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Assessment of Waterbird Composition in Kalkundamaduwewa Tank at Vavuniya, Sri Lanka

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ABSTRACT

Changes in abundance of waterbirds reflect the habitat changes of a tank ecosystem. Ephemeral tanks in Vavuniya district are known as habitats for rich birds diversity during different periods of a year. A short-term field study was made to assess the pattern of waterbird distribution at Kalkundamaduwewa tank during June to August of the year 2015. Visual observations were made twice a week at predefined sampling blocks of the tank. Standard methods were employed to count and identify the species of waterbirds. Data obtained were subjected to compute Species richness index, Shannon-Wiener index, Species evenness, Simpson's diversity index, and Species similarity. Results suggest that the study tank had species diversity and abundance attributable to a wide variety of habitat along the water body. Nearly 94% of the encountered birds belonged to only eight species out of the total 15 recorded bird species. No significant influence in the bird counts for the rainfall and ambient temperature during the study period. Higher number of waterbirds were encountered in the blocks with higher vegetation. The high correlation of vegetation with the Species evenness and Shannon index justifies the species abundance in the tank. The investigation shows that the tank should be maintained for the birds' conservation.

Key Words: Bird Distribution; Bird Count; Richness; Species Indices

INTRODUCTION

Being an island, Sri Lanka is known for its resident and migratory waterbird biodiversity. Bird diversity is one of the significant factors that attract tourists and researchers to this small island. Sri Lanka is home to an abundance of endemic bird species and also a destination for the migratory birds. The Vavuniya district lying in the lower part of the Northern province of Sri Lanka shares the characteristic dry zone climate and low land topography of the province. This district is well known for its ancient, man-made cascade system of tanks (Shanmuga-nathan et a1. 2010). Though few tanks have been filled to build a human settlement, most of them are still catering their purpose. Tanks in Vavuniya provide ample habitat for birds in addition to serving the purpose of agricultural irrigation. These man-made tanks render an ideal habitat and microhabitat for the majority of the

resident and migratory birds. Such tanks, or in other terms wetlands in this district are ecologically very supportive for biodiversity conservation.

Wetlands are defined as lands transitional between terrestrial and aquatic ecosystems where the water table is usually at or near the surface, or the land covered by shallow water (Mitsch and Gosselink 1986). Wetlands are among the most productive ecosystems in the world and play a vital role in flood control, aquifer recharge, nutrient absorption, and erosion control. Also, wetlands provide a home for a tremendous diversity of wildlife such as birds, mammals, fish, frogs, insects,' and plants (Buckton 2007, Kumar and Gupta 2009). Waterbirds are an essential component of most wetland systems as they occupy several trophic levels in the food web of wetlands and form a links In many aquatic food chains (Custer and Osborne 1977). Activities of waterbirds are·considered as indicators of the quality of the wetland ecosystem, and they reflect changes. Therefore, the estimation of local densities of waterbirds helps to understand the abundances of various species of other organisms (Turner 2003, Indika and Mahaulpatha 2015).

Kalkundamaduwewa is one of the ephemeral tanks in Vavuniya district, 8 km southward to the central town. Therefore, human influence is less compared to other tanks in the town periphery. Half of its capacity is depleted by the summer season during which the rainfall· is scarce in the district. A salient observation during the season is that the aquatic plants and waterbirds succeed according to their niches. The observed bird nests in the adjacent log plants indicate that this tank serves a critical function to the ecosystem in terms of providing habitat and breeding ground to the waterbirds.

Therefore, the objectives of this study were to assess the pattern and abundance of waterbird (i.e., avifauna) distribution of Kalkundamaduwewa tank arid identify the possible reasons for a particular distribution of observed birds in the tank ecosystem.

METHODOLOGY

Study Area

The study was conducted at Kalkundamaduwewa tank in Vavuniya, which is in the Northern province of Sri Lanka (Figure 1). The tank is known for its rich bird diversity compared to the other tanks in the district. It holds at least 10% of its irrigation capacity throughout the year. Kalkundamaduwewa is a minor tank with a relatively longer tank bund. The tank has an area of about 12 ha, a mean depth of 2.1 m, and a total water capacity of 25 ha-m. The catchment area of the tank is spread over 18 sq. km. Geomorphologically, the catchment has an undulated topography with broad valleys and small rock ridges (Samarakoon 2004) forming cascade-based irrigation tanks in Vavuniya (Akther et al. 2015, Shanmuganathan et al. 2010). The district experiences a mean temperature of 28°C and an annual rainfall of 1400 mm.

Data Collection

Kalkundamaduwewa is nearly rectangular in shape with one longer side having the tank bund. For the convenient observation, the tank area was divided into eight blocks. The bund was marked at 100 m intervals. A permanent landmark was fixed at the other end. A moderately accurate GPS was used. During the period of early summer (June, July, and August) 2015, we surveyed the field twice-a-week to collect the data of birds. The observations were made by the observer from the middle of each block while traversing along the tank bund. One block was considered at a time. The birds flying over and along these virtual transects were not taken into consideration. Birds that landed during the observation were counted separately and added to the total count at the end, following the method by Dayawansa and Wijesinghe (2002). Waterbirds were identified following Kotagama (2012). Various indices **were** used to assess the waterbird distribution over the tank.

Community Indices

The data were used to compute the species richness, Shannon-Wiener index, species evenness, Simpson's diversity index, and species similarity. The NDVI (Normalized Difference Vegetation Index) was used to estimate the vegetation percentage in the tank during the consecutive months.

