**SECTION: Basic Biology, Agriculture and Food Science - Ecology**

**A STUDY ON THE ECOLOGY OF WETLAND AVIFAUNA IN THE POKKALI FIELDS OF ERNAKULAM DISTRICT, KERALA**

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**Abstract**

The Pokkali wetlands of Ernakulam District, Kerala, are special tidal ecosystems within the Central Asian Flyway (CAF) and the Vembanad Ramsar site. This exceptional environment holds high nutritive value and offers umpteen services. An intensive study on the ecology of wetland avifauna in the five selected Pokkali fields of Ernakulam District, was carried out from 01 June 2016 to 31 May 2022. During the study, a total of 102 true wetland and wetland-associated bird species belonging to 13 orders, 23 families and 75 genera were recorded. The species diversity was maximum in the order Charadriiformes (36 species), followed by Ciconiiformes (18 species) and minimum for Podicipediformes, Pelecaniformes, Phoenicopteriformes and Galliformes (one species each). Direct observation and Point count methods were used. Various parameters, including Status, Abundance, Density, Relative Density, and Alpha Diversity Indices were meticulously computed and documented. Also, their habitat, feeding, breeding and nesting ecology. The physico-chemical parameters of the habitat were studied and correlated with the ecological aspects of waterfowl. For statistical analysis, PAST and R software were used. Preserving and comprehending the dwelling habitat holds paramount importance in the realm of biodiversity conservation and management, as it sustains a delicate interplay among species and contributes to ecological equilibrium. The presence of wetland birds in the study area reflects the healthy nature of the dwelling habitat. To ensure the effective implementation of conservation strategies, a fundamental prerequisite entails the meticulous collection of foundational data concerning wetland avifauna, notably encompassing Threatened and Near Threatened species.

**Keywords:** Pokkali wetlands, CAF, Vembanad Ramsar site, Avifauna, Conservation

**Introduction**

Wetlands are unique environments with a substantial impact on avian populations (Mitsch & Gosselink 1993). The least ornithologically studied ecosystems are the wetlands of Kerala (Nameer 1998). Notably, the Ernakulam District has the largest area under Pokkali cultivation (Joy, 2013).Bottom of Form

Pokkali cultivation, named after the traditional rice variety that is tagged by Geographical Indication (GI), is a sustainable and organic technique practiced in the water-logged coastal areas of Ernakulam, Alappuzha and Thrissur Districts of Kerala, India. The cultivation is carried out during the kharif season (May-October/mid November) and is followed by shrimp cultivation (mid November-April). These wetlands represent tidal zones influenced by salinity and flooding (Shylaraj & Sasidharan, 1998; Suchitra & Venugopal, 2005). These areas are within the Central Asian Flyway (CAF) and the Vembanad Ramsar site in India. This unique ecosystem is an Important Bird Area (IBA), serving as a habitat for numerous avifauna and stopover locations for migratory birds (Islam & Rahmani, 2004; Wetlands International, 2007).

Waterbirds are crucial indicators of ecological health, productivity, trophic structure and contamination within wetland ecosystems (Custer & Osborn, 1977; Ali, 2002). As a result, the collection of fundamental ecological data (habitat, feeding and breeding) pertaining to wetland avifauna is imperative for effectively executing conservation strategies.

**Materials and Methods**

 An intensive study on the ecology of wetland avifauna was carried out in the five selected Pokkali wetlands within Ernakulam District, Kerala. The selected wetlands encompassed Valiya Kadamakkudy **(**10.0634º N, 76.2494ºE),Ezhikkara **(**10.1053º N, 76.2392º E),Thathappilly(10.1272º N, 76.2655º E),Elamkunnapuzha **(**10.0268º N, 76.2233º E) and Kandakkadavu (9.8595º N, 76.2667º E). The study period was from 01 June 2016 to 31 May 2022. The observations during the period of 2020-21 were affected by Covid-19 lockdown. The study stations each had an area of five hectares.Fortnightly visits were carried out from 06.00 a.m. to 06.30 p.m. A spotting scope (10-45 X) and an 8 x 40 (Bushnell) binocular were used. The direct observation method was used (Altman, 1974). The method of point counting was also employed to study the ecological activity of the wetland birds (Ali, 2002). Most of the observations were carried out from distances of 50-200 m, taking care not to interrupt the activity of birds. The physico-chemical parameters of the habitat were studied and correlated with the ecological aspects of waterfowl. Photographs were taken with the help of a 36 X optical zoom camera (Canon). Identification was done with the help of reference books (Ali, 1996; Neelakantan et al., 1993) and experts. Parameters including Status, Abundance, Density, Relative Density and Alpha Diversity Indices (Dominance, Shannon, Evennenss and Margalef) were calculated and documented. For statistical analysis, PAST and R software were used.

