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Cover: Parts of *Vachellia nilotica*, medium - watercolours. © P Kritika

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ARTICLE

A decadal study on the waterbirds and an analysis of the declining species in Perur-Sundakamuthur Lake, Coimbatore, Tamil Nadu, India

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Abstract: The results of a decade-long systematic monthly monitoring of birds in Perur-Sundakamuthur Lake, an urban wetland in Coimbatore, Tamil Nadu, conducted from May 2014 to April 2024, are presented. The status and population trends of 129 species that comprise 51 waterbirds and 78 non-waterbirds were analysed. The analysis was focused solely on 37 species of waterbirds by categorising them into 10 guilds. Of these, seven species were each treated as a separate category based on their distribution status. Among them, 65% of the species were present in high numbers when the water level was medium. Also, about 78% of the winter migrant ducks and shorebirds were present only during the aforesaid condition, feeding on the shallow pools and moist mudflats. The abundance of 73% of the analysed waterbird species declined, ranging from 3% to 99%. The population of shorebirds and winter migrant ducks declined by 67% and 99.5%, respectively. From the findings, it is believed that maintaining full water levels in the wetland to aid commercial fishing is the most probable reason for the decline of these winter migrants. Monthly bird counts are suggested in the wetlands of greater Coimbatore to expand the scope of long-term monitoring of the urban avian population.

Keywords: Anthropogenic disturbance, avian population trends, foraging guilds, habitat heterogeneity, long-term monitoring, migratory waterfowl, wetland management.

சுருக்கம்: கோவை நகரப்பகுதியில் அமைந்துள்ள பேரூர்-சுண்டக்காமுத்தூர் குளத்தில், மே 2014 முதல் ஏப்ரல் 2024 வரை மேற்கொள்ளப்பட்ட பத்தாண்டு மாதாந்திரப் பறவைக் கணக்கெடுப்பின் தரவுகள் பகுப்பாய்ந்துத் தரப்பட்டுள்ளது. இவ்வாய்வில், 51 நீர்ப்பறவை இனங்கள் மற்றும் 78 நீர் சாராப் பறவை இனங்கள் உட்பட மொத்தம் 129 பறவை இனங்களின் பரவல் நிலையும் எண்ணிக்கை மாற்றங்களும் ஆய்வு செய்யப்பட்டன. அவற்றுள் 37 நீர்ப்பறவை இனங்கள் பத்துக் குழுக்களாக வகைப்படுத்தப்பட்டு சீராய்வு செய்யப்பட்டன. மேலும், எண்ணிக்கைப் பரவல் தன்மையின் அடிப்படையில் ஏழு இனங்கள் தனித்தனியாக ஆய்வு செய்யப்பட்டன. குளத்தின் நீர்மட்டம் நடுத்தரமாக இருந்த காலங்களில், 65 விழுக்காடு நீர்ப்பறவை இனங்கள் அதிக எண்ணிக்கையில் பதிவாகியுள்ளன. இந்நீர்மட்டத்தில் உருவாகும் ஆழமற்ற நீர்ப்பகுதிகளும் சேற்றுச் சமவெளிகளும் இரைதேடுவதற்கு ஏற்ற வாழிடங்களாக அமைவதால், வலசை வரும் வாத்துகள் மற்றும் கரையோரப் பறவைகளில் 78 விழுக்காடு இனங்கள் இந்நிலையிலேயே பதிவாகியுள்ளன. ஆய்வுக் காலத்தில் சீராய்வுக்கு உட்படுத்தப்பட்ட நீர்ப்பறவை இனங்களில் 73 விழுக்காடு இனங்கள், எண்ணிக்கையில் 3 முதல் 99 விழுக்காடு வரை சரிவைக் காட்டியுள்ளன. கரையோரப் பறவைகளும் வலசை வரும் வாத்துகளும் முறையே 67 விழுக்காடு 99.5 விழுக்காடு குறைந்துள்ளன. இந்தத் தரவுகள், வணிக மீன்பிடிப்பு நடவடிக்கைகளும், அதனைத் தொடர்ந்து குளத்தில் செயற்கையாக அதிக நீர்மட்டம் நீடித்துப் பராமரிக்கப்படுவதும், நீர்ப்பறவைகளின் எண்ணிக்கைக் குறைவுக்கான முக்கிய காரணிகளாக இருக்கக்கூடும் என்பதைக் காட்டுகின்றன. எனவே, கோவை மற்றும் அதன் சுற்றுவட்டாரப் பகுதிகளில் உள்ள ஏரிகள் மற்றும் குளங்களில் நீண்டகால மாதாந்திரப் பறவைக் கணக்கெடுப்புகளை மேற்கொள்வது, நீர்ப்பறவைகளின் எண்ணிக்கை மாற்றங்களையும் வாழிட மாற்றங்களையும் கண்காணிப்பதற்கு இன்றியமையாததாகும்.

