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Research Article

Abundance and diversity of waterbirds around the Begnas Lake of Pokhara Valley, Nepal

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Abstract

We studied the seasonal abundance and diversity of waterbirds around the Begnas lake of Pokhara Valley. The status of waterbirds in Begnas wetland is not documented so; we monitored the waterbirds using the point count method in 12 different plots around the lake and compared the seasonal abundance and diversity during the 2019 Summer and 2020 winter with 24 hours of observation in each plot. A total of 585 individuals of 25 waterbird species from 10 families were recorded during the study period. Among the recorded species two species were globally threatened and the remaining were the least concerned categories. The greater abundance of waterbirds was recorded during winter ($t = -5.98$, $p < 0.001$). The abundance of all feeding guilds was found higher during winter. Cattle egret was recorded with the greatest abundance (N = 85) and Relative abundance (RA = 14.52), it was followed by great cormorant (N = 57, RA = 9.74) and common pochard was the least abundant (N = 2, RA = 0.34). There was no seasonal variation in the Shannon Wiener index (H') and species evenness however, the species richness was higher during winter ($W = 16.5$, $p < 0.01$). Distance to the forest, road, and settlement did not affect the abundance and diversity of waterbirds however, the abundance of insectivore birds was increased with the decrease of distance to croplands ($t = -3.13$, $p < 0.05$). The Begnas wetland was found with a lower abundance and diversity of waterbirds in comparison to the Phewa and other wetlands of the Terai region of Nepal. The lake water pollution, infrastructural development, anthropogenic activities, recreational activities, and infestation of invasive plants like water hyacinth were the main threats to the waterbirds around Begnas lake. An awareness program about the conservation of waterbirds and regular monitoring of waterbirds in Begnas was recommended.

Introduction

Wetlands are distinguished as the transition zone between aquatic and terrestrial habitats and that provide essential natural territory for numerous faunal groups such as insects, birds, reptiles, and many aquatic animals [1,2]. All the waterbirds are wetland-dependent birds, they use wetlands mainly for breeding, nesting, and foraging activities [3-6]. However, wetlands are facing many threats globally, the greatest loss of wetlands is seen mainly in Asia due to degradation and fragmentation of habitat and biological invasion [6], resulting in a declining population of many waterbirds [7,8]. There are 10 Ramsar sites in Nepal, out of which Lake Cluster of Pokhara Valley (LCPV) is the latest and largest ecologically important Ramsar site with an area of 26,106 hectors and was established on 2nd February 2016 [9]. LCPV is located within the Chitwan-Annapurna Landscape and supports 128 species of vertebrates including 32 species of mammals with 18 Families, 140 birds with 37 Families, 24 species of reptiles, 27 species of fish, and 11 species of amphibians [9,10]. The LCPV consists of nine lakes, among them Phewa is the largest and Begnas is the second largest lake. Among 886 species of birds found in Nepal [11], wetland-dependent birds (25%) are taken as the second most threatened group after lowland grassland birds (55%) [12]. Pokhara Valley supports 467 species of bird species [13].

Lakes in LCPV are vulnerable and facing great anthropogenic pressure including eutrophication, siltation, sedimentation, industrial and chemical pollution, encroachment, deforestation, over-fishing and invasion of non-native invasive weeds such

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as water hyacinth, water lettuce, cut grass, etc. [1,14,15]. Therefore, the wetland habitats are degrading speedily and dangerously resulting the adverse effect on the structure and diversity of the waterbird community. As a result, the foraging and nesting sites for the waterbirds in Begnas wetland are narrowing these days and the population of waterbirds especially winter migratory birds is declining during these days. There is a regular census of waterbirds during the winter season by Bird Conservation Nepal and other conservation organizations. However, the scientific study of the seasonal abundance and diversity of waterbirds is lacking in Begnas lake areas. Therefore, we aimed to prepare a checklist of waterbirds and compare the seasonal abundance and diversity of waterbirds around the Begnas lake of LCPV. Our findings will be the baseline for future researchers and conservationists for the conservation of waterbirds in lakes of LCPV.

