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43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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COMMUNICATION

Diversity and abundance of aquatic birds in Koonthankulam village pond, Tamil Nadu, India

Selvam Muralikrishnan [1], **Esakkimuthu Shanmugam** [2], **Natarajan Arun Nagendran** [3] & **Duraisamy Pandiaraja** [4]

[1] National Centre of Excellence (MHRD), Thiagarajar College, Madurai Kamaraj University, Madurai, Tamil Nadu 625009, India.
[2] Basic Engineering, Tamilnadu Government Polytechnic College, Madurai, Tamil Nadu 625011, India.
[3] Department of Zoology, Thiagarajar College, Madurai Kamaraj University, Madurai, Tamil Nadu 625009, India.
[4] Department of Mathematics, Thiagarajar College, Madurai Kamaraj University, Madurai, Tamil Nadu 625009, India.
[1] nilaasmurali@gmail.com (corresponding author), [2] shamphdmat@gmail.com, [3] narunnagendran@gmail.com, [4] pandiaraja.d@gmail.com

Abstract: The diversity of birds in Koonthankulam pond, located in Koonthankulam village (8.495N, 77.755E), Tirunelveli district, southern Tamil Nadu, was studied. A total of 90 species belonging to 21 orders, 42 families, and 73 genera were recorded. The study recorded seasonal migrants such as Black Ibis, Oriental White Ibis, Bar-headed Goose & Spoonbill and indigenous species including the Pond Heron, Cattle Egret, White-breasted Kingfisher, Red-wattled Lapwing, Rose-ringed Parakeet, Purple-rumped Sunbird, Hoopoe, and Indian Robin. The primary data were analyzed by principal component analysis, cluster, and analysis of variance. Analysis of variance showed that the Menhinick index is statistically significant $P < 0.05$. A structural equation model was applied to analyze the physico-chemical parameters of water samples collected from the sampling site. Analysis of experimental data through the structural equation model indicates temperature and dissolved oxygen may indirectly affect bird diversity.

Keywords: Avian fauna, migrants, principal compound analysis, structural equation modeling.

Abbreviations: PCA—Principal compound analysis | ANOVA—Analysis of variance | SEM—Structural equation model | TDS—Total dissolved solids | DO—dissolved oxygen | CFI—Comparative Fit Index | TLI—Tucker-Lewis Index | RMSEA—Root Mean Square Error of Approximation | IUCN—International Union for Conservation of Nature | GFI—Goodness of Fit.

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Author details: S. Muralikrishnan is a research scholar in the National Centre of Excellence (MHRD), Thiagarajar College, Madurai. His research field is ecology with special reference to birds. He documents wetland birds of Tirunelveli, Madurai, Virudhunagar, Sivagangai and Ramanathapuram. E. Shanmugam is currently working as lecturer in Mathematics in Tamilnadu Government Polytechnic College, Madurai. He is pursuing his Doctoral Programme in the National Centre of Excellence (MHRD), Thiagarajar College, Madurai as Part time research scholar. His field of research is graph theoretical modelling. N. Arun Nagendran is serving as associate professor of Zoology, and Joint Director of National Centre of Excellence, Thiagarajar College, Madurai funded by MHRD, Government of India. He is interested in ecology and conservation. D. Pandiaraja is associate professor of Mathematics and serving as Principal, Thiagarajar College, Madurai. He is also the Director of National Centre of Excellence, Thiagarajar College, Madurai funded by MHRD, Government of India. He is specialized in Mathematical modelling and presently provides modelling for biological problems.

Author contributions: SM implemented the field surveys and collected the data; wrote the first draft. DP designed data analysis and done by ES. NAN supervised the research and provided multiple revisions in the early stages of writing. All authors read and approved the final manuscript.

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INTRODUCTION

The process of urbanization has fragmented and degraded different types of habitats. One such habitat is ponds of varied sizes, especially in urban and semi-urban areas. Under such conditions, the existing ponds provide little hope for life and support for the survival of organisms. Wetlands are among the most productive ecosystems in the world and play vital roles in flood control, aquifer recharge, nutrient absorption, and erosion control. In addition, wetlands provide home for a huge diversity of wildlife such as birds, mammals, fish, frogs, insects, and plants (Buckton 2007). Among several organisms surviving in and around water bodies, birds occupy a significant position, as they are one of the critical ecosystem functionaries.

Birds play prominent roles in ecosystems, serving as pollinators (Stiles 1978), predators (Rudebeck 1950), scavengers (Roen 2005), prey (Rudebeck 1950), and regulators of pest populations (Peterson 1980). Their interactions are wide and varied with abiotic and biotic components of different ecosystems, i.e., they are not restricted to one particular system but also to adjacent systems as they enjoy the power of flight. India hosts around 1,353 species of birds (Praveen & Jaypal 2023). Analysis of avian diversity portrays the status of their aquatic habitats and neighboring ecosystems. As there is no detailed report on the diversity of Koonthankulam village pond, the present study was carried out to analyze seasonal variation in bird diversity and their relationship with water quality parameters.

