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Seasonal distribution and diversity of aquatic avifauna at lentic ecosystem of Kollegala, southern Karnataka, India

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Abstract

Seasonal distribution and diversity of aquatic bird species at Chikkaranganatha, Doddaranganatha, Kongala, Papanakere and Dhanagere Lakes of Kollegala of Chamarajanagar District of Karnataka was conducted during 2016 to 2018. Around 43 bird species which belong to 15 families of the eight orders were recorded at different Lakes during summer, rainy and winter seasons. Amongst aquatic bird species, Pelecaniformes were more predominant and represented by 12 species and it was followed by Charadriiformes (10 species), Anseriiformes (8 species) and Ciconiiformes (4 species). Aquatic bird's dominance was 0.206, 0.209 and 0.201 respectively during summer, rainy and winter seasons. The Simpson index was ranged in between 0.791 to 0.794, the Shannon diversity index ranged between 1.586 to 1.607 and the Fisher alpha value ranged between 1.002 and 1.211 at various Lakes of Kollegala during different seasons. Moreover, Shannon 'J' (Equitability) and Evenness indices were more than 0.9. Further, Fisher alpha value was ranged between 1.002 and 1.211 during summer and winter seasons. Thus, Lakes of Kollegal have shown specificity with their aquatic bird species composition and exhibited uniqueness by hosting different bird species with varied population size. Lakes are ideal habitats for various aquatic birds, which offer food, shelter and breeding ground to have safe survival during different seasons. Hence, Lakes located at towns/rural areas should be preserved to save local biodiversity.

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Introduction

Birds are beautifully coloured creatures, live at diversified habitats at different ecosystems midst rural and urban areas. Amongst birds, many species prefer to live in or nearby aquatic bodies and known to have well established power of flight to access both aquatic and terrestrial ecosystems. Such birds are called 'aquatic birds', which are ubiquitous in their existence (Gaston, 1975; Hardy *et al.,* 1987) and become inseparable elements of lentic ecosystems by supporting food chain and food web at different tropic levels (Custer and Osborne, 1977; Grimmett and Inskipp, 2007). Moreover, aquatic bird species play a pivotal role while indicating the quality of lentic ecosystems and help maintain the native flora and fauna (Grimmet and Inskipp, 2007). Hence, their presence is essential to restore local biodiversity at rural and urban areas.

Across the world, several ornithologists have conducted basic and applied research on different species of aquatic birds to record their distribution, diversity, foraging, breeding and nesting activities at different lentic ecosystems. Mark *et al.* (1994), Musil and Fuchs (1994), Maloney *et al.* (1997), 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) and Wijesundara *et al.* (2017) have reported the birds distribution, diversity and nesting, breeding activities at different ecosystems of Florida, Czechoslovakia, New Zealand, China, Turkey, Italy, Malaysia, Nigeria, Brazil, Tanzania, Norway, Pakistan and Sri Lanka. In India, Mohan and Gaur (2008), Kumar and Gupta (2009), Hussain *et al.* (2012), Kanaujia *et al.* (2013), Bhadouria *et al.* (2014), Teneson and Ravichandran (2015), Cross *et al.* (2015), Wanjari and Washim (2016), Puri and Virani (2016) and Bora *et al.* (2017), Basavarajappa and Shruthi (2016 and 2017), Sujosha *et al.* (2020), Likith and Basavarajappa (2023) have researched respectively on birds distribution and diversity at Jodhpur in Rajasthan, wetland ecosystem of Kurukshtra, Wular Lake of Jammu and Kashmir, Lucknow District of Uttar Pradesh, Keloladeo National Park of Bharatpur, wetland of Koothapar Periyakulam at Tiruchanapalli District of Tamil Nadu, coastal area of Gulf of Mannar, Ekburji reservoir of Maharashtra, Khairbandha Lake in Gondia District of Maharashtra, Nagaon town in Nagaon District of Assam and Mysore district in Karnataka. Further, several published reports are available on the aquatic bird's diversity in different Lakes/ponds of Karnataka. Bhat *et al.* (2009) have reported the diversity of birds in Anekere wetland of Karkala, Udupi District. Birasal (2010) has studied the water birds diversity at Heggeri Lake, Haveri District. Ravikumar (2011) has studied the density and diversity of aquatic birds in the wetland of Hassan District.

