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HABITAT SPECIFICITY OF AQUATIC BIRDS DURING MORNING AND EVENING HOURS MIDST LAKES OF URBAN AREA OF MYSORE, KARNATAKA, INDIA

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Abstract: Systematic field investigations were made on weekly basis by following various standard methods such as an all out search method, variable width line transect method and visual count methods to record the aquatic bird species during morning and evening hours of the day at Kukkarahalli, Dalvoy and Hebbal Lakes of urban area of Mysore during May to August, 2023. Total 28 aquatic bird species which belong to 13 families of five orders such as Anseriformes, Charadriiformes, Coracciformes, Gruiformes and Pelecaniformes and their per cent occurrence varied considerably. Gruiformes members predominated more (78.6%) compared to other orders. Moreover, among the families, aquatic birds belong to Ardeidae family were more (28.5%) compared to other families. Interestingly, birds belong to different families, their population size, density and frequency of occurrence during morning and evening hours at different Lakes indicated considerable statistical difference. Further, analysis of variance of aquatic bird species distribution at Lakes between the weeks indicated the significant difference during morning ($F=77.750$; $P>0.05$) and evening ($F=19.071$; $P>0.05$) hours. Thus, aquatic bird species distribution was uneven among the Lakes. Furthermore, the diversity indices of aquatic bird species during morning and evening hours at these Lakes showed considerable variation of dominance ('D'), Shannon ('H'), Simpson ('1-D'), Evenness ('H/S'), Menhinick, Margalef, Equitability ('J'), Fisher-alpha and Berger-Parker indices. Surprisingly, few bird species which are in the international union for nature and natural resources (IUCN) list were enlisted during the present investigation as least concerned (75%), near threatened (14.2%) and critically endangered (7.3%) amidst these Lakes. Since, Mysore is fast growing urban area; more human interferences prevailed at these Lakes. Realizing the importance of aquatic bird species presence and their role in maintaining the local biodiversity, it is imperative to create awareness among the people who are visiting these Lakes for various purposes and protect these Lakes in an undisturbed manner. On this line in depth investigations are necessitated further. This kind of studies should be undertaken more and more during different seasons to create inventory and prepare suitable measures to protect the resident and migratory birds at their preferred habitats midst urban areas.

Key words: Habitat specificity, Aquatic bird species, Lakes, Urban Area, Mysore

I. INTRODUCTION

Birds play a major role in the growth, development, protection and restoration of various aquatic habitats. They are considered as main biotic components of various food chains and food webs of different ecosystems (Sandhyakupekar *et al.*, 2015). Bird species presence in a habitat or ecosystem is depended mainly with food availability, habitat type along with ecological, social and economical values extended by the local communities. Aquatic birds are feathered bipeds (Jordan and Verma, 2006) live at diversified ecosystems often spends more time in aquatic habitat or nearby water bodies. Aquatic birds exhibit different morphological variations with webbed feet, different feeding habits and physiological adaptations which make them to show swimming, diving, paddling through water and wading also. They have adapted well to both aquatic and terrestrial mode of life.

Barrowclough and Cross *et al*. (2015) have reported18,043 bird species around the world. In India, more than 1,333 bird species are recorded byvarious ornithologists. Since, Indian sub-continent is enriched with differenttypes of habitats namely: aquatic, terrestrial and aerial habitats. However, the aquatic habitat is further diversified with semi-aquatic i.e.,

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wet lands, shore areas, river banks, back waters of reservoirs, inland water bodies such as lakes, ponds, brooks and ditches, which have hosted different species of aquatic birds. Various researchers have reported the bird species, their diversity and status at various aquatic habitats, revealed their importance at different parts of India. Shivaperuman and Jayson (2000) have reported 161 species of birds which belonging to 39 families of 16 orders from Kole wetlands in Thrissur, Kerala. During one year observation (November, 1998 to December, 1999), identified 81 wetland bird species. Among them, 53 species were winter visitors and 31 species were migratory waders. Vasudeva *et al.* (2007) have studied the avifaunal diversity of the Kolleru wetlands a largest freshwater Lake in Andhra Pradesh. Abhishek *et al.* (2014) have surveyed the aquatic birds in irrigation tanks at Tirunelveli and Tuticorin Districts of TamilNadu. Abdar (2014) has recorded 47 species which belonging to 13 families of six orders in Ramling Island, Maharashtra. Sonali and Nishith (2016) have recorded 92 species of aquatic birds which belonging to 21 families at 34 wetlands, where 18 in urban areas and 16 in desert area Gujarat. Savitree (2014) has listed 110 species of aquatic birds which belonging to 13 families from Aravali ranges of Durgapur in Rajasthan. Vasudeva *et al*. (2013) have listed recorded 145 species aquatic birds which belonging to 48 families of 16 orders at Srikakulam district of Andhra Pradesh. Devendra *et al.* (2014) has recorded 143 species of birds which belonging to 48 families at Gidhwa and Porsada wetlands in Nandghat and Bemtara districts of Chhattisgarh. Singh *et al.* (2016) have recorded 61 species of aquatic birds which belong to 16 families from four different water bodies such as Fateh Sagar Lake, Mewar Lake, Bhatewar Lake Vallabh Nagar Dam of Udaipur district of Rajasthan. Basavarajappa and Priyadarshini (2016) have recorded 57 aquatic bird species belonging to 30 families from few places in and around Rourkela urban area of Sundargarh district, Odisha. Puri and Virani (2016) have recorded 86 species aquatic birds which belonging to 33 families at Khairatabandha Lake in Gondia district of Maharashtra. Singh *et al.* (2016) have recorded 33 species of aquatic birds which belonging to 23 families from 10 orders at Sakhare dam in Dahanu taluk, Palghar district of Maharashtra. Ashish and Singh (2021) have identified 145 species of aquatic birds which belonging to 54 families from Ramnagar Uttarakhand. Rahankar and Kothare (2020) have recorded 17 species of aquatic birds which belonging to 16 families in and around of Saikhheda Dam of Yavatamal district Maharashtra. Rathod (2021) has recorded 34 aquatic bird species of birds at Vasanth Sagar, Maharashtra.

