Volume: 3, Issue: 1, (June, 2021), pp -146-166
www.rjt.ac.lk/agri/sljae

SRI LANKAN JOURNAL OF AGRICULTURE AND ECOSYSTEMS *e*ISSN: 2673-1401

SLJAE

ORIGINAL ARTICLE

Avifaunal Diversity and Water Quality Analysis of Urban Wetlands of Colombo, Sri Lanka

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DOI: http://doi.org/10.4038/sljae.v3i1.65

Abstract

The present study was carried out to determine the effect of water quality on the diversity and distribution of avifauna in urban wetlands. The bird aggregation and physical and chemical parameters of water bodies were assessed using standard field-based methods. The study recorded 67 bird species of 35 families. The bird population parameters were influenced by total dissolved solids, dissolved oxygen, salinity, and visibility. The Shannon- Wiener species diversity index (H′) ranged between 0.99±0.05 - 1.71±0.03. The density of aquatic birds and species richness ranged between 1677.45±137.2 - 4990.09±151.3 birdskm-^{2} and 14.85±0.36 - 22.07±0.68 respectively in the five wetlands studied. Shannon-Wiener diversity index (H′) resulted in significant negative relationships with total dissolved solids (R^2=0.716; p<0.05), and salinity (R^2=0.919; p<0.01). Bird density was positively related with Secchi disk depth (R^2 = 0.457; p<0.05). Further, bird density negatively correlated with salinity (R^2 = 0.568; p<0.05) and total dissolved solids (BD = -0.003TDS + 3.903; R^2 = 0.566; p<0.05). The results of the principal component analysis indicated Secchi disk depth and dissolved oxygen were extremely influenced on *Thalangama* tank followed by *Heen Ela* marsh. For the wetland sites of *Beddagana* and *Kiribathgoda*, salinity and total dissolved solids were the extremely influential parameters, where *Beddagana* and *Diyasaru Park* had an influence from electrical conductivity on the variation of diversity, density, and species richness of the aquatic birds.

***Keywords**: Aquatic birds, Aquatic habitats, Bird assemblage, Physical and chemical parameters, Water pollution*

Date of Submission: 06-01-2021 Date of Acceptance: 17-06-2021

1. Introduction

A wetland can be defined as a transitional land between the terrestrial and aquatic ecosystem with a water table, which is at or near the land surface, covered by shallow water (Cherry 2011). The wetland environment is rich with an array of biodiversity in which water birds can be considered as an important component, occupying several trophic levels in the wetland nutrient cycles indicating a special cultural and social role in the local communities (Green 2014). Birds utilize wetlands as a habitat, mainly for nesting, roosting, breeding, feeding, shelter, resting, social interaction, and many other activities (Stewart 2007). Also, wetlands support congregation of a large number of migratory birds as it has high nutritional value and productivity (Paracuellos 2006). These birds use wetland habitats either throughout or during a certain part of their life and support to keep the ecological balance of this delicate ecosystem (Keten et al. 2020).

From an urban perspective, wetlands play a vital role in the assemblage and conservation of aquatic birds (Green 2014). In an urban environment, wetlands act as the last resort for many resident and migratory bird species (Murray et al. 2013). In local context, urban wetlands are highly prioritized for avifaunal conservation and to identify the international recognitions for wetland managements (https://www.ramsar.org). Among them, wetlands in Colombo are highly promising and recognized as critical areas for the conservation of biodiversity including a rich avifaunal population (Wetland management strategy 2016). Being one of the world's first wetland cities, Colombo is rich with clusters of wetlands and still, about 20 km^2 of wetlands are located in the Colombo metropolitan area (Wetland management strategy 2016). These wetlands are providing vital habitats for more than 115 bird species including some rare migrants (Wetland management strategy 2016). Among them, several species are endemic and listed under threatened categories (Goonatilake 2020).

Colombo as the most commercialized city in Sri Lanka, these wetlands are alarmingly diminishing and subjected to pollution and reclamation events due to substantial development priorities and rapid population growth (Kotagama and Bambaradeniya 2006). These pollution sources directly alter the bio-physical condition of aquatic ecosystem and directly impair the natural water quality (Mitsch and Gossenlink 2000). The physical and chemical water parameters can be considered as major factors influencing the biotic components of the ecosystem including aquatic birds (Rameshkumar et al. 2016). The measurement of avifauna species becomes essential to evaluate the current status of a wetland ecosystem and also that demonstrates the wellbeing of specific wetland and can be considered an indicator species (Krebs 1999; Osborne 2000). Effects of water quality on aquatic bird diversity can be treated as the robustness of the wetland ecosystem and to established conservation priorities of aquatic birds in urban settings. Though there are many observations on annual bird migration and status of the resident bird population in Sri Lanka, no proper study has been conducted to reveal the threats on them. Hence, importance of this study is strongly justified as a baseline for the prospective studies and decision making. An attempt was made to evaluate the effect of water quality parameters on bird diversity in critical wetland clusters in Colombo and evaluate the ecological status. We propose the hypothesis that the impairment of water quality in urban wetlands is a direct influence on the diversity and distribution of aquatic bird species.

2. Materials and Method

Study area

The study was carried out in five urban wetlands in the Colombo and its suburbs of Sri Lanka (Fig. 1) *viz. Beddagana* Wetland Park (BG), *Diyasaru* Park (DS) situated at *Thalawathugoda*, *Heen Ela* marsh (HE) at *Nawala*, *Kiribathgoda* wetland area (KG) and *Thalangama* Tank (TL), ranging in size from 15- 25 ha (IUCN Sri Lanka and Central Environmental Authority (2006); Wetland management strategy 2016). The locations of these wetlands are highly urbanized and enclosed with human or commercial settlements. The annual mean minimum and maximum temperature varies around 26.5- 29.5 °C and 2687 mm rainfall can be expected annually (http://en.climate-data.org). These wetlands are dominated by herb species, including the extensive active and abandoned paddy lands. Woodlands are also observable in the Colombo wetland complex. One third of all the studied wetlands are covered with tall and short herbs and open water habitats. Open water wetlands, such as tanks and canals cover represent just over 20% of all the wetlands (Wetland management strategy 2016). Variation of annual weather patterns and diversity of vegetation are the key factors of the bird aggregation of these wetland clusters in the study area.

