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Evaluating The Seasonal Diversity, Habitat Preference And Assemblages Of Water Birds In Agroecosystem At Central Kerala

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Abstract:

The study proposes to discuss the seasonal water bird diversity, habitat preference, assemblages of water bird species and their conservation problems in different agroecosystems. Field visits were done once in a week during Jan. 2021-Jan. 2023. Freshwater and saline agroecosystems are the study areas used for the water bird survey. The water bird study was conducted by direct observation method, point count method and line transect method. Observations were made using binoculars (10 × 50 Nikon) and video camera (Nikon Coolpix p1000). Based on the pilot study in 2020, we decided to concentrate on 16 species of waterbirds coming in the 3 different orders i.e., Order Pelecaniformes, Ciconiiformes and Suliformes. Compared to the different study areas, a greater abundance of water birds was recorded in the winter season, while a lesser abundance was observed in the monsoon season. The species richness was highest in saline agroecosystem and water bird congregation was more in freshwater agroecosystem. Saline agroecosystem was the most preferred habitat used for water bird species. Agroecosystems support the globally threatened water bird species such as spot billed pelican, darter, black headed ibis and painted stork. Many factors that are listed below threaten the agroecosystem and it causes the decreasing assemblages of water bird species. They are high water intake due to heavy rain, electric lines, high growth of water hyacinth, fishing nets, solid wastes and garbage deposited from toddy shops, pesticides used in fresh water rice farming, tourism, crackers, high level of fishing activities, habitat destruction, communication towers, predators and white flags were introduced by farmers.

Keywords: Agroecosystem, Water birds, Environmental Parameters, Conservation problems

Introduction

Waterbirds are an important component of the biotic community in wetland ecosystems and highly sensitive to changing habitat including climate and weather (Ramesh *et al.*, 2020). Rice fields are common throughout the agricultural landscape of Southeast Asia and sustain various bird species. These birds can provide ecosystem services, such as pest control, that improve agricultural yields while minimising the use of agrochemicals (Amira *et al.,* 2018). Agricultural habitats are increasingly recognised for the conservation

opportunities they present (Dewi *et al.*, 2023). Rice fields show particular promise for waterbirds and 'wildlife-friendly' farming initiatives, but most work has focussed on conspicuous, well-known species and the value of flooding harvested fields to provide non-breeding habitat (Herring *et al.*, 2019). In recent years, there has been great concern regarding agricultural land uses and their importance for the conservation of biodiversity. Rice fields are managed as a unique wetland for wildlife, especially waterbirds (Nam *et al.*, 2015).Rice fields are important habitats for waterbirds, although their ecological role and relevance for conse rvation remains uncertain (Paulino *et al.*, 2023). Diversity of avifauna is one of the most important ecological indicators to evaluate the quality of habitats (Neelgund *et al*., 2020).

The study area was freshwater and saline agroecosystem. The saline agroecosystem is commonly known as Pokkali farming. Pokkali farming is a unique system of rice cultivation found only in coastal regions of central Kerala (Ranjith *et al.*, 2019). It is a traditional and organic method of rice farming practices in three districts such as Alappuzha, Ernakulam and Thrissur bordering the Arabian Sea (Shamna *et al.*, 2017) and freshwater rice farming observed in every district in Kerala. Culture and practice for rice in freshwater are distinct to freshwater rice farming but the Pokkali system utilizes the relationship between rice farming and shrimp or fish farming (Vijayan., 2016). Compared to the different agroecosystem, freshwater rice cultivation is not profitable but the Pokkali farming includes both rice and prawn cultivation and it is highly profitable (Jayan *et al.*, 2010).

The study aimed to record seasonal diversity & assemblages of specific water bird species, including globally threatened species across various agroecosystems in central Kerala. The significance of the study was also to examine physico-chemical parameters and conservation challenges at different sites. The significance of the study was to observe the resident selected water bird species and to analyse the conservation problems in the study area. Water birds are sensitive ecological indicators, which contribute to a healthy ecosystem in the wetland. Many water bird species face a steady decline in their global population.

Materials and Methods

Study area

Freshwater Agroecosystem - South Kainakary (9°27 '46.49 " N 76°22 '11.65" E) is a village in Kuttanad taluk, Alappuzha district, central Kerala. The Kuttanad wetland system in Kerala is located 1.0-2.5 m below sea level and it has a poor tree wealth with an extensive area of wetland crops, especially paddy and coconut. Kainakary was part of the Chembakassery dynasty and is known for its scenery. Five rivers including the Pamba River flow from the western Ghats and converge into Vembanad Lake at the tip of Kainakary.

Saline Agroecosystem - The Pokkali field (Kochuvavakkad Padashekharam) was located near Pallithode bridge (9° 46' 35.99"N, 76° 17' 9.71"E), Thuravoor. Pallithode is a village in the Alappuzha district, central Kerala on the shores of the Arabian Sea. Pallithode is within the gram panchayat of Kuthiathode, Pattanakkad block of Cherthala taluk. Pallithode is a green, palm-fringed scenic village in the coastal region of Kerala, on a narrow strip of land with white, sandy beaches bordering the Arabian sea to the west and a lake. Pallithode Pozhi, a part of the Cochin estuary to the east, as well as extensive interconnected paddy fields and backwaters to the east of the Pozhi.

Water bird survey

The study area has been observed once in a week from 6:00h–12:00h (Hoves & Bakewell., 1989). The present study was conducted during the period of Jan. 2021 to Jan. 2023. Observations were made through binoculars (10 × 50 Nikon) and Nikon Coolpix p1000 video camera. Bird surveys were conducted using the following methods - Direct observation method (Hoves & Bakewell., 1989). Point count (Ralph *et al.*, 1995 & Hamel *et al.*, 1996) and Line transect method (Burnham *et al.*, 1980). Bird species were identified with the help of a field guide (Ali *et al.*, 2002), (Grimmett *et al.*, 2012) from the field itself. Different activities of birds were recorded as foraging and feeding, moving, resting, calling, preening, chasing, etc. (Akhtar *et al.*, 2009). All the visible water birds present in the study area were counted. The purpose of the Direct observation method is to observe the wetland water birds directly and also to determine the various conservation problems affecting the wetlands and also water birds (Veeramani *et al.*, 2018). Using the Point count method, the observer reaches the centre of the point count plots and records all water birds seen or heard for a period of 10 or 15 minutes (Hamel *et al.*, 1996). Point count is not performed on days with heavy rain and strong wind (Ralph *et al.*, 1995). For Line transect method, the total no. of water birds was recorded by walking through the transect from one scanning point to the adjoin one (approximately 500m) along a transect line (Burnham *et al.*, 1980). When standing at each transacted sample point for ten minutes, birds seen or heard were recorded (Buckland

et al., 1993). Counting of all water birds and logging them in a different datasheet were carried out.
The present study aims to document the water bird count in resident species in different agroecosystems. Based on the pilot study in 2020, we decided to concentrate on 16 species of water bird species coming under three different orders in the agroecosystem such as:

Order Pelecaniformes: Little Egret (*Egretta garzetta)*, Median Egret (*Ardea intermedia)*, Large Egret (*Ardea alba)*, Indian Pond Heron (*Ardeola grayii)*, Western Reef Heron (*Egretta gularis)*, Grey Heron (*Ardea cinerea)*, Purple Heron (*Ardea purpurea)*, Little Green Heron (*Butorides virescens)*, Oriental Ibis (*Threskiornis melanocephalus)*, Glossy Ibis (*Plegadis falcinellus)*

Order Ciconiiformes: White Necked Stork (*Ciconia episcopus)*, Black Stork (*Ciconia nigra)*, Asian Openbill Stork (*Anastomus oscitans)*

Order Suliformes: Little Cormorant (*Microcarbo niger)*, Large Cormorant (*Phalacrocorax carbo)*, Darter (*Anhinga melanogaster).*

Statistical analysis
Data analysis was done by using Species richness, Species abundance, Shannon-wiener index and species evenness. The water bird count data were categorized by seasons (Summer, Winter and Monsoon) during Jan. 2021-Jan. 2023.

Measurement of Environmental parameters in agroecosystem
Water and soil samples were collected once in a month during Jan. 2021-Jan. 2023. Soil quality parameters such as pH, Total Nitrogen, Total Phosphorus, Potassium, Organic carbon and water parameters such as pH, Phosphate, Nitrate, Potassium, Ca+ ions, Mg+ ions and Salinity were analysed during Jan. 2021-23. Estimation of nitrogen was done using Kjeldahl method, estimation of phosphorus by molybdenum method, estimation of potassium by flame photometry, estimation of organic carbon by Walkey and Black's method. Soil pH was determined using pH meter and salinity by TDS meter (Manju *et al.*, 2012). Water pH was determined using a pH meter. Estimation of nitrate was done by using the cadmium reduction method, potassium by flame photometry, phosphate by spectrophotometry, calcium and magnesium by EDTA Titrimetric method. Salinity was checked by using TDS Conductivity meter (APHA 2005)

Results

Seasonal water bird count in agroecosystem
The present study documented the diversity, habitat preference and assemblages of water birds in different agroecosystem during Jan. 2021 to Jan. 2023. The study sites were observed once in a week during 6:00h–12:00h. Observations were made using binoculars (10 × 50 Nikon) and video camera (Nikon Coolpix p1000). Based on the pilot study in 2020, we decided to concentrate on 16 species of waterbirds coming in the 3 different orders i.e., Order Pelecaniformes, Ciconiiformes and Suliformes. The Little Egret (*Egretta garzetta*), Median Egret (*Ardea intermedia*), Large Egret (*Ardea alba*), Indian Pond Heron (*Ardeola grayii*), Western Reef Heron (*Egretta gularis*), Grey Heron (*Ardea cinerea*), Purple Heron (*Ardea purpurea*), Little Green Heron (*Butorides virescens*), Oriental Ibis (*Threskiornis melanocephalus*) and Glossy Ibis (*Plegadis falcinellus*) are under the order Pelecaniformes. White necked stork (*Ciconia episcopus*), Black stork (*Ciconia nigra*) and Asian openbill stork (*Anastomus oscitans*) are under the order Ciconiiforms. Little Cormorant (*Microcarbo niger*), Large Cormorant (*Phalacrocorax carbo*) and Darter (*Anhinga melanogaster*) are under the order Suliformes are the selected water bird species.

1. Water bird sampling in freshwater agroecosystem
Analysis of water bird diversity in freshwater agroecosystem was carried out during Jan. 2021- Jan. 2023. Among the 16 species of waterbirds, 11 species of water birds belonging to 3 orders were observed in the study area (Table 1). The observed water birds in freshwater agroecosystem were the Little Egret (*Egretta garzetta*), Median Egret (*Ardea intermedia*), Large Egret (*Ardea alba*), Indian Pond Heron (*Ardeola grayii*), Grey Heron (*Ardea cinerea*), Purple Heron (*Ardea purpurea*), Oriental Ibis (*Threskiornis melanocephalus*) and Glossy Ibis (*Plegadis falcinellus*) are under the order Pelecaniformes. Asian openbill stork (*Anastomus oscitans*) are under the order Ciconiiforms. Little Cormorant (*Microcarbo niger*) and Darter (*Anhinga melanogaster*) are under the Order Suliformes. Large Cormorant (*Phalacrocorax carbo*), Western Reef Heron (*Egretta gularis*), Little

Green Heron (*Butorides virescens*), White necked stork (*Ciconia episcopus*), Black stork (*Ciconia nigra*) was absent during Jan. 2021-23.

The most abundant resident water bird species observed in the study area were egrets, herons and little cormorants. Other water birds such as glossy ibis, oriental ibis, asian openbill stork, darter were counted many in the winter season (Table 1). The highest water bird congregations were recorded in the winter season especially in Nov to March & the lowest in the Monsoon season in July. Globally threatened water birds such as Black-headed ibis and darter were observed during Jan. 2021-23.

Among 16 species of water birds, only 4 species were observed in Summer and Monsoon season. In addition to this, 7 species of water birds were observed in the winter season (Fig. 1). 5 species of water birds not observed in the field visits. The Winter visitors are little egret, large egret, grey heron, oriental ibis, glossy ibis, asian openbill stork and darter. In addition to this, median egret, Indian pond heron, purple heron and little cormorant, were observed every month. Western reef heron, little green heron, white necked stork, Black stork and large cormorant were absent during Jan. 2021-23.

1.1 Assemblages of water bird species

Water bird assemblages are classified into Common (COM): Seen on most of the visits, Uncommon (UC): seen on a few visits, and Rare (R): seen once or absent. A total of 11 species of water birds were observed, 25.00 % were Common (COM), 43.75 % were Uncommon (UC) and 31.25% are Rare (R) water birds. Of these, the median egret, pond heron, purple heron, little cormorant was Common. Little egret, large egret, grey heron, Oriental ibis, Glossy ibis, asian openbill stork and darter was Uncommon and western reef heron, little green heron, white necked stork, black stork, large cormorant was are birds (Fig 2).

1.2 Water bird count in Jan 2021-22 & Jan 2022-23

The study was conducted in Jan. 2021-22 & Jan. 2022-23 as weekly surveys. The water bird count in Jan. 2021-22 was 12,855 & in Jan. 2022-23 was 12,682 (Fig 3). The water bird count in freshwater agroecosystem was found decreasing from Jan. 2021-22 compared to Jan. 2022-23. During Jan. 2021-22, the total number of water bird species was 12,855. Of these, for the order Pelecaniformes, 12,321 birds were observed which comes under 8 species. Two species such as western reef heron and little green heron are not observed in the field visits. Under the order Ciconiiformes, which comes under 3 species. Asian openbill stork (34 birds) was observed in freshwater agroecosystem under this order. For the Order Suliformes, 500 birds were observed which comes under 2 species such as little cormorant and darter. Large cormorant was absent during Jan 2021-22.