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INTRODUCTION

Many ecosystems, at scales ranging from local to global, are now heavily human-influenced and are undergoing large, far-reaching changes that have extremely negative consequences for human well-being (Millennium Ecosystem Assessment 2005a; Biggs et al. 2010; Intergovernmental Panel on Climate Change (IPCC) 2021; Mundkur et al. 2023). The loss of habitat through human action and resource extraction impacts wildlife population, including birds (Şekercioğlu et al. 2004; Lees et al. 2022; Parameswaran et al. 2023a; Byju et al. 2024a).

Birds contribute many important ecological functions through their roles as predators, pollinators, scavengers, seed dispersers, and ecosystem engineers. Many of these ecosystem functions also translate to ecosystem services such as supporting fish and fibre, water purification, climate and flood regulation, along with recreational opportunities (Millennium Ecosystem Assessment 2005b; Whelan et al. 2008; Şekercioğlu 2010). The abilities of birds to fly and migrate long distances enable them to respond to eruptive resources and to connect varying landscapes in ways that other organisms cannot (Şekercioğlu et al. 2016), as they are one of the reliable indicators of biodiversity and ecosystem health (Frazier 1999; Gregory et al. 2003; Gregory & Van Strien 2010; Fraixedas et al. 2020; Mundkur et al. 2023).

Wetlands constitute some of the most productive ecosystems in India, and their health is often correlated with the waterbird communities that play vital roles in their effective functioning (Millennium Ecosystem Assessment 2005b; Raju 2015). In urban areas, inland wetlands remain some of the last natural ecosystems that not only provide refuge to a wide variety of flora and fauna but also offer important space for humans to interact with nature (Raju 2015). Also, inland wetlands are extremely important for migratory waterbirds either as resting locations or wintering grounds (Mundkur et al. 2023). Although many urban wetlands in India are extremely polluted, they still attract a large number of birds (Parameswaran et al. 2023a). Urban wetlands are also continuously disturbed by development activities, which affect their bird populations (Fluet-Chouinard et al. 2023). In Tamil Nadu, fast-growing cities like Coimbatore still have some wetlands with a good bird population. A few earlier studies relating to birds on some of the Coimbatore lakes are from Singanallur (Reginald et al. 2007; Guptha et al. 2011), Ukkadam (Guptha et al. 2011; Kumar et al. 2014), Perur (Parameswaran & Sivashankar 2018; Parameswaran et al. 2023a), Kuruchi, Valankulam, and Sulur (Guptha et al. 2011), and Chinnavedampatti (Kumar et al. 2025).

The primary aim of this study is to monitor the waterbird population and their changes in terms of conservation perspective in Perur-Sundakamuthur Lake (hereinafter, Perur Lake), Coimbatore, for a decade. In order to effectively analyse the data, a methodology was devised to define the distribution status of the waterbird species, focusing on common waterbirds that frequent the lake. The population changes of the common waterbird species were closely analysed in association with local threats occurring at the lake. Perur Lake was chosen for its size and accessibility to conduct continuous bird monitoring, representing one of the lakes in a fast-developing urban area.