Rajashekara and Venkatesha (2011) have studied the aquatic birds in Lakes of Bangalore. Renu *et al.* (2016) have prepared a checklist of avifauna of Rourkela urban area of Sundargarh district of Odisha. Shruthi and Basavarajappa (2016) have studied the avian diversity at few aquatic ecosystems of Mysore district. Rubina *et al.* (2016) have studied the diversity and status of birds in the Lakes of Dharwad. Harisha (2016) has evaluated the status, diversity and conservation threats of wetland birds of Kondajji Lake in Davanagere District. Shruthi and Basavarajappa (2016) have studied the diversity of aquatic birds at Mysore District. Baraker and Kadadevaru (2017) have studied the diversity of birds in Malaprabha River at Badami Taluk of Gadag District. Basavarajappa and Shruthi (2017) have studied the habitat conditions of few aquatic bird species in Mysore district. Basavarajappa and Shruthi (2017) have studied the resting, roosting, foraging and nesting sites of bird species at Mysore district. Sujosha *et al.* (2020) have reported the population distribution, density and diversity of aquatic avifauna at different lakes in and around Mysore. Lakshmi *et al.* (2020) have assessed the status of aquatic birds and suggested the mitigation measures to preserve the aquatic birds in urban ecosystem of Mysore.

Satish *et al.* (2020) have reported the aquatic birds at dry agro-climatic regions of Chamarajanagar district. Likhith and Basavarajappa (2023) have reported the habitat specificity of aquatic birds during different hours of the day at different lakes of urban area of Mysore.

Although, above cited literature revealed the sufficient information on diversity, distribution and abundance of aquatic birds at different parts of the world including India and Karnataka.

However, all these published reports revealed the avifauna composition in aquatic and terrestrial habitats. However, no reports are available about the seasonal occurrence of bird species at aquatic ecosystems in southern Karnataka. Assessment of aquatic birds during different seasons, distribution and diversity during summer, rainy and winter is poor. Hence the present study was necessitated.

Materials and methods

Study area

Kollegal is one of the Taluks in Chamarajanagar District and one of the major Taluks in Karnataka State. It lies at 12°5' 9" to 77° 21' 20.1"N latitude and 12°4' 14.9" to 75° 28' 16.1"E longitude and covered by hills with a forest cover more than 69% of the geographical area under dry agro-climatic zone (Kamath, 2001). Kollegala experiences minimum 16 to maximum 34°C temperature with relative humidity 27 to 90%. Moreover, Kollegala receives more than 600 mm annual rainfall. The River Cauvery flows some parts of Kollegal Taluk and becomes major water source to many Lakes, ponds, pools (Satish *et al.*, 2020). Moreover, agricultural and horticultural croplands are located at the vicinity of Cauvery basin which is attracting innumerable local and migratory birds during different seasons (Kamath, 2001; Anonymous, 2015).

Methods

Seasonal survey was conducted systematically by selecting five lakes such as Chikkaranganatha, Doddaranganatha, Kongala, Papanakere and Dhanagere nearby Kollegala. Aquatic birds were observed by following line transects (LTs) and point transects (PTs) and variable width line transacts (VWLTs) as described by Burnham *et al.* (1980), Jayson and Mathew (2002) and Basavarajappa (2006). More than 36 line transects with a length 200 to 300 meters were laid and bird species were observed using a Nikon action 16x50CF binocular. Birds were observed and counted as and when they alight on the water surface or on the bank of Lakes with the help of Canon EOS 70D (W/Ef-S18-135mm) camera (Satish *et al.*, 2020). Observed birds were recorded carefully in the pre-tested questionnaire and they were photographed for identification. Recorded bird species were identified with the help of field guides published by Ali (1996), Ali and Ripley (1983 and 1987), Sonobe and Usui (1993) and Woodcock (1980).

