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Population dynamics of wetland birds in the Kole Wetlands of Kerala, India

C. Sivaperuman[1*] and E.A. Jayson[2]

[1]Zoological Survey of India, Andaman & Nicobar Regional Station Haddo, Port Blair - 744 102, Andaman & Nicobar Islands, India

[2]Division of Forest Ecology and Biodiversity Conservation Kerala Forest Research Institute, Peechi, Thrissur, Kerala - 680 653, India

Abstract

Population dynamics of wetland birds in the Kole Wetlands of Kerala, India were examined from November 1998 through October 2001. The species richness of avifauna varied in different months with highest being recorded in the month of December and lowest in June. The total number of birds in the area varied from 35 to 8033 individuals in a month with tthe highest being recorded during November 2000 and lowest during June 1999. Shannon Index (H') for the whole wetland bird community was 3.11, which indicated a high diversity of birds. The highest density of birds was recorded in December (29,158 birds/ha) followed by November (24,373 birds/ha). The species-abundance distribution of birds in this wetland followed the truncated lognormal model, which indicated the presence of a natural bird community. The seasonal abundance of selected species correlated with the rainfall and the water depth, namely, *Bubulcus ibis* (rainfall, r = -0.7080; water depth, r = -0.7730); *Egretta garzetta* (rainfall, r = -0.3704; water depth, r = -0.4296); *Phalacrocorax niger* (rainfall, r = -0.4051; water depth, r = -0.4967); *Ardea cinerea* (rainfall, r = -0.5110; water depth, r = -0.5191); *Ardeola grayii* (rainfall, r = -0.5274; water depth, r = -0.6073).

Keywords : density, diversity, Kerala, kole wetlands, population, wetland birds

INTRODUCTION

The number of individuals in a population increases under favourable environmental conditions while sudden or violent changes in the environment or in the biological characteristics of the individual could lead to decline. Fluctuation in the population is usually because of the effect of a combination of several factors responsible for their survival, growth and reproduction. It is necessary to understand the cause of such fluctuations for better scientific management of the population as well as the habitat. In most of the studies, the community has largely been expressed in terms of species richness, abundance, density and diversity. All these have been used as indicators of habitat quality, because an increase in the value of each of the component is generally thought to reflect larger amounts of the necessary resources to sustain larger population within a given area. Moreover, it is believed that if the factors determining the distribution of the animals are known, predictions can be made concerning the responses of animals to specific perturbations and hence, such animals can be used to monitor environment quality. Many studies have been conducted on diversity and seasonal variations of tropical forest bird community in India (Vijayan, 1975; Zacharias, 1979; Price, 1979; Yahya, 1980; Toor and Sandhu, 1980; Vijayan, 1984; Vijayan, 1989; Daniels, 1996; Thiyagesan, 1991; Sundaramoorthy, 1991; Johnsingh and Joshua, 1994; Jayson and Mathew, 2000), but studies on tropical wetlands birds are meagre. Therefore, the present paper is aimed to describe the diversity and seasonal distribution of wetland birds in Indian conditions in relation to environmental factors by selecting the Kole wetland, Kerala, South India, which is one of the important staging and wintering area for migratory waterfowl in the Central Asian Indian Flyway. This wetland is of regional importance to transcontinental migratory waders and is comparable to the known other wetlands and Ramsar sites such as Chilka Lake, Orissa, Keoladeo National Park, Rajasthan, Kolleru Lake, Andhra Pradesh and Point Calimere, Tamil Nadu, of India.

STUDY AREA

The study was carried out in Thrissur and Malappuram District of Kerala State, (10°20′ - 10° 40′ N, 75° 58′ - 76° 11′ E) Southern India with an extent of 13,632 ha and it extends from the northern banks of Chalakudy River in the South to the southern banks of Bharathapuzha River in the North (Fig. 1). Eastern side of Kole wetlands is Thrissur town and western side extends up to Arabian Sea. These wetlands are low lying tracts located 0.5 to 1 m below MSL and remain submerged for about six months in a year.

The climate of the area is moderate and there are three different distinct seasons. The dry season (December to April), wet season-I (May to August) during the period of southwest monsoon and wet season-II (September to November) during northeast monsoon. The average annual rainfall is 3,200 mm and there is a variation in the temporal distribution of rainfall. The maximum rainfall is received during the month of June followed by July and the temperature varies from 28.0°C to