Study area

Perur Lake (10.970º N, 76.928º E) lies in the southwestern corner of metropolitan Coimbatore, Tamil Nadu. It is a freshwater wetland and part of a network of approximately 30 interconnected lakes constructed during the Kongu-Chola regimes in the 8th–9th centuries CE within the Noyyal River basin (Pragatheesh & Jain 2013). These lakes were designed to regulate monsoon floods, store surface runoff, and enhance groundwater recharge in this semi-arid region. Over time, this wetland of the Noyyal Basin has developed into an ecologically important habitat supporting diverse assemblages of birds, fishes, molluscs, and other aquatic biota. In addition to supplying irrigation water, they provide ecosystem services such as flood mitigation, groundwater recharge, nutrient retention, water purification, and biodiversity conservation. In short, its ecological function is primarily to act as a flood plain for the river Noyyal Basin with its attendant flow.

The lake has a catchment area of 5.768 km² and receives inflow through a single channel from the Kuniyamuthur Anicut, which conveys surplus water from the upstream Ganganarayanasamudhram Lake. The wetland has seven outlets (one weir and six sluices) and a surplus escape channel of 35.67 m. Water levels fluctuate seasonally depending on rainfall, influencing habitat structure and waterbird assemblages (Pragatheesh & Jain 2013). The eastern margin of the lake is bordered by a crescent-shaped bund, approximately 2 km in length, which was formerly vegetated and walkable but has since been converted into a two-lane roadway with a containment wall that partially encroaches into the wetland. The southwestern shoreline supports trees and emergent vegetation used by birds for roosting and occasional nesting, and

remains largely inaccessible except during dry periods. The western edge of the lake gradually transitions into agricultural land (Parameswaran et al. 2023a).

Owing to the absence of major industrial activity and sewage inflow, Perur Lake remains relatively unpolluted (Mohanraj et al. 2000; Chandra et al. 2009). Invasive aquatic macrophytes such as *Eichhornia crassipes* are absent, although floating plants, including water lilies (Nymphaeaceae), occur sporadically. This lake is subjected to anthropogenic pressures such as sandmining, commercial fishing (ongoing), road construction and encroachment (Pragatheesh & Jain 2013; Parameswaran et al. 2023a).

MATERIALS AND METHODS

Perur Lake was monitored once a month from May 2014–April 2024, usually on second Saturdays by walking on a fixed 2 km road transect in the morning at 0700–1000 h, counted all birds that were seen or heard and recorded the information in a checklist. This method can be characterized as a "total count". Binoculars (Nikon 10 x 42.5, Zeiss 10 x 42 & Eagle Optics 10 x 42), a spotting scope (Bausch & Lomb 20–80 x magnification), and cameras were used for the monitoring and documentation. The number of volunteers who participated in the count on any given day varied from three to eight. During the decade, there were 108 actual monthly counts conducted, amounting to c. 900 h of volunteer time. Of the counts missed, four were due to sand mining operations between June and September 2017, and the rest were due to COVID-19 restrictions in 2020 and 2021.

The standard field guides (Ali & Ripley 1968a,b,c,d; Hayman et al. 1986; Kazmierczak 2000; Ali 2002; Paulson 2005; Grimmett et al. 2011; Rasmussen & Anderton 2012) were used to identify birds. Birds were categorised as follows: resident (R): a species that stays year-round but also breeds in the area (e.g., Indian Spot-billed Duck *Anas poecilorhyncha*). Local migrant (LM): a species that stays in the area throughout (or most of) the year and whose adult population moves outside the area to breed. Occasionally, when resources are available, these species may also breed in the area (e.g., Lesser Whistling Duck *Dendrocygna javanica*). Winter migrant (WM): a species that spends its non-breeding winter months (mostly from September–April) in the area (e.g., Wood Sandpiper *Tringa glareola*). Passage migrant (PM): a species that is present between February–April and September–November in the area. Uncertain (U): a species that occasionally visits an area and whose pattern cannot be discerned (e.g., Woolly-necked Stork *Ciconia episcopus*). To enable integrated analysis of waterbird population, especially winter migrants, the 'wetland year' is calibrated from May of the current year to April of the succeeding year.

