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ARTICLE

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Factors affecting diversity and distribution of threatened birds in Chitwan National Park, Nepal

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Abstract: Factors affecting diversity and distribution of globally threatened birds were studied by dividing Chitwan National Park (CNP) into five study blocks consisting of 17 birding routes. CNP provides major habitats for the feeding and breeding of a large number of migratory birds from many parts of the globe and also plays a vital role in the conservation of threatened species. We recorded a total of 437 individuals of globally threatened birds belonging to 19 species of nine families and eight orders. There was considerable variation (F=2.94, df=44.43, p=0.05) in species diversity of threatened birds in different study blocks: the highest diversity was in Block E (Pithauli, Amaltari, and Narayani Island area; H=2.108), followed by Block C (Kasara to Sukibhar area; H=2.047), Block B (Barandabhar Corridor Forest; H=2.033), Block A (Khagendra Malli, Kathar, Sauraha to Old Padampur; H=1.744), and Block D with the least diversity (Madi area; H=1.69). The higher dominance index was found in blocks A (D=0.2407) and D (0.2361) compared to other blocks. The lower diversity of threatened birds was reported in those blocks (A & D) located nearer to human settlements that experienced higher disturbance. Presence of livestock and people caused significantly negative effects on species richness and abundance of threatened birds, mainly in Block A. Distance from roads and villages also had a negative effect on the diversity and abundance of most of the threatened birds. This study suggests that human disturbance caused a significantly negative impact on the presence, distribution, diversity, and abundance of threatened birds in CNP and adjoining areas.

Keywords: Abundance, anthropogenic disturbance, avian diversity, distribution.

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Author Contribution: JNA & BPB designed and carried out research, BPB & TBT performed analyses. JNA, BPB & TBT wrote the paper.

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INTRODUCTION

Nepal, the mountainous country, supports a total of 886 species of birds (8.87% of the global bird species) including 39 globally threatened species, 31 Near Threatened species, and one endemic species, the Spiny Babbler *Turdoides nipalensis* (Grimmett et al. 2016; Inskipp et al. 2016; BCN & DNPWC 2018). The National Red List Series for birds of Nepal shows nearly 19% of Nepal's birds (168 species) as listed in the nationally threatened category. Among them are 68 (40%) Critically Endangered, 38 (23%) Endangered, and 62 (37%) Vulnerable species. Besides this, 62 species are also listed as Near Threatened (Inskipp et al. 2017). Nine species of birds are nationally protected according to the National Parks and Wildlife Conservation Act-NPWC Act 1973 (DNPWC 1973) and 113 birds are listed in CITES category (DNPWC 2018). Eight species (1% of the total threatened) are regionally extinct from Nepal and were not reported since the 19th Century; also, 22 species (2.5% of the total) are considered Data Deficient (Inskipp et al. 2016; DNPWC 2018).

Grasslands, wetlands, and forests not only provide feeding and breeding sites for a large number of threatened birds, mammals, reptiles, amphibians, fish, and invertebrates but also play a vital role in their conservation and in meeting the needs of the local people residing near those areas. Habitat degradation and loss are the major threats (86%) to birds (Baral et al. 2013). Fifty-five per cent of grassland specialist birds of lowland Nepal are threatened, followed by 25% of wetlands birds and 24% of tropical and subtropical forest birds (Inskipp et al. 2016). Most of the protected areas of Nepal face human and livestock pressure, creating continuous disturbance of various levels to wildlife (Bhattarai et al. 2017). Modernization in agriculture practices such as heavy use of pesticides in crops and exotic crop varieties, development activities such as roads and industries, eutrophication of lakes and ponds, succession in grasslands, and the introduction of exotic and alien plant species such as *Mikania micrantha, Chromolena odorata, Lantana camara,* and *Parthenium hysterophorus* are considered as the major threats to wildlife habitats. Shrinking of grasslands due to forest encroachments is the major threat to grassland-dependent birds (Chhetri & Shakya 2016)

Chitwan National Park (CNP) harbours spectacular birdlife due to high habitat heterogeneity (Bhattarai & Kindlmann 2012). The freshwater swamp of Reu, Rapti, and Narayani river floodplain stands with Sal *Shorea robusta,* Sissoo *Dalbergia sissoo*, and Khair *Acacia catcheu* vegetation and the profuse aquatic vegetation is the prime habitat for rich micro and macro living forms including many species of snails, fish, and herpetofauna (Bhattarai 2012; CNP 2018). Such abundant food renewed annually by the floodwater of rivers is a suitable habitat for resident water birds and also attracts thousands of migratory water birds each year. The large patches of grasslands inside the park support many grassland-dependent birds as well as mammals and reptiles. More than 600 species of birds were recorded in Chitwan District in which 544 species were recorded in the CNP (CNP 2018). Wetlands face a serious eutrophication problem that significantly decreases the quantity (shrinking area of wetlands) and quality (physicochemical parameters) of water (Thapa & Saund 2012). Ecologic succession and introduction of exotic and alien species of plants destroy the grasslands (Shrestha 2016). Therefore, the present study was designed to explore the factors associated with the distribution, diversity, and abundance of globally threatened birds of CNP.

