Original Research Article

Diversity and abundance of wetland birds in Udayamarthandapuram Bird Sanctuary, Tiruvarur district, Tamil Nadu, India

Abstract

Wetland birds are integral components of wetland ecosystems, providing ecological, economic, cultural, and regulatory benefits. The study conducted from 2021 to 2024 in the Udayamarthandapuram Bird Sanctuary of Tiruvarur district aimed to assess year-wise species diversity, richness, relative diversity, evenness, density, and relative abundance of wetland birds. A total of 104 bird species comprising 18 orders and 49 families were recorded. During this study, 17 species were migrant, while the remaining 87 birds were resident. Three bird species were classified as Near Threatened, including the Spot-billed Pelican (Pelecanusphilippensis), Black-headed Ibis (Threskiornismelanosephalus), and Oriental Darter (Anhinga melanogaster). Additionally, two bird species were classified as Vulnerable, namely the Greater Spotted Eagle (Clanga clanga) and River Tern (Sterna hirundo), while 99 bird species were classified as Least Concern. Regarding species diversity in the Udayamarthandapuram Bird Sanctuary during different years, the highest species diversity was recorded in 2021 (2.75), while the lowest species diversity was observed in 2024 (1.64). In terms of species richness, the maximum richness was observed in 2023 (68), whereas the minimum species richness was recorded in 2022 (29).

Keywords: - *Wetland, Water birds, Udayamarthandapuram bird sanctuary, Year-wise Variations, Species diversity*

Introduction

Wetlands are transitional zones between permanently aquatic and dry terrestrial eco-systems. Wetlands, which encompass roughly 6% of the Earth's land area, comprise various types including marshes, lagoons, bogs, fens, open water bodies, and mangroves (Ramamurthy and Rajakumar, 2014). According to the Ramsar convention of the IUCN at Iran in 1981, Wetland is an “Area of marsh, fen, peatland or water whether natural or artificial, permanent or temporary with water, that is static or flowing, fresh, brackish or salt including areas of marine water, the depth of which does not exceed 6 meters” (Ramsar convention, 2004; Gupthaet *al.*, 2011). Wetlands, thesecond most productive ecosystems after

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tropical rainforests (Ekhande *et al*., 2012), nurturemigratoryaquaticavianandresidentavianspecies,enhancingwetlandrichnessandproductivity(Gibbs,1993;Paracuellos,2006).Wetlands serve as crucial habitats for birds, providing essential areas for feeding, roosting, and breeding. Wetlands are facing lot of threats and the primary threat to wetlands is human activity, including urbanization, agricultural expansion, pollution, drainage for development, and climate change. These factors have resulted in significant impacts on wildlife populations, water quality, hydrological cycles, and other vital functions and values of wetlands. It can be anticipated that migratory species are more vulnerable to threats because they rely on different sites and habitats during breeding and non-breeding seasons. A threat affecting just one of these areas could have a significant impact (Salathe, 1991). Numerous studies indicate that habitat destruction is a primary cause of bird population decline. For instance, it has been reported that over 90% of globally threatened birds and 86% of other bird species face serious threats primarily due to habitat degradation (Kauzeni and Kiwasila, 1994; Kidegheshoet *al.*, 2006). Information on the status and distribution of threatened and endemic birds, therefore, assists in predicting disturbance levels and implementing conservation measures at all potential sites where they occur. In 2000, the 'Threatened Birds of the World' listed 1,186 species worldwide and 123 species in India (Kaur, and Brraich, 2021). So, the preserving wetlands is critical to protecting endangered and threatened species (Abir *et al*., 2014). The Udhayamarthandapuram Bird Sanctuary serves as a vital habitat for numerous wetland birds, including both threatened and migratory species. Despite its significance, there has been a noticeable lack of systematic studies focusing on wetland birds, particularly regarding yearly patterns, diversity, evenness, richness, and density. Therefore, this study was conducted with the primary aim of conducting an inventory of wetland birds within the Udhayamarthandapuram Bird Sanctuary.

Materials and Methods

Study Area

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The UdayamarthandapuramBird Sanctuary, situated in the Thiruvarur District of the Indian state of Tamil Nadu, was designated as a protected area in December 1999. Spanning approximately 0.45 km^2, this sanctuary is a vital habitat for a diverse range of bird species. Positioned at coordinates 10°26’59’N 79°27’58’E and the sanctuary comprises human-made irrigation tanks interconnected by an ancient network of canals, which are primarily fed by the Mettur dam through the Koraiyar canal and receives water in the northeast monsoon from August to December. However, the tank typically dries up between April and August. Additionally, the sanctuary plays a crucial role in replenishing groundwater and nourishing adjacent smaller wetlands and agricultural areas. However, the site faces

various threats, including storms, flooding, unregulated harvesting of aquatic resources, and recreational and tourism activities.

Methodology

The field survey was conducted over the past three years, from 2021 to 2024, utilizing the total count method. Researchers walked within and around the wetlands or stationed themselves at specific vantage points to observe and count all birds whenever feasible (Gupta *et al.,* 2011). Surveys were conducted during the dawn and dusk periods, from 6:30 am to 10:00 am in the morning and 4:00 pm to 6:30 pm in the evening. Binoculars (Nikon 7x50) were used for observations, and bird photography was facilitated with a Nikon P900 camera. Bird identification was corroborated with the assistance of reference books such as "Birds of the Indian Subcontinent" (Grimmett *et al.,* 1999) and "The Book of Indian Birds" by Salim Ali (1996).