Materials and methods

Study area (Figure 1)

Begnas is the second largest natural freshwater lake among the nine lakes of the Lake Cluster of Pokhara Valley in Gandaki Province. It is located at an altitude of 650 m.a.s.l. about 13 km far towards the east of Pokhara city and the catchment area lies in 28, 30 and 31 wards of Pokhara Metropolitan City with an area of about 18.6 km^2. It lies between the Grater Himalaya and Mahabharat range between 28.13 N to 28.21 N and 84.08 E to 84.17 E with an area of 3.13 km^2 water surface and depth of water ranges from 6.6 m to 10 m [9]. It is located in the subtropical climatic region; annual temperatures range from 12 °C to 29 °C and more than 80% of the rainfall occurs during the monsoon season [16]. Begnas lake is surrounded by sub-tropical broad-leaved sal forest (*Shorea robusta*) in the west, riparian forests (*Acacia catechu* and *Dalbergia sisoo*) and *Schima-Castanopsis* forests in the north, east, and west. The invasive species found around Phewa wetland are Tilapia (*Tilapia nilotica*), African catfish (*Clarias gariepinus*), Parthenium (*Parthenium hysterophorus*), Mikania (*Mikania micrantha*), Water hyacinth (*Eichornia crasssipes*), Southern cut grass (*Leerisa hexandra*), and Water lettuce (*Pistia stratiotes*) [9]. The Begnas wetland is the natural home for several species of winter migratory and residential waterbirds.

Methods

A total of 12 sampling plots each of a 50 m circular radius were established in the Begnas lake area from *Shyangkhudi* to the *outlet* of the lake based on the hot spots of waterbirds habitat. The distance between the two plots was not less than 200 meters. The coordinates of each plot were recorded from the center using GPS (Garmin eTrex Touch 35). The nearest distance to the forest, agricultural land, road, and settlement from each plot was determined using a measuring tape. Species and the number of waterbirds in each plot were observed within a 50 m radius from 7.00 AM to 11.00 AM. Waterbirds were observed four times during Summer 2019 (July 10 and 11, August 11 and 12) and during Winter 2020 (January 7 and 8, February 10 and 11). We observed the birds for 12 hours during

