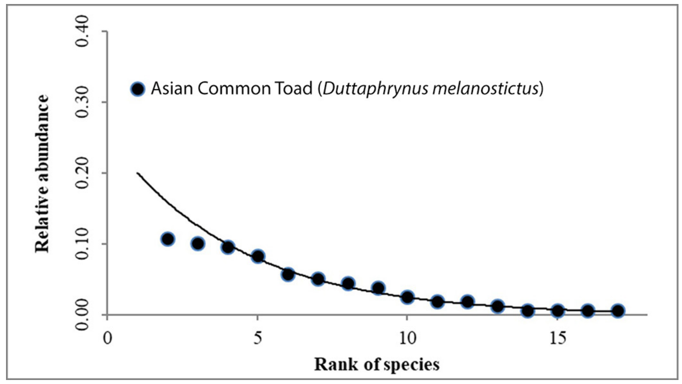

Fig. 3. Rank-abundance curve of observed herpetofauna in Nijhum Dwip National Park, Bangladesh.

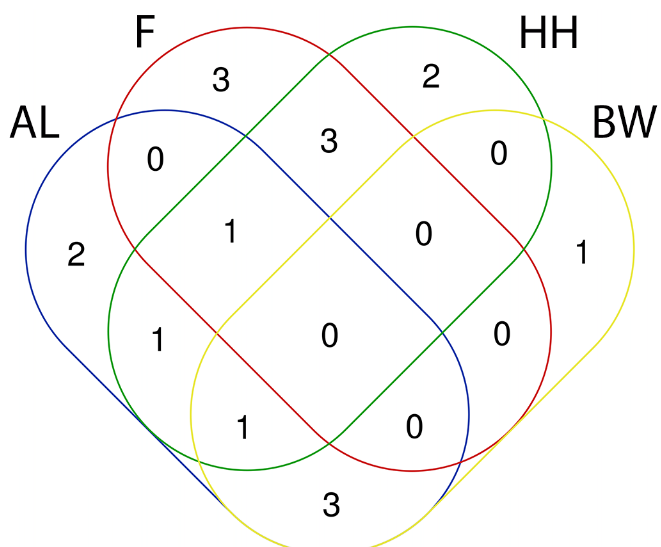

Fig. 4. The number of species in single and multiple habitats in Nijhum Dwip National Park, Bangladesh. AL = Agricultural land, F = Forest, HH = Human habitation, BW = Bodies of water.

Discussion

Detection of herpetofaunal species in Nijhum Dwip National Park has increased with additional studies (Fig. 5). However, previous surveys did not focus on herpetofauna. We suspect that the number of species will increase further with rigorous sampling. Our data also suggest that more species could be found in all habitats except agricultural land. Rice monocultures dominate Nijhum Dwip because of salinity and climate problems (SRCWP 2014), and monocultures generally support only a low diversity of generalist species. Generalist species use all types of habitats whereas the diversity of species assemblages increases in complex vegetative structures like forest (Maisonneuve and Rioux 2001).

Some studies (e.g., Gardner et al. 2007a; Rubio and Simonetti 2011) suggest that plantations can support many herpetofaunal species, but this is true only for habitat generalists. Species found in single habitats during our surveys

Table 2. Species richness, diversity, and evenness of herpetofaunal species in various habitats in Nijhum Dwip National Park, Bangladesh.

Factor	Total	Agricultural Land	Forest	Human Habitation	Bodies of Water
Species richness	17	8	7	8	5
Simpson index (D_s)	0.750	0.777	0.808	0.708	0.700
Evenness (E)	0.489	0.832	0.900	0.750	0.836

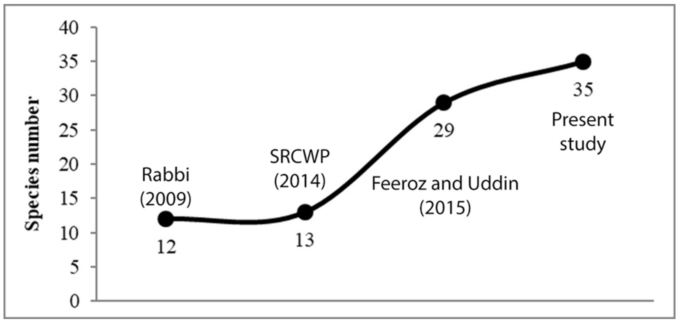

Fig. 5. Number of herpetofaunal species recorded in different studies in Nijhum Dwip National Park, Bangladesh.