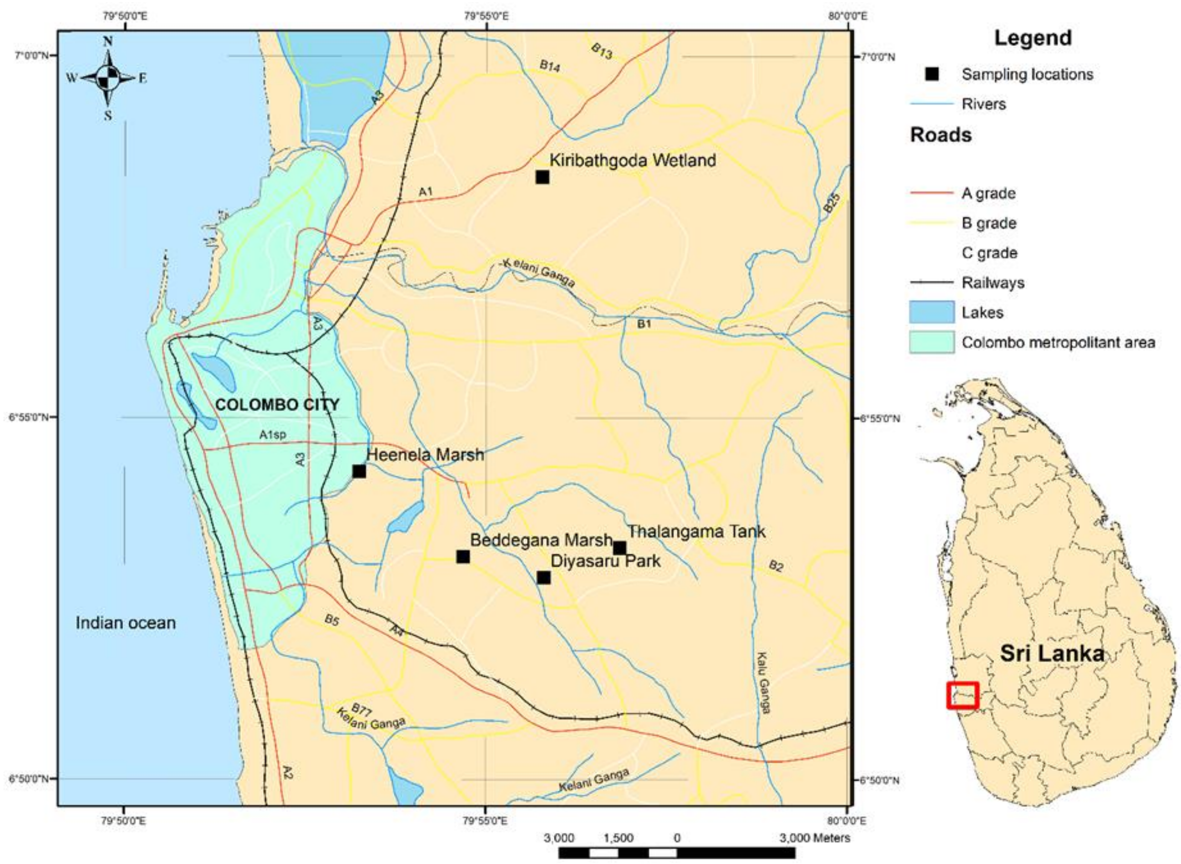

Figure 1. Geographic locations of the five urban wetlands studied in Colombo and suburbs. Inset shows the location of five studied wetlands relative to Colombo metropolitan area

Field sampling

This study was carried out from February 2018 to January 2019, visiting each wetland once a month. In the present study, the species diversity of wetland birds during migratory and non-migratory seasons was investigated. Four separate locations were selected in each wetland and point observations were made around 0600-0800 hrs with a binocular (Nikon Compact PROSTAFF) of 8x42 magnification with ten minutes observations in each point while rotating 360° (Vijayan 1991; Bibby et al. 1992). Several species and individuals were counted in a 50 m radius. The birds were identified using standard field guides by Harrison and Worfolk (1999); Kotagama and Ratnavira (2017). Water quality data were taken per individual wetland in the selected locations. Three locations were selected in each site and water temperature (Tm), Total Dissolved Solids (TDS), pH, Dissolved Oxygen (DO), salinity, Electrical Conductivity (EC) were measured using previously calibrated HANNA HQ 40D multi-parameter. To determine the visibility of the water, Secchi disk depth (SDD) was obtained.

Statistical analysis

The recorded bird species were divided into two groups, as aquatic birds (water birds) and terrestrial birds. The Shannon Wiener index (Shannon and Weaver 1949), species richness (Krebs 1999), and the density (Rodger and Panwar 1990) of water birds were calculated for considering sole aquatic birds and considering both aquatic and terrestrial birds separately (results were not shown) observed in the wetlands. For the statistical analysis, the data of different locations in each wetland were pooled for the study period and average values and standard errors (SE) were calculated. Regression analysis was used to determine the relationship of each population parameter of aquatic birds (e.g. diversity, density, and richness) with few physical and chemical parameters of water. Bird count data were log transferred before the analysis. The correlation of overall bird population parameters (including terrestrial birds) with physical and chemical parameters was evaluated with Pearson correlation analysis. Principal component analysis (PCA) was used to define critical physical and chemical parameters for the variation of Shannon wiener index, species richness and the density of aquatic birds in each wetland studied. Prior to analyses, all variables were square root-transformed to better approximate the multi-normality. The statistical analysis was performed using MINITAB 14 (Maat 2015) and Primer V.5.2.2 software (Clarke and Warwick 2001).

