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Cover: Nilgiri Large Burrowing Spider *Haploclastus nilgirinus*. Acrylic on canvas. © Aakanksha Komanduri.

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ARTICLE

Avifaunal diversity and conservation status of waterbirds in Pillaimadam Lagoon, Palk Bay, India

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Abstract: Avifaunal surveys are important for developing targeted conservation strategies for specific sites and species, especially in undocumented critical wintering grounds for shorebirds within the Central Asian Flyway. In this context, we present a first-time avifaunal checklist at the Pillaimadam Lagoon, Ramanathapuram District, Tamil Nadu. A total of 108 species of birds belonging to 43 families under 16 orders were recorded. Order Charadriiformes was the most prevalent (34 species), followed by Passeriformes (28 species), and Pelecaniformes (15 species). Family-wise, the highest species richness was recorded for Scolopacidae and Laridae (11 species each). Winter visitors accounted for 33.3% (36 species), with other categories including Resident (51 species), Resident/Non-Breeding (17 species), Local Migrant (3 species), and one Passage Migrant—Rosy Starling *Pastor roseus*. The lagoon harbours five 'Near Threatened', two 'Vulnerable', one 'Endangered' (Siberian Sand Plover *Charadrius mongolus*), and one unassessed species (Hanuman Plover *Charadrius seebohmi*) as per the IUCN Red List of Threatened Species, and 35 species enlisted in Appendix II of the Convention of the Conservation of Migratory Species of Wild Animals (CMS), emphasizing the need for conserving this coastal wetland as a 'protected area.' Hence, the current baseline data on avifaunal diversity is the first comprehensive bird list from Pillaimadam Lagoon.

Keywords: Central Asian Flyway, Gulf of Mannar, habitat, lagoon, protected area, shorebirds, waterbirds, wetland, winter visitors

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Author details: Byju H, has worked on the shorebirds and waterbirds in the Gulf of Mannar region for the past decade and presently a member of the biodiversity panel of five bird sanctuaries, including three Ramsar sites in the district and the Gulf of Mannar Biosphere Reserve. Maitreyi H is a PhD scholar working on seabirds in the region. Raveendran N is a naturalist with a decade of experience in birds and awareness education, and serves as a biodiversity member in the bird sanctuaries and the Gulf of Mannar Biosphere Reserve. Ravichandran S is a professor with three decades of experience in marine ecology. Reshmi Vijayan is an associate professor working on birds and marine systems.

Author contributions: BH—conceptualisation, design of work, writing, and editing; MH—data curation, analysis, mapping, and writing; RN—data compilation, writing; SR—writing and editing; RV—writing.

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INTRODUCTION

The study of avifaunal distribution is pivotal in understanding the ecological health of an area (Llanos et al. 2011; Fraixedas et al. 2020; Byju et al. 2024a), as birds serve as excellent bioindicators (Sekercioglu 2012; Egwumah et al. 2017) due to their sensitivity to environmental changes (Callaghan et al. 2019; Piersma & Lindstrom 2024) especially in diverse coastal environments (Jayanthi et al. 2021; Rashiba et al. 2022). Avifauna, encompassing all bird species within a particular region, provides critical insights into the broader ecological dynamics (Kati & Sekercioglu 2006; Byju et al. 2023a), including habitat quality (Naujokaitis-Lewis et al. 2009), food availability, and the impact of anthropogenic activities (Todd et al. 2016). Since global environment changes, such as habitat loss, and climate change, continue to accelerate, there is an increasing need to document and analyze the distribution patterns of bird species to initiate conservation strategies (Gadgil 1996; Gaston 2000; Byju et al. 2023b). Birds occupy varied ecological niches, making their distribution patterns reflective of the health of different ecosystems (Kazmierczak 2006; Grimmett et al. 2011). Changes in bird distribution can reveal changes in habitat conditions and biodiversity over the time (Kattan & Franco 2004; Hasuia et al. 2024). Understanding the patterns is particularly important in regions undergoing environmental changes (Huang et al. 2023; Byju et al. 2024b), as they can help prioritize conservation efforts and guide habitat management practices (Newton 2004; Paul & Cooper 2005).

Avifaunal distribution is influenced by habitat structure, food availability, predation pressure, and interspecific competition among the primary biotic factors, while climate, topography, water depth, salinity, and tidal patterns constitute important abiotic factors (Cody 1985; Day et al. 2012). Human activities, including urbanization, deforestation, and agricultural expansion, which often lead to habitat fragmentation and degradation, also have significant impact (Ma et al. 2023). In addition to these factors, broader climatic patterns, such as temperature and precipitation, play a crucial role in determining the geographical range of bird species (Thomas & Lennon 1999). Coastal lagoons are not an exception to these environmental changes and anthropogenic pressures (Kennish & Paerl 2010). Coastal lagoons are important for migratory waterbirds in their long inter-continental journeys (Alfaro & Clara 2007; Miotto et al. 2023) and are vital feeding, breeding, and resting grounds for numerous other bird species (Chandana et al. 2012; Silva et al. 2013). Coastal lagoon like Pillaimadam is one of such vital habitats and is also an important breeding site for the newly discovered taxa Hanuman Plover *Charadrius seebohmi* (Byju et al. 2023e). It is essential to monitor and study these ecosystems to formulate effective conservation strategies.

On the southeastern coast of India, the Ramanathapuram District of Tamil Nadu has five bird sanctuaries, including three Ramsar sites (Kanjirankulam Bird Sanctuary, Therthangal Bird Sanctuary and Chitrangudi Bird Sanctuary) and the Gulf of Mannar Biosphere Reserve (GoM) (Byju et al. 2023c). Recent studies from the area have been highlighted on the coastal regional avifauna from Valinokkam Lagoon (Byju et al. 2023b), 21 islands of GoM (Byju et al. 2023c) and Karangadu mangroves (Byju et al. 2023d). Pillaimadam Lagoon on Palk Bay is an unexplored area in terms of avifauna. Hence, the present study aimed to create comprehensive data on the avifauna with a focus on diversity, migratory status, and national and global conservation issues. This will assist the forest department in future for the conservation and management of the lagoon and upgrading it to a protected status.