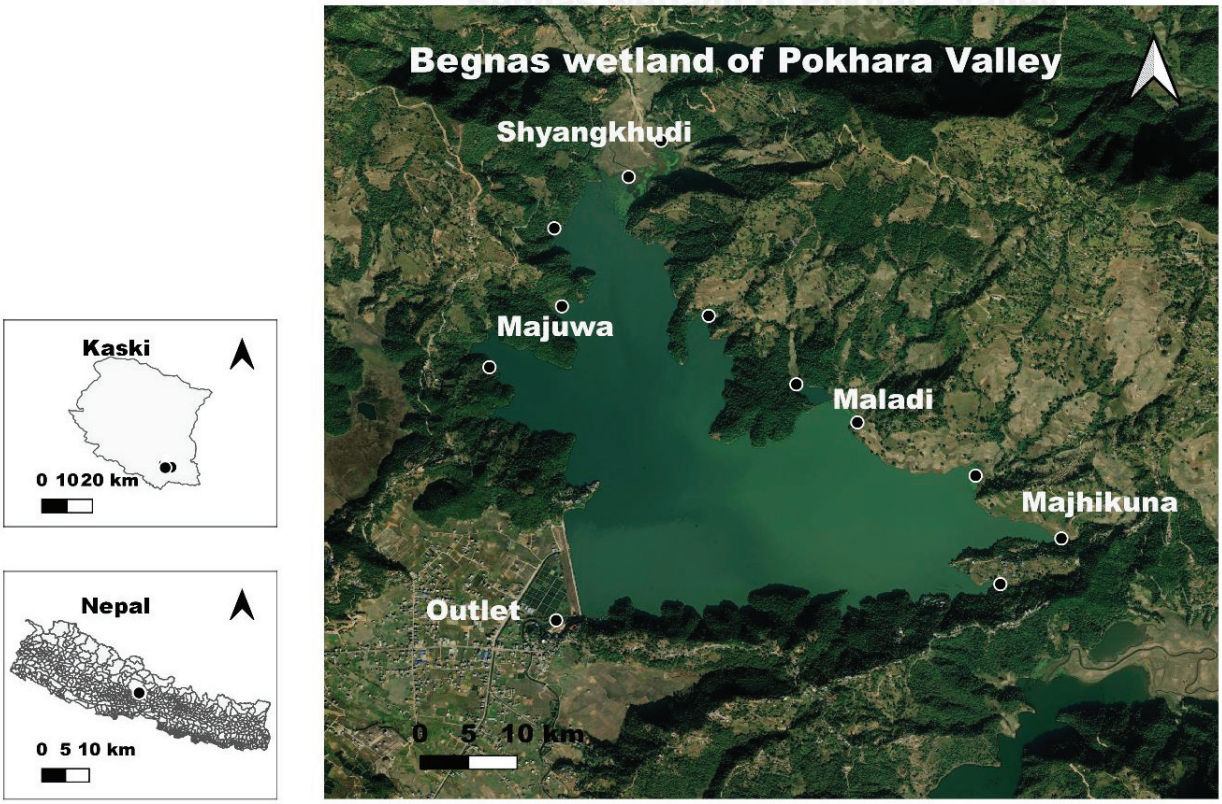

Figure 1: Study Area.

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Summer and 12 hours during Winter. So we spent a total of 24 hours on the bird observation in each plot. Waterbirds were counted through direct observation using binoculars following Bibby, et al. [17]. In each plot, 30 minutes were spent on the observation of waterbirds, and the maximum number of individuals and species of the waterbirds recorded within the given period was used for data analysis. All the observed birds were identified using available reference keys/experts following the taxonomic monographs [8,18].

Data analysis

Shannon-Weiner diversity (H') [19], Pielou's species evenness (J) [20], and species richness (S) of the waterbirds during Summer and Winter were calculated. All waterbirds were categorized into four feeding guilds: piscivorous, insectivorous, omnivorous, and herbivorous [18,21,22]. The abundance and diversity of waterbirds during the Summer and Winter seasons were compared using the Wilcoxon rank sum test for non-normally distributed data and the independent sample t-test for normally distributed data. Multiple linear regression (MLR) analysis was used to identify the factors affecting waterbird abundance and species diversity of waterbirds around Begnas lake. All data were analyzed using vegan [23]; ggplot2, and ggpubr [24] packages in the R program [25]. We also used Microsoft excel 2019 for the graphical representation of the results.

