

Diversity and conservation threats of water birds in and around Barandabhar corridor forest, Chitwan, Nepal

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ABSTRACT

Wetlands provide major ecological services for feeding and breeding places of a large number of water birds in many parts of the globe and also play a vital role in conservation of threatened species. Wetlands in Nepal support a total of 27% of nationally threatened birds. Barandabhar forest is only one vertical (south-north) bio-corridor that links two different ecosystems, CNP and the Mahabharat hill range. Eight wetlands were selected for water birds monitoring by using area search and point count methods to explore the diversity and conservation threats of water birds in Barandabhar corridor forest. This study recorded 3664 individuals of water birds belonging to 54 species, 11 orders and 13 families in which the highest numbers of the species were belonged to order Anseriformes (17 species). The diversity of water birds in eight different wetlands showed the highest diversity in Rapti river ($H= 3.403$), followed by Beeshazari lake system ($H= 3.401$), Batulpokari lake area ($H= 3.377$) and the rest of others. The least diversity of water birds was found in Gundremandre lake ($H=2.210$). Similarly, the species dominance was more in Gundremandre lake ($D=0.189$) than Beeshazari ($D=0.046$) and Batulpokhari ($D=0.042$). The species richness in various habitats association with wetlands showed that *Shorea* forest association was utilized very less as compared to its availability. Fishermen ($r = -0.391, t = 10.6, P < 0.0001$) and livestock pressure ($r = -0.276, t = 6.63, P = 0.0009$) caused the significant negative impact on the occurrence of water birds in many parts of the study sites. The study suggests that annual flooding in the rivers (e.g., Rapti, Budhirapti and Khageri rivers), human disturbance (e.g., livestock grazing and fishing), habitat loss and degradation, declining water quality and quantity caused by eutrophication and chemical pollution are the major threats of water bird communities in Barandabhar corridor forest.

Keywords: Barandabhar, water birds, wetlands, diversity

INTRODUCTION

Nepal supports 8.87% of the global bird species due to its landscape heterogeneity (DNPWC, 2017). A total of 887 species has been recorded from Nepal, among them, 37 are globally threatened species, 19 near threatened species and 15 restricted-range species (DNPWC, 2017; IUCN, 2017). Nepal has only one endemic bird named Spiny babbler (*Turdoides nipalensis*). According to NPWC Act 1973, nine species of birds are Nationally Protected and 111 birds have enlisted in CITES category (DNPWC, 2017). More than 15% of the total birds

(130 species) have enlisted in nationally threatened category. Habitat degradation and loss are the major threats (86%) to the birds. Till date, eight species of the birds have extinct from Nepal (Baral *et al.*, 2012).

Wetlands provide a major ecosystem services for feeding and breeding places of a large number of threatened birds, mammals, reptiles, amphibians and fishes and also play a vital role in conservation of those species. Freshwater wetlands hold more than 40% bird species of the entire world and 12% of all animal species (Paracuellos, 2006). Wetlands of Asia support at least 20% of the threatened bird species including a large number of migratory and resident bird species (Kumar *et al.*, 2005; Paracuellos, 2006). Birds are the most prominent and significant component of freshwater wetland ecosystems and their presence or absence may indicate the ecological conditions or health of the wetlands (Rajpar & Zakaria, 2010). Wetland of Nepal supports a total of 40 (27%) nationally threatened birds (DNPWC, 2017). About six percentage of total global land is covered by water however Nepal occupies approximately 5% (743,500 ha) of the total area. Out of the total wetland area, 60,561 ha have been declared as the Ramsar sites for wetland preservation. Now, Nepal has ten Ramsar sites (Koshi Tappu, Beeshazari and associated lakes, Ghodaghodi Lake area, Jagadishpur Reservoir, Gokyo and associated lakes, Gosaikunda and associated lakes, Phoksundo Lake, Rara Lake, Mai Pokhari and Lake clusters of Pokhara Valley) (NLCDC, 2017).

The Chitwan National Park (CNP) harbors a spectacular bird life. The Fresh water swamp of Rapti and Khageri river flood plain stands with Sal (*Shorea robusta*) and Khair (*Acacia catechu*) vegetation and the profuse aquatic vegetation are the prime habitats for rich micro and macro living forms including many species of snails, fishes and herpetofauna. Such abundant food renewed each year by floodwater of Narayani and Rapti rivers, has been a suitable habitat for resident water birds and also attracting thousands of migratory water birds every year. More than 600 species of birds have been recorded in CNP (CNP, 2017; Bhattarai, 2012). Barandabhar forest is only one vertical (south-north) bio-corridor that links two different ecosystems, CNP and the Mahabhrat hill range. Furthermore, many popular lakes (Beeshazari lake system, declared as a Ramsar sites in 2003, Batulpokhari lake, Rhino lake, Gundremandre lake) and Rapti river, Khageri river, Budhirapti and Devanagar khola etc. supports the many wetland dependent birds and other animals. These wetlands are under grave threats due to high pressure of people from two sides (east and west) of BCF. Wetlands have been facing a serious eutrophication problem that significantly decreases the quantity (shrinking area of wetlands) and quality (physicochemical parameters) of water. Therefore, the present study was designed to explore the diversity and conservation threats of water birds in Barandabhar corridor forest (BCF).

