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No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road, Saravanampatti,
Coimbatore, Tamil Nadu 641035, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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Cover: *Euphaea pseudodispar* shot at Kalindi River, Thirunelly, Wayanad district, Kerala. © Muneer P.K.

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COMMUNICATION

Waterbird assemblage along Punatsangchhu River, Punakha and Wangdue Phodrang, Bhutan

Nima [1] & **Ugyen Dorji** [2]

[1,2] College of Natural Resources, Royal University of Bhutan, 1264, Lobesa, Punakha 14001, Bhutan.
[1] sunnyberley@gmail.com, [2] ugyen.cnr@rub.edu.bt (corresponding author)

Abstract: Crossing Bhutan is one of the shortest transits, and Bhutan holds the main breeding refuge/habitats for many Central Asian migratory birds. Our study assessed the community structure of waterbirds along the Punatsangchhu River basin, located towards the western part of Bhutan. The study determined the species composition, habitat use and preference of waterbirds, together with the different habitats present. Furthermore, the study examined the potential drivers of habitat fragmentation along the river. The entire study area was classified into five different habitats: dam, dredged area, farmland, urban, and pristine. The Cummings method of habitat assessment for high gradient river and streams was used to assess the habitat variables such as bank stability, vegetative protection and the riparian vegetation zone along the river and the association with the diversity of aquatic birds. A questionnaire survey was also used to evaluate the degree of threats caused by human disturbances. Among the five habitats, the dam area recorded the highest diversity (H` = 2.13) against their total count of 103 (8.7%) and the least diversity was recorded from farmland area (H` = 1.1) against their total count of 282 (23.8%) birds. Most waterbirds preferred an open area with shallow river depth. Habitats with emergent vegetation negatively correlated with the waterbird species composition. The study also recorded one Vulnerable species *Aythya ferina*, one Near Threatened species *Vanellus duvaucelii*, and one Endangered species *Haliaeetus leucoryphus*. Punatsangchhu is a major habitat to both resident and migratory waterbirds which stop here enroute from the Palaearctic and Indo-Malayan Region corroborating the need for habitat conservation and management regimes in the basin.

Keywords: Avifauna, dam, diversity, dredged area, farmland, habitat, pristine, threats, town.

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Author details: Mr. Nima pursued BSc in forestry from the College of Natural Resources, Royal University of Bhutan. He is a fervent bird lover and he has specificalized on aquatic birds. He wishes to focus more on conservation biology, ecology and migration patterns of waterbirds in future. Mr. Ugyen Dorji is a freshwater ecologist with teaching and research in the field of freshwater fauna and flora in the College of Natural Resources, Bhutan. He pursued MSc in forestry with specialization in freshwater ecosystems. He is proficient in handling freshwater research projects and fluent in array of statistical and geospatial software.

Author contributions: N—conceived and designed the research from the initial stage. He was also actively involved in collection of data from the field. In addition, he analyzed the data and wrote the first draft of manuscript. UD—supervised the study. He assisted in developing research framework and proposal since the initial stage. As a corresponding author, he also performed the analysis using statistical tool R and reviewed the manuscript after getting comments from reviewers.

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INTRODUCTION

Waterbirds are the most visible visitors to wetlands, and they are also useful bio-indicators and models for investigating a number of environmental issues (Datta 2011). Wetland avifauna serve as indicators of wetland quality, as well as criteria for evaluating restoration success and regional biodiversity (Kumar & Gupta 2009). They account for roughly 10% of all bird species globally and are frequently employed as surrogate indicators of water quality, chemical contamination, prey availability, and vegetation characteristics in wetland ecosystems (Datta 2011).

Bhutan is home to 753 (Tshultrium & Wangchuk 2021) different bird species, with 137 (UWICER 2014) being waterbirds. Bhutan is also the pivotal transit and nesting place for many Central Asian migratory birds. Bhutan considers its resident waterbirds, as well as wintering and passage migrating waterbirds, to be national treasures, and has enacted legislation to safeguard them. "Waterfowl" is defined by the Ramsar Convention as species of birds that are ecologically dependent on wetlands, and "Waterbird" is defined as synonymous with "waterfowl" to apply the Convention (Mundkur & Nagy 2012). Effective conservation and management of wetlands biodiversity involves data on species status and threats to inform decision-making (Stephenson et al. 2020). Therefore, diversity of waterbirds in Bhutan needs more documentation to bring out further conservation strategies.

In Bhutan, winter migratory waterbirds have been found in abundance in along Punatsangchhu basin (Spierenburg 2005). Numerous birders in the country consider Punatsangchhu, the expanse between Punakha and Wangdue Phodrang, a central stopover home for many waterbirds and any instability in the area due to anthropogenic activities would impede the migration of the bird species enroute through Bhutan (Nidup et al. 2020). Large numbers of migratory waterbirds such as Ruddy Shelduck, Common Pochard, Northern Pintail and others, rely on the Punatsangchhu basin for their survival (Ghemiray 2016).