MATERIALS AND METHODS

Study Area

The Pillaimadam Lagoon (9.282º N & 79.108º E) is situated in the Palk Bay region, a shallow marine region between India and Sri Lanka. The bottom of the lagoon is mostly muddy. The lagoon is bordered by grass on the landward area, invasive *Neltuma juliflora* and palm *Borassus flabellifer* trees, which provide a habitat for numerous land birds with sand dunes on the seaward side (Figure 1). The salinity fluctuates significantly between the monsoon and summer season. Rainwater from surrounding areas is emptied into the lagoon during the monsoon, and in the summer, it is cut off from the sea. The maximum salinity is 25 parts per thousand (ppt) in rainy seasons, and salt formations occur during summer as small fresh-water puddles are formed along the border of the lagoon during the monsoon (Balachandran 1990) which supports the breeding activities of a few waterbirds. Fishing activities are found only during a few months when the water is abundant. The presence of halophytes like *Arthocnemum macrostachyum* and the occasional presence of *Saueda* sp. is seen on the edges of the lagoons.

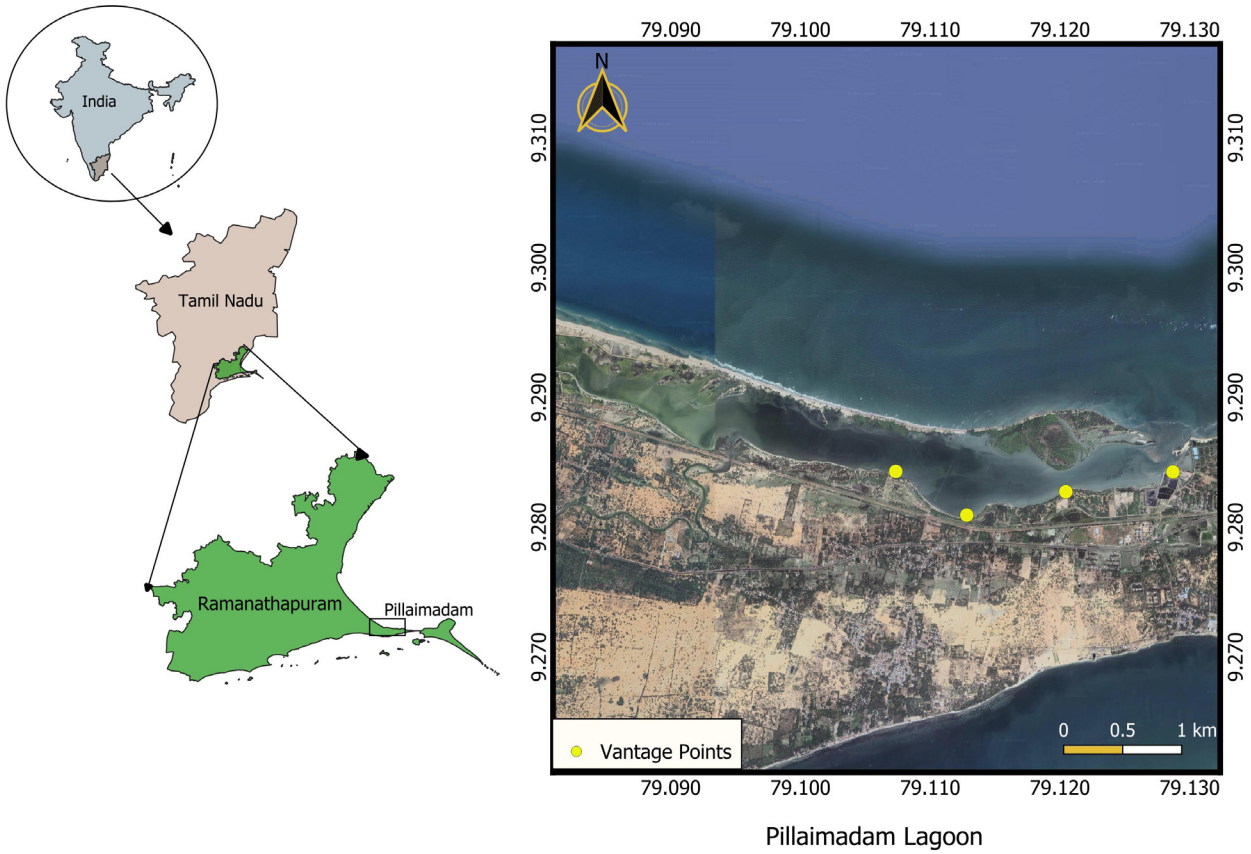

Figure 1. Pillaimadam Lagoon with scanning points.

Bird surveys and data analysis

Bird surveys were done once a month between August 2021 and July 2022 in all regional seasons – summer, pre-monsoon, monsoon, and post-monsoon to establish an avifaunal checklist. Surveys were conducted during low tides during the monsoon time for shorebirds, as in other seasons the sea mouth was closed to the lagoon, during the peak hours of their activity, from 0600–1000 h and 1600–1800 h. We followed both block count and direct visual count methods (Howes & Bakewell 1989; Bibby et al. 2000). In this method, four scanning points were used as points of count (Figure 1), birds in the blocks were observed using field binoculars (10 × 50) and spotting scopes (Vanguard 14*70) and photographed with a digital camera with 100–400 mm telephoto lens, and species not identified in the field were later identified with the help of field guides (Grimmett et al. 2011; Hayman et al. 2011). After arriving at each scanning point, the bird counts for the waterbirds started after five minutes, for birds to get acclimatized to the human presence. The observations recorded while moving from one scanning point to another were entered as incidental records. The data analysis was done using MS Excel 2019.