Statistical analysis

Seasonal distribution, per cent occurrence, analysis of variance and diversity indices were calculated by following standard methods. Percent occurrence = number of individuals of the species /number of individuals of all species × 100 of aquatic bird species was calculated as per Basavarajappa (2006). Analysis of variance (ANOVA) of aquatic birds during different seasons was calculated as per Saha (2009). The aquatic avifaunal diversity was calculated by using PAST version 2.10 and using the method as per Maguran (2004). Shannon Diversity Index (H^1): $H^1 = -\sum(pi\ In\ pi)$, where, pi is the proportion of the i^{th} species in the total sample and in pi is the natural log of pi. Moreover, aquatic bird species evenness within a lake was calculated using Pielovu's Evenness Index (J^1) to identify the variation within the community among the species. Pielovu's Evenness Index: $J^1 = H^1/In\ S$, where, S is the number of species present in the site and H^1 is the diversity index (Satish *et al.*, 2020). Collected data was systematically compiled by following standard methods.

Results

Table 1 shows the distribution of aquatic birds during summer, rainy and winter seasons at

Chikkaranganatha Lake in Kollegala. Summer scored highest (457) birds and it was followed by winter (319) and rainy season (124) (Table 1). Altogether, 26 bird species which belong to 12 families were recorded (Table 6) and they represented 16.9% (Fig. 1) with an aquatic birds population size 900 (Table 7) and that represented 9.4% of the overall aquatic birds of this Lake (Fig. 1). Moreover, analysis of variance of different aquatic bird species which occurred during different seasons at Chikkaranganatha Lake indicated significant difference ($F=2.277$; $P<0.05$) (Table 1).

Table 1. Aquatic birds recorded during different seasons at Chikkaranganatha lake in Kollegal, Karnatak

SL	Order: Family	Common name of bird	S	R	W
1.	Charadriiformes: Charadriidae	Red wattle lapwing	15	18	2
2.	Charadriiformes: Jacanidae	Bronze winged jacana	4	-	16
3.	Charadriiformes: Scolopacidae	River tern	3	-	-
4.	-do-	Black tailed godwit	42	-	8
5.	Ciconiiformes:Ciconidae	Painted stork	23	-	36
6.	-do-	Woolly necked stork	3	-	-
7.	Coraciiformes: Alcedinidae	Small blue kingfisher	7	7	2
8.	-do-	White throated kingfisher	2	3	1
9.	Gruiformes:Rallidae	Common coot	47	10	18
10.	-do-	Purple moorhen	72	32	28
11.	-do-	Water cock	8	1	9
12.	Pelecaniformes:Ardeidae	Grey heron	3	8	3
13.	-do-	Indian pond heron	33	17	35
14.	-do-	Intermediate egret	42	10	26
15.	-do-	Large egret	2	1	-
16.	-do-	Little egret	20	2	11
17.	-do-	Night heron	9	2	13
18.	-do-	Purple heron	9	2	6
19.	-do-	Western reef heron	-	-	1
20.	Pelecaniformes:Pelecanidae	Spot billed pelican	16	-	17
21.	Pelecaniformes:Threskiornithidae	Black headed ibis	14	-	-
22.	-do-	Red napped ibis	6	5	5
23.	-do-	Glossy ibis	13	6	15
24.	Suliformes:Phalacrocoracidae	Great cormorant	23	-	9
25.	-do-	Little cormorant	36	-	49
26.	Suliformes:Anhingidae	Oriental darter	5	-	9
Total			457	124	319
'F'				2.277	

Note: S: Summer; R: Rainy and W: Winter season

Table 2. Aquatic birds recorded during different seasons at Doddaranganatha lake in Kollegal, Karnataka

SL	Order: Family	Common name of bird	S	R	W
1.	Anseriformes:Anatidae	Common shell duck	3	-	-
2.	-do-	Cotton pygmy goose	15	-	-
3.	-do-	Garganey	45	-	-
4.	-do-	Greylag goose	11	-	3
5.	-do-	Spot billed duck	43	-	22
6.	-do-	White winged duck	12	-	-
7.	Charadriiformes:Charadriidae	Red wattle lapwing	-	10	32
8.	Charadriiformes: Jacanidae	Bronze winged jacana	23	2	5
9.	Charadriiformes:Laridae	River tern	-	2	-
10.	Charadriiformes:Recurvirostridae	Black winged stilt	211	-	33
11.	Charadriiformes: Scolopacidae	Black tailed godwit	197	-	74
12.	Ciconiiformes: Ciconidae	Asian open bill stork	2	-	2
13.	-do-	European white stork	3	-	-
14.	-do-	Painted stork	63	3	5
15.	-do-	Woolly necked stork	5	3	3
16.	Coraciiformes:Alcedinidae	Small blue kingfisher	1	-	2
17.	-do-	White throated kingfisher	6	-	1
18.	Gruiformes:Rallidae	Common coot	153	9	69
19.	-do-	Purple moorhen	23	3	6
20.	-do-	Water cock	9	1	3