3. Results and discussion

During the present study, 67 bird species were observed at five wetlands. Among them, 26 species were considered aquatic birds, and 04 species were migrant (Table 1). The distribution of the species was scattered through the five wetlands. However, several species (e.g., *Porzana fusca* and *Pastor roseus*) were only observed in particular habitats. A few of these species such as Oriental darter (*Anhinga melanogaster*) and Spot-billed pelican (*Pelecanus philippensis*) have special conservation status and considered as near threatened according to IUCN red list criteria (Goonatilake 2020). The highest aquatic bird diversity indicated by Shannon-Wiener species diversity index (H′) was recorded in the *Thalangama* tank wetland (1.71±0.03), while the lowest (0.99±0.05) was recorded from *Diyasaru Park* (Fig. 2). The total bird density was maximum in *Thalangama* tank, with 4990.09±151.3 birdskm^{-2}, and minimum in *Heen Ela* marsh with 1677.45±137.2 birdskm^{-2} (Fig. 2).

The species richness was also maximum in *Thalangama* (22.07±0.68) and minimum in

Kiribathgoda wetland (14.85±0.36) (Fig. 2). Shannon- Wiener species diversity index (H′), bird density, and species richness were highest in *Thalangama* Tank wetland. Those three population parameters in *Thalangama* Tank were significantly different across the other wetlands studied ($p < 0.05$).

Shannon- Wiener species diversity index (H′), bird density, species richness and water quality parameters in five wetlands are given in Table. 2.

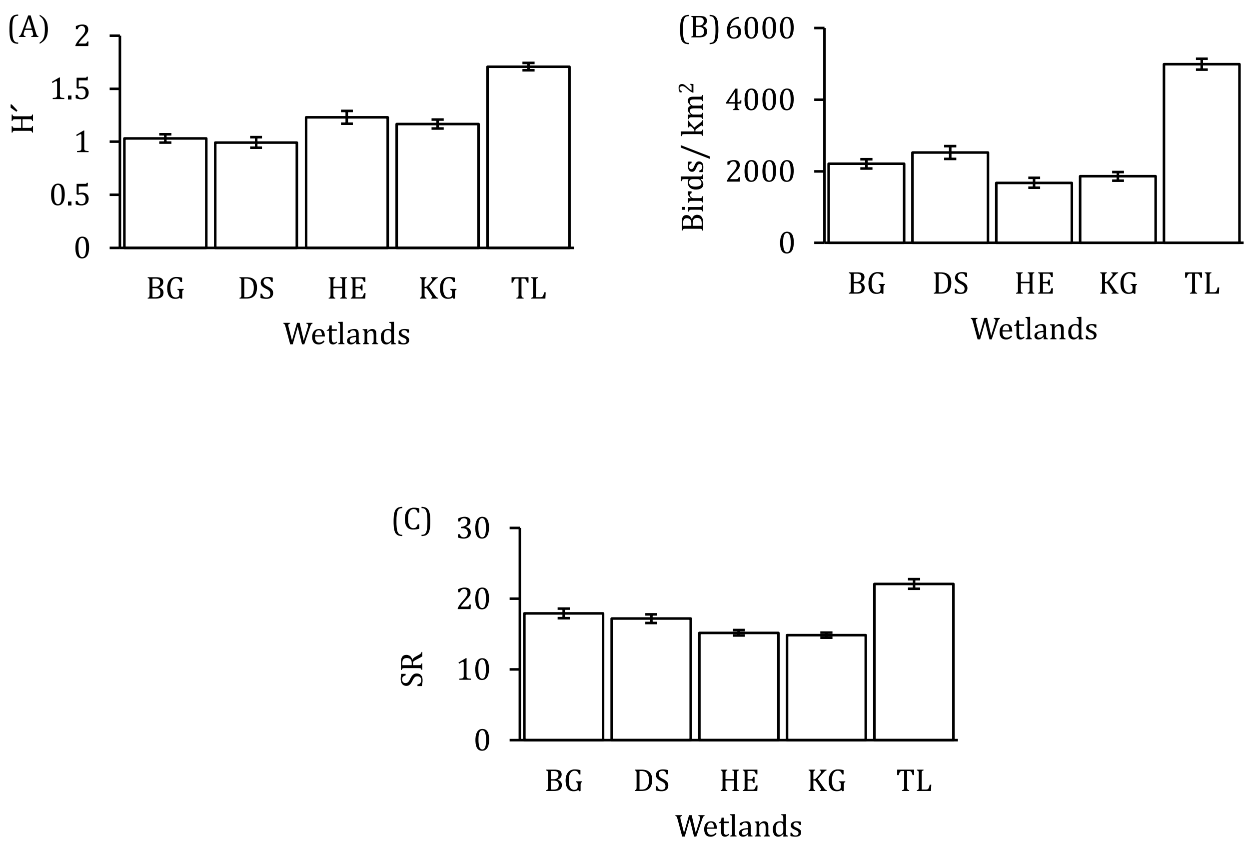

Figure 2. Variation of bird population parameters among the wetlands studied. (A) Shannon- Wiener species diversity index (H′); (B) bird density (BD); (C) species richness (SR). Abbreviations of wetlands: *Beddagana* Wetland Park (BG), *Diyasaru* Park (DS), *Heen Ela* marsh (HE), *Kiribathgoda* wetland area (KG) and *Thalangama* Tank (TL).

Table 1. Checklist of birds recorded during the study in five wetlands.