Shannon-Weiner index (H)

The Shannon-Weiner index (Shannon and Weaver 1964) is commonly used to associate species abundance and relative richness amongst species (Barbour et al. 1998) It mathematically measures the proportions of abundance and richness (Stirling and Wilsey 2001). This index assumes that random sample represents all the species. It was calculated using the formula:

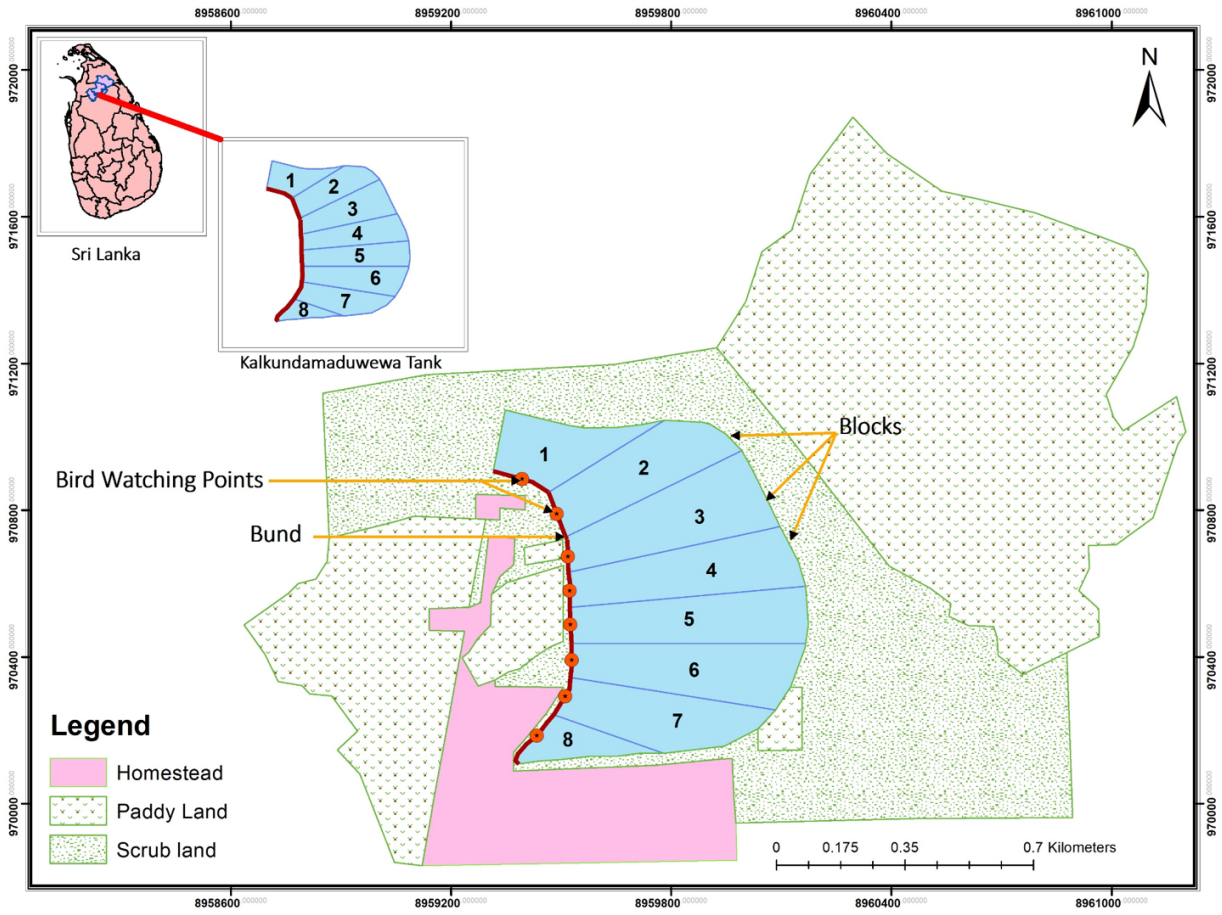


Figure1. Geographical location of the Kalkundamaduwewa tank in Vavuniya district of Sri Lanka

$$H = -\sum_{i=1}^{S}(P_i \times lnP_i) \quad (1)$$

where, H is the Shannon-Wiener index, is the fraction of the entire population made up of ith species, S is the number of encountered species.

The value of the Shannon-Weiner index usually lies between 1.5 and 3.5, and higher values indicate that the numbers of individuals are evenly distributed among all the species (Bibi and Ali 2013).

Species evenness (E)

Species evenness is a measure of the relative abundance of the different species making up the richness of an area. It is calculated by following equation (Soini 2006). The less variation in communities between the species indicated by the lower values.

$$E = \frac{H}{ln\ S} \quad (2)$$

A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance.

Simpson diversity index (D)

Simpson's diversity index (Simpson 1949) measures community diversity. It measures the probability that two individuals can be selected randomly from a sample which belongs to the same species. The D gives the probability of any two individuals drawn from a noticeably large community belonging to different species.

$$D = 1 - \frac{\sum n(n-1)}{N(N-1)} \quad (3)$$

where n denotes the number of individuals per species and N denotes the number of total individuals.

The values of the Simpson index range between 0 and 1. Relatively larger index values indicate higher diversity.

Species richness index (r)

The number of species in a location is a measure of richness. If more species are present in a location, the location is considered as 'richer'. Species richness as a measure on its own takes no account of the number of individuals of each species present (Leinster and Cobbold 2012).

Species similarity (SS)

The species similarity between blocks is calculated to compare the blocks in terms of species count. It can be estimated using the Sørensen coefficient (), which has a value ranging between 0 and 1. It is estimated using the equation:

$$SS = \frac{2C}{S_1 + S_2} \quad (4)$$

where c indicates the number of species common in 2 blocks, S_1 and S_2 indicate the total number of species in block 1 and block 2, respectively.