*Corresponding Author
email: *c_sivaperuman@yahoo.co.in*

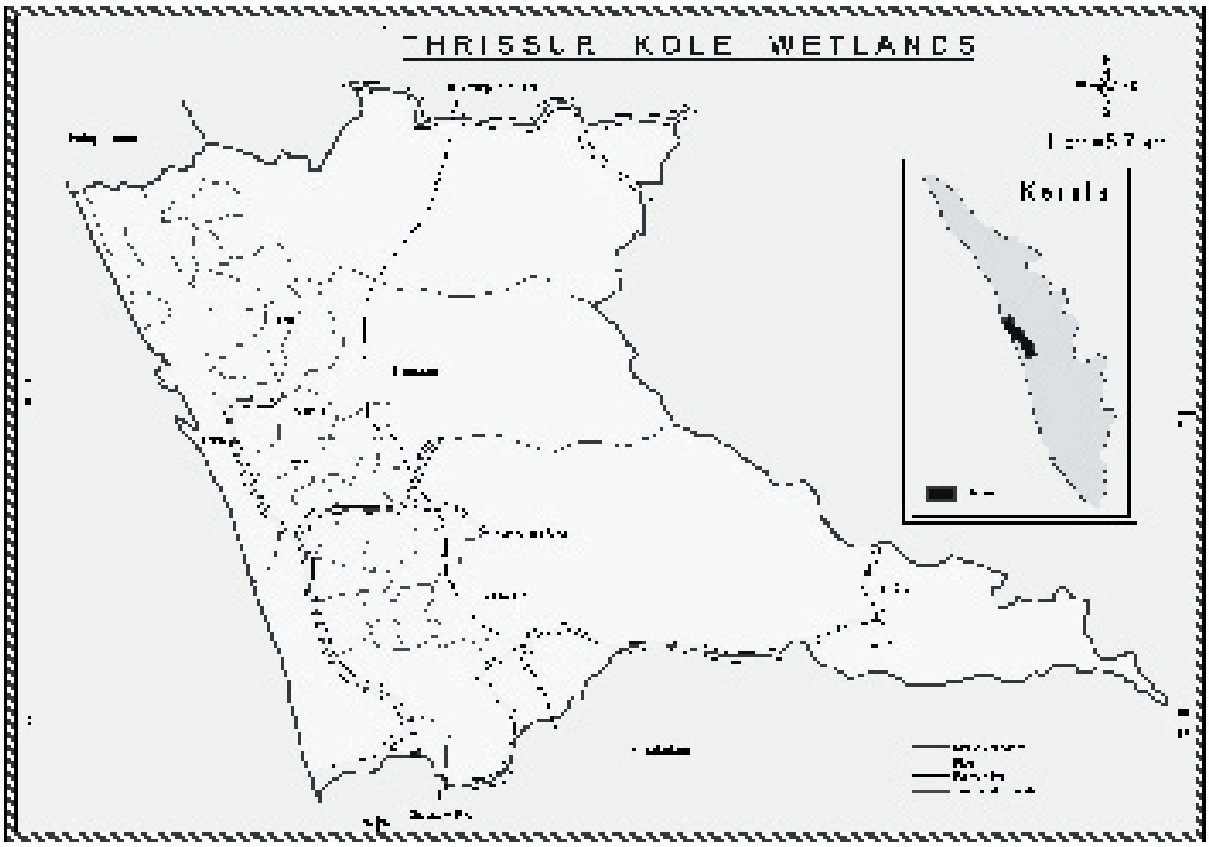

Figure 1. Kole wetlands of Thrissur

31.5°C in a year.

METHODS

The study was conducted from November 1998 through October 2001 and the bird population was estimated using total count method (Hoves and Bakewell, 1989; Grimmett *et al*., 1998). In this method, representative blocks were identified and birds in the blocks were counted using telescope (15x - 45x). These blocks had natural boundaries in the form of bunds. On an average, 20 days were spent in the field in a month and no census was made during heavy rain. The time of observation was from 07.00 hour to 10.00 hour. In each intensive study area, four blocks of 10 ha were selected for bird census. Four counts were made in each block in each month and pooled average was used for estimating species richness and abundance. The community parameters like species richness, abundance, diversity indices and density of birds were calculated and presented for all the months. The collector's curve (Pielou, 1975) is used for assessing the sampling efficiency. This curve was drawn by plotting the cumulative number of species observed in each month against the month of observation (Pielou, 1975).

Species richness, abundance and diversity

Species richness and abundance of birds in every month were calculated from the census data and field observations. Species richness indices like Margalef Index (R1) and Menhinick Index (R2), Shannon-Weiner (H'), Simpson's (l), and Hill's diversity number N1 and N2 were calculated using the computer program SPDIVERS.BAS developed by Ludwig and Reynolds (1988).

Density: Density of birds in each month and individual density of selected species were calculated for the whole area. The density was estimated from the daily census of birds. The extent of each census block was collected form the Kole Land Development Corporation (KLDC), Thrissur, Kerala, South India.

***Species abundance model*:** Species-abundance model was constructed as explained in Magurran (1988). Species of birds were ranked in order of abundance, as represented by individuals seen for each species and this was plotted in decreasing order for all species against the number of individuals for the whole area. Truncated lognormal distribution was fitted to species-abundance data, using maximum likelihood estimation (Slocomb *et al*., 1977).

***Dominance Index*:** The dominance of the each bird species in the Kole wetlands was calculated using the dominance index.

Rainfall, temperature and water depth: The rainfall and temperature data was collected from the Irrigation Department, Thrissur. Water depth was measured using a nylon rope tied with a weight of 1 kg and lowered down till it touched. Measurements were recorded from different locations and four such measurements were taken and noted. The depth is expressed in centimeter

RESULTS

Sampling efficiency

An increase in the number of species was recorded from the month of November 1998 to January 2001. After that, there was no change in the species richness, which indicated that the sampling was adequate (Fig. 2).