Comment [hi4]: Explain this wetland ecosystem in detail! Are there any plant species growing at the research location? Which is a dominant? How long, how many hours, or how often do you observe birds in a month or year?

Data Analysis

Shannon-Weiner index of diversity (Shannon and Wiener, 1963) was used to assess the bird species diversity in Udayamarthandapuram Bird Sanctuary.

The formula for calculating the Shannon diversity index is

$$H' = -\sum Pi \, Ln \, Pi$$

Where H' = Shannon index of diversity, Pi = the proportion of the ith species in the landscape element, Ln Pi = Natural logarithm of the proportion of each species.

Richness was calculated by counting the number of species observed in a particularseasonand particularplace (HarishaandHosetti, 2009).

$$Speciesrichness = Numberofspeciesrecorded$$

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Pielou's evenness index was utilized to estimate the species evenness within the Udayamarthandapuram Bird Sanctuary. This index provides a measure of how evenly distributed the individuals are among different species, indicating the level of evenness in the community (Ekhande *et al.,* 2012).

$$Evenness/Equitability = H'/H'max$$

Where, H' = Value recorded from Shannon-Weiner diversity index and H' max = Maximum possible value of H'.

The Relative Abundance (Anjos, 2004 and Ayenalem& Bekele, 2008) was analyzed from the collected data during the study period using the following formula:

$$\text{Relative Abundance} = \frac{\text{Number of individual of species}}{\text{Number of individuals of all species}} \times 100$$

The density is an utterance of the numerical strength of a particular species where the total number of individuals of each species in a particular season divided by the total area of the wetland (Ramamurthy and Rajakumar, 2014).

Results and Discussion

The current study informed that totally 104 bird species comprising of 18 orders and 49 families were recorded during last 4 years in Udayamarthandapuram bird sanctuary. During this study, 17 species were migrant and the remaining 87 birds were resident and three birds were under Near Threatened viz., Spot billed Pelican *Pelacanusphilippensis*, Black Headed Ibis *Threskiornismelanosephalus*and Oriental Darter *Anhinga melanogaster*; two birds were under Vulnerable viz., Greater Spotted Eagle *Clanga clanga* and River Tern *Sterna hirundo* and 99 birds are under Least concern were recorded (Figure 1). The previous study was conducted by Ramamurthy and Rajakumar (2014) in the Udhayamarthandapuram Bird Sanctuary during 2011 to 2012. They recorded forty species of water birds belonging to 14 families.This research finding aligns with the findings of Baranidharan*et al.* (2022), which identified a total of 36 bird species across 13 families and 4 orders in the Karaivetti Bird Sanctuary. Among these, six Near Threatened species were observed, including the Oriental darter (*Anhinga melanogaster*), Painted Stork (*Mycteria leucocephala*), Spot-billed Pelican (*Pelecanusphilippensis*), White-necked Stork (*Ciconia episcopus*), White Ibis (*Threskiornismelanocephalus*), and Black-Tailed Godwit (*Limosalimosa*), along with one IUCN Red List Vulnerable Species, the River Tern (*Sterna aurantia*). A similar study conducted by Krishnamoorthi *et al.* (2020) in the Vellode Bird Sanctuary found 72 bird species across 38 families and 17 orders, with three Near Threatened species: the Oriental darter (*Anhinga melanogaster*), Painted Stork (*Mycteria leucocephala*), and Spot-billed Pelican (*Pelecanusphilippensis*). Additionally, Vas *et al.* (2023) conducted a similar analysis in Neyveli Lignite Corporation India Limited (NLCIL) in Neyveli, Tamil Nadu, identifying 107 different bird species comprising 21 orders and 45 families, with three Near Threatened species.

Comment [hi6]: You only reveal the results of the research but don't discuss why the data is like this or like that. The reasons underlying these changes from year to year or why the value of certain birds is higher or lower compared to the value of other birds are not explained in detail.

Comment [hi7]: It must be capitalized. Check and please revise other similar errors