However, in Karnataka, few published reports are available on aquatic bird species and their distribution at different aquatic ecosystems. Dayananda (2009) has recorded 54 aquatic bird species in Gudavi Bird Sanctuary of Soraba in Shimoga district of Karnataka. Birasal (2010) has recorded 30 aquatic bird species which belonging to 10 families in Heggaeri Lake of Haveri district in Karnataka. Bhatt *et al.* (2005) have recorded migratory aquatic bird species from 11 different lakes/ponds/tanks of north Bangalore. Basavarajappa (2006) has reported 27 aquatic bird species which belonging to 13 families from different wetlands midst agro-ecosystems of Maidan area of Channageri taluk of Davangere of Karnataka. Donar and Deshpande (2012) has recorded 49 aquatic bird species which belonging to 19 families in Nippani reservoir of Belgaum district of Karnataka. Kumar *et al.* (2005) have recorded nine aquatic bird species in Mallathalli Lake of Bangalore. Barve and Warrior (2013) have surveyed Sharavathi area, Western Ghats of Karnataka and recorded 215 bird species, of which 15 species were endemic to Western Ghats. Harisha and Hosetti (2009) have studied avifaunal diversity of Lakkavalli Range forest of Shimoga district of Karnataka. Satish *et al*. (2020) have reported 43 species of aquatic birds which belonging to 15 families of eight orders from five different Lakes midst dry agro-climatic region of Southern Karnataka. Overall, at different parts of Karnataka, 524 bird species were recorded by various researchers. Reports on aquatic birds from different lakes located in and around Mysore is sparse. As these ponds/Lakes have specific physiographic and ecological conditions (Table 1) due to various man-made or natural conditions may not provide similar conditions for all the aquatic bird species. Moreover, population size, density, frequency and diversity of aquatic birds during morning and evening hours of the day are not available. Hence, presented study was conducted by selecting randomly Kukkarahalli, Hebbal and Dalvoy Lakes midst urban area of Mysore city.

II. MATERIALS AND METHODS

Study area: Mysore is commonly known is 'heritage city' of Karnataka geographically located at 12° 18′ 26″North latitude and 76° 38′ 59″ East longitude spreads across an area of 152.05 sq. km. It is housed with five major lakes namely: Kukkarahalli Lake, Hebbal Lake, Devanoor Lake, Karanji Lake, Dalvoy Lake and Linghabudhi Lake which covers more than 363.5 hectares of land (Kamath, 2001; Sujosha*et al*., 2021). **Kukkarahalli Lake**: It is located midst University of Mysore campus and considered as heart of the Mysore city.It was constructed in 1864 for the irrigation and domestic purposes. It has 150 acres catchment area with 89 Mcuft of water storage capacity. **DalvoyLake:** It was constructed for irrigation and domestic purposes in 19th century, located five kilometers away in southern part of Mysore city.It possesses 133.437 acres of catchments area of getting water source mainly from rainfall and urban residential sewage water from elevated areas of Mysore city. **Hebbal Lake**: It is located six kilometers away from Mysore city and located at north part of Mysore city. It possesses 48 acres of catchments area and getting water source from rainfall. For the present study, only three lakes are selected. The physiographic features and environmental factors are depicted in Table 1 and Figure 1.

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Methodology: Systematic field survey was conducted at Hebbal Lake, Dalvoy Lake and Kukkarahalli Lake by earmarking study sites randomly seven each and 11 respectively. The Lakes were visited during morning hours (6 am to 9 am) and evening hours (4 pm to 6:30 pm) once in a week and altogether 14 visits were made to each and every Lake from May to August, 2023. Aquatic birds observation was made using various methods such as line transect, variable width line transect, quadrate and all out-search methods with the help of Olympus Binoculars (10 x 60 DPSI fields 6.5^0) and photographed with Nikon D6500 Camera. Observed birds were identified with the field guides and as per the description published by Ali and Ripley (1983). During the observation, more than 25 parameters were considered and all those parameters were enlisted in the Questionnaire at every study site in every Lake.

Statistical analysis: Collected data was systematically compiled and analyzed by following standard methods as perBasavarajappa (2006), Shruthi and Basavarajappa (2016), Sathish*et al*. (2020) and Saha (2009). Density (D): This measures the number of individuals of a particular species or group of aquatic birds were calculated using Density (D) = Number of Individuals (N) / Area (A), where, D is the density of aquatic birds, 'N' is the number of individuals and 'A' is the lake habitat.Frequency of occurrence (F) = Species occur at number of sampling sites in the lake habitat / Total number of sampled sites in the lake habitat) × 100. Where, frequency of occurrenceof the bird species is presented in terms of percentage and calculated as per Basavarajappa (2006). Moreover, Shannon – Wiener Diversity Index is a quantitative measure used to assess the diversity of species in an ecosystem and accounts both the abundance (number of individuals) and the evenness (equitability of abundance) of aquatic bird species and summarize the diversity within a lake habitat. Following formula was employed for calculating the Shannon-Wiener Diversity ('H') Index.

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

or H' = - ∑ **[(ni / N) ln (ni / N)]**

Where, 'H = Shannon's Index, ni = Numberof species, N = Total number of species, S = species richness (Total species present), Pi = Proportion of total sample belonging to thei^{th} species and Ln = Natural log. And, the Simpson's Diversity Index, Pielou's Evenness Index, Margalef's Diversity Index, Menhinick's Index of Species Richnesswas calculated as per Maguran (2004),Burnham *et al*. (1990). Further recorded aquatic bird species were identified as per the description of Ali (1996), Ali and Ripley (1983).