In Jan. 2022-23, the total number of water bird species was 12,682. Of these, for the order Pelecaniformes, 12,151 birds were observed which comes under 8 species. Under order Ciconiiformes, which comes under 3 species. But, asian openbill stork (41 birds) was observed in freshwater agroecosystem. For the order Suliformes, 490 birds were observed which comes under 2 species. western reef heron, little green heron under the order Pelecaniformes, white necked stork and black stork come under the order Ciconiiformes and large cormorants under the order Suliformes were absent in Jan. 2021-2023. Glossy ibis was the highest bird count during Jan. 2021-2023. But glossy ibis were observed only in the winter season. Other water bird species such as egrets, herons and cormorants have the least count compared to the bird count of glossy ibis. Compared to water bird count in freshwater agroecosystem, Jan. 2021-22 was the highest water bird count than Jan. 2022-23. The reasons behind the decreasing level of water birds were analysed in fresh water agroecosystem and showed that anthropogenic activities are the main reason for decreasing the water bird diversity. The wetland is a freshwater habitat that protects many freshwater species. So, the decreasing level of water bird count in the fresh water agroecosystem proves that this area is under conservation problems.

1.3 Data Analysis

Data analysis was done by using species richness, species abundance, species evenness and Shannon-wiener index. Species richness of water birds in freshwater agroecosystem was 11. In Jan. 2021-22, total number of water birds in 11 species was 12,855 and Jan. 2022-23 was 12,682. The Shannon index (H) of water birds in Jan. 2021-22 was 4.41 and species evenness was 1.84 (Table 4). The Shannon index (H) of water birds in Jan. 2022-23 was 6.24 and species evenness was 2.6 (Table 5). The diversity of waterbirds in the freshwater agroecosystem was high in Jan. 2021-22 and low in Jan. 2022-23.

1.4 Measurement of Environmental parameters in freshwater agroecosystem

Analysis of soil and water quality parameters were carried out in Jan. 2021-22 & Jan. 2022-23. The soil parameters such as pH, Total Nitrogen, Phosphorous, Potassium and Organic Carbon were analysed (Table 8). In Jan. 2021-22; pH, Total Nitrogen, Total Phosphorus, Potassium and Organic Carbon was 7.46, 2.96%, 1.15mg/kg, 3.4mg/kg, 34.4% respectively. In Jan. 2022-23, pH, Total Nitrogen, Total Phosphorus, Potassium and Organic Carbon was 7.97, 2.96%, 1.15mg/kg, 3.28mg/kg, 30.2% respectively.

Water quality parameters such as pH, Phosphate, Nitrate, Potassium, Ca+ ions, Mg+ ions and salinity were determined (Table 9). In Jan. 2021-22; pH, phosphate, nitrate, potassium, Ca+ ions, Mg+ ions and salinity was 7.36, 0.07mg/l, 0.77mg/l, 3.26mg/l, 80.66mg/l, 96.33 and 0.522ppt respectively. In Jan. 2022-23, pH, phosphate, nitrate, potassium, Ca+ ions, Mg+ ions and salinity was 7.95, 0.04 mg/l, 0.75 mg/l, 2.90 mg/l, 70 mg/l, 82 and 0.83ppt respectively.

2. Water bird sampling in saline agroecosystem

Analysis of water bird diversity in saline agroecosystem was carried out during Jan. 2021-Jan. 2023. Among the 16 water bird species, a total of 11 species of water birds belonging to 2 orders were observed in the study area (Table 2). The observed water birds are the Little Egret (*Egretta garzetta*), Median Egret (*Ardea intermedia*), Large Egret (*Ardea alba*), Indian Pond Heron (*Ardeola grayii*), Western Reef Heron (*Egretta gularis*), Grey Heron (*Ardea cinerea*), Purple Heron (*Ardea purpurea*), Oriental Ibis (*Threskiornis melanocephalus*) and Glossy Ibis (*Plegadis falcinellus*) are under the order Pelecaniformes. Little Cormorant (*Microcarbo niger*) and Darter (*Anhinga melanogaster*) are under the Order Suliformes. Little Green Heron (*Butorides virescens*) (Order Pelecaniformes), White necked stork (*Ciconia episcopus*), Black stork (*Ciconia nigra*), Asian openbill stork (*Anastomus oscitans*) are under the order Ciconiiforms, Large Cormorant (*Phalacrocorax carbo*) (Order Suliformes) was not observed during Jan. 2021-Jan. 2023.

The most abundant resident water bird species observed in the study area were egrets, herons and little cormorants. Other water birds such as darter, glossy ibis, oriental ibis were observed only in the winter season (Table 2). The highest water bird congregations were recorded in the winter season especially in Nov-March & the lowest in the Monsoon season in July. In saline agroecosystem, shrimp farming occurs in the winter season. So, many water birds came to the area for their feeding activity. Globally threatened water birds such as black-headed ibis, darter, spot billed pelican were observed during Jan. 2021-2022. In addition to this, painted stork was observed in the Winter season (Nov-Mar, 2022).

A total of 11 species of water birds were observed during Jan. 2021-22 and Jan. 2022-23. Of these, 6 species of water birds were observed in Summer and Monsoon season. In addition to this, 5 species of water birds were observed in the Winter season (Fig. 4). The Winter visitors are large egret, western reef heron, oriental ibis, glossy ibis and darter. In addition to this little egret, Median egret, Indian pond heron, grey heron, purple heron and little cormorant were observed every month. Little green heron, white necked stork, black stork, asian openbill stork and large cormorant were absent during Jan. 2021-Jan.23.

2.1 Assemblages of water bird species in saline agroecosystem

Water bird assemblages are classified into Common (COM): Seen on most of the visits, Uncommon (UC): seen on a few visits, and Rare (R): seen once or absent. Out of 11 species of water birds observed, 37.50% were Common (COM), 31.25% were Uncommon (UC) and 31.25% are Rare (R) water birds. Of these, the little egret, median egret, Indian Pond heron, grey heron, purple heron, little cormorant is Common. Large egret, western reef heron, oriental ibis, glossy ibis and darter are uncommon and heron, white necked stork, black stork, asian openbill stork and large cormorant are Rare birds (Fig 5).