Species richness and abundance

Species richness of birds varied in different months and the highest of 97 species was recorded during December 1999 and the lowest of 15 during June 1999 (Table 1). The overall variation in the species richness during the study period is presented in Fig. 3 and it was significantly negatively correlated with rainfall ($r = -0.6594$; $P < 0.02$; $n = 12$). Species richness increased during the migratory season and decreased during the southwest monsoon.

Total number of birds varied from 35 to 8,033 individuals in a month. The highest number of birds (8,033) was recorded during November 2000 and the lowest (35) during June 1999 (Table 1). However, when all the months are taken together, the highest number of birds was observed during December and the lowest in July. As in the case of species richness, total number of birds was also low during the southwest monsoon (Fig. 3). The abundance of birds negatively correlated with rainfall ($r = -0.4903$; $P < 0.01$; $n = 12$).

***Density*:** As observed in the species richness and abundance of birds, density of birds also varied in different months. The highest density of 29,158 birds/ha was recorded in December followed by November (24,373 birds/ha). The lowest density of birds was observed in July (272 birds/ha) and in June (673 birds/ha). The densities of birds in different months with standard errors are presented in Fig. 3. The bird density was negatively correlated with rainfall ($r = -0.4880$; $P < 0.01$; $n = 12$).

***Diversity indices*:** The diversity indices for overall bird community were (H′) 3.11 and (λ) 0.08. The species richness index R1 was 13.96 and R2 was 0.28. Similarly, high values were obtained for Hill's number N1 and N2. Hill's number N1 was 22.38 and Hill's numbers N2 was 12.36. Evenness index (E1) was 0.60 and E2 0.12. The highest diversity index (H′) was recorded in the month of December (3.01) followed by July (2.96) and the lowest H′ value (2.11) was in the month of October (Fig. 4).

Evenness indices measure the evenness of species-abundance and are complimentary to the diversity index concept. It is a measure of how the individuals are appropriated among the species. Two different evenness measures were calculated, the Shannon Evenness (E1) and Sheldon Evenness (E2). Evenness indices of bird community recorded in different months are given in Fig. 4. High evenness values were obtained during July (0.80) and June (0.72).

Species-abundance distribution

Another way of describing diversity in a community is through species-abundance or distribution model introduced by Fisher *et al*. (1943). A species-abundance model utilises all information gathered in a community and is the most complete mathematical description of the data (Magurran, 1988). The data analysis showed that the truncated lognormal model is fitting to the bird community at the Kole wetlands.

The distribution model indicates the absence of a single dominant species or group of species and the presence of long series of very rare species at the wetlands. The species, which is represented by less than 2 individuals, can be called as rare. The observed and expected number of species was compared using the χ^2 goodness of fit test. The test showed that there is no significant difference between the observed and expected distribution ($\chi^2 = 18.31$; $P = 0.08$). Table 2 indicates that the bird community is following the truncated lognormal distribution pattern.

Dominance of wetland species

Out of 82 wetland bird species observed in this area, *Chlidonias hybridus* (23 per cent) was highest in dominance followed by *Egretta garzetta* (13 per cent) and *Phalacrocorax niger* (11 per cent) (Table 3). Sixty-eight species were represented in less than 1 per cent. The *Ixobrychus cinnamomeus*, *Scolopax rusticola*, *Rallina eurizonoides*, *Gallinula chloropus*, *Mycteria leucocephala*, *Platalea leucorodia*, *Pelecanus philippensis*, *Ciconia ciconia*, *Phalacrocorax fuscicollis*, *Ciconia nigra* and *Butorides striatus* were the least dominance species. Among the migratory waders, *Tringa glareola*, *Calidris minuta* and *Charadrius dubius* were the most abundant species.

Correlation analyses between rainfall and water depth with the six orders of wetland species indicated that significant positive correlation was found between the Order Ciconiiformes and the water depth and rainfall (Table 4). Similarly, significant correlation was found between the Anseriformes and water depth (Table 4).

Population fluctuations of certain wetland species in relation to environmental factors

Table 1. Species richness and total number of birds (in parenthesis) recorded in different months (1998 - 2001) in the Kole wetlands, Kerala, South India

Years	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
1998	--	--	--	–	--	–	–	–	–	--	32	34
	--	--	--	–	--	–	–	–	–	--	(414)	(891)
1999	49	46	51	40	33	15	23	25	38	71	61	97
	(690)	(918)	(378)	(348)	(150)	(35)	(72)	(147)	(355)	(3071)	(7860)	(5843)
2000	49	39	64	43	49	39	31	34	76	56	70	67
	(2721)	(918)	(1403)	(1200)	(1232)	(265)	(97)	(294)	(2772)	(2725)	(8033)	(3934)
2001	55	56	64	61	19	26	31	31	34	49	–	--
	1705	5266	5072	6211	1196	531	214	421	2105	1233	–	--

- = no data recorded

Table 2. Truncated lognormal distribution of bird community (χ^2 test) in the Kole wetlands, Kerala, South In-

