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Diversity, Habitat Utilization and Nesting Characteristics of Waterbirds in and around Maduru Oya Reservoir in Maduru Oya National Park, Sri Lanka

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Abstract

Maduru Oya National Park (MONP) including its largest reservoir, Maduru Oya Reservoir (MOR), has been identified with a high waterbird density. However, a limited number of researches have been conducted on waterbirds in MONP. In this study, diversity, habitat use of waterbirds at MOR and their nesting characteristics were analyzed. Bird survey was carried out using the point count method and block count method. A common ethogram was constructed to identify the behavior categories. Percentage cover of habitat types was estimated by quadrat method. A total of 30 species belonging to 15 families were recorded, including two globally threatened species and three winter visitors. Year around Shannon-Weiner index for MOR was 1.491. Little Cormorant had the highest relative abundance. Percentage coverage of grass had increased gradually from March to September with the highest in September (69.27%) while open water had the highest coverage in the other months. Significantly high number of individuals used areas of grass, open water and mud for feeding and exposed rocks, dead trees/logs for resting (One-way ANOVA, $p \leq 0.05$). Four waterbird species were observed building nests. Occupied nesting tree species were *Senna spectabilis* (Kaha Kona), *Dymorphocalyx glabellus* (Weliwanna) and *Alstonia scholaris* (RukAththana). The number of nests observed in three layers of canopy was significantly different ($p \leq 0.05$). The highest average number of nests was observed in middle layer (8.90 ± 2.67). Black-headed Ibises had high preference to nest in *Dymorphocalyx glabellus* ($p \leq 0.05$, 3.30 ± 1.32) while Great Cormorants ($p \leq 0.05$, 2.38 ± 0.74) and Grey Herons ($p \leq 0.05$, 4.27 ± 2.12) in *Alstonia scholaris*. Little Cormorants had no significant difference in their preference for nesting trees. As a preliminary study, this can be used for future research on

waterbirds and to compose management and conservation plans.

Keywords

Aquatic Avifauna, Conservation, Wetlands, Nesting Ecology

1. Introduction

Wetland habitats constitute permanent or temporary accumulation of water with associated floral and faunal communities [1]. Wetlands support and maintain a diverse community of waterbirds by providing important habitats for their feeding, resting, breeding and other social interactions [2] [3]. The Ramsar Convention defines waterbirds as "species of birds that are ecologically dependent upon wetlands" [4]. Some important factors affecting the relationship between wetlands characteristics and waterbirds include the availability of habitats, quality water, food, shelter and protection from predators. Comprehension of waterbird species diversity and abundance in wetland ecosystems is important in selecting areas for designing regional conservation strategies [5]. Approximately 164 species of waterbirds recorded in Sri Lanka belong to the 23 families [6] [7]. Waterbirds inhabit a wide variety of wetlands throughout Sri Lanka and large concentrations are found in the coastal and inland wetlands of the dry zone [6].

Maduru Oya National Park (MONP) lying within the dry zone of Sri Lanka, was established as an integral part of the Mahaweli Protected Area Complex to provide refuge for many native fauna and flora, particularly elephants and a large number of waterbird species [8] [9]. The park is 58,850 ha in extent of which the wetlands constitute around 10,000 ha. The wetlands within MONP constitute the immediate catchments of five reservoirs including the Maduru Oya (6100 ha), Ulhitiya (2270), Ratkinda (1100 ha), NDK (700 ha) and Henanigala (800 ha) [8]. The mean annual rainfall within the area is 1650 mm received mostly during the northeast monsoon season and the mean annual temperature of the area is about 27˚C [10]. Wetlands of MONP have been identified as Important Bird and Biodiversity Area (IBA) with high waterbird density and it supports globally threatened (VU) species including Asian Woollyneck (*Ciconia episcopus*) and Lesser Adjutant Stork (*Leptoptilos javanicus*) [6] [11] [12].

A number of studies have been conducted focusing the bird diversity in several national parks in Sri Lanka including Wilpattu National Park, Wasgomuwa National Park, Minneriya National park, Gal-oya National Park and in Yala protected area complex [13] [14] [15] [16] [17]. However, the amount of research work conducted on birds in MONP is incipient. Up to date only the avifaunal diversity in the peripheral areas of the MONP has been studied [18]. Despite being the third largest national park in Sri Lanka, the avifauna inside the MONP has not been systematically documented leading to the gaps in the knowledge on the waterbirds and their habitat use. A sound understanding of

how waterbird species interact with existing habitats around wetlands is essential to aid with developing effective conservation plans. Therefore, the objectives of this study were to investigate diversity, habitat use of waterbirds and their nesting characteristics at MOR.

2. Materials and Methods

2.1. Study Area

The study was conducted monthly from January to December 2019 at the Maduru Oya Reservoir (MOR). MOR is the largest reservoir found within the park with a catchment area of 453 km^2 and a storage capacity of 596,000,000 m^3 [8] [10]. Although MOR is a very large reservoir, one of the main constrains faced is selecting the sites for bird sampling due to inaccessibility to the sites throughout the year. Four representative sampling sites were selected covering all the accessible parts of the reservoir during the preliminary survey, considering the accessibility and the highest visibility of the sites. The four sites were 7˚38'44"N, 81˚09'59"E (Site 1), 7˚38'21"N, 81˚11'56"E (Site 2), 7˚39'55"N, 81˚12'41"E (Site 3) and 7˚34'47"N, 81˚06'35"E (Site 4) (**Figure 1**). Bird sampling and collection of data to determine habitat variation and habitat use were carried out at the four sites. Survey on nesting habitat characteristics was conducted in a nesting site (7˚38'25.00"N, 81˚11'44.22"E) situated within the sampling site 1 which appears as an island during the dry season of the year.

2.2. Bird Sampling

The study time period covered one dry season (March-September) and one wet season (October-February) [19]. Bird census was carried out at four sampling sites monthly, for four consecutive days per month using the point count method [20] [21]. All bird species and individuals seen from a fixed point were recorded to a radius of approximately 300 m, depending on visibility [22]. Each count was recorded for a duration of fifteen minutes during the early morning (0060 h - 1000 h) when bird activity was high. Fifteen minutes count enabled recording all the individuals with minimal efforts and disturbances [23] [24]. Tally counters were used for the counting of birds. Bird observations were done using Nikon Monarch (15 - 60) × 25 spotting scopes and Nikon Monarch 12 × 42 binoculars. Species those were difficult to identify on-site were photographed or identifying characteristics were noted on field note book and later clarified using field guide [25]. Flocks larger than hundred individuals were estimated by counting blocks of 10, 20, 50 or 100 birds and estimating similar-sized groups in the flock [26]. Possible predators of the waterbird species were identified through direct observations and via photographs captured in camera traps of an ongoing research inside the MONP. Species identification was done using the standard field guide of Harrison and Worfolk and classification, nomenclature of the bird's checklist were done according to Birdlife International 2020a [27] [28].