Human actions leading to habitat fragmentation and loss are constantly threatening biodiversity around the world (Gayk & Lindsay 2012). Human activities have encroached on waterbird habitats, putting them at a greater risk. The feeding area of aquatic birds, particularly migrating birds, are rapidly diminishing owing to numerous development activities and poor water quality (Tshering 2010). Many birds have been harmed as a result of sand mining and other contemporary developmental activities such as hydropower construction. Forests, grasslands, and wetlands are being degraded or lost across the region as a result of overexploitation, and bird populations are under threat (BirdLife 2004). The direct effects of habitat transformation provide biologists with the opportunity to investigate the impacts of habitat size, quality, habitat isolation, and the effects of edges and disturbances on gene flow, populations, species, communities and ecosystems (Fukami & Wardle 2005; Laurance 2008). In addition, birds are suitable for the examination of changes in response to habitat disturbance and loss because they are reliable indicators of broader biodiversity trends (Barlow et al. 2007). Therefore, this study aimed to determine the waterbird composition, assess habitat use and preference of waterbirds along with the different habitats along the river. Furthermore, the study examined the potential drivers of habitat fragmentation of waterbirds along the Punatsangchhu.

MATERIALS AND METHODS

Study Area

The study was conducted in the Punatsangchhu River (27.4620 N–89.9010 E and 27.5790 N –89.8670 E) flowing across the two districts: Punakha and Wangdue Phodrang located towards the western part of the country at an altitude ranging 1,200–4,800 m (Figure 1). The river basin is the longest and widest, extending from the extreme north of Gasa with an elevation of 6,500 m to the extreme south of Dagana with an elevation of 200 m covering four districts in Bhutan (Tobgay 2017).

The study site was located at Mochhu River and along the basin where the river is still much less fast-flowing and where there are the greatest number of agriculture fields and also a mixture of grassland and small area of pine forest along the Punatsangchhu Hydroelectric Project and Authority 1 (PHPA 1). The area is also under constant disturbance with large area of sand under extraction and also the place where two mega-hydropower projects are under construction (Dorji & Nidup 2016). The river course was dominated by the presence of rocks and boulders with fast flowing waters in the upper stretches, mainly of cobbles, pebbles, sand and silt (Haq et al. 2021) along the middle stretches and exposed rocks and boulders towards the lower stretches of the basin.

Sampling Design

The study area covered a total distance of 15 km

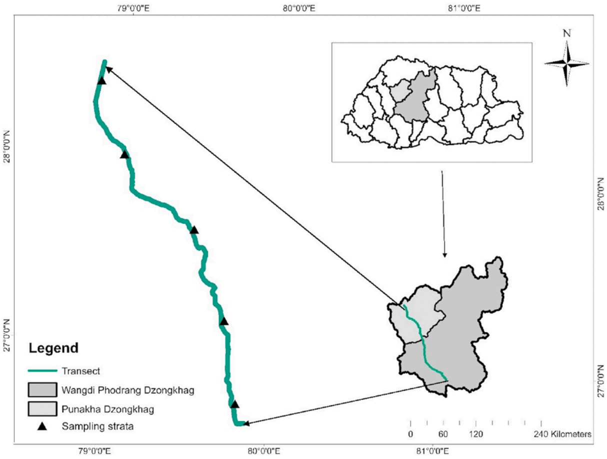

Figure 1. Location of the study area with five different habitats along the Punatsangchhu River basin, covering two districts of Punakha and Wangdue Phodrang, Bhutan.

along the Punatsangchhu river basin. Stratified random sampling was carried out at the study site which composed of five strata, namely, dam, dredged area, farmland, urban, and pristine habitats. The sampling was carried out to stratify the study site into five habitats; one, under undisturbed natural habitat (Rimchu area) and four other strata from the disturbed habitat that are settlement area (Khuruthang town), along the farmland above the Punakha *dzong* up to Zomlingthang area, area of sand extraction (dredged area) and hydropower area respectively. Each habitat covered a distance of 3 km. The transect was laid out systematically in five different habitats along with a total of 10 point counts at a distance of 300 m (Bibby et al. 2000) between each of the point count station. The starting point was laid out randomly at convenience. Overall, a total of 50 point count stations was laid out (Dorji & Nidup 2016). The data were collected from November 2020 to early May 2021 in the winter, post- winter, and spring seasons.

Bird Survey

Birds were recorded by locating transects along a predefined route within a defined survey unit using the line transect method (Burnham et al. 1980). Then the point count approach (Bibby et al. 2000) was used to sample the birds along the designated transects. The birds were counted by strolling along the river concomitantly, halting every 300 m (Bibby et al. 2000) to survey the region within a 50 m radial distance from the observer considering the location as plot center.

At each location, a time of 15 minutes was spent observing, identifying and recording the waterbirds. Owing to the conspicuous activities of birds, the observation period was from 0630 h to 1030 h in the morning, and 1500 h to 1700 h in the afternoon. The observation period began around 30 minutes after sunrise and extended until mid-morning (Bibby et al. 1998). The line transects were put along any riverfront that was accessible and easy to assess for the survey. This was also done to account for the birds that use various features of riparian ecosystems. For identification of the birds, reference guides of Inskipp et al. (2004) and UWICER (2014) were used.