Class	Upper boundary	Observed	Expected	χ^2
Behind veil line	0.5	--	7.21	–
1	2.5	7	14.92	4.20
2	4.5	16	9.15	5.13
3	8.5	14	12.51	0.18
4	16.5	18	15.09	0.56
5	32.5	13	18.02	1.40
6	64.5	19	20.34	0.09
7	128.5	16	20.01	0.80
8	256.5	15	20.08	1.29
9	512.5	14	17.49	0.70
10	1024.5	11	15.59	1.35
11	2048.5	9	12.04	0.77
12	4096.5	13	9.52	1.27
13	8192.5	5	6.74	0.45
14	∞	12	10.82	0.13
	Total	182	209.53	18.31

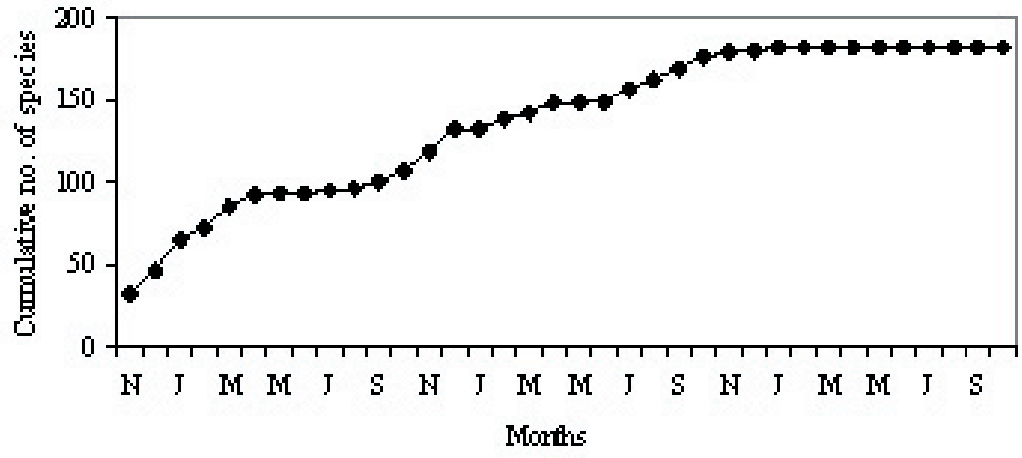

Figure 2. Collector's curve for the wetland bird species in the Kole wetlands, Kerala, South India

***Bubulcus ibis*:** Monthly variations in the population of *Bubulcus ibis* revealed that the population was high in December (2182) and no birds were recorded during the southwest monsoon (Fig. 5). The variations of *Bubulcus ibis* population were negatively correlated with the rainfall (r = -0.7080; $P < 0.02$; $n = 12$) and water depth (r = -0.7730; $P < 0.02$; $n = 12$).

***Egretta garzetta*:** The highest population of *Egretta garzetta* was in November (5772) followed by December (3647) and October (1590). During the month of June and July, no *Egretta garzetta* was observed (Fig. 5). No significant correlation was found with the rainfall (r = -0.3704). Similar there was no significant correlation with the water depth (r = -0.4296, $P < 0.10$, $n = 12$).

***Phalacrocorax niger*:** *Phalacrocorax niger* was recorded from all the areas of the wetlands. Population of *Phalacrocorax niger* fluctuated every month and it was highest in the month of October (3080) followed by November (2165) and December (2340) (Fig. 6). The monthly variation of *Phalacrocorax niger* was negatively correlated with rainfall (r = -0.4051; $P < 0.10$; $n = 12$) and water depth (r = -0.4967; $P < 0.10$; $n = 12$).

***Mesophoyx intermedia*:** Population size of the *Mesophoyx intermedia* increased from 72 individuals in August to 3,996 individuals in November. The highest population was observed in November followed by December (3891) (Fig. 6). The monthly variations of *M. intermedia* were not significantly correlated with the rainfall and the water depth.

***Ardea cinerea*:** Population of *Ardea cinerea* varied from 4 individuals in June to 175 individuals in December. Highest population was recorded in December followed by February (118) (Fig. 7). The population had a negative correlation with the rainfall (r = -0.5110; $P < 0.02$; $n = 12$) and the water depth (r = -0.5191; $P < 0.02$; $n = 12$).

***Ardea purpurea*:** High population numbers of *Ardea purpurea* were observed in December (28), March (34) and July (22) (Fig. 7). No Significant correlation was obtained between the abundance of Purple Heron with rainfall and water depth.

***Ardeola grayii*:** Highest number of *Ardeola grayii* was recorded in December (2163) followed by November (2048) and the species was absent during southwest monsoon (Fig. 8). Population of *Ardeola grayii* was negatively correlated with the rainfall (r = -0.5274; $P < 0.05$; $n = 12$) and the water depth (r = -0.6073; $P < 0.02$; $n = 12$).