MATERIALS AND METHODS

Study area

The Barandabhar Corridor Forest (BCF), located in between 27°34' to 27°40'N latitude and 84°21' to 84°28'E longitude is a functional bio-corridor that connects two different ecosystems of lowland Chitwan National Park and the highland Mahabharat range in central Nepal. This project area covers 166 km² area including forests, grasslands, water bodies and associated

farmlands (approx. 300 m from forest boundary) (fig. 1). The forest is regarded as the only one remaining wildlife corridor in the central Nepal that links the lowland to mid-hill ecosystems (Lamichhane *et al.*, 2016). Due to high biodiversity including birds, this corridor forest and wetlands have been delineated as the Important Bird and Biodiversity Areas (NP02-IBAs) among the 32 IBAs in Nepal (Baral & Inskipp, 2005). The East-West Highway bisects the Barandabhar Corridor Forest into two executive jurisdictions. The forest south of the highway is managed under the patronage of Chitwan National Park's buffer zone, while the northern part is under the patronage of Chitwan district forest office.

The CNP, the world heritage site, including BCF supports rare and threatened fauna such as more than 70 mammal species, 600 bird species, 56 species of herpetofauna, 156 species of butterflies and 120 species of fish (CNP, 2017). The BCF is dominated by almost monotypic stands of *Shorea robusta* and small fragments of riverine and mixed-hardwood forests (NTNC, 2003; Thapa, 2003). Majority areas of BCF comprise *Shorea* (Sal) forest, which extends up to the foothills of the Mahabharat range (Lamichhane *et al.*, 2016; Thapa, 2011). BCF is also rich in wetlands that are the pristine habitats for the wetland dependent birds. The major wetlands of this area are four rivers (Narayani, Rapti, Budhirapti, Khageri and Devnagar Khola) and lakes (Beeshazari lake- a Ramsar site, Batulpokhari, Rhino lake and association, Gundremandre lake system) (Thapa, 2011).