include two (*Duttaphrynus stomaticus* and *Minervarya asmati*) in agricultural land, three (*Fejervarya cancrivora*, *Varanus bengalensis*, and *Gekko gecko*) in forest, two (*Hemidactylus flaviviridis* and *Subdoluseps bowringii*) in human habitation, and one (*Euphlyctis kalasgramensis*) in bodies of water. However, those species that tolerate or even thrive in conditions such as those associated with agricultural lands and human habitations are unlikely to be habitat specialists. Instead, these ecologically versatile species and other human commensals are almost certainly generalists able to adapt to the presence of humans (e.g., Henderson and Powell 1999; Powell and Henderson 2005). That their presence was limited to a single human-altered habitat is almost certainly the result of limited sampling over a relatively short period of time. Similarly, although species observed in multiple habitat types (i.e., *Duttaphrynus melanostictus* in agricultural land, forest, and human habitation, and *Eutropis carinata* in agricultural land, human habitation, and bodies of water) are almost certainly generalists, essentially all of the amphibians are likely to have been associated with bodies of water if sampling had coincided with peak breeding seasons, and other species probably would have been found in more habitats with prolonged sampling over multiple seasons.

Nevertheless, species composition, richness, and abundance are strongly affected by habitat and landscape type (Kurz et al. 2014). Generalist species can adapt easily in all types of habitat and their assemblages are not dependent on habitat types (Maisonneuve and Rioux 2001). For example, in this study, the Asian Common Toad, which was found in all habitats except bodies of water (where it certainly would occur during the breeding season), is commonly found in all types of habitat throughout Bangladesh (Hasan et al. 2014). This obvious generalist was the most abundant species in the rank abundance curve (Fig. 2). That the rank abundance curve slopes gently indicates high species evenness in various habitats (Fig. 2), whereas a steep slope would indicate low evenness as high-ranking species would have much higher abundances than low-ranking species (Magurran 2004).

Confirming our expectations, forest had the highest diversity in this study despite a lower species richness than agricultural land and human habitation (Table 2). This suggests that this habitat forms a low-contrast edge for many species and might even allow spillover of forest populations into other habitats or maintenance of independent sub-populations; bodies of water instead form sharp high-contrast edges that potentially render their inhabitants more predator-prone while resting, basking, or feeding (Kurz et al. 2014). However, the low diversity we observed in bodies of water likely reflects the period during which we sampled (see above).

Despite the limitations of rapid surveys conducted over short time periods and the fact that many amphibians and reptiles are sensitive to habitat disturbances (MacNeil et al. 2013), our results generally support the assumption that habitats surrounding remnant forests benefit in species richness by proximity to the forests (Kupfer et al. 2006) that provide a higher diversity of habitats and a higher abundance of food resources for herpetofauna than other habitats (Costa et al. 2016). Reptiles and amphibians are integral components of predator-prey dynamics (e.g., Congdon et al. 1986; deMaynadier and Hunter 1995; Campbell and Campbell 2000, 2001), influence litter decomposition (e.g., IUCN Bangladesh 2015), and can serve as seed dispersers (e.g., Kimmons and Moll 2010). Despite these critical roles,

Fig. 6. Deforestation (left) and Agro-forestry (right) in Nijhum Dwip National Park, Bangladesh. Photographs by Md. Fazle Rabbe.

30% of reptilian and amphibian species are threatened with extinction (Vié et al. 2009), with habitat loss, particularly forest conversion, regarded as a primary threat (Donald 2004; Gardner et al. 2007a). Sadly, despite the importance of forests in sustaining the biotic diversity in Nijhum Dwip National Park, we observed an ongoing range of threats to the integrity of the remaining forest in the park (Fig. 6). Effective management must address these anthropogenic threats or the viability of the park as a reservoir of biotic diversity will cease.

