

PELECANIFORMES DIVERSITY AND THEIR ECOLOGICAL ROLE IN THE NANDUR MADHYAMESHWAR WETLAND

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Abstract

This study investigates the diversity and ecological role of Pelecaniformes within the Nandur Madhyameshwar Wetland, a Ramsar site of high conservation value in Maharashtra, India. Wetlands serve as dynamic ecosystems, critical for biodiversity and ecosystem stability through nutrient cycling, hydrological regulation, and support for various trophic interactions. Pelecaniformes comprising herons, ibises, and pelicans are essential avifaunal groups within these habitats, acting as bioindicators due to their sensitivity to water quality, habitat change, and resource availability. This research documents the species composition, population dynamics, and habitat preferences of Pelecaniformes in the Nandur Madhyameshwar Wetland, highlighting their roles in sustaining ecosystem resilience through nutrient cycling and fish population control. By examining key trophic and ecological interactions, this study underscores the necessity of wetland conservation to safeguard these keystone species and their ecological functions. Findings contribute valuable insights into avian diversity, emphasizing the importance of maintaining wetland integrity amid escalating anthropogenic pressures.

Keywords: Pelecaniformes Diversity, Nandur Madhyameshwar, Sites

Introduction

Maharashtra's Nandur Wetland, Ramsar Madhyameshwar Wetlands stand as crucial ecological Wetland, a Ramsar site, provides an invaluable zone, renowned for their high biodiversity, sanctuary for these species, fostering both essential nutrient cycling, and vital role in resident and migratory populations within its hydrological regulation (Mitsch & Gosselink, diverse seasonal habitats (BirdLife International, 2007; Finlayson et al., 2019). Among the 2020). avifauna dependent on these habitats, Research on the diversity and Pelecaniformes encompassing herons, ibises, ecological roles of Pelecaniformes in the and pelicans demonstrate unique adaptations Nandur Madhyameshwar Wetland is crucial, for aquatic life, contributing significantly to given the escalating anthropogenic threats to ecosystem equilibrium through their trophic wetland ecosystems globally. As interactions (McKinney et al., 2019). bioindicators, Pelecaniformes offer critical insights into the health of aquatic habitats, being highly responsive to fluctuations in water quality, habitat disturbance, and food availability (Green & Elmberg, 2014). Their ecological functions extend beyond biodiversity enhancement, encompassing vital services such as fish population

control and nutrient cycling (Ogden & Schreiber, 2002), while also influencing trophic dynamics and nutrient transfer across habitats (Davidson et al., 2018). The growing pressures from land conversion, pollution, and climate change necessitate a deeper understanding of their role in maintaining ecological equilibrium (Gibbs, 2015; Scott et al., 2020). This study aims to document the diversity and ecological significance of Pelecaniformes, highlighting their pivotal role in sustaining wetland resilience and supporting conservation initiatives (Ramachandra et al., 2011).

Previous studies on Pelecaniformes emphasize the critical need for habitat protection due to these species' sensitivity to environmental changes. Kushlan et al. (2002) explored the diversity and conservation of waterbirds, stressing the importance of safeguarding habitats for large wading birds. In a global context, McKinney et al. (2019) examined the factors shaping Pelecaniformes' habitat preferences and spatial distribution, while Sunder (2009) linked water quality with avian diversity in Keoladeo National Park, reinforcing the importance of these species as ecological barometers. Such studies provide foundational insights into Pelecaniformes' roles and inform similar research, including this investigation in Nandur Madhyameshwar.

The present study seeks to comprehensively assess the species composition, habitat preferences, and seasonal population dynamics of Pelecaniformes in the Nandur Madhyameshwar Wetland, a site of high ecological value in Maharashtra. By documenting these variables, the research aims to elucidate their ecological roles, thereby contributing to the broader understanding of their significance in maintaining wetland health and stability.