DISCUSSION

Wetlands have been distinctively described as "biological supermarkets" because of the exclusive food webs and rich biodiversity. Wetlands dependent species are often rare, threatened or found only in a very restricted geographical area. Freshwater wetlands and rivers contain 0.008 per cent of the world's water but are of great importance for biodiversity as they hold 12 per cent of all animal species (Shine and de Klemm, 1999). The species richness and abundance of birds observed in the present study showed high values in the wetlands, which is comparable to other wetlands in Kerala (Kurup, 1991) and India (Nagarajan and Thiyagesan, 1996; Sampath *et al*., 1995). The highest number of birds was recorded during November, which showed the influx of birds into the region due to the trans-continental migration. Population was low during June to July when the migratory species were absent and few resident species also moved away to avoid the heavy rain. As the whole wetland lay inundated during this period, availability of food was also low. Only diving species like *Phalacrocorax niger*, *Anhinga melanogaster* and *Tachybaptus ruficollis* preferred the area during the months of southwest monsoon. Occurrence of 97 species of birds in a month is remarkable, which showed the importance of the area for the migratory species. The increase in wetland species from September to March implies the presence of their preferred microhabitat and higher production of benthic and macro fauna. As reported earlier from the Western Ghats, highest number of birds was recorded during winter and there was a reduction in population size during the monsoon (Daniels, 1996).

In the Kole wetlands of Thrissur, diversity indices were higher. As the evenness measures also showed high values, it could be concluded that species were uniformly presented in individuals and this indicated the conservation value of the wetlands. Shannon Index obtained for the area is comparable with other wetlands in India *viz*. Pichavaram Mangroves (Nagarajan and Thiyagesan, 1996), and Great Vedaranyam Swamp (Sampath *et al*., 1995). Even though the total number of birds and species richness got was less during the southwest monsoon, it was not reflected in the diversity indices. All the study years showed high diversity index values. Evenness indices indicated high values during June to July, when the abundance of birds was lowest.

Many models are available for describing the species-abundance distribution. Preston (1948) introduced the lognormal distribution to explain the species-abundance data. Usually in ecological work, distribution of species is always truncated at the left side (Preston, 1962). Geometric series patterns are usually found in species poor or harsh environments. Log series patterns are usually observed where one or a few factors dominate the ecology of a community. Lognormal distribution is found in most biological populations. The Broken-stick model distribution shows the maximum equitable distribution of available resources. Species-abundance distribution at this wetland followed the truncated

Table 3. Abundance and dominance of wetland species in the Kole wetlands, Kerala, South India (+ = dominance less than 0.01)

Sl No.	Common name	Abundance	Sighting Frequency	Dominance Index
1.	*Chlidonias hybridus*	85540	282	23.0
2.	*Egretta garzetta*	47938	261	12.8
3.	*Phalacrocorax niger*	39691	360	10.7
4.	*Bubulcus ibis*	29708	215	7.9
5.	*Mesophoyx intermedia*	24785	156	6.7
6.	*Anas querquedula*	21513	10	5.8
7.	*Ardeola grayii*	21214	387	5.7
8.	*Tringa glareola*	13871	151	3.7
9.	*Calidris minuta*	12846	39	3.5
10.	*Anas acuta*	9204	6	2.5
11.	*Larus ridibundus*	6889	4	1.9
12.	*Charadrius dubius*	6536	43	1.8
13.	*Porphyrio porphyrio*	4604	45	1.2
14.	*Larus brunnicephalus*	4502	4	1.2
15.	*Actitis hypoleucos*	3274	103	0.9
16.	*Calidris ferruginea*	3206	25	0.9
17.	*Anastomus oscitans*	3174	21	0.9
18.	*Phalacrocorax carbo*	2700	1	0.7
19.	*Cosmerodius alba*	2685	25	0.7
20.	*Numenius arquata*	2404	25	0.7
21.	*Glareola lactea*	2258	7	0.6
22.	*Tachybaptus ruficollis*	2167	103	0.6
23.	*Philomachus pugnax*	2103	28	0.6
24.	*Dendrocygna javanica*	1708	70	0.5
25.	*Charadrius dubius*	1464	15	0.4
26.	*Anas crecca*	1319	9	0.4
27.	*Tringa stagnatilis*	1305	67	0.4
28.	*Ardea cinerea*	1276	64	0.3
29.	*Threskiornis melanocephalus*	1230	13	0.3
30.	*Vanellus indicus*	1186	170	0.3
31.	*Tringa ochropus*	985	17	0.3
32.	*Calidris temminckii*	820	11	0.2
33.	*Fulica atra*	702	25	0.2
34.	*Himantopus himantopus*	665	19	0.2
35.	*Tringa nebularia*	612	34	0.2
36.	*Anas strepera*	579	1	0.2
37.	*Nycticorax nycticorax*	500	2	0.1
38.	*Limicola falcinellus*	441	8	0.1
39.	*Ardea purpurea*	434	78	0.1
40.	*Platalea leucorodia*	346	4	0.1