The probable values of the species similarity index are same as the Simpson diversity index. For instance, the closer the value is to 1, the more communities exist in common, if it is equal to 1, is an indication for the complete overlapping community, and there will be a block dissimilarity when the value is equal to 0.

Normalized Difference Vegetation Index (NDVI)

The NDVI is a simplified spatial representation of the vegetation using maps (Tucker 1979). The NDVI maps were prepared using the Landsat 8 OLI_TIRS satellite imageries acquired from the United States Geological Survey site for June, July and August of 2015. NDVI was computed as:

$$NDVI = \frac{(Near\ Infrared - Red)}{(Near\ Infrared + Red)} \quad (5)$$

The range of the NDVI values lies in between -1 and +1. Different classes of features in water bodies such as the vegetation cover (i.e., trees and canopy cover), aquatic plants and water surface were assigned appropriate threshold values. To validate the NDVI outputs, field photographs and GoogleEarth images were used as a reference. The resulting raster formats were converted to vector, and block-wise vegetation area (both vegetation cover and aquatic plants) was calculated in percentage of total area of the corresponding block. Finally, the percentage of vegetation cover occupied in each block was extracted, and the relationship between indices and vegetation cover (%) were analysed using Pearson correlation coefficient technique. The analysis was performed using the ArcGIS ver. 10.5.

RESULTS AND DISCUSSION

In this section, we present the results for the species composition, temporal distribution, and spatial distribution of the resident and migrant bird species recorded at the Kalkundamaduwewa tank during the study period of June, July, and August of 2015.

Species Composition

Altogether fifteen species of waterbirds were identified in the Kalkundamaduwewa tank ecosystem. The common sighted birds were: (1) Brahminy Kite (*Haliastur indus*), (2) Black-headed Ibis (*Threskiornis melanocephalus*), (3) Common Kingfisher (*Alcedo atthis*), (4) Cormorant (*Phalacrocorax niger*), (5) Egret, (6) Little Grebe (*Tachybaptus ruficollis*), (7) Darter (*Anhinga melanogaster*), (8) Pheasant-tailed Jacana (*Hydrophasianus chirurgus*), (9) Pond Heron (*Ardeola grayii*), (10) Purple Heron (*Ardea purpurea*), (11) Purple Swamphen (*Porphyrio porphyrio*), (12) Red-wattled Lapwing (*Vanellus indicus*), (13) Stork-billed Kingfisher (*Halcyon capensis*), (14) White-breasted Waterhen (*Amaurornis phoenicurus*), and (15) White-throated Kingfisher (*Halcyon smyrnensis*).

The Cormorant was the most commonly encountered waterbird with the relative abundance of 46%, and on rare occasions, Stork-billed Kingfisher was recorded (Table 1). Among the 15 species, Cormorant, Egret, Little Grebe, Pheasant-tailed Jacana, Pond Heron, Purple Swamphen, White-breasted Waterhen, and White-throated Kingfisher were the eight species made up almost majority of the observation with the total relative abundance of 94% in Kalkundamaduwewa during the study period. This bird frequency of occurrence and relative abundance described in Table 1 were adapted from Bull (1974).

The most commonly found eight species of water-birds that made up the majority of the observation in the Kalkundamaduwewa (Figure 2) are listed below with brief identification features, which was utilised during the field expedition.

Table 1. Status and relative abundance of the species at Kalkundamaduwewa during the study period

Occurrence (Counts per day)*	Waterbirds	Relative abundance (%)	Cumulative %
Very Abundant (>1000)	Cormorant	46	46
Abundant (200-1000)	Pheasant-tailed Jacana and Egret	23	69
Very Common (51-200)	White-breasted Waterhen, Purple Swamphen, Little Grebe, White-throated Kingfisher, and Pond Heron	25	94
Common (21-50)	Common Kingfisher and Red-wattled Lapwing	3	97
Fairly Common (7-20)	Purple Heron, Darter, Brahminy Kite, and Black-headed Ibis	2	99
Rare (1-6)	Stork-billed Kingfisher	<1	~100

* Reference: Bull 1974

Figure 2. Actual images of the dominant bird species at Kalkundamaduwewa, (a) Little Cormorant, (b) Pheasant-tailed Jacana, (c) Egret, (d) White-breasted Waterhen, (e) Little Grebe, (f) White-throated Kingfisher, (g) Pond Heron, and (h) Purple Swamphen

Little Cormorant: The long-tailed and short-billed birds can be seen very commonly in stagnant water pools like tanks, lagoons and also rivers (Figure 2a). The relative abundance of the Little Cormorant in Kalkunda-maduwewa was 46% during the study period. It was the all-time highest abundant species in the tank.

Pheasant-tailed Jacana: Long curved tail can separate males during the breeding season. They have a dark brown body with white wings, foreneck and head are white, and hindneck is yellowish (Figure 2b). Very common in marshes and aquatic plant covered ponds. The relative abundance of the Pheasant-tailed Jacana in Kalkundamaduwewa was 12% during the study period.

Egret: Mainly three types such as Little, Intermediate and Great egret were there (Figure 2c). However, it was hard to separate them because of the considerable distance between the observation point and the bird. They are common in Marshes, paddy fields, tank edges, mangroves, and lagoons. The relative abundance of the Egret in Kalkundamaduwewa was 11% during the study period.

White-breasted Waterhen: It can be identified by the white coloured breast, throat, and face with dark coloured wings and upper parts (Figure 2d). Also with cinnamon coloured lower belly and under the tail. Very common in marshes, paddy-fields, mangroves in all zones. The relative abundance of the White-breasted Waterhen in Kalkundamaduwewa was nearly 6% during the study period.