MATERIALS AND METHODS

Study area

CNP, the world heritage site, is situated in southern central Nepal in the subtropical lowlands of the inner Terai of Chitwan, Makawanpur, Parsa, and Nawalparasi districts. It lies between 27.276–27.837 ^{0}N & 83.837 –84.770 ^{0}E, covering an area of 952.63km^{2} (CNP 2018). The area of 729.37km^{2} surrounding the park was declared a buffer zone, which consists of forests and private lands including cultivated lands (CNP 2018). The park consists of a diversity of ecosystems including the Churia Hill forests, ox-bow lakes (Tal, including Beeshazari, the Ramsar site; Ministry of Forests and Environment 2018), and the floodplains of the Rapti, Reu, and Narayani rivers (Fig. 1). Churia Hills in Chitwan are characterized by steep, sloppy, and dissected topography, which is made by sedimentary rocks (sandstone, mudstone, and conglomerates). The Churia Hills rise slowly towards the east from 150m to more than 850m and are covered by CNP (DMG 2007; CNP 2018).

The Chitwan Valley consists of tropical and subtropical forests. The CNP is mainly covered by various types of forests (80%) including Sal forest, succession forest, and mixed hardwood forest. Besides, there are grasslands (12%), water bodies (3%), and exposed surface and floodplain (5%) (Thapa 2011). The riverine forests consist of Khair *Acacia catechu*, Sissoo *Dalbergia*

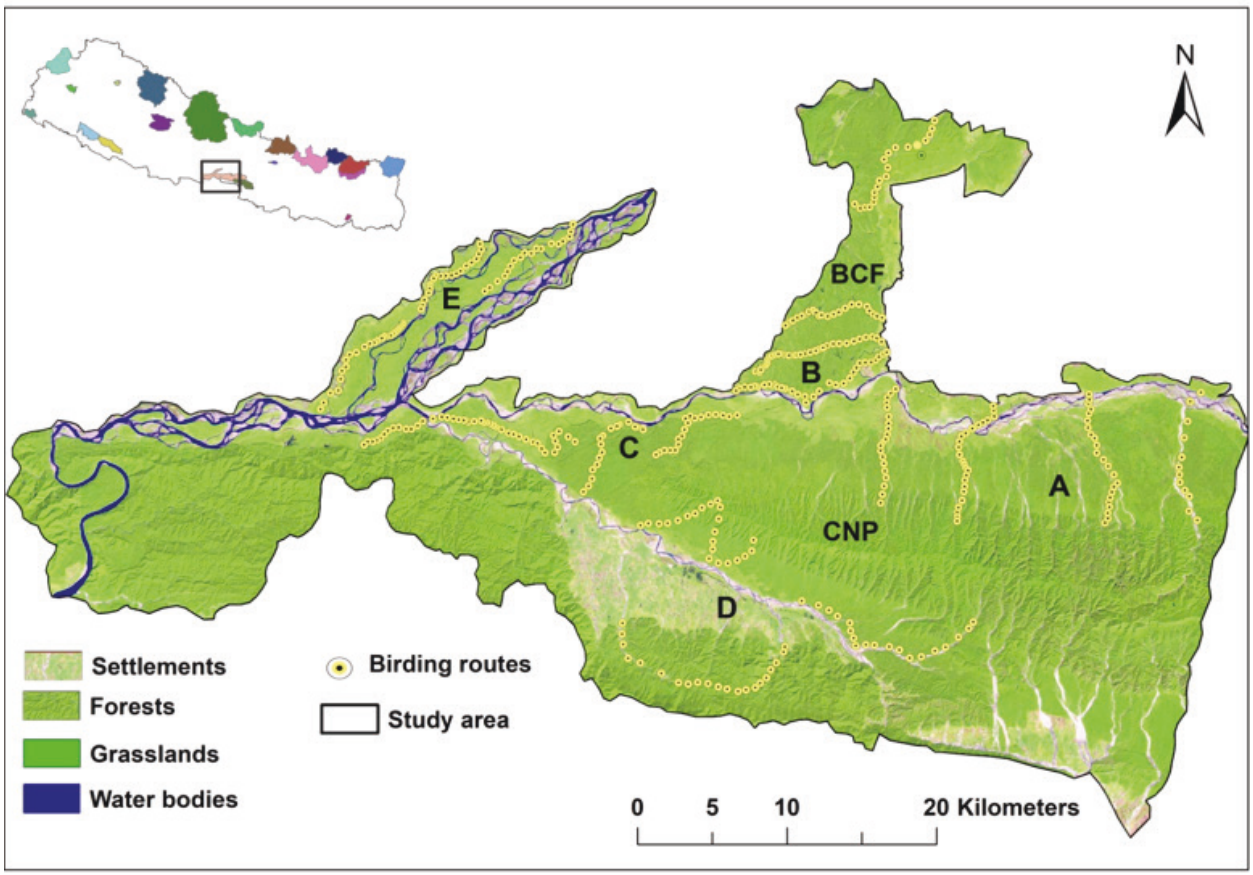

Figure 1. The study area in Chitwan National Park, Nepal, showing major landcover characteristics including study blocks and birding routes. A - Block A (Khagendramalli to Sauraha and old Padampur), B - Block B (Barandabhar Corridor Forest), C - Block C (Kasara to Golaghat), D - Block D (Madi and Someshor hill area), E - Block E (Narayani Island and Pithauli area).

sisoo, and Simal *Bombax ceiba*. There are more than 50 different types of grasses including the elephant grass *Saccharum* spp., renowned for its immense height (Lamichhane et al. 2016; CNP 2018). The CNP supports rare and threatened fauna with more than 68 species of mammals, 544 birds, 56 reptiles and amphibians, and 126 fish (CNP 2018).