Habitat Assessment

A variation of the line-intercept method (Cummings & Smith 2000) was used to assess the percentage of the riverbank, bank-side open area, shrub cover and canopy cover. Three transects of 30 m each running parallel to each other and perpendicular to the river course, with the middle transect passing through the center of the point count station were laid out. Transects were spaced 10 m away from each other. The lengths of the transect line intercepted by the river-bank, open area, shrub cover and canopy cover were measured (Pasang 2017).

Potential Threats of Habitat Fragmentation

A snowball sampling method was used for preliminary surveys to document risks, including anthropogenic activities, and to provide disturbance scores at each primary sampling site based on Shenoy et al. (2006). A questionnaire survey initially included the forest officials from the Wangdue Forest Division possessing keen interests in birds along the Punatsangchhu River and following the snowball method, the interviewees' recommendations were traced and surveyed. Based on the factors affecting the activity of waterbird communities, anthropogenic disturbances were assigned a score of one, two, or three. A score of three indicated the most severe disturbance while a score of two indicated mild disturbance. Disturbance by visitors was deemed to have the least harmful impact on waterbird communities and was given a score of one (Shenoy et al. 2006).

Data Analysis

The data were analyzed using MS Excel and R software (Oksanen et al. 2018). Descriptive statistics were used to check the summary such as mean, standard deviation, maximum, minimum, and range of the data generated. A Shapiro Wilks test was used to test the normality of the data.

Kruskal-Wallis *H* test was performed to evaluate the habitat comparison. The post-hoc Dunnets test was performed to further test the difference in the distribution of waterbirds. Spearman's correlation was used to evaluate the association between diversity indices within plots with the habitat assessment scores of the environmental variables. Principal component analysis (PCA) was used to analyze the potential drivers of habitat fragmentation from the environmental variables (Andrade et al. 2018). The principal components were selected based on their eigen value higher than 1 and explained data showed 70–80 % of proportions of variance.

Dendrogram through a hierarchical clustering, was extracted from the *GGdendro package* following Ward's (1963) clustering criterion and using Bray Curtis on standardized data. The similarity distance at 0.5 (50%) by (Gonzalez-Gajardo et al. 2009) was taken to distinguish the habitat plots into groups of similar characteristics.

Measurement of diversity

Diversity of aquatic birds was determined by Shannon's diversity index *H'*

Shannon's diversity index $(H') = H' = \Sigma\ Pi*LnPi$

Where:

S = total number of species in the sample

Pi = proportion of individuals belonging to an i^{th} species in a plot or an area

$1n$ = natural logarithm

Measurement of species richness

Species richness index (Mg) was used as a simple measure of species richness.

Mg = (S – 1) / Log N

S = total number of species

N = total number of individuals in the sample

In = natural logarithm

Measurement of species evenness

$E_H = H`/ LN$ (n)

Where n = total number of species recorded

Spearman's correlation was used to evaluate the association between diversity indexes between each plot with the habitat assessment scores of the environmental variables.

r values vary between -1 and +1

r value near 1 indicates strong correlation and near 0 no correlation

RESULTS

Species Composition and Abundance

A total count of 1,186 individuals in 11 families was recorded along the Punatsangchhu River basin adjoining the Mochhu River (Table 1). The bird species belonged to the families: Anatidae, Muscicapidae, Motacillidae, Cinclidae, Scolopacidae, Phalacrocoracidae, Charadriidae, Ibidorhynchidae, Alcedinidae, Accipitridae, and Turdidae. The highest number of species was recorded in Anatidae (27.3%, n = 9) which consists of ducks, followed by Muscicapidae (18.2%, n = 6) and Charadriidae (12.1%, n = 4). Along the Punatsangchhu River all duck species were spotted in open water area characterized mainly by sandy banks, and less dense and dry vegetation along the banks. Motacillidae and Alcedinidae recorded three each (9.09%, n = 3) followed by Scolopacidae and Phalacrocoracidae (6.1%, n = 2). Cinclidae, Ibidorhynchidae, Accipitridae, and Turdidae constituted of one species each (3.0%, n = 1).

Among the five habitats, the dam area recorded the highest diversity (H` = 2.13) with an abundance of 103, while the least diversity was recorded from the farmland area ($H$` = 1.10) with their total count of 282 birds (Figure 2). The highest numbers of waterbirds species and abundance were recorded along the dredged area with species richness (SR = 7.56). The dredged area was more open compared to other habitats and had patches of sand where the birds were found resting. Birds from the Anatidae family could be found in huge flocks either dabbling across the river or resting along the riverside. Some species of diving ducks were seen diving into the river for a period of five to ten seconds for fishing.

Habitat Preference

Habitat heterogeneity and their conditions significantly influence the waterbirds species composition and the diversity indices (H (4) = 31.64, p = 0.00). Most of the waterbirds preferred the dredged area (Median (Mdn)) (Mdn = 18.00) compared to the urban (Mdn = 10.50), farmland (Mdn = 8.00), dam (Mdn = 7.50) and pristine (Mdn = 4.50) habitats.

Post-hoc Dunn's test using a Bonferroni-adjusted alpha level of 0.025(0.05/2) showed a significant influence in the waterbird assemblage and population between farmland and the dredged area (p = 0.008), pristine area and dam (p = 0.001), pristine area and dredged area (p = 0.00), town and farmland (p = 0.02), and town and pristine habitats (p = 0.00). The difference in the waterbird distribution was mainly attributed to pristine habitat, which was an undisturbed habitat

Table 1. Checklist of waterbirds species encountered during the study.