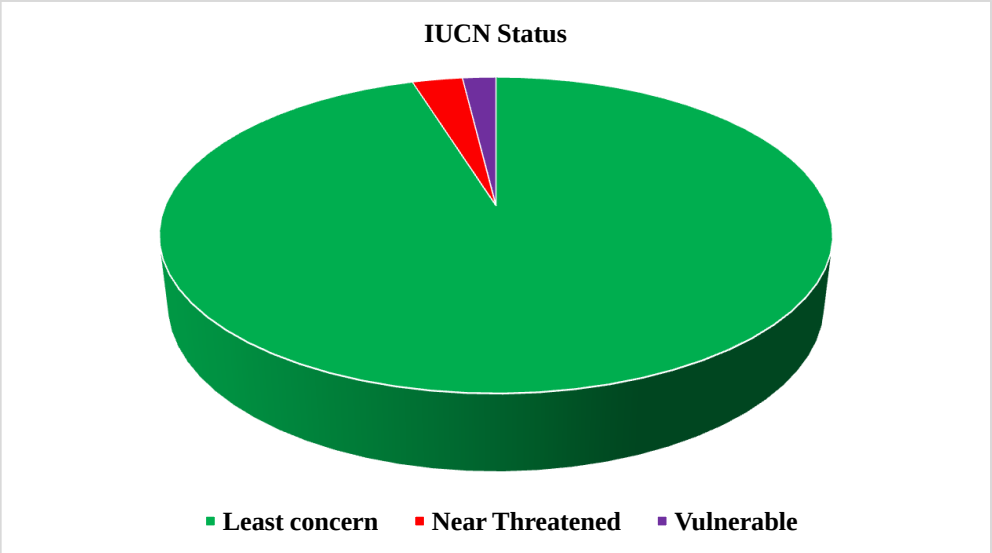

Figure 1. IUCN status of Udayamarthandapuram bird sanctuary

Species diversity

Pertaining to the species diversity in Udayamarthandapurambird sanctuary during different years, the highest species diversity was recorded in the 2021 (2.75) followed by 2023 (2.24) and 2022 (1.80) while the lowest species diversity was obtained in the 2024 (1.64). Similar findings were reported by Manohara *et al.* (2016) in their analysis of species diversity in the Magadi Bird Sanctuary, Karnataka. They noted that the maximum diversity was observed in 2012-2013 (1.01), while the minimum diversity was recorded in 2015-2016 (0.64). Regarding to the species richness of Udayamarthandapuram bird sanctuary, the maximum richness was observed in the 2023 (68) followed by 2024 (57) and 2021 (48) while the minimum species richness was recorded in the 2022 (29). The previous studies in Udhayamarthandam bird sanctuary revealed that the species diversity of 1.47 was recorded by Gupth*aet al.* (2011) during January to March 2006.Concerning to evenness of Udayamarthandapuram bird sanctuary the highest evenness was obtained during 2021 (0.37) followed by 2023 (0.27) and 2024 (0.19) whereas the lowest evenness was recorded during 2022 (0.18) (Table 1 & Figure 2 & 3). The results were consistent with the findings of Anika and Parasharya (2013), who observed maximum evenness during summer (0.6273 ± 0.0518) and minimum evenness in winter (0.5117 ± 0.0285).

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Comment [hi9]: Capital font. Rather than often writing letters incorrectly, you should always use abbreviations after the phrase is written completely the first time; for example Udaya..... Bird Sanctuary (UBS).

Table 1. Year-wise avian species diversity, total density richness and evenness of Udayamarthandapuram bird sanctuary

Year	Total density	Richness	Diversity	Evenness
2021	39.36	48	2.75	0.37
2022	526.41	29	1.80	0.18
2023	95.73	68	2.24	0.27
2024	156.69	57	1.64	0.19

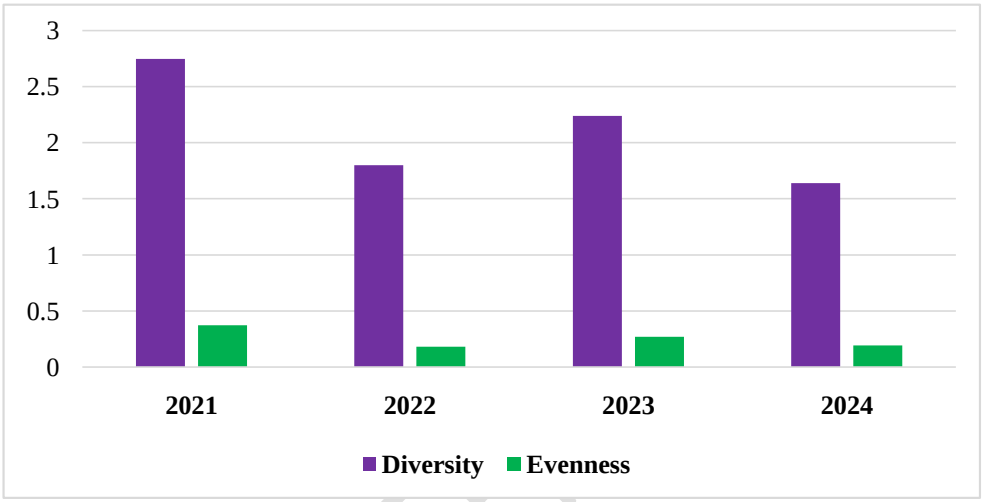

Figure 2. Year-wise avian diversity and evenness of Udayamarthandapuram bird sanctuary

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Total density

The current investigation revealed that the highest total density of Udayamarthandapuramlake was obtained in 2022 (526.41/ha) followed by 2024 (156.69/ha) and 2023 (95.73/ha) whereas the lowest total density was recorded in 2021 (39.36/ha) (Table 1 & Figure 3). This result aligns with the findings of Krishnamoorthi *et al.* (2020), who noted that the maximum total density was observed during the monsoon season (1556.99/sq.km), while the lowest density was observed during the winter season (948.18/sq.km).Based on the study data, the maximum species density was quantified in the Baya weaver (9.840/ha) followed by Rosy Starling (9.201/ha) and Common Myna (2.694/ha) while the minimum species density was occurred in the Small Minivet (0.046/ha) followed by Ashy Prinia (0.068/ha), Yellow Wagtail (0.068/ha), Golden Oriole (0.068/ha) and Common Woodshrike (0.068/ha) in 2021. In 2022, the highest species density was observed in the Asian Openbill (164.315/ha) followed by Black -Headed Ibis (134.155/ha), Indian Shag (98.744/ha) and Little Cormorant (58.630/ha) and the lowest species density (0.023/ha) was noted in the Little