2.2 The water bird count in Jan. 2021-2022 & Jan. 2022-23

The study was conducted in Jan. 2021-23 as weekly surveys. The water bird count in Jan. 2021-22 was 4697 & Jan. 2022-23 was 4577 (Fig 6). The water bird count in the saline agroecosystem was found decreasing from Jan. 2021-22 to Jan. 2022-23. During Jan. 2021-22, the total number of water bird species was 4697. Of these, order Pelecaniformes includes 3048 birds which comes under 9 species. For the order Suliformes, 1649 birds were observed which comes under 2 species. Little green heron (order pelecaniformes), large cormorant (order suliformes) and order ciconiiformes, which comes under 3 species such as asian openbill stork, black stork white necked was absent during Jan. 2021-2022.

In Jan. 2022-23, the total number of water birds was 4577. Of these, order Pelecaniformes includes 2866 birds which come under 8 species. Order Suliformes, 1711 birds were observed which comes under 2 species. Little green heron and glossy ibis (order Pelecaniformes), large cormorant (order Suliformes) and order Ciconiiformes, which comes under 3 species such as white necked stork, black stork, asian openbill stork was

absent in Jan. 2022-23. Compared to the water bird count during the year, Jan. 2021-22 was the highest water bird count than Jan. 2022-23. The reasons behind the decreasing level of water birds analysed in saline agroecosystem showed that anthropogenic activities were the main reason for the decreasing bird diversity. The wetland is very important and protects many bird species. So, the decreasing level of water bird count in the saline agroecosystem proves that this area is under conservation problems.

2.3 Data Analysis

Data analysis was done by using Species richness, Species abundance, species evenness and Shannon-wiener index. Species richness of water birds in the saline agroecosystem was 11. In Jan. 2021-22, total number of water birds was 4697 and Jan. 2022-23 was 4577. The Shannon index (H) of water birds in Jan. 2021-22 was 1.52 and species evenness was 0.63 (Table 6). The Shannon index (H) of water birds in Jan. 2022-23 was 3.12 and species evenness was 1.3 (Table 7). The diversity of waterbirds in the saline agroecosystem was high in Jan. 2021-22 and low in Jan. 2022-23.

2.4 Measurement of Environmental parameters in saline agroecosystem

Analysis of soil and water quality parameters were carried out in Jan. 2021-23. The soil parameters such as pH, Total Nitrogen and Phosphorous, Potassium and Organic Carbon were analysed (Table 10). In Jan. 2021-22; pH, Total Nitrogen, Total Phosphorus, Potassium and Organic Carbon was 7.51, 44.8%, 0.03mg/kg, 2.6mg/kg, 21.73% respectively. In Jan. 2022-23, pH, Total Nitrogen, Total Phosphorus, Potassium and Organic Carbon was 7.91, 44.8%, 0.03mg/kg, 2.4mg/kg, 20.66% respectively.

Water quality parameters such as pH, Phosphate, Nitrate, Potassium, Ca+ ions, Mg+ ions and salinity were determined (Table 11). In Jan. 2021-22; pH, Phosphate, Nitrate, Potassium, Ca+ ions, Mg+ ions and Salinity was 7.75, 0.09mg/l, 0.73mg/l, 3.03mg/l, 147.4 mg/l, 46.60 and 1.02ppt respectively. In Jan. 2022-23, pH, Phosphate, Nitrate, Potassium, Ca+ ions, Mg+ ions and salinity was 7.92, 0.09 mg/l, 0.50 mg/l, 3.1 mg/l, 1.28mg/l, 82 and 0.93ppt respectively.

Habitat preference of water birds in agroecosystem

Based on the habitat preference, water birds are mainly divided into two; Open Water species and Water edged species. Open Water species are cormorants and darters and Water Edged Water bird species are egrets, herons, ibis were observed in Jan. 2021-23. The different study sites are freshwater agroecosystem and saline agroecosystem. Compared to the different sampling sites, saline agroecosystem was the most preferred habitat used for water birds. Based on the pilot study, we selected 16 species of water birds. Of these, 10 species were observed under the order Pelecaniformes, 3 species are under the order Ciconiiformes and 3 species in the order Suliformes. Order Pelecaniformes and Ciconiiformes are the water edged waterbird species and order Suliformes includes open water bird species. Compared to the different sampling sites, saline agroecosystem was observed in high count of species congregation and low in freshwater agroecosystem. Water bird congregations were low in saline agroecosystem compared to that of freshwater areas because of the seasonal food preference. Little cormorants and darters are high in the winter season. Because, in case of saline agroecosystem, shrimp farming occurs in the Nov-March. So, many cormorants, daters, and ibis came to the saline agroecosystem to do their feeding activity.

Globally threatened water bird species at agroecosystem

Agroecosystem support the globally threatened water bird species. Oriental darter and black headed ibis were the globally threatened water bird species observed in the freshwater agroecosystem and four globally threatened water bird species were observed in Saline agroecosystem (Table 3). They are Spot billed pelican, darter and black headed ibis during Jan. 2021- 22. In addition to this, painted stork was observed only in the winter season at Nov. 2022. Darter was the highest diversity level compared to other threatened water bird species.

During the winter season (Jan. 2021- 22) in saline agroecosystem, we had observed few nests of Spot-billed Pelicans. The nesting and parental care of spot-billed pelicans are very interesting. Using their large beaks, they damage the top of coconut trees and construct their nest. In addition to water birds, we counted the shorebirds also. They are green sandpiper, wood sandpiper, whiskered tern, red wattled lapwing, yellow wattled lapwing and black-winged stilt.

Conservation Problems in different agroecosystem

Many factors that are listed below threaten the agroecosystem and it causes the decreasing level of the water bird population in different sampling sites.

a. Electric Lines: Water birds use their resting and preening time on electric lines. Sometimes the electric shock may affect and can cause death.
b. High growth level of water hyacinth: Water hyacinth was observed on the surface of the water sources near the agroecosystem. It will decrease the count of water birds.
c. Fishing nets: Farmers use different types of fishing nets having different sizes. Small-sized nets dipped inside the water cause the death of open-water species of water birds like cormorants and darters.
d. Solid and Garbage waste: Solid and garbage waste were found to be deposited from many toddy shops near the study sites.
e. Water contamination: Some chemicals are being used to remove the unwanted plants in the pathways. This causes the pollution of water.
f. Tourism: Agroecosystem in central Kerala are tourist areas, many foreigners and local peoples come to this place and this brings disturbance for water birds.
g. Crackers: During shrimp farming, many little cormorants and darters came to the area for their feeding activity. To avoid the high count of water birds, farmers use some sound-producing materials which cause disturbance for cormorants and darters.
h. High level of fishing activities: Fishermen disturb the foraging behaviour of water birds which leads to decreasing count of birds.
i. Habitat destruction: Habitat destruction is one of the reasons observed in the freshwater agroecosystem. The rice farming area is converted into building toddy shops, resorts and placing communication towers.
j. Pesticides: Many pesticides were used in the freshwater rice farming. Farmers use the pesticides to remove the unwanted plants and pests or insects observed in the freshwater rice plants. Small insects are the food ingredient for egrets and herons. So, this affects the declined level of egrets and also herons.
k. Communication tower: Most of the water birds such as darter and little cormorants use the communication tower for their resting and preening behaviour. Radiations in these towers affect these water birds.
l. White flags: Egrets and herons are the main visitors in the freshwater and saline agroecosystems. Egrets feed mainly small insects observed in the rice plants. To avoid high counts of egrets, white flags were introduced by farmers. So, the count of egrets and herons declined.
m. Predators: Predators such as feral dogs, brahminy kite, black kite and Osprey were observed during the field time. Predators cause the decreasing count of water birds.
n. High water intake: agroecosystem located near the rivers and shorelines. Due to the heavy rain and high-water intake during the farming time affects water-edged bird species like egrets and herons. But it will be helpful for Cormorants and Darters.