Table 3. contd.,

42.	*Nettapus coromandelianus*	317	25	0.1
43.	*Sterna caspia*	316	2	0.1
44.	*Egretta gularis*	294	28	0.1
45.	*Limosa limosa*	242	7	0.1
46.	*Calidris alba*	222	2	0.1
47.	*Calidris alpina*	216	3	0.1
48.	*Hydroprogne caspia*	200	12	0.1
49.	*Amaurornis phoenicurus*	200	67	0.1
50.	*Metopidius indicus*	121	16	0.03
51.	*Anhinga melanogaster*	117	27	0.03
52.	*Aythya nyroca*	82	1	0.02
53.	*Recurvirostra avocetta*	70	3	0.02
54.	*Charadrius alexandrinus*	62	4	0.02
55.	*Limosa lapponica*	60	3	0.02
56.	*Anas clypeata*	60	3	0.02
57.	*Ciconia episcopus*	58	10	0.02
58.	*Rostratula benghalensis*	54	7	0.01
59.	*Arenaria interpres*	53	2	0.01
60.	*Tringa totanus*	50	7	0.01
61.	*Porzana fusca*	47	11	0.01
62.	*Larus cachinnans*	45	2	0.01
63.	*Gallinago stenura*	41	4	0.01
64.	*Ixobrychus sinensis*	41	15	0.01
65.	*Pseudibis papillosa*	38	13	0.01
66.	*Ciconia ciconia*	36	1	0.01
67.	*Gallinago gallinago*	34	9	0.01
68.	*Numenius phaeopus*	34	2	0.01
69.	*Dupetor flavicollis*	33	21	0.01
70.	*Gallicrex cinerea*	32	9	0.01
71.	*Calidris temminckii*	24	4	0.01
72.	*Larus cirrocephalus*	22	4	0.01
73.	*Ixobrychus cinnamomeus*	16	9	+
74.	*Scolopax rusticola*	15	6	+
75.	*Rallina eurizonoides*	9	2	+
76.	*Gallinula chloropus*	9	3	+
77.	*Mycteria leucocephala*	5	3	+
78.	*Platalea leucorodia*	4	1	+
79.	*Pelecanus philippensis*	4	2	+
80.	*Phalacrocorax fuscicollis*	2	1	+
81.	*Ciconia nigra*	1	1	+
82.	*Butorides striatus*	1	1	+
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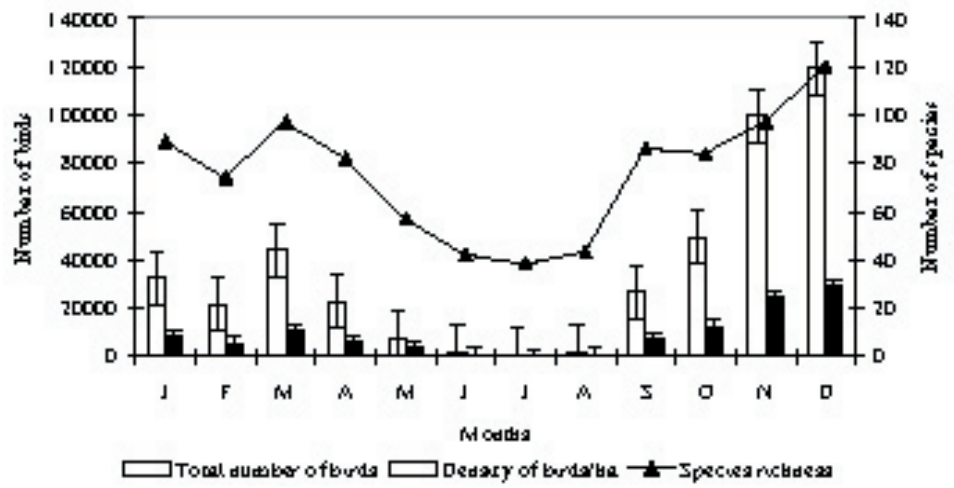

Figure 3. Species richness, abundance and density of birds in different months of the study period in the Kole wetlands, Kerala, South India

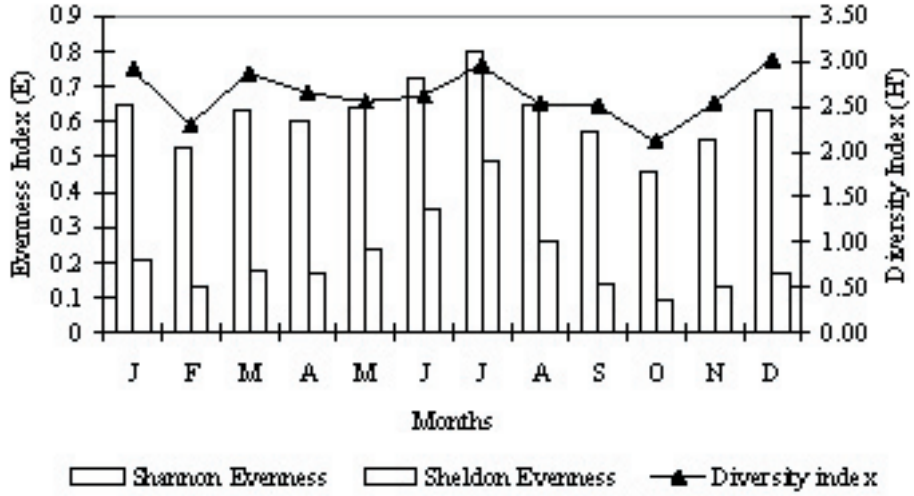

Figure 4. Diversity index (H′) and Evenness indices (E) in different months of the study period in the Kole wetlands, Kerala, South India