Heron, Yellow Bittern and Common coot. In 2023, the maximum species density was found in the Asian Open bill (34.247/ha) followed by Black headed Ibis (27.397/ha), Little Cormorant (9.132/ha) and Little Egret (2.283/ha) whereas the minimum species density (0.023/ha) was obtained in the Eurasian Hoopoe, Indian Blue Robin, Sirkeer Malkoha, Asian Brown Flycatcher, Long tailed shrike, Shikra, Pheasant tailed Jacana, Cinnamon Bittern and Whiskered Tern. In 2024, the highest species density was registered in the Black-headed Ibis (89.041/ha) followed by Asian Openbill (36.530/ha) and Grey Heron (4.384/ha) and the lowest species density (0.023/ha) was observed in the Common Snipe, Common Sandpiper, Common Woodshrike, Brown Shrike, Orange-headed Thrush and Tricolored Munia (Table 2, 3, 4&5). This result was in consonance with the results of Baranidharan*et al*. (2022) who stated that the maximum density was recorded in Large egret (57/sq. km) followed by Cattle Egret(56/sq.km), Little Cormorant (50/sq.km), Spot Bill duck (32/sq.km) and the lowest density as recorded in Darter, Purple Heron, Eurasian Spoon Bill and Common Teal (1.5/sq.km) in Karaivetti Bird Sanctuary.

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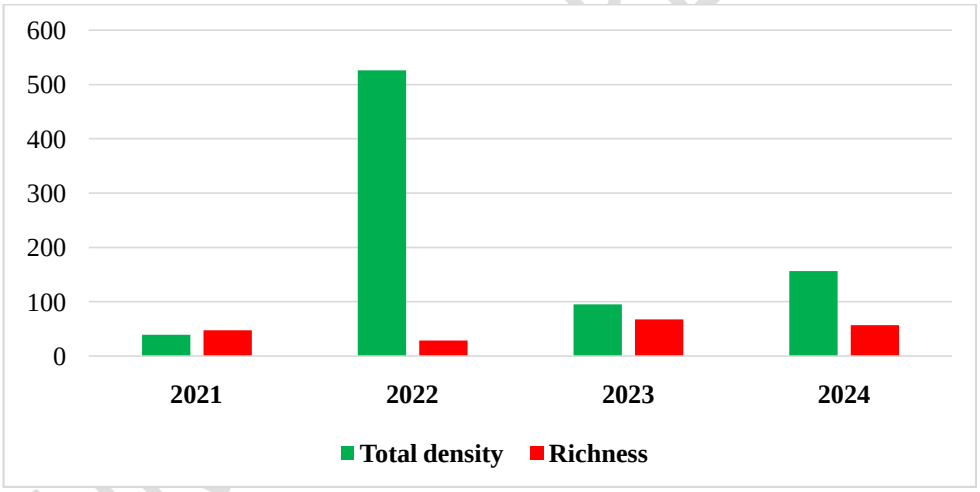

Figure 3. Year-wise avian density and richness of Udayamarthandapuram bird sanctuary

Relative abundance

Concerning to the relative abundance during four different years, the highest relative abundance was obtained in the Baya weaver (25.00%) followed by Rosy Starling (23.376%) and Common Myna (6.845%) while the lowestrelative abundance was reported in the Small Minivet (0.116%) followed by Ashy Prinia (0.174%), Yellow Wagtail (0.174%), Golden Oriole (0.174%) and Common Woodshrike (0.174%) in 2021. In 2022, the maximum relative

abundance was noted in the Asian Openbill (31.218%) followed by Black-Headed Ibis (25.488%), Indian Shag (18.760%) and Little Cormorant (11.139%) and the minimum relative abundance (0.004%) was noted in the Little Heron, Yellow Bittern and Common coot. In 2023, the highest relative abundance was observed in the Asian Open bill (35.774%) followed by Black headed Ibis (28.619%), Little Cormorant (9.540%) and Little Egret (2.385%) whereas the lowestrelative abundance (0.024%) was recorded in the Eurasian Hoopoe, Indian Blue Robin, Sirkeer Malkoha, Asian Brown Flycatcher, Long tailed shrike, Shikra, Pheasant tailed Jacana, Cinnamon Bittern and Whiskered Tern.In 2024, the maximum relative abundance was noted in the Black-headed Ibis (56.835%) followed by Asian Openbill (23.317%) and Grey Heron (2.798%) and the minimum relative abundance (0.015%) was observed in the Common Snipe, Common Sandpiper, Common Woodshrike, Brown Shrike, Orange-headed Thrush and Tricolored Munia (Table 2, 3, 4 & 5). Bibi *et al.* (2003) reported similar findings in the Taunsa Barrage Wildlife Sanctuary, Pakistan, where they observed Eurasian Coot as the most abundant species (13.3%), followed by Cattle Egret (12.3%), Little White Egret (11.5%), Common Pochard (8.9%), House Crow (5.8%), and so forth.

Table 2. Avian density and relative abundance during 2021 of Udayamarthandapuram Bird Sanctuary

S.No.	Species name	Density	Relative abundance
1.	Black Ibis	0.137	0.348
2.	Common Crow	1.073	2.726
3.	Large billed Crow	0.297	0.754
4.	Indian Treepie	0.091	0.232
5.	Common Swallow	0.548	1.392
6.	Asian palm Swift	0.822	2.088
7.	Common Tailor bird	0.114	0.290
8.	Ashy Prinia	0.068	0.174
9.	Plain Prinia	0.114	0.290
10.	Pied Crested Cuckoo	0.297	0.754
11.	Greater Coucal	0.228	0.580
12.	Asian Koel	0.274	0.696
13.	Black Drango	1.187	3.016
14.	White-browed Wagtail	0.091	0.232
15.	Yellow Wagtail	0.068	0.174
16.	Brahminy Kite	0.662	1.682
17.	Black Kite	0.160	0.406
18.	Black Shoulder Kite	0.091	0.232
19.	Greater Spotted Eagle	0.114	0.290
20.	Barn Owl	0.205	0.522
21.	Spotted Owl	0.205	0.522