Table 1. Water bird count in freshwater agroecosystem

Sl. No.	Species (Common Name)	Season	Assemblages of water birds	IUCN	Count (Jan. 2021-22)	Count (Jan. 2022-23)
1.	Little Egret	W	UC	LC	50	42
2.	Median Egret	S, M, W	C	LC	2016	1834
3.	Large Egret	W	UC	LC	4	5
4.	Indian Pond Heron	S, M, W	C	LC	1070	994
5.	Western Reef Heron	0	R	LC	0	0
6.	Grey Heron	W	UC	LC	19	14
7.	Purple Heron	S, W, M	C	LC	82	58
8.	Little Green Heron	0	R	LC	0	0
9.	Oriental Ibis	W	UC	NT	47	27
10.	Glossy Ibis	W	UC	LC	9033	9177
11.	White necked stork	0	R	LC	0	0
12.	Black stork	0	R	LC	0	0
13.	Asian open bill stork	W	UC	LC	34	41
14.	Little Cormorant	S, M, W	C	LC	472	470
15.	Large Cormorant	0	R	LC	0	0
16.	Darter	W	UC	NT	28	20
	Total				12,855	12,682

Table 2. Water bird count in saline agroecosystem

Sl.No	Species (Common Name)	Season	Assemblages of water birds	IUCN	Count (Jan. 2021-22)	Count (Jan. 2022-23)
1.	Little Egret	S, M, W	C	LC	298	307
2.	Median Egret	S, M, W	C	LC	1617	1371

3.	Large Egret	W	UC	LC	41	58
4.	Indian Pond Heron	S, M, W	C	LC	752	828
5.	Western Reef Heron	W	UC	LC	9	6
6.	Grey Heron	S, M, W	C	LC	109	102
7.	Purple Heron	S, W, M	C	LC	167	146
8.	Little Green Heron	0	R	LC	0	0
9.	Oriental Ibis	W	UC	NT	45	48
10.	Glossy Ibis	W	UC	LC	10	0
11.	White necked stork	0	R	LC	0	0
12.	Black stork	0	R	LC	0	0
13.	Asian openbill stork	0	R	LC	0	0
14.	Little Cormorant	S, M, W	C	LC	1556	1639
15.	Large Cormorant	0	R	LC	0	0
16.	Darter	W	UC	NT	93	72
	Total				4697	4577

Table 3. Globally Threatened Water birds in agroecosystem

Sl. No.	Species (Common Name)	Scientific Name	Current status at agroecosystem (P-Present, A- Absent)	
			Freshwater agroecosystem	Saline agroecosystem
1.	Oriental Darter	*Anhinga melanogaster*	P	P
2	Spot-billed Pelican	*Pelecanus philippensis*	A	P
3.	Black headed ibis	*Threskiornis melanocephalus*	P	P
4.	Painted stork	*Mycteria leucocephala*	P	P