III. RESULTS

Aquatic bird species: Table 2 shows the aquatic birds recorded at different Lakes in Mysore. The common name, scientific name, order and family of recorded aquatic birds, international union for the conservation of nature and natural resources (IUCN) and local status are also depicted in the Table 2. Total 28 aquatic bird species which belong to 13 families of five orders recorded during the present investigation. Aquatic birds belong to the Anseriformes, Charadriiformes, Coracciformes, Gruiformes and Pelecaniformes and their per cent occurrence is given in Table 3. Among these orders, Gruiformes members predominated more (78.6%) and it was followed by Coracciformes and Pelecaniformes (7.1% each) and Anseriformes and Charadriiformes (1.7% each) members. Moreover, recorded aquatic birds represented 13 families and their per cent occurrence is given in Table 3. Among the families, aquatic bird species belong to Ardeidae were more (28.5%) and it was followed by Rallidae (14.3%), Phalacrocridae (10.7%) and Ciconiidae and Alcedinidae (7.1% each) members. Further, aquatic birds belong to other families have represented 3.6% each during the present investigation (Table 3). Interestingly, Scolopacidae member found only at Hebbal Lake and Pelecanidae member found only at Kukkarahalli Lake. Moreover, Anhingidae, Ciconiidae and Phalacrocridae family members were found only at Hebbal and Kukkarahalli Lakes. But, Charidridae family member found at Delovy and Hebbal Lakes. However, remaining aquatic birds which belong to other families were found at all the three Lakes (Tables 2 and 3) and showed the habitat specificity by the aquatic bird species considerably.

Aquatic bird's population size: Population size of aquatic birds recorded during morning and evening hours during different weeks of May, June, July and August months of 2023 at Dalvoy, Hebbal and Kukkarahalli Lakes are presented in Table 4. Analysis of variance of population size of aquatic birds at Dalvoy Lake indicated significant statistical difference ($F=4.006$; $P>0.05$) between morning and evening hours respectively. However, the population size of aquatic birds recorded at Hebbal and Kukkarahalli Lakes didn't indicate significant statistical differences respectively during morning ($F=0.1944$; $P<0.05$) and evening ($F=0.2546$; $P<0.05$) hours (Table 4). Further, number of aquatic bird species recorded during different weeks in morning and evening hours at three lakes are presented in Table 4).

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Aquatic bird species population density: Population of density of aquatic bird species recorded during morning and evening hours at Dalvoy, Hebbal and Kukkarahalli Lakes are presented in Table 5. Total 16 bird species found at Dalvoy Lake and their density was ranged between 0.59 and 0.85 respectively during morning and evening hours. At Hebbal Lake, 23 and 25 bird species found during morning and evening hours respectively. The population density was ranged between 0.63 and 0.82 during morning and evening hours respectively. However, at Kukkarahalli Lake, 24 bird species found during both morning and evening hours respectively. The population size was little higher compared to Dalvoy and Hebbal Lake and it was ranged between 1.45 and 1.20 during morning and evening hours respectively (Table 5). Overall, aquatic bird's density was high during evening hours and it was little less during morning hours at Dalvoy and Hebbal Lakes. Surprisingly, it was reverse at Kukkarahalli Lake, where the aquatic birds density was high (1.45) during morning hours and it was little less (1.20) during evening hours (Table 5). Further, average population density (including morning and evening hours) of different bird species indicated quite interesting facts. Every aquatic bird species indicated specific population density and obviously it was not overlapped between different bird species. Recorded 28 aquatic bird species density is depicted in Table 5. Eurasian Coot showed highest (4.04) density and it was followed by Black headed ibis (3.55), Asian open billed stork (2.40), Cattle egret (2.00), Little Grebe (1.49), little cormorant (1.44), Spot billed Pelican (1.43) and Purple swamp hen (1.24). However, remaining aquatic bird's population density was less than one (Table 5). Thus, population density of aquatic bird species was species specific, not uniform and varied considerably during morning and evening hours of the day at different aquatic habitats. The reason beyond this fact is multifarious, but it definitely kindles the interest of ornithologists, hobbyists, bird watchers and conservationists. Few attempts are being made to mention possible reasons to justify the aquatic bird's species specificity with their aquatic habitats in their natural abode in the later part of this article.

Aquatic bird species frequency of occurrence: Aquatic bird species frequency of occurrence observed during morning and evening hours at Dalvoy, Hebbal and Kukkarahalli Lakes are presented in Table 6. Total 16 bird species found at Dalvoy Lake and their frequency of occurrence was 6.56 and 5.76 respectively during morning and evening hours. However, at Hebbal Lake, 23 and 25 bird species were observed during morning and evening hours respectively. The bird species frequency of occurrence was 4.83 and 4.27 during morning and evening hours respectively and that didn't varied considerably. However, at Kukkarahalli Lake, 24 bird species found during both morning and evening hours. The bird's frequency of occurrence was little higher compared to Hebbal Lake, but slightly lower with Dalvoy Lake. It was ranged between 6.48 and 2.96 during morning and evening hours respectively (Table 6). Overall, aquatic bird species frequency of occurrence was high during morning hours and it was little less during evening hours at Dalvoy, Hebbal and Kukkarahalli Lakes (Table 6). Further, frequency of occurrence different species of aquatic birds (including morning and evening hours) indicated quite interesting facts and it was similar to that of their density. Every aquatic bird species occurred with specific frequency and obviously it was dissimilar between different bird species. Recorded 28 aquatic bird species frequency of occurrence is depicted in Table 6. Among all the recorded birds, Spot billed Pelican frequently observed (17.22) and it was followed by Eurasian coot (14.99), Black headed ibis (14.47), Cattle egret (13.8). However, other bird's frequency of occurrence was less than 10 (Table 6). Thus, frequency of occurrence of different aquatic bird species was uneven and varied considerably during morning and evening hours of the day at different aquatic habitats. The reason beyond this would be explained in the discussion part of this article.