Family	Scientific Name	Common Name	National Conservation Status (Goonatilake, 2020)
Accipitridae	*Spilornis cheela*	Crested serpent-eagle	LC
	Accipiter badius	Shikra	LC
	Haliaeetus leucogaste	White-bellied sea eagle	LC
Alcedinidae	*Halcyon smyrnensis*	White-throated kingfisher*	LC
	Ceryle rudis	Pied kingfisher*	LC
	Pelargopsis capensis	Stork billed kingfisher*	LC
	Alcedo atthis	Common kingfisher*	LC
Aegithinidae	*Aegithina tiphia*	Common iora	LC
	Cypsiurus balasiensis	Asian palm-swift	LC
Apodidae	*Apus caffer*	White-rumped swift	LC
Cisticolida	*Prinia inornata*	Plain prinia	LC
	Prinia sylvatica	Jungle prinia	LC
Chloropseidae	*Chloropsis jerdoni*	Jerdon's leafbird	LC
Columbidae	*Ducula aenea*	Green imperial-pigeon	LC
	Chalcophaps indica	Emerald dove	LC
	Stigmatopelia chinensis	Spotted dove	LC
	Treron bicinctus	Orange-breasted green pigeon	LC
	Columba livia	Rock pigeon	LC
Corvidae	*Corvus levaillantii*	Jungle crow	LC
	Corvus splendens	House crow	LC
Cuculidae	*Centropus sinensis*	Greater coucal	LC
Dicruridae	*Dicrurus caerulescens*	White-bellied drongo	LC
Dicaeidae	*Dicaeum erythrorhynchos*	Pale billed flower pecker	LC
Estrildidae	*Lonchura punctulate*	Scaly Breasted Munia	LC
	Lonchura striata	White rumped munia	LC
	Lonchura malacca	Tricoloured munia	LC
Hirundinidae	*Cecropis daurica*	Red rumped swallow	En/ LC
	Hirundo rustica	Barn swallow	M/LC

Table 1. Checklist of birds recorded during the study in five wetlands.

Family	Scientific Name	Common Name	National Conservation Status (Goonatilake, 2020)
	Cypsiurus balasiensis	Palm swift	LC
Nectariniidae	*Nectarinia zeylonica*	Purple rumped sunbird	LC
	Nectarinia lotenia	Long billed sunbird	LC
Oriolidae	*Oriolus xanthornus*	Black hooded oriole	LC
Muscicapida	*Copsychus saularis*	Oriental magpie robin	LC
	Saxicoloides fulicatus	Indian robin	LC
Picidae	*Dinopium benghalense*	Black-rumped flame back	En/ LC
Psittacidae	*Psittacula krameri*	Rose-ringed parakeet	LC
Pycnonotidae	*Pycnonotus cafer*	Red-vented bulbul	LC
	Pycnonotus luteolus	White browed bulbul	LC
Ramphastidae	*Megalaima zeylanica*	Brown-headed barbet	LC
Sturnidae	*Acridotheres tristis*	Common myna	LC
	Gracula religiosa	Hill myna	LC
	Pastor roseus	Rosy starling	M/LC
Meropidae	*Merops philippinus*	Blue tailed bee eater	M/LC
Sylviidae	*Orthotomus sutorius*	Common tailorbird	LC
Timaliidae	*Turdoides affinis*	Yellow billed babbler	LC
Laridae	*Chlidonias hybrid*	Whiskered tern*	M/LC
Pelecanidae	*Pelecanus philippensis*	Spot-billed pelican*	NT
Rallidae	*Amaurornis phoenicurus*	White-breasted water hen*	LC
	Porzana fusca	Ruddy breasted crake*	NT
	Porphyrio porphyrio	Purple swamp hen*	LC
	Gallinula chloropus	Common moorhen*	LC
Podicipedidae	*Tachybaptus ruficollis*	Little grebe*	LC
Anatidae	*Nettapus coromandelianus*	Cotton teal*	LC
	Dendrocygna javanica	Lesser whistling duck*	LC
Phalacrocoracidae	*Phalacrocorax fuscicollis*	Indian cormorant*	LC
	Microcarbo niger	Little cormorant*	LC

Table 1. Checklist of birds recorded during the study in five wetlands.

Family	Scientific Name	Common Name	National Conservation Status (Goonatilake, 2020)
Anhingidae	*Anhinga melanogaster*	Oriental darter*	NT
Ardeidae	*Egretta garzetta*	Little egret*	LC
	Ardea intermedia	Intermediate egret*	LC
	Ardea alba	Great egret*	LC
	Ardeola grayii	Indian pond heron*	LC
	Butorides striata	Striated heron*	LC
Threskiornithidae	*Threskiornis melanocephalus*	Black headed ibis*	NT
Ciconiidae	*Mycteria leucocephala*	Painted stork*	NT
	Anastomus oscitans	Asian open bill*	LC
Ardeidae	*Ardea purpurea*	Purple heron*	LC
	Ardea cinerea	Grey heron*	LC

LC-Least Concern; NT- Near threatened; M-Migrants; *- birds considered as aquatic birds for the analysis

Table 2. Shannon-Wiener diversity index (Ħ); bird density (BD); species richness (SR); (±SE) and water quality parameters (±SE) in five wetlands studied. Abbreviations of the wetlands are given in Fig. 2.

Wetland	H′	BD (Birds/ km^2)	SR	T (°C)	DO (mg/L)	pH	SL (PSU)	EC (μS/cm)	TDS (mg/L)	SDD (m)
BG	1.04±0.04	2208.06±130.1	17.91±0.66	29.91±0.30	3.31±0.33	6.16±0.23	0.214±0.03	444.13±69.2	215.5±31.69	0.97±0.11
DS	0.99±0.05	2521.47±179.2	17.17±0.61	30.37±0.10	0.28±0.28	5.89±0.2	0.157±0.01	321.57±32.1	162.6±17.77	0.47±0.04
HE	1.23±0.06	1677.45±137.2	15.16±0.38	29.7±0.20	6.93±0.07	5.99±0.15	0.14±0.009	241.77±19.7	158.0±5.5	0.79±0.04
KG	1.17±0.04	1860.02±121.2	14.85±0.36	29.66±0.25	3.54±0.44	7.54±0.07	0.21±0.002	208.76±61.7	213.0±19.17	0.55±0.02
TL	1.71±0.03	4990.09±151.3	22.07±0.68	30.15±0.21	7.13±0.11	6.74±0.21	0.068±0.01	209.06±7.1	103.01±33.58	1.27±0.04

Abbreviations: T-Temperature, DO- Dissolved Oxygen, SL-Salinity, EC- Electron Conductivity, TDS-Total dissolved Solid, SDD- Secchi Disc Depth