Results and Discussions

Abundance and diversity of waterbirds

A total of 585 individuals (Summer 2019, N = 174 and Winter 2020, N = 411) of 25 waterbird species from 10 families were recorded in Begnas lake during the study period (Table 1, Figure 2). Out of 10 families, the family Anatidae had the highest species richness (8 species) which was followed by the family Ardeidae (4 species), families Rallidae and Passeridae (3 species), and 1 species from each of the remaining families during Winter 2020. We did not record the birds from Anatidae, Phalacrocoracidae, and pedicipedidae families during the Summer of 2019 (Figure 2). We recorded the highest abundance and Relative abundance of Cattle Egret (N = 85, RA = 14.52) it was followed by Great Cormorant (N = 57, RA = 9.74) and the lowest was of Common Pochard (N = 2, RA = 0.34; Table 1). Four types of feeding guilds were categorized from the observed birds viz, Omnivores (N = 11), Insectivores (N = 9), Piscivores (N = 4), and Herbivores (N = 1; Table 1). Gautam and Kafle [14] recorded 43 species of waterbirds from Phewa lake but they did not record seven species that were recorded during this study. These birds were Black-headed Gull, Blue-eared Kingfisher, Crested Kingfisher, Common Snipe, Grey Heron, Black-crowned Night Heron, and White Wagtail. Similarly, we did not record seven species of waterbirds during our study but were recorded by Gautam and Kafle [14]. These birds were Common Shelduck (*Tadorna tadorna*), Garganey (*Anas querquedula*), Falcated Duck (*Anas falcata*), Cotton Pygmy-goose (*Nettapus coromandelianus*), Darter (*Anhinga melanogaster*), Great Egret (*Casmerodius albus*) and Marsh Sandpiper (*Tringa stagnatilis*). Other seven species which were not recorded during our study are Greater Painted-snipe (*Rostratula benghalensis*), Jack Snipe (*Lymnocryptes minimus*), Green Sandpiper (*Tringa ochropus*), Common Redshank (*Tringa totanus*), Great White Egret (*Ardea alba*), Goosander (*Mergus merganser*) and Greylag Goose (*Anser anser*) but these species were recorded from Phewa lake during the winter water bird census in 2017 [26]. 39 species of waterbirds from 17 families were reported by Giri and Chalise [15] but they did not record the species such as Baer's Pochard (*Aythya baeri*), Bar-headed Goose (*Anser indicus*), Comb Duck (*Sarkidiornis melanotos*), Common Goldeneye (*Bucephala clangula*), Darter (*Anhinga melanogaster*), Little Cormorant (*Phalacrocorax niger*) and Purple swamphen (*Porphyrio porphyrio*). 148 species of birds from 44 families were recorded by Khatri, et al. [1] from the Phewa watershed area, out of which 63 species were wetland-dependent birds. Similarly, Dhakal, et al. [27] reported 101 species of birds from 34 families in the Khaste lake complex, out of which 33 species were waterbirds. Further, Basaula, et al. [21] recorded 32 species of waterbirds from 11 families in lakes of the Lake Cluster of Pokhara Valley. The waterbirds species richness in Begnas lake was declining, it could be attributed to the higher water traffic, infestation of aquatic weeds, excessive movement of humans, and increasing loads of infrastructure. The wetlands' ability to provide shelter and feeding possibilities may increase the abundance and the species richness of the waterbirds [28-31].

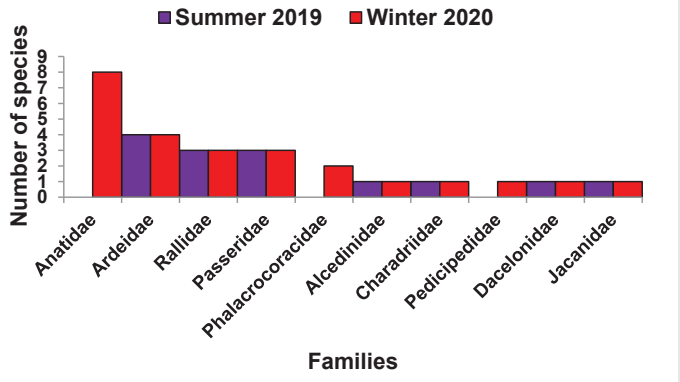

Figure 2: Families of waterbirds with the number of species recorded during Summer 2019 and Winter 2020 in Begnas lake of Pokhara Valley, Nepal.

The greatest number of waterbirds (N = 22) was recorded in plot *Shyangkhudi* 2 and the lowest (N = 1) was recorded in plot *Majhikuna* 1 during the Summer of 2019. Similarly, the greatest number of waterbirds (N = 47) was recorded in plot *Majuwa* 2 and the lowest (N = 18) in plot *Maladi* 1 during Winter 2020 (Figure 3). Plots *Majuwa* 1, *Majuwa* 2, and *Maladi* 2 were found most disturbed areas for waterbirds and observed a lower abundance and diversity during Summer because there were more human disturbances due to agricultural activity, fishing, and boating. These plots were lack of aquatic vegetation, and large water volume and were closer to the road, settlements, and parks. It could be attributed to human exploitation and habitat degradation of waterbirds [32]. Interestingly, all the Plots were found to be more abundant and diverse during Winter because winter migratory birds arrived in the wetland it could be due to large areas with open water access and wetland areas with emergent and floating vegetation. In addition, the habitats such as swamp areas, open water bodies, patches of

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Table 1: Waterbirds recorded around Begnas lake, Pokhara, Nepal, 2019–2020. IUCN status: Critically Endangered (CR), Vulnerable (VU), Least Concerned (LC). *SC-Summer count, WC-Winter count, Relative abundance (RA).