Little Grebe: They are small waterbirds with reddish brown coloured body flanks and cheeks are brownish coloured (Figure 2e). It can be seen mostly in stagnant fresh or slightly saline waters with weeds. The relative abundance of the Purple Swamphen in Kalkunda-maduwewa was nearly 6% during the study period.

White-throated Kingfisher: It is a widespread bird in all parts of Sri Lanka. The upper part of the bird is blue in colour, and the breast is white with the chocolate brown head (Figure 2f). The relative abundance of the White-throated Kingfisher in Kalkundamaduwewa was nearly 5% during the study period.

Pond Heron: Can be seen in most wetlands. It has a dark body but one can see white in wings and tails during flight. It is a common species all over the island (Figure 2g).The relative abundance of the Pond Heron in Kalkundamaduwewa was nearly 5% during the study period.

Purple Swamphen: It is mainly identified with its purplish-blue body colour. They have a large, red-coloured bill with a red frontal shield. Usually seen at low country tanks and swamps in both wet and dry zones. The relative abundance of the White-breasted Waterhen in Kalkundamaduwewa was nearly 3% during the study period. Purple Swamphen (Figure 2h) was the lowest abundant species among the eight dominant species mentioned above.

Kingfisher species recorded at Kalkundamaduwewa had the relative abundance of nearly 6% of the total species. The actual composition of the Kingfisher species was: White-throated Kingfisher (5%) >Common Kingfisher (<1%)> Stork-billed Kingfisher (<1%).

Notably, few species recorded at Kalkundamaduwewa were already sighted in the nearby tank such as Virava-puliyankulam and Vavuniya tank. Previous studies by Sivanesan and Anukulan 2015, Kishoran and Luximini 2015) reported for such bird species were Little Cormorants, Little Grebe, Egrets, Purple Heron and Black-headed Ibis recorded at adjacent tanks in the same region but during a different period.

Temporal Distribution

Summary of the calculated index value ranges for Shannon-Wiener index, Evenness, Simpson's diversity index and species richness are presented in Table 2. The index ranges cover the temporal distribution of water birds in Kalkundamaduwewa. Figure 3 presents the temporal changes in these indices.

Table 2. Summary of calculated index ranges during the study period at Kalkundamaduwewa

Index	Range of values
Shannon-Wiener index	1.34-2.11
Species evenness	0.49-0.82
Simpson's diversity index	0.59-0.87
Species richness index	10-14

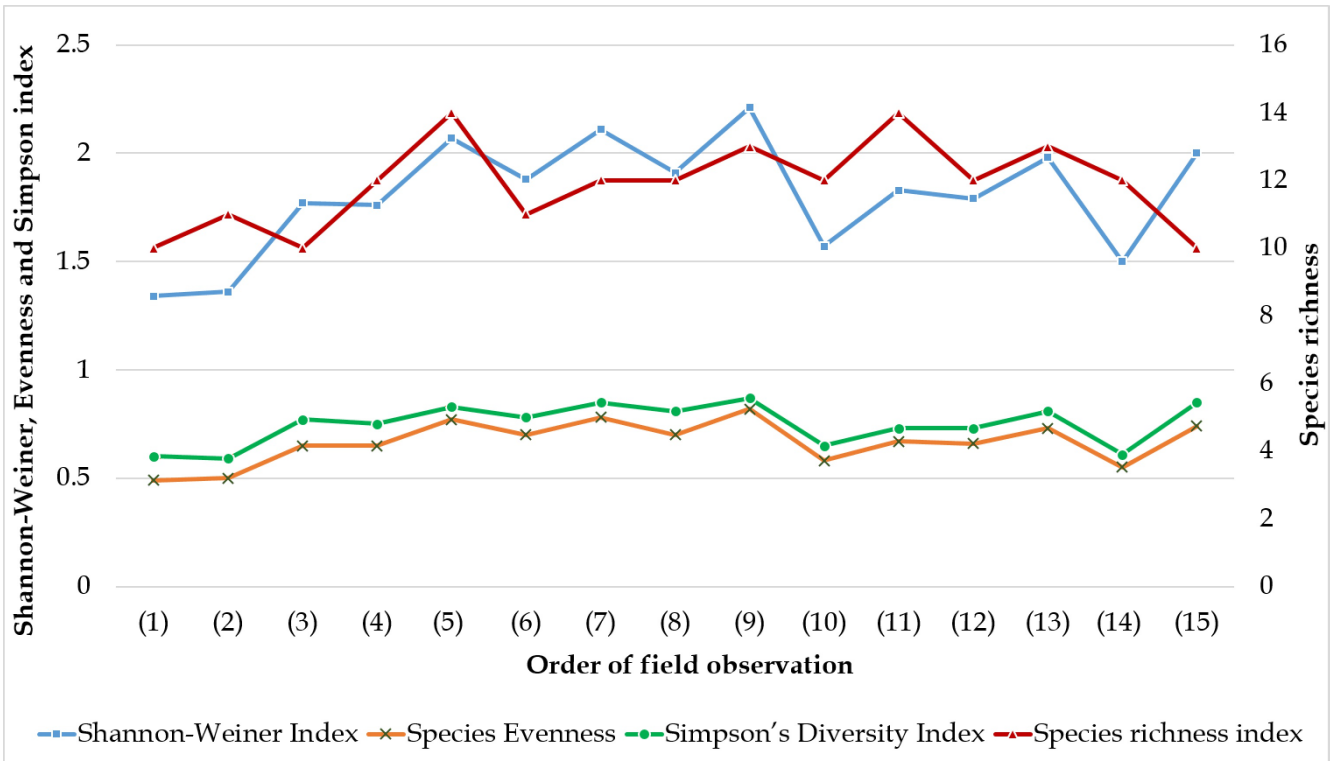


Figure 3. Changes in the waterbird biodiversity indexes in Kalkundamaduwewa in Vavuniya district of Sri Lanka