Block A: Khagendramalli to Sauraha and old Padampur

This block is located in the eastern part of CNP. The area is mainly covered by riverine forest and grassland. The old Padumpur area is now covered with elephant grass *Saccharum* spp. and water holes, the key habitat of many grassland and wetland birds. The floodplain of the Rapti River near Sauraha is covered with short grass and riverine forest.

Block B: Barandabhar Corridor Forest area

Barandabhar Corridor Forest (BCF) is only the bio-corridor that connects CNP with the Mahabharat range. Most of the area of BCF is covered with Sal forest. This area is rich with lakes including the biologically significant Ramsar site Beeshhazari lake systems, Batulpokhari Lake, Rhino Lake, Tiger Lake, and Ratomate Lake and associates, and small streams such as Rapti, Budi Rapti, Khageri, and Devnagar Khola. The floodplain of Rapti is covered with grassland and riverine forest. Small grass patches are present inside the Sal *Shorea robusta* forest, which provide significant habitats for wildlife.

Block C: Kasara to Golaghat

This block is located in the central part of CNP. Most of the area of this block is covered with Sal forest associated with small patches of grasslands and lakes. The floodplain of the Rapti River is covered with riverine forest. Sukibhar is the largest grassland that provides key habitat for grassland-dependent animals. Tamor Tal, Lami Tal, and Devi Tal and associates provide good shelter for wetland-dependent animals.

Block D: Madi and Someshwar hills

Madi Valley is the floodplain of Reu River, Baghai,

and other small streams. The Someshwor Hill area has Sal forest. This is the holy hill. The floodplain of the Reu River is covered with grassland and provides shelter and feeding and breeding grounds for many grassland specialist birds. Most of the area of this block is covered with Sal *Shorea robusta* forest.

Block E: Narayani Islands and Pithauli

This block is located in the southern part of CNP. This area is mainly covered with the Narayani floodplain and islands. Most of the island is covered with grassland and riverine forest. Pithauli is a buffer zone area of CNP. This area is famous for vultures and other wetland birds. A locally managed vulture restaurant is also located in this block, which provides safe feeding sites for vultures. The habitat of individual birds where they performed their activities such as feeding, nesting, roosting, and breeding was recorded.

Data collection

Threatened birds were recorded by direct observation method ("look-see" counting method) and scanning was used to identify and record the individuals of bird species in birding routes (BR) including the area searches (AS) method for areas considered as bird hotspots between January and December 2017. By including both summer (May–June) and winter (November–January) seasons, the chances of recording migrant species were maximized (Bibby et al. 2000; Dieni & Jones 2002; Siegel 2009; Basnet et al. 2016; Katuwal et al. 2016; Jia et al. 2018). The study area was divided into five different study blocks where 17 birding routes were established. There were four birding routes in Block A, four in Block B, three in Block C, three in Block D, and three in Block E (Fig. 1). In each birding route, the birds were observed at an interval of 100m in all directions and up to the height of the trees with the help of binoculars. The birds were observed by two observers in one birding route, then the list was combined as a single list. We spent 10min on each point. We used two sets of field guide books for birds (Grimmett et al. 2016), GPS (Garmin eTrex 35 and eTrex10), four binoculars (Nikon 20x50), and digital cameras (Nikon Coolpix B700, with 60x zoom) for two observers. All birds seen were recorded and identified using field guide books. Images were taken for identification and documentation. During the field study, most of the birding routes of the blocks were covered on foot for the monitoring of birds. During the survey, the number of individuals, associated habitat types, and human disturbance indicators such as distance to roads (DiR), distance to villages (DiV), number of livestock grazing (LivG), number of people including tourists (Peop), collection of prey animals (fish, snails, crabs) of birds (PrCo), and collection of chick or eggs of birds (ChEc) were recorded in standard field data sheets. Birds were monitored early in the morning from 7.00h to 11.00h and in the evening from 14.00h to 17.00h (Bibby et al. 2000; Siegel 2009; Katuwal et al. 2016; Kandel et al. 2018).

Data analysis

The normality test was performed before calculating the diversity indexes to identify whether the data were normally distributed or not. The various indices of species diversity were calculated in PAST V 3.18 (Hammer et al. 2001).

The diversity of the recorded animals was analysed by using different diversity and dominance indexes such as Shannon's index and Simpson index. A diversity index is a mathematical measure of species diversity in a community.

Shannon's index: The Shannon diversity index (*H*) is commonly used to characterize species diversity in a community (Shannon 1948).

Shannon Index (H) = $\sum_{i=1}^{s} p_i \ln p_i$

where p_i is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species.