SN	Scientific name	Common name	Family	IUCN Status	Feeding guilds	SC	WC	Total	Abundance	RA%
1	*(Mareca) Anas penelope* Linnaeus, 1758	Eurasian Wigeon	Anatidae	LC	Herbivore	0	4	4	4	0.97
2	*Anas platyrhynchos* Linnaeus, 1758	Mallard	Anatidae	LC	Omnivore	0	7	7	7	1.69
3	*Anas creeca* Linnaeus, 1758	Common Teal	Anatidae	LC	Omnivore	0	7	7	7	1.69
4	*Tadorna ferruginia* Pallas, 1764	Ruddy Shelduck	Anatidae	LC	Omnivore	0	14	14	14	3.38
5	*Aythya baeri* Güldenstädt, 1770	Baer's Pochard	Anatidae	**CR**	Omnivore	0	3	3	3	0.72
6	*Aythya ferina* Linnaeus, 1758	Common Pochard	Anatidae	**VU**	Omnivore	0	2	2	2	0.48
7	*Aythya fuligula* Linnaeus, 1758	Tufted Duck	Anatidae	LC	Omnivore	0	3	3	3	0.72
8	*Dendrocygna javanica* Horsfield, 1821	Lesser Whistling Duck	Anatidae	LC	Omnivore	0	27	27	27	6.52
9	*Alcedo atthis* Linnaeus, 1758	Common Kingfisher	Alcedinidae	LC	Piscivore	2	3	5	3	0.72
10	*Halcyon smyrnensis Linnaeus*, 1758	White-throated Kingfisher	Dacelonidae	LC	Piscivore	21	24	45	24	5.80
11	*Amaurornis phenicurus* Pennant, 1769	White-breasted Waterhen	Rallidae	LC	Omnivore	7	10	17	10	2.42
12	*Gallinula chloropus Linnaeus*, 1758	Common Moorhen	Rallidae	LC	Omnivore	15	22	37	22	5.31
13	*Fulica atra* Linnaeus, 1758	Commpn Coot	Rallidae	LC	Omnivore	11	17	28	17	4.11
14	*Metopidius indicus Latham*, 1790	Bronze-winged Jacana	Jacanidae	LC	Omnivore	12	9	21	12	2.90
15	*Vanellus indicus* Boddaert, 1783	Red-wattled Lapwing	Charadriidae	LC	Insectivore	4	8	12	8	1.93
16	*Tachybaptus ruficollis* Pallas, 1764	Little Grebe	Pedicipedidae	LC	Insectivore	0	12	12	12	2.90
17	*Phalacrocorax carbo Linnaeus*, 1758	Great Cormorant	Phalacrocoracidae	LC	Piscivore	0	57	57	57	13.77
18	*Phalacrocorax niger* Gmelin, 1789	Little Cormorant	Phalacrocoracidae	LC	Piscivore	0	14	14	14	3.38
19	*Bubulcus ibis* Linnaeus, 1766	Cattle Egret	Ardeidae	LC	Insectivore	29	56	85	56	13.53
20	*Egretta grazetta* Linnaeus, 1766	Little Egret	Ardeidae	LC	Insectivore	13	24	37	24	5.80
21	*Mesophoyx intermedia* Wagler, 1829	Intermediate Egret	Ardeidae	LC	Insectivore	11	16	27	16	3.86
22	*Ardiola grayii* Sykes, 1832	Indian Pond Heron	Ardeidae	LC	Insectivore	22	34	56	34	8.21
23	*Motacilla maderaspatensis* Gmelin, 1789	White-browed Wagtail	Passeridae	LC	Insectivore	12	18	30	18	4.35
24	*Motacilla cinerea* Tunstall, 1771	Grey wagtail	Passeridae	LC	Insectivore	4	6	10	6	1.45
25	*Motacilla alba* Linnaeus, 1758	White Wagtail	Passeridae	LC	Insectivore	11	14	25	14	3.38
	Total					174	411	585	414	100