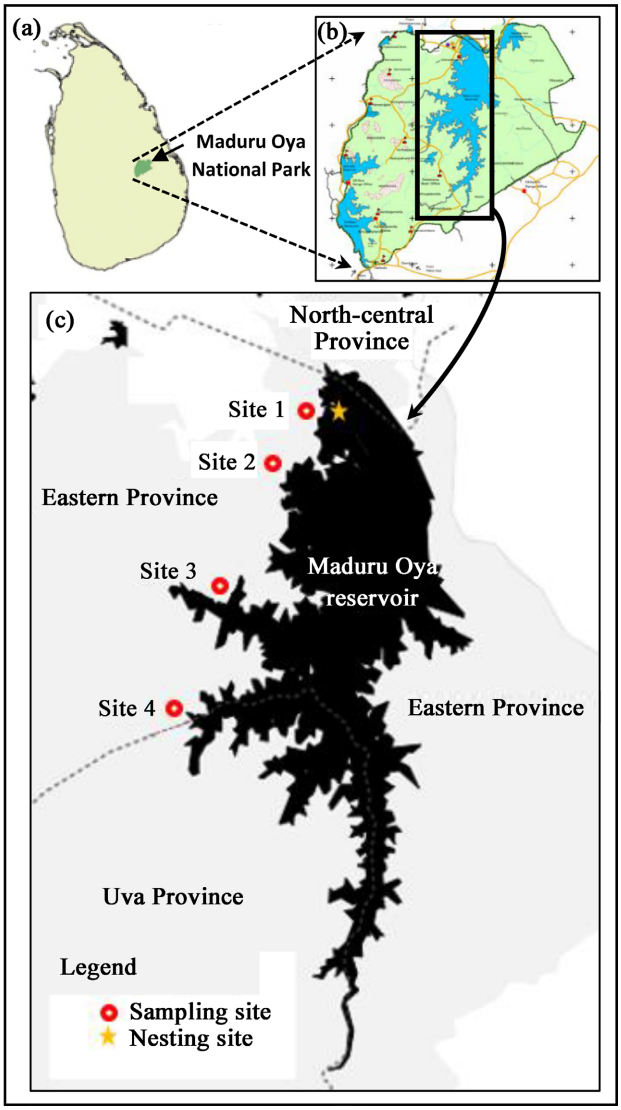

Figure 1. (a) Study area map that shows the location of MONP in Sri Lanka; (b) MOR inside the MNOP; and (c) four sampling sites and the nesting site of the survey, Image source; Google Earth Pro Software.

2.3. Habitat Variation and Habitat Use

A common ethogram was constructed using behavioral sampling methods to identify the behavior categories of waterbirds [29]. Behavioral data were collected under the categories of feeding, resting, breeding and comfort activities (Appendix A). Behavior at the first sight and the habitat type they used to exhibit the particular behavior were recorded for each bird in each point count to assess habitat utilization [30]. Habitat types used by waterbirds were identified based on field observations done in the preliminary survey and categorized as open water, grass, mud, rock, invasive plants, non-vegetative cover, dead trees/logs and trees. Monthly habitat variation was assessed by estimating the percentage cover of each habitat type at each sampling site along three 300 m long fixed line transects. Along each line transect, eight large quadrates (20 × 20 m) were laid

keeping a 20 m distance between each two quadrates. Within each 20 × 20 m quadrate four random quadrates (5 × 5 m) were laid to estimate the percentage cover of habitats ([31] with modifications) (**Figure 2**). The large quadrates (20 × 20 m) were used to locate the small quadrates easily. The number of dead trees/logs and trees in each quadrate were also counted and recorded.

2.4. Nesting Habitat Characteristics

Data collection was carried out monthly for three consecutive days per month from March to June 2019 during the breeding season. Visual surveys of nesting birds were conducted in the early morning (half an hour before sunrise until one hour later) and evening (one hour before sunset until dark) using Nikon Monarch (15 - 60) × 25 spotting scopes and Nikon Monarch 12 × 42 binoculars [32].

Identification of nesting trees was done with the aid of standard tree identification guides. Locations of nesting trees were determined using Global Positioning System (GPS-Garmin e Trex Euro). GPS points were entered into an online Google Earth map of MOR to calculate the area of the nesting site. Random quadrats (10 × 10 m) were laid for the sampling of nesting trees. The canopy of each nesting tree was visually divided into three approximately equal parts as upper canopy layer, middle canopy layer and lower canopy layer [33] (**Figure 3(a)**). Number of nests belonging to each waterbird species in each layer of the canopy was counted. Bole height and canopy height of those identified nesting trees were measured using SUNTO, PM-5/360PC Clinometer [34] (**Figure 3(b)**). Diameter at breast height (DBH) of nesting trees was measured at approximately 1.3 m above ground using a measuring tape [35].

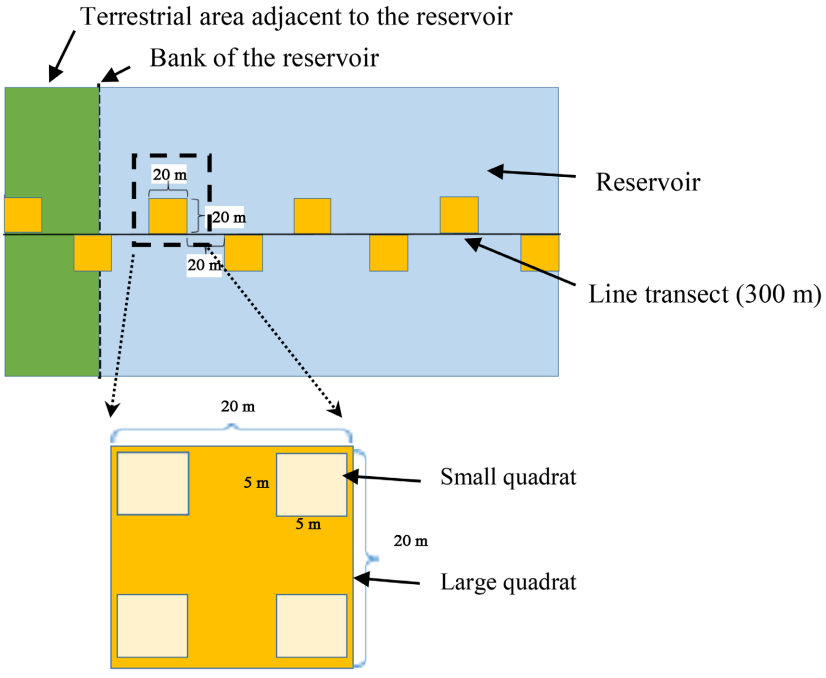

Figure 2. Illustration of quadrate method used to determine percentage habitat cover along line transects.

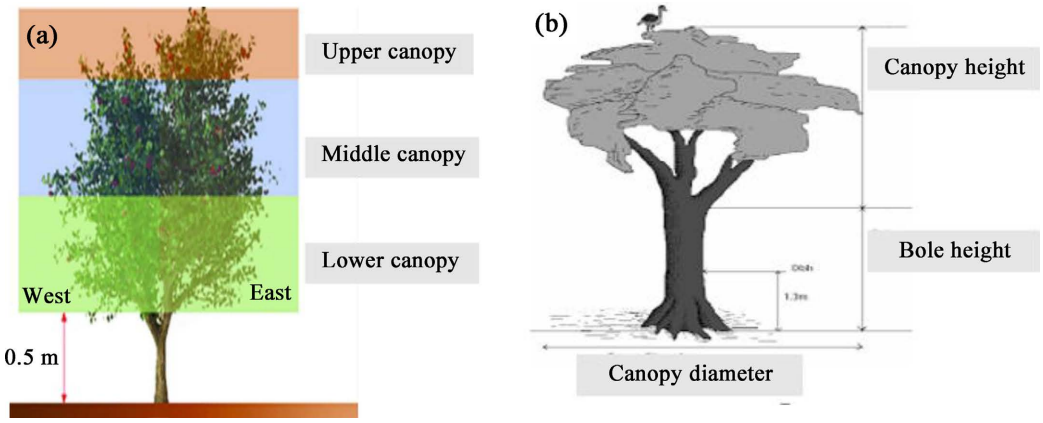

Figure 3. (a) Illustration of the layers of the canopy of a nesting tree; (b) Illustration of the Bole height and canopy height and canopy diameter of a nesting tree.