Simpson index: The Simpson index is a dominance index because it gives more weight to common or dominant species. In this case, a few rare species with only a few representatives will not affect diversity (Simpson 1949).

$$\text{Simpson Index (D)} = \frac{1}{\sum_{i=1}^{s} p_i^2}$$

where p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is still the sum of the calculations, and s is the number of species.

Evenness (e): Evenness is a statistical tool that compares actual diversity value to the maximum possible diversity by using evenness. The evenness of the sample is obtained from the formula:

Evenness = H'/Hmax

By definition, E is constrained between 0 and 1.0. As with H', evenness assumes that all species are represented within the sample.

Jacob's Equitability (J): The equitability is calculated by dividing the Shannon index of diversity by the logarithm of the number of taxa. This measures the

evenness with which individuals are divided among the taxa present.

Equitability (J)= H'/lnS

where, H' is Shannon's index of diversity, and S is the number of taxa.

Fisher's diversity index describes mathematically the relation between the number of species and the number of individuals in those species (Fisher & Yates 1943):

$S = a \times \ln(1 + \frac{n}{a})$

where *S* is the number of taxa, *n* is the number of individuals, and *a* is the Fisher's alpha.

In a sample, an ordinary count of the number of species usually gives a biased underestimate of the true number of species found in the environment. Increasing the sampling effort (sampling a larger area or counting more individuals or examining more sampling units) certainly increases the number of species (Nicholas & Anne 2013). This effect is illustrated in a species accumulation curve in which the x-axis is the number of individuals recorded and the y-axis is the number of species observed or species richness. Canonical correspondence analysis (CCA) was used to show the species response to different environment variables in CNP. The significance of the predictors was tested by using a Monte Carlo permutation test in CANOCO 4.52 (ter Braak & Smilauer 2002).

RESULTS AND DISCUSSION

Species diversity

The present study recorded 437 individuals of globally threatened and near threatened birds belonging to 19 species, nine orders, and 10 families in CNP (Table 1). A total of 12 species recorded are globally threatened in CNP (five Critically Endangered, two Endangered, and five Vulnerable) and seven are Near Threatened (Table 1). The highest number of threatened species belonged to the order Accipitriformes (eight species), followed by Ciconiiformes (two species), Psittaciformes (two species), Passeriformes (two species), Otidiformes (one species), Bucerotiformes (one species), Anseriformes (one species), Charadriiformes (one species), and Suliformes (one species) (Table 1). As much as 42 species of birds in Nepal are globally threatened (nine Critically Endangered, nine Endangered, and 24 Vulnerable) and 31 are Near Threatened (BirdLife International 2018). This shows that CNP alone supports around 29% (12 out of 42 species) of globally threatened birds of Nepal. Two (Bengal Florican *Houbaropsis bengalensis* and Great Hornbill *Buceros bicornis*) out of nine nationally protected birds (DNPWC 1973) were also reported in this park during the study. Sharma (2004) recorded 12 nationally threatened species of birds including two Critically Endangered birds in BCF. CNP listed 22 species of threatened birds including Lesser Florican *Eupodotis indica*, Greater Adjutant *Leptoptilos dubius*, Kashmir Flycatcher *Ficedula subrubra*, and Lesser Kestrel *Falco naumanni* (CNP 2018), but these bird species were not recorded during our study.

The species diversity of threatened birds in five different study blocks showed significant variation ($F_{(4, 90)}$ =2.94, p=0.02). The species diversity was significantly highest in Block E (H=2.073), followed by Block B (H=2.056), Block C (H=1.978), Block A (H=1.689), and Block D with the least diversity (H=1.655; Table 2). The species dominance index was more in Block A (D=0.2482) and Block D (D=0.2431), which indicates the low Simpson index of diversity in these areas (1-D=0.7518 and 1-D=0.7569, respectively). Human disturbance was found to be the highest in blocks A and D as these blocks are located nearer to the human settlements. The species evenness of threatened birds (0.4967) and Jacob's coefficient of equality (0.7476) was low in Block E, as this block is the main site for Critically Endangered vultures (Table 2). This area is provided with a vulture restaurant that is located in Namuna Community Forest, Pithauli, Nawalparasi. This area also includes many islands created by the Narayani River and is considered as the prime habitat for many forest, grassland, and wetland birds.

The species diversity profile of the threatened birds at a 95% confidence interval showed that Block E possessed the highest diversity compared to the other blocks. The Fisher alpha diversity index was higher in Block C (α=4.502), as the number of individuals was low in comparison with species number. In Block E, the species diversity was higher, but due to the presence of more individuals of the bird species, Fisher alpha was lower (α=4.121) than that of Block C. Block D had the lowest diversity profile (Fisher alpha=3.322; Fig. 2).

Accumulation or rarefaction curves attained asymptote and signified that the number of individuals of birds we observed was complete enough to cover all the threatened species present in the sampling sites. The accumulation curve of threatened bird species exponentially increased up to 150 individuals, slowly increased up to 250 individuals, very slowly increased up to 350, and remained nearly constant up to 437 (Fig. 3). The encounter rates of Critically Endangered species of birds were very low. The curve continues to rise as more individuals are sampled (Tokeshi & Schmid 2002). These

Table 1. List of threatened birds recorded in Chitwan National Park, Nepal. NRDB - National Red Data Book Nepal; CR - Critically Endangered; EN - Endangered; VU - Vulnerable; NT - Near Threatened; ** - nationally protected birds under NPWC Act 1973; I, II, III - CITES appendices.