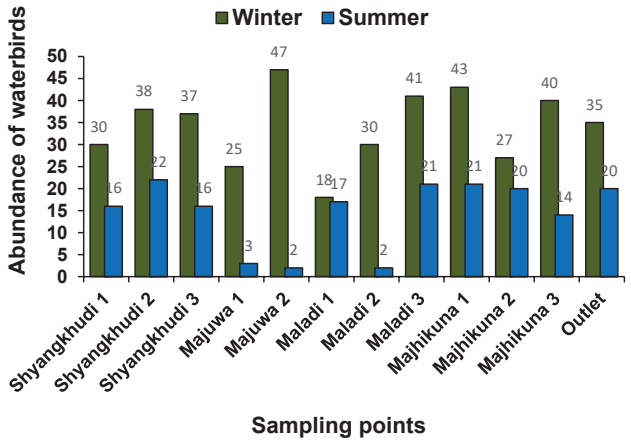

Figure 3: Samling points and the total number of waterbirds during Summer 2019 and Winter 2020 in Begnas lake of Pokhara Valley, Nepal.

shrubs, and forest edges provide abundant food resources, such as insects, worms, mollusks, and grains as well as safe roosting and breeding sites mainly in the plots around *Shyankhudi* areas [1,21].

Among the observed birds, all were in the least concern category except for two species: the critically endangered Baer's pochard (*Aythya baeri*), and the vulnerable Common pochard (*Aythya ferina*) (Table 1). A similar result was reported by Basaula, et al. [21] from the Lake Cluster of Pokhara Valley Nepal. The areas with open water access containing submerged and emergent vegetation were preferred by ducks and geese including globally threatened water birds in Begnas wetland. However, the plots in *Shyangkudi*, *Maladi*, and *Majhikuna* were invaded with invasive weeds like water hyacinth (*Eichhornia crassipes*), southern cut grass (*Leersia hexandra*), and water lettuce (*Pistia stratoides*) [21,33]. The invasive weeds decreased the open water access and it could be the cause for the decline in the population of winter migratory waterbirds and globally threatened waterbirds in Begnas lake during these years. Furthermore, residential birds like Common moorhen, Bronze-winged jacana, Egrets, and Herons benefited from these weeds as they provide the best shelter as well as foraging, nesting, and hiding places for these birds. A similar finding was reported in the mat of water hyacinth by Villamagna, et al. [28] in Lake Chapala, Mexico and Basaula, et al. [21] in the Lake Cluster of Pokhara Valley, Nepal.

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The total abundance of birds, an abundance of Insectivores, Piscivores, and Omnivores birds were found significantly higher during the Winter season (p = 0.000, 0.005, 0.002 and 0.001 respectively; Figure 4 a-d). A similar type of Shannon Weaner index and evenness of the birds was recorded during both seasons however, the species richness was found significantly higher during Winter (p = 0.001; Figure 4 e-g). The greater abundance and species richness of waterbirds during the Winter season were probably because of the arrival of winter migratory waterbirds from different regions of the world in the Begnas wetland to pass their winter [15,21,31]. It could be due to the higher mobility of winter migratory waterbirds in response to factors like cold, food resources, and change in water levels. Winter migratory birds, like ducks, geese, and cormorant species, typically steer clear of dense emergent plants because the extra cover limits movement and decreases foraging effectiveness [4,28,34].

Factors affecting the abundance and diversity of waterbirds

The abundance, H', and S were used as response variables whereas the distance to a forest (m), distance to the road (m), distance to croplands (m), and distance to the settlement (m) were used as predictor variables in MLR analysis. The results indicated that the abundance of insectivore birds increased