2.5. Statistical Analysis

Counts of birds were pooled to produce a single dataset per month. The number of water birds of each species recorded was used to calculate Shannon-Weiner index (H') [36]. Relative abundance of each species was calculated as a percentage of the proportion between average number of individuals per species and average number of all individuals [37]. Commonness was assessed as, very common (VC) (seen on 75% - 100% of visits), common (C) (50% - 74%), uncommon (UC) (25% - 49%) and rare (RA) (<25%) [38]. Minitab Version 17' statistical software package and Microsoft excel 2013 were used for statistical analysis and graphical representation of results. One-way analysis of variance (ANOVA) was used to compare the number of waterbirds performing different behavior categories in each habitat type. An Arc-sin transformation was performed prior to analysis of the diurnal activity data as the percentage activity values were not normally distributed. Tukey's test was used to determine which means are significantly different from each other. Finally the most utilized habitat types by water birds to perform each behavior were assessed. One-way ANOVA was used to compare the canopy height, bole height, tree height, canopy diameter, DBH between three different nesting tree species. Same test was employed to compare the mean number of nests in three different canopy layers (Upper, Middle, Lower) and to compare the mean number of nests of each water bird species observed in three different tree species. Tukey's test was used to determine which means are significantly different from each other.

3. Results

3.1. Bird Sampling

A total of 41,151 individuals were recorded in and around MOR during the study period, covering six orders, fifteen families and 30 species (Appendix B). This included two globally threatened species; Lesser Adjutant Stork (*Leptoptilos javanicus*) (**Figure 4(a)**) and Asian Woollyneck (*Ciconia episcopus*) (**Figure**

4(b)), two locally threatened species including Little Ringed Plover (*Charadrius dubius*) (Figure 4(e)), three locally nearly threatened species including Great Cormorant (*Phalacrocorax carbo*), Black-crowned Night-heron (*Nycticorax nycticorax*) (Figure 4(d)). It also included three winter visitors; Common Sandpiper (*Tringa hypoleucos*) (Figure 4(c)), Common Greenshank (*Tringa nebularia*) and Whiskered Tern (*Chlidonias hybridus*).

A great variation in monthly waterbird abundance was observed in and around the MOR. The highest waterbird abundance was recorded in June which was 7292 and the lowest was recorded in December which was 338 (Figure 5(a)). The highest species richness of 27 was recorded in August while the lowest of 19 was recorded in January (Figure 5(b)). A very high abundance of waterbirds was recorded in the dry season compared to wet season (Figure 5(c)). The

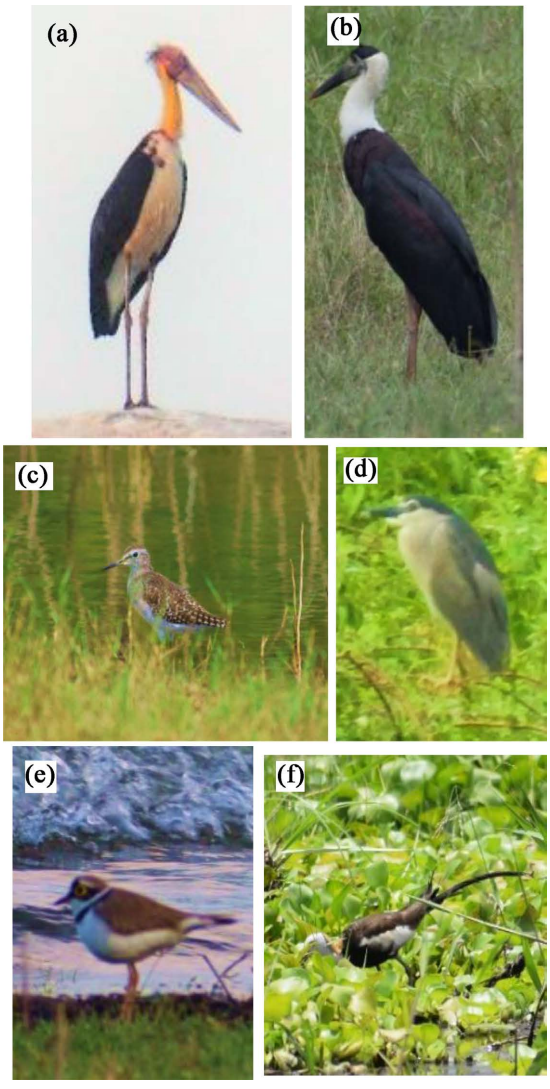

Figure 4. (a) Lesser Adjutant Stork (*Leptoptilos javanicus*); (b) Asian Woolyneck (*Ciconia episcopus*); (c) Common Sandpiper (*Tringa hypoleucos*); (d) Black-crowned Night-heron (*Nycticorax nycticorax*); (e) Little Ringed Plover (*Charadrius dubius*); (f) Pheasant-tailed Jacana (*Hydrophasianus chirurgus*).

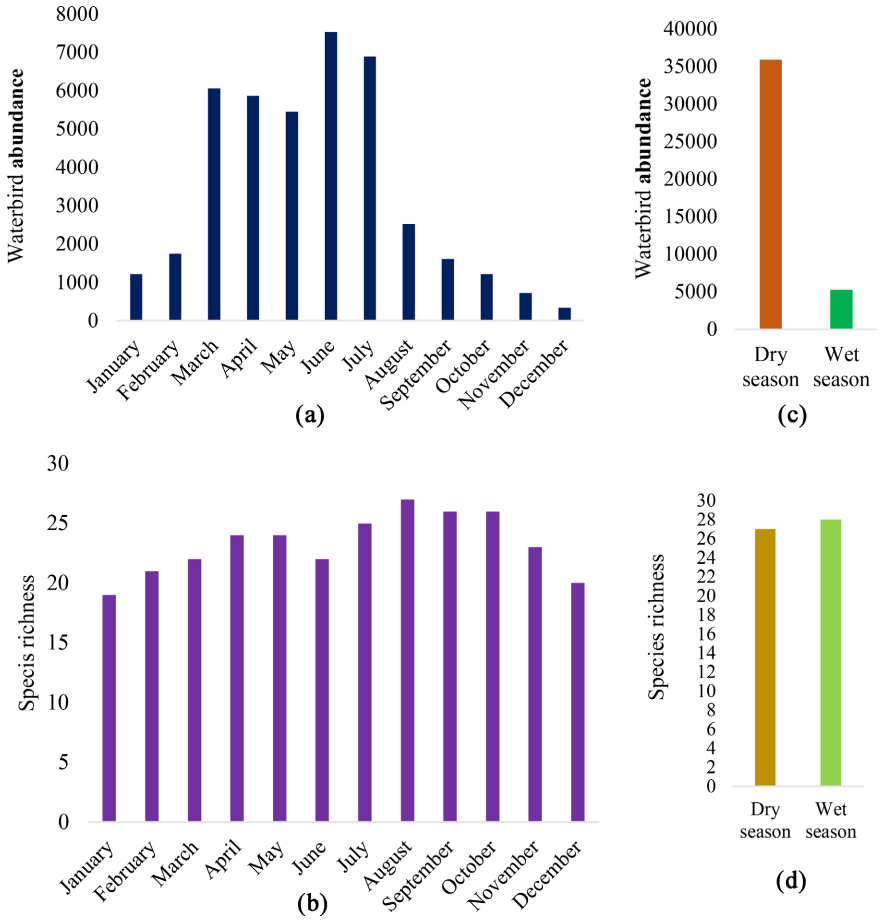

Figure 5. (a) Monthly variation of waterbird abundance, (b) Monthly variation of species richness, (c) Seasonal variation of waterbird abundance, (d) Seasonal variation of species richness.

species richness of the dry season was 27 and for the wet season 28. Therefore, there was no considerable difference between species richness between the dry season and the wet season (**Figure 5(d)**).