MATERIALS AND METHODS

The study was carried out in Koonthankulam village pond (8.495N, 77.755E), Tirunelveli, southern Tamil Nadu, from January 2017 to November 2018. This pond is surrounded by agricultural fields, where different crops are grown throughout the year. Macro-invertebrates of the agricultural fields and grains scattered around after harvesting along with the pond allure avifauna to this region. Bird watching and recording have been carried out for six seasons (namely, spring, summer, early monsoon, late monsoon, early winter, and late winter) by point count protocol as per Newson et al. (2009). Observations were made using a binocular (Nikon 16x50 AculonA211), and photography was done with Canon 6D Mark II with zoom lenses. The birds recorded were identified by referring to Ali & Ripley (1981).

Physical and chemical parameters such as temperature, pH, total dissolved solids (TDS), conductivity, salinity, and dissolved oxygen (DO), were measured on the spot using a water analyzer (Systronic make 371). Other parameters (Hardness, magnesium, calcium, chloride, alkalinity, and acidity) were determined following the standard procedure from American Public Health Association (APHA) and Trivedy & Goel (1984). The map has been generated using the software QGIS 3.6.

Structural equation modeling (SEM) is a multivariate statistical tool that can be used to describe linear relationships among variables (McCune & Grace 2002; Grace 2006). SEM provides explicit regression estimations for all parameters (Byrne 2001). Structural equation modeling of groundwater physicochemical parameters data was used to characterize the groundwater quality and to identify the controlling factors on bird diversity. IBM SPSS AMOS 22.0 was used to analyze the structured model's fit and estimate the parameters of both observed and latent variables. Chi-square test, the root mean square error of approximation (RMSEA), and the goodness fit index are used as measures of model fit. A measure of minimum sample discrepancy is indicated by the value chi-square divided by the degrees of freedom (CMIN/df) (Belkhiri & Narany 2015). This measure was used to analyze the fit of the model. A value of less than 5 indicates the model's fit is adequate (Arbuckle 2012), less than 3 reflects that the model is acceptable (Kline 1998), whereas a value of 2 or less represents the model was fit as a good model. Goodness-of-Fit statistics (GFI) was calculated as the variance proportion accounted for by the estimated covariance (Tabachnick & Fidell 2007). The RMSEA provides a way to understand optimally chosen parameter estimates that would fit the covariance matrix (Byrne 1998). When the proposed structural model has a (comparative fit index) CFI>0.95 and an RMSEA <0.05, then the structural model is to be considered a good model (Byrne 2010). The diversity indices were calculated using PAST 3.14 software.

RESULT AND DISCUSSION

A total of 90 species of birds belonging to 21 orders and 42 families were recorded. Of this, 87 species of birds are of 'Least Concern', and three species are 'Near Threatened' (Table 1). Of these, 41 were waterbirds, and 49 were terrestrial birds (Table 1). Waterbirds constitute 12 species of waterfowl (swimmers), 25 species of waders, and three species were divers. Out of 49 terrestrial birds, 35 species were passerine birds, five were birds of prey,