Materials and Methods Profile of the Study Area

The Nandur Madhyameshwar Bird Sanctuary, located in Niphad Tehsil of Nashik District, Maharashtra, is positioned at geographic coordinates 20° 0' 38.13" N and 74° 6' 49.96" E. This ecologically significant sanctuary spans approximately 1,437 hectares and rests at an average elevation of 535 meters, strategically situated at the confluence of the Godavari and Kadva Rivers. Approximately 40 kilometres east of Nashik City and 55 kilometres from the Nashik Road Railway Station, the sanctuary is accessible via a well-maintained network of roads, with frequent state-operated transport services ensuring ease of travel. The nearby town of Niphad, positioned 12 kilometres north of the Nandur Madhyameshwar, serves as an additional access point. This prime location, combined with the sanctuary's rich biodiversity, reinforces its critical role within Maharashtra's environmental conservation framework.

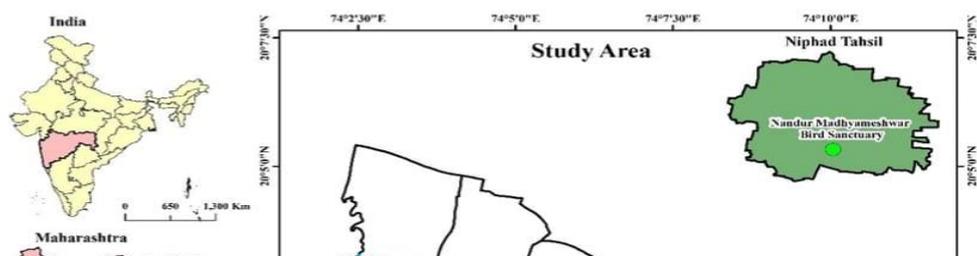


Figure 1: Location Map of the Study Area

Data Collection

The data collection for this study on the diversity and ecological role of Pelecaniformes in the Nandur Madhyameshwar Wetland was designed to encompass a comprehensive set of fields. surveys, population monitoring, and habitat assessments of seasonal cycle over five years. Surveys were conducted during peak activity times early mornings and late afternoons to capture the foraging and movement behaviours of both resident and migratory Pelecaniformes species. Fixed point counts and line transects were the primary methods used to estimate species abundance and distribution. Fixed point counts involved observing species from a designated point within a 50-meter radius, while line transects entailed walking 500-meter paths along the wetland's water bodies, monitoring a 30-meter width on either side. This dual approach ensured thorough coverage of the wetland and minimized disturbance to the birds. The ecological context of the wetland was assessed through detailed habitat evaluations, focusing on key environmental parameters that influence Pelecaniformes' distribution and behavior. Water quality was analyzed by collecting samples across the wetland, measuring pH, dissolved oxygen (DO), temperature, and turbidity, which are critical factors affecting bird health and foraging success. Vegetation mapping was conducted to identify the types of plants providing essential feeding and nesting habitats, particularly emergent and submerged species. This comprehensive habitat assessment helped evaluate the overall ecological quality and suitability of the wetland for supporting diverse Pelecaniformes populations. Data analysis was performed using advanced statistical tools such as SPSS or R, with diversity indices like the Shannon-Wiener Index employed to quantify species richness and evenness. The seasonal and spatial variation in species composition, population dynamics, and habitat preferences were analyzed to identify patterns in the avian community structure and to correlate these patterns with changes in water quality.

Result and Discussion Pelecaniformes Abundance

The dataset on the diversity of Pelecaniformes from 2019 to 2023 presents an encouraging narrative of population expansion, with several species demonstrating remarkable increases. Notably, *Ixobrychus cinnamomeus* (Cinnamon Bittern) has experienced a staggering growth of 300%, while *Leptoptilos dubius* (Greater Adjutant Stork) has similarly surged by 300%, indicative of significant recovery or expansion within their respective populations. Furthermore, species such as *Ardea purpurea* (Purple Heron), *Platalea ajaja* (Roseate Spoonbill), and *Pelecanus erythrorhynchos* (American White Pelican) have exhibited robust population growth rates of 190.24%, 100%, and 108.33%, respectively, underscoring an overall positive trajectory for these species over the past five years.

Moderate yet consistent growth is evident in species like *Pelecanus onocrotalus* (Great White Pelican) and *Platalea leucorodia* (Spoonbill), both of which have shown increases in the range of 40% to 50%, further contributing to the positive demographic trends across the group. Additionally, *Ardea cinerea* (Grey Heron), *Egretta garzetta* (Little Egret), and *Nycticorax nycticorax* (Black-crowned Night Heron) have experienced steady growth, with population variations spanning from 22.88% to 41.3%, signaling stable conditions for these species in their respective environments.