Comment [hi12]: tables 2, 3, 4, 5 can be combined into one table. The alternative is to create graphic illustrations. Through graphs, readers can easily see changes in parameter values from year to year

Comment [hi13]: What does this data mean? You should discuss the reasons why one data is greater, lower, or even the same as another data.Also discuss why bird data in certain years is higher, lower, or the same as bird data in other years

22.	Common Myna	2.694	6.845
23.	Rosy Starling	9.201	23.376
24.	Brahminy Starling	1.553	3.944
25.	Rose Ringed Parakeet	0.594	1.508
26.	Purple Sunbird	0.457	1.160
27.	Purple-rumped Sunbird	0.457	1.160
28.	Spotted Dove	0.571	1.450
29.	Ring-necked dove	0.434	1.102
30.	Indian Roller	0.091	0.232
31.	Small Bee-eater	0.685	1.740
32.	Blue-tailed Bee eater	0.205	0.522
33.	Indian Peafowl	1.781	4.524
34.	Grey francolin	0.548	1.392
35.	Scaly-breasted Munia	0.502	1.276
36.	Black-headed Munia	0.114	0.290
37.	Golden Oriole	0.068	0.174
38.	Baya weaver	9.840	25.000
39.	Oriental magapie-robin	0.205	0.522
40.	Indian paradise flycatcher	0.320	0.812
41.	Yellow-billed babbler	0.959	2.436
42.	Blyth's reed warbler	0.091	0.232
43.	Red-vented Bulbul	0.457	1.160
44.	Red-wiskered Bulbul	0.251	0.638
45.	Ashy-crowned sparrow-lark	0.228	0.580
46.	Black-rumbedFlameback	0.091	0.232
47.	Small Minivet	0.046	0.116
48.	Common Woodshrike	0.068	0.174

Table 3. Avian density and relative abundance during 2022 of Udayamarthandapuram Bird Sanctuary

S.No.	Species name	Density	Relative abundance
1.	Little Grebe	0.068	0.013
2.	Little Cormorant	58.630	11.139
3.	Indian Shag	98.744	18.760
4.	Darter	1.393	0.265
5.	Little Heron	0.023	0.004
6.	Yellow Bittern	0.023	0.004
7.	Grey Heron	7.443	1.414
8.	Purple Heron	4.247	0.807
9.	Indian Pond Heron	3.630	0.690
10.	Black-crowned Night Heron	27.694	5.262
11.	Cattle Egret	14.429	2.741
12.	Little Egret	3.721	0.707
13.	Intermediate Egret	1.667	0.317
14.	Large Egret	0.502	0.095
15.	Asian Openbill	164.315	31.218
16.	Black -Headed Ibis	134.155	25.488
17.	Glossy Ibis	1.210	0.230

18.	Common Moorhen	0.114	0.022
19.	Indian Purple Moorhen	2.192	0.416
20.	White-breasted waterhen	0.274	0.052
21.	Common coot	0.023	0.004
22.	Pheasant-tailed Jacana	0.137	0.026
23.	Red-wattled Lapwing	0.799	0.152
24.	Common Sandpiper	0.091	0.017
25.	Black winged Stilt	0.228	0.043
26.	River Tern	0.114	0.022
27.	Indian Pied Kingfisher	0.068	0.013
28.	Small Blue Kingfisher	0.228	0.043
29.	Whiter-breasted Kingfisher	0.251	0.048

Table 4. Avian density and relative abundance during 2023 of Udayamarthandapuram Bird Sanctuary

S.No.	Species name	Density	Relative abundance
1.	Indian Peafowl	0.868	0.906
2.	Rock Pigeon	0.114	0.119
3.	Eurasian Collared Dove	0.845	0.882
4.	Spotted Dove	0.548	0.572
5.	Greater Caucal	0.160	0.167
6.	Pied Cuckoo	0.228	0.238
7.	Asian Koel	0.228	0.238
8.	Common Hawk-Cuckoo	0.274	0.286
9.	Asian Palm Swift	1.027	1.073
10.	White-breasted waterhen	0.114	0.119
11.	Red-Wattled Lapwing	0.228	0.238
12.	Common Sandpiper	0.046	0.048
13.	Eurasian Hoopoe	0.023	0.024
14.	Green Bee-Eater	0.320	0.334
15.	Blue-tailed bee-Eater	0.183	0.191
16.	Black-RumpedFlameback	0.046	0.048
17.	Rose ringed Parakeet	0.274	0.286
18.	Indian Golden Oriole	0.228	0.238
19.	Black Drongo	0.342	0.358
20.	Rufous Treepie	0.137	0.143
21.	House Crow	0.320	0.334
22.	Indian Jungle Crow	0.251	0.262
23.	Common Tailorbird	0.297	0.310
24.	Blyth's Red Warbler	0.685	0.715
25.	Red vented Bulbul	0.913	0.954
26.	White-Browed Bulbul	1.370	1.431
27.	Yellow billed babbler	0.913	0.954
28.	Brahminy Starling	0.616	0.644
29.	Common Myna	1.142	1.192
30.	Oriental Magie Robin	0.046	0.048
31.	Indian Blue Robin	0.023	0.024
32.	Common Iora	0.137	0.143