	Family	Common name	Scientific name	IUCN Red List category
1	Anatidae	Ruddy Shelduck	*Anas ferruginea*	Least Concern
2		Mallard	*Anas platyrhynchos*	Least Concern
3		Gadwall	*Anas strepera*	Least Concern
4		Common Merganser	*Mergus merganser*	Least Concern
5		Common Shelduck	*Tadorna tadorna*	Least Concern
6		Common Pochard	*Aythya ferina*	Vulnerable
7		Red-crested Pochard	*Rhodonessa rufina*	Least Concern
8		Eurasian Wigeon	*Anas penelope*	Least Concern
9		Northern Pintail	*Anas acuta*	Least Concern
10	Muscicapidae	Little Forktail	*Enicurus scouleri*	Least Concern
11		Slaty-backed Forktail	*Enicurus immaculatus*	Least Concern
12		Black-backed Forktail	*Enicurus schistaceus*	Least Concern
13		Hodgson Redstart	*Phoenicurus hodgsoni*	Least Concern
14		White-capped Water Redstart	*Chaimarrornis leucocephalus*	Least Concern
15		Plumbeous Water Redstart	*Rhyacornis fuliginosus*	Least Concern
16	Motacillidae	White Wagtail	*Motacilla alba*	Least Concern
17		White-browed Wagtail	*Motacilla maderaspatensis*	Least Concern
18		Grey Wagtail	*Motacilla cinerea*	Least Concern
19	Cinclidae	Brown Dipper	*Cinclus pallasii*	Least Concern
20	Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	Least Concern
21		Marsh Sandpiper	*Tringa stagnatilis*	Least Concern
22	Phalacrocoracidae	Little Cormorant	*Phalacrocorax niger*	Least Concern
23		Great Cormorant	*Phalacrocorax carbo*	Least Concern
24	Charadriidae	River Lapwing	*Vanellus duvaucelii*	Near Threatened
25		Yellow-wattled Lapwing	*Vanellus malabaricus*	Least Concern
26		Red-wattled Lapwing	*Vanellus indicus*	Least Concern
27		Long-billed Plover	*Charadrius placidus* J.E.	Least Concern
28	Ibidorhynchidae	Ibisbill	*Ibidorhyncha struthersii*	Least Concern
29	Alcedinidae	Crested Kingfisher	*Halcyon smyrnensis*	Least Concern
30		Common Kingfisher	*Alcedo atthis*	Least Concern
31		White-throated Kingfisher	*Megaceryle lugubris*	Least Concern
32	Accipitridae	Palla's Fish Eagle	*Haliaeetus leucoryphus*	Endangered
33	Turdidae	Blue Whistling Thrush	*Myiophonus caeruleus*	Least Concern

with relatively higher diversity (H` = 2.03) compared to other habitats. The four other habitats were categorized as disturbed habitats although each of these has its characteristic features to attract a number of species and waterbird population.

Relationship between Waterbird Composition with Physical Parameter

A dissimilarity distance at 0.5 (50%) was taken to distinguish the data into four groups (Figure 3) as follows:

Group I Transition Zone

The first cluster is one of the major parts of the ecosystem and is characterized by 38% of the plots from town and 31% each from dredged area and farmland. The cluster area is named the bio-geographical transition zone. The study area of river comprises shallow water, sandy bank and open area, which favored maximum assemblage of waterbirds including both residents and migratory waterbirds. The area throughout saw more than 23 m^2 flock of migratory Ruddy Shelduck *Anas*

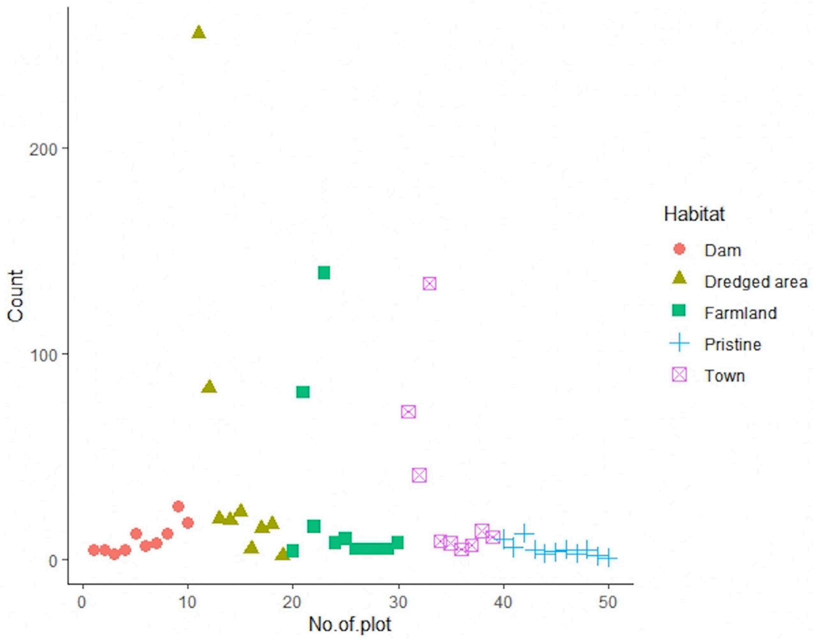

Figure 2. Distribution of waterbirds abundance along each habitat. The graph denotes the counts per plot in each transects line of five different habitats.

ferruginea, River Lapwing *Vanellus duvaucelii*, White Wagtail *Motacilla alba*, Common Merganser *Mergus merganser*, and Little Cormorant *Phalacrocorax niger*. Common Sandpiper *Actitis hypoleucos* was found in every plot throughout the stretch of the habitats.