1. Migratory Status: The residential status of the birds is grouped under different categories like Resident (R), Resident/Not Breeding (R/NB), Passage Migrant (PM), and Winter Visitor (WV) depending on their timing and duration of occurrence (Grimmett et al. 2011).

2. Relative abundance: Based on the frequency of bird sightings the relative abundance of birds is documented as common (C) seven to nine times; uncommon (UC) three to six times; and rare (Ra) once or twice (MacKinnon & Phillipps 1993).

3. Relative Diversity: Relative diversity (RDi) was calculated to represent the percentage of total species within a family to the total number of species. It was calculated using the following formula (Koli 2014).

RDi = Number of species in a family / Total number of species × 100

4. IUCN status: IUCN Red List focus includes species classified as 'Least Concern' (LC), 'Near Threatened' (NT), 'Vulnerable' (VU), and 'Endangered' (EN) highlighting their conservation importance in Pillaimadam Lagoon. The common name, scientific name, IUCN Red List status, and migratory status are followed (Praveen & Jayapal 2023).

5. SOIB population trends: We considered the State of India's Bird (SOIB) report to analyze the current population trend of the bird species in India from the Pillaimadam Lagoon. The current trend corresponds to the average annual change in species abundance over the past eight years (2015–2022). According to SOIB, different categories of population trend indices are, Insufficient Data which means too few reports, Trend Inconclusive means 95% confidence interval >2%, Rapid Decline is decline >2.7%, Decline is >1.1%, Increase is >0.9%, and Rapid Increase is >1.6% (State of India's Bird 2023).

6. CMS status: We analyzed the conservation priority species based on the Convention for the Conservation of Migratory Species of Wild Animals (CMS). The avifaunal species listed in Appendix II of CMS correspond to migratory species that need international cooperation and international agreements for conservation and management (CMS 2024).

RESULTS

A total of 108 species of birds belonging to 43 families under 16 orders were recorded from the Pillaimadam Lagoon (Table 1). Order-wise, Charadriiformes were the most predominant (34 species in five families), followed by Passeriformes (28 species in 17 families), and Pelecaniformes (15 species in six families). In contrast, the orders Pheonicopteriformes, Caprimulgiformes, Gruiformes, Bucerotiformes, Strigiformes, Piciformes, and Psittaciformes were each represented by a single species (Figure 2). Families Scolopacidae and Laridae had 11 representative species each; followed by Charadriidae with nine species and Ardeidae with seven. Anatidae with three species was followed by Ciconiidae, Threskiornithidae, Phalacrocoracidae, and Burhinidae representing two species each, and Phoenicopteridae, Rallidae, Pelicanidae, Anhingidae, and Recurvirostridae with one species each (Table 1).

Migratory status

The residential status of the birds indicated that Winter Visitors (WV) constituted 33.3% (36 species) of the observed species (Figure 3). All the species recorded from Scolopacidae and Laridae are Winter Visitors (11 species each) and Charadriidae has seven Winter visitors and two Residents, i.e., Hanuman Plover *Charadrius seebohmi* and Red-wattled Lapwing *Vanellus indicus*. Resident species were the most dominant (51 species), followed by Resident/Not Breeding (17 species), three Local Migrants (LM) Western Reef Heron *Egretta gularis*, Oriental Honey Buzzard *Pernis ptilorhynchus* and White-bellied Sea Eagle *Haliaeetus leucogaster* and

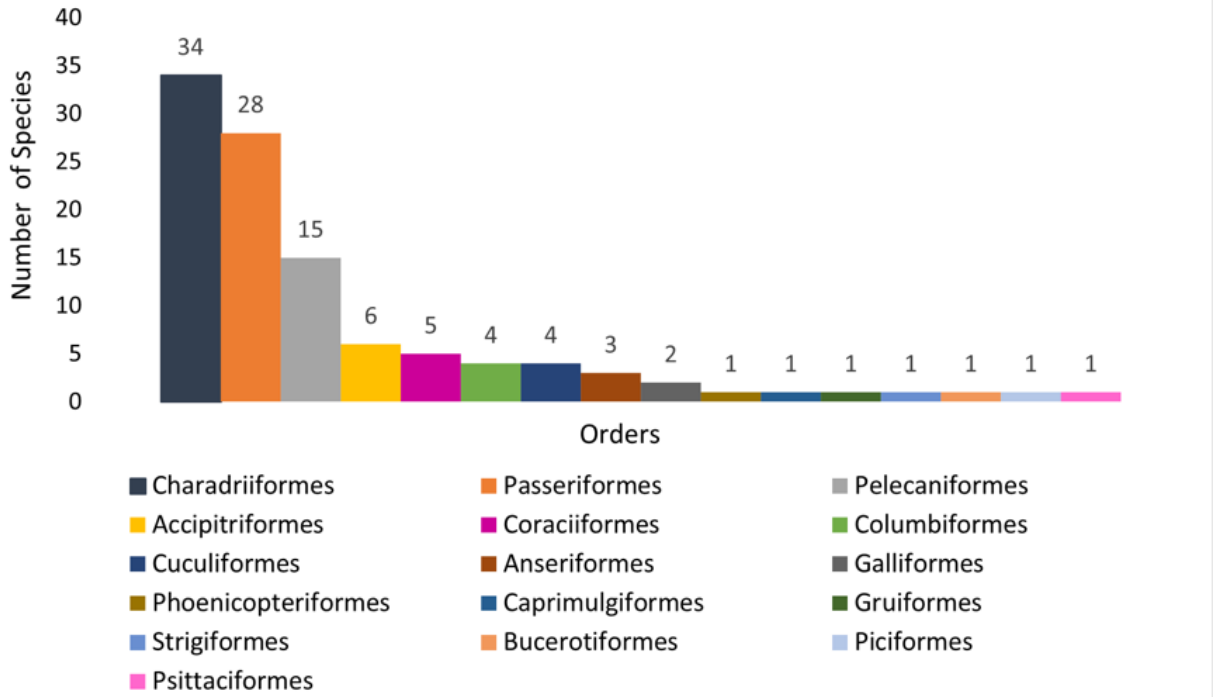

Figure 2. Order-wise graph representing the number of species in each order.