21.	Pelecaniformes:Ardeidae	Grey heron	1	2	10
22.	-do-	Indian pond heron	41	13	49
23.	-do-	Intermediate egret	32	26	20
24.	-do-	Large egret	2	-	2
25.	-do-	Little egret	49	2	10
26.	-do-	Night heron	15	1	-
27.	-do-	Purple heron	7	8	4
28.	-do-	Western reef heron	3	-	1
29.	Pelecaniformes:Threskiornithidae	Black headed ibis	18	-	-
30.	-do-	Glossy ibis	22	21	8
31.	-do-	Red napped ibis	1	-	4
32.	Suliformes:Phalacrocoracidae	Great cormorant	31	4	17
33.	-do-	Little cormorant	94	-	24
34.	Suliformes:Anhingidae	Oriental darter	7	1	11
Total			1148	111	420
'F' value				2.950	

Note: S: Summer; R: Rainy and W: Winter season

Table 3. Aquatic birds recorded during different seasons at Kongala lake in Kollegal, Karnataka

SL	Order : Family	Common name of bird	S	R	W
1.	Anseriformes:Anatidae	Lesser whistling duck	309	1	80
2.	-do-	Spot billed duck	11	-	-
3.	Charadriiformes:Charadriidae	Golden plover	25	-	-
4.	-do-	Red wattle lapwing	40	13	-
5.	Charadriiformes: Jacanidae	Bronze winged jacana	43	-	9
6.	Charadriiformes: Laridae	River tern	7	2	-
7.	Charadriiformes:Scolopacidae	Common redshank	38	3	-
8.	-do-	Black tailed godwit	1051	-	54
9.	-do-	Marsh sand piper	102	4	-
10.	-do-	Spotted red shank	161	-	-
11.	Charadriiformes:Recurvirostridae	Black winged stilt	106	-	81
12.	Ciconiiformes:Ciconidae	Asian open bill stork	4	-	3
13.	-do-	European white stork	3	-	-
14.	-do-	Painted stork	3	3	2
15.	-do-	Woolly necked stork	13	-	-
16.	Coraciiformes:Alcedinidae	Small blue kingfisher	5	3	3
17.	-do-	White throated kingfisher	7	-	1
18.	Gruiformes:Rallidae	Common coot	110	17	13
19.	-do-	Purple moorhen	61	-	40
20.	-do-	Water cock	29	5	-
21.	Passeriformes:Motacillidae	White browed wagtail	29	40	18
22.	Plecaniformes:Anhingidae	Oriental darter	2	-	2
23.	Plecaniformes:Ardeidae	Grey heron	4	1	4
24.	-do-	Indian pond heron	33	21	17
25.	-do-	Intermediate egret	40	24	4
26.	-do-	Large egret	2	1	5
27.	-do-	Little egret	17	5	24
28.	-do-	Night heron	5	-	-
29.	-do-	Purple heron	8	2	9
30.	Plecaniformes: Pelecanidae	Spot billed pelican	10	-	8
31.	Plecaniformes:Threskiornithidae	Black headed ibis	219	15	90
32.	-do-	Glossy ibis	10	21	22
33.	-do-	Red napped ibis	5	1	1
34.	Suliformes:Phalacrocoracidae	Great cormorant	27	7	15
35.	-do-	Little cormorant	19	8	10
Total			2558	182	515
'F' value				15.326	

Note: S: Summer; R: Rainy and W: Winter season

Table 2 shows the distribution of aquatic birds during summer, rainy and winter seasons at Doddaranganatha Lake in Kollegala. Summer scored highest (1148) birds and it was followed by winter (420) and rainy season (111) (Table 2). Altogether, 34 bird species which belong to 13 families were recorded (Table 6) and they represented 22.1% (Fig. 1) with an aquatic birds