The calculated Shannon-Weiner index varied throughout the year. The highest waterbird species diversity was obtained in September (2.41) followed by December (2.35). The lowest species diversity 0.94 was obtained in March (**Figure 6(a)**). The Shannon-Weiner index of waterbirds was 1.073 and 2.033 for the dry season and wet season respectively (**Figure 6(b)**). The year around Shannon-Weiner index obtained for the MOR reservoir was 1.491. The relative abundance of waterbirds varied within a range of 64.81% - 0.01%. Among all other recorded species, Little Cormorant had the highest relative abundance (64.81%) while Asian Woollyneck (0.01%) had the lowest relative abundance (Appendix C). Twenty one species of waterbirds were recorded as very common bird species, whereas; three species were recorded as common bird species; Oriental Darter, Eurasian Spoon Bill and Asian Woollyneck. Pheasant-tailed Jacana (**Figure 6(f)**) and Lesser Whistling-duck were recorded as uncommon bird species. The only rare bird species recorded was Black-crowned Night-heron

(Appendix D). Fishing cat (*Prionailurus viverrinus*), fresh water crocodile (*Crocodylus palustris*), Sri Lankan Leopard (*Panthera pardus kotiya*) and Land monitor (*Varanus bengalensis*) (Figure 7) were recorded as possible predators of waterbirds in and around the reservoir.

3.2. Habitat Variation and Habitat Use

Availability of habitat types varied greatly throughout the year. The reservoir was eventually dried out from April to September with the lowest obtained percentage cover of open water in September (12.49%). Percentage cover of grass was gradually increased from March to September with the highest obtained cover in September (69.27%). During the rest of the months, open water was the most prominent habitat type in the MOR with the highest in December (91.1%). No invasive plant cover was recorded from June to September (Figure 8). *Eichhornia crassipes* (Water Hyacinth), *Salvinia molesta* (Salvinia) and *Ludwigia sp.* were the invasive plant species found within the reservoir (Figure 9).

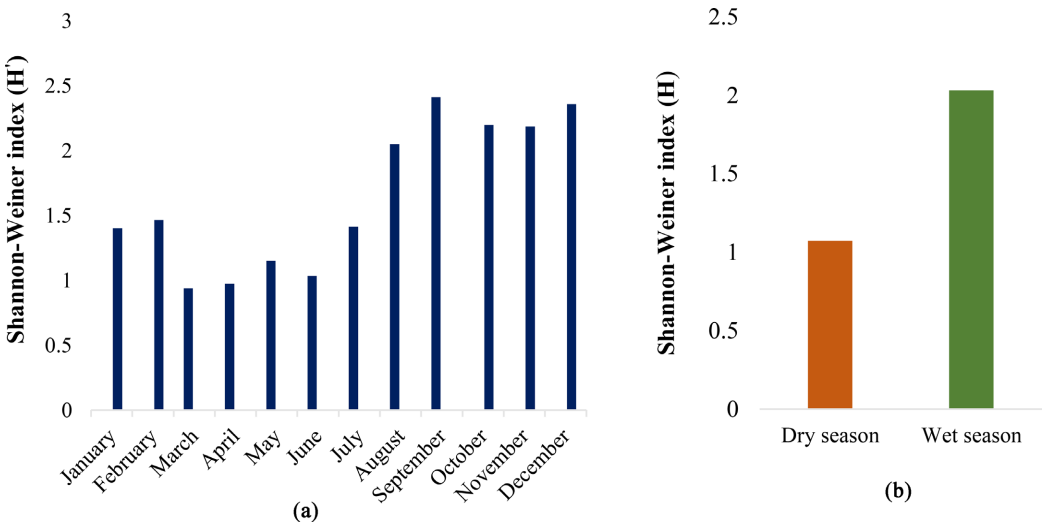

Figure 6. (a) Monthly variation of the Shannon-Weiner index (H') of waterbirds; (b) Seasonal variation of the Shannon-Weiner index (H') of waterbirds.

Figure 7. Predation of Little Cormorant by *Varanus bengalensis* captured in a camera trap (Photo: Dulan Jayasekara).

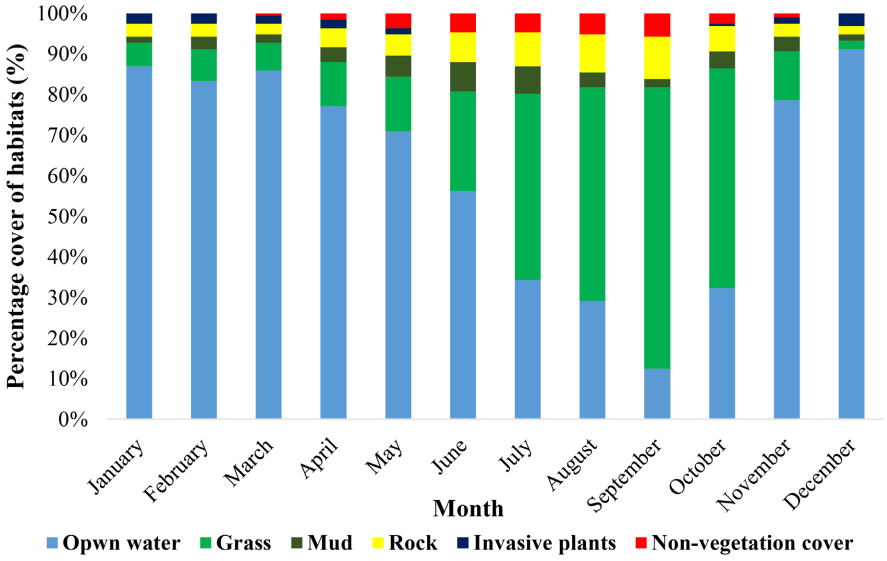

Figure 8. Monthly variation of the percentage of habitat types in and around the MOR.

Figure 9. (a) *Eichhornia crassipes* (Water Hyacinth), (b) *Salvinia molesta* (Salvinia) and (c) *Ludwigia sp.*

The dead trees/logs and rocks were fully inundated when the reservoir was filled with water and they gradually emerged from April to September with the eventual drying up of the reservoir. The number of trees which were utilized by waterbirds around the reservoir was almost constant throughout the year.

The most utilized habitat type of waterbirds was trees, followed by rocks and open water. The most underutilized habitat was invasive plants (**Figure 10**). Feeding was the highest observed behavior in open water, grassy areas and in areas with mud ($p \leq 0.05$; Tukey's pairwise test after one-way ANOVA) when compared to the other behaviors. Resting the highest observed behavior in areas with rock, dead trees/logs and invasive plants ($p \leq 0.05$; Tukey's pairwise test after one-way ANOVA). Tree habitat was the only habitat type which was accommodated for the breeding behavior of the waterbirds (**Table 1**).

3.3. Nesting Habitat Characteristics

The calculated area of the nesting site was 6542 m^2. Little Cormorant (*Microcarbo niger*) and Great Cormorant (*Phalacorocorax carbo*) belonging to family Phalacrocoracoracidae, Grey Heron (*Ardea cinerea*) belonging to family Ardeidae and Black-headed Ibis (*Threskiornis melanocephalus*) belonging to family

Threskiornithidae were observed building nests (Figure 11). Little Cormorant was the most abundant nesting species throughout the nesting season. Kaha Kona (*Senna spectabilis*), Weliwanna (*Dymorphocalyx glabellus*) and Ruk Aththana (*Alstonia scholaris*) were the most recorded nesting tree species (Figure 12).