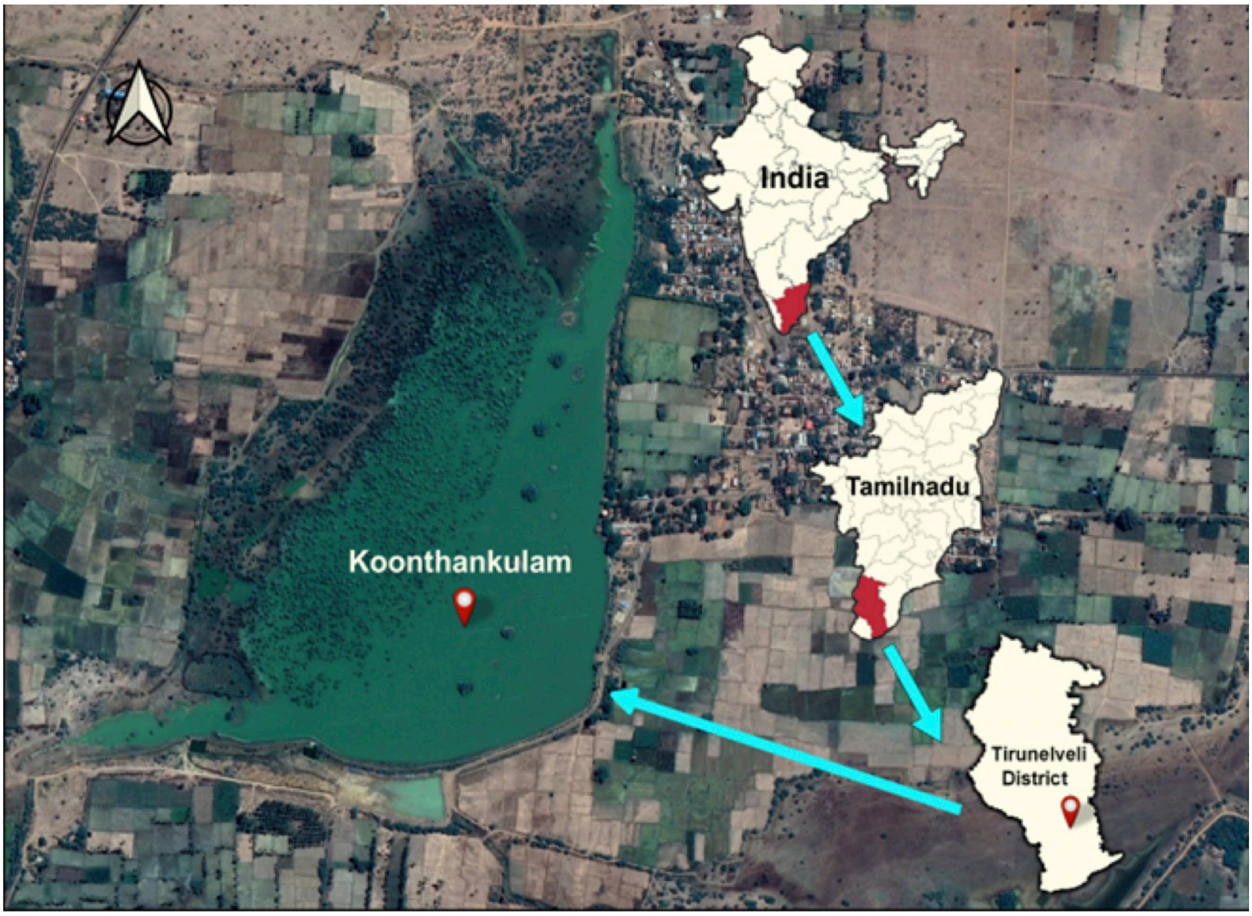

Image 1. Map of the study area.

six were upland ground birds, two were night birds, and two were tree-clinging birds. It is evident from the data that the order Passeriformes is represented by the most families (Sturnidae, Motacillidae, Corvidae, Dicruridae, Estrildidae, Muscicapidae, Alaudidae, Motacillidae, Nectariniidae, Passeridae, Pycnonotidae, Muscicapidae, Monarchidae, and Leiothrichidae). In contrast, the highest numbers of species recorded were from Ardeidae, Anatidae, Cuculidae, Columbidae, Rallidae, and Threskiornithidae. The highest abundance index (9.2) was seen for *Anastomus oscitans*. *Bubo bubo* and *Pandion haliaetus* had a low abundance index (0.02). Of the 90 species, 26 species have more than 1 abundance index.

The distribution of various species was analyzed using the principal component analysis (PCA) method (Dauda et al. 2017). The distribution of the occurrence of various species and their variance-covariance matrices were analyzed through scatter diagrams generated from PCA, and the results were further evaluated by 95% ellipses (Figure 1). The results revealed that the species clustering differs with seasons. In spring, *Threskiornis melanocephalus* (THME), *Psittacula krameri* (PSKR), *Passer domesticus* (PADO), and *Corves splendens* (COSP) were found, while *Ardeola grayii* (ARGR), *Turdoides striata* (TUST), *Acridotheres tristis* (ACTR), *E. garzetta* (EGGA) and *T. melanocephalus* (THME) were recorded during summer. Similarly, *A. tristis* (ACTR), *E. garzetta* (EGGA), *C. splendens* (COSP), *Bubulcus ibis* (BUIB), and *Pseudibis papillosa* (PSPA) were recorded in early monsoon, while *A. oscitans* (ANOS), *P. papillosa* (PSPA), *Himantopus himantopus* (HIHI), *A. tristis* (ACTR), and *C. splendens* (COSP) were found during late monsoon. In early winter, *A. oscitans* (ANOS), *Anser indicus* (ANIN), *Mycteria leucocephala* (MYLE), and *C. splendens* (COSP) were recorded, which distinguish themselves from other species in abundance. More species were abundant in late winter than in other seasons. From the results, it could be seen that the pond has been dominated by *C. splendens* (COSP), *E. garzetta* (EGGA), *A. tristis* (ACTR), etc.

The similarity in the species composition and abundance among the six seasons analyzed by Bray-Curtis coefficient (Cluster analysis) clustered the

Table 1. Occurrence, IUCN Red List, and abundance index of avian communities in the Koonthankulam village pond, Tirunelveli, Tamil Nadu, India.