population size 1679 (Table 7) and that represented 17.4% of the overall aquatic birds of this Lake (Fig. 1). Moreover, analysis of variance of different aquatic bird species which occurred during different seasons at Doddaranganatha Lake indicated significant difference (F=2.950; P<0.05) (Table 2). Table 3 shows the distribution of aquatic birds during summer, rainy and winter seasons at Kongala Lake in Kollegala. Summer scored highest (2558) birds and it was followed by winter (515) and rainy season (182) (Table 3). Altogether, 35 bird species which belong to 15 families were recorded (Table 6) and they represented 22.7% (Fig. 1) with an aquatic birds population size 3252 (Table 7) and that represented 33.9% of the overall aquatic birds of this Lake (Fig. 1). Moreover, analysis of variance of different aquatic bird species which occurred during different seasons at Kongala Lake indicated significant difference (F=15.320; P>0.01) (Table 3).

Table 4. Aquatic birds recorded during different seasons at Papana lake in and around Kollegal, Karnataka

SL	Order : Family	Common name of bird	S	R	W
1.	Anseriformes:Anatidae	Grey lag goose	5	-	4
2.	Charadriiformes:Charadriidae	Red wattle lapwing	-	7	23
3.	Charadriiformes:Recurvirostridae	Black winged stilt	24	-	61
4.	Charadriiformes:Scolopacidae	Marsh sand piper	102	-	-
5.	-do-	Black tailed godwit	520	17	381
6.	Ciconiiformes:Ciconidae	Asian open bill stork	-	-	1
7.	-do-	European white stork	-	-	1
8.	-do-	Painted stork	75	-	-
9.	-do-	Woolly necked stork	2	-	3
10.	Coraciiformes:Alcedinidae	Small blue kingfisher	1	-	2
11.	-do-	White throated kingfisher	6	39	2
12.	Gruiformes:Rallidae	Common coot	138	-	2
13.	-do-	Purple moorhen	2	8	33
14.	-do-	Water cock	6	-	1
15.	Passeriformes:Motacillidae	White browed wagtail	32	-	7
16.	Pelecaniformes: Ardeidae	Grey heron	5	1	6
17.	-do-	Indian pond heron	12	-	14
18.	-do-	Intermediate egret	19	23	24
19.	-do-	Large egret	-	-	8
20.	-do-	Little egret	63	22	19
21.	-do-	Purple heron	13	1	4
22.	Pelecaniformes:Threskironithidae	Black headed ibis	31	-	6
23.	-do-	Glossy ibis	19	13	21
24.	-do-	Red napped ibis	6	-	2
25.	Suliformes:Anhingidae	Oriental darter	-	-	2
26.	Suliformes:Phalacrocoracidae	Great cormorant	31	-	20
27.	-do-	Little cormorant	33	11	2
Total			1145	106	649
'F' value				0.970	

Note: S: Summer; R: Rainy and W: Winter season

Table 5. Aquatic birds recorded during different seasons at Dhanagere lake in Kollegal, Karnataka

SL	Order : Family	Common name of bird	S	R	W
1.	Anseriformes:Anatidae	Cotton pygmy goose	17	-	-
2.	-do-	Ferruginous duck	19	-	5
3.	-do-	Spot billed duck	34	-	-
4.	-do-	White winged duck	3	-	-
5.	Charadriiformes:Laridae	River tern	23	-	5
6.	Charadriiformes:Recurvirostridae	Black winged stilt	95	10	19
7.	Charadriiformes:Scolopacidae	Common redshank	15	-	-
8.	-do-	Green sandpiper	160	5	-
9.	-do-	Black tailed godwit	177	-	12
10.	-do-	Marsh sand piper	181	-	-
11.	Charadriiformes:Charadriidae	Red wattled lapwing	34	14	5
12.	Ciconiiformes:Ciconidae	Asian open bill stork	4	-	10
13.	-do-	European white stork	8	-	-