33.	Pale billed Flower peaker	0.137	0.143
34.	Purple Rumbed sunbird	0.274	0.286
35.	Purple Sun bird	0.091	0.095
36.	White Browed wagtail	0.091	0.095
37.	Blue paled Malkoha	0.091	0.095
38.	Sikkeer Malkoha	0.023	0.024
39.	Grey billed Cuckoo	0.046	0.048
40.	Brown Strike	0.046	0.048
41.	Loten's Sunbird	0.114	0.119
42.	Asian Brown Flycatcher	0.023	0.024
43.	Indian Paradise Flycatcher	0.091	0.095
44.	Common Wood shrike	0.776	0.811
45.	Brahminy Kite	0.274	0.286
46.	Long tailed shrike	0.023	0.024
47.	Shikra	0.023	0.024
48.	Wood sandpiper	0.137	0.143
49.	Asian Open bill	34.247	35.774
50.	Black winged stilt	1.370	1.431
51.	Pheasant tailed Jacana	0.023	0.024
52.	Grey Heron	0.913	0.954
53.	Purple Heron	0.068	0.072
54.	Indian Pond Heron	0.913	0.954
55.	Little Cormorant	9.132	9.540
56.	Oriental Darter	0.114	0.119
57.	Great Egret	1.370	1.431
58.	Little Egret	2.283	2.385
59.	Intermediate Egret	0.913	0.954
60.	Cattle Egret	0.685	0.715
61.	Black headed Ibis	27.397	28.619
62.	Common Kingfisher	0.091	0.095
63.	Pied Kingfisher	0.160	0.167
64.	White Throated Kingfisher	0.342	0.358
65.	Grey headed Swamp hen	0.342	0.358
66.	Cinnamon Bittern	0.023	0.024
67.	Painted Stork	0.114	0.119
68.	Whiskered Tern	0.023	0.024

Table 5. Avian density and relative abundance during 2024 of Udayamarthandapuram Bird Sanctuary

S.No.	Species name	Density	Relative abundance
1.	Lesser Whistling-Duck	0.571	0.364
2.	Indian Peafowl	0.160	0.102
3.	Gray Francolin	0.274	0.175
4.	Eurasian Collared-Dove	0.913	0.583
5.	Spotted Dove	0.548	0.350
6.	Southern Coucal	0.091	0.058
7.	Blue-faced Malkoha	0.183	0.117
8.	Pied Cuckoo	0.160	0.102

9.	Asian Koel	0.297	0.189
10.	Common Hawk-Cuckoo	0.137	0.087
11.	Asian Palm-Swift	0.388	0.248
12.	Eurasian Moorhen	0.274	0.175
13.	Gray-headed Swamphen	0.959	0.612
14.	White-breasted Waterhen	0.411	0.262
15.	Black-winged Stilt	1.872	1.195
16.	Red-wattled Lapwing	0.342	0.219
17.	Bronze-winged Jacana	0.114	0.073
18.	Common Snipe	0.023	0.015
19.	Common Sandpiper	0.023	0.015
20.	Green Sandpiper	0.091	0.058
21.	Wood Sandpiper	1.575	1.006
22.	Asian Openbill	36.530	23.317
23.	Oriental Darter	0.479	0.306
24.	Little Cormorant	2.717	1.734
25.	Indian Cormorant	0.365	0.233
26.	Spot-billed Pelican	0.388	0.248
27.	Black Bittern	0.046	0.029
28.	Grey Heron	4.384	2.798
29.	Purple Heron	1.553	0.991
30.	Great Egret	1.667	1.064
31.	Little Egret	0.365	0.233
32.	Indian Pond-Heron	1.416	0.904
33.	Striated Heron	0.068	0.044
34.	Black-crowned Night-Heron	1.301	0.831
35.	Glossy Ibis	0.068	0.044
36.	Black-headed Ibis	89.041	56.835
37.	Brahminy Kite	0.114	0.073
38.	Common Kingfisher	0.160	0.102
39.	White-throated Kingfisher	0.114	0.073
40.	Green Bee-eater	0.183	0.117
41.	Black-rumpedFlameback	0.046	0.029
42.	Rose-ringed Parakeet	0.411	0.262
43.	Common Woodshrike	0.023	0.015
44.	Black Drongo	0.320	0.204
45.	Indian Paradise-Flycatcher	0.046	0.029
46.	Brown Shrike	0.023	0.015
47.	Rufous Treepie	0.137	0.087
48.	House Crow	0.183	0.117
49.	Plain Prinia	0.091	0.058
50.	Red-vented Bulbul	0.411	0.262
51.	Yellow-browed Bulbul	0.685	0.437
52.	Yellow-billed Babbler	1.142	0.729
53.	Brahminy Starling	2.374	1.516
54.	Common Myna	0.342	0.219
55.	Orange-headed Thrush	0.023	0.015
56.	Oriental Magpie Robin	0.046	0.029

57.	Tricolored Munia	0.023	0.015

Conclusion

The study conducted over four years in Udayamarthandapuram Bird Sanctuary recorded 104 bird species, including migrant and resident species. Three species were Near Threatened, and two were Vulnerable according to the IUCN Red List. Comparison with previous studies highlighted the sanctuary's regional importance for avian diversity. Fluctuations in species diversity, richness, and evenness across years emphasized the need for ongoing conservation efforts. Overall, these findings not only contribute to the scientific understanding of avian ecology but also have implications for the conservation and management of Udayamarthandapuram Bird Sanctuary and similar habitats. Continued research and monitoring efforts are essential for ensuring the preservation of biodiversity in the face of environmental challenges.