	Scientific Name	Family	Order	IUCN Red List status	Abundance index	Behavior category
1	*Accipiter badius*	Accipitridae	Accipitriformes	LC	0.15	Bird of prey
2	*Acridotheres tristis*	Sturnidae	Passeriformes	LC	5.33	Percher
3	*Alcedo atthis*	Alcedinidae	Coraciiformes	LC	0.24	Percher
4	*Amaurornis phoenicurus*	Rallidae	Gruiformes	LC	0.41	Swimmer
5	*Anas acuta*	Anatidae	Anseriformes	LC	0.31	Swimmer
6	*Anas arcuata*	Anatidae	Anseriformes	LC	0.51	Swimmer
7	*Anas crecca*	Anatidae	Anseriformes	LC	0.44	Swimmer
8	*Anas poecilorhyncha*	Anatidae	Anseriformes	LC	0.79	Swimmer
9	*Anas querquedula*	Anatidae	Anseriformes	LC	0.22	Swimmer
10	*Anastomus oscitans*	Ciconiidae	Ciconiiformes	LC	9.2	Wader
11	*Anhinga melanogaster*	Anhingidae	Suliformes	NT	0.46	Diver
12	*Anser indicus*	Anatidae	Anseriformes	LC	2.7	Swimmer
13	*Anthus rufulus*	Motacillidae	Passeriformes	LC	0.26	Percher
14	*Ardea cinerea*	Ardeidae	Pelecaniformes	LC	0.52	Wader
15	*Ardea purpurea*	Ardeidae	Pelecaniformes	LC	0.15	Wader
16	*Ardeola grayii*	Ardeidae	Pelecaniformes	LC	1.32	Wader
17	*Artamus fuscus*	Artamidae	Passeriformes	LC	2.7	Percher
18	*Athene brama*	Strigidae	Strigiformes	LC	0.25	Night bird
19	*Bubo bubo*	Strigidae	Strigiformes	LC	0.02	Night bird
20	*Bubulcus ibis*	Ardeidae	Pelecaniformes	LC	3.61	Wader
21	*Butorides striatus*	Ardeidae	Pelecaniformes	LC	0.53	Wader
22	*Calidris alpina*	Scolopacidae	Charadriiformes	LC	0.15	Wader
23	*Casmerodius albus*	Ardeidae	Pelecaniformes	LC	0.45	Wader
24	*Centropes sinensis*	Cuculidae	Cuculiformes	LC	0.29	Percher
25	*Charadrius dubius*	Charadriidae	Charadriiformes	LC	0.32	Wader
26	*Clamator jacobinus*	Cuculidae	Cuculiformes	LC	0.29	Percher
27	*Columba livia*	Columbidae	Columbiformes	LC	2.47	Upland ground
28	*Coracias benghalensis*	Coraciidae	Coraciiformes	LC	0.75	Percher
29	*Corves macrorhynchos*	Corvidae	Passeriformes	LC	1.28	Percher
30	*Corves splendens*	Corvidae	Passeriformes	LC	8.11	Percher
31	*Cuculus poliocephalus*	Cuculidae	Cuculiformes	LC	0.16	Percher
32	*Dendrocitta vagabunda*	Corvidae	Passeriformes	LC	0.39	Percher
33	*Dicrurus leucophaeus*	Dicruridae	Passeriformes	LC	0.44	Percher
34	*Dicrurus macrocercus*	Dicruridae	Passeriformes	LC	1.45	Percher
35	*Dinopium benghalense*	Picidae	Piciformes	LC	0.15	Tree clinging bird
36	*Dupetor flavicollis*	Ardeidae	Pelecaniformes	LC	0.06	Wader
37	*Egretta garzetta*	Ardeidae	Pelecaniformes	LC	4.22	Wader
38	*Egretta intermedia*	Ardeidae	Pelecaniformes	LC	1.59	Wader
39	*Eudynamys scolopacea*	Cuculidae	Cuculiformes	LC	0.34	Percher
40	*Euodice malabarica*	Estrildidae	Passeriformes	LC	1.85	Percher
41	*Falco peregrinus*	Falconidea	Falconiformes	LC	0.09	Bird of prey
42	*Francolinus pondicerianus*	Phasianidae	Galliformes	LC	0.57	Upland ground
43	*Fulica atra*	Rallidae	Gruiformes	LC	1.27	Swimmer
44	*Gallinula chloropus*	Rallidae	Gruiformes	LC	0.61	Swimmer
45	*Halcyon smyrnensis*	Alcedinidae	Coraciiformes	LC	0.57	Percher