Analysis of variance of aquatic bird species distribution: Distribution of aquatic bird species during morning hours of the day during different weeks between Dalvoy, Hebbal and Kukkarahalli Lakes are given in the Table 7. Analysis of variance of distribution of aquatic birds indicated that there is a considerable variation existed between the weeks and that indicated the significant difference ($F=77.750$; $P>0.05$) between the Lakes during morning hours of the day. Similarly, during evening hours significant difference ($F=19.071$; $P>0.05$) existed between the weeks at these Lakes (Table 7). Thus, aquatic bird species distribution was uneven among the Lakes during both morning and evening hours of the day.

Diversity indices of aquatic bird species: The diversity indices of aquatic bird species during morning and evening hours at Kukkarahalli, Dalvoy and Hebbal Lakes showed considerable difference of dominance ('D'), Shannon ('H'), Simpson ('1-D'), Evenness ('H/S'), Menhinick, Margalef, Equitability ('J'), Fisher-alpha and Berger-Parker indices (Table 8). The dominance was ranged between 0.075 to 0.079, Shannon index was in between the range of 2.567 to 2.608, Simpson index was in between 0.921 to 0.925, evenness was in between 0.931 to 0.975, Menhinick index was 0.957 to 1.228, Margalef index was in between 2.423 to 2.671, equitability was ranged between 0.973 to 0.990, Fisher-alpha index was 3.474 to 3.982 and Berger-Parker index was in the range of 0.099 to 0.115 (Table 8). All these diversity indices values are not even between the Kukkarahalli, Dalvoy and Hebbal Lakes and indicated the difference during morning hours of the day. Similar type of difference was also recorded during evening hours of the day at Kukkarahalli, Dalvoy and Hebbal Lakes (Table 8). Thus, diversity of aquatic bird species during morning and evening hours of the day at Kukkarahalli, Dalvoy and Hebbal Lakes showed considerable variation.

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Status of aquatic bird species: The international union for nature and natural resources (IUCN) and local status (based on the density and frequency of occurrence as mentioned in Tables 6 and 5 and the aquatic bird species status is prepared and results are depicted in Table 9. As per IUCN status, among the recorded aquatic birds, four types of bird species were found namely: least concerned (LC), near threatened (NT), not threatened (NoT) and critically endangered (CE) and their per cent occurrence is depicted in Table 9. Of all, 75% of the aquatic bird species represented least concerned status and it was followed by near threatened (14.2%) and critically endangered (7.3%) and the not threatened aquatic bird species per cent occurrence was only 3.5 (Table 9). Further, 60.7% of the aquatic birds were resident migrants (RM) and it was followed by local residents (39.3%) (Table 9). Thus, Kukkarahalli, Dalvoy and Hebbal Lakes attracted different types of aquatic birds which belong to IUCN category and majority of them were local migrants and local residents.

IV. DISCUSSION

Aquatic birds live at diversified amphibious habitats, access both aquatic and terrestrial ecosystems. Their ubiquitous habit and habitat supports different food chains and food webs midst various tropic levels (Grimmett and Inskipp, 2007). Aquatic bird species requires diversified habitat for foraging, roosting, resting, nesting and breeding activities (Satish *et al.*, 2020). Hence, their role is vital to the native flora and fauna and thus essential to restore the local biodiversity. During the present investigation, total 28 aquatic bird species were recorded at three lakes, which are located amidst Mysore. Recorded aquatic bird species dominance (ranged from 0.075 to 0.079), Shannon index (ranged from 2.567 to 2.608), Simpson index (ranged from 0.921 to 0.925), evenness (ranged from 0.931 to 0.975), Menhinick index (ranged from 0.957 to 1.228), Margalef index (ranged from 2.423 to 2.671), equitability (ranged from 0.973 to 0.990), Fisher-alpha index (ranged from 3.474 to 3.982) and Berger-Parker index (ranged from 0.099 to 0. 115) at Kukkarahalli, Dalvoy and Hebbal Lakes during morning hours of the day varied considerably. Similar type of considerable variations was recorded even during evening hours of the day at these Lakes. All these diversity indices values clearly demonstrated that there is a normal aquatic bird's diversity with little evenness between the Lakes and suggested a little variation between the Lakes. Every Lake habitat has specific ecological conditions which would help host good number of bird species with specific population density and frequency of occurrence during different hours of the day that could help avoid competition between and within the aquatic bird species to have healthy survival midst Lake Environment. Moreover, there was a constant and consistent human interference to these Lakes due to various domestic activities (Example, walking, fishing, sewage dumping etc.). Perhaps, it might have discouraged the even distribution of different aquatic bird species midst Kukkarahalli, Dalvoy and Hebbal Lakes in Mysore.