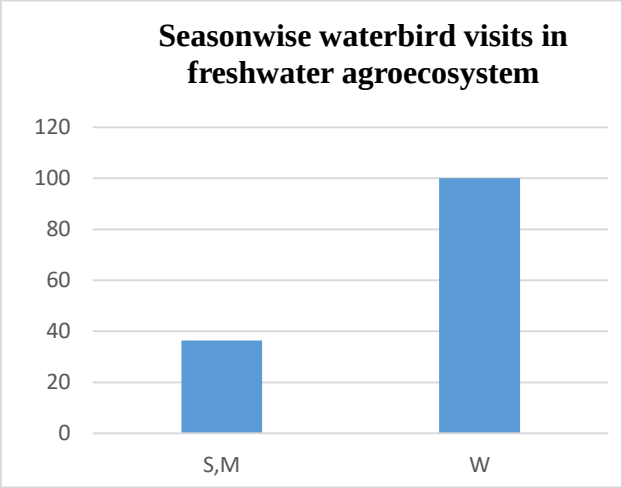

Fig 1. Water birds visit (season wise) in freshwater agroecosystem

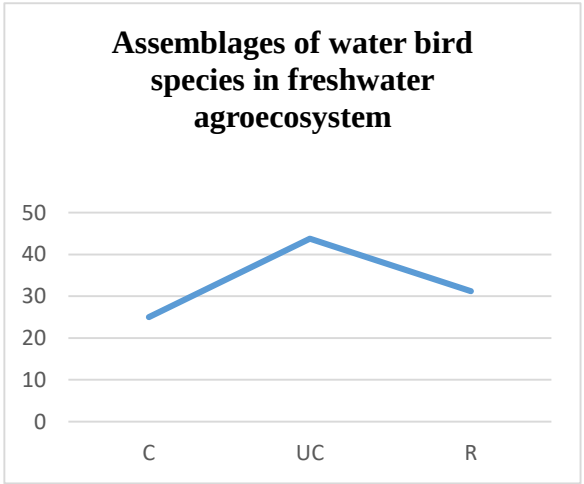

Fig 2: Water bird assemblages in freshwater agroecosystem

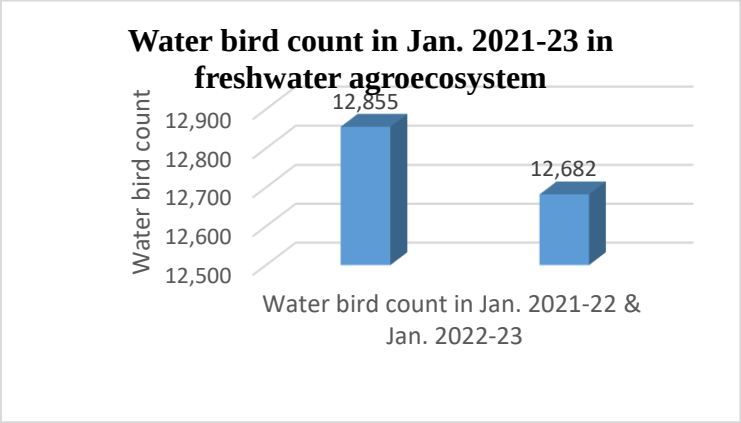

Fig 3. Compared the water bird count in Jan. 2021-23 in freshwater agroecosystem

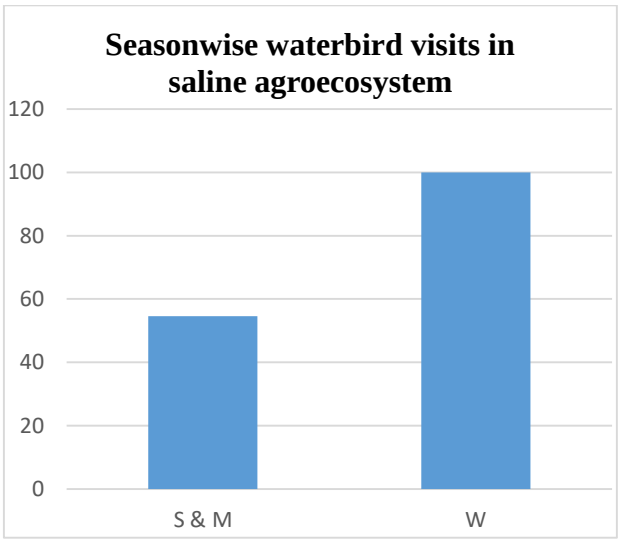

Fig 4. Water birds visit (season wise) in saline agroecosystem

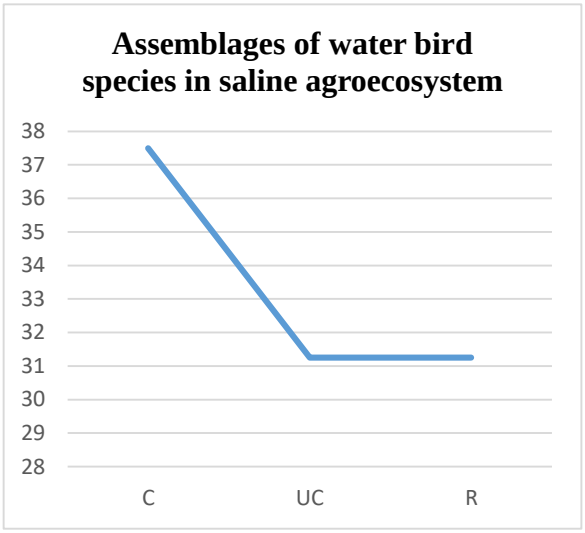

Fig 5. Water bird assemblages in saline agroecosystem

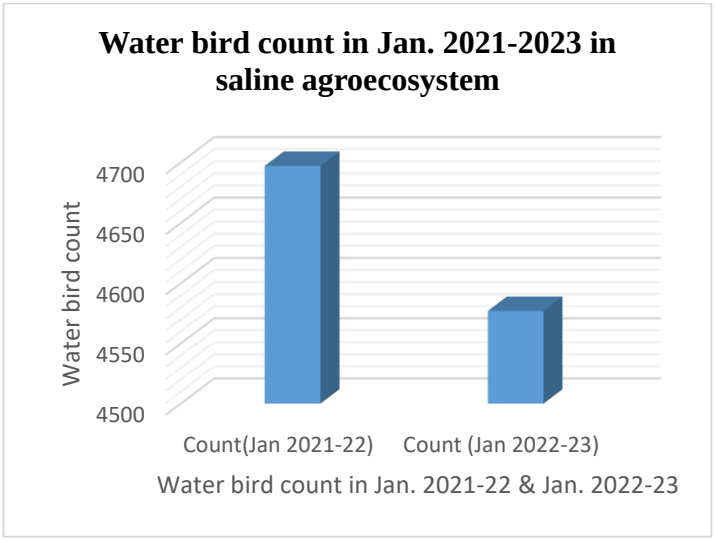

Fig 6. Water bird count in Jan. 2021-23 in saline agroecosystem

Discussion

Species abundance and Shannon – Wiener index of water bird species in agroecosystem during Jan. 2021 -Jan. 2023

The present study documented the diversity, habitat preference, assemblages of water bird species and environmental parameters in different study areas from Jan. 2021-Jan. 2023. Water birds were observed including egrets, herons, cormorants and darters. Along with that, we had observed different varieties of shore birds and globally threatened water bird species. Sampling sites are the major feeding grounds of many egrets, herons, cormorants and other water birds.

The Shannon-Wiener index is used to calculate the relative abundance and diversity of water birds in the different agroecosystem. In freshwater agroecosystem, Jan. 2021- Jan. 2022, the total number of water birds was 12,855 and the Shannon index was 4.41 (Table 4). In Jan. 2022- Jan. 2023, the total number of water birds was 12,682 and Shannon index was 6.24 (Table 5). In saline agroecosystem, the total number of water

birds during Jan. 2021-22 was 4697 and the Shannon index was 1.52 (Table 6). In Jan. 2022-23, the total number of water birds was 4577 and Shannon index was 3.12 (Table 7). The abundance of water birds was high in saline agroecosystem. Because, most of the time the study area contains high water levels. So, all water birds prefer their habitat including open water and water edged water bird species in saline areas. This is the reason why most water birds were observed in saline sites. Diversity of avifauna is one of the most important ecological indicators to evaluate the integrity and stability of ecosystem structure and functions (Kumar *et al.,* 2019). Wetlands are very important for the conservation of water birds. Many avian species are very limited in population and hence these are very close to extinction because of disturbance, destruction or conversion of their habitats and poaching by humans and animals (Arya *et al.,* 2019). Due to past and ongoing destruction and degradation of coastal and inland wetlands, many of these species are now threatened with extinction. Habitat protection is important to conserve bird communities. Large wetlands normally receive all the importance while smaller and isolated wetlands receive least attention and are often neglected from conservation priorities (Karikar *et al.,* 2021).

In India, 153 bird species are globally threatened (Deepa *et al.,* 2017). Three globally threatened water birds are observed in the Pokkali area, Alappuzha district (Narayanan, N., 2022). The Common pochard (*Aythya farina*), Marbled duck (*Marmaronetta angustirostris*), White headed duck (*Oxyura leucocephala*) are three globally threatened water birds collected from Morocco at winter time (Ouassou *et al.,* 2021). Four species of water birds are globally threatened and these are observed from our sampling sites. They are: oriental darter (*Anhinga melanogaster*), spot-billed pelican (*Pelecanus philippensis*) black headed ibis (*Threskiornis melanocephalus*) and painted stork (*Mycteria leucocephala).* 13 species of globally threatened shorebirds had been observed at Nijhum Dwip National Park (Chowdhury *et al.,* 2021). The blue winged goose (*Cyanochen cyanoptera*) observed from Lake Arekit, Southern Ethiopia. The abundance of globally threatened waterbirds has been reduced by the effect of invasive plant species, water hyacinth in Nepal (Basaula *et al.,* 2021). Globally threatened water birds are mainly threatened from anthropogenic factors (Ouassou *et al.,* 2021). The different shorebirds had been observed in paddy fields, i.e., black-tailed godwits (*Limosa limosa*), common greenshanks (*Tringa nebularia*), and wood sandpipers (*T. glareola*) (Choi *et al.,* 2022). Lesser Yellowlegs (*Tringa flaviped*) is a medium sized shorebird and it can be identified from interior Alaska (Martin *et al.,* 2022). 12 Plovers including Piping Plover (*Charadrius melodus*) from Michigan's Lake Superior Shoreline (Waterman *et al.,* 2022). Shorebirds are migratory and resident birds inhabiting different ecological conditions, mainly shorelines, inland and coastal wetlands, agricultural fields (Gutierrez *et al.,* 2015) and interior grasslands (Sivaperuman *et al.,* 2012).