To quantify and determine the distribution status of each species, a method was adopted based on the field experience (Parameswaran et al. 2023a). The bird categories were split into two, namely, waterbirds and non-waterbirds. Parameters such as reporting frequency (RF) and mean count (MC) were defined as follows:

RF = No. of surveys that have the species / Total no. of surveys

MC = Total count of the species in all surveys / Total no. of surveys

By multiplying MC and RF, the benchmark value for each species was obtained. The species with the highest benchmark value for that category (waterbird / non-waterbird) was designated as the Benchmark species. The population index (PI) of each species was calculated as PI = mean count of the species / mean count of the benchmark species. Finally, the distribution status given as a percentage is calculated by the formula [(RF + PI)/2] * 100 (Table 1A), and the distribution status of each species is determined. Some examples of waterbirds and non-waterbirds are provided in Table 1B.

Prior to the start of every count, the water level is estimated visually (Table 2). We then obtained the corresponding mean count (MC) for every water level, which was calculated using the formula given below:

MC of a species per water level = Sum of all counts of a species in that water level / Number of surveys in that water level.

During surveys, potential threats (threat events) were documented within the wetland and associated the threats with the months. Both waterbird species diversity were compared, as well as population numbers before and after a threat event, to assess the impact of the threat. For this analysis, we eliminated the species whose distribution status is rare, because they are

Table 1A. Distribution status codes.

Distribution status	Percentage
Abundant	≥ 90 %
Common	60–89 %
Fairly Common	30–59 %
Uncommon	10–29 %
Rare	< 10 %

Table 1B. Examples of distribution status calculation.

Species	Total count of birds	MC (Total count / 108)	No. of sightings	RF (No. of sightings / 108)	Benchmark value (MC * RF)	PI (MC / MC of species with highest benchmark value)	Distribution status [(RF+PI)/2]*100%	
							%	Distribution status
Waterbirds								
Indian Spot-billed Duck#	4542	42.05	102	0.94	39.72#	1.00	97%	Abundant
Little Cormorant	3843	35.58	98	0.91	32.29	0.85	88%	Common
Common Sandpiper	414	3.83	72	0.67	2.56	0.09	38%	Fairly Common
Little Grebe	608	5.63	44	0.41	2.29	0.13	27%	Uncommon
Striated Heron	15	0.138	12	0.11	0.02	0.0005	6%	Rare
Non-waterbirds								
House Crow#	6228	57.67	108	1.00	57.67#	1.00	100%	Abundant
Common Myna	3690	34.17	107	0.99	33.85	0.59	79%	Common
Rock Pigeon	1354	12.54	93	0.86	10.80	0.22	54%	Fairly Common
Black Drongo	148	1.37	61	0.56	0.77	0.02	29%	Uncommon
Paddyfield Pipit	25	0.23	16	0.15	0.03	0.004	7.7%	Rare

MC—mean count | RF—reporting frequency | PI—population index.
Indian Spot-billed Duck *Anas poecilorhyncha* is the benchmark species for waterbirds as House Crow *Corvus splendens* for non-waterbirds.

less than 10% of the distribution status (Table 1A) and categorized the rest of the waterbirds into guilds (Pearce et al. 2007), primarily based on order and secondarily on their yearly mean population trend. Some individual species are treated separately and not included in the guilds, as their yearly mean population trend is significantly different from that of the waterbirds in the same order.

The mean of their population counts was calculated for the first five years (May 2014–April 2019) and the next five years (May 2019–April 2024) and used the difference in their percentages to show the population decline. A sparkline or a trend line graph of the annual mean over the decade was drawn for all guilds and individual species. The annual population change with the standard error and compared it with the global trends from the International Union for Conservation of Nature's Red List of Threatened Species (IUCN 2025-2) and national current annual trends during 2014–2020 available from the State of India's Birds (SoIB 2023). The IUCN 2025-2 and SoIB 2023 were chosen because their periodicity significantly overlaps with our study.