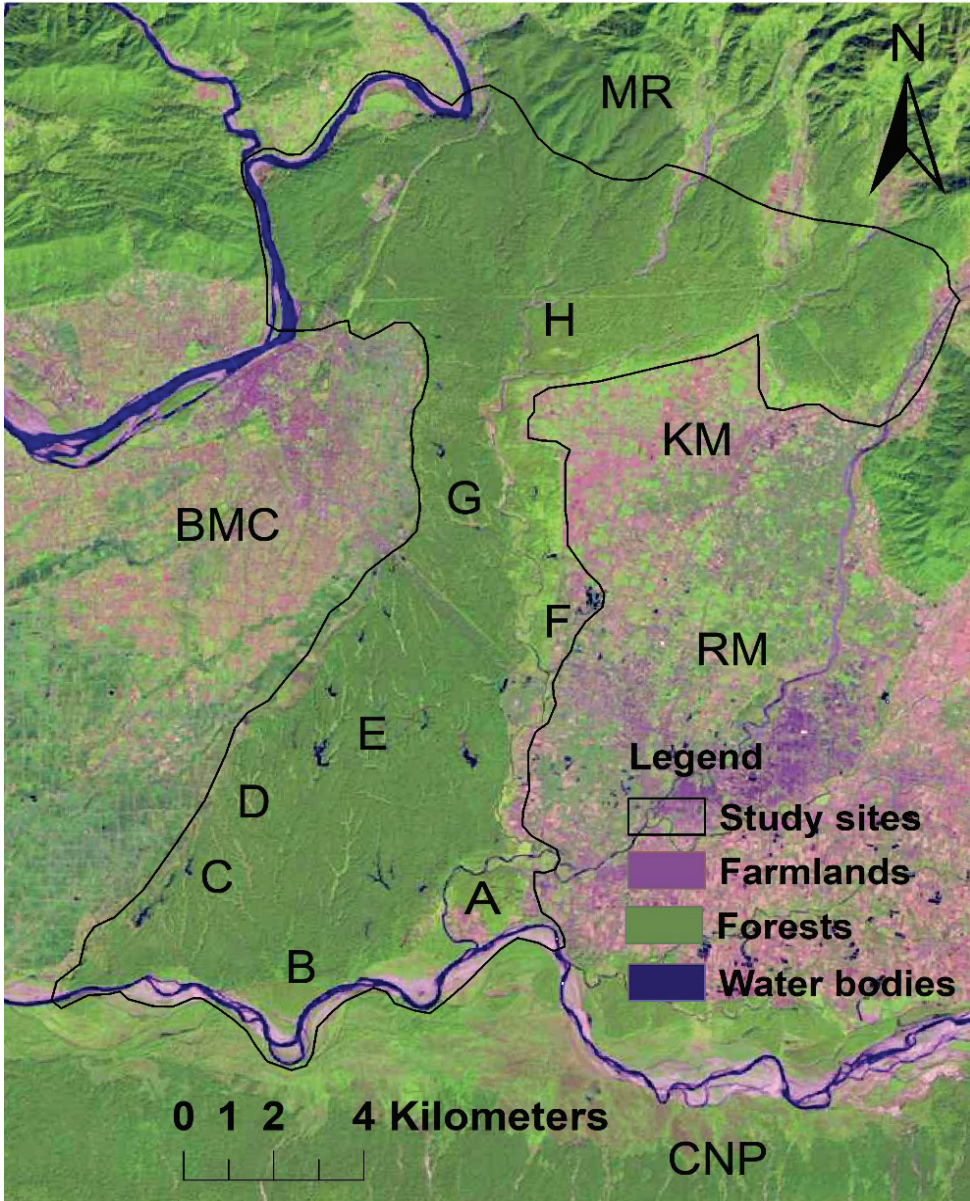


FIG. 1. Map of Barandabhar corridor forest: the study area, showing major study sites (A=Budhirapti river, B=Rapti river, C= Batulpokhari lake area, D= Devnagar khola, E= Beeshhazari river system, F= Khageri river basin, G= Rhino lake area, H= Gundremandre lake area. Here, CNP= Chitwan National Park, MR= Mahabharat Range, BMC= Bharatpur Metropolitan City, KM= Kalika Municipality, RM= Ratnanagar Municipality).

Data collection

Birds were surveyed using birding routes (BR) and area searches (AS) method for the areas considered as the hotspots of birds during November 2016 to October 2017. Eight hotspots areas (major wetlands of BCF) were identified for the monitoring of water birds (Bibby *et al.*, 2000; Dieni & Jones, 2002). The eight wetlands under this study are: Budhirapti river (A), Rapti river (from Khorsor to Ghatghain) (B), Batulpokari lake area (C), Devnagar stream (D), Beeshazari lakes system (E), Khageri river (F), Rhino lake area (G), Gundremandre lake area (H). Narayani river was excluded as this part of river is highly disturbed by Narayangarh city. In each lake, certain points were fixed at its periphery for the bird monitoring and in the rivers, a birding route was fixed and the birds were recorded at an interval of 100m, with the help of binoculars. Direct observation method ("look-see" counting method) was used to identify and record the individuals of bird species (Bibby *et al.*, 2000; Sigdel, 2009). During the survey, the number of individuals, associated habitat types, human disturbance indicators such as number of livestock grazing, number of fishermen etc. were recorded in standard field data sheet. Birds were monitored early in the morning from 6 AM to 10 AM and in the evening from 4 PM to 6 PM (Bibby *et al.*, 2000; Sigdel, 2009).

Data analysis

The collected data were entered into MsExcel and further statistical analyses were performed in S-Plus and the various indices of species diversity were determined in PAST V 3.18 (Hammer *et al.*, 2001). These diversity indices include Simpson's dominance and diversity, Shannon, Evenness indices, Jacob's Equitability index.

RESULTS AND DISCUSSION

Species diversity

This study recorded 3664 individuals of water bird belonging to 54 species, 11 orders and 13 families in Barandabhar corridor forest. The highest number of the species belonged to order Anseriformes (17 species) followed by Pelecaniformes (11 species), Coraciiformes (6 species), Gruiformes (6 species) and so on (table 1, fig. 2). Earlier studies of birds in Koshi Tappu Wildlife Reserve described a total of 485 bird species including residents and migrants that represents 61 bird families of the world. The study showed that the highest number of bird species from the Muscicapidae (44 species) followed by Accipitridae (42 species), Sylviidae (40), Corvidae (31), Passeridae (31), Anatidae (28) and Scolopacidae (20) (Baral, 2005). However, Koshi Tappu had a large number of wetland dependent birds compared to BCF. Bhattarai (2012) reported four species of Ciconiidae, Lesser adjutant stork (52 individuals); black stork (6); Woolly-necked stork (148) and Asian open bill stork (363). However, present study reported Lesser adjutant stork (72 individuals); Black stork (12); Woolly-necked stork (7) and Asian open bill stork (252). Similarly, the study on population status and diversity of wetland birds in Rapti and Narayani rivers reported 46 species of water birds including 12 species of water fowl in 2011 (Khadka *et al.*, 2017). This study recorded comparatively higher number of waterfowls. Recent survey of water birds in and around the wetlands of Chitwan National Park shows decline of 1,128 water birds compared to last survey (10,032) (BCN, 2017). A total of 36 species of water birds have been recorded in the Rupa lake, the third largest lake of

Pokhara valley that represents 19% of the total 193 wetland-dependent birds found in Nepal Kafle (2008) and Giri & Chalise (2008) recorded 39 water bird species belonging to 17 families of 5 orders at Phewa lake. Chhetry (2006) reported 98 species of wetland birds belonging to 60 genera and 18 families around the Koshi barrage area. Thapa & Saund (2012) reported a total of 77 bird species representing 8 orders and 31 families in Jagadishpur reservoir. Kumar & Gupta (2009) reported 54 species of wetland birds belonging to 36 genera and 15 families distributed in 5 orders around Kurukshetra, India. Hence, wetland of BCF supported more species of wetland bird than Rupa, Phewa and Jagadishpur Reservoir. Comparatively, high water bird diversity and abundance in BCF is mainly due to large and diverse areas of wetlands within a small area. Furthermore, the high diversity of residential and migratory water birds in BCF may reflect its corridor function, connecting lowland and highlands.