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Comment [hi14]: learn and apply the rules for writing references correctly or consistently

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Appendix 1. Species composition of wetland birds and wetland associated birds of Udayamarthandapuram Bird Sanctuary

S.No.	Order	Family	Species	Scientific name	IUCN Status	Migration Status	2021	2022	2023	2024
1.	Accipitriformes	Accipitridae	Black kite	*Milvus migrans*	LC	R	✓			
2.			Black Shoulder Kite	*Elanus caeruleus*	LC	R	✓			
3.			Brahminy Kite	*Haliasturindus*	LC	R	✓		✓	✓
4.			Greater Spotted Eagle	*Clanga clanga*	VU	M	✓			
5.			Shikra	*Accipiter badius*	LC	R			✓	
6.	Anseriformes	Anatidae	Lesser Whistling Duck	*Dendrocygnajavanica*	LC	R				✓
7.	Bucerotiformes	Upupidae	Eurasian hoopoe	*Upupa epops*	LC	R			✓	
8.	Caprimulgiformes	Apodidae	Asian Palm-Swift	*Cypsiurusbalasiensis*	LC	R	✓		✓	✓
9.	Charadriiformes	Charadriidae	Red-wattled Lapwing	*Vanellus indicus*	LC	R		✓	✓	✓
10.		Jacanidae	Bronze-winged Jacana	*Metopidius indicus*	LC	R				✓
11.			Pheasant-tailed Jacana	*Hydrophasianuschirurgus*	LC	R		✓	✓	
12.		Laridae	River tern	*Sterna aurantia*	VU	R		✓		
13.			Whiskered tern	*Chlidoniashybrida*	LC	M			✓	
14.		Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*	LC	M		✓	✓	✓
15.		Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	LC	M		✓	✓	✓
16.			Common Snipe	*Gallinagogallinago*	LC	M				✓
17.			Green Sandpiper	*Tringaochropus*	LC	M				✓

18.			Wood Sandpiper	*Tringaglareola*	LC	M			✓	✓
19.	Ciconiiformes	Ciconiidae	Asian Openbill	*Anastomusoscitans*	LC	R		✓	✓	✓
20.			Painted stork	*Mycteria leucocephala*	LC	R			✓	
21.	Columbiformes	Columbidae	Eurasian collared dove	*Streptopeliadecaocto*	LC	R	✓		✓	✓
22.			Rock pigeon	*Colombalivia*	LC	R			✓	
23.			Spotted dove	*Spilopelia chinensis*	LC	R	✓		✓	✓
24.	Coraciiformes	Alcedinidae	Common Kingfisher	*Alcedo atthis*	LC	R		✓	✓	✓
25.			Pied kingfisher	*Cerylerudis*	LC	R		✓	✓	
26.			White-throated Kingfisher	*Halcyon smyrnensis*	LC	R		✓	✓	✓
27.		Coraciidae	Indian Roller	*Coracias benghalensis*	LC	R	✓			
28.		Meropidae	Blue-tailed Bee eater	*Meropsphilippinus*	LC	M	✓		✓	
29.			Green Bee-eater	*Meropsorientalis*	LC	R			✓	✓
30.	Cuculiformes	Cuculidae	Asian Koel	*Eudynamysscolopaceus*	LC	R	✓		✓	✓
31.			Blue-faced Malkoha	*Phaenicophaeus tristis*	LC	R			✓	✓
32.			Common Hawk-Cuckoo	*Hierococcyxvarius*	LC	R			✓	✓
33.			Grey bellied cuckoo	*Cacomantispasserinus*	LC	R			✓	
34.			Indian coucal	*Centropus sinensis*	LC	R	✓		✓	✓

35.			Pied Cuckoo	*Clamatorjacobinus*	LC	R	✓		✓	✓
36.			Sirheer malkoha	*Taccocualeschenaultii*	LC	R			✓	
37.	Galliformes	Phasianidae	Grey francolin	*Fracolinuspondicerianus*	LC	R	✓			✓
38.			Indian Peafowl	*Pavo cristatus*	LC	R	✓		✓	✓
39.	Gruiformes	Rallidae	Common coot	*Fulicaatra*	LC	R		✓		
40.			Eurasian Moorhen	*Gallinula chloropus*	LC	R		✓		✓
41.			Gray-headed Swamphen	*Porphyriopoliocephalus*	LC	R		✓	✓	✓
42.			White breasted waterhen	*Amaurornisphoenicurus*	LC	R		✓	✓	✓
43.	Passeriformes	Acrocephalidae	Blyth's reed warbler	*Acrocephalus dumetorum*	LC	M	✓		✓	
44.		Aegithinidae	Common Iora	*Aegithina tiphia*	LC	R			✓	
45.		Alaudidae	Ashy-crowned sparrow-lark	*Eremopterix griseus*	LC	R	✓			
46.		Campephagidae	Small Minivet	*Pericrocotuscinnamomeus*	LC	R	✓			
47.		Cisticolidae	Ashy prinia	*Prinia socialis*	LC	R	✓			
48.			Common tailorbird	*Orthotomussutorius*	LC	R	✓		✓	
49.			Plain Prinia	*Priniainornata*	LC	R	✓			✓
50.		Corvidae	House Crow	*Corvus splendens*	LC	R	✓		✓	✓
51.			Indian jungle crow	*Corvus macrorhynchosculminatus*	LC	R	✓		✓	