Group II Dam Zone

The second cluster grouped all the plots from the dam area. All of the plots (P) ranging from P1 to P10 were designated from the dam habitat and hence, the name of the zone. The zone had all the plots falling under a high gradient and fast-flowing river. The abundant species found were Little Forktail *Enicurus scouleri*, Slaty-backed Forktail *Enicurus immaculatus* Hodgson, White-capped Water-Redstart *Chaimarrornis leucocephalus*, and Plumbeous Water Redstart *Rhyacornis fuliginosus*. In contrast, there was a shallow depth of water pools from P6 to P9, due to serious habitat degradation, and the Anatidae species were not found to prefer this area.

Group III Human Interaction Zone

Plots (P11, P12, P23, and P34) falling under three strata: dredged area, farmland, and urban were grouped. The plots shared similar characteristics of being under constant touch with anthropogenic activities and human settlements. All the plots categorized under the group reported the presence of waterbirds species such as Great Cormorant *Phalacrocorax carbo* and Plumbeous Water Red-start *Rhyacornis fuliginosus* along both the banks of the river throughout the stretch in these three habitats. This group indicated a major disturbance to waterbirds' habitat due to vigorous developmental and anthropogenic activities.

Group IV Undisturbed Zone

This cluster consisted of all the plots belonging to the pristine habitat. Since all the plots have been reported from pristine habitat, the zone was named the undisturbed zone. Throughout the plots, there was high canopy cover and very minimal disturbance from the development activities. Waterbird species recorded include Brown Dipper *Cinclus pallasii* and Blue Whistling Thrush *Myiophonus caeruleus*.

Relationship between the Waterbird Composition and Habitat Parameters

Spearman's rho correlation was used to determine the association between the waterbird count and the environmental variables of the right bank (RB) of the river (Figure 4a, b). The bank sides were attributed in a way that was against the flow of the river. The correlation test found no significant association between the waterbird count and elevation (r_s = -1.60, p = 0.28). Conversely, the waterbird counts along the RB showed a significant association with environmental variables: bank stability (BS) (r_s = -0.34, p = 0.01), vegetative protective (VP) (r_s = -0.29, p = 0.03) and riparian vegetation zone (RVZ) (r_s = -0.48, p = 0.00).