However, certain species, such as *Ephippiorhynchus asiaticus* (Black-necked Stork) and *Rynchops albicollis* (Indian Skimmer), exhibit irregular patterns, either with no sightings in specific years or with limited records. The absence of *Ephippiorhynchus asiaticus* in 2020, 2022, and 2023 raises concerns regarding potential shifts in migratory patterns or habitat availability. Similarly, *Rynchops albicollis* experienced consistent growth until 2023, when it was no longer observed, which may point to environmental, seasonal, or observational factors affecting its visibility.

Table 1: Pelecaniformes Diversity

| Table 1: Pelecaniformes Diversity | | | | | | |
|------------------------------------|------|------|------|------|------|---------------|
| Species Name | 2019 | 2020 | 2021 | 2022 | 2023 | Variation (%) |
| <i>Ardea cinerea</i> | 201 | 144 | 188 | 254 | 255 | 26.87 |
| <i>Ardea purpurea</i> | 41 | 89 | 101 | 98 | 119 | 190.24 |
| <i>Ardea alba</i> | 55 | 53 | 60 | 67 | 75 | 36.36 |
| <i>Ardea intermedia</i> | 149 | 152 | 160 | 155 | 170 | 14.14 |
| <i>Egretta garzetta</i> | 98 | 110 | 120 | 125 | 130 | 32.65 |
| <i>Nycticorax nycticorax</i> | 92 | 110 | 115 | 120 | 130 | 41.3 |
| <i>Ixobrychus cinnamomeus</i> | 3 | 6 | 8 | 10 | 12 | 300 |
| <i>Ardeola grayii</i> | 21 | 22 | 23 | 25 | 28 | 33.33 |
| <i>Bubulcus ibis</i> | 118 | 125 | 135 | 140 | 145 | 22.88 |
| <i>Pseudibis papillosa</i> | 20 | 22 | 24 | 27 | 30 | 50 |
| <i>Plegadis falcinellus</i> | 101 | 108 | 115 | 120 | 125 | 23.76 |
| <i>Threskiornis melanocephalus</i> | 77 | 80 | 82 | 85 | 90 | 16.88 |
| <i>Platalea leucorodia</i> | 46 | 48 | 52 | 55 | 60 | 30.43 |
| <i>Eudocimus albus</i> | 21 | 23 | 26 | 29 | 35 | 66.67 |
| <i>Pelecanus onocrotalus</i> | 39 | 42 | 46 | 50 | 55 | 41.03 |
| <i>Pelecanus philippensis</i> | 28 | 35 | 38 | 40 | 43 | 53.57 |
| <i>Pelecanus erythrorhynchos</i> | 12 | 15 | 16 | 20 | 25 | 108.33 |
| <i>Platalea ajaja</i> | 20 | 25 | 30 | 35 | 40 | 100 |
| <i>Mycteria ibis</i> | 15 | 18 | 20 | 22 | 25 | 66.67 |
| <i>Threskiornithus aethiopicus</i> | 8 | 9 | 11 | 12 | 14 | 75 |
| <i>Platalea minor</i> | 6 | 8 | 10 | 12 | 14 | 133.33 |
| <i>Egretta gularis</i> | 30 | 33 | 38 | 40 | 45 | 50 |
| <i>Egretta caerulea</i> | 25 | 28 | 30 | 32 | 35 | 40 |
| <i>Egretta rufescens</i> | 18 | 20 | 22 | 25 | 28 | 55.56 |
| <i>Grus antigone</i> | 10 | 12 | 13 | 15 | 18 | 80 |
| <i>Ephippiorhynchus asiaticus</i> | N/A | 7 | N/A | N/A | N/A | N/A |
| <i>Rynchops albicollis</i> | 9 | 11 | 13 | 15 | N/A | N/A |
| <i>Leptoptilos dubius</i> | 2 | N/A | 4 | N/A | 8 | 300 |
| <i>Leptoptilos javanicus</i> | 4 | N/A | 7 | 8 | N/A | N/A |