During the present investigation, surprisingly, members of Gruiformes were more commonly found at Kukkarahalli, Dalvoy and Hebbal Lakes and represented by 22 species which belong to Anhingidae, Ardeidae, Charidridae, Ciconiidae, Jacanidae, Pelecanidae, Phalacrocridae, Podicipedidae and Rallidae families. Similar type of observations was reported by Rajashekara and Venkatesha (2010), Harisha (2016), Rubina *et al.* (2016) and Shruthi and Basavarajappa (2016) at different ponds/Lakes in Karnataka. Birds species belong to these families are very specific in their roosting, resting, nesting, feeding behaviour and never compete for their food and shelter at different aquatic habitats. Hence, they live together and become part of different food chains and food web at aquatic habitats (Rubina *et al.*, 2016; Shruthi and Basavarajappa, 2016). Thus, our observations nearer to the observations of Inac *et al.* (2008), Mohan and Gaur (2008), Hussain *et al.* (2012), Birasal (2010), Rajashekara and Venkatesha (2010), Rubina *et al.* (2016). However, aquatic bird species belong to Anseriformes (Family:Anatidae), Charadriiformes (Family: Scolopacidae), Coracciformes (Family: Alcedinidae) and Pelecaniformes (Family: Threskiornithidae) composition was very less compared to Gruiformes at Kukkarahalli, Dalvoy and Hebbal Lakes. Thus, many bird species have direct relationship with different water habitats viz., ponds, lakes, rivers, reservoirs, bays, lagoons, gulf and wetlands, their presence is essential for the sustenance of local biodiversity. However, their distribution, density and frequency of occurrence during different hours of the day i.e., morning and evening hours is habitat specific but, dissimilar among various aquatic habitats (Inac *et al.*, 2008; Lameed, 2011; Donatelli *et al.*, 2013; Geofrey *et al.*, 2013; Shao *et al.*, 2014; Henkanththgedara and Amarasinghe, 2015; Shruthi and Basavarajappa, 2016; Dauda *et al.*, 2017; Odewumi*et al.*, 2017; Wijesundara *et al.*, 2017).Interestingly, Kukkarahalli, Dalvoy and Hebbal Lakes attract migratory birds besides local resident and resident migrant bird species. Few migratory birds are visiting regularly to these Lakes during different seasons. During the present investigation, few near threatened (14.2%), not threatened (3.5%) and critically endangered (7.3%) aquatic bird species were recorded midst Kukkarahalli, Dalvoy and Hebbal Lakes. Around 75% aquatic bird species were least concerned. Published reports on these aspects are poor and hence on this line further in depth investigations are necessitated. And, awareness should be created on these bird species which are enlisted under IUCN category. Further, classifying the aquatic birds into local resident and resident migrant would help understand their distribution and habitat range. Similar type of observations was made by Shruthi and Basavarajappa (2016). Because, aquatic bird species feed on wild grass, hydrophytes rootlets, tender shots, aquatic insects, mollusks, fishes, amphibians, lizards, water snakes etc, (Basavarajappa, 2006). Therefore, to fulfill their insectivorous, carnivorous, piscivorous, omnivorous and herbivorous feeding habits, provisions should be made to

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provide all these sources. It could be protected and thereby it is possible to restore the healthy status of aquatic bird species midst local Lakes amidst urban environment. Thus, our reports are on par with the published reports of Yang *et al.* (2005), Inac *et al.* (2008), Boldreghini and Dall'alpi (2008), Rajpar and Zakaria (2010), Lameed (2011), Donatelli *et al.* (2013), Geofrey *et al.* (2013), Klemetsen and Knudsen (2013), Shao *et al.* (2014), Henkanththgedara and Amarasinghe (2015), Odewumi*et al.* (2017), Dauda *et al.* (2017) Wijesundara *et al.* (2017) who have investigated on various aspects of aquatic birds at China, Turkey, Italy, Malaysia, Brazil, Norway, Sri Lanka and Pakistan. However, in India, Mohan and Gaur (2008), Kumar and Gupta (2009), Bhatt *et al.* (2009), Birasal (2010), Rajashekara and Venkatesha (2010), Ravikumar (2011), Hussain *et al.* (2012), Bhadouria *et al.* (2014), Teneson and Ravichandran (2015), Cross *et al.* (2015), Harisha (2016), Wanjari and Washim (2016), Puri and Virani (2016), Rubina *et al.* (2016), Shruthi and Basavarajappa (2016), Baraker and Kadadevaru (2017), Sujosha*et al.* (2020) and (Satish *et al.*, 2020) have investigated on various aspects of aquatic birds such as distribution, species composition, diversity, seasonal abundance and their role at Jajiwal pond (Jodhpur, Rajasthan), wetland ecosystem (Kurukshtra, UP), Wular Lake (Jammu & Kashmir), wetlands around Keloladeo National Park (Bharatpur), wetland of KoothaparPeriyakulam (Tamil Nadu), Ekburji reservoir (Maharashtra), Khairbandha Lake (Maharastra), Anekere wetland (Karkala, Karnataka), Heggeri Lake (Haveri, Karnataka), wetland (Hassan District, Karnataka), Lakes of Bangalore (Karnataka), Lakes of Dharwad (Karnataka), Kondajji Lake (Davanagere District, Karnataka) Lakes of Mysore (Karnataka), Lake of Hebballi (Gadag District, Karnataka). All these investigations revealed the importance of aquatic birds and their role in different ecosystems. Hence, present study supported the findings of previously reported research investigations on aquatic birds and provided an insight about the distribution, diversity and species composition of aquatic bird species along with their habitat specificity during morning and evening hours of the day midst urban area.

V. CONCLUSION

A total 28 aquatic bird species which belong to five orders and 13 familiesat Kukkarahalli, Dalvoy and Hebbal Lakes were recorded midst urban area of Mysore during morning and evening hours of the day. Recorded few aquatic bird species represented IUCN category (LC, NT, NoT and CE). All the aquatic birds were local resident and resident migrants. Their population size, density, frequency of occurrence and diversity indices were dissimilar during morning and evening hours of the day at these Lakes. Further, Gruiformes members were more predominant at these Lakes. The Anseriformes, Charadriiformes, Coracciformes and Pelecaniformes members were less. Hence, during the present investigation, aquatic bird species exhibited habitat specificity with respect to their population size and diversity during morning and evening hours of the day. Therefore, it is essential to record their presence at different aquatic habitats preferably midst urban areas. Moreover,aquatic habitats at urban area provide good platform for several migratory birds and extend life supporting conditions for their normal survival. Therefore, in depth investigations are necessitated to record the aquatic birds during different seasons midst aquatic habitats of urban area to restore their population and species composition undisturbed way.