The mean canopy height and mean canopy diameter were significantly different between three tree species ($p \leq 0.05$), with the maximum values were recorded in Rukaththana followed by Kahakona and Waliwanna. The highest values of mean bole height, mean tree height and mean DBH were recorded in Rukkaththana and these values were significantly different than the corresponding values of other two tree species (Table 2).

There was no significant difference between the mean numbers of nests built in three nesting tree species by the Little Cormorants ($p > 0.05$). However the

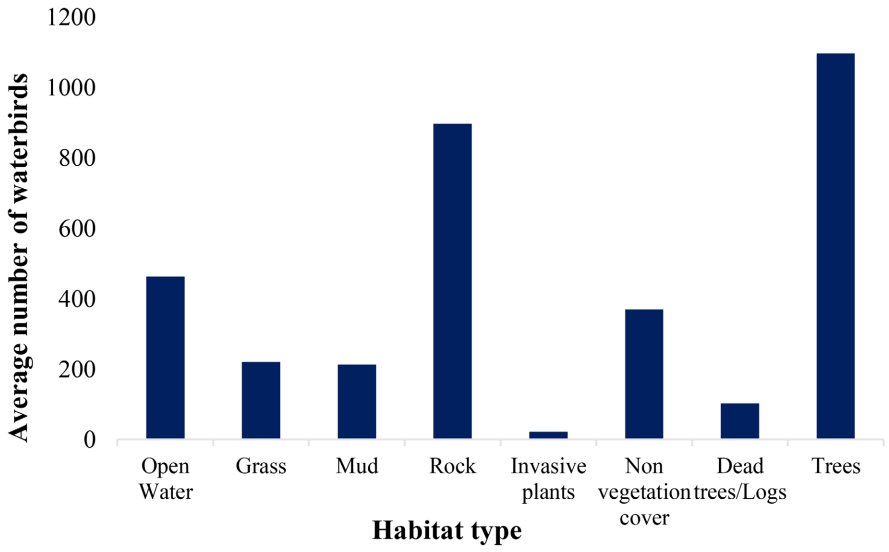

Figure 10. Average number of individuals observed in different habitat types.

Table 1. Variation between the different behaviors shown by waterbirds in different types of habitats.

Habitat	Behavior category				p value
	Feeding	Resting	Comfort activities	Breeding	
Open water	407.00^{A}	0.58^{B}	29.50^{B}	-	0.000*
Grass	106.20^{A}	57.20^{B}	33.17^{BC}	-	0.042*
Mud	142.10^{A}	38.17^{B}	24.00^{B}	-	0.028*
Rock	-	288.1^{A}	45.25^{B}	-	0.011*
Invasive plants	4.750^{B}	14.25^{A}	3.33^{B}	-	0.003*
Non vegetation cover	142.8^{B}	212.10^{A}	12.42^{B}	-	0.175
Dead trees / logs	-	895.00^{A}	12.75^{B}	-	0.000*
Trees	-	45.40^{B}	0	1009.10^{A}	0.000*

*Differ significantly (One-way ANOVA test, $p \leq 0.05$) between behavior categories. Means followed by the same superscript letter do not differ significantly (Tukey's test, $p \leq 0.05$).

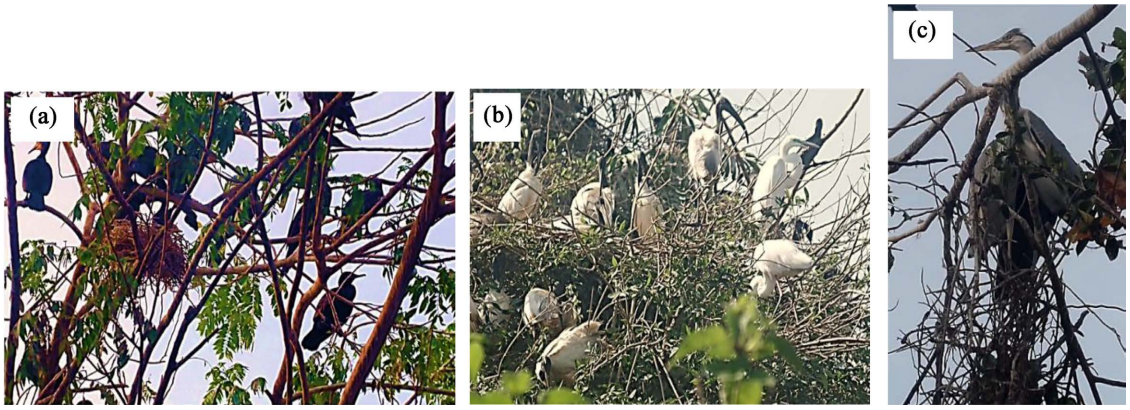

Figure 11. (a) Cormorants; (b) Black headed Ibis (*Threskiornis melanocephalus*); (c) Grey Heron (*Ardea cinerea*).

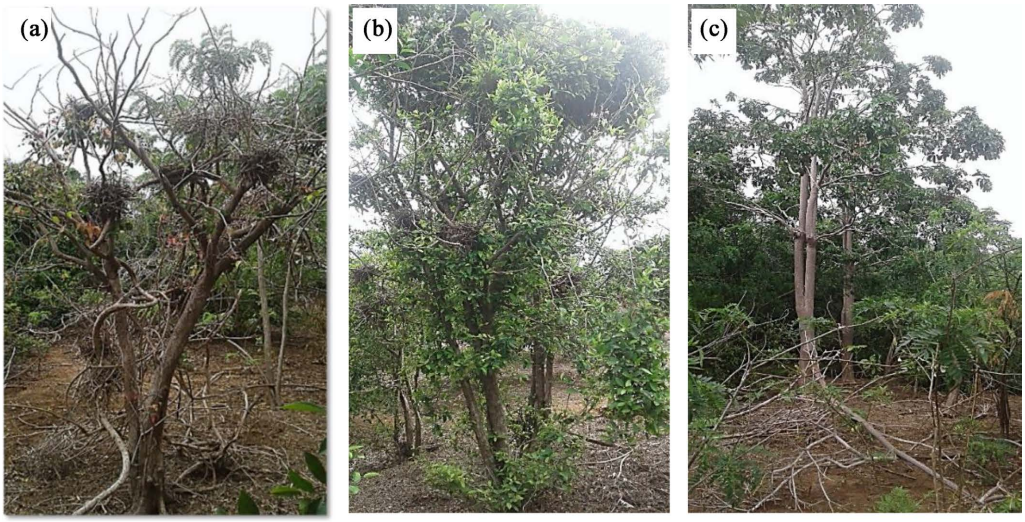

Figure 12. 12 Kaha Kona (*Senna spectabilis*), Weliwanna (*Dymorphocalyx glabellus*). Ruk Aththana (*Alstonia scholaris*).

Table 2. Variation in mean values of canopy height, bole height, tree height, canopy diameter and DBH of nesting tree species.

Nesting tree characteristic	*Senna spectabilis* Kahakona (Mean ± SD)	*Dymorphocalyx glabellus* Waliwanna (Mean ± SD)	*Alstonia scholaris* Rukkaththana (Mean ± SD)	p value
Canopy height/m	5.27 ± 1.05^{B}	4.91 ± 0.98^{C}	9.46 ± 1.22^{A}	0.000*
Bole height/m	1.82 ± 0.71^{B}	1.80 ± 0.83^{B}	8.22 ± 1.90^{A}	0.000*
Tree height/m	7.10 ± 1.15^{B}	6.71 ± 1.23^{B}	17.69 ± 2.28^{A}	0.000*
Canopy diameter/m	8.19 ± 6.53^{B}	6.51 ± 0.81^{C}	12.60 ± 0.74^{A}	0.000*
DBH/m	0.41 ± 0.04^{B}	0.42 ± 0.06^{B}	0.79 ± 0.12^{A}	0.000*

*Differ significantly (One-way ANOVA test, $p \leq 0.05$) between different nesting tree species. Means followed by the same subscript letter do not differ significantly (Tukey's test $p \leq 0.05$).

highest number of nests observed in Kahakona trees were belonged to Little Cormorants (3.36 ± 2.39). Black-headed Ibises had higher preference to construct nests on Waliwanna trees (3.30 ± 1.32) whereas, Grey Herons exhibited

higher preference to construct nests on Rukaththana trees (4.27 ± 2.12) (Table 3). The mean number of nests observed in the upper, middle and lower layers in canopy were significantly different from each other. The highest number of nests was observed in middle layer followed by upper layer and lower layer (Table 4).