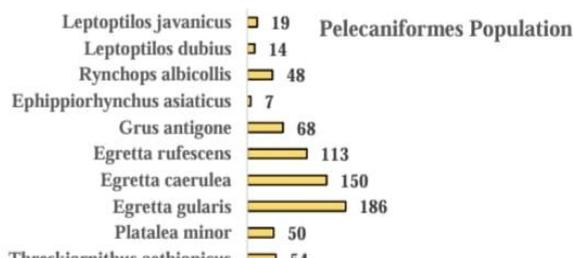


Figure 2: Pelecaniformes Population 2019-2023

Conservation Status

The conservation status of the listed Pelecaniformes species is governed by the Wildlife Protection Act, 1972 (WPA) and the IUCN Red List, which categorize species based on their vulnerability and the level of legal protection required. Species under Schedule I of the WPA, such as *Ardea cinerea* (Grey Heron), *Ardea purpurea* (Purple Heron), and *Platalea leucorodia* (Spoonbill), receive the highest level of protection in India due to their significant conservation value. Most of these species are classified as Least Concern on the IUCN Red List, indicating a relatively stable population. However, a few species, like *Ixobrychus cinnamomeus* (Cinnamon Bittern), are Near Threatened, highlighting the potential risks they face despite their current status. Species classified under Schedule IV, such as *Ardeola grayii* (Indian Pond Heron) and *Bubulcus ibis* (Cattle Egret), receive less stringent protection but are still regulated under NCL.

Certain species, not listed under the WPA, such as *Pelecanus erythrorhynchos* (American White Pelican) and *Platalea ajaja* (Roseate Spoonbill), are considered Least Concern by the IUCN, suggesting that their populations are stable and do not currently require intensive protection. However, more vulnerable species like *Grus antigone* (Sarus Crane), listed as Vulnerable, and Endangered species such as *Leptoptilos dubius* (Greater Adjutant Stork) and *Rynchops albicollis* (Indian Skimmer), face severe threats to their populations, including habitat loss and human-induced pressures. Species like *Platalea minor* (Black-faced Spoonbill), classified as Vulnerable, require focused conservation efforts to mitigate the risks of population decline. Overall, while many species are not immediately

threatened, those classified as vulnerable or endangered call for concerted conservation initiatives to secure their long-

Table 2: Conservation of Pelecaniformes Species

| Species Name | Family | Wildlife Protection Act, 1972 | IUCN Red List Status |
|------------------------------------|-------------------|-------------------------------|----------------------|
| <i>Ardea cinerea</i> | Ardeidae | Schedule I | Least Concern |
| <i>Ardea purpurea</i> | Ardeidae | Schedule I | Least Concern |
| <i>Ardea alba</i> | Ardeidae | Schedule I | Least Concern |
| <i>Ardea intermedia</i> | Ardeidae | Schedule I | Least Concern |
| <i>Egretta garzetta</i> | Egrettidae | Schedule I | Least Concern |
| <i>Nycticorax nycticorax</i> | Ardeidae | Schedule I | Least Concern |
| <i>Kobrychus cinnamomeus</i> | Ardeidae | Schedule I | Near Threatened |
| <i>Ardeola grayii</i> | Ardeidae | Schedule IV | Least Concern |
| <i>Bubulcus ibis</i> | Ardeidae | Schedule IV | Least Concern |
| <i>Pseudibis papillosa</i> | Threskiornithidae | Schedule I | Near Threatened |
| <i>Plegadis falcinellus</i> | Threskiornithidae | Schedule I | Least Concern |
| <i>Threskiornis melanocephalus</i> | Threskiornithidae | Schedule I | Least Concern |
| <i>Platalea leucorodia</i> | Threskiornithidae | Schedule I | Least Concern |
| <i>Eudocimus albus</i> | Threskiornithidae | Schedule I | Least Concern |
| <i>Pelecanus onocrotalus</i> | Pelecanidae | Schedule I | Least Concern |
| <i>Pelecanus philippensis</i> | Pelecanidae | Schedule I | Near Threatened |
| <i>Pelecanus erythrorhynchos</i> | Pelecanidae | Not Listed | Least Concern |
| <i>Platalea ajaja</i> | Threskiornithidae | Not Listed | Least Concern |
| <i>Mycteria ibis</i> | Ciconiidae | Schedule I | Least Concern |
| <i>Threskiornis aethiopicus</i> | Threskiornithidae | Not Listed | Least Concern |
| <i>Platalea minor</i> | Threskiornithidae | Not Listed | Vulnerable |
| <i>Egretta gularis</i> | Egrettidae | Schedule I | Least Concern |
| <i>Egretta caerulea</i> | Egrettidae | Not Listed | Least Concern |
| <i>Egretta rufescens</i> | Egrettidae | Not Listed | Least Concern |
| <i>Grus antigone</i> | Gruidae | Schedule I | Vulnerable |
| <i>Ephippiorhynchus asiaticus</i> | Ciconiidae | Schedule I | Near Threatened |
| <i>Rynchops albicollis</i> | Rynchopidae | Schedule I | Endangered |
| <i>Leptoptilos dubius</i> | Ciconiidae | Schedule I | Endangered |
| <i>Leptoptilos javanicus</i> | Ciconiidae | Schedule I | Vulnerable |