	Scientific Name	Family	Order	IUCN Red List status	Abundance index	Behavior category
46	*Haliastur indus*	Accipitridae	Accipitriformes	LC	0.4	Bird of prey
47	*Himantopus himantopus*	Recurvirostridae	Charadriiformes	LC	1.85	Wader
48	*Hydrophasianus chirurgus*	Jacanidea	Charadriiformes	LC	0.78	Wader
49	*Lonchura punctulata*	Estrildidae	Passeriformes	LC	0.16	Percher
50	*Luscinia brunnea*	Muscicapidae	Passeriformes	LC	0.15	Percher
51	*Merops orientalis*	Meropidae	Coraciiformes	LC	0.53	Percher
52	*Merops philippinus*	Meropidae	Coraciiformes	LC	0.74	Percher
53	*Milvus migrans*	Accipitridae	Accipitriformes	LC	0.13	Bird of prey
54	*Mirafra cantillans*	Alaudidae	Passeriformes	LC	0.55	Percher
55	*Motacilla maderaspatensis*	Motacillidae	Passeriformes	LC	1.07	Percher
56	*Mycteria leucocephala*	Ciconiidae	Ciconiiformes	NT	3.18	Wader
57	*Nectarinia asiatica*	Nectariniidae	Passeriformes	LC	0.74	Percher
58	*Nectarinia zeylonica*	Nectariniidae	Passeriformes	LC	0.44	Percher
59	*Nycticorax nycticorax*	Ardeidae	Pelecaniformes	LC	0.88	Wader
60	*Oriolus oriolus*	Oriolidae	Passeriformes	LC	0.27	Percher
61	*Pandion haliaetus*	Pandionidea	Accipitriformes	LC	0.02	Bird of prey
62	*Passer domesticus*	Passeridae	Passeriformes	LC	2.15	Percher
63	*Pavo cristatus*	Phasianidae	Galliformes	LC	1.45	Upland ground
64	*Pelecanus onocrotalus*	Pelecanidae	Pelecaniformes	LC	0.4	Swimmer
65	*Pelecanus philippensis*	Pelecanidae	Pelecaniformes	LC	1.28	Swimmer
66	*Phaenicophaeus viridirostris*	Cuculidae	Cuculiformes	LC	0.28	Percher
67	*Phalacrocorax carbo*	Phalacrocoracidae	Phalacrocoracidae	LC	0.13	Diver
68	*Phalacrocorax niger*	Phalacrocoracidae	Phalacrocoracidae	LC	1.87	Diver
69	*Platalea leucorodia*	Threskiornithidae	Pelecaniformes	LC	0.75	Wader
70	*Plegadis falcinellus*	Threskiornithidae	Pelecaniformes	LC	0.81	Wader
71	*Porphyrio porphyrio*	Rallidae	Gruiformes	LC	0.52	Swimmer
72	*Pseudibis papillosa*	Threskiornithidae	Pelecaniformes	LC	1.88	Wader
73	*Psittacula krameri*	Psittacidae	Psittaciformes	LC	3.32	Percher
74	*Pteroclesnamaqua*	Pteroclidea	Pterocliformes	LC	0.09	Percher
75	*Pycnonotuscafer*	Pycnonotidae	Passeriformes	LC	0.16	Percher
76	*Sarkidiornis sylvicola*	Anatidae	Anseriformes	LC	0.87	Swimmer
77	*Saxicoloides fulicata*	Muscicapidae	Passeriformes	LC	0.34	Percher
78	*Stactolaema olivacea*	Lybiidae	Piciformes	LC	0.42	Tree clinging bird
79	*Streptopelia chinensis*	Columbidae	Columbiformes	LC	0.18	Upland ground
80	*Streptopelia decaocto*	Columbidae	Columbiformes	LC	0.3	Upland ground
81	*Streptopelia senegalensis*	Columbidae	Columbiformes	LC	0.19	Upland ground
82	*Tachybaptus ruficollis*	Podicipedidae	Podicipediformes	LC	0.72	Swimmer
83	*Tachymarptis melba*	Apodidae	Apodiformes	LC	2.5	Percher
84	*Terpsiphone paradise*	Monarchidae	Passeriformes	LC	0.19	Percher
85	*Threskiornis melanocephalus*	Threskiornithidae	Pelecaniformes	NT	6.21	Wader
86	*Tringa nebularia*	Scolopacidae	Charadriiformes	LC	0.36	Wader
87	*Turdoides striata*	Leiothrichidae	Passeriformes	LC	1.33	Percher
88	*Upupa epops*	Upupidae	Bucerotiformes	LC	0.32	Percher
89	*Vanellus indicus*	Charadriidae	Charadriiformes	LC	0.57	Wader
90	*Vanellus malabaricus*	Charadriidae	Charadriiformes	LC	0.48	Wader