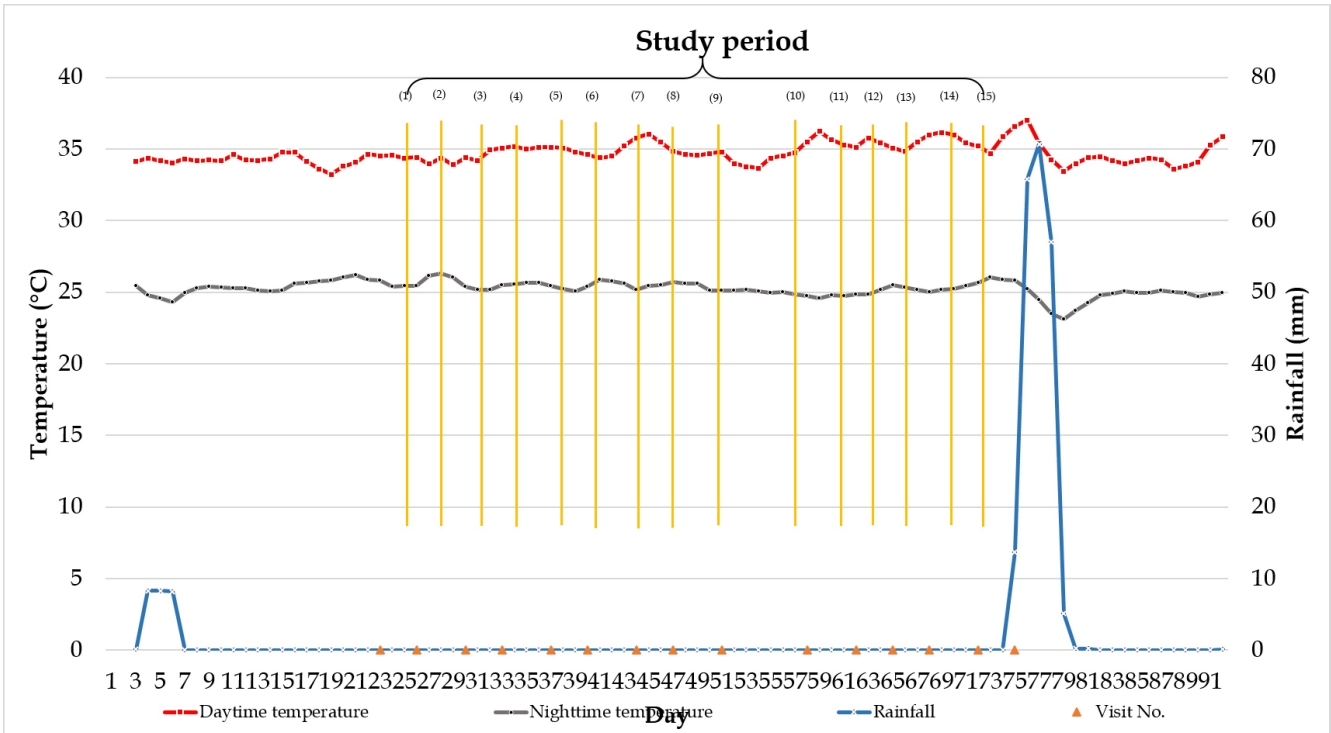


Figure 4. Rainfall and ambient temperature from June to August of 2015 in Vavuniya district of Sri Lanka

The values of Shannon-Weiner index for the encountered waterbirds (1.34-2.11) clearly suggests the diversity of species in Kalkundamaduwewa. This result agrees with a study by Bibi and Ali (2013). The waterbird species at Kalkundamaduwewa were however not evenly distributed; the evenness value ranged from 0.49 to 0.82 during the study period. It indicates that the uneven distribution of bird species that may be due to the specific niche, which varies within the identified species. The trend line of the species evenness and the Simpson index were approximately the same with slightly higher index values observed for the species evenness for corresponding Simpson index value (Figure 3).The Simpson's diversity index ranged between 0.59 and 0.87 indicating a unique species diversity among the blocks. It confirms a diversified waterbird population in Kalkundamaduwewa during the study period. During the middle of July, bird diversity was higher than in the middle of June. During the study period, the average daytime and nighttime ambient temperatures were observed to be 34.9 °C and 25.3 °C, respectively. There was not much change in the daytime and nighttime ambient temperature in the district during the study period. A rainfall event was observed far apart such as weeks before the field investigation and towards the end of the study period (Figure 4). Notably, the rainfall and ambient temperature seem to have little relation with the temporal distribution of the waterbird population.

Spatial Distribution

Table 3 and Figure 5 show a block-wise summary of the calculated values for Shannon-Weiner index, Species Evenness, Simpson's diversity index, and Species richness. Species richness values varied in between 10 and 14, and it was greater in blocks 2, 3 and 6. A higher number of species were observed during the beginning of July and August. More than ten species were observed in each field visit, which indicates that the study area was rich in terms of waterbird diversity. Egret, Cormorant, White-breasted Waterhen, White-throated Kingfisher and Pond Heron were the species observed at almost all the blocks. The Purple Heron were observed in fewer blocks as compared with the other birds. A lower number of Stork-billed Kingfisher and Darter were recorded throughout blocks.

Block-wise correlation results vouch for the strong and positive relationship when correlated with the values of Species evenness and Shannon index values (Table 4). The correlation coefficient for the average vegetation cover and Species evenness was found as 0.93 followed by the Shannon index having the correlation coefficient value of 0.92. Notably, the species richness and species similarity indexes resulted in the negative and weak correlation.