A detailed annotated checklist with bar charts that represents the presence/absence of the species across the year, line graphs depicting population trends, and notable differences from existing literature are provided in the supplementary dataset archived on Zenodo (Parameswaran et al. 2025). The software used to plot graphs and visualizations are Microsoft Power BI and Microsoft Excel.

RESULTS

Around 129 species of birds (Table S5 in the supplementary dataset (Parameswaran et al. 2025) were recorded in Perur Lake, including 51 species of waterbirds (Table 3). The 51 waterbird species comprise 14 residents, 14 local migrants, 13 winter migrants and 10 of uncertain status (Table 4). The list was pared down to 37 species by eliminating 14 species falling under the rare category. The 37 species are further categorized as 10 guilds comprising 30 species and seven species treated individually. The reason that five out of these seven species, such as Indian Spot-billed Duck *Anas poecilorhyncha*, Asian Openbill *Anastomus oscitans*, Eurasian Coot *Fulica atra*, Lesser Whistling Duck *Dendrocygna javanica*, and Glossy Ibis *Plegadis falcinellus*, were treated individually because their inclusion in a guild would dominate and mask the data of the entire guild (Adhurya et al. 2019). In the context of Perur Lake, the other two species, such as Little Grebe *Tachybaptus ruficollis* and Whiskered Tern *Chlidonias hybrida*, are singular by their very nature and therefore cannot be included with the rest of the analysed waterbirds.

The first year of the study, 2014–2015, had the highest mean waterbird population of 732 birds per month. This population dropped in subsequent years to the level of 123.5 in 2017–18 and followed by a slow revival from 2021–22 until the last year of this study, when the second-highest mean population of 629 birds

per month was recorded in 2023–24. Similarly, the first two years, 2014–15 & 2015–16 registered the highest mean species diversity of 22.8 per month, dropping to the lowest of 15.4 in 2020–21 and increasing to 19.8 in 2022–23 and 2023–24. Image 1 provides the trend of monthly waterbird counts across the ten years and their corresponding water levels and threats due to anthropogenic actions. Image 2 provides the yearly waterbird population trend and waterbird species diversity over the decade.

Impact of water levels

The highest counts of waterbirds were obtained when the water level of the lake was 'Medium' (Image 3), when large flocks of dabbling ducks like Indian Spot-billed Duck *Anas poecilorhyncha*, egrets like Little Egret *Egretta garzetta*, and shorebirds like Wood Sandpiper *Tringa glareola* were seen feeding in the mudflats, shoreline and shallow water pools. Of the 37 waterbirds analysed, 24 (65%) are present in high numbers when the water level is Medium (Image 4).

Decline of waterbirds

The population of several waterbird species and their corresponding guilds declined steeply in Perur Lake during the study period, sometimes resulting in total disappearance (Table 5). Overall waterbird numbers declined by 14% during the decade. The decline was 60.4% during the first nine years, i.e., from May 2014 to April 2023 (Image 2).

From the analysis of data provided in Table 5 for the waterbird guilds and individual species, we would like to restate that 73% of the waterbirds have declined in population, ranging 3–99 % (Table 6). Winter migrant

Table 2. Description of water level.

Water level	Description
Dry	The absence of water in the lake or the presence of a negligible wet ground.
Low	The presence of a small amount of water in a few isolated puddles.
Medium	The presence of water in the whole lake with shoreline exposed in the periphery.
Full	The lake is completely filled with water without any exposed shoreline.