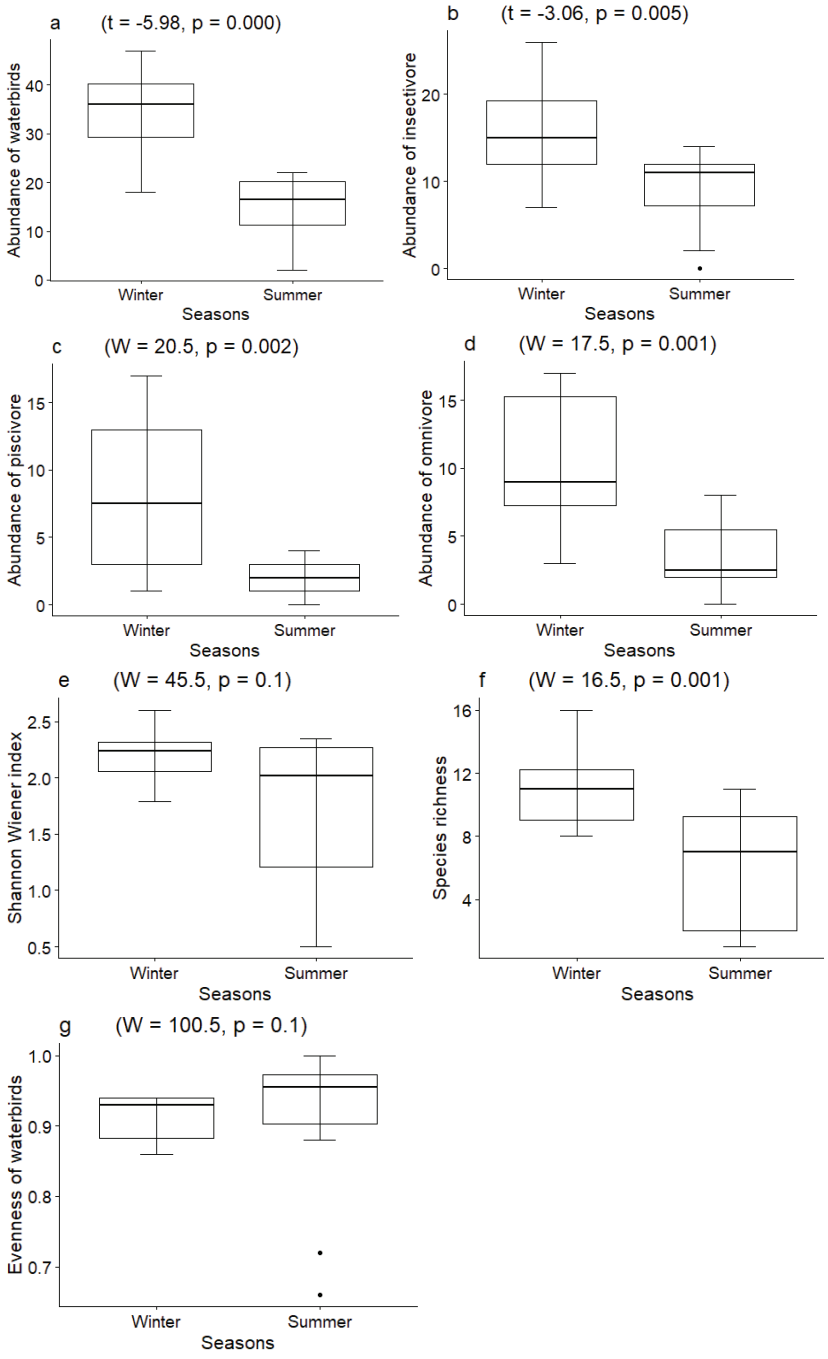

Figure 4: Comparison of abundance and diversity of waterbirds during Summer 2019 and Winter 2020 in Begnas lake of Pokhara Valley, Nepal.

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with the decrease in the distance of cropland (Table 2). Food availability is taken as one of the vital factors for the abundance and diversity of birds, the abundance and species richness of waterbirds were positively associated with the distance to the forest, the Shannon-Wiener diversity index was positively associated with distance to the forest and negatively associated with distance to the settlements. Similar types of results were explained by Adhikari, et al. [31] on threatened birds of Chitwan National Park, Nepal, and Neupane, et al. [35] on the avifauna of Kaligandaki River Basin, central Himalaya, Nepal. According to the current study, the *Shyangkhudi* area with higher tree diversity and lack of weeds appeared to offer a variety of food sources, roosting and nesting places, and protection from terrestrial predators. The dumping of animal excrement nearer to the lake provided nutrient-rich food for the migratory birds. The distribution and abundance of food resources have been intimately associated with the ecology of water birds [36].