14.	-do-	Painted stork	95	-	218
15.	-do-	Woolly necked stork	2	3	4
16.	Coraciiformes:Alcedinidae	Small blue kingfisher	2	2	-
17.	Gruiformes:Rallidae	Common coot	22	-	4
18.	-do-	Purple moorhen	62	-	-
19.	-do-	Water cock	6	-	5
20.	Passeriformes:Motacillidae	White browed wagtail	41	-	42
21.	Pelecaniformes:Ardeidae	Grey heron	4	4	8
22.	-do-	Indian pond heron	30	16	30
23.	-do-	Intermediate egret	12	2	10
24.	-do-	Large egret	5	1	7
25.	-do-	Little egret	15	2	7
26.	-do-	Purple heron	4	1	8
27.	Pelecaniformes:Pelecanidae	Spot billed pelican	136	-	155
28.	Pelecaniformes:Threskiornithidae	Black headed ibis	3	-	5
29.	-do-	Glossy ibis	8	5	4
30.	-do-	Red napped ibis	-	-	1
31.	Suliformes:Phalacrocoracidae	Great cormorant	5	3	-
32.	-do-	Little cormorant	9	-	-
33.	Suliformes:Anhingidae	Oriental darter	2	-	4
Total			1233	68	568
'F' value				2.202	

Note: S: Summer; R: Rainy and W: Winter season

Table 6. Orders, families and species of aquatic birds recorded at five lakes of Kollegala of Karnataka

SL	Order	Aquatic birds	CL	D_1L	KL	PL	D_2L	Total	Mean
1.	Anseriformes	Families	-	1	1	1	1	4	0.8
		Species	-	16	2	1	4	13	2.6
2.	Charadriiformes	Families	4	5	5	3	4	21	4.2
		Species	4	5	9	4	7	29	5.8
3.	Ciconiiformes	Families	1	1	1	1	1	5	1.0
		Species	2	4	4	4	4	18	3.6
4.	Coraciiformes	Families	1	1	1	1	1	5	1.0
		Species	2	2	2	2	1	9	1.8
5.	Gruiformes	Families	1	1	1	1	1	5	1.0
		Species	3	3	3	3	3	15	3.0
6.	Passeriformes	Families	-	-	1	1	1	3	0.6
		Species	-	-	1	1	1	3	0.6
7.	Pelecaniformes	Families	3	2	3	2	3	13	2.6
		Species	12	11	11	9	10	53	10.6
8.	Suliformes	Families	2	2	2	2	2	10	2.0
		Species	3	3	3	3	3	15	3.0
Total		Families	12	13	15	12	14	66	13.2
		Species	26	34	35	27	33	155	31.0

Note: CL: Chikkaranganatha Lake; D_1L: Doddaranganatha Lake; KL: Kongala Lake; PL: Papana Lake; D_2L Dhanagere Lake. Each value is a total of 36 observations.

Table 4 shows the distribution of aquatic birds during summer, rainy and winter seasons at Papana Lake in Kollegala. Summer scored highest (1145) birds and it was followed by winter (649) and rainy season (106). Analysis of variance of aquatic birds occurred between different seasons at Papana Lake didn't show significant variation ($F=0.970$; $P<0.05$) (Table 4). Moreover, different bird species which occurred during different seasons at Papana Lake are depicted in Table 4. Altogether, 27 bird species which belong to 12 families were recorded (Table 6) and they represented 17.5% (Fig. 1) with aquatic birds population size 1900 (Table 7) and that represented 19.8% of the overall aquatic birds of this Lake (Fig. 1). Table 5 shows the distribution of aquatic birds during summer, rainy and winter seasons at Dhanagere Lake in Kollegala. Summer scored highest (1233) birds and it was followed by winter (568) and rainy season (68 only). Analysis of variance of aquatic birds occurred between different seasons at Dhanagere Lake indicated significant variation ($F=2.202$; $P<0.05$) (Table 5).

Table 7. Analysis of variance of aquatic bird species at different lakes of Kollegala, India

SL	Name of Lake	Aquatic bird species found during		
		Summer	Rainy	Winter
1.	Chikkaranganatha Lake	25	15	22
2.	Doddaranganatha Lake	32	17	26
3.	Kongala Lake	35	19	24
4.	Papana Lake	22	10	25
5.	Dhanagere Lake	32	13	22
Mean ± SD		29.2 ± 5.44	14.8 ± 3.49	23.8 ±1.78
'F' value			15.7*	

Note: Data is based on Tables 1 to 5. *Value is significant at 1% level (P<0.001).