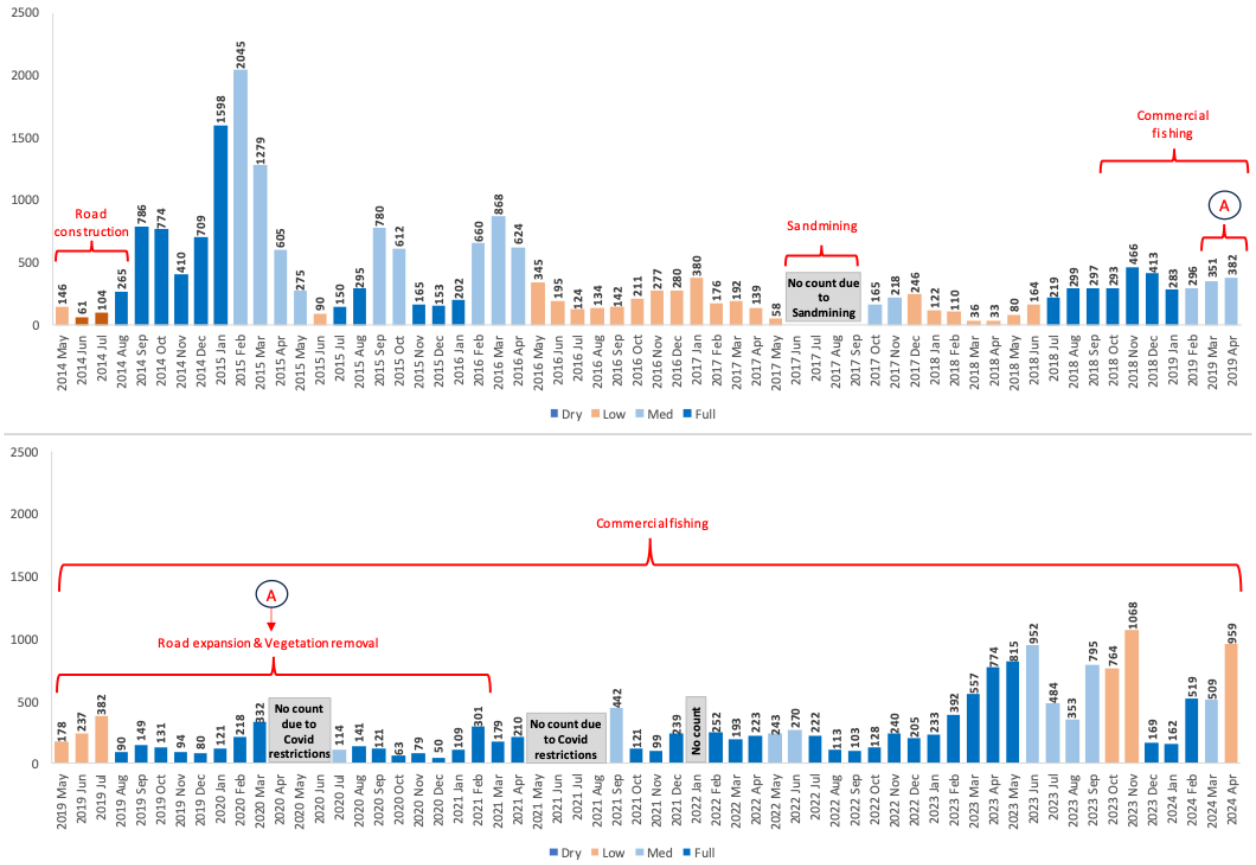


Image 1. Monthly trend from May 2014–April 2024 of the total number of birds and the various threats, colour-coded with water levels.

Table 3. Waterbirds of Perur Lake, Coimbatore.