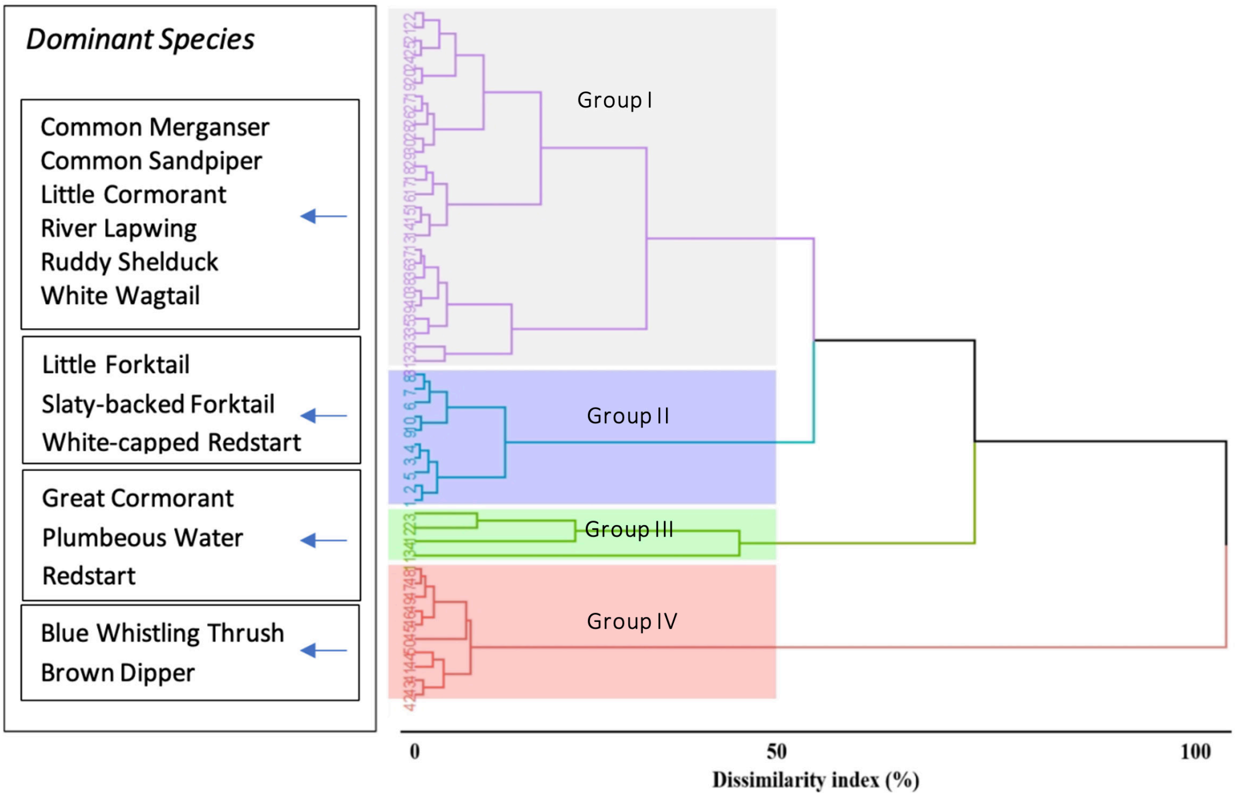

Figure 3. A dissimilarity distance at 0.5 (50%) showing the grouping of similar plots.

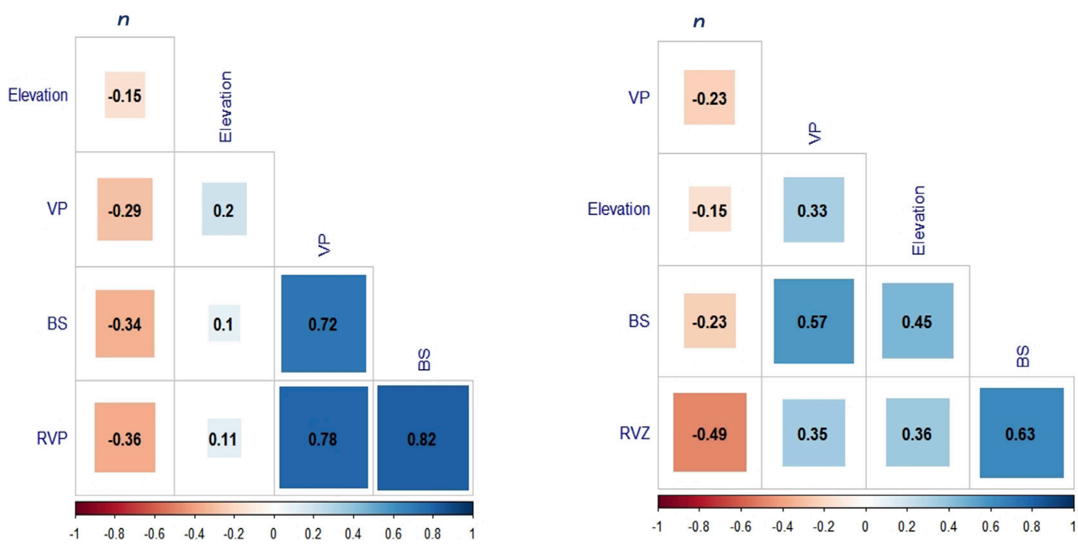

Figure 4. a—correlation along RB | b—correlation along LB

Throughout the habitat, the national highway passing through the region, human settlements, farmlands, and the dredged area sites were situated toward the RB of the river. The national highway connecting the Gasa-Punakha Road passed along the RB of the river. The major portion of Khuruthang town was also established along with the RB of Punatsangchhu River where all of the sewerage drains were observed to run into the river. The farmland of Zomlingthang village was also along the RB of the river.

The BS and VP were interfered with anthropogenic activities which were constantly decreasing the stability

Table 2. Correlation coefficient in each principal component. The table shows the 10 anthropogenic activities that deduced four principal components used as an explanatory variable for analysis.

	EF	RC	WP	D	M	SE	CRC	IF	TEX	FD	SD	Cumulative proportion (*CP*)	Proportion of Variance (*V*)
PC1	-0.24	-0.26	0.03	0.22	0.03	-0.43	0.3	-0.47	-0.35	-0.41	1.11	0.29	0.29
PC2	0.73	-0.1	0.03	-0.11	-0.34	-0.14	0.03	0.147	0.02	-0.5	0.85	0.46	0.17
PC3	0.01	-0.06	-0.40	-0.11	-0.05	0.16	-0.70	-0.19	-0.48	-0.12	0.80	0.62	0.15
PC4	-0.09	-0.52	-0.36	-0.46	-0.12	0.37	0.46	0.04	-0.09	0.05	0.74	0.74	0.13