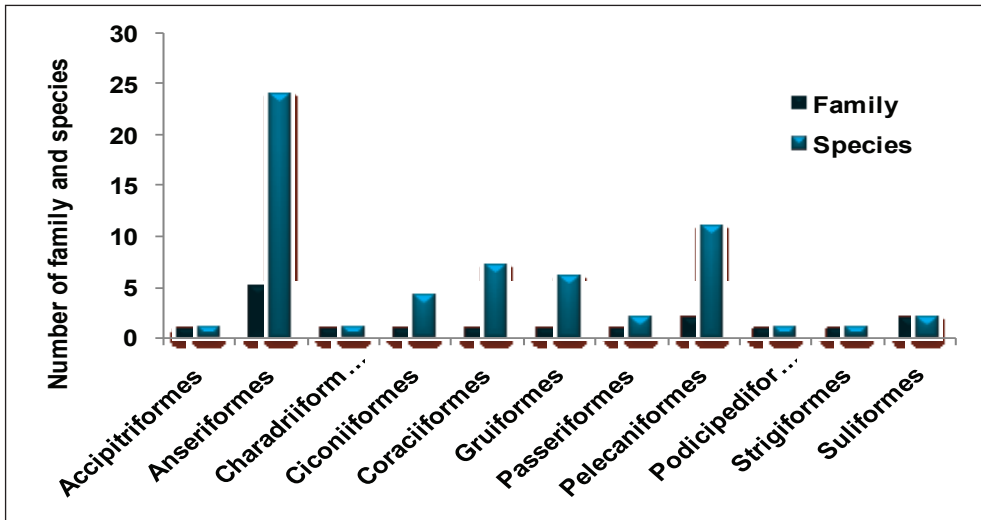


FIG. 2. Taxonomic order wise family and species richness in BCF.

TABLE 1. Checklist of water birds of BCF.

S.N.	Common name	Scientific name	Abundance	IUCN status
Order: Accipitriformes, Family: Accipitridae				
1.	Pallas's fish eagle	<i>Haliaeetus leucoryphus</i> Pallas, 1771	4	VU
2.	Grey-headed fish eagle	<i>Ichthyophaga ichthyaetus</i> Horsfield, 1821	14	NT
Order: Anseriformes, Family: Anatidae				
3.	Northern pintail	<i>Anas acuta</i> Linnaeus, 1758	143	LC
4.	Common teal	<i>Anas crecca</i> Linnaeus, 1758	122	LC
5.	Mallard	<i>Anas platyrhynchos</i> Linnaeus, 1758	76	LC

6.	Indian spot-billed duck	<i>Anas poecilorhyncha</i> Forster, 1781	121	LC
7.	Gadwall	<i>Anas strepera</i> Linnaeus, 1758	57	LC
8.	Bar headed goose	<i>Anser indicus</i> Latham, 1790	6	LC
9.	Ferruginous duck	<i>Aythya nyroca</i> Gldenstdt, 1770	10	NT
10.	Lesser whistling-duck	<i>Dendrocygna javanica</i> Horsfield, 1821	40	LC
11.	Little pratincole	<i>Glareola lactea</i> Temminck, 1820	15	LC
12.	Pheasant-tailed jacana	<i>Hydrophasianus chirurgus</i> Scopoli, 1786	30	LC
13.	Goosander	<i>Mergus merganser</i> Linnaeus, 1758	53	LC
14.	Bronze-winged jacana	<i>Metopidius indicus</i> Latham, 1790	12	LC
15.	Cotton pigmy-geese	<i>Nettapus coromandelianus</i> Gmelin, 1789	43	LC
16.	Ruddy shelduck	<i>Tadorna ferruginea</i> Pallas, 1764	188	LC
17.	Common shelduck	<i>Tadorna tadorna</i> Linnaeus, 1758	12	LC
18.	Red-wattled lapwing	<i>Vanellus indicus</i> Boddaert, 1783	54	LC
19.	Yellow-wattled lapwing	<i>Vanellus malarbaricus</i> Boddaert, 1783	81	LC
Order: Charadriiformes, Family: Scolopacidae				
20.	Green sandpiper	<i>Tringa ochropus</i> Linnaeus, 1758	158	LC
Order: Ciconiiformes, Family: Ciconiidae				
21.	Asian openbill stork	<i>Anastomus oscitans</i> Boddaert, 1783	252	LC
22.	Woolly-necked stork	<i>Ciconia episcopus</i> Boddaert, 1783	7	VU
23.	Black stork	<i>Ciconia nigra</i> Linnaeus, 1758	12	LC
24.	Lesser adjutant stork	<i>Leptoptilos javanicus</i> Horsfield, 1821	72	VU
Order: Coraciiformes, Family: Alcedinidae				
25.	Common kingfisher	<i>Alcedo atthis</i> Linnaeus, 1758	89	LC
26.	Blue-eared kingfisher	<i>Alcedo meninting</i> Horsfield, 1821	65	LC
27.	Pied kingfisher	<i>Ceryle rudis</i> Linnaeus, 1758	8	LC
28.	Black-capped kingfisher	<i>Halcyon pileata</i> Boddaert, 1783	12	LC
29.	White-breasted kingfisher	<i>Halcyon smyrnensis</i> Linnaeus, 1758	46	LC
30.	Stork-billed kingfisher	<i>Pelargopsis capensis</i> Linnaeus, 1766	9	LC
Order: Gruiformes, Family: Rallidae				
31.	Brown crane	<i>Amaurornis akool</i> Sykes, 1832	46	LC
32.	White-breasted waterhen	<i>Amaurornis phoenicurus</i> Pennant, 1769	146	LC
33.	Common coot	<i>Fulica atra</i> Linnaeus, 1758	55	LC
34.	Common moorhen	<i>Gallinula chloropus</i> Linnaeus, 1758	17	LC