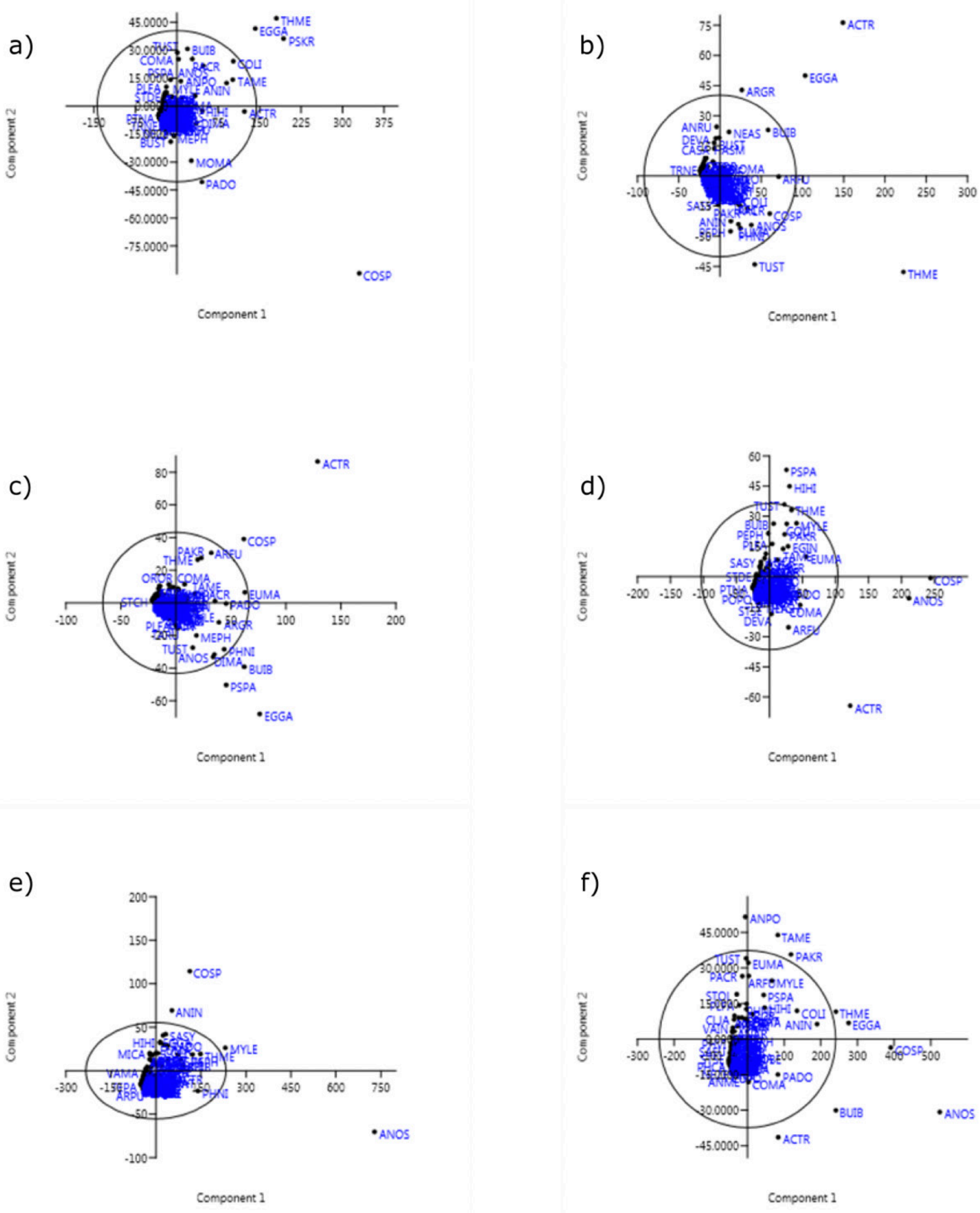

Figure 1. Scatter diagrams of bird species using PCA for a— spring| b— summer | c— early monsoon | d— late monsoon | e— early winter | f— late winter.

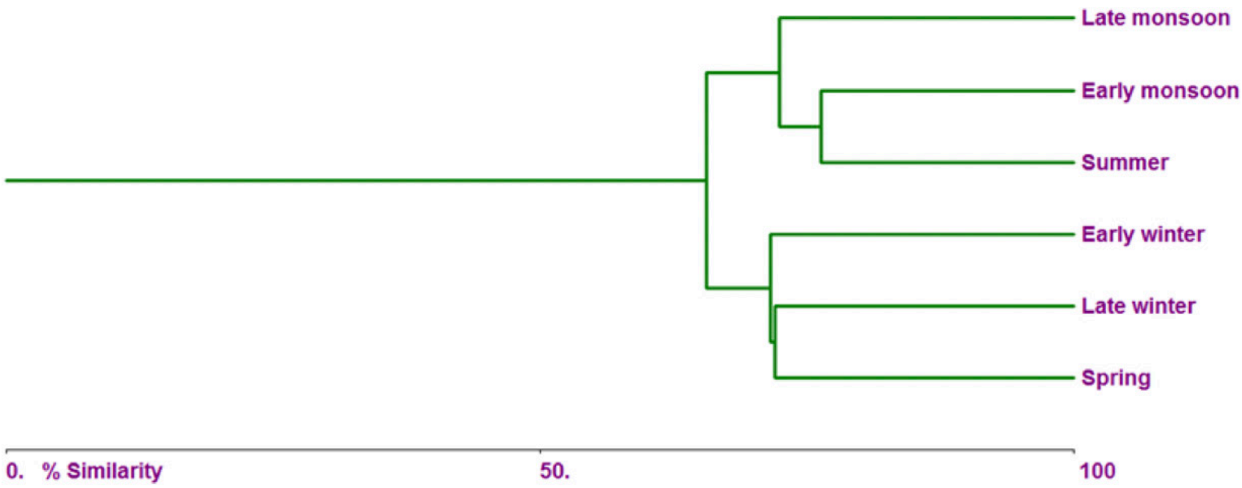

Figure 2. Single linkage cluster analysis of the population of birds among seasons using Bray-Curtis cluster analysis of similarity.

Table 2 Avifaunal diversity in different seasons of the Koonthankulam. *significant (P <0.05).

Biodiversity indices	Spring	Summer	Early monsoon	Late Monsoon	Early winter	Late winter	Sum of squares	F value
	Feb–Mar	Apr–May	Jun–Jul	Aug–Sep	Oct–Nov	Dec–Jan		
Taxa_S	84.33 ± 3.18	82.00 ± 1.53	83.33 ± 2.40	80.66 ± 0.33	84.00 ± 2.08	85.00 ± 1.73	39.111	0.61
Individuals	2980.33 ± 316.26	1902.66 ± 266.89	1408.33 ± 215.13	1315.00 ± 158.24	1741.66 ± 168.94	3027.33 ± 498.27	8665477.111	6.673*
Shannon_H	3.36 ± 0.19	3.53 ± 0.09	3.64 ± 0.09	3.70 ± 0.06	3.61 ± 0.11	3.55 ± 0.17	0.214	0.898
Buzas & Gibson's	0.35 ± 0.06	0.42 ± 0.03	0.46 ± 0.03	0.50 ± 0.03	0.45 ± 0.04	0.42 ± 0.06	0.038	1.24
Menhinick	1.56 ± 0.12	1.91 ± 0.11	2.25 ± 0.12	2.25 ± 0.13	2.03 ± 0.08	1.57 ± 0.09	1.435	7.811*
Chao-1	94.77 ± 3.09	101.27 ± 9.26	94.48 ± 5.46	90.89 ± 0.37	93.73 ± 1.51	93.57 ± 3.34	179.678	0.518

seasons into five, in the range of 55.25–100.00 (Figure 3). The five clusters show that each season has a different composition of the bird populations. The dendrogram showed that summer and early monsoon have a maximum similarity of 76.30. Two groups were identified among the six seasons. Early winter, late winter, and spring formed a group and early monsoon, late monsoon, and summer formed another group.