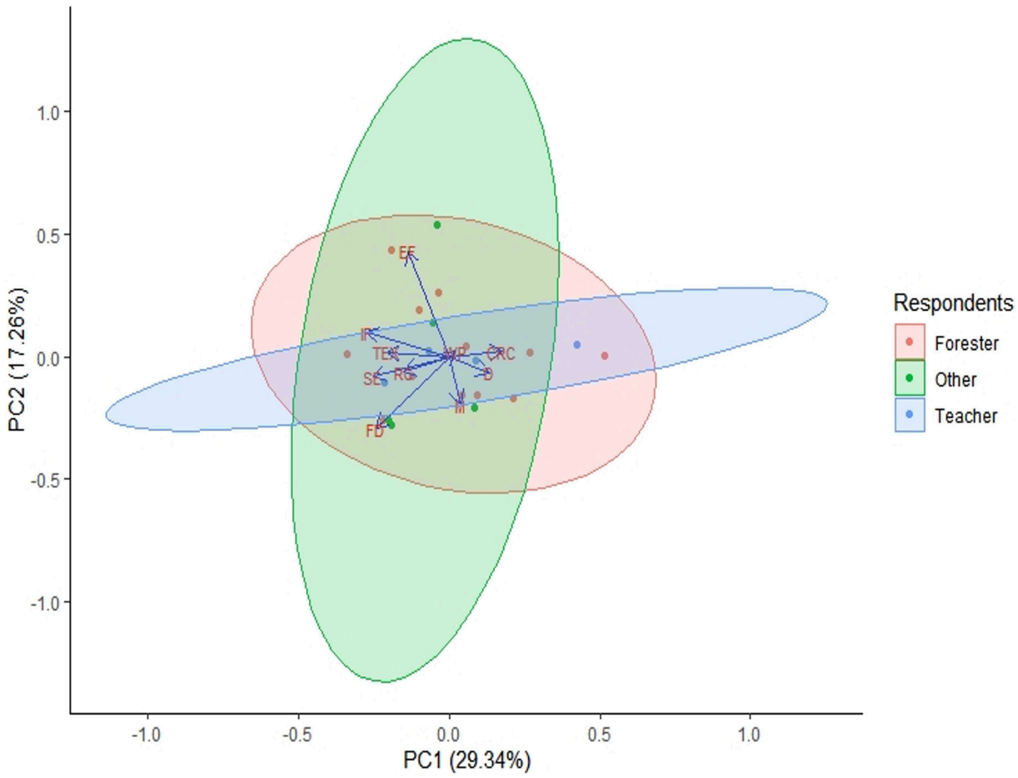

Figure 5. Principal component analysis bi-plot for potential drivers that lead to habitat degradation based on 10 different anthropogenic activities. The PCA biplot shows the categories of respondents and directions values of impact scores used as an explanatory variable for analysis.

of BS and VP hence, directly affecting the waterbird assemblage. The RB of the bank throughout the study area was covered with bushes of *Desmodium* sp., *Phyllanthus officinale*, *Artemisia vulgaris*, a mixed stand of *Ficus semicordata*, *Pinus roxburghii*, and *Macaranga* sp. Although the percentage coverage varied from plot to plot along the habitat, the composition of waterbirds did not depend on it. It can also be seen that most of the waterbirds were found along the riverside feeding near the river and bank.

Similarly, Spearman's rho correlation coefficient was used to determine the association between the waterbird count and environmental variables of the left bank (LB) side of the river. There was no significant association between the count and the environmental variables: elevation (r_s = -0.160, p = 0.283), BS (r_s = -231, p = 0.105), and VP (r_s = -0.223, p = 0.102). Elevation, BS, and VP do not influence the waterbird's assemblage and distribution.

On the other hand, the correlation reported a significant association between the waterbird count and RVZ (r_s = -0.487, p = 0.000, N = 50). The LB of the river was mostly covered with Riparian Vegetation (RV) and the correlogram showed a moderate correlation corroborating the influence of assemblage by RVZ cover. With the increase in the canopy cover and presence of thick vegetation along the riparian zone, the waterbirds assemblage decreased.

Relationship with Waterbirds and Anthropogenic Activities

PCA was conducted for 10 parameters considering the various anthropogenic activities as a potential threat to habitat degradation. The activities listed are: change in the river course (CRC), damming (D), electric fencing (EF), fire disturbance (FD), illegal fishing (IF), mining (M), road construction (RC), sand extraction (SE), town expansion (TE) and water pollution (WP). Reduction to four Principal Components accounted for 74.70% of the anthropogenic activities from the total number of respondents. The resulting components that had an eigenvalue summed to >1 was selected to represent the original variation in the environmental data (Kaiser 1960).

The PC1 showed a weak positive correlation with 40% of anthropogenic activities such as (WP, D, M, and CRC) and 60% of activities (EF, RC, SE, IF, TEX) showing a negative correlation with the PC1 (Table 2). Similarly, a 50% positive correlation (EF, WP, CRC, IF, TEX) and 50% negative correlation (RC, D, M, and SE) were found with the PC2. In addition, PC3 showed a positive correlation with 30% (EF, RC, and SE) of the anthropogenic activities and a 70% negative correlation (WP, D, M, CRC, IF, TEX, and FD). PC4 showed a 40% positive correlation (SE, CRC, IF, and FD) and a 60% negative correlation with (EF, RC, WP, D, M, and TEX).

According to the bi-plot (Figure 4), D, CRC, WP, and M were highly correlated to one another. All of the above activities were all related to impacts on the river which will further affect the waterbird habitat. Anthropogenic activities such as FD, RC, and TEX were associated with the environment nearby the waterbird's habitat. The groups were highly correlated with each other concerning habitat degradation from the impact of nearby settlements and activities. The next group of activities was SE and IF which directly disturbed the river and therefore, affected the feeding and habitat of waterbirds. Activity such as EF had a negative correlation with the rest of the anthropogenic activities depicting a weak effect on the waterbird community.