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Literature Cited

Ahmed, F.A., A. Das, and S.K. Dutta. 2009. *Amphibians and Reptiles of Northeast India. A Photographic Guide*. Aaranyak, Guwahati, India.

Bell, K.E. and M.A. Donnelly. 2006. Influence of forest fragmentation on community structure of frogs and lizards in northeastern Costa Rica. *Conservation Biology* 20: 1750–1760. https://doi.org/10.1111/j.1523-1739.2006.00522.x.

Bender, D.J. and L. Fahrig. 2005. Matrix spatial structure can obscure the relationship between inter-patch movement and patch size and isolation. *Ecology* 86: 1023–1033. https://doi.org/10.1890/03-0769.

Campbell, K.R. and T.R. Campbell. 2001. The accumulation and effects of environmental contaminants on snakes: A review. *Environmental Monitoring and Assessment* 70: 253–301. https://doi.org/10.1023/a:1010731409732.

Campbell, K.R. and T.R. Campbell. 2000. Lizard contaminant data for ecological risk assessment. *Review of Environmental Contamination and Toxicology* 165: 39–116. https://doi.org/10.1007/978-1-4612-1172-3_2.

Chowdhury, S.U., M. Foysal, O. Shahadat, N.U. Prince, S. Mohsanin, and M.T. Islam. 2020. Globally threatened shorebirds of Nijhum Dwip National Park and management implications. *Wader Study Group Bulletin* 127: 244–251. http://dx.doi.org/10.18194/ws.00202.

Clark, N.E., E.H. Boakes, P.J. McGowan, G.M. Mace, and R.A. Fuller. 2013. Protected areas in South Asia have not prevented habitat loss: A study using historical models of land-use change. *PloS ONE* 8: e65298. https://doi.org/10.1371/journal.pone.0065298.

Congdon, J.D., J.L. Greene, and J.W. Gibbons. 1986. Biomass of freshwater turtles: A geographic comparison. *American Midland Naturalist* 115: 165–173. https://doi.org/10.2307/2425846.

Costa, A., M. Posillico, M. Basile, and A. Romano. 2016. Conservation of herpetofauna as a function of forestry. *Italian Journal of Agronomy* 11: 38–41.

deMaynadier, P.G. and M.L. Hunter, Jr. 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. *Environmental Reviews* 3: 230–261. https://doi.org/10.1139/a95-012.

Donald, P.F. 2004. Biodiversity impacts of some agricultural commodity production systems. *Conservation Biology* 18: 17–37. https://doi.org/10.1111/j.1523-1739.2004.01803.x.

Faria, D., M.L.B. Paciencia, M. Dixo, R.R. Laps, and J. Baumgarten. 2007. Ferns, frogs, lizards, birds and bats in forest fragments and shade cacao plantations in two contrasting landscapes in the Atlantic forest, Brazil. *Biodiversity and Conservation* 16: 2335–2357. https://doi.org/10.1007/s10531-007-9189-z.

Feeroz, M.M. and M.Z. Uddin. 2015. *Biodiversity of Nijhum Dweep National Park*. Bangladesh Forest Department (BFD), Dhaka, Bangladesh.

Forest Department. 2020. *National Parks*. Government of the People's Republic of Bangladesh, Dhaka, Bangladesh. <http://www.bforest.gov.bd/site/page/7304f3af-8d7b-4fcd-a237-41b5be4de286/->.

Gardner, T.A., M.A. Ribeiro-Júnior, J.O.S. Barlow, T.C.S Ávila-Pires, M.S. Hoogmoed, and C.A. Peres. 2007a. The value of primary, secondary, and plantation forests for a Neotropical herpetofauna. *Conservation Biology* 21: 775–787. https://doi.org/10.1111/j.1523-1739.2007.00659.x.

Gardner, T.A., J. Barlow, and C.A. Peres. 2007b. Paradox, presumption and pitfalls in conservation biology: the importance of habitat change for amphibians and reptiles. *Biological Conservation* 138: 166–179. http://dx.doi.org/10.1016/j.biocon.2007.04.017.

Gent, A.H. and S.D. Gibson (eds.). 1998. *Herpetofauna Workers' Manual*. Joint Nature Conservation Committee, Peterborough, UK.