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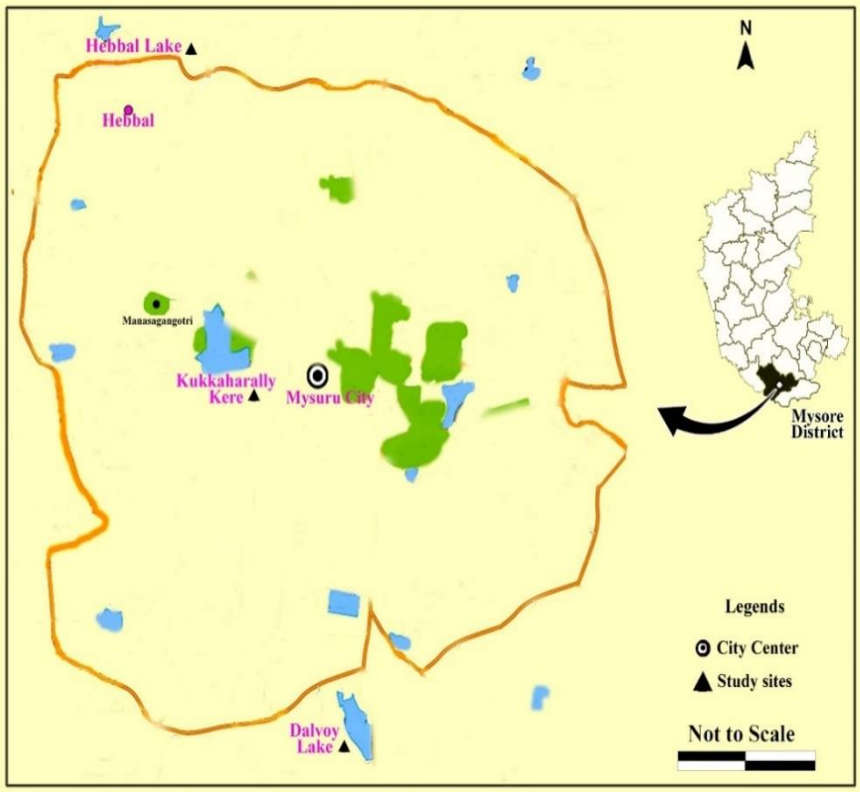

Figure 1. Map showing the study sites in Mysore City

Table 1. Physiographic features and environmental factors recorded at different lakes in Mysore

Sl. No.	Lake	Physiographic features		Environmental factors				
		Latitude and Longitude	Altitude (m)	Temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)
				Morning	Evening	Morning	Evening	
1.	Dalvoy	$12^0 25^1 17.29^{11}$E and $76^0 39^1 17.81^{11}$N	711	22.0	27.0	88.0	69.0	810.0
2.	Hebbal	$12^0 21^1 31.32^{11}$E and $76^0 36^1 42.20^{11}$N	800	21.0	27.0	89.0	71.0	800.0
3.	Kukkarahalli	$12^0 18^1 0.00^{11}$E and $76^0 37^1 48.00^{11}$N	759	21.0	27.0	90.0	78.0	800.0

Source: Google earth. Com; Kamath (2001).

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Table 2. Aquatic bird species recorded at different Lakes in Mysore

Sl. No.	Order	Sl. No.	Family	Sl. No.	Common Name	Scientific Name	Birds found at	IUCN Status	Local Status
1.	Anseriformes	1.	Anatidae	1.	Spot billed duck	*Anas poecilorhyncha*	DL, HL, KKL	LC	R
2.	Charadriformes	2.	Scolopacidae	2.	Common Sandipiper	*Actitis hypoleucos*	HL	LC	RM
3.	Coraciiformes	3.	Alcedinidae	3.	Common Kingfisher	*Alcedo atthis*	HL, KKL	LC	RM
				4.	White breasted Kingfisher	*Halcyon smyrnensis*	DL, HL, KKL	NoT	R
4.	Gruiformes	4.	Anhingidae	5.	Darter bird	*Anhingia melanogaster*	HL, KKL	NT	RM
		5.	Ardeidae	6.	Black crowned night heron	*Nycticoraxnycticorax*	HL, KKL	LC	R
				7.	Cattle egret	*Bulbulus ibis*	DL, HL,	LC	RM
				8.	Indian pond heron	*Ardeolagrayii*	DL, HL, KKL	LC	R
				9.	Great egret	*Ardeola alba*	DL,HL, KKL	LC	RM
				10.	Little egret	*Egrettagarzetta*	DL, HL, KKL	LC	RM
				11.	Grey Heron	*Ardea cinera*	DL, HL, KKL	CE	RM
				12.	Medium Egret	*Ardea intermedia*	DL, HL, KKL	LC	RM
				13.	Purple Heron	*Ardea purpurea*	DL, HL, KKL	LC	RM
		6.	Charadridae	14.	Red wattle lapwing	*Vanellus indicus*	DL,HL,	LC	R
		7.	Ciconiidae	15.	Asian open billed stork	*Anastomusoscitans*	HL, KKL	LC	R
				16.	Painted stork	*Mycteria leucocephala*	HL, KKL	NT	RM
		8.	Jacanidae	17.	Bronze winged Jacana	*Metopidius indicus*	DL, HL, KKL	LC	R
		9.	Pelecanidae	18.	Spot billed Pelican	*Pelecanusphillippensis*	KKL	NT	RM
		10.	Phalacrocaridae	19.	Great Cormorant	*Phalacrocorax carbo*	HL, KKL	LC	RM
				20.	Indian Cormorant	*Phalacrocorax fuscicollis*	HL, KKL	LC	RM
				21.	Little Cormorant	*Microcarboniger*	HL, KKL	LC	RM
		11.	Podicipedidae	22.	Little Grebe	*Tachybaptus ruficollis*	DL, HL, KKL	CE	R
		12.	Rallidae	23.	Eurasian Coot	*Fulicaatra*	DL, HL, KKL	LC	RM
				24.	Eurasian Moorhen	*Gallinula chloropus*	DL, HL, KKL	LC	RM
				25.	Purple swamp hen	*Porphyrioooporphyrio*	DL, HL, KKL	LC	R
				26.	White breasted water hen	*Amaurornisphoenicurus*	DL, HL, KKL	LC	R
5.	Pelecaniformes	13.	Threskiornithidae	27.	Black headed ibis	Threskiornismelanoephalus	DL, HL, KKL	NT	R
				28.	Glossy ibis	Plegadisfalcinellus	KKL	LC	RM

Note: DL: Dalvoy Lake; HL: Hebbal Lake; KKL: Kukkarahalli Lake; LC: Least Concern; CE: Critically Endangered; NT: Near Threatened; NoT: Not Threatened; R: Resident; RM: Resident Migrant.