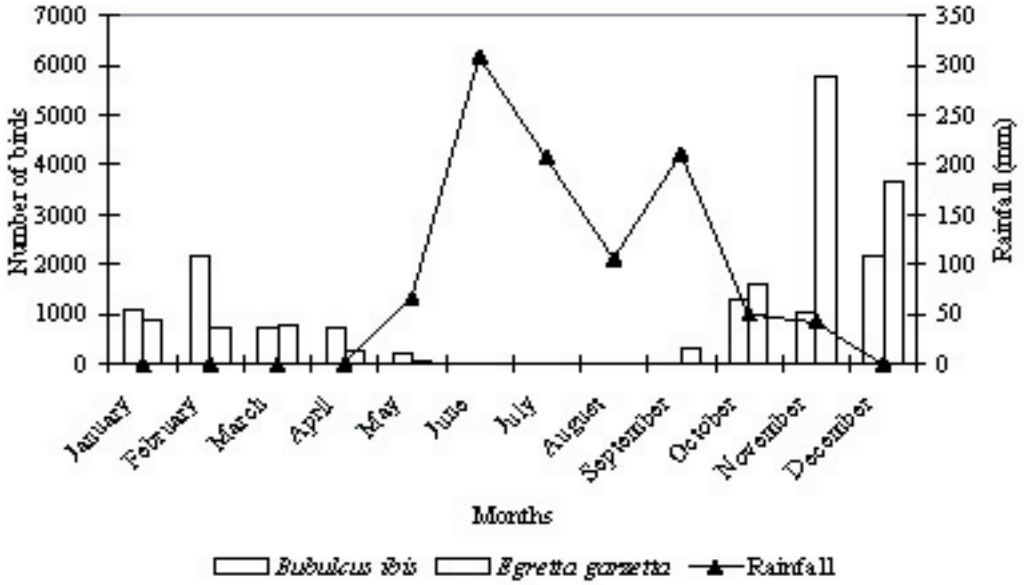

Figure 5. Population dynamics of *Bubulcus ibis* and *Egretta garzetta* in relation to rainfall during the study period in the Kole wetlands, Kerala, South India

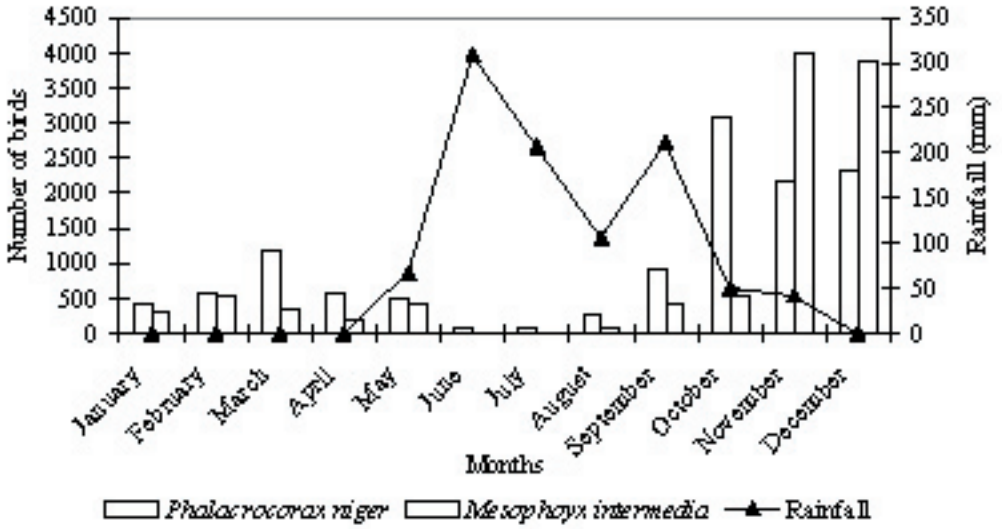

Figure 6. Population dynamics of *Phalacrocorax niger* and *Mesophoyx intermedia* in relation to rainfall during the study period in the Kole wetlands during the study period