35.	Purple swaphen	<i>Porphyrio porphyrio</i> Linnaeus, 1758	144	LC
36.	Ruddy-breasted crane	<i>Zapornia fusca</i> Linnaeus, 1766	87	LC
Order: Passeriformes, Family: Muscicapidae				
37.	White caped water redstart	<i>Phoenicurus leucocephalus</i> Vigors, 1831	35	LC
38.	Plumbeous water redstart	<i>Rhyacornis fuliginosus</i> Vigors, 1831	23	LC
Order: Pelecaniformes, Family: Ardeidae				
39.	Grey heron	<i>Ardea cinerea</i> Linnaeus, 1758	64	LC
40.	Intermediate egret	<i>Ardea intermedia</i> Wagler, 1829	46	LC
41.	Purple heron	<i>Ardea purpurea</i> Linnaeus, 1766	22	LC
42.	Indian pond heron	<i>Ardeola grayii</i> Sykes, 1832	146	LC
43.	Green backed heron	<i>Butorides striata</i> Linnaeus, 1758	176	LC
44.	Great white egret	<i>Casmerodius albus</i> Linnaeus, 1758	58	LC
45.	Little egret	<i>Egretta garzetta</i> Linnaeus, 1766	306	LC
46.	Cinnamon bittern	<i>Ixobrychus cinnamomeus</i> Gmelin, 1789	28	LC
47.	Yellow bittern	<i>Ixobrychus sinensis</i> Gmelin, 1789	40	LC
48.	Black-crowned night heron	<i>Nycticorax nycticorax</i> Linnaeus, 1758	76	LC
Family: Threskiornithidae				
49.	Black ibis	<i>Pseudibis papillosa</i> Temminck, 1824	32	LC
Order: Podicipediformes, Family: Podicipedidae				
50.	Black-necked grebe	<i>Podiceps nigricollis</i> Brehm, 1831	45	LC
Order: Strigiformes, Family: Strigidae				
51.	Brown fish owl	<i>Ketupa zeylonensis</i> Gmelin, 1788	25	LC
Order: Suliformes, Family: Anhingidae				
52.	Oriental darter	<i>Anhinga melanogaster</i> Pennant, 1769	23	NT
Family: Phalacrocoracidae				
53.	Great cormorant	<i>Phalacrocorax carbo</i> Linnaeus, 1758	174	LC
54.	Little cormorant	<i>Phalacrocorax niger</i> Vieillot, 1817	39	LC

(VU=Vulnerable, NT= Near Threatened, LC= Least Concern)

The species diversity of water birds in eight different study sites indicates the higher diversity in Rapti river ($H= 3.403$), followed by Beeshazari lake system ($H= 3.401$), Batulpokari lake area (Shannon's index of diversity $H= 3.377$) and so on. The least diversity was in Gundremandre lake ($H=2.21$). Due to the livestock grazing pressure and human disturbance, the species diversity in Khageri river was low in comparison to other rivers ($H= 2.926$). Similarly, the species dominance was more in Gundremandre lake (*Dominance index*= 0.1882) than

Beeshhazari ($D=0.046$, $J=0.89$), Batulpokhari ($D=0.04132$), that indicates low species diversity in Gundramadre lake (Simpson index $1-D= 0.811$, Evenness= 0.56, Jacob's equitability index= 0.764) (table 2). Similar type of study conducted by Ali *et al.* (2011) found a high species diversity of water birds ($H = 3.31$ and $1-D= 0.94$) in Mangala Dam, India. Giri & Chalise (2008) found the highest diversity of birds ($H =2.6228$) in February and lowest ($H = 1.2014$) in June in the Phewa Lake. These findings indicated that BCF possess a low species diversity of water birds compared to the high diversity of wetlands available (e.g., rivers and lakes).

TABLE 2. Water birds species diversity and dominance indices in BCF.

Study sites	No. of species	Abundance	Dominance (D)	Simpson (1-D)	Shannon (H)	Evenness	Equitability (J)
Rapti river	50	1112	0.04763	0.9524	3.403	0.6013	0.87
Beeshhazari lake	45	999	0.04672	0.9533	3.401	0.6667	0.8935
Batulpokhari	39	552	0.04132	0.9587	3.377	0.7512	0.9219
Budhirapti	39	329	0.06969	0.9303	3.103	0.5706	0.8469
Devnagar	27	245	0.05266	0.9473	3.106	0.8271	0.9424
Gundremandre	18	133	0.1882	0.8118	2.21	0.5063	0.7645
Khageri river	22	83	0.0614	0.9386	2.926	0.8481	0.9467
Rhinolake and association	23	183	0.08615	0.9139	2.725	0.663	0.8689