Table 1. Avifaunal checklist of Pillaimadam Lagoon.

Order/Family/Common name	Scientific name	IUCN Red List status	Population trends in India (SOIB 2023)	Resident status	Relative abundance	CMS status
Anseriformes						
Anatidae						
Garganey	*Spatula querquedula*	LC	Rapid decline	WV	Ra	Appendix II
Northern Shoveler	*Spatula clypeata*	LC	Rapid decline	WV	Ra	Appendix II
Northern Pintail	*Anas acuta*	LC	Rapid decline	WV	Ra	Appendix II
Phoenicopteriformes						
Phoenicopteridae						
Greater Flamingo	*Phoenicopterus roseus*	LC	Rapid decline	R/NB	UC	Appendix II
Columbiformes						
Columbidae						
Rock Pigeon	*Columba livia*	LC	Increase	R	C	—
Spotted Dove	*Spilopelia chinensis*	LC	Increase	R	C	—
Laughing Dove	*Spilopelia senegalensis*	LC	Trend inconclusive	R	C	—
Eurasian Collared Dove	*Streptopelia decaocto*	LC	Increase	R	C	—
Caprimulgiformes						
Apodidae						
Asian Palm Swift	*Cypsiurus balasiensis*	LC	Insufficient data	R	C	—
Cuculiformes						
Cuculidae						
Asian Koel	*Eudynamys scolopaceus*	LC	Increase	R	C	—
Greater Coucal	*Centropus sinensis*	LC	Rapid increase	R	C	—
Blue-faced Malkoha	*Phaenicophaeus viridirostris*	LC	Stable	R	C	—
Jacobin Cuckoo	*Clamator jacobinus*	LC	Stable	R/NB	C	—
Gruiformes						
Rallidae						
White-breasted Waterhen	*Amaurornis phoenicurus*	LC	Trend inconclusive	R/NB	C	—
Galliformes						
Phasianidae						
Grey Francolin	*Ortygornis pondicerianus*	LC	Increase	R	C	—
Indian Peafowl	*Pavo cristatus*	LC	Rapid increase	R	C	—
Pelecaniformes						
Ciconiidae						
Asian Openbill	*Anastomus oscitans*	LC	Trend inconclusive	R/NB	C	—
Painted Stork	*Mycteria leucocephala*	LC	Decline	R/NB	C	—
Pelecanidae						
Spot-billed Pelican	*Pelecanus philippensis*	NT	Rapid decline	R/NB	C	—
Ardeidae						
Cattle Egret	*Bubulcus ibis*	LC	Stable	R/NB	C	—
Grey Heron	*Ardea cinerea*	LC	Trend inconclusive	R/NB	C	—
Indian Pond Heron	*Ardeola grayii*	LC	Stable	R/NB	C	—
Intermediate Egret	*Ardea intermedia*	LC	Trend inconclusive	R/NB	C	—
Great Egret	*Ardea alba*	LC	Trend inconclusive	R/NB	C	Appendix II
Little Egret	*Egretta garzetta*	LC	Trend inconclusive	R/NB	C	—