Begnas wetland is facing remarkable anthropogenic pressure which can greatly influence the structure of the bird community. The main threats to waterbirds in Begnas wetland are habitat degradation due to the construction of roads, recreational activities like fishing, boating, and swimming, pollution due to domestic sewage, human encroachment, rapid urbanization, siltation, cattle grazing and invasion of unwanted weeds like water hyacinth, water lettuce, cut grass, etc. [1,9,14]. The greatest hazard to waterbirds' long-term survival has been identified as habitat loss and degradation [37]. The threat to the ponds from filling, sewerage discharge, residential rubbish disposal, and the purposeful or accidental introduction of invasive weeds like water hyacinth were the likely causes of the fall in the bird population in various ponds/ water bodies [38]. The severely contaminated water associated with throwing every last item into the lakes/waterbodies has been acknowledged as a threat to the waterfowl [39]. The number of bird species was found to be higher around the lakes with less pollution and human involvement, as well as those that met their fundamental needs, such as food and shelter [40].

Conclusion

From the results of the present study, it can be concluded that the Begnas area is a potential site for both resident and winter migratory waterbirds. However, the abundance was found higher during the winter season. The study plots near *Shyangkhudi*, *Maladi*, and *Majhikuna* were more abundant and diverse in Begnas wetland. However, the population of waterbirds is declining at present in comparison to the past population trend because the Begnas wetland is facing the pressure of many threats such as pollution, infrastructural development, anthropogenic activities, recreational activities, and infestation of invasive weeds like water hyacinth, water lettuce, cut grass, etc. More species of waterbirds with higher populations can be expected from Begnas lake. Therefore, we recommended a regular survey of waterbirds for their conservation and updating the checklist as well as the management of invasive weeds like water hyacinth. Organizing the awareness program about the conservation of waterbirds including globally threatened waterbirds and mitigation of the major threats by NGOs/ INGOs, local government and different organizations related to birds is essential to schools, colleges, and local people living in the catchment areas of the lake. It requires rigorous community awareness to gain local support for instructing conservation actions.

Table 2: Multiple linear regression showing the factors affecting the abundance and diversity of waterbirds during Summer 2019 and Winter 2020 in Begnas wetland of Pokhara Valley, Nepal.

Variables	Estimate	Std. Error	t value	p	Estimate	Std. Error	t value	p
	Abundance of waterbirds					Piscivore birds		
Intercept	22.37	12.15	1.84	0.08	3.35	4.86	0.69	0.50
Distance to forest (m)	0.06	0.10	0.58	0.57	0.00	0.04	0.04	0.97
Distance to road (m)	0.01	0.03	0.21	0.84	-0.01	0.01	-0.53	0.60
Distance to cropland (m)	-0.01	0.02	-0.71	0.48	0.00	0.01	0.56	0.58
Distance to settlement (m)	0.00	0.01	-0.31	0.76	0.01	0.01	1.02	0.32
	Shannon Wiener index					Insectivore birds		
Intercept	2.03	0.50	4.06	0.00	13.64	4.37	3.12	0.01
Distance to forest (m)	0.00	0.00	0.53	0.60	0.05	0.03	1.53	0.14
Distance to road (m)	0.00	0.00	1.03	0.32	0.00	0.01	0.29	0.77
Distance to cropland (m)	0.00	0.00	-1.75	0.10	-0.02	0.01	-3.13	0.01
Distance to settlement (m)	0.00	0.00	-1.23	0.23	-0.01	0.01	-1.55	0.14
	Species richness					Omnivore birds		
Intercept	8.30	3.83	2.16	0.04	5.36	4.85	1.11	0.28
Distance to forest (m)	0.00	0.03	0.08	0.94	0.00	0.04	0.07	0.94
Distance to road (m)	0.01	0.01	0.92	0.37	0.01	0.01	0.77	0.45
Distance to cropland (m)	0.00	0.01	0.14	0.89	0.00	0.01	0.40	0.69
Distance to settlement (m)	-0.01	0.00	-1.16	0.26	0.00	0.01	-0.48	0.64

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Author contributions

RB and BRD conceptualized the research. RB and OPS conducted field research, data curation, RP formal analyzed data, and drafted manuscript. RB, OPS and BRD revised and edited the manuscript. All authors read and approved the final manuscript.

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