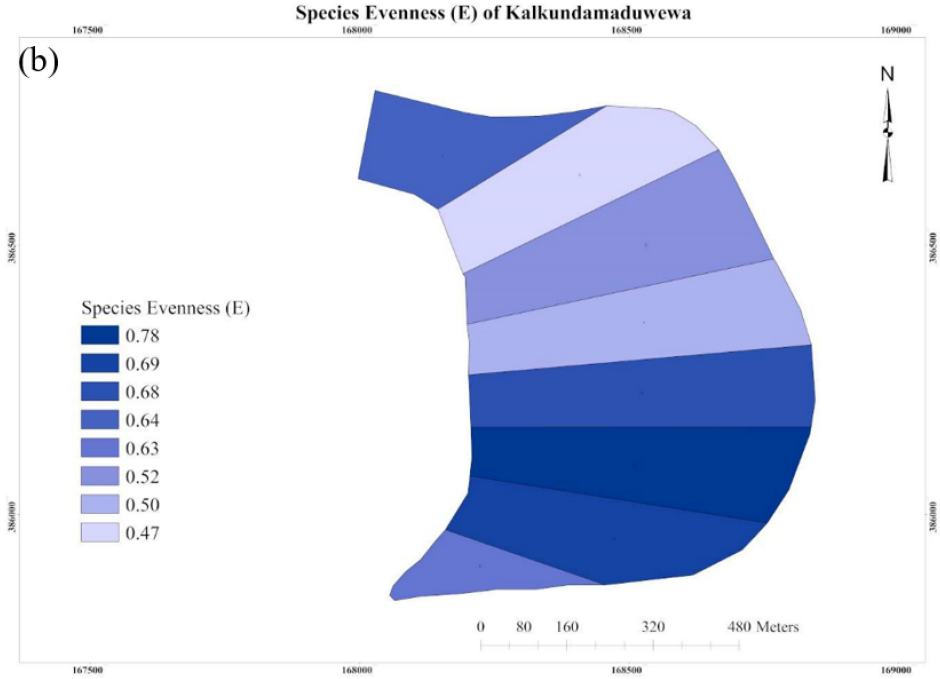
Table 3. Block-wise diversity index values and aquatic vegetation cover (%) in Kalkundamaduwewa

Block	Shannon-Weiner Index	Species Evenness Index	Simpson's Diversity Index	Species Richness	Vegetation cover (%)
1	1.72	0.64	0.77	6	50.8
2	1.28	0.47	0.53	13	32.1
3	1.42	0.52	0.64	13	36.9
4	1.36	0.50	0.36	12	36.6
5	1.84	0.68	0.64	10	59.4
6	2.12	0.78	0.36	13	64.9
7	1.88	0.69	0.64	12	63.3
8	1.70	0.63	0.36	9	63.9

A pairwise comparison of the blocks for Species Similarity (SS) shows that the blocks 3 and 4 and 7 and 8 had similar species throughout the study period. It was estimated for the value of 0.92 as a minimum for the Sørenson coefficient, which indicates that these four blocks had more common species and the overlap is very high. Most of the birds were found in blocks 2 to 7 and fewer were found in the block 1 and 8. The major birds observed in blocks 3 and 4 were Egret, Cormorant, Pheasant-tailed Jacana and Pond Heron. The major bird species found in blocks 7 and 8 were White-breasted Waterhen, White-throated Kingfisher, Red-wattled Lapwing and Little Grebe.

The dendrogram (Figure 6) shows the block similarity in terms of the species count at Kalkundamaduwewa revealing three different distinct clusters. They are, Cluster 1; blocks 2 and 3, Cluster 2; block 4 and Cluster 3; blocks 5, 6, 7 and 8. It may be attributable to the existence of the aquatic plants and depth differences in the tank. The existence of aquatic plant availability in the blocks of 2 and 3 may be the reason for the higher number of observation in those blocks.

The trends of Simpson/Evenness index for bird distribution in Kalkundamaduwewa agree with the NDVI output. Nearly 62% of the vegetation cover was (including aquatic floating plants) observed during the