Order/Family/Common name	Scientific name	IUCN Red List status	Population trends in India (SOIB 2023)	Resident status	Relative abundance	CMS status
Western Reef Heron	*Egretta gularis*	LC	Decline	LM	UC	—
Threskiornithidae						
Black-headed Ibis	*Threskiornis melanocephalus*	LC	Stable	R/NB	UC	—
Glossy Ibis	*Plegadis falcinellus*	LC	Stable	R/NB	UC	Appendix II
Phalacrocoracidae						
Indian Cormorant	*Phalacrocorax fuscicollis*	LC	Trend inconclusive	R/NB	C	—
Little Cormorant	*Phalacrocorax niger*	LC	Stable	R/NB	C	—
Anhingidae						
Oriental Darter	*Anhinga melanogaster*	LC	Stable	R/NB	UC	—
Charadriiformes						
Recurvirostridae						
Black-winged Stilt	*Himantopus himantopus*	LC	Trend inconclusive	R	C	Appendix II
Burhinidae						
Indian Thick-knee	*Burhinus indicus*	LC	Insufficient data	R	C	—
Great Thick-knee	*Esacus recurvirostris*	NT	Rapid decline	R	UC	—
Charadriidae						
Black-bellied Plover	*Pluvialis squatarola*	VU	Decline	WV	C	Appendix II
Pacific Golden Plover	*Pluvialis fulva*	LC	Stable	WV	Ra	—
Siberian Sand Plover	*Charadrius mongolus*	EN	Decline	WV	C	Appendix II
Greater Sand Plover	*Charadrius leschenaultii*	LC	Data Not available	WV	C	Appendix II
Kentish Plover	*Charadrius alexandrinus*	LC	Rapid decline	WV	C	Appendix II
Common Ringed Plover	*Charadrius hiaticula*	LC	Data Not available	WV	UC	Appendix II
Hanuman Plover	*Charadrius seebohmi*	NA	Data not available	R	C	
Little Ringed Plover	*Charadrius dubius*	LC	Rapid decline	WV	C	—
Red-wattled Lapwing	*Vanellus indicus*	LC	Trend inconclusive	R	C	—
Scolopacidae						
Whimbrel	*Numenius phaeopus*	LC	Trend inconclusive	WV	C	Appendix II
Eurasian Curlew	*Numenius arquata*	NT	Rapid decline	WV	C	Appendix II
Little Stint	*Calidris minuta*	LC	Rapid decline	WV	C	Appendix II
Curlew Sandpiper	*Calidris ferruginea*	VU	Decline	WV	C	Appendix II
Common Sandpiper	*Actitis hypoleucos*	LC	Decline	WV	UC	Appendix II
Ruddy Turnstone	*Arenaria interpres*	NT	Rapid decline	WV	C	Appendix II
Marsh Sandpiper	*Tringa stagnatilis*	LC	Rapid decline	WV	UC	Appendix II
Wood Sandpiper	*Tringa glareola*	LC	Decline	WV	UC	Appendix II
Common Greenshank	*Tringa nebularia*	LC	Rapid decline	WV	C	Appendix II
Common Redshank	*Tringa totanus*	LC	Decline	WV	C	Appendix II
Bar-tailed Godwit	*Limosa lapponica*	NT	Trend inconclusive	WV	UC	Appendix II
Laridae						
Slender-billed Gull	*Chroicocephalus genei*	LC	Rapid decline	WV	UC	Appendix II
Black-headed Gull	*Chroicocephalus ridibundus*	LC	Decline	WV	C	—
Brown-headed Gull	*Chroicocephalus brunnicephalus*	LC	Decline	WV	C	—
Lesser Black-backed Gull	*Larus fuscus*	LC	Stable	WV	UC	—
Greater Black-headed Gull	*Ichthyaetus ichthyaetus*	LC	Decline	WV	UC	Appendix II
Little Tern	*Sternula albifrons*	LC	Decline	WV	UC	Appendix II

Order/Family/Common name	Scientific name	IUCN Red List status	Population trends in India (SOIB 2023)	Resident status	Relative abundance	CMS status
Caspian Tern	*Hydroprogne caspia*	LC	Decline	WV	C	Appendix II
Greater Crested Tern	*Thalasseus bergii*	LC	Trend inconclusive	WV	C	Appendix II
Lesser Crested Tern	*Thalasseus bengalensis*	LC	Stable	WV	C	Appendix II
Gull-billed Tern	*Gelochelidon nilotica*	LC	Rapid decline	WV	Ra	Appendix II
Whiskered Tern	*Chlidonias hybrida*	LC	Rapid decline	WV	Ra	—
Accipitriformes						
Accipitridae						
Booted Eagle	*Hieraaetus pennatus*	LC	Trend inconclusive	WV	UC	Appendix II
Black Kite	*Milvus migrans*	LC	Trend inconclusive	R	C	Appendix II
Brahminy Kite	*Haliastur indus*	LC	Stable	R	C	—
Shikra	*Accipiter badius*	LC	Stable	R	C	Appendix II
Oriental Honey-buzzard	*Pernis ptilorhynchus*	LC	Stable	LM	UC	Appendix II
White-bellied Sea Eagle	*Haliaeetus leucogaster*	LC	Stable	LM	C	—
Strigiformes						
Strigidae						
Spotted Owlet	*Athene brama*	LC	Data not available	R	C	—
Bucerotiformes						
Upupidae						
Common Hoopoe	*Upupa epops*	LC	Trend inconclusive	R	C	—
Piciformes						
Picidae						
Black-rumped Flameback	*Dinopium benghalense*	LC	Trend inconclusive	R	C	—
Coraciiformes						
Meropidae						
Blue-tailed Bee-eater	*Merops philippinus*	LC	Rapid increase	R	C	—
Green Bee-eater	*Merops orientalis*	LC	Stable	R	C	—
Coraciidae						
Indian Roller	*Coracias benghalensis*	LC	Decline	R	C	—
Alcedinidae						
Pied Kingfisher	*Ceryle rudis*	LC	Decline	R	C	—
White-throated Kingfisher	*Halcyon smymensis*	LC	Trend inconclusive	R	C	—
Psittaciformes						
Psittacidae						
Rose-ringed Parakeet	*Psittacula krameri*	LC	Trend inconclusive	R	C	—
Passeriformes						
Artamidae						
Ashy Wood Swallow	*Artamus fuscus*	LC	Stable	R	C	—
Dicruridae						
Black Drongo	*Dicrurus macrocercus*	LC	Stable	R	C	—
Laniidae						
Brown Shrike	*Lanius cristatus*	LC	Stable	WV	UC	—
Corvidae						
House Crow	*Corvus splendens*	LC	Trend inconclusive	R	C	—
Large-billed Crow	*Corvus macrorhynchos*	LC	Stable	R	C	—
Rufous Treepie	*Dendrocitta vagabunda*	LC	Stable	R	C	—