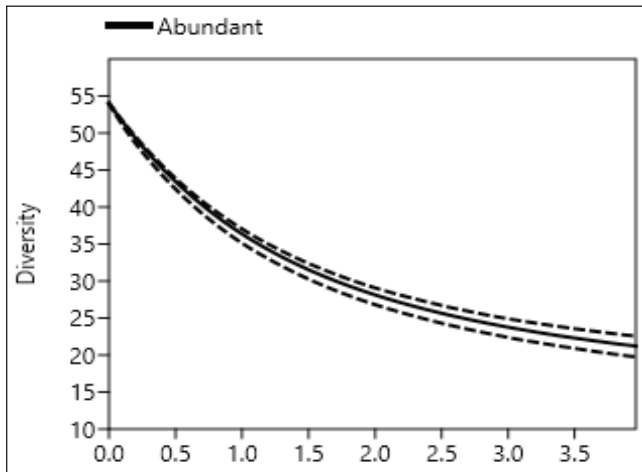


FIG. 2. Species Diversity profiles of water birds in BCF at 95% confidence interval.

Species accumulation curves.

Arrhenius (1921) was the first to fit a model to data on the increase in number of species with increased size of the area sampled. It is important to distinguish between the species–area relationships (Ugland *et al.*, 2003). An ordinary count of number of species in a sample is usually a biased underestimate of the true number of species in the environment, simply because increasing the sampling effort (through counting more individuals, examining more sampling units, or sampling a larger area) inevitably increases the number of species (Gotell & Chao, 2013). This effect illustrated in a species accumulation curve, in which x-axis is the number of individuals recorded and y-axis is the number of species observed or species richness.

The water bird species accumulation curve was exponentially increased up to 1,000 individuals, slowly increased up to 1,500 individuals, very slowly increased up to 3,664 (fig. 3). The encounter rates of rare and the endangered species of water birds were very low, where common species were encountered very high. The curve continues to rise as more individuals are sampled, but the slope becomes shallower because progressively more sampling effort is required to detect the rare species (Tokeshi & Schmid, 2002). These imperial findings suggest that BCF harbors critical populations of many rare and threatened water birds.

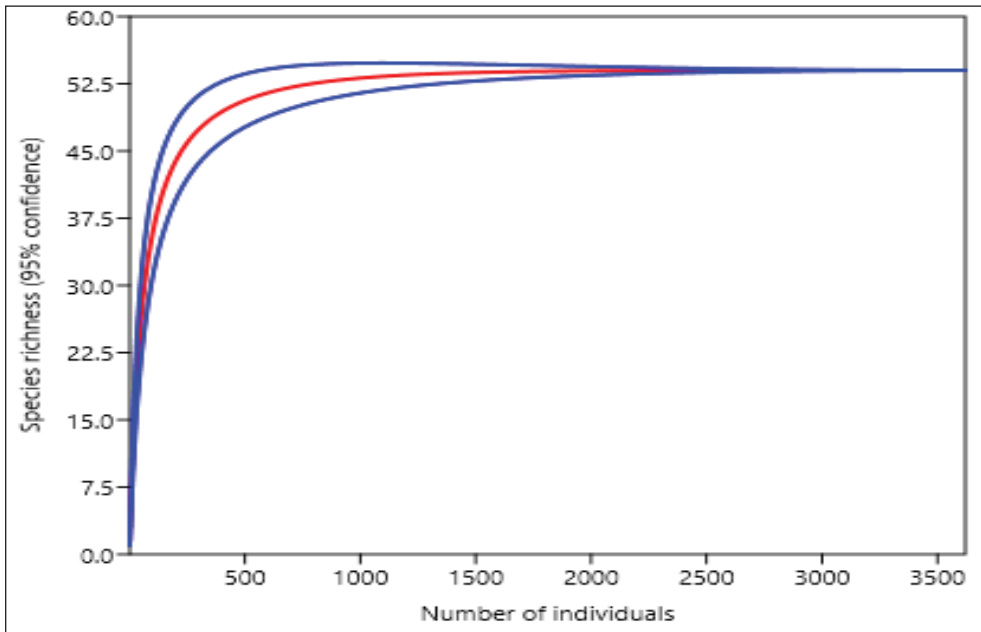


FIG. 3. Species accumulation curve. The curve was generated by assuming an assemblage of 54 species whose relative abundances were created from a broken stick distribution (Tokeshi & Schmid, 2002). The x-axis is the number of individuals and the y-axis is species richness at 95% confidence limit. The shape of this species accumulation curve is typical, it rises rapidly at first as the common species are initially encountered, and then continues to rise very slowly, as much more sampling is needed to encounter all of the rare species.

Habitat association of water birds

More than 80% area of BCF is covered by *Shorea* forest and rest of the area includes grasslands, riverine forest, mixed forest and wetlands. The peripheries of Beeshazari lake, Batulpokhari lake and Rhino lake are mainly surrounded by *Shorea* forest. Khageri, Budhirapti and Gundremandre lake areas are associated with riverine type of vegetation while most parts of Rapti river are associated with sal forest, riverine forest and tall grassland. The correlation matrix obtained from principal component analysis (PCA) of species richness in different habitats showed that sal forest was utilized very less as compared to its availability. However, riverine forest, open areas and farmlands were positively selected by the water birds (fig. 4). Present study confirms the role of habitats such as water bodies and vegetation cover affect the abundance of water bird (Ramachandran *et al.*, 2017). Avian species diversity in different habitat types in and around North Nandi Forest, Kenya reported a significant difference in bird abundance across the four habitats (indigenous forest, disturbed forest, plantation forest and farmlands: $F = 15.141$, $P \leq 0.05$) (Bett *et al.*, 2016) similar to our study (Welch $F=907.9$, $df = 1813$, $p < 0.0001$).