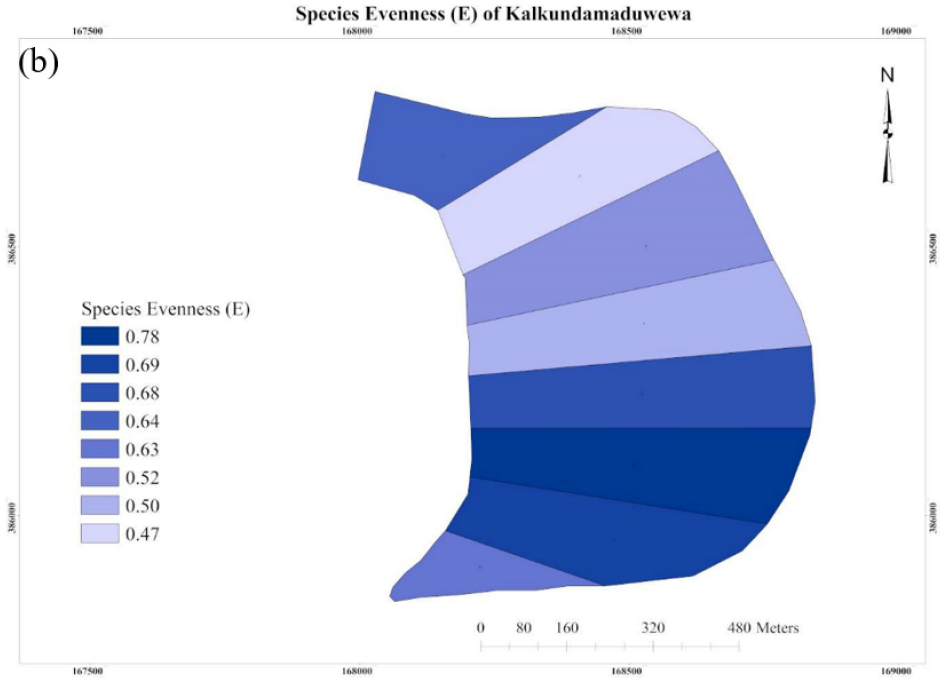


Figure 5. Spatial distribution of block-wise waterbird diversity indexes in Kalkundamaduwewa, (a) Shannon-Wiener index (b) Species Evenness (c) Simpson index, and (d) Species richness index. (Continued on next page)

mid of July while it was only 42% during the mid of June (Figure 6). It is true especially in the blocks 2, 3, and 4, which had attracted more birds during July during which aquatic vegetation cover was high (Figure 7b). The adequate amount of water availability couple with an increased percentage of vegetation cover might be an ideal environment to attract and accommodate more species could be the reason for the increase in species diversity during July in Kalkundamaduwewa.

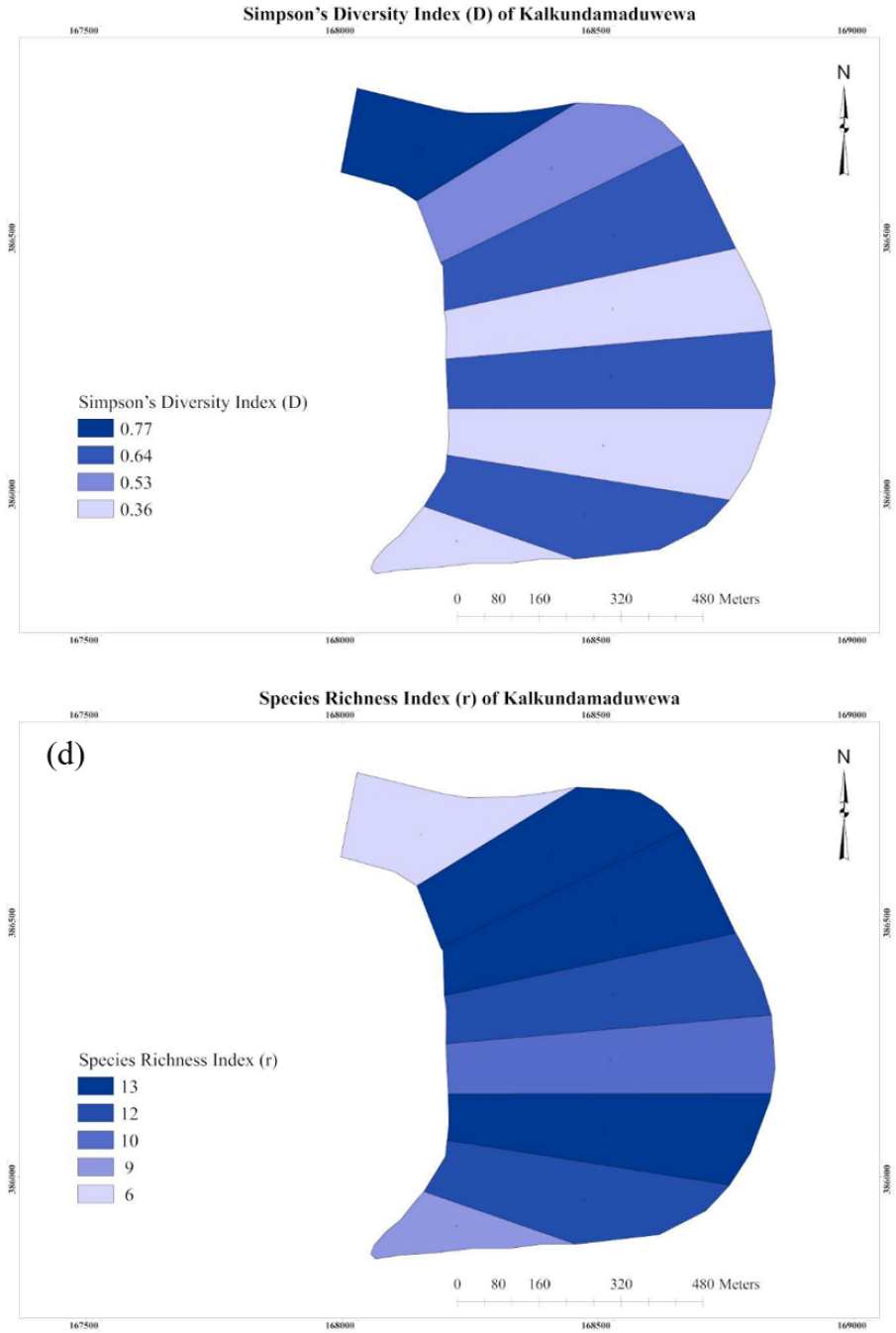


Figure 5. Spatial distribution of block-wise waterbird diversity indexes in Kalkundamaduwewa, (a) Shannon-Wiener index (b) Species Evenness (c) Simpson index, and (d) Species richness index. (Continued from previous page)

CONCLUSION

The temporal and spatial distribution of waterbird species at Kalkundamaduwewa demonstrates the tank's service as a bird habitat in the district. The most common waterbird found in the tank was Little Cormorant, which has 46% of the relative abundance of the total count. The Little Cormorant, Egret, Little Grebe, Pheasant-tailed Jacana, Pond Heron, Purple Swamphen, White-breasted Waterhen, and White-throated Kingfisher were the eight species that made-up the majority of the observation with the total relative abundance of 94% in Kalkunda-maduwewa, during the study period. Though rainfall and ambient temperature had little influence in determining