Order/Family/Common name	Scientific name	IUCN Red List status	Population trends in India (SOIB 2023)	Resident status	Relative abundance	CMS status
Monarchidae						
Indian Paradise-flycatcher	*Tersiphone paradisi*	LC	Stable	R	UC	—
Nectariniidae						
Purple-rumped Sunbird	*Leptocoma zeylonica*	LC	Trend inconclusive	R	C	—
Purple Sunbird	*Cinnyris asiaticus*	LC	Trend inconclusive	R	C	—
Estrildidae						
Indian Silverbill	*Euodice malabarica*	LC	Trend inconclusive	R	C	—
Passeridae						
House Sparrow	*Passer domesticus*	LC	Decline	R	C	—
Motacillidae						
Paddy Field Pipit	*Anthus rufulus*	LC	Decline	R	C	—
White-browed Wagtail	*Motacilla maderaspatensis*	LC	Stable	R	C	—
Aegithinidae						
Common Iora	*Aegithina tiphia*	LC	Increase	R	Ra	—
Alaudidae						
Ashy Crowned Sparrow Lark	*Eremopterix griseus*	LC	Trend inconclusive	R	C	—
Jerdons Bushlark	*Mirafra affinis*	LC	Stable	R	C	—
Oriental Skylark	*Alauda gulgula*	LC	Rapid decline	R	C	—
Cisticolidae						
Common Tailorbird	*Orthotomus sutorius*	LC	Rapid increase	R	C	—
Ashy Prinia	*Prinia socialis*	LC	Increase	R	C	—
Leiotrichidae						
Yellow-billed Babbler	*Argya affinis*	LC	Stable	R	C	—
Acrocephalidae						
Blyth's Reed Warbler	*Acrocephalus dumetorum*	LC	Stable	WV	UC	—
Hirundinidae						
Barn Swallow	*Hirundo rustica*	LC	Decline	WV	Ra	—
Red-rumped Swallow	*Cecropis daurica*	LC	Stable	R	UC	—
Pycnonotidae						
Red-vented Bulbul	*Pycnonotus cafer*	LC	Trend inconclusive	R	C	—
White-browed Bulbul	*Pycnonotus luteolus*	LC	Rapid increase	R	UC	—
Sturnidae						
Brahminy Starling	*Sturnus pagodarum*	LC	Trend inconclusive	R	UC	—
Common Myna	*Acridotheres tristis*	LC	Stable	R	C	—
Rosy Starling	*Pastor roseus*	LC	Rapid decline	PM	UC	—

IUCN Red List status: LC—Least Concern | NT—Near Threatened | VU—Vulnerable | EN—Endangered | NA—Not assessed | Resident status: WV—Winter Visitor | LM—Local Migrant | R—Resident | R/NB—Resident/Non-Breeding | Relative abundance: C—Common | UC—Uncommon | Ra—Rare.

one Passage Migrant (PM) Rosy Starling *Pastor roseus.* The breeding shorebirds in the lagoon include Black-winged Stilt *Himantopus himantopus*, Indian Thick-knee *Burhinus indicus*, Great Thick-knee *Esacus recurvirostris*, regional endemic Hanuman Plover, and Red-wattled Lapwing (Table 1).

Relative abundance

The relative abundance indicated that 76 species were common (C), 24 were uncommon (UC), and eight were rare (Ra). The rare species include ducks like Garganey *Spatula querquedula*, Northern Shoveler *Spatula clypeata*, and Northern Pintail *Anas acuta*; shorebirds like Pacific Golden Plover *Pluvialis fulva;*

Image 1. Greater Flamingo *Phoenicopterus roseus*, an uncommon visitor to the site.

terns like Gull-billed Tern *Gelochelidon nilotica* and Whiskered Tern *Chlidonias hybrida*, and land birds namely, Common Iora *Aegithina tiphia* and Barn Swallow *Hirundo rustica*. The Uncommon ones were waterbirds like Greater Flamingo *Phoenicopterus roseus* (Image 1), Western Reef Heron, Black-headed Ibis *Threskiornis melanocephalus*, Glossy Ibis *Plegadis falcinellus*, Oriental Darter *Anhinga melanogaster*, Great Thick-knee, Common Ringed Plover *Charadrius hiaticula,* Common Sandpiper *Actitis hypoleucos*, Marsh Sandpiper *Tringa stagnatilis*, Common Greenshank *Tringa nebularia*, Bar-tailed Godwit *Limosa lapponica*, Slender-billed Gull *Chroicocephalus genei*, Lesser Black-backed Gull *Larus fuscus*, Greater Black-backed Gull *Ichthyaetus ichthyaetus* and Little Tern *Sternula albifrons* and land birds like Booted Eagle *Hieraaetus pennatus*, Oriental Honey Buzzard, Brown Shrike *Lanius cristatus*, Indian Paradise Flycatcher *Tersiphone paradisi*, Red-rumped Swallow *Cecropis daurica*, White-browed Bulbul *Pycnonotus luteolus*, Brahminy Starling *Sturnus pagodarum* and Rosy Starling (Table 1).

Relative Diversity (RDi)

Relative diversity index shows that families, i.e., Scolopacidae and Laridae dominate the landscape (10.2% and 11 species each), followed by Charadriidae (8.3% with 9 species), Ardeidae (6.5% with 7 species), and Accipitridae (5.6% with 6 species); Columbidae and Cuculidae (3.7% and 4 species each); Anatidae, Corvidae, Alaudidae, and Sturnidae (2.78% with 3 species each); Phasianidae, Ciconiidae, Threskiornithidae, Phalacrocoracidae, Burhinidae, Meropidae, Alcedinidae, Nectariniidae, Motacillidae, Cisticolidae, Hirundinidae, and Pycnonotidae (1.81 % and 2 species each); remaining 20 families constitute 0.93% and one species each (Table 2).

IUCN Red List Status

The site supported five 'Near Threatened' species which include four shorebirds and one waterbird: Bar-tailed Godwit, Eurasian Curlew *Numenius arquata,* Great Thick-knee, Ruddy Turnstone *Arenaria interpres* and Spot-billed Pelican *Pelecanus philippensis.* Two 'Vulnerable' species, Black-bellied Plover *Pluvialis squatarola* and Curlew Sandpiper *Calidris ferruginea,* one 'Endangered' species, namely, Siberian Sand Plover *Charadrius mongolus* and one species Hanuman Plover is Not Evaluated, remaining 99 species were assessed 'Least Concern' according to the IUCN Red List (IUCN 2024) (Figure 4).