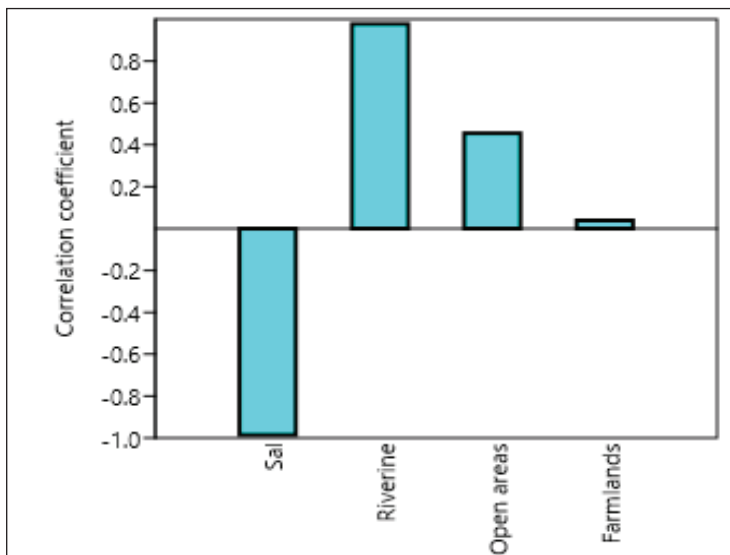


FIG. 4. Correlation coefficients obtained from PCA of species distribution in various habitats showed the various ranges of strength of preference with different habitat associations of wetlands.

Conservation threats of water birds in BCF

Present study found three globally vulnerable species *Haliaeetus leucoryphus* (Pallas's fish eagle), *Leptoptilos javanicus* (Lesser adjutant stork), *Ciconia episcopus* (Woolly-necked stork) and three globally near-threatened species *Ichthyophaga ichthyæetus* (Grey-headed fish eagle), *Aythya nyroca* (Ferruginous duck), and *Anhinga melanogaster* (Oriental darter) (IUCN, 2017; BCN & DNPWC, 2011; Bhattarai, 2012). Pallas's fish eagle and Lesser adjutant stork

enlisted in vulnerable category since 1994 and Woolly-necked stork enlisted in same category since 2014 (IUCN, 2017). Similar type of study by Sharma (2004) recorded twelve nationally threatened species of birds including two critically endangered birds in the Barandabar corridor forest. Baral & Inskipp (2009) found a total of 15 globally threatened and 13 near-threatened species in Suklaphanta Wildlife Reserve and BCN & DNPWC (2011) described 149 bird species (17%) of Nepal's birds as nationally threatened that included 61 critically endangered species, 38 endangered and 50 vulnerable.

Fishing, livestock grazing pressure and human disturbances were the major threats to the water birds in this area. The abundance of species was greatly affected by the number of fisherman presence for collection of prey species of water birds (e.g., fishes, snails etc.). The relationship between number of fishermen and abundances of water bird species showed negative relationship ($r = -0.3907$, $t = 10.6$, $P < 0.0001$) (fig. 5). Likewise, number of livestock present in the habitats of water birds caused significantly negative effect on species richness and abundance of water birds ($r = -0.276$, $t = 6.63$, $P = 0.0009$) (fig. 6). Zou *et al.* (2017) found the great influence of microhabitat condition including forage availability in human dominated wetlands (e.g., human disturbance, habitat alternation and degradation, mudflats) for water birds especially winter visitors in Caisang Lake particularly at other Ramsar wetlands. Similar problems also occurred in Rapti river flood plains (e.g., loss of a large patch of riverine forest and grasslands) and Beeshazari lake system (e.g., depleted Satrahazar and Sorahazar lakes). Many water birds including migratory species are now threatened with extinction due to past and ongoing destruction, and degradation of wetlands (Szabo & Mundkur, 2017). Recent studies show that climate change and invasive species are two major drivers of ecosystem degradation and biodiversity loss (Lamsal *et al.*, 2017).