Table 4. Pair-wise comparison of the blocks for Species similarity (C) at Kalkundamaduwewa tank

Block No.	1	2	3	4	5	6	7	8
1	**1**	0.53	0.53	0.56	0.63	0.63	0.71	0.8
2	0.53	**2**	0.92	0.88	0.7	0.85	0.75	0.64
3	0.53	0.92	**3**	0.96	0.78	0.85	0.75	0.55
4	0.56	0.88	0.96	**4**	0.82	0.8	0.7	0.57
5	0.63	0.7	0.78	0.82	**5**	0.78	0.67	0.74
6	0.63	0.85	0.85	0.8	0.78	**6**	0.96	0.82
7	0.71	0.75	0.75	0.7	0.67	0.96	**7**	0.95
8	0.8	0.64	0.55	0.57	0.74	0.82	0.95	**8**

Legend: 1, 0.8, 0.6, 0.4, 0.2, 0

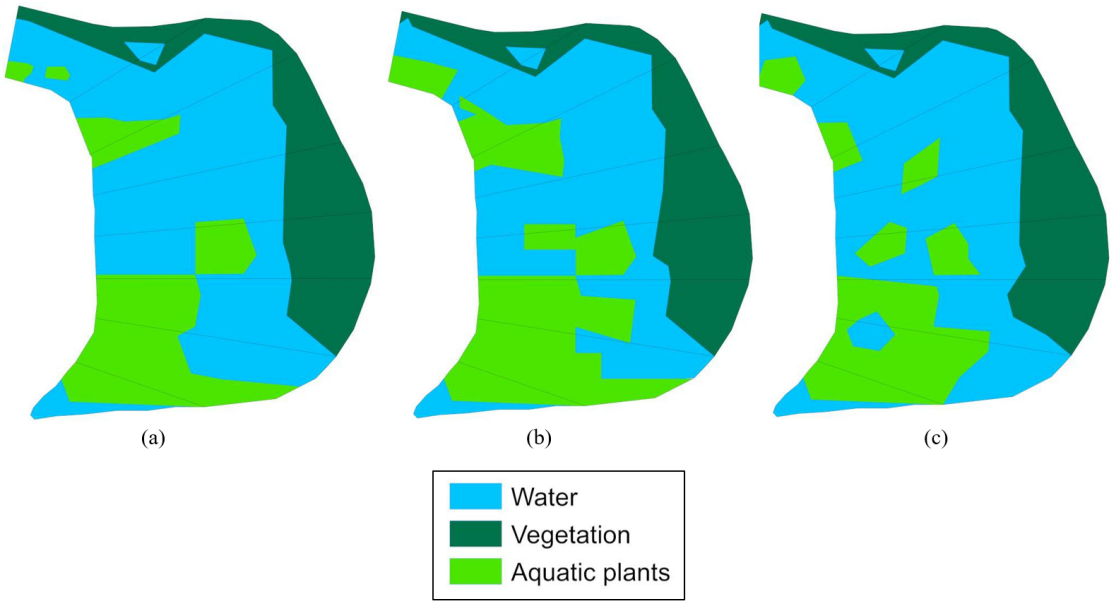


Figure 7. Classified vegetation cover using the NDVI (Normalized Difference Vegetation Index) at Kalkundamaduwewa for the months of (a) June, (b) July, and (c) August in the year 2015.

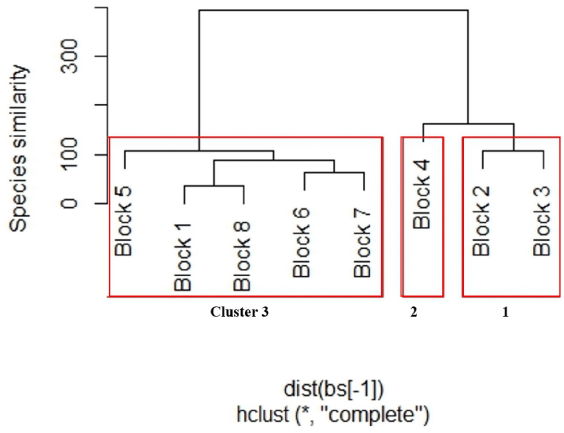


Figure 6. A dendrogram showing block similarity in terms of birds count at Kalkundamaduwewa.

the temporal variation of the bird population at Kalkundamaduwewa, they might have provided the conducive environment for the quick growth of aquatic weeds which attracted more birds. The overall block-wise results indicate that the blocks 2, 3 and 4were very productive for the more affluent bird count during the study period. Such observation was supported by the simplified graphical forms of the NDVI map, which showed a quick increase in the vegetation during July. The block-wise comparison also reiterates that the prevailing vegetation resources for the waterbird population were uneven. The repeated abundance of birds in particular blocks confirmed the importance of vegetation resources for the abundance of waterbirds in Kalkundamaduwewa. For the well being of the ecosystem and to preserve the existing waterbird population, the tank preservation is highly important.

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Author Contributions: M.R. Samith Indika Maddumage conceptualized the study, joined the field study; M.S.R. Akther joined in conceptualizing the study, methodology development, field study and spatial analysis; M.A.R. Ashifa helped with statistical analysis; A.R.H. Mohideen conducted field survey, and photography of birds; G. Tharani helped with methodology development, and data analysis; G. Naveendrakumar did the Statistical analysis and field study. All authors contributed to the preparation of the manuscript.

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