The number of individuals across seasons differed significantly (ANOVA, $F_{5,12}$ = 6.673, P <0.05; Table 2). A higher number of individuals was present in late winter (3027.33 ± 498.27), whereas the lowest number was recorded in late monsoon (1315.00 ± 158.24). The second-highest population of birds appeared in spring (2980.33 ± 316.26). This implies that the number of birds from December–March was high. The maximum Taxa_S was found in late winter (85.00 ± 1.73), whereas the minimum was in late monsoon (80.66 ± 0.33), with the range of Taxa_S over all the seasons being 5. The results reveal minimum deviation in species composition with high variation in population. However, the highest Shannon_H diversity (3.70 ± 0.06) was in late monsoon and the lowest (3.36 ± 0.19) in spring, indicating a more diverse and even species distribution in late monsoon. The Shannon_H diversity of birds among various seasons was not significantly different (ANOVA, $F_{5, 12}$ = 0.898, P >0.05).

The species evenness among the various seasons was measured by Buzas and Gibson's index. Evenness was maximum in late monsoon (0.50 ± 0.03) and minimum in spring (0.35 ± 0.06). However, the Buzas and Gibson's evenness indices across various seasons were not significantly different (ANOVA, $F_{5, 12}$ = 1.24, P >0.05). The richness was measured by the Menhinick species richness index. The Menhinick richness index differed significantly among the seasons (ANOVA, $F_{5, 12}$ = 7.811, P <0.05). Early (2.25 ± 0.12) and late monsoon (2.25 ± 0.13) have a high value of Menhinick richness index, and spring (1.56 ± 0.12) and late winter (1.57 ± 0.09) have a low value. The Chao-1 estimator was used to analyze singleton and doubleton species in the bird community. The maximum singleton and doubleton species occurred

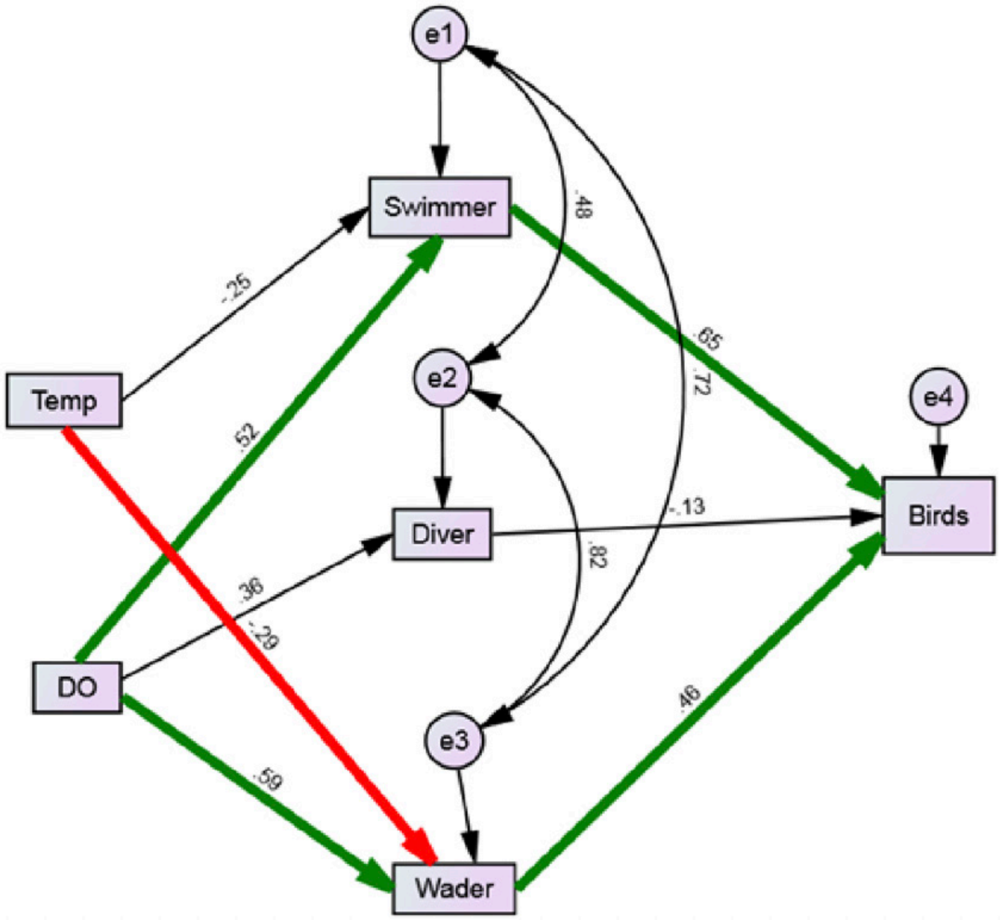

Figure 3. SEM of regression model.

in summer (101.27 ± 9.26) and the minimum in late monsoon (90.89 ± 0.37). Among all the seasons, the Chao-1 estimator was not significantly different (ANOVA, $F_{5,12}$ = 0.518, P >0.05).