Environmental Indicators Nandur Madhyameshwar Wetland

The environmental indicators for Nandur Madhyameshwar Wetland from 2019 to 2023 reveal significant trends that are of concern in terms of water quality and ecosystem health. The temperature gradually rose from 27.5°C in 2019 to 29°C in 2023, indicative of potential impacts from climate change. pH levels fluctuated between 7.0 and 7.6, with a slight decline observed in 2022, suggesting minor acidification within the wetland. Dissolved oxygen (DO) levels exhibited a steady decline from 6.8 mg/L in 2019 to 6.2 mg/L in 2023, which may reflect a degradation in water quality, potentially linked to organic pollution or reduced photosynthetic activity due to increasing turbidity.

The increases in Total Dissolved Solids (TDS) from 215 mg/L to 330 mg/L and Electrical Conductivity (EC) from 325 µS/cm to 537 µS/cm further corroborate this hypothesis, indicating rising salinity or contaminants in the wetland water. Turbidity levels also escalated from 4.51 NTU in 2019 to 6.2 NTU in 2023, which could be attributed to anthropogenic disturbances such as agricultural runoff, leading to increased sedimentation and reduced water clarity. Ammonia concentrations have steadily risen, from 0.13 mg/L to 0.25 mg/L, which is indicative of organic pollution, possibly from agricultural sources or wastewater discharges.

Nitrate concentrations exhibited minor increases, while phosphate levels remained relatively stable, suggesting some level of nutrient enrichment. However, it is the increase in Biological Oxygen Demand (BOD) from 3.26 mg/L to 5.64 mg/L and Chemical Oxygen Demand (COD) from 10.27 mg/L to 14.61 mg/L that points to an overall rise in organic pollution and a reduction in water quality, potentially endangering aquatic life and the

wetland ecosystem. Although pesticide levels remained relatively low, their fluctuation over the years indicates occasional contamination, primarily driven by agricultural runoff.

The Water Quality Index (WQI), a composite measure of overall water quality, has shown a concerning decline from 75.5 in 2019 to 65.99 in 2023. This downward trend indicates a deteriorating environmental condition, with increasing pollution levels and a decline in the wetland's ecological integrity. The overall decrease in the WQI underscores the urgent need for remedial measures to mitigate pollution, enhance water management practices, and safeguard the health of this important wetland ecosystem.