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Table 3. Per cent occurrence of different aquatic birds orders, families at different lakes in Mysore

Sl. No.	Order	% Occurrence	Sl. No.	Family	% Occurrence	Found at
1.	Anseriformes	3.6 each	1.	Anatidae	3.6 each	DL, HL, KKL
2.	Charadriiformes		2.	Scolopacidae		HL
3.	Coracciformes	7.1	3.	Alcedinidae	7.1	DL, HL, KKL
4.	Gruiformes	78.6	1.	Anhingidae	3.6	HL, KKL
			2.	Ardeidae	28.5	DL, HL,KKL
			3.	Charidridae	3.6	DL, HL
			4.	Ciconiidae	7.1	HL, KKL
			5.	Jacanidae	3.6 each	DL, HL, KKL
			6.	Pelecanidae		KKL
			7.	Phalacrocridae	10.7	HL, KKL
			7.	Podicipedidae	3.6	DL, HL, KKL
			8.	Rallidae	14.3	DL, HL, KKL
5.	Pelecaniformes	7.1	1.	Threskiornithidae	7.1	DL, HL, KKL
Total		100.0	Total		100.0	-

Note: Data is based on Table 2.

Table 4. Aquatic bird's population size recorded during morning and evening hours at different lakes in Mysore

Month	Week No.	Dalvoy Lake		Hebbal Lake		Kukkarahalli Lake	
		Morning	Evening	Morning	Evening	Morning	Evening
May	1.	48	51	77	137	72	140
	2.	43	56	63	126	90	140
	3.	42	32	76	92	83	93
	4.	26	72	68	147	193	252
June	5.	49	34	84	128	283	261
	6.	56	27	114	125	448	213
	7.	92	88	97	110	405	270
	8.	29	71	97	133	339	289
July	9.	45	82	67	132	447	324
	10.	34	91	75	162	402	373
	11.	61	133	108	109	335	376
	12.	52	80	79	88	324	293
August	13.	51	62	115	153	407	553
	14.	56	49	121	139	368	358
Total		684	928	1241	1781	4196	3835
'F' value		**4.006***		**0.194****		**0.255****	

Note: Each value is a mean of 12 observations.
***Value is significant at 5% level. **Values are not significant.**

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Table 5. Aquatic bird species density recorded at different lakes in Mysore

Sl. No.	Aquatic bird	Dalvoy Lake		Hebbal Lake		Kukkarahalli Lake		Mean
		Morning	Evening	Morning	Evening	Morning	Evening	
1.	Spot billed duck	0.60	0.64	0.76	0.53	0.98	0.70	0.70
2.	Common Sandipiper	-	-	-	0.14	-	-	0.14
3.	Common Kingfisher	-	-	0.19	0.28	-	0.09	0.19
4.	White breasted Kingfisher	0.30	0.28	0.20	0.21	0.23	0.30	0.25
5.	Darter bird	-	-	0.39	0.23	0.18	0.22	0.26
6.	Black crowned night heron	-	-	0.21	0.22	0.19	0.18	0.20
7.	Cattle egret	2.23	4.56	0.33	0.89	-	-	2.00
8.	Indian pond heron	0.98	2.07	0.88	0.95	0.51	0.49	0.98
9.	Great egret	0.37	0.40	0.37	0.39	1.59	0.25	0.56
10.	Little egret	0.30	0.35	0.39	0.38	0.37	0.46	0.38
11.	Grey Heron	0.14	0.28	0.17	0.14	0.18	0.27	0.19
12.	Medium Egret	0.42	-	0.23	0.52	0.22	0.23	0.32
12.	Purple Heron	0.26	0.30	0.21	0.28	0.16	0.20	0.24
14.	Red wattle lapwing	0.42	0.39	0.25	0.26	-	-	0.33
15.	Asian open billed stork	-	-	-	0.14	0.24	0.09	0.16
16.	Painted stork	-	-	0.28	0.21	4.96	4.14	2.40
17.	Bronze winged Jacana	0.28	0.28	0.28	0.21	0.40	0.77	0.37
18.	Spot billed Pelican	-	-	-	-	2.18	0.68	1.43
19.	Great Cormorant	-	-	1.47	1.55	0.36	0.34	0.93
20.	Indian Cormorant	-	-	0.82	0.67	0.18	0.16	0.46
21.	Little Cormorant	-	-	1.22	1.71	0.50	2.31	1.44
22.	Little Grebe	0.35	0.47	2.39	2.38	1.57	1.78	1.49
23.	Eurasian Coot	0.36	0.61	2.06	2.13	11.24	7.84	4.04
24.	Eurasian Moorhen	-	0.14	0.52	0.23	1.00	0.29	0.55
25.	Purple swamp hen	0.70	0.90	1.15	1.40	1.68	1.58	1.24
26,	White breasted water hen	0.42	0.42	0.28	0.21	0.32	0.40	0.20
27.	Black headed ibis	1.30	1.46	0.33	4.93	7.17	6.10	3.55
28.	Glossy ibis	-	-	-	-	0.13	0.13	0.13
Mean		0.59	0.85	0.63	0.82	1.45	1.20	0.92

Note: Data is based on Table 4.