52.			Rufous treepie	*Dendrocittavagabunda*	LC	R	✓		✓	✓
53.		Dicaeidae	Pale billed flowerpecker	*Dicaeumerythrorhynchos*	LC	R			✓	
54.		Dicruridae	Black Drongo	*Dicrurusmacrocercus*	LC	R	✓		✓	✓
55.		Estrildidae	Scaly-breasted Munia	*Lonchurapunctulata*	LC	R	✓			
56.			Tricolored Munia	*Lonchuramalacca*	LC	R	✓			✓
57.		Hirundinidae	Barn swallow	*Hirundorustica*	LC	M	✓			
58.		Laniidae	Brown Shrike	*Lanius cristatus*	LC	M			✓	✓
59.			Long tailed shrike	*Lanius schach*	LC	R			✓	
60.		Leiothrichidae	Yellow-billed Babbler	*Argyaaffinis*	LC	R	✓		✓	✓
61.		Monarchidae	Indian paradise flycatcher	*Terpsiphone paradisi*	LC	R	✓		✓	✓
62.		Motacillidae	White browed wagtail	*Motacillamaderaspatensis*	LC	R	✓		✓	
63.			Yellow wagtail	*Motacilla flava*	LC	M	✓			
64.		Muscicapidae	Asian brown flycatcher	*Muscicapadauurica*	LC	M			✓	
65.			Indian blue robin	*Larvivorabrunnea*	LC	M			✓	
66.			Oriental Magpie Robin	*Copsychussaularis*	LC	R	✓		✓	✓
67.		Nectariniidae	Loten’s sunbird	*Cinnyrislotenius*	LC	R			✓	
68.			Purple Sunbird	*Cinnyris asiaticus*	LC	R	✓		✓	

69.			Purple-rumped Sunbird	*Leptocomazeylonica*	LC	R	✓		✓	
70.		Oriolidae	Golden Oriole	*Orioluskundoo*	LC	M	✓		✓	
71.		Ploceidae	Baya weaver	*Ploceusphilippinus*	LC	R	✓			
72.		Pycnonotidae	Red-vented Bulbul	*Pycnonotuscafer*	LC	R	✓		✓	✓
73.			Red-wiskered Bulbul	*Pycnonotusjocosus*	LC	R	✓			
74.			White browed bulbul	*Pycnonotusluteolus*	LC	R			✓	
75.			Yellow-browed Bulbul	*Acritillas indica*	LC	R	✓			✓
76.		Sturnidae	Brahminy Starling	*Sturniapagodarum*	LC	R	✓		✓	✓
77.			Common Myna	*Acridotheres tristis*	LC	R	✓		✓	✓
78.			Rosy starling	*Pastor roseus*	LC	M	✓			
79.		Turdidae	Orange-headed Thrush	*Geokichlacitrina*	LC	R				✓
80.		Vangidae	Common Woodshrike	*Tephrodornispondicerianus*	LC	R	✓		✓	✓
81.		Ardeidae	Black Bittern	*Ixobrychusflavicollis*	LC	R				✓
82.			Black-crowned Night-Heron	*Nycticoraxnycticorax*	LC	R		✓		✓
83.			Cattle egret	*Bubulcus ibis*	LC	R		✓	✓	
84.			Cinnamon bittern	*Ixobrychuscinnamomeus*	LC	R			✓	
85.			Great Egret	*Ardea alba*	LC	R		✓	✓	✓
86.			Grey Heron	*Ardeolacinera*	LC	R		✓	✓	✓

87.	Pelecaniformes		Indian Pond-Heron	*Ardeolagrayii*	LC	R		✓	✓	✓
88.			Intermediate Egret	*Ardea intermedia*	LC	R		✓	✓	
89.			Little Egret	*Egrettagarzetta*	LC	R		✓	✓	✓
90.			Purple Heron	*Ardea purpurea*	LC	R		✓	✓	✓
91.			Striated Heron	*Butorides striata*	LC	R		✓		✓
92.			Yellow bittern	*Ixobrychus sinensis*	LC	R		✓		
93.		Pelecanidae	Spot-billed Pelican	*Pelecanusphilippensis*	NT	R				✓
94.		Threskiornithidae	Black ibis	*Pseudibispapillosa*	LC	R	✓			
95.			Black-headed Ibis	*Threskiornismelanocephalus*	NT	R		✓	✓	✓
96.			Glossy Ibis	*Plegadisfalcinellus*	LC	M		✓		✓
97.	Piciformes	Picidae	Black-rumpedFlameback	*Dinopiumbenghalense*	LC	R	✓		✓	✓
98.	Podicipediformes	Podicipedidae	Little grebe	*Tachibaptus ruficollis*	LC	R		✓		
99.	Psittaciformes	Psittaculidae	Rose ringed parakeet	*Psittaculakrameri*	LC	R	✓		✓	✓
100.	Strigiformes	Strigidae	Spotted Owl	*Athene brama*	LC	R	✓			
101.		Tytonidae	Barn Owl	*Tyto alba*	LC	R	✓			
102.	Suliformes	Anhingidae	Oriental Darter	*Anhinga melanogaster*	NT	R		✓	✓	✓
103.		Phalacrocoracidae	Indian Cormorant	*Phalacrocorax fuscicollis*	LC	R		✓		✓
104.			Little Cormorant	*Microcarboniger*	LC	R		✓	✓	✓