Highest dissolved oxygen level (DO) and Secchi disk depth (SDD) were observed in *Thalangama* Tank and they were 7.13±0.11 mgL^{-1} and 1.27±0.04 m respectively. The DO and SDD in *Thalangama* Tank showed a significant difference with *Beddagana* and *Diyasaru* ($p<0.01$). The higher DO level of water is probably due to sufficient aquatic vegetation and less load of organic pollutants. This may have resulted in less microbial activities and less utilization of DO in water. The highest total dissolved solids (TDS) were observed in *Beddagana* wetland (215±31.69 mg/L), followed by *Kiribathgoda* wetland (213±19.17 mgL^{-1}) and dropped further to *Thalangama* Tank (103.01±33.58 mg/L) (Table. 3). The reason for high accumulations of TDS probably due to the accumulation of sewage from adjacent human dwellings (personnel observations by authors). Temperature (29.66±0.25-30.37±0.10 °C) and pH (5.89±0.2-7.54±0.07) among the wetlands were varied in short range. Maximum EC was noted in *Beddagana* Wetland Park (444.13±69.2 μScm^{-1}) and was lowest in *Kiribathgoda* wetland (208.76±61.7 μScm^{-1}). The lowest salinity (SL) was observed in *Thalangama* Tank (0.068±0.01 PSU), while the maximum was recorded in *Beddagana* Wetland Park (0.214±0.03 PSU) (Table 2).

Shannon- Wiener species diversity index (H′) positively correlated with SDD (Fig. 3A) and DO of water (Fig. 3B). TDS, EC, and salinity were main physical parameters which affect the bird population indices of wetlands. Shannon- Wiener species diversity index (H′) had significant negative relationships with TDS (Fig. 3C) and salinity (Fig. 3E). Bird density among the five wetlands studied was positively correlated with SDD and Temperature ($p>0.05$) (Fig. 4A and 4B). Moreover, bird density was negatively correlated with salinity (Fig. 4C) and TDS (Fig. 4D). When the correlation was carried out between the physical and chemical parameters with the species richness, a significant positive correlation was established between the species richness and SDD (Fig. 4E). Species richness was negatively correlated with TDS (Fig. 4G) and salinity (Fig. 4H). Therefore, these factors (e.g., TDS, Salinity, SDD and DO) can be considered as the limiting factors for the bird distribution and in addition to distribution of the aquatic organisms that are directly consumed by aquatic birds (Balasubramanian and Kannan 2005; Sridhar et al. 2006). Hence, it can be suggested that there is a possible relationship between measured water quality parameters and abundance of bird's prey items in the wetland waters.

According to Baldassarre and Arengo (2000), availability of food was high in both low salinity ponds (0.063-0.073 PSU) and high salinity ponds (0.078-0.136 PSU), where less food was found in intermediate salinity ponds. In the present study, the salinity ranged from 0.068-0.214 PSU suggesting current results approximately confirm the above finding through polynomial regression relationship between salinity and bird diversity (Fig. 3E), density (Fig. 4C), and richness (Fig. 4H).

Further, there are diverse forms of dissolved solids in nature and in addition to the natural sources of input, sewage also can be considered as a most important source of dissolved solids (Borges 2002). Transparency or the amount of light, which penetrates is considered a factor that fluctuates according to seasons. Water transparency strongly depends on the dissolved solids in the water (http://water.epa.gov). Timms and Midgley, (1970) have revealed an inverse relationship in between transparency and suspended sediment load. The rain-water can bring large amounts of dissolved and suspended inorganic and organic materials from upper catchment areas as well as from lower floodplains during the rainy season making the water to be more turbid. This causes a reduction in water transparency and high turbidity highlight the habitat unsuitability for the aquatic lives. That makes a direct impact on abundance of aquatic birds, as aquatic organisms are their major food sources. In the present study, highest TDS was recorded in *Beddagana* Wetland Park. In *Kiribathgoda* wetland, soil erosion and industrial effluents may be the major concerning factors for the high amount of TDS. Even though the temperature and pH in a water body play a significant role as a regulatory factor for both biological activities and the physical and chemical characters of the ecosystem (Sonal et al. 2010), present study was not able to record significant relationships between population parameters of aquatic birds and pH or temperature (Fig. 4B;4F). Temperature and pH of the water body is affected by several factors such as basin altitude, morphology, vegetation, and topography (You et al. 2019). In the present study, all those factors can be considered similar in all studied wetlands. That can be the main reason to detect a short range of water temperature (29.66±0.25 - 30.37±0.10 °C) and pH (5.89±0.2-7.54±0.07) (Table 2). It is observed that, there was a high accumulation of electrolytes runoff thus, higher EC in *Beddagana* and *Diyasaru* Parks (Table 2). It is revealed the population parameters of aquatic birds at the *Diyasaru* and *Beddagana* Wetland Parks were simultaneously influenced by the EC. The closest reason could be the effluent from industries and households of the vicinity. Though there were no strong evidence, agricultural chemicals could also be added to these waters from the plenty of commercial plant nurseries in vicinity.