	Threatened birds	Species code	Zoological name	Family	Order	NPWC	CITES	NRDB	IUCN
1	Red-headed Vulture	RHV	*Sarcogyps calvus* (Scopoli, 1786)	Accipitridae	Accipitriformes		II	EN	CR
2	Slender-billed Vulture	SBV	*Gyps tenuirostris* Gray, 1844	Accipitridae	Accipitriformes		II	CR	CR
3	White-rumped Vulture	WRV	*Gyps bengalensis* (Gmelin, 1788)	Accipitridae	Accipitriformes		II	CR	CR
4	Long-billed Vulture	LBV	*Gyps indicus* (Scopoli, 1786)	Accipitridae	Accipitriformes		II	VU	CR
5	Bengal Florican	BeF	*Houbaropsis bengalensis* (Gmelin, 1789)	Otididae	Otidiformes	**	I	CR	CR
6	Egyptian Vulture	EGV	*Neophron percnopterus* (Linnaeus, 1758)	Accipitridae	Accipitriformes		II	VU	EN
7	Lesser Adjutant Stork	LAS	*Leptoptilos javanicus* (Horsfield, 1821)	Ciconiidae	Ciconiiformes			VU	VU
8	Asian Woolly-necked Stork	WNS	*Ciconia episcopus* (Boddaert, 1783)	Ciconiidae	Ciconiiformes			NT	VU
9	Grey-crowned Prinia	GCP	*Prinia cinereocapilla* Hodgson, 1854	Cisticolidae	Passeriformes			NT	VU
10	Bristled Grassbird	BrG	*Chaetornis striata* (Jerdon, 1841)	Locustellidae	Passeriformes			VU	VU
11	Pallas's Fish Eagle	PFE	*Haliaeetus leucoryphus* (Pallas, 1771)	Accipitridae	Accipitriformes		II	CR	EN
12	Grey-headed Fish Eagle	GFE	*Icthyophaga ichthyaetus* (Horsfield, 1821)	Accipitridae	Accipitriformes		II	CR	NT
13	Ferruginous Duck	FeD	*Aythya nyroca* (Güldenstädt, 1770)	Anatidae	Anseriformes			VU	NT
14	Great Hornbill	GrH	*Buceros bicornis* Linnaeus, 1758	Bucerotidae	Bucerotiformes	**	I	EN	VU
15	River Lapwing	RiL	*Vanellus duvaucelii* (Lesson, 1826)	Charadriidae	Charadriiformes			NT	NT
16	Alexandrine Parakeet	AlP	*Psittacula eupatria* (Linnaeus, 1766)	Psittacidae	Psittaciformes		II	NT	NT
17	Red-breasted Parakeet	RBP	*Psittacula alexandri* (Linnaeus, 1758)	Psittacidae	Psittaciformes		II	VU	NT
18	Oriental Darter	OrD	*Anhinga melanogaster* Pennant, 1769	Anhingidae	Suliformes			NT	NT
19	Himalayan Griffon	HiG	*Gyps himalayensis* Hume, 1869	Accipitridae	Accipitriformes		II	VU	NT

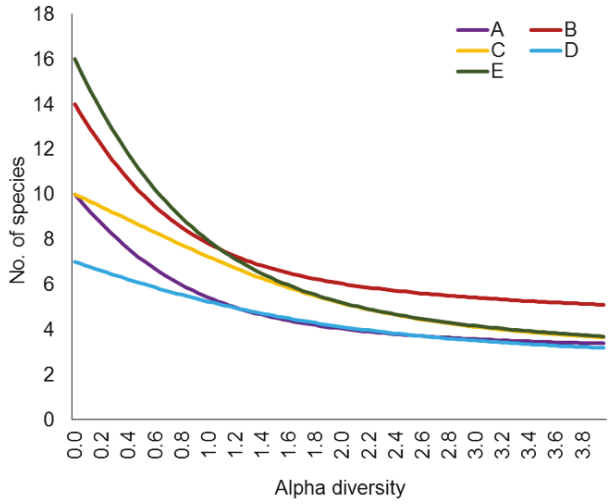

Figure 2. Species Diversity profiles of threatened birds in five study blocks (A–E) in Chitwan National Park, Nepal, at 95% confidence interval (A - Block A (Khagendramalli to Sauraha and old Padampur), B - Block B (Barandabhar Corridor Forest), C - Block C (Kasara to Golaghat), D - Block D (Madi and Someshor hill area), E - Block E (Narayani Island and Pithauli area).