A correlation analysis has been carried out for all physico-chemical parameters with swimmer, diver and wader species to understand the influence of the water-quality parameters on the bird population (Table 3). The following results were noticed in that analysis. The temperature was negatively correlated with swimmer and wader populations at p = 0.01, and DO was positively correlated with all the three water bird communities encountered in this study at p = 0.05. In addition to this, a SEM model was designed and analyzed to confirm that temperature and DO were the most important parameters that affect bird counts. Thus, a structural equation model has been framed with the following six parameters, temperature, DO, swimmer, diver, and wader abundances. Bird's abundance has been studied with reference to the effect of temperature using structural equation modeling, as in Duclos et al. (2017). Patra et al. (2010) used stepwise multiple regression analysis to study the physico-chemical parameters affecting the avifaunal abundance; e1, e2, and e3 are added to the SEM to reduce the error value between the variables. Temperature, DO, and errors are exogenous variables, and swimmer, diver, and wader birds are endogenous variables.

Figure 3 expresses the conceptual framework for the model. The fitness of a SEM is important to understand the reliability of the results. The measure CMIN/df (0.518) <2, GFI (0.95) >0.90, and RMSEA (0.00) <0.05 revealed that the model represented a realistic fit of the data. The regression equations for the four endogenous variables with standardized coefficients are

Birds = (-.13) Diver + (.65) Swimmer + (.46) Wader + (1) e4

Diver = (.36) DO + (1) e2

Swimmer = (.52) DO + (-.25) Temp + (1) e1

Wader = (.59) DO + (1) e3 + (-.29) Temp

Five path coefficients were significant at 0.05 (Table 4). From the significance of these path coefficients,

Table 3. Correlation of physico-chemical parameters, swimmer, diver, and wader. *significant at the level of 0.05 | **significant at the level of 0.01

	Swimmer	Diver	Wader	Temperature (°C)	pH	DO (ppm)	TDS (ppm)	Salinity (ppt)	Conductivity (uS)	Acidity (mg/l)	Alkalinity (mg/l)	Free Co2 (mg/l)	Chloride (mg/l)	Calcium (mg/l)	Total hardness (mg/l)	Magnesium (mg/l)	Nitrogen (mg/l)
Swimmer	1.000																
Diver	0.553*	1.000															
Wader	0.874**	0.721**	1.000														
Temperature (°C)	-0.659**	-0.454	-0.692*	1.000													
pH	-0.168	-0.081	-0.014	0.463	1.000												
DO (ppm)	0.583*	0.585*	0.682*	-0.352	0.226	1.000											
TDS (ppm)	0.160	-0.127	0.088	-0.398	0.066	0.227	1.000										
Salinity (ppt)	-0.083	-0.225	-0.197	-0.028	0.313	-0.044	0.730**	1.000									
Conductivity(uS)	0.050	-0.012	0.008	-0.281	0.178	0.210	0.934**	0.861**	1.000								
Acidity(mg/l)	-0.259	-0.241	-0.341	0.248	0.670*	0.052	-0.349	0.067	-0.223	1.000							
Alkalinity (mg/l)	-0.110	-0.263	-0.165	0.344	0.662*	-0.019	0.055	0.344	0.105	0.647*	1.000						
Free Co2 (mg/l)	-0.361	-0.098	-0.460	0.347	0.508	-0.177	-0.471	0.068	-0.246	0.819**	0.461	1.000					
Chloride (mg/l)	0.212	-0.360	-0.025	0.298	0.329	-0.124	-0.147	0.089	-0.238	0.488	0.593*	0.410	1.000				
Calcium (mg/l)	-0.110	-0.417	-0.319	-0.402	-0.535	-0.405	0.376	0.316	0.320	-0.405	-0.537	-0.309	-0.160	1.000			
Total hardness (mg/l)	0.038	-0.432	-0.297	0.033	-0.085	-0.283	0.541	0.726**	0.529	-0.030	0.327	0.041	0.457	0.421	1.000		
Magnesium (mg/l)	0.033	-0.369	-0.209	0.016	-0.069	-0.201	0.519	0.679*	0.512	-0.151	0.316	-0.022	0.405	0.300	0.934**	1.000	
Nitrogen (mg/l)	-0.204	-0.067	-0.061	0.501	0.505	0.135	-0.337	-0.172	-0.337	0.620*	0.647*	0.386	0.414	-.603*	-0.239	-0.228	1.000

it is revealed that DO positively influences swimmer and wader counts, while temperature negatively influences wader counts. Duclos et al. (2017) reveal that temperature directly affects the abundance of birds. Waders have a negative direct effect from temperature. Dissolved oxygen positively influenced total avifaunal abundance (Patra et al. 2010). Both correlation analyses and SEM model confirmed that temperature and DO are the main parameters that affect bird count in this study area.

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Table 4. Regression weights between parameters of the SEM.

			Unstandardized Estimate	Standardized Estimate	S.E.	C.R.	P
Swimmer	<---	Temp	-12.284	-0.253	10.072	-1.220	0.223
Swimmer	<---	DO	61.548	0.516	28.169	2.185	0.029
Diver	<---	DO	17.555	0.363	13.003	1.350	0.177
Wader	<---	DO	243.994	0.586	90.907	2.684	0.007
Wader	<---	Temp	-49.556	-0.292	21.093	-2.349	0.019
Birds	<---	Swimmer	3.645	0.650	0.625	5.828	0.000
Birds	<---	Wader	0.739	0.460	0.244	3.024	0.002
Birds	<---	Diver	-1.779	-0.129	1.436	-1.239	0.215

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