**Results and Discussion**

 During the study, a total of 102 true wetland and wetland-associated bird species (50 true wetland and 52 wetland-associated species) belonging to 13 orders, 23 families and 75 genera were recorded, which comprised 33% of the wetland birds in India**.**

 A total of 1,340 bird species were counted from India (Ali and Ripley, 1987) of which 310 were wetland dependants (Manakandan and Pittie, 2001). Deepa (2015) reported 64 wetland species, comprising 50 true water birds belonging to 13 families and 14 wetland associated species belonging to seven families from the Pokkali wetlands of Ernakulam. Tomy (2016) reported 186 bird species representing 16 orders and 52 families from the Kole wetlands of Thrissur. Any area that holds 1% of the world avian population can be declared as an Important Bird Area (IBA) (Rao and Rao, 2018).

 During the study, it was noticed that the species diversity was maximum in the order Charadriiformes (36 species), followed by Ciconiiformes (18 species) and minimum in Podicipediformes, Pelecaniformes, Phoenicopteriformes and Galliformes (one species each).

 Similar findings were reported by Jayson and Sivaperuman (2005), Deepa (2015), and Tomy (2016). Among the 208 bird species belonging to 63 families and 16 orders reported by Asha and Neeraj (2020) from the heterogeneous lands around Jammu and Kashmir, the dominant order was Passeriformes (106 species).

 During the study, it was recorded that the highest number of individuals (52,791) was from Ardeidae, with a maximum Relative Abundance 22.23% and a density of 3147.24 birds per hectare, followed by Accipitridae with 24,351 individuals (RA 11.14% and density of 1571.11 birds per hectare). The least number of individuals were from the Phoenicopteridae family (two individuals, 0.00091% RA and a density of 0.143 birds per hectare). The average monthly abundance varied from 2,142 to 2,912 individuals, the species between 57 to 89 and the total population from 1,7815 to 10,143 individuals.The species richness was high during November (89) and low in April (57). A rise in their population was noticed during June to December and then slightly decreases till May. The abundance was high during December (18,804) and low in June (9748). The highest density was recorded in December (RD 14.91%), followed by November (RD 13.59%) and lowest during June (RD 7.31%). The species richness of wetland avifauna was high during 2018-19 (102), followed by 2021-22 (96) and low in 2016-17 (84) and 2020-21 (50). A total of 2,82,723 individuals were reported. The relative density of wetland avifauna during 2016-21 was 313.44%. The abundance and relative density were high during 2021-22 (87691 individuals, 61.41% RD), followed by 2019-20 (69,147 individuals, 42.11% RD) and low in 2016-17 (55,256 individuals, 36.84% RD) and 2020-21 (54,351 individuals, 33.17% RD). The 2020-21 was the lockdown period. These variations can be attributed to changes in land use, migratory patterns and climate. The observations during the period of 2020-21 were affected by Covid-19 lockdown.

 The total number of waterbirds reported from the Pokkali wetlands during 2016-22 was much higher when compared with the reports of Bibi and Ali (2013), Deepa (2015), Asha and Neeraj (2020) and lower than the observations of Tomy (2016).

 On analysing the Alpha Diversity Indices of the wetland birds during the study, the species dominance and evenness were high in 2016-17 (Dominance D 0.038 & e^H/S 0.43) and low in 2018-19 (D 0.035 & e^H/S 0.38) and 2020-21 (D 0.033 & e^H/S 0.35). High diversity and richness were noticed during 2018-19 (Shannon H 3.65 & Margalef 9.2) and low in 2016-17 (Shannon H 3.58 & Margalef 7.6). On analysing the Alpha Diversity Indices of the wetland birds during different seasons, the species dominance (D) was high during the south-west monsoon (0.091) and low during the north-east monsoon (0.089). In the north-east monsoon, the diversity (H) was high (3.77) and was low during the south-west monsoon (3.41). The evenness (e^H/S) was high in summer (0.631) and low during the north-east monsoon (0.379). High species richness (Margalef Index) was recorded in the north-east monsoon (9.91) and low during the summer (6.74).