Table 8. Overall aquatic bird's species composition and population size at different lakes of Kollegala, Karnataka

SL	Name of lake	No. of species recorded	Population size
1.	Chikkaranganatha lake	26	900
2.	Doddaranganatha lake	34	1679
3.	Kongala lake	35	3252
4.	Papana lake	27	1900
5.	Dhanagere lake	32	1869
Total		154	9600
Mean ± SD		30.8 ± 31.01	1920 ± 2064.34

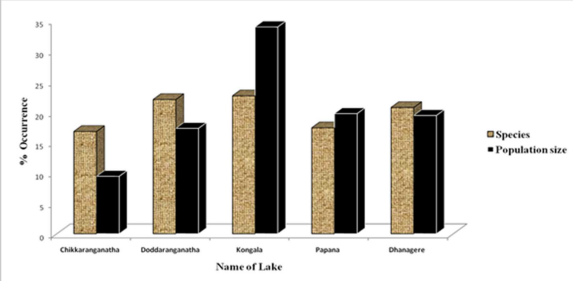

Fig. 1. Overall aquatic bird species composition and population size at different lakes of Kollegala, Karnataka

Altogether, 33 bird species which belong to 14 families were recorded (Table 6) and they represented 20.8% (Fig. 1) with aquatic birds population size 1869 (Table 7) and that represented 19.5% of the overall aquatic birds of this Lake (Fig. 1). Further, on an average 30 ± 31.0 bird species were recorded from five different Lakes with a population size 1920 ± 2064.3 (Table 7). Fig. 1 shows the overall aquatic bird species composition and population size at different Lakes of Kollegala.

Interestingly, in all the five Lakes (e.g., Chikkaranganatha, Doddaranganatha, Kongala, Papana and Dhanagere) aquatic bird's population size was high (Tables 1 to 5) with bird species 29.2 ± 5.44 during summer season and it was followed by winter (23.8 ± 1.78 bird species) and rainy season (14.8 ± 23.49) (Table 8). Thus, similar trend was recorded with respect to the distribution of bird species in all the five Lakes of Kollegala during summer, rainy and winter seasons. Overall, summer season favoured better for more bird species in all the Lakes compared to winter and rainy season in Kollegala. Analysis of variance between the aquatic bird species distribution and the seasons indicated significant difference (F=15.7; P>0.01) at different Lakes of Kollegala.

Table 9. Aquatic bird species diversity at different lakes of Kollegala, India

SL	Diversity indices	Summer	Rainy	Winter
1.	Dominance_D	0.206	0.209	0.201
2.	Simpson 1-D	0.794	0.791	0.799
3.	Shannon 'H'	1.595	1.586	1.607
4.	Evennes H/S	0.986	0.977	0.9987
5.	Brillouin	1.529	1.475	1.530
6.	Menhinick	0.414	0.581	0.458
7.	Equitability 'J'	0.991	0.9867	0.999
8.	Margalef	0.803	0.929	0.837
9.	Fisher alpha	1.002	1.211	1.056
10.	Berger Parker	0.240	0.257	0.219

Aquatic bird's diversity

Aquatic bird's dominance was 0.206, 0.209 and 0.201 respectively during summer, rainy and winter seasons at different Lakes of Kollegala (Table 9). The Simpson index was low (0.791) during rainy season, and it was 0.794 and 0.799 during summer and winter seasons respectively. However, the Shannon diversity index was 1.586 during rainy season and 1.595 and 1.607 respectively during summer and winter seasons. The Shannon Evenness, Shannon Equitability, Brillouin and Berger Parker indices indicated similar trend during rainy, summer and winter seasons. However, Menhinick, Margalef and Fisher alpha indices indicated the highest values during rainy season and it was followed winter and summer seasons. Thus, aquatic birds diversity indices did vary considerably during different seasons at different Lakes of Kollegala of Karnataka State.