4. Discussion

Wetlands of MONP have been identified as areas of high density of waterbirds [6]. The recorded 30 species included Lesser Adjutant Stork (*Leptoptilos javanicus*), Asian Woollyneck (*Ciconia episcopus*) and Little Ringed Plover (*Charadrius dubius*) which are considered as globally and locally vulnerable species. Areas of MONP also have been considered as one of 70 Important Bird & Biodiversity Areas (IBA) in Sri Lanka as it accommodates suitable habitats for these threatened species [39]. Moreover the breeding of one globally near threatened species; Black-headed Ibis and one locally near threatened species; Great Cormorant was recorded at MOR during the study period. Situated within the major Central Asian migrant pathway, Sri Lanka supports around 213 migrant bird species, including a larger proportion of waterbirds [40]. Occurrence of three species of winter visitors during the study period provides insights on availability of suitable stopover sites for migratory waterbirds within the MOR.

The highest waterbird abundance was recorded in the month of June during the study period. A greater proportion of the individuals recorded in this month comprised with two species; Little Cormorants and Black-headed Ibises. Juveniles gathering in the vicinity of the reservoir in large numbers were the reason for this observation. Bird populations are influenced by a variety of factors including the presence of suitable nesting habitats [41]. The occurrence of a comparatively

Table 3. Variations in mean number of nests of four water bird species observed in three nesting tree species.

	Senna spectabilis Kahakona (Mean ± SD)	*Dymorphocalyx glabellus* Waliwanna (Mean ± SD)	*Alstonia scholaris* Rukkaththana (Mean ± SD)	P value
Little Cormorant	3.36 ± 2.39^{A}	3.28 ± 2.46^{A}	2.89 ± 2.21^{A}	0.537
Great Cormorant	0.21 ± 0.41^{B}	0.30 ± 0.45^{B}	2.38 ± 0.74^{A}	0.000*
Black-headed Ibis	0.38 ± 0.52^{B}	3.30 ± 1.32^{A}	0.09 ± 0.30^{B}	0.000*
Grey Heron	0.12 ± 0.32^{B}	0.00	4.27 ± 2.12^{A}	0.000*

*Differ significantly (One-way ANOVA test, $p \leq 0.05$) between different nesting tree species. Means followed by the same subscript letter do not differ significantly (Tukey's test $p \leq 0.05$).

Table 4. Variations in mean number of nests between different layers of the canopy.

	Upper layer (Mean ± SD)	Middle layer (Mean ± SD)	Lower layer (Mean ± SD)	P value
Mean number of nests	3.731 ± 1.57^{B}	8.901 ± 2.67^{A}	3.080 ± 1.42^{B}	0.000*

*Differ significantly (One-way ANOVA test, $p \leq 0.05$) between different layers in the canopy. Means followed by the same subscript letter do not differ significantly (Tukey's test $p \leq 0.05$).

high number of individuals of Little Cormorants and Black-headed Ibises could be partly attributed to the resulted juveniles from the nesting area at the proximity of the reservoir hence the month of June was the end of the breeding season of above two species. Although there was a great difference in abundance values between seasons, the species richness of two seasons remains more or less the same. Comparatively higher abundance in the dry season was due to the increment in the number of already recorded species, but not due to the increment of the number of species.

The Shannon-Weiner index (H') is a measure of diversity that combines species richness and their relative abundances [42]. Highest diversity was obtained in September and lowest in March. The reason for the highest diversity in September may be relatively high species richness and relative low bird abundance. Although species richness is not very low, which is 22 in the month of March the obtained lowest diversity may partly described by the very high abundance of certain species. Large number of individuals of Little Cormorants and Black-headed Ibises were observed building their nests in the trees around the reservoir in the beginning of March. The Shannon-Weiner index of waterbirds for the dry season was relatively low when compared to the wet season. The breeding season of four waterbird species were overlapped within the dry season, therefore the number of waterbirds gathered in the nesting trees around the reservoir was very high. This was the reason for the high abundance of waterbirds in the dry season. Although species richness of the dry season was close to that of the wet season diversity was low due to high bird abundance. A high year around diversity was obtained to MOR. This could be attributed to the variety of habitats provided by the reservoir. Mosaic habitat structure and habitat heterogeneity may lead to increased wildlife diversity [43]. Open water habitats are used by pelicans, cormorants and ducks while the shallow bank areas and muddy areas allow egrets, herons, ibises and spoonbills to hunt for food. Furthermore, as the reservoir dries up, the exposed bed becomes covered by grass, providing foraging grounds for many grassland associated waterbird species, e.g. herons, egrets, lapwings, thick knees and plovers. Also, grassy areas provide breeding grounds for lapwings. The floating invasive plants provide foraging habitats for a number of other different waterbird species, including Purple Swamphen and Pheasant-tailed Jacana. This variety of habitat types provided by the reservoir could be the possible reason for having a high year around waterbird diversity in MOR.

Relative abundance and commonness indicated that Little Cormorant was the most common bird followed by Black-headed Ibis. Little Cormorant is a very common resident bird species and large flocks can be seen in water bodies of the dry zone of Sri Lnaka [27]. Little Cormorants dive underwater to capture their prey, usually sit for longer period on dead trees, half-merged rocks and river banks with its wings spread to dry their wings and breeds in colonies during December to May in Sri Lanka [44] [45]. Therefore, they are well adapted to the variety of habitats offered by MOR throughout the year. When the reservoir was

filled with water during the wet season, a large number of Little Cormorants dive in the open water for foraging purposes and they exhibited wing spread resting behavior on emerging rocks, dead trees and on the bank of the reservoir. Although the relatively low abundance of Little Cormorants was expected in the dry season due to the decrement of open water in the reservoir, the highest abundance was recorded in dry season. That was due to the resulted juveniles at the end of the breeding season. The minimum relative abundance was observed in Asian Woollyneck. Asian Woollyneck is found across South Asia and South East Asia with an estimated population up to 35,000 individuals and it is recognized as a species facing rapid population decline [11]. It is an uncommon breeding resident inhabiting the low country dry zone Sri Lanka [27]. They are more attracted to fires in grasslands and newly plowed crop fields where they capture insects trying to escape from disturbances [46]. Although land of MNOP is mainly for biodiversity and catchment conservation, some areas have been encroached by people for chena and paddy cultivation and much of the park consist of open grasslands [19]. Moreover, frequent forest fires which were conducted by poachers were recorded within the open grasslands of MONP during the dry months of the study period. A large number of gassy areas in the forest and paddy fields in the MONP could be more preferred by Asian Woollyneck, hence shifting many individuals to forest areas and this could be attributed to the minimum relative abundance of them around MOR.