Gilliam, J.W. 1994. Riparian wetlands and water quality. *Journal of Environmental Quality* 23: 896–900. https://doi.org/10.2134/jeq1994.00472425002300050007x.

Hasan, M.K., M.M.H. Khan, and M.M. Feeroz. 2014. *Amphibians and Reptiles of Bangladesh. A Field Guide*. Arannayk Foundation Bangladesh, Dhaka, Bangladesh.

Henderson, R.W. and R. Powell. 1999. West Indian herpetoecology, pp. 223–268. In: B.I. Crother (ed.), *Caribbean Amphibians and Reptiles*. Academic Press, San Diego, California, USA.

IUCN Bangladesh. 2015. *Red List of Bangladesh Volume 4: Reptiles and Amphibians*. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh.

Kanowski, J.J., T.M. Reis, C.P. Catterall, and S.D. Piper. 2006. Factors affecting the use of reforested sites by reptiles in cleared forest landscapes in tropical and subtropical Australia. *Restoration Ecology* 14: 67–76. https://doi.org/10.1111/j.1526-100X.2006.00106.x.

Kimmons, J.B. and D. Moll. 2010. Seed dispersal by Red-eared Sliders (*Trachemys scripta elegans*) and Common Snapping Turtles (*Chelydra serpentina*). *Chelonian Conservation and Biology* 9: 289–294. https://doi.org/10.2744/CCB-0797.1.

Kupfer, J.A., G.P. Malanson, and S.B. Franklin. 2006. Not seeing the ocean for the islands: the mediating influence of matrix-based processes on forest fragmentation effects. *Global Ecology Biogeography* 15: 8–20. https://doi.org/10.1111/j.1466-822X.2006.00204.x

Kurz, D., A.J. Nowakowski, M.W. Tingley, M.A. Donnelly, and D.S. Wilcove. 2014. Forest-land use complementarity modifies community structure of a tropical herpetofauna. *Biological Conservation* 170: 246–255. https://doi.org/10.1016/j.biocon.2013.12.027.

Lesbarrères, D., S.L. Ashpole, C.A. Bishop, G. Blouin-Demers, R.J. Brooks, P. Echaubard, P. Govindarajulu, D.M. Green, S.J. Hecnar, T. Herman, J. Houlahan, J.D. Litzgus, M.J. Mazerolle, C.A. Paszkowski, P. Rutherford, D.M. Schock, K.B. Storey, and S.C. Lougheed. 2014. Conservation of herpetofauna in northern landscapes: Threats and challenges from a Canadian perspective. *Biological Conservation* 170: 48–55. http://dx.doi.org/10.1016/j.biocon.2013.12.030.

MacNeil, J., B.J. MacGowan, A. Currylow, and R.N. Williams. 2013. *Forest Management for Reptiles and Amphibians: A Technical Guide for the Midwest*. Purdue University Cooperative Extension Service, West Lafayette, Indiana, USA. https://doi.org/10.13140/2.1.1977.9842.

Magurran, A.E. 2004. *Measuring Biological Diversity*. Blackwell Publishing Ltd., Oxford, UK.

Maisonneuve, C. and S. Rioux. 2001. Importance of riparian habitats for small mammal and herpetofaunal communities in agricultural landscapes of southern Québec. *Agriculture, Ecosystems & Environment* 83: 165–175. http://dx.doi.org/10.1016/S0167-8809(00)00259-0.

Mazerolle, M.J. and A. Desrochers. 2005. Landscape resistance to frog movements. *Canadian Journal of Zoology* 83: 455–464. https://doi.org/10.1139/z05-032.

Mukul, S.A., M.B. Uddin, M.S. Uddin, M.A.S.A. Khan, and B. Marzan. 2008. Protected areas of Bangladesh: current status and efficacy for biodiversity conservation. *Proceedings of the Pakistan Academy of Sciences* 45: 59–68.

Nishorgo. 2018. *Nijhum Dwip National Park*. <http://nishorgo.org/project/nijhum-dweep-national-park/>.