Analysis of soil & water quality parameters in different agroecosystem

- **Water and soil quality measurement in freshwater agroecosystem**

Analysis of soil and water quality parameters was carried out in Jan. 2021-Jan. 2023. The Soil parameters such as pH, Total Nitrogen and Phosphorous, Potassium and Organic Carbon were analysed (Table 8). In Jan. 2021-22; pH, Total Nitrogen, Total Phosphorus, Potassium and Organic Carbon was 7.46, 2.96%, 1.15mg/kg, 3.4mg/kg, 34.4% respectively. In Jan. 2022-Jan 2023, pH, Total Nitrogen, Total Phosphorus, Potassium and Organic Carbon was 7.97, 2.96%, 1.15mg/kg, 3.28mg/kg, 30.2% respectively (Ramesh *et al.,* 2020).

Water quality parameters such as pH, Phosphate, Nitrate, Potassium, Ca+ ions, Mg+ ions and salinity were determined (Table 9). In Jan. 2021-Jan. 2022; pH, Phosphate, Nitrate, Potassium, Ca+ ions, Mg+ ions and salinity was 7.36, 0.07mg/l, 0.77mg/l, 3.26mg/l, 80.66mg/l, 96.33 and 0.522ppt respectively. In Jan. 2022-Jan. 2023, pH, Phosphate, Nitrate, Potassium, Ca+ ions, Mg+ ions and Salinity was 7.95, 0.04 mg/l, 0.75 mg/l, 2.90 mg/l, 70 mg/l, 82 and 0.83ppt respectively (Manju *et al*., 2012)

- **Water and soil quality measurement in Saline agroecosystem**

Analysis of soil and water quality parameters was carried out in Jan. 2021-Jan 2022. The soil parameters such as pH, Total Nitrogen and Phosphorous, Potassium and Organic Carbon were analysed (Table 10). In 2021; pH, Total Nitrogen, Total Phosphorus, Potassium and Organic Carbon was 7.51, 44.8%, 0.03mg/kg, 2.6mg/kg, 21.73% respectively. In Jan 2022-Jan 2023, pH, Total Nitrogen, Total Phosphorus, Potassium and Organic Carbon was 7.91, 44.8%, 0.03mg/kg, 2.4mg/kg, 20.66% respectively (Ramesh *et al.,* 2020).

Water quality parameters such as pH, Phosphate, Nitrate, Potassium, Ca+ ions, Mg+ ions and Salinity were determined (Table 11). In Jan. 2021-Jan. 2022; pH, Phosphate, Nitrate, Potassium, Ca+ ions, Mg+ ions and salinity was 7.75, 0.09mg/l, 0.73mg/l, 3.03mg/l, 147.4 mg/l, 46.60 and 1.02ppt respectively. In Jan. 2022-Jan. 2023, pH, Phosphate, Nitrate, Potassium, Ca+ ions, Mg+ ions and Salinity was 7.92, 0.09 mg/l, 0.50 mg/l, 3.1 mg/l, 1.28mg/l, 82 and 0.93ppt respectively.

Conservation aspects in different agroecosystem

Many water bird species are close to extinction because of habitat conversion and disturbance of other animals (Arya *et al.*, 2019). Human beings are the main threats to these areas that were observed during the study. Inland wetlands are now threatened by many factors. Protection of their habitat is one of the methods to conserve the water bird population (Karikar *et al.*, 2021). Heavy metals are the major pollutant threats to the wetland environment (Zhang *et al.*, 2022). Other threats being faced by the wetlands are habitat loss (Wang *et al.*, 2022), climate change (Gutierrez *et al.*, 2022), solid waste dumping (Narayanan, N., 2022), reclamation (Nameer *et al.*, 2015), pollution (Veeramani *et al.*, 2018), waterfowls hunting at wetlands (Waterman *et al.*, 2022), use of chemical pesticides (Anoop *et al.*, 2015), flood or sea level rise (Marchesiello *et al.*, 2019), microplastics (Raipar *et al.*, 2022), waste disposals, siltation, and intensive agricultural expansion (Tilahun *et al.*, 2022), building dams (Hasan *et al.*, 2020), disturbance by livestock (Mohsanin., 2014), accidental bycatch shore fishing nets (Chowdari *et al.*, 2021) results in the decline in water bird population. Migrant birds were disturbed by the action of tourists and local fishermen (Narayanan, N., 2022), Ferrel dogs (Narayanan, N *et al.*, 2023), Illegal killing (deliberate hunting, poisoning and trapping) (Gallo-Cajiao *et al.*, 2020). Threats identified for the shorebirds are trapping, lime shell mining, pesticide contamination (Kannan., 2012) and shorebirds in fishing gear (Chowdhury *et al.*, 2021). Urbanization is a threat that causes the extinction of many animals. In Kerala, wetland birds are adapted to fresh urban conditions (Charutha *et al.*, 2021).

Table 4. Relative abundance & Shannon- Wiener index in freshwater agroecosystem (Jan. 2021- Jan. 2022)

Sl.No.	Species	No. of water bird count (Jan. 2021-22)	Relative Abundance (Pi)	In (Pi)	Pi (In (Pi)
1.	Little egret	50	0.033	-5.80	-0.01
2.	Median egret	2016	0.156	-1.85	-0.28
3.	Large egret	4	3.111	1.13	3.51
4.	Indian pond heron	1070	0.083	-2.48	-0.20
5.	Western reef heron	0	0	0	0
6.	Grey heron	19	0.001	-6.90	-0.00
7.	Purple heron	82	0.006	-5.11	-0.03
8.	Little green heron	0	0	0	0
9.	Oriental ibis	47	0.003	-5.80	-0.01
10.	Glossy ibis	9033	0.702	-0.35	-0.24
11.	White-necked stork	0	0	0	0
12.	Black stork	0	0	0	0
13.	Asian openbill stork	34	0.002	-6.21	-0.01
14.	Little cormorant	472	0.036	-3.32	-0.11
15.	Large cormorant	0	0	0	0
16.	Darter	28	0.002	-6.21	-0.01
	Total	12,855			H=4.41 EH= 1.84