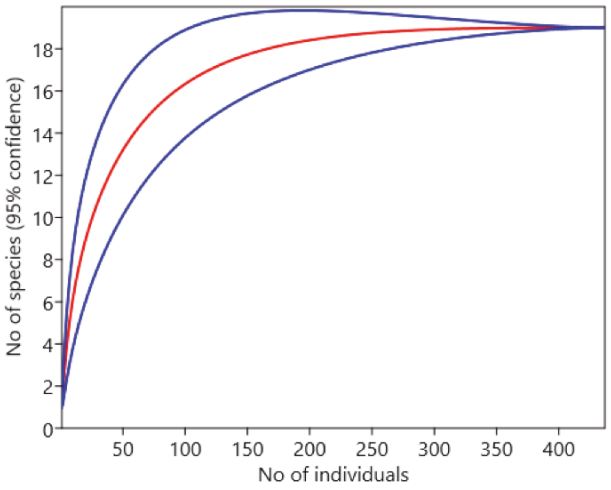

Figure 3. Species accumulation curve. Curve (red) was generated by assuming an assemblage of 19 species whose relative abundances were created from a broken stick distribution (Tokeshi & Schmid 2002). The x-axis is the number of individual recorded and the y-axis is the number of species at 95% confidence interval. Blue lines indicate the 95% confidence interval.

Table 2. Threatened bird diversity and dominance indices in Chitwan National Park, Nepal.

Block	A	B	C	D	E
No. of species	10	14	10	7	16
No. of individuals	63	117	37	24	196
Dominance (D)	0.2482	0.1658	0.1936	0.2431	0.1925
Simpson (1-D)	0.7518	0.8342	0.8064	0.7569	0.8075
Shannon (H)	1.689	2.056	1.978	1.655	2.073
Evenness (e^H/S)	0.5416	0.558	0.7227	0.7477	0.4967
Equitability (J)	0.7337	0.779	0.8589	0.8506	0.7476
Fisher alpha	3.348	4.149	4.502	3.322	4.121

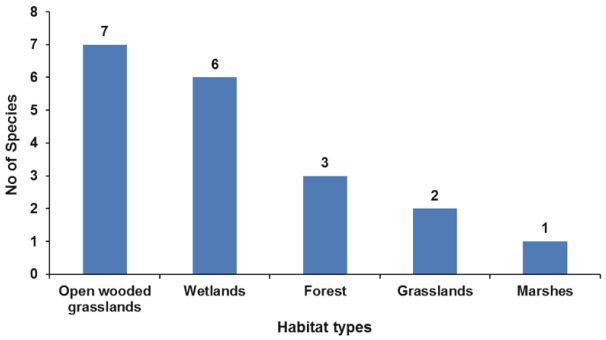

Figure 4. Threatened bird species richness in various habitats showing the preference of different habitats in Chitwan National Park, Nepal.

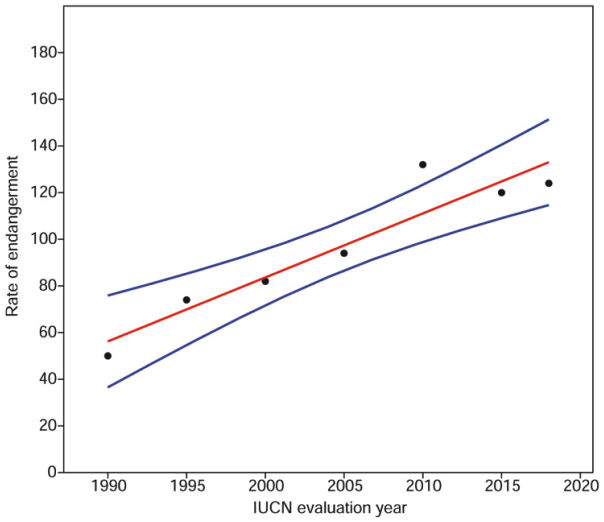

Figure 5. Rate of endangerment of threatened birds of Chitwan National Park, Nepal, as per IUCN Red List categories from 1990 to 2018. The score for each category is assigned as the greatest to the lowest risk: CR=10, EN=8, VU=6, NT=4, and LC=2 (linear regression model: r^2=0.89, t=6.29, p=0.003 at 95% bootstrapped confidence intervals N=1999). The red line shows the rate of endangerment and blue line shows 95% confidence limit.

empirical findings suggest that CNP harbours critical populations of globally threatened birds.

Habitat preference

More than 70% area of CNP is covered by *Shorea* forest and the rest of the area is comprised by grasslands, open wooded forest, riverine forest, floodplains, and wetlands (CNP 2018). This park consists of three rivers of the Gandaki river system and many ox-bow lakes such as Beeshhazari, Lamital, Tamor, Devi, Nandan, Nanda-Bhauju, and Batulpokhari, and many other swampy areas associated with grasslands. Most of the threatened birds were recorded in wetland (wetland birds) and open wooded land (e.g., vultures). Some grassland specialist birds such as Bengal Florican was recorded in the large grass patches of Sukibhar and Pithauli (Fig. 4). A total of 10–14 individuals of Bengal Florican was recorded in the grassland of CNP in 2008 (Poudyal et al. 2008). High habitat diversity may harbour many coexisting species within habitat types, resulting in high species turnover between different habitats (Jankowski et al. 2009; Quintero & Jetz 2018). High habitat diversity of CNP could be another reason for harbouring many threatened bird species (Bhattarai & Kindlmann 2012). Bird species diversity in different habitat types in and around North Nandi Forest, Kenya, reported a significant difference in bird abundance across habitats (indigenous forest, disturbed forest, plantation forest; F=15.141, p≤0.05; Bett et al. 2016) similar to our study.