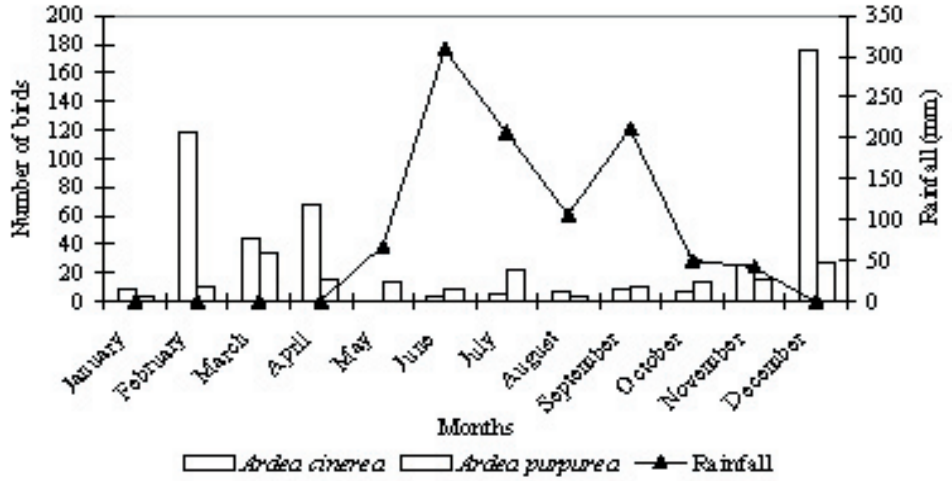

Figure 7. Population dynamics of *Ardea cinerea* and *Ardea purpurea* in relation to rainfall during the study period in the Kole wetlands during the study period

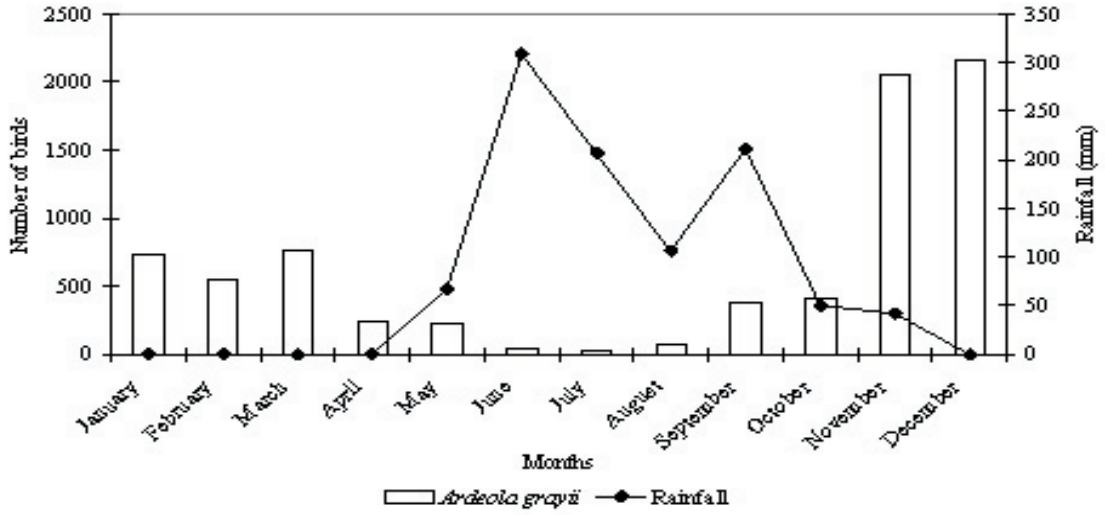

Figure 8. Population dynamics of *Ardeola grayii* in relation to rainfall during the study period, in the Kole wetlands, Kerala, South India

Table 4. Correlation (r) between rainfall, water depth and wetland bird orders in the Kole wetlands, Kerala, South India

Sl No.	Order	Rainfall	Water depth
1.	Podicipediformes	0.1380 ▪▪	0.0525 ▪▪
2.	Pelecaniformes	0.3872 ▪▪	0.4783 *
3.	Ciconiiformes	0.5130 **	0.5763 **
4.	Anseriformes	0.4496 *	0.4075 *
5.	Gruiformes	0.1203 ▪▪	0.0846 ▪▪
6.	Charadriiformes	0.2761 ▪▪	0.4500 *

* = Significant at 10 % level; ** = Significant at 5 % level; n.s. = not significant

Table 5. Comparison of present study with other habitat types of India

Forest type	Number of species recorded	Number of individuals recorded	Diversity Index (H')	Reference
Tropical evergreen forest	99	5,412	3.30	Jayson & Mathew, 2000
Tropical moist deciduous forest	96	2,641	3.45	Jayson & Mathew, 2000
Tropical shola forest	76	716	2.51	Nameer, 2001
Tropical wetlands	182	4,32,663	3.11	Present study

lognormal model, which indicated the presence of natural bird community in the area.

Water depth was another important factor, which could be used to predict the wetland bird population of this area. A relationship between the habitat use of birds and water depth was also reported from the Great Vedaranyam Salt Swamp (Sampath and Krishnamurthy, 1989) and Pichavaram Mangroves (Nagarajan and Thiyagesan, 1996), which is comparable with this wetlands.

Comparison of bird species richness, abundance and diversity in different habitats are presented in Table 5. The species richness, abundance was highest in tropical wetland habitat and diversity was higher in tropical moist deciduous forest followed by evergreen forest. This Ramsar site (Kole Wetlands) is one of the important staging and wintering areas for migratory waterfowl in the Central Asian Indian Flyway. This region supported transcontinental migratory waders similar to the known other wetlands and Ramsar sites such as Chilka Lake, Orissa, Pulicate Lake, Andhra Pradesh and Point Calimere, Great Vedaranyam Swamp, Gulf of Mannar, Pichavaram Mangroves, Tamil Nadu.

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