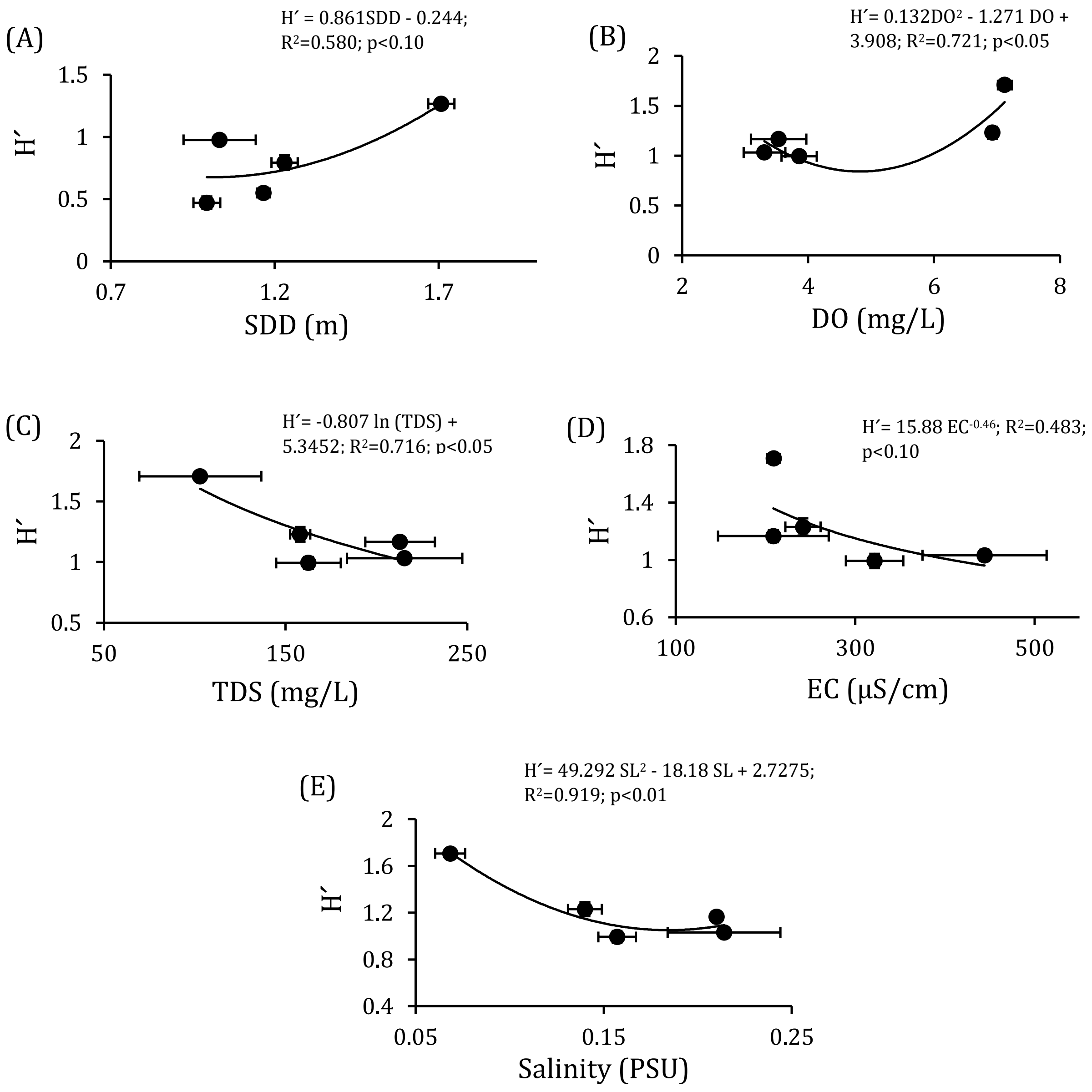

Figure 3. Regression relationships of Shannon-Wiener diversity index (Ħ) with (A) Secchi Disk Depth (SDD); (B) Dissolved Oxygen (DO);(C) Total Dissolved Solids (TDS); (D) Electron Conductivity (EC); (E) Salinity (SL) in five wetlands studied. Regression equations, significant levels and correlation co-efficient (R^2) values of the estimated relationships are also given