Conservation threats

We recorded 12 globally threatened (five Critically Endangered, two Endangered, five Vulnerable) and seven Near Threatened birds in CNP (BirdLife International 2018; Table 1). The rate of increase of endangerment of birds according to the IUCN Red List categories from 1990 to 2018 showed rapid increase of endangerment. The linear regression model shows positive increment of the vulnerability of birds from 1990 to 2018 (r=0.991, t=16.622, p=0.0001 at 95% bootstrapped confidence intervals, N=1999; Fig. 5). Risk of extinction of birds in the global scenario increases day by day (White & Bennett 2015). Such cases are also evident in other areas of Nepal. BirdLife International (2018) declared 42 of Nepal's bird species as being in the globally threatened category, including two vagrants (Long-tailed Duck *Clangula hyemalis* and Indian Vulture *Gyps indicus*) and three regionally extirpated species. Inskipp et al. (2016) described a total of 167 bird species (19% of total birds in Nepal) as nationally threatened that included 67 (40%) Critically Endangered, 38 (23%) Endangered,

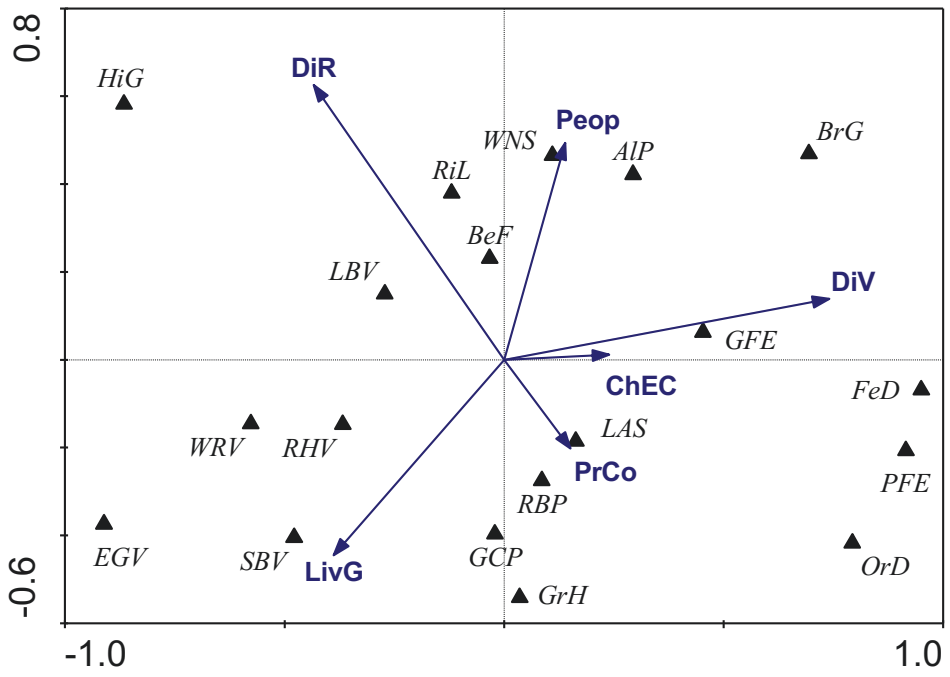

Figure 6. CCA ordination diagram (biplot) showing species response to different environment variables in Chitwan National Park, Nepal. Monte-Carlo permutation test of significance of all canonical axes: Trace=0.643, F=1.464, p=0.01 (with 499 permutations). First two axes are displayed. The first axis accounts for 46% and the second axis for 23.8% of the variability. DiR - distance to road, DiV - distance to village, LivG - livestock grazing, Peop - number of people, PrCo - prey collection, ChEc - chick or egg collection.

and 62 (37%) Vulnerable species. Later, Inskipp et al. (2017) assessed 168 species (19%) of birds of Nepal as nationally threatened species that included 68 (40%) Critically Endangered species, 38 (23%) Endangered species, and 62 (37%) Vulnerable species. As many as eight species of birds were extirpated from Nepal and were not recorded since the 19th Century (Inskipp et al. 2016). Official checklist of CNP listed 22 species of globally threatened birds including Lesser Florican *Sypheotides indicus* (CNP 2018). According to previous observations and reports, however, there was no record of Lesser Florican in CNP since 1999 (BES 2018; Basu Bidari pers. comm. 13 January 2018). There is the potentiality of occurrence of Lesser Florican in Sukibhar and old Padampur areas (this study).