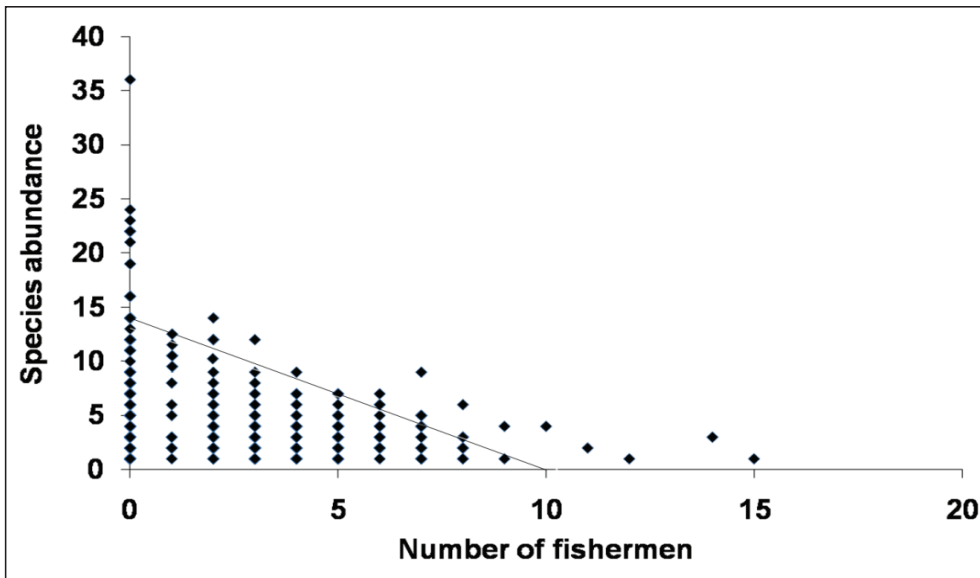


FIG. 5. Effect of fishermen on the occurrence and abundance of water birds in BCF ($r = -0.3907$, $t = 10.6$, $P < 0.0001$).

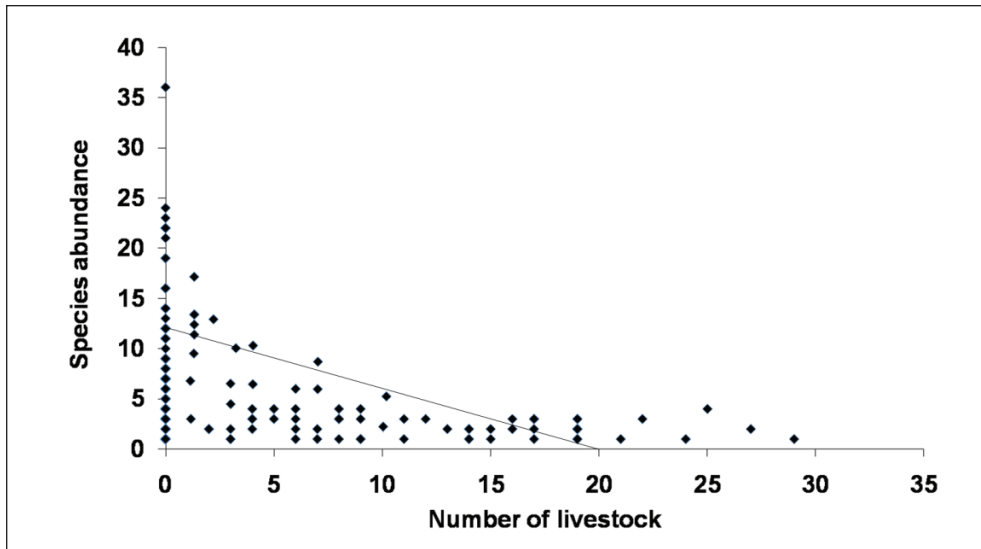


FIG. 6. Effect of livestock pressure on the occurrence and abundance of water birds in BCF ($r = -0.276$, $t = 6.63$, $P = 0.0009$).

This study recorded 3664 individuals of water birds belonging to 11 orders, 13 families and 54 species in Barandabhar corridor forest. Among them, the highest number of species were belonged to order Anseriformes (17 species) followed by Pelecaniformes (11 species), Coraciiformes (6 species), and Gruiformes (6 species). This study found three globally vulnerable water birds Pallas's fish eagle (*Haliaeetus leucoryphus*), Lesser adjutant stork (*Leptoptilos javanicus*) and Woolly-necked stork (*Ciconia episcopus*) together with near-threatened Grey-headed fish eagle (*Ichthyophaga ichthyaetus*), Ferruginous duck (*Aythya nyroca*), and Oriental darter (*Anhinga melanogaster*). The water bird diversity in eight different wetlands indicating the highest diversity in Rapti river ($H= 3.403$), followed by Beeshazari lake system ($H= 3.401$), Batulpokari lake area ($H= 3.377$) and others. The least species diversity of water birds was found in Gundremandre lake ($H=2.21$). Similarly, the species dominance was more in Gundre Mandre lake ($Dominance\ index= 0.1882$) than Beeshazari ($D=0.046$) and Batulpokhari ($D=0.04132$). The species richness in different habitat association with wetlands showed that *Shorea* forest association was utilized very less as compared to its availability. Human (fishermen: $r = -0.3907$, $t = 10.6$, $P<0.0001$) and livestock pressure ($r = -0.276$, $t = 6.63$, $P = 0.0009$) caused the significant impact on the occurrence of water birds in many parts of the study sites. The study found annual flooding in the rivers (e.g., Rapti, Budhirapti and Khageri rivers), human disturbance (e.g., livestock grazing and fishing), habitat loss and degradation, declining water quality and quantity caused by eutrophication and chemical pollution are the major drivers of water bird communities in BCF. Therefore, strict habitat protection, regular monitoring, adaptive management of wetlands in both protected and unprotected areas and preservation and restoration of wetlands with minimum human pressure are essential for maintaining functional wetland ecosystems and combating declines

of wetland-dependent residential and migratory water birds in BCF.

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