Discussion

Five Lakes located at Kollegala hosted 43 bird species which represented by eight orders and, 15 families. The 'H' indices (2.031 and 2.867) and Fisher alpha values (5.002 and 6.053) indicated the normal diversity with little evenness among the five Lakes. Moreover, these Lakes showed specific aquatic bird species composition during different seasons and indicated significant difference. Therefore, every Lake habitat has specific biotic composition, would capable to host bird species accordingly to meet their feeding requirements. Distinct bird species composition could help maintain the healthy status of ecosystem thereby foraging, roosting, resting, nesting and breeding sites are fulfilled to achieve normal survival. Hence, aquatic bird species habit and habitats are distinct and not identical. Surprisingly, Pelecaniformes were more common at different Lakes and represented by 12 species which belong to Ardeidae, Pelecanidae and Threskiornithidae families. The Pelecaniformes are relatively medium-size to large water birds, have the habit of living at inland lentic ecosystems (Ali, 1996; Ali and Ripley, 1983 and 1989; Jordan and Verma, 2000), where fish fauna is more abundant. Rajashekara and Venkatesha (2011), Harisha (2016), Rubina *et al.* (2016) and Shruthi and Basavarajappa (2016) have reported more species of Pelecaniformes at different Lakes located respectively at south-eastern region (e.g., Bangalore), maidan region (e.g., Davangere), northern Karnataka (e.g. Dharwad) and south-western region (e.g. Mysore), where fish fauna was comparatively good in all these Lakes. The order Charadriformes include diverse group of small to medium-large birds, they have diversified feeding habit and have very specific roosting, resting and nesting behaviour and never compete for similar type of habitats. These birds live together and become part of various food chain and food web at different lentic ecosystems (Rubina *et al.,* 2016; Shruthi and Basavarajappa, 2016). Similar types of observations were reported by Rajashekara and Venkatesha (2011), Rubina *et al.* (2016) and Satish *et al.* (2021). Moreover, species belong to Gruiformes, Suliformes, Coraciformes and Passeriformes composition was very less compared to other aquatic bird species. Gruiformes are wading birds; Suliformes include cormorants, whereas Coraciformes includes kingfisher's which lead amphibious life (Ali, 1996, Ali and Ripley, 1983 and 1989; Jordan and Verma, 2000). However, Passeriformes are small sized perching birds, known for their very high diversity at both terrestrial and aquatic ecosystems (Ali, 1996, Ali and Ripley, 1983 and 1989; Jordan and Verma, 2000). Perhaps, all these bird species amphibious life might have lessen their population size at different Lakes of Kollegala. Moreover, those bird species might have visited some other aquatic bodies during the present observation. Ravikumar (2011), Rajashekara and Venkatesha (2011), Hussain *et al.* (2012), Kanaujia *et al.* (2013), Bhadouria *et al.* (2014), Teneson and Ravichandran (2015), Wanjari and Washim (2016), Shruthi and Basavarajappa (2016) have reported similar type of findings at different lentic ecosystems of India. Thus, presence of aquatic bird species during different seasons with increased or decreased population size indicates the uniqueness and ubiquitous state of the lentic ecosystems. Lentic bodies host innumerable local resident birds along with many migratory bird species. Several migratory birds are visiting regularly to different lakes/wetlands during different seasons to access and avail prevailed congenial climate.

Locally available food during different seasons midst lentic habitats safeguards the migratory birds some extent and help allow staying and performing breeding-cum-nesting activities. Similar type of observations was reported by Wanjari and Wasim (2016), Bhat *et al.* (2009), Ravikumar (2011), Rubina *et al.* (2016), Shruthi and Basavarajappa (2016), Puri and Virani (2016) Basavarajappa and Shruthi (2017), Sujosha *et al.* (2020) and Likhith and Basavarajappa (2023) at Maharashtra, Udapi, Haveri, Hassan, Dharwad and Mysore Districts. Thus, our observations corroborate the published earlier few reports specific to seasonal distribution and diversity of aquatic birds at different Lakes of Kollegala of Karnataka. Hence, present study high light the aquatic bird species composition during different seasons and the population size of aquatic bird species related with the prevailed foraging source along with the suitable nesting and resting sites midst different Lakes (Basavarajappa and Shruthi, 2016 and 2017). Therefore, on this line further in-depth investigations are necessitated to undertake suitable measures to restore the locally existed aquatic avifauna at every lentic ecosystem (Lakshmi *et al.*, 2020). Finally, to conclude that the present investigation clearly demonstrated that inland water bodies (e.g., Lakes) located in and around rural areas have provided favourable habitat to different bird species, which show specific habit and habitat for their safe survival. Moreover, this type of investigations is necessitated at every rural area/village, town and urban area, where the locally existed water bodies such as Lakes and ponds provide suitable habitat to various aquatic bird species during different seasons. Simple observations on locally available birds at or nearby aquatic water bodies reveal the status of local biodiversity. On this line many more in depth investigations to be conducted to formulate suitable conservation measures to protect the inland water bodies, aquatic bird species and the local biodiversity as well.

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