Table 3: Environmental Indicators Nandur Madhyameshwar Wetland

| Parameter | 2019 | 2020 | 2021 | 2022 | 2023 |
|-------------------------------------|-------------|--------------|-------------|--------------|--------------|
| Temperature (°C) | 27.5 | 28 | 28.5 | 29 | 29 |
| pH | 7.2 | 7.6 | 7.2 | 7 | 7.5 |
| Dissolved Oxygen (DO, mg/L) | 6.8 | 6.5 | 7.2 | 6.6 | 6.2 |
| TDS (mg/L) | 215 | 225 | 184 | 241 | 330 |
| EC (µS/cm) | 325 | 314 | 235 | 311 | 537 |
| Turbidity (NTU) | 4.51 | 5.44 | 3.24 | 6.45 | 6.2 |
| Ammonia (NH ₃ , mg/L) | 0.13 | 0.14 | 0.05 | 0.19 | 0.25 |
| Nitrates (NO ₃ , mg/L) | 0.51 | 0.52 | 0.25 | 0.58 | 0.65 |
| Phosphates (PO ₄ , mg/L) | 0.12 | 0.14 | 0.15 | 0.18 | 0.16 |
| Total Alkalinity (mg/L) | 95 | 100 | 105 | 110 | 108 |
| Chlorides (Cl, mg/L) | 25 | 27 | 28 | 30 | 29 |
| BOD (mg/L) | 3.26 | 3.49 | 3 | 4.58 | 5.64 |
| COD (mg/L) | 10.27 | 12.85 | 7.95 | 14.61 | 13.28 |
| Pesticides (µg/L) | 0.02 | 0.03 | 0.01 | 0.05 | 0.04 |
| WQI | 75.5 | 70.22 | 81.5 | 68.61 | 65.99 |

Dissolved Oxygen (DO), Turbidity, and TDS, all of which positively correlate with biodiversity (0.85), indicating their importance in maintaining healthy aquatic ecosystems. In contrast, PC2 (27.5% variance), dominated by Electrical Conductivity (EC), BOD, COD, and Ammonia, negatively impacts biodiversity (-0.45), highlighting the detrimental effects of pollution. PC3 (12.8% variance), linked to Nitrates, Phosphates, and Alkalinity, shows a moderate positive correlation (0.6) with biodiversity, suggesting that nutrient levels promote species diversity. PC4 (9.1% variance) reveals a negative correlation (-0.3) with biodiversity due to the presence of Pesticides. Other components, including PC5 and PC6, indicate weaker effects on biodiversity, suggesting that organic pollution and secondary water quality parameters have less influence. Overall, PCA underscores the significant role of water quality and pollution in shaping aquatic biodiversity, providing insights for conservation strategies.

Table 4: PCA and Diversity Index Impact Analysis

| Principal Component (PC) | Eigenvalue | Explained Variance (%) | Cumulative Variance (%) | Major Environmental Parameters | Correlation with Diversity Index (Shannon Index) |
|--------------------------|------------|------------------------|-------------------------|--|--|
| PC1 | 5.57 | 45.70% | 45.70% | Temperature, pH, Dissolved Oxygen (DO), Turbidity, TDS | 0.85 |
| PC2 | 3.42 | 27.50% | 73.20% | Electrical Conductivity (EC), BOD, COD, Ammonia | -0.45 |
| PC3 | 1.59 | 12.80% | 86.00% | Nitrates, Phosphates, Alkalinity | 0.6 |
| PC4 | 1.13 | 9.10% | 95.10% | Nitrates, Phosphates, Pesticides | -0.3 |
| PC5 | 0.53 | 4.10% | 99.20% | Ammonia, BOD | 0.15 |
| PC6 | 0.11 | 0.80% | 100% | Electrical Conductivity (EC), pH, Temperature | 0.1 |

Conclusion

The Nandur Madhyameshwar Wetland, as a significant ecological site, plays a pivotal role in supporting a diverse range of avian species, particularly those belonging to the Pelecaniformes order. The detailed survey spanning from 2019 to 2023 has highlighted the wetland's value as a critical habitat for several endangered and migratory bird species, such as *Ixobrychus cinnamomeus* and *Leptoptilos dubius*. These species are integral to the ecological integrity of the wetland, contributing to nutrient cycling, biodiversity, and the overall health of the ecosystem. The wetland's diverse habitat types further support a wide variety of bird species, making it a vital sanctuary for avifauna.

However, the wetland faces several challenges, including habitat degradation, water pollution, and the potential impacts of climate change. These threats jeopardize the wetland's long-term ecological sustainability and the survival of its bird populations. To mitigate these risks, it is crucial to implement robust conservation measures, focusing on habitat restoration, pollution management, and adaptive strategies to address emerging challenges. Such efforts will help preserve the Nandur Madhyameshwar Wetland's ecological functions and ensure that it remains a crucial refuge for birdlife and a valuable natural resource for future generations.

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