DISCUSSIONS

Punatsangchhu is one of the biggest rivers, and the basin is a significant habitat in Bhutan for resident and migrant waterbirds (Nidup et al. 2020). Large numbers of winter migratory waterbirds in Bhutan have been found in this location (Spierenburg 2005). The most abundant species reported were under the family Anatidae. From the Kurichhu basin, which has similar characteristics, Dorji & Nidup (2016) also reported up to eight Anatidae species. Changthang Wildlife Sanctuary in Ladakh reported up to 34% of the bird's species belonging to the Anatidae (Jamwal et al. 2020). The high number of Anatidae may be due to the presence of passage migratory species inhabiting different habitats (Dorji & Nidup 2016). The study area was an open wetland that could have attracted a greater number of dabbling birds.

One main cause of the decline in waterbird population is the increase in anthropogenic land-use which reduce habitat availability at stopover and wintering sites (Page & Gill 1994). The bird assemblages are affected by various factors such as food availability, the size of the wetland (Paracuellos 2006), and the abiotic changes in the wetlands (Jaksic 2004; Lagos et al. 2008). Not only the birds but all organisms, belonging to the plant and the animal communities, are affected by the physical characteristics of the environment (Gillings et al. 2008).

The variation in the distribution of waterbirds in different habitats is attributed to prime habitat preference: "Each species may have a different habitat preference and feed throughout this habitat on all kinds of food, or all the species may share the entire habitat with each species feeding on a variety of food in the different situation within the habitat" (Onoja et al. 2011). Many studies have demonstrated the importance of habitat heterogeneity in wetland bird richness and abundance (Gonzalez-Gajardo et al. 2009).

Open areas are of utmost importance for bird populations as these areas provide better visibility for vigilance against predators and free movement for food procurement (Elafri et al. 2017). Open water provides optimum feeding and resting conditions to waterbirds and the least impact of human disturbances (Elafari et al. 2017).

The river gradient along the study area was characterized by fast-flowing and running river, where species such as Plumbeous Water Redstart, White-capped Water Redstart, Little Forktail, White Wagtail, and Blue Whistling Thrush of Muscicapidae family were widespread (Dorji & Nidup 2016). This could be attributed to the river being pristine and fast-flowing, where the Muscicapidae are widespread (Tyler & Ormerod 1993). Plumbeous Water Redstart is the most widespread species found along fast-flowing rivers and streams, dam areas, and pristine habitat and is also a common altitudinal migrant, ranging 350–4,270 m (Tyler & Ormerod 1993; Inskipp et al. 2004).

Brown Dippers were mostly spotted along the rapidly flowing river. When foraging, Brown Dipper mainly catches prey from submerged rocks or the slowing river-bed, whereas Little Forktail picks prey from spray-drenched rocks at a waterfall or from the hygropetric area of rocks (Tyler & Ormerod 1993). Diving waterbirds with long necks, bills, and legs can feed in deeper habitats than smaller taxa, and their access to foraging is limited by the minimum water depth (Ma et al. 2010).

A bio-geographical transition zone is an area where physical features, environmental conditions, and ecological factors forms mixture and co-occurrence of two or more biotic components but also constrain their distribution further into one another (Ferro & Morrone 2014). Habitat choice of birds is primarily influenced by the availability of food (Collin 1998), suitable nesting sites, and the presence of potential predators (Martin 1993). Waterfowl migrate from their Palearctic breeding grounds and accumulate in different wetland bodies of the valley at the arrival of winter (Ali 1979). Birds such as the Common Sandpiper *Actitis hypoleucos* prefer stone, gravel, rocky, muddy, or sandbanks along rivers during the breeding season (Snow & Perrins 1998).

Higher canopy cover saw a significantly lower diversity of waterbirds (Tobgay 2017). Along with the river segments with high canopy cover, the waterbirds were sighted in lesser numbers of individuals (Passang 2017). Bird diversity negatively correlated with canopy density (Daniels 1991). Tall emergent vegetation, open shore, and canopy appeared to be primary habitat elements affecting waterbirds' presence. All waterbirds were negatively associated with tall emergent vegetation (Traut 2003). Waterbirds were recorded significantly less in the plots with a high percentage of canopy cover (Tena et al. 2007). A smaller number of waterbirds species was found along the river segments with high canopy cover (Passang 2017). However, ecological studies show that lower altitude has more bird species than higher altitude while some species are restricted to certain zones and others occur throughout a range of altitudes (Jankowski et al. 2009).

Regardless of their importance, global waterbirds populations are declining (Wetlands International 2012). One main cause of the decline is the increase in anthropogenic landuse, reducing habitat availability at stopover and wintering sites (Page & Gill 1994). While the implications and Conservation Action Plans (CAP) are prepared by the government and NGOs RSPN, only one has been prepared in Bhutan for river birds. This CAP is for the globally Critically Endangered White Bellied Heron *Ardea insignis*, there are several other waterbirds species occurring in the river that are missing from the list under the IUCN Red List criteria. These species are: Common Pochard *Aythya ferina*, Palla's Fish Eagle *Haliaeetus leucoryphus* and River Lapwing *Vanellus duvaucelii*. A CAPs for these waterbirds are important too and should be considered before we declare it to be just too late for the same.

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