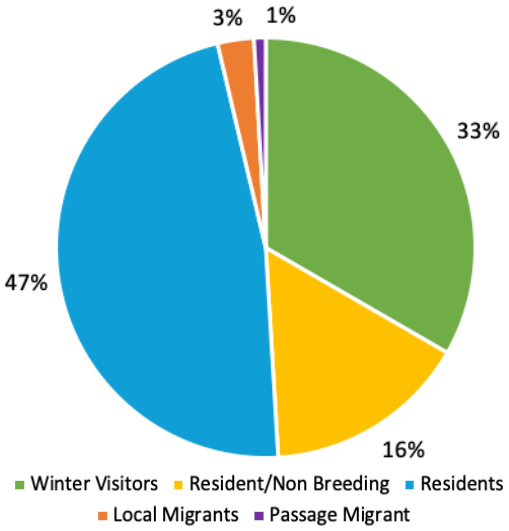

Figure 3. Representation of the residential status of the avifauna.

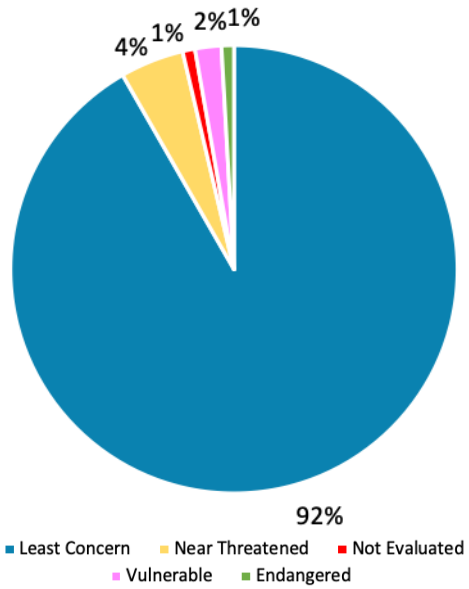

Figure 4. Representation of the IUCN Red List status of the avifauna.

SOIB population trends

Based on SOIB indices, we calculated the Indian national trends of the avifauna in Pillaimadam Lagoon as follows, 26% of species populations are stable; 24% are trend inconclusive and the rest are rapid increase (5%); increase (7%); decline (17%); and rapid decline (17%). The trend of four species was not available in SOIB including Spotted Owlet, Hanuman Plover, Common Ringed Plover, and Greater Sand Plover *Charadrius leschenaultii* (Table 1).

CMS Status

Among the 108 species from the Pillaimadam Lagoon, 32.4% (30 water birds and 4 land birds) are protected under the Convention on the Conservation of Migratory Species of Wild Animals under Appendix II (Table 1).

DISCUSSION

Among the 108 species, 50% were landbirds, and the order Passeriformes with 30 species dominated the terrestrial birds. This showed the lagoon supported these birds with suitable vegetative cover on the peripheries. The high representation of waterbirds in Pillaimadam Lagoon is consistent with the importance of such habitats as critical stopovers and wintering sites for migratory species (Skagen 2018). The dominance of the order Charadriiformes, with 34 species, aligns with studies of coastal ecosystems globally, where shorebirds are often the most abundant due to the availability of feeding grounds along intertidal zones (Warnock & Takekawa 2006; Manikannan et al. 2012). The Siberian Sand Plover, Little Stint, and Kentish Plover dominated the bird species populations. A minimum of a few hundred to one thousand individuals of these species were observed from the lagoon. In particular, the dominance of species such as Siberian Sand Plover and Little Stint reflects the lagoon's role in supporting many long-distance migrants. Similar patterns have been observed in wetland systems across India, where coastal and inland wetlands serve as essential wintering grounds for migratory shorebirds (Rahmani et al. 2016).

Most shorebird species were documented from late August until the end of May, while a few were found over the summer in small numbers during 15 June–31 July (Balachandran 1990) in the study area. We observed that 11 species of shorebirds over-summering here: Common Redshank *Tringa totanus,* Common Greenshank, Black-bellied Plover, Curlew Sandpiper, Ruddy Turnstone, Whimbrel *Numenius phaeopus,* Eurasian Curlew, Siberian Sand Plover, Greater Sand Plover, Kentish Plover *Charadrius alexandrines*, and Little Stint *Calidris minuta*. We also found some Lesser Crested Tern *Thalasseus bengalensis* and Greater Crested Terns *Thalasseus bergii* throughout the year. Similarly, several over-summering shorebird species have been reported from Kadalundi Vallikkunnu Community Reserve (KVCR) (Aarif et al. 2020) and Changaram wetlands (Anand et al. 2023) on the west coast and various sites on the south-east coast of India (Byju et al. 2024a). Hence, this leads to the elucidation that food resources for the over-summering shorebirds are available throughout the year

Table 2. Relative diversity index (RDi) of various avifaunal families in Pillaimadam Lagoon.

Families	Number of species	RDi (%)
Scolopacidae	11	10.19
Laridae	11	10.19
Charadriidae	9	8.33
Ardeidae	7	6.48
Accipitridae	6	5.56
Columbidae	4	3.70
Cuculidae	4	3.70
Anatidae	3	2.78
Corvidae	3	2.78
Alaudidae	3	2.78
Sturnidae	3	2.78
Phasianidae	2	1.85
Ciconiidae	2	1.85
Threskiornithidae	2	1.85
Phalacrocoracidae	2	1.85
Burhinidae	2	1.85
Meropidae	2	1.85
Alcedinidae	2	1.85
Nectariniidae	2	1.85
Motacillidae	2	1.85
Cisticolidae	2	1.85
Hirundinidae	2	1.85
Pycnonotidae	2	1.85
Phoenicopteridae	1	0.93
Apodidae	1	0.93
Rallidae	1	0.93
Pelecanidae	1	0.93
Anhingidae	1	0.93
Recurvirostridae	1	0.93
Strigidae	1	0.93
Upupidae	1	0.93
Picidae	1	0.93
Coraciidae	1	0.93
Psittacidae	1	0.93
Artamidae	1	0.93
Dicruridae	1	0.93
Laniidae	1	0.93
Monarchidae	1	0.93
Estrildidae	1	0.93
Passeridae	1	0.93
Aegithinidae	1	0.93
Leiotrichidae	1	0.93
Acrocephalidae	1	0.93

in this lagoon due to fresh seawater coming into the lagoon during the dry season as it gets completely cut off from the sea.