 Brahminy Kite and Grey-headed Swamphen were the abundant wetland and wetland-associated species observed during the study. The population of Indian Pond Heron (5,047), Great Cormorant (5,089), Red-wattled Lapwing (5,566), Black Kite (5,702), Common Sandpiper (5,899), Large Egret (6,205), Grey Heron (6,720), Purple Heron (7,243), Intermediate Egret (7,320), Oriental White Ibis (7,468), Little Cormorant (8,651) and Little Egret (9,991) were also high. The occasionally sighted species include Ruddy Shelduck, Booted Eagle, Amur Falcon, Red Knot, Whimbrel, Pintail Snipe, Common Snipe, Black-headed Gull and Slender-billed Gull. All the occasional wetland species were noticed during November except Red Knot, which was spotted during September.

 The Cochin Natural History Society (CNHS) conducted Asian Waterfowl Census (AWC) at the Pokkali wetlands of Devaswom Paadam, Varapuzha and Kadamakkudy during February 2011 (Dilip, 2011). A total of 52 and 41 bird species were recorded from Devaswom Paadam and Kadamakudy Pokkali fields respectively during the one-day survey and the abundant species were Whiskered Tern (442), Little Cormorant (40) and Pond Heron (34).

During the study, the highest species richness (98) and abundance (52,257) of wetland birds was recorded in the north-east monsoon. Low species richness (60) was recorded during the summer and abundance (35,899) in the south-west monsoon. A total of 72 species and 51,007 individuals were recorded during the winter; 77 species and 31,857 individuals during the south-west monsoon. The south-west monsoon, north-east monsoon, winter and summer seasons hold 19.44%, 30.56%, 29.77% and 20.98% respectively of the total wetland bird population. The relative density was maximum during the north-east monsoon (34.5%), followed by winter (33.74%), summer (26.73%) and south-west monsoon (21.57%).

According to the findings, the avifauna migrating along the Central Asian-Indian Migratory Flyway (CAF) used the study area as a stop-over site for resting and re-fuelling. Migratory birds are known to feed on a high-protein diet on their wintering grounds. During their migratory season, which coincided with the prawn cultivation period, a large number of migratory fish eating waterfowl species were observed. The increased density of fishes, crustaceans and molluscs influenced the density and diversity of wetland avifauna in the study area. The findings showed that the link between fishes, crustaceans and molluscs, as well as water quality, flora and wetland avifauna can be utilised to analyse the health of the study area.

The richness, abundance and density of waterfowl in the study area were high when compared with the reports of Deepa (2015).

 During 2016-22, an increase in the number of wetland species was noticed in Valiya Kadamakkudy (102), followed by Kandakkadavu (74), Ezhikkara (60), Elamkunnapuzha (51) and Thathappilly (50). The population was high in Valiya Kadamakkudy (53,740), followed by Kandakkadavu (44,432), Ezhikkara (30,603), Thathappilly (21,413) and least in Elamkunnapuzha (19,825).Valiya Kadamakkudy comprised 31.61%, the Kandakkadavu constituted 26.13%, Ezhikkara, Thathappilly and Elamkunnapuzha incorporated 18%, 12.59% and 11.67% respectively of the total wetland population reported during the study. The maximum relative density of wetland avifauna was noticed in Valiya Kadamakkudy (35.82%), followed by Kandakkadavu (29.62%), Ezhikkara (20.4%), Thathappilly (14.28%) and Elamkunnapuzha (13.22%). Rotational paddy and prawn cultivation was observed in Valiya Kadamakkudy, Kandakkadavu and Ezhikkara Pokkali fields during the study period. As a result, the stable wetland ecosystem supported diverse avifauna. The rotational cultivation pattern was not properly followed in Thathappilly and Elamkunnapuzha fields. The decreased species richness, abundance and density of waterfowl in these wetlands may be due to the changes in the land use patterns and decreased availability of fish.