Availability of habitat types varied greatly among the months with the availability of rainfall. The reservoir was eventually dried out from April to September during the dry season due to the scarcity of rainfall. The moist exposed area soon after the gradual decrement of open water of the reservoir was rich with mud flats and provided a good substrate for the emergence of grasses. The dead trees, logs and rocks were fully inundated with water when the reservoir was filled with water and they gradually emerged when the reservoir was drying out. This exposed habitats provided more platforms to stay during the foraging periods especially for diving and wading waterbirds. The invasive plant cover was absent from June to September in the dry season due to the scarcity of open water cover which required for their growth.

This study identified that waterbirds exhibit different behaviors in different habitat types. Trees around the reservoir were identified as the most utilized habitat type for both breeding and resting purposes. Colonial waterbirds of Orders Ciconiiformis and Pelicaniformis nest together in large aggregations called mixed breeding colonies of up to thousands of nests [33]. Nesting areas must provide protection from predators, nesting materials, as well as sufficient quantity and quality of foraging habitat and large waterbirds prefer the trees with higher DBH for building their nests [47] [48]. Most colonial waterbirds nest in woody trees surrounded by water, which acts as a barrier to predators [49] [50]. The large trees with higher DBH in the vicinity of the reservoir provided breeding habitats for large waterbirds such as Grey herons. Easy access to the available foraging grounds of the reservoir and the provided protection from predators

could be partly attributed to the selection of trees around MOR as their breeding areas. Although nests are disintegrated and fallen down due to continuous heavy rain in the wet season, breeding again starts with constructing new nests in the trees in the same sites.

The Rocks was the second most utilized habitat type which accommodated both resting and comfort activities of waterbirds. Specially diving waterbirds, for example cormorants, require places to stay during their foraging periods to consume the captured prey and also to take the aim to catch the prey item during foraging. Not only diving birds, wading birds belonging to the Order Ciconiiformes were observed resting on rocks. Comfort activities, especially the wing stretching and sun basking of large flocks of cormorants were highly observed on rocks.

Open water was available as the most abundant habitat type for eight months. The majority of the waterbird species showed all the behavior categories in open water except breeding. MOR has been identified as a reservoir with a good potential for fish production. Fishing is being carried out under license from the Department of Fisheries and Aquatic Resources reservoirs [10] [19]. Based on the information gathered from fisherman during the study period it was found that around approximately 200 fisherman families make their living through fisheries in MOR. Furthermore, they launch a program of releasing the fingerlings to the MOR every year in the months of February and March. Ultimately, it provides a good food source for waterbirds, especially for the pelicans, cormorants and larger storks. Some of piscivorous waterbirds forage using group methods called mixed-flock fishing, which make the prey more accessible and correspondingly it increase the foraging efficiency [51]. Pelicans often exhibit mixed-flock fishing with cormorants [52]. This mixed-flock fishing was frequently seen between pelicans and cormorants in deeper open water areas of MOR where fish schools were available. Asian Openbills feed mainly on shelled mollusks, including fresh water snails, especially *Pila globosa* and also on crabs, frogs and small fish [53]. The tip of the bill is inserted into the opening of the snail and the body is extracted with the bill still under water [54]. Asian open bills were frequently found foraging in the shallow water areas near the banks of the reservoir, which accommodated a large number of freshwater snails which is a preferred prey item of them.

Areas of grass and mud were also identified as good foraging habitats for a variety of waterbirds. Muddy areas hold especially waterbird species of Charadriiformes and migratory species recorded in the study period. Water depth has an important influence on the distribution and foraging behavior of waterbirds [55]. Painted Storks prefer to feed in shallow muddy waters which have a water depth less than 25 cm and feed on prey items including fish and frogs [56]. As the rainfall begins after a long dry period, the water filled depressions were formed in the grassy areas on the exposed bed of the dried up reservoir. These are often characterized with shallow muddy water which supports considerable numbers of frogs, tadpoles and aquatic invertebrates attracting both adults and

juveniles of painted storks. The mammals that frequently visit the MOR include the Asian elephant (*Elephas maximus*), water buffalo (*Bubalus bubalis*) and spotted deer (*Cervus axis*) [8]. Cattle Egrets were also frequently observed in grassy areas. Cattle Egrets are usually found within large grazing and browsing animals and catches small creatures disturbed by the mammals and their foraging success is much higher when foraging near a larger animal than feeding singly [57]. A large number of water buffalos were gathered in the available low amount of open water of the reservoir in the dry season for the cooling purposes. The newly emerged grass at the proximity of the reservoir also attracts elephants as well as herds of deer. This resulted in the grassy areas being manipulated into muddy areas due to the activities of these mammalian species. This indirectly increases the availability of small prey items, for example grasshoppers, soil invertebrates and frogs by habitat enrichment and it provided foods for waterbirds especially for egrets and herons.

The most underutilized habitat type was invasive plants and resting behavior was the highly observed behavior in invasive plants. Previously it was recorded that MOR has been infested with the exotic floating weed *Salvinia molesta* [19]. Another two invasive plants, which were recorded during the study period in MOR were identified as *Eichhornia crassipes* and *Ludwigia sp*. Interestingly, the Black-crowned Night-heron which is a nocturnal waterbird of family Ardeidae was observed resting on the invasive plant *Ludwigia sp.* together with other recorded species of Ardeidae and Little Cormorants. Some waterbird species prefer wetlands with plenty of floating vegetation, especially Pheasant-tailed Jacanas and Purple Swamphens. They have greatly elongated toes as an adaptation for walking over floating vegetation for foraging purposes [58] [59]. However the relatively low percentage cover of invasive plants was observed throughout the year with being completely absent in several months. This could be a possible reason for the relatively low number of waterbirds recorded in invasive plants.

Considering about the nesting site selection of waterbirds, nesting site was situated very close to the reservoir. Highly isolated patch from the main land and almost having island characteristics throughout the breeding season could be attributed to the protection from land predators. The nesting site was situated at the opposite side of the wind direction to remain shielded from speedy winds. Little Cormorants were the very first occupants of the nesting site, so as taking advantage of the plenty of the available spaces in trees to build their nests. Kahakona trees provide more angles between the branches to place the relatively smaller and rounded nests of Cormorants. Black headed ibises indicated higher preference to construct nests on Waliwanna trees as these trees provided more flat surfaces due to the bushy arrangement of leaves to construct their expanded, larger and irregular shaped nests. Grey heron had the widest wing span compared to other three nesting waterbird species in the site which may lead to choose the Rukkaththana trees with more space in the canopy.

The highest number of nests was observed in the middle layer of the canopy. The possible reason might be the reduced predation which could occur from the

ground as well as from the air. A relatively higher protection is gained being covered by upper canopy layer which provides protection from aerial predators, for example predatory birds and also being covered by the lower canopy leads to get protection from ground predators for example fishing cats.

Moreover, waterbirds are considered as key indicators as they provide an overall view of the proper functioning and health of the wetland ecosystems [60]. By accommodating a rich waterbird community, MOR provides an insight of having ideal habitats for waterbirds. Therefore, conservation of this large reservoir is required as an important habitat for the conservation of waterbirds.