Livestock pressure and human disturbances were the major threats to birds in CNP, mainly in blocks A and D as these blocks are located nearer to human settlements. Numbers of livestock present in the habitats of threatened birds caused a significantly negative effect on species richness and abundance of threatened birds (r=-0.61, t=3.15, p=0.006). The presence of people (both local people and tourists) in the habitats of the birds caused a significantly negative effect on the occurrence and abundance of threatened birds in CNP (r=-0.36, t=1.66, p=0.09). Jia et al. (2018) described flooding phenology, human disturbance, habitat loss and degradation, and declining water quality caused by eutrophication and pollution as the major threats of waterbird communities in Yangtze River floodplain lakes. Similar problems also occurred in Narayani, Rapti River, and Rew floodplains (e.g., loss of a large patch of riverine forest and grasslands). Earlier studies also indicated the same problem. For example, grassland specialist birds in lowlands are the most threatened group of birds (55% of the birds threatened), followed by wetland birds (25%) and tropical and subtropical broadleaved forest birds (24%) (Inskipp et al. 2016). Human pressure was the major cause of habitat disturbance of threatened birds. Collection of grasses, forest products, and snails and fishing from the wetlands were the major activities of the people that disturbed the threatened birds. The CCA shows a significantly close association of Lesser Adjutant Stork and villages as the species commonly visited farmlands for foraging. Most of the threatened birds were recorded from undisturbed areas of CNP (F=1.464, p=0.01; Fig. 6).

Distribution of birds was highly affected by disturbance variables such as distance from roads and distance from settlements or villages. The diversity of birds was found to be low close to villages or roads. As the distance from roads increased, the abundance of

threatened birds was found to significantly increase. There was a strong positive Pearson correlation between the distance from roads and the abundance of threatened birds (r=0.61, t=10.75, p=0.0001). Similar type of strong positive correction was found between distance from villages and the abundance of birds (r=0.73, t=15.14, p=0.0001). These empirical findings showed that there was a negative impact of roads and settlements on threatened birds of this area.

CONCLUSION

This study recorded 437 individuals of 12 globally threatened (five Critically Endangered, two Endangered, five Vulnerable) and seven Near Threatened species of birds in CNP. The diversity and abundance of threatened birds were found to be higher in wetlands, open wooded lands, and grasslands. The species diversity of threatened birds was recorded as the highest in Block E (H=2.073), followed by Block B (H=2.056), Block C (H=1.978), Block A (H=1.698), and Block D with the least diversity (H=1.655). The lower diversities of birds in blocks A and D were due to the high disturbance caused by closer proximities of human settlements as compared to other blocks. The species evenness of threatened birds (0.4967) and Jacob's coefficient of equality (0.7446) was low in Block E, as this block was the main site for Critically Endangered vultures. Livestock and human disturbances were the major threats to the birds in CNP and that was so in blocks A and D. The presence of livestock and people in the habitats of threatened birds caused a significantly negative effect on species richness and abundance. The diversity and abundance of threatened birds were significantly low nearer to human settlements or roads. Therefore, the study suggests that maintaining heterogeneous habitats (forests, grasslands, and wetlands) with low human disturbances could be a better strategy for the long-term survival of resident and migratory threatened birds in CNP.

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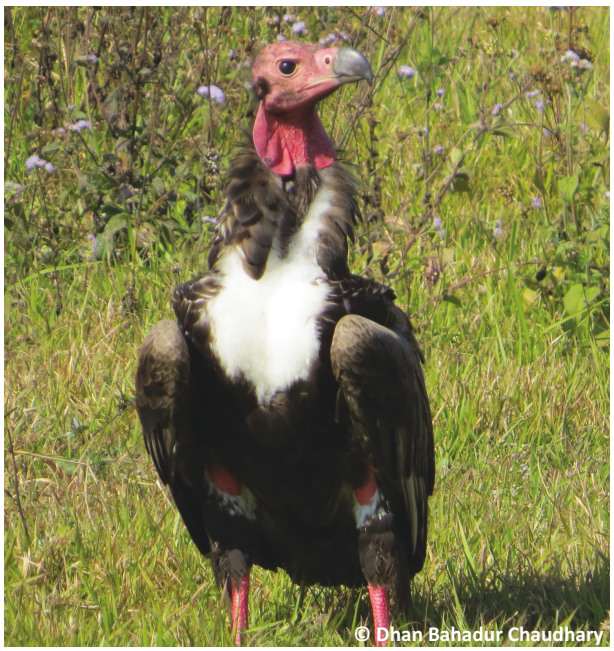

Image 1. Red-headed Vulture *Sarcogyps calvus* (IUCN-CR).

Image 2. Grey-headed Fish Eagle *Icthyophaga ichthyaetus* (IUCN-NT).

Image 3. White-rumped Vulture *Gyps bengalensis* (IUCN-CR).

Image 4. Bengal Florican *Houbaropsis bengalensis* (IUCN-CR).

Image 5. Egyptian Vulture *Neophron percnopterus* (IUCN-EN).

Image 6. Asian Woolly-necked Stork *Ciconia episcopus* (IUCN-VU).

Image 7. Lesser Adjutant Stork *Leptoptilos javanicus* (IUCN-VU).

Image 8. Slender-billed Vulture *Gyps tenuirostris* (in front) (IUCN-CR).

Image 9. Oriental Darter *Anhinga melanogaster* (IUCN-NT).

Image 10. Himalayan Griffon *Gyps himalayensis* (IUCN-NT).

Image 11. Nest of White-rumped Vulture with chicks.

Image 12. Safe feeding site of vultures inside Namuna Buffer Zone Community Forest, Chitwan National Park, Nepal.

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