Among other water birds, including herons, egrets, and ibises, only one was a local migrant (LM), the Western Reef Heron, and the rest were residents and not breeding on the site. Twelve species were common, and five species were uncommon. The most dominant waterbird species identified in the lagoon were Intermediate Egret *Ardea intermedia*, Little Egret *Egreta garzeta*, and Indian Cormorant *Phalacrocorax fuscicollis*. Apart from the shorebirds and other waterbirds mentioned, five species of gulls, viz., Slender-billed Gull, Black-headed Gull *Chroicocephalus ridibundus,* Brown-headed Gull *Chroicocephalus brunnicephalus*, Lesser Black-backed Gull, and Greater Black-headed Gull were documented from this site. Of these, the most dominant ones were Black-headed and Brown-headed Gulls. Six species of terns, viz., Little Tern, Gull-billed Tern, Caspian Tern *Hydroprogne caspia*, Whiskered Tern, Greater Crested Tern and Lesser Crested Tern were also encountered. Greater Crested Tern, followed by the Lesser Crested Tern, were the most dominant of the group throughout the study period (Image 2).

Conservation status

Anthropogenic activities such as land reclamation, pollution, and over-extraction of water resources have degraded India's wetlands (Sundar & Kittur 2013), posing a serious threat to the bird species. The presence of five 'Near Threatened' species, two 'Vulnerable' and one 'Endangered' species highlights the ecological significance of this lagoon for bird conservation. The presence of probing birds like Bar-tailed Godwit, Curlew Sandpiper, and Eurasian Curlew reflects the lagoon's critical role as a stopover site during migration, providing essential feeding and resting areas. Great Thick-knee, a species typically found in coastal areas, further reinforces the site's ecological value. Hanuman Plover (Image 3), currently unassessed by the IUCN Red List, adds to the lagoon's conservation relevance, as little is known about this species' population trends and ecological requirements (Byju et al. 2023e), making it a subject of interest for further studies. The lagoon's suitability for these waterbirds may be attributed to its rich aquatic biodiversity, prey availability, and relatively undisturbed environment compared to other wetlands in the region. The observation that 32.4% of the recorded species from the study are being protected under CMS Appendix II suggests the need for international cooperation in managing and conserving this wetland (CMS 2024). As

Image 2. Greater Crested Tern *Thalasseus bergii* congregation is mostly seen throughout the year with few Caspian Terns *Hydroprogne caspia*.

Image 3. Regional endemic Hanuman Plover *Charadrius seebohmi* with chick.

noted in other studies, such recognitions highlight the importance of coordinated conservation efforts across migratory pathways (Kirby et al. 2008). Three species recorded in Pillaimadam, Bar-tailed Godwit, Whimbrel, and Curlew Sandpiper are also enlisted as Central Asian Flyway Priority Species in the Arctic Migratory Birds Initiative (AMBI), further emphasizing the need to secure this wetland (Arctic Council 2024).

According to the SoIB report, the national trends for many wetland-dependent species, especially the coastal wetland species indicate a population decline (State of India's Birds 2023). In Pillaimadam Lagoon, the trend analysis based on SoIB indices shows a mixed picture, with 34% of species populations declining or rapidly declining. This is a concerning statistic, reflecting broader patterns of wetland degradation, loss of breeding habitat, and declining prey availability (Wetlands International 2020). SoIB analysis results also mark the importance of extensive scientific documentation in such wetlands, as 24% of the species population trend in Pillaimadam could not be concluded because of too few reports. The results of this study align with the broader trends in wetland bird populations across the Indian subcontinent, even though the methods are not completely reliable (Maitreyi 2024).

Conservation Significance

Removal of invasive trees like *Neltuma juliflora* from the peripheries of the lagoon has dented the breeding population of Great Thick-knee and Black-winged Stilt in the area. These trees served as a natural barrier for the birds in the lagoon. The removal of these invasive trees should be carried out scientifically in phases to avoid any disturbance during the breeding season rather

than removal in a single stroke, as a few landbirds also use these trees for nesting. The freshwater puddles that formed after the rains have completely exposed the area, making those patches vulnerable for birds for roosting and breeding due to consistent human activities. A basic avifaunal checklist in an unexplored area like this study provides baseline data for identifying potential new sites for conservation priority. Moreover, it attracts bird watchers, helps tourism with the local community's support and helps conservationists develop strategies to mitigate threats in the new wintering site in the CAF.

CONCLUSION

This study is noteworthy as this is the first avifaunal study from the area. Even though earlier avifaunal studies in the area were restricted to bird-ringing studies of gulls, terns, and shorebirds. This study could aid in filling knowledge gaps and help in conservation management understanding the distribution of bird species and prioritizing conservation of numerous waterbirds and shorebirds. Establishing this preliminary data could provide a basis for tracking bird population changes over time, which helps conservation efforts. Lack of formal protection for the habitat may also make it vulnerable to coastal reclamation projects. Prioritization of habitat conservation in the Lagoon should also be considered to save the breeding areas of regional endemic species like Hanuman Plover.

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