5. Conclusion

This study revealed that the availability of valuable habitats in the MOR varies throughout the year being a determining factor in the variation and in the high abundance and diversity of waterbirds in the place. Habitats of grass, open water and mud provided the best foraging habitats while areas with rock, dead trees/logs and invasive plants provided resting habitats for waterbirds. The best breeding habitat was trees around the reservoir and it is important to conserve the tree species in order to conserve waterbirds. The park supports a large number of habitats, which in turn supports a rich waterbird assemblage. As a preliminary study, this can be used as an approach for future research on waterbirds and to compose management and conservation plans to conserve them. By promoting the diverse bird assemblage inhabiting MONP, bird watchers and tourists can be attracted to the park, which will directly and indirectly uplift the socio-economy of the area. Moreover, conservation of the important habitats of this large reservoir is required for the conservation of waterbirds.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix A. Common Ethogram for Waterbirds

Behavior	Description
Resting	Resting of waterbird comprised of loafing, sleeping and roosting. 1. Loafing Waterbird may be simply standing or sitting down on the ground or shows a variety of fatigue or relaxing moves. 2. Sleeping is with standing or sitting on ground or holding themselves motionless in water. Eyes are closed with neck held in normal or retracted position or with the bill tucked under scapular. 3. Roosting-birds choose a site to sleep and rest as trees.
Feeding	All the behaviors associated with actively searching for food, capturing it, and manipulating or ingesting 1. Pecking, penetration of substrate by less than one-quarter of bill length to catch prey items. Use visual means for detecting prey items in water's edge or muddy areas out of water. 2. Probing, penetration of substrate by more than one-quarter of bill length using tactile means to discover buried prey. 3. Ploughing-moving slightly opened bills rapidly through the water in shallow waters. The bird immerses the lower half of its bill in water at a shallow angle and run forward very quickly. 4. Sweeping, side to side movements of bill introduced in water 5. Stabbing, walk slowly through shallow water searching for prey or stood motionless watching for the prey and stabbing it when found. 6. Plunging head and neck enter in water to catch prey 7. Diving 8. Plung diving 9. Up ending 10. Head submergence 11. Filtering
Locomotion	Moving from one place to another by walking, running (speed faster than walking with its head held high and extended) swimming (the waterbird is completely in the water and moving either treading or propelling forward legs) and flying (the waterbird rises up out of the substrate) into flight, and lands back in the substrate or continues flying out of sight).
Comfort activities	Comfort activities are further divided into preening, bathing ant stretching. 1. Preening, care of body surface and relative activities which involve the contact between the bill and the feathers. 2. Bathing, Dipping the head in water accompanied by the beating of wings as also by short dives. 3. Stretching.
Agonistic	This range from simple threat and avoidance to energetically costly chasing in pursuit flights.
Alert	Waterbird in the alert mode, remains motionless, with its eyes open and with the neck fully extended in a posture of standing on the ground or water. Also usually held their heads further up stretched and watched and listened for potential intruders, predators or disturbance.
Other	Any other behavior that the animal is exhibiting that is not described within the above ethogram categories.

Appendix B. Species Composition and Commonness of the Waterbird Species in and around MONP during the Study Period

Order	Family	Common name	Scientific name	NCS	GCS
Pelecaniformes	Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo*	NT	LC
		Indian Cormorant	*Phalacrocorax niger*	LC	LC
		Little Cormorant	*Phalacrocorax fuscicollis*	LC	LC
	Anhingidae	Oriental Darter	*Anhinga melanogaster*	LC	NT
	Pelecanidae	Spot-billed Pelican	*Pelicans philippensis*	LC	NT
Ciconiiformes	Ardeidae	Great White Egret	*Ardea alba*	LC	LC
		Intermediate Egret	*Mesophoyx intermedia*	LC	LC
		Little Egret	*Egretta garzetta*	LC	LC
		Cattle Egret	*Bubulcus ibis*	LC	LC
		Grey Heron	*Ardea cinerea*	LC	LC
		Indian Pond -heron	*Ardeola grayii*	LC	LC
		Purple Heron	*Ardea purpurea*	LC	LC
		Black-crowned Night-heron	*Nycticorax nycticorax*	NT	LC
	Threskiornithidae	Black-headed Ibis	*Threskiornis melanocephalus*	LC	NT
		Eurasian Spoonbill	*Platalea leucorodia*	LC	NT
	Ciconiidae	Painted Stork	*Mycteria leucocephala*	LC	NT
		Asian Openbill	*Anastomus oscitans*	LC	LC
		Asian Woollyneck	*Ciconia episcopus*	NT	VU
		Lesser Adjutant Stork	*Leptoptilos javanicus*	VU	VU
Charadriiformes	Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*	LC	LC
	Scolopacidae	Common Sandpiper	*Tringa hypoleucos*		LC
		Common Greenshank	*Tringa nebularia*		LC
	Jacanidae	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	LC	LC
	Charadridae	Red-wattled Lapwing	*Vanellus indicus*	LC	LC
		Little Ringed Plover	*Charadrius dubius jerdoni*	VU	LC
	Laridae	Whiskered Tern	*Chlidonias hybridus*		LC
	Burhinidae	Great Thick Knee	*Esacus recurvirostris*	LC	NT
Podicipediformes	Podicipedidae	Little Greb	*Tachybaptus ruficollis*	LC	LC
Gruiformes	Rallidae	Purple Swamphen	*Porphyrio porphyrio*	LC	LC
Anseriformes	Anatidae	Lesser Whistling Duck	*Dendrocygna javanica*	LC	LC

NCS = National conservation status: GCS = Global conservation status: LC = Least Concern: NT = Near Threatened: V = Vulnerable: *Reference sources: BirdLife International 2017: BirdLife International 2020.

Appendix C. Relative Abundance of Waterbird Species

Abundance rank	Species	Relative abundance (%)
1	Little Cormorant	64.8123
2	Black-headed Ibis	9.0239
3	Asian Open bill	6.1879
4	Painted Stork	5.4565
5	Spot-billed Pelican	2.4993
6	Grey Heron	2.0198
7	Little Egret	1.6154
8	Intermediate Egret	1.5742
9	Purple Heron	1.3514
10	Cattle Egret	0.9808
11	Great White Egret	0.9300
12	Great Cormorant	0.5788
13	Indian Pond -heron	0.4286
14	Red-wattled Lapwing	0.3947
15	Indian Cormorant	0.3487
16	Whiskered Tern	0.2325
17	Black-crowned Night -heron	0.2034
18	Black Winged Stilt	0.1985
19	Common Sandpiper	0.1889
20	Common Greenshank	0.1622
21	Lesser Whistling Duck	0.1380
22	Little Ringed Plover	0.1210
23	Purple Swamphen	0.1065
24	Little Greb	0.1041
25	Great Thick Knee	0.1017
26	Oriental Darter	0.0871
27	Lesser Adjutant	0.0823
28	Eurasian Spoon Bill	0.0387
29	Pheasant-Tailed Jacana	0.0169
30	Asian Woollyneck	0.0145

Appendix D. Commonness of the Waterbirds in and around MOR

Common name	Number of visits seen the bird	Percentage of the bird occurrence	Commonness of the bird
Great Cormorant	10	83.3	VC
Indian Cormorant	12	100	VC
Little Cormorant	12	100	VC
Oriental Darter	4	33.3	UC
Spot-billed Pelican	7	58.3	C
Great White Egret	12	100	VC
Intermediate Egret	12	100	VC
Little Egret	12	100	VC
Cattle Egret	12	100	VC
Grey heron	12	100	VC
Indian Pond-heron	12	100	VC
Purple Heron	12	100	VC
Black-crowned Night-heron	2	16.7	RA
Black Headed Ibis	10	83.3	VC
Eurasian Spoon Bill	4	33.3	UC
Painted Stork	12	100	VC
Asian Openbill	12	100	VC
Asian Woollyneck	4	33.3	UC
Lesser Adjutant	10	83.3	VC
Black Winged Stilt	12	100	VC
Common Sandpiper	9	75	VC
Common Greenshank	9	75	VC
Pheasant-Tailed Jacana	3	25	UC
Red-wattled Lapwing	12	100	VC
Little Ringed Plover	10	83.3	VC
Whiskered Tern	11	91.7	VC
Great Thick Knee	9	75	VC
Little Greb	8	66.7	C
Purple Swamphen	6	50	C
Lesser Whistling Duck	3	25	UC
Total number of visits	12		

VC = very common: C = Common: UC = uncommon: RA = Rare.