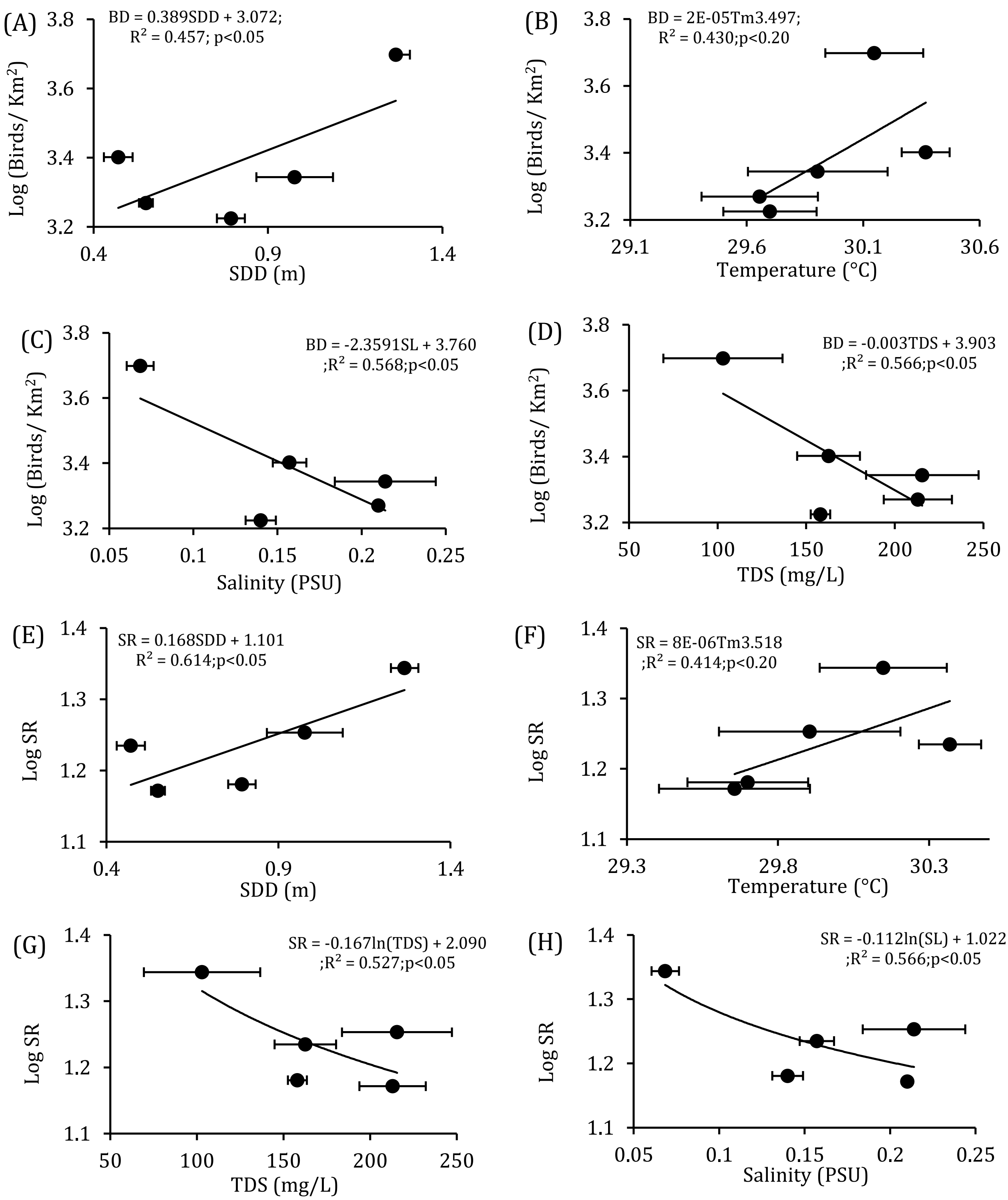

Figure 4. Regression relationships of log bird density (BD) with (A) Secchi Disk Depth (SDD); (B) Temperature (T_m); (C) Salinity (SL); (D) Total Dissolved Solids (TDS) in five wetlands studied and the regression relationships of log species richness (SR) with (E) Secchi Disk Depth (SDD); (F) Temperature (T_m); (G) Total Dissolved Solids (TDS); (H) Salinity (SL) in five wetlands studied. Regression equations, correlation co-efficient (R^2) and significant levels of the estimated relationships are also given.

Correlation coefficients showed a weak correlation pattern comparing with regression relationships obtained only for aquatic birds (Table 3). Therefore, these results suggest that there was a substantial effect of water quality towards the aquatic birds than the wetland associate terrestrial birds.

PC 1 score and correlation of three measured population parameters are also explained in Fig. 5 B-5D. Bird population parameters have (e.g. diversity, density and species richness) negatively correlated with PC 1 scores (Fig. 5B, 5C and 5D). Negative PC 1 scores were denoted by SDD and DO.

Table 3. Pearson's correlation coefficients calculated for both terrestrial and aquatic birds together. Significant levels are also given.

	T_m	DO	pH	SL	EC	TDS	SDD
Ḣ	-0.25	0.43^{*}	0.24	-0.33	-0.02	-0.26	0.94^{***}
BD	0.68^{*}	0.14	-0.04	-0.52^{*}	0.17	-0.52^{*}	0.68^{*}
SR	0.52^{*}	-0.01	-0.28	-0.24	0.57^{*}	-0.23	0.70^{**}

Significant levels= $p<0.2^{*}$; $p<0.1^{**}$; $p<0.001^{***}$

Results of the Principal component analysis (PCA) which was performed to find out the physical and chemical parameters that influenced the variation of bird population parameters are shown in Fig. 5A. Eigenvalues of PCA 1 explain the 50.5 % variance (Table 4).

Table 4. Eigen values and variance explain by the principal component analysis

PC	Eigenvalue	% variance
1	3.54	50.5
2	1.91	27.3
3	0.96	13.7
4	0.60	8.6

Hence, SDD and DO were extremely influenced on *Thalangama* Tank followed by *Heen Ela* marsh (Fig. 5A). For the sites of *Beddagana* and *Kiribathgoda,* salinity and TDS were the extremely influencing physical and chemical parameters. Other than these factors, *Beddagana* had an influence from EC (Fig. 5A). Further, *Diyasaru* Park had an effect from EC on the variation of diversity, density and species richness of the water birds (Fig. 5A)