Pineda, E., C. Moreno, F. Escobar, and G. Halffter. 2005. Frog, bat, and dung beetle diversity in the cloud forest and coffee agroecosystems of Veracruz, Mexico. *Conservation Biology* 19: 400–410. http://dx.doi.org/10.1111/j.1523-1739.2005.00531.x.

Powell, R. and R.W. Henderson. 2005. Conservation status of Lesser Antillean reptiles. *Iguana* 12: 62–77.

Rabbi, G.M. 2009. Documenting and registering biodiversity of Nijhum Dwip, Noakhali. M.Sc. Research Project, Department of Zoology, University of Dhaka, Dhaka, Bangladesh.

Ricketts, T.H. 2001. The matrix matters: Effective isolation in fragmented landscapes. *The American Naturalist* 158: 87–99. https://doi.org/10.1086/320863.

Rothermel, B.B. and R.D. Semlitsch. 2002. An experimental investigation of landscape resistance of forest versus old-field habitats to emigrating juvenile amphibians. *Conservation Biology* 16: 1324–1332. https://doi.org/10.1046/J.1523-1739.2002.01085.X.

Rubio, A.V. and J.A. Simonetti. 2011. Lizard assemblages in a fragmented landscape of central Chile. *European Journal of Wildlife Research* 57: 195–199. http://dx.doi.org/10.1007/s10344-010-0434-5.

Simpson, E.H. 1949. Measurement of diversity. *Nature* 163: 688. https://doi.org/10.1038/163688a0.

SRCWP (Strengthening Regional Co-operation for Wildlife Protection Project). 2014. *Nijhum Dwip National Park Management Plan 2015–2025*. Ministry of Environment and Forests (MoEF), Bangladesh Forest Department (BFD), Dhaka, Bangladesh.

Stuart, S.N., J.S. Chanson, N.A. Cox, B.E. Young, A.S.L. Rodrigues, D.L. Fischman, and R.W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* 306: 1783–1786. https://doi.org/10.1126/science.1103538.

Toral, E., P. Feinsinger, and M.L. Crump. 2002. Frogs and a cloud-forest edge in Ecuador. *Conservation Biology* 16: 735–744. https://www.jstor.org/stable/3061220.

Urbina-Cardona, J.N., M. Olivares-Pérez, and V.H. Reynoso. 2006. Herpetofauna diversity and microenvironment correlates across a pasture-edge-interior ecotone in tropical rainforest fragments in the Los Tuxtlas Biosphere Reserve of Veracruz, Mexico. *Biological Conservation* 132: 61–75. http://dx.doi.org/10.1016/j.biocon.2006.03.014.

Vallan, D. 2002. Effects of anthropogenic environmental changes on amphibian diversity in the rain forests of eastern Madagascar. *Journal of Tropical Ecology* 18: 725–742. https://doi.org/10.1017/S026646740200247X.

Van Rooy, P.T.J.C. and A.H.P. Stumpel. 1995. Ecological impact of economic development on Sardinian herpetofauna. *Conservation Biology* 9: 263–269. https://doi.org/10.1046/j.1523-1739.1995.9020263.x.

Vié, J.C., C. Hilton-Taylor, and S.N. Stuart. 2009. *Wildlife in a Changing World: An Analysis of the 2008 IUCN Red List of Threatened Species*. IUCN (International Union for Conservation of Nature and Natural Resources), Gland, Switzerland.

Vought, L.B.M., G. Pinay, A. Fuglsang, and C. Ruffinoni. 1995. Structure and function of buffer strips from a water quality perspective in agricultural landscapes. *Landscape and Urban Planning* 31: 323–331. https://doi.org/10.1016/0169-2046(94)01057-F.

Watling, J.I., A.J. Nowakowski, M.A. Donnelly, and J.L. Orrock. 2011. Meta-analysis reveals the importance of matrix composition for animals in fragmented habitat. *Global Ecology and Biogeography* 20: 209–217. https://doi.org/10.1111/j.1466-8238.2010.00586.x.

Whittaker, R.H. 1965. Dominance and diversity in land plant communities: Numerical relations of species express the importance of competition in community function and evolution. *Science* 147: 250–260. https://doi.org/10.1126/science.147.3655.250.