	Common name	Scientific name	Status	Distribution status
	Anseriformes: Anatidae			
1	Lesser Whistling-Duck	*Dendrocygna javanica*	LM	Fairly Common
2	Cotton Pygmy-Goose	*Nettapus coromandelianus*	LM	Rare
3	Garganey	*Spatula querquedula*	WM	Fairly Common
4	Northern Shoveler	*Spatula clypeata*	WM	Uncommon
5	Northern Pintail	*Anas acuta*	WM	Uncommon
6	Common Teal	*Anas crecca*	U	Rare
7	Indian Spot-billed Duck	*Anas poecilorhyncha*	R	Common
	Podicipediformes: Podicipedidae			
8	Little Grebe	*Tachybaptus ruficollis*	R	Uncommon
	Gruiformes: Rallidae			
9	Common Moorhen	*Gallinula chloropus*	R	Uncommon
10	Eurasian Coot	*Fulica atra*	R	Common
11	Grey-headed Swamphen	*Porphyrio poliocephalus*	R	Fairly Common
12	White-breasted Waterhen	*Amaurornis phoenicurus*	R	Uncommon
	Charadriiformes: Recurvirostridae			
13	Black-winged Stilt	*Himantopus himantopus*	LM	Uncommon
	Charadriiformes: Charadriidae			
14	Red-wattled Lapwing	*Vanellus indicus*	R	Fairly Common
15	Kentish Plover	*Anarhynchus alexandrinus*	U	Rare
16	Little Ringed Plover	*Thinornis dubius*	R/ WM	Uncommon
	Charadriiformes: Jacanidae			
17	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	U	Rare
18	Bronze-winged Jacana	*Metopidius indicus*	U	Rare
	Charadriiformes: Scolopacidae			
19	Ruff	*Calidris pugnax*	U	Rare
20	Temminck's Stint	*Calidris temminckii*	WM	Rare
21	Little Stint	*Calidris minuta*	WM	Uncommon
22	Common Sandpiper	*Actitis hypoleucos*	WM	Fairly Common
23	Green Sandpiper	*Tringa ochropus*	WM	Uncommon
24	Common Greenshank	*Tringa nebularia*	WM	Uncommon
25	Marsh Sandpiper	*Tringa stagnatilis*	WM	Rare
26	Wood Sandpiper	*Tringa glareola*	WM	Uncommon
	Charadriiformes: Laridae			
27	Whiskered Tern	*Chlidonias hybrida*	WM	Uncommon
28	River Tern	*Sterna aurantia*	WM	Rare
	Ciconiiformes: Ciconiidae			
29	Asian Openbill	*Anastomus oscitans*	LM	Common
30	Asian Woolly-necked Stork	*Ciconia episcopus*	U	Rare
31	Painted Stork	*Mycteria leucocephala*	LM	Fairly Common
	Suliformes: Anhingidae			
32	Oriental Darter	*Anhinga melanogaster*	R	Fairly Common
	Suliformes: Phalacrocoracidae			
33	Little Cormorant	*Microcarbo niger*	R	Common
34	Indian Cormorant	*Phalacrocorax fuscicollis*	R	Fairly Common
35	Great Cormorant	*Phalacrocorax carbo*	LM	Uncommon
	Pelecaniformes: Pelecanidae			
36	Spot-billed Pelican	*Pelecanus philippensis*	LM	Uncommon
	Pelecaniformes: Ardeidae			
37	Yellow Bittern	*Botaurus sinensis*	U	Rare
38	Cinnamon Bittern	*Botaurus cinnamomeus*	U	Rare
39	Grey Heron	*Ardea cinerea*	R	Common
40	Purple Heron	*Ardea purpurea*	R	Fairly Common
41	Great Egret	*Ardea alba*	LM	Fairly Common
42	Intermediate Egret	*Ardea intermedia*	LM	Fairly Common
43	Little Egret	*Egretta garzetta*	LM	Common
44	Western Reef-Egret	*Egretta gularis*	U	Rare
45	Eastern Cattle-Egret	*Ardea coromanda*	LM	Fairly Common
46	Indian Pond-Heron	*Ardeola grayii*	R	Common
47	Striated Heron	*Butorides striata*	U	Rare
48	Black-crowned Night Heron	*Nycticorax nycticorax*	R	Uncommon
	Pelecaniformes: Threskiornithidae			
49	Glossy Ibis	*Plegadis falcinellus*	LM	Uncommon
50	Black-headed Ibis	*Threskiornis melanocephalus*	LM	Uncommon
51	Eurasian Spoonbill	*Platalea leucorodia*	LM	Uncommon

R—resident | LM—local migrant | WM—winter migrant | U—uncertain.