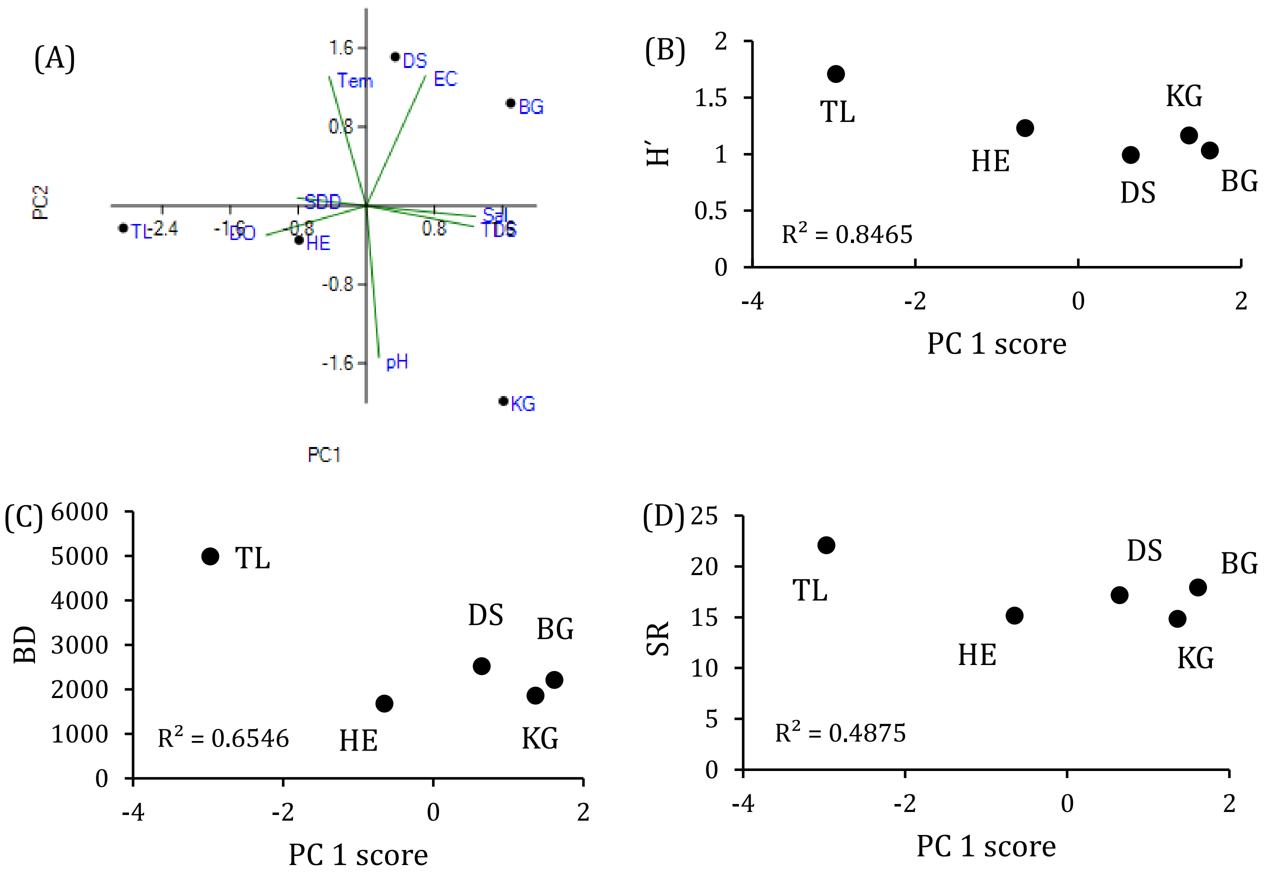

Figure 5. Results of Principal Component Analysis. (A) PCA plot of physical and chemical parameters of water in the studied wetlands. PC 1 score (driven by mainly SDD and DO) and correlation of three measured population parameters (B) Shannon-Wiener diversity index; (C) Bird density and (D) Species richness

The overall species diversity, richness and density were higher in *Thalangama* Tank wetland system. It was evident that particularly less turbidity and high DO levels in water which create a suitable habitat for fish (Steinberger and Wohl 2003) and macro invertebrates (Van de Meutter et al. 2005). In the present study, DO level ranged between 0.28±0.28 –7.13±0.11 mgL^{-1} (Table. 2). Manahan (1993) described the high level of DO in water is resulted due less organic matter and industrial waste present in a waterbody. A low DO level of the water body indicates the stress problems for aquatic organisms and if DO level is high or close to saturation (7 mgL^{-1}, it is considered a healthy lotic ecosystem (Manahan, 1993). Among the multiple limiting factors in wetlands, DO levels are considered prominent due to the larger effects it could have on chemical and biological processes of the system (Heimann and Femmer, 1998). Therefore, reduced oxygen level in the water has a direct impact on the biotic community of water body while also being a threat to waters' self-purification capacity. These low values of DO indicate the presence of untreated waste in *Diyasaru* Park, *Beddagana* Park and *Kiribathgoda* wetlands. Fish and other invertebrates act as the main food sources for aquatic birds and a positive correlation can be observed between abundance of fish and abundance of birds (Labe et al. 2018). Those trophic relationships are predominantly important for the bird population, and it could be a stout reason for the observed high species richness in *Thalangama* Tank. Wetland Management Strategy (2016) has recorded the highest freshwater fish and amphibian diversity in *Thalangama* Tank system and those could be the main food items for aquatic birds. *Beddagana* Wetland Park and *Diyasaru* Park are maintaining as wetland parks and were formerly degraded lands due to various anthropogenic activities which are now being recovered. Some species such as *Porzana fusca, Pastor roseus* and *Aegithina tiphia* were recorded only in *Diyasaru* Park. The determination of bird congregation can be done considering the area of open water as an important factor (González et al. 2009). The quality of water in smaller water bodies can significantly change along with amount of migratory birds due to the addition of extra loads of nutrients (Andrikovics et al. 2003). *Thalangama* Tank is comparatively a large open water body when compared with other areas and therefore sudden fluctuations of water quality may be less frequent. This can be another reason to have favorable physical and chemical parameters in *Thalangama* Tank.

The present study revealed multiple factors which could threaten both the wetland ecosystem and its bird population since birds utilize wetland ecosystem for feeding, shelter and other social interactions. Several local wetlands are seriously threatened with the declining of local bird population. Unplanned economic development, solid waste dumping and illegal encroachments could be some major reasons which bring water birds in danger. Pollution through industrial and household effluents is also a major threat to the birds in this aquatic ecosystem (Elizabeth 2000; Mahaulpatha et al. 2008). Based on the diversity, richness and species density, high priority efforts should be dedicated for the conservation of *Thalangama* Tank wetland system, due to comprising of a high bird diversity being popularized with many local and foreign birds. Since *Diyasaru* Park and *Beddagana* Wetland Park are maintaining as public parks, the habitats and their conservation have already been assured. During the dry season some of the major ponds in *Beddagana* Wetland Park get dried-off. Therefore, such an extreme level of disturbance may also influence the reduction of bird diversity. *Heen Ela* area is currently undergoing a rapid development. The conservation priorities should be subsequently adopted to *Heen Ela* for the long-term survival of aquatic birds. Identifying sources of pollution is particularly important for the future conservation of aquatic birds. In order to bring the conservational efforts to reality, it is very important to reduce the anthropogenic disturbances for the wetland eco systems (Bobbink et al. 2016; Aronson et al. 2017). Even though the interrelationship between human and wetlands can bring many economic advantages, it will ultimately increase the challenge of protecting different threatened and vulnerable wetlands and associate avian species.

4. Conclusion

Similar to many tropical countries, the urban wetlands in Sri Lanka are diminishing at an alarming rate. Wetlands act as the prime habitats for aquatic birds, and in this study the distribution of the bird species was scattered throughout the five wetlands. Transparency and high dissolved oxygen levels in the waters enhance the species diversity and richness. Conversely, high electrical conductivity, salinity and total dissolve solids decrease the species diversity and richness of these avifauna. Apart from these factors, water temperature was an influential factor to regulate the density and richness of aquatic birds. Current study revealed that the bird population parameters were influenced by multiple physical and chemical parameters. Water transparency and dissolved oxygen levels were extremely influencing on *Thalangama* Tank followed by *Heen Ela* marsh. For the sites of *Beddagana* and *Kiribathgoda*, salinity and total dissolved solids were the extremely influencing physical and chemical parameters. Similarly, *Beddagana* and *Diyasaru* Park had a great effect from electrical conductivity on the variation of diversity, density and species richness of the water birds. Therefore, the present study has shown that variations in water quality parameters are directly affecting the distribution and diversity of aquatic birds in urban wetlands.

Conflicts of interest: The authors have no conflicts of interest regarding this publication.

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