Table 5. Relative abundance & Shannon-Wiener Index in freshwater agroecosystem (Jan. 2022-Jan. 2023)

Sl.No.	Species	No. of water bird count (Jan. 2022-23)	Relative Abundance (Pi)	In (Pi)	Pi (In (Pi)
1.	Little egret	42	0.003	-5.80	-0.01
2.	Median egret	1834	0.144	-1.93	-0.27
3.	Large egret	5	3.942	1.37	5.40
4.	Indian pond heron	994	0.078	-2.55	-0.19
5.	Western reef heron	0	0	0	0
6.	Grey heron	14	0.001	-6.90	-0.00
7.	Purple heron	58	0.004	-5.52	-0.02
8.	Little green heron	0	0	0	0
9.	Oriental ibis	27	0.002	-6.21	-0.01
10.	Glossy ibis	9177	0.723	-0.32	-0.20
11.	White-necked stork	0	0	0	0
12.	Black stork	0	0	0	0
13.	Asian openbill stork	41	0.003	-5.80	-0.01
14.	Little cormorant	470	0.037	-3.29	-0.12

15.	Large cormorant	0	0	0	0
16.	Darter	20	0.001	-6.90	-0.00
	Total	12,682			H=-6.24 EH= 2.6

Table 6. Relative abundance & Shannon-Wiener Index in saline agroecosystem (Jan. 2021-Jan. 2022)

Sl.No.	Species	No. of water bird count (Jan. 2021-22)	Relative Abundance (Pi)	In (Pi)	Pi (In (Pi)
1.	Little egret	298	0.063	-2.76	-0.17
2.	Median egret	1617	0.344	-1.06	-0.36
3.	Large egret	41	0.008	-4.82	-0.03
4.	Indian pond heron	752	0.160	-1.83	-0.29
5.	Western reef heron	9	0.001	-6.90	-0.00
6.	Grey heron	109	0.023	-3.77	-0.08
7.	Purple heron	167	0.035	-3.35	-0.11
8.	Little green heron	0	0	0	0
9.	Oriental ibis	45	0.009	4.71	-0.04
10.	Glossy ibis	10	0.002	-6.21	-0.01
11.	White-necked stork	0	0	0	0
12.	Black stork	0	0	0	0
13.	Asian openbill stork	0	0	0	0
14.	Little cormorant	1556	0.331	-1.10	-0.36
15.	Large cormorant	0	0	0	0
16.	Darter	93	0.019	-3.96	-0.07
	Total	4697			H= -1.52 EH= 0.63

Table 7. Relative abundance & Shannon-Wiener index in saline agroecosystem (Jan. 2022-Jan.2023)

Sl.No.	Species	No. of water bird count (Jan. 2022-23)	Relative Abundance (Pi)	In (Pi)	Pi (In (Pi)
1.	Little egret	307	0.067	-2.70	-0.18
2.	Median egret	1371	0.299	-6.53	-1.95
3.	Large egret	58	0.012	-4.42	-0.05
4.	Indian pond heron	828	0.180	-1.71	-0.30
5.	Western reef heron	6	0.001	-6.90	0.00
6.	Grey heron	102	0.022	-3.81	-0.08
7.	Purple heron	146	0.031	-3.47	-0.10
8.	Little green heron	0	0	0	0
9.	Oriental ibis	48	0.010	-4.60	-0.04
10.	Glossy ibis	0	0	0	0
11.	White-necked stork	0	0	0	0
12.	Black stork	0	0	0	0
13.	Asian openbill stork	0	0	0	0
14.	Little cormorant	1639	0.358	-1.02	-0.36
15.	Large cormorant	0	0	0	0
16.	Darter	72	0.015	-4.19	-0.06
	Total	4577			H= -3.12 ZEH= 1.3

Table 8. Soil quality measurements in freshwater agroecosystem (Jan. 2021-22 & Jan. 2022-23)

Sl.No.	Soil	Parameters	Jan. 2021-22	Jan. 2022-23
1.	Habitat type	Freshwater agroecosystem		
2.	Ph	6.5-8.0	7.46	7.97
3.	Total Nitrogen (N) (%)	0.5-1.0	2.96	2.96
4.	Total Phosphorous (P) (mg/kg)	10-25	1.15	1.15
5.	Potassium (K) (mg/kg)	50-125	3.4	3.28
6.	Organic Carbon (OC) (%)	0.75-1.5	34.4	30.20

Table 9. Water quality measurements in freshwater agroecosystem (Jan. 2021-22 & Jan. 2022-23)

SlNo.	Water (Parameter)	Desirable limits as per IS: 10500-2012	Jan. 2021-22	Jan. 2022-23
1.	Habitat type	Freshwater agroecosystem		
2.	Ph	6.5-8.5/l	7.36	7.95

3	Phosphate	0.1mg/l	0.07	0.04
4.	Nitrate	45mg/l as NO3	0.77	0.75
5	Pottassium	300mg/l as CaCO3	3.26	2.90
6.	Ca+ ions	75mg/l	80.66	70
7.	Mg + ions	80mg/l	96.33	82
8.	Salinity	3ppt	0.522	0.83

Table 10. Soil quality measurements in saline agroecosystem (Jan. 2021-22 & Jan. 2022-23)

Sl.No.	Soil	Parameters	Jan. 2021-22	Jan. 2022-23
1.	Habitat type	Saline agroecosystem		
2.	pH	6.5-8.0	7.51	7.91
3.	Total Nitrogen (N) (%)	0.5-1.0	44.8	44.8
4.	Total Phosphorous (P) (mg/kg)	10-25	0.03	0.03
5.	Potassium (K) (mg/kg)	50-125	2.6	2.4
6.	Organic Carbon (OC) (%)	0.75-1.5	21.73	20.66

Table 11. Water quality measurements in saline agroecosystem (Jan. 2021-22-Jan. 2022-23)

Sl No.	Water (Parameter)	Desirable limits as per IS: 10500-2012	Jan. 2021-22	Jan. 2022-23
1.	Habitat type	Saline agroecosystem		
2.	Ph	6.5-8.5/l	7.75	7.84
3	Phosphate	0.1mg/l	0.09	0.09
4.	Nitrate	45mg/l as NO3	0.73	0.50
5	Pottassium	300mg/l as CaCO3	3.03	3.1
6.	Ca+ ions	75mg/l	40.93	1.28
7.	Mg + ions	80mg/l	8.06	1.0
8.	Salinity	3ppt	1.02	1.13

Conclusion

Agroecosystem are the ecologically productive wetlands and protect many water birds, shorebirds and globally threatened water bird species. Water birds use the agroecosystem for feeding and roosting ground of many egrets, herons, cormorants, shorebirds and also support important populations of globally threatened water bird species such as oriental darter, spot-billed pelican, black headed ibis and painted stork. Anthropogenic activities are the major threats of these water birds and it cause the decreasing water bird count in different sampling sites.

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