 Out of the 102 wetland bird species recorded during the study, a total of 15 bird species (8.43%) belonging to the Threatened (four) and Near Threatened (eleven) category were reported (IUCN, 2022). They represented six orders and eight families. A total of 148 Threatened (T) and 16,891 Near Threatened (NT) birds were counted. The NT species include Spot-billed Pelican,Oriental Darter, Painted Stork, Oriental White Ibis, Ferruginous Pochard,Rufous-bellied Eagle,Curlew Sandpiper,Black-Tailed Godwit,Bar-Tailed Godwit,Red Knot and River Tern. The White-necked Stork, Greater Spotted Eagleand Grey-headed Fish Eaglewere categorised as Vulnerable and Gull-billed Tern as Endangered. All of these were migrant species. Their population was high during the migratory season. According to the findings, the study area is a preferred site for threatened and near threatened avian species. Availability of water, food, shelter and an ideal climate, suitable environmental parameters and the lack of predators contribute to their appearance.

Among the 313 bird species identified from the Thrissur District, 11 Threatened and Near Threatened species were recorded (Jayson and Sivaperuman, 2005). Ten globally threatened species including Oriental White Ibis, Oriental Darter and Spot-billed Pelican were recorded from the Kuttanad wetland area by Prasanth *et al*. (2011). Deepa (2015) reported Oriental Darter, Oriental White Ibis and Spot-billed Pelican as globally threatened species representing three orders, three families and three genera from the Pokkali wetlands. A total of 10 species including two Vulnerable and seven Near Threatened species were recorded from the Kole wetlands, Thrissur (Tomy, 2016).

 When the family wise correlation of fish eating avifauna was carried out with the physico-chemical parameters during 2016-22, it was reported that the family Anatidae (Ducks) was found to be positively correlated with the water depth and temperature and negatively correlated with Dissolved Oxygen and turbidity. During the monsoon, migratory birds arrive, and resident ducks have been seen using the same habitat. If the number of birds increases, the dissolved oxygen content in the wetland decreases. The families such as Pelecanidae, Anhingidae (Darters), Phalacrocoracidae (Cormorants) and Podicipedidae (Grebes) were positively correlated with the temperature, humidity, rainfall, water level, water pH and electrical conductivity and negatively correlated with Dissolved Oxygen and turbidity. The Alcedinidae family showed a significant positive correlation with the rainfall and a significant negative correlation with the Dissolved Oxygen and Turbidity. Ciconiidae (Storks), Threskiornithidae (Ibises), Recurvirostridae (Stilts) and exhibited a positive correlation with water temperature and negative with water depth. The wader species were observed in the habitat with decreased water depth. Ardeidae (Herons and Egrets), Laridae (Gulls and Terns), Charadriidae (Plovers and Lapwings), Accipitridae (Harrier and Kites) and Pandionidae (Ospreys) are positively correlated with water and air temperature. A significant negative correlation with the water depth and Dromadidae (Crab Plover) was recorded. Also, Rallidae (Moorhen, Waterhens, Coots) and Jacanidae (Jacanas) showed a significant positive correlation with water temperature and rainfall. Overall, the correlation results between physico-chemical parameters and the wetland avifauna revealed that no single abiotic parameter solely regulates the bird density.

 The ecology of waterbirds was closely related to the distribution and abundance of food resources (Safran *et al*., 1997).

 The increased fishes and suitable environmental parameters supported rich waterfowl population in the study area. As birds are termed as eco-indicators their behavioural pattern and ecology can be used to analyse the habitat changes and climatic variations.

**Conclusion**

Waterbirds are important indicators of ecosystem. During the study, it was noticed that the productive Pokkali wetlands which are part of the Vembanad Ramsar site provides important feeding, roosting and breeding grounds for a variety of birds. Increased wetland avian diversity indicates the healthy nature of these wetlands. Preserving and comprehending the dwelling habitat holds paramount importance in the realm of biodiversity conservation and management, as it sustains a delicate interplay among species and contributes to ecological equilibrium. The presence of wetland birds in the study area reflects the healthy nature of the dwelling habitat. To ensure the effective implementation of conservation strategies, a fundamental prerequisite entails the meticulous collection of foundational data concerning wetland avifauna, notably encompassing species such as Threatened and Near Threatened species.

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