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Table 6. Aquatic bird species frequency of occurrence at different lakes in Mysore

Sl. No.	Aquatic bird	Dalvoy Lake		Hebbal Lake		Kukkarahalli Lake		Mean
		Morning	Evening	Morning	Evening	Morning	Evening	
1.	Spot billed duck	9.72	8.40	5.87	2.99	5.78	3.00	5.96
2.	Common Sandipiper	-	-	-	0.92	-	-	0.92
3.	Common Kingfisher	-	-	1.28	1.77	-	-	1.53
4.	White breasted Kingfisher	3.30	1.70	1.54	1.11	0.86	0.38	1.48
5.	Darter bird	-	-	3.25	1.44	0.80	0.37	1.47
6.	Black crowned night heron	-	-	1.76	1.15	0.56	0.62	1.02
7.	Cattle egret	18.48	28.31	3.06	5.38	-	-	13.80
8.	Indian pond heron	11.14	10.29	7.12	4.73	3.07	1.44	7.56
9.	Great egret	4.90	4.49	3.04	1.78	7.00	0.56	3.63
10.	Little egret	2.92	3.63	2.79	2.11	1.49	1.45	2.39
11.	Grey Heron	0.02	0.02	1.40	0.84	0.55	0.29	0.52
12.	Medium Egret	6.37	-	1.98	2.91	2.95	1.72	3.19
12.	Purple Heron	2.28	1.69	1.43	1.58	0.79	0.23	1.60
14.	Red wattle lapwing	4.93	3.2	1.65	1.51	-	-	2.82
15.	Asian open billed stork	-	-	-	0.75	1.23	0.09	0.69
16.	Painted stork	-	-	2.59	1.34	15.06	11.55	7.64
17.	Bronze winged Jacana	3.92	3.86	1.73	1.04	1.24	1.08	2.15
18.	Spot billed Pelican	-	-	-	-	28.91	5.53	17.22
19.	Great Cormorant	-	-	12.39	7.45	1.11	0.59	5.39
20.	Indian Cormorant	-	-	6.21	3.17	0.53	0.28	2.55
21.	Little Cormorant	-	-	8.15	9.71	1.63	6.59	6.52
22.	Little Grebe	4.84	4.12	16.27	12.70	5.28	3.71	7.82
23.	Eurasian Coot	4.86	1.29	14.80	15.32	39.93	13.78	14.99
24.	Eurasian Moorhen	-	0.01	4.57	1.17	7.12	0.56	2.09
25.	Purple swamp hen	8.57	6.87	8.67	7.30	6.94	3.08	6.91
26,	White breasted water hen	5.84	2.25	1.73	1.02	0.96	0.42	2.04
27.	Black headed ibis	12.90	12.09	2.64	24.49	21.38	13.34	14.47
28.	Glossy ibis	-	-	-	-	0.39	0.36	0.38
Mean		6.56	5.76	4.83	4.27	6.48	2.96	5.14

Note: Data is based on Table 4.

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Table 7. Analysis of variance of aquatic bird species distribution during morning and evening hours at few Lakes of Mysore

Week No.	Aquatic bird species occurrence during					
	Morning hours			Evening hours		
	KKL	DL	HL	KKL	DL	HL
1.	8	6	10	11	5	10
2.	9	8	10	11	6	10
3.	12	9	15	11	8	14
4.	14	8	14	15	8	14
5.	19	9	14	18	8	13
6.	12	8	17	11	6	14
7.	17	7	13	13	6	17
8.	17	8	14	17	9	14
9.	16	11	11	18	7	17
10.	18	9	14	20	9	15
11.	19	11	18	17	14	15
12.	15	15	15	18	12	16
13.	20	11	18	21	14	18
14.	18	10	19	19	13	18
Total	324	100	361	361	169	324
'F' value	77.750*			19.071*		

Note: Data is based on Table 2. Each value is a mean of 12 observations. KKL: Kukkarahalli Lake; DL: Dalvoy Lake; HL: Hebbal Lake. *Values are significant at 5% level.

Table 8. Diversity indices of aquatic birds during morning and evening hours at few Lakes of Mysore

Sl. No.	Diversity indices	Diversity indices of aquatic birds during					
		Morning hours			Evening hours		
		KKL	DL	HL	KKL	DL	HL
1.	Dominance (D)	0.076	0.075	0.079	0.075	0.079	0.073
2.	Shannon (H)	2.608	2.614	2.567	2.613	2.585	2.625
3.	Simpson (1-D)	0.925	0.925	0.921	0.925	0.921	0.927
4.	Evenness (H/S)	0.970	0.975	0.931	0.975	0.947	0.986
5.	Menhinick	0.957	1.228	1.010	0.944	1.252	0.978
6.	Margalef	2.423	2.671	2.473	2.410	2.692	2.442
7.	Equitability (J)	0.988	0.990	0.973	0.990	0.980	0.995
8.	Fisher alpha	3.357	3.982	3.474	3.328	4.042	3.402
9.	Berger-Parker	0.093	0.115	0.099	0.095	0.112	0.088

Note: Data is based on Table 7.

Table 9. IUCN and Local status of aquatic birds at different lakes in Mysore

Aquatic birds					
IUCN Status			Local status		
Sl. No.	Type	% Occurrence	Sl. No.	Type	% Occurrence
1.	Least Concerned (LC)	75.0	1.	Local Resident (LR)	39.3
2.	Near Threatened (NT)	14.3	2.	Resident Migrant (RM)	60.7
3.	Not Threatened (NoT)	3.6.	3.	Migrant (M)	-
4.	Critically Endangered (CE)	7.4			
Total		100.0	Total		100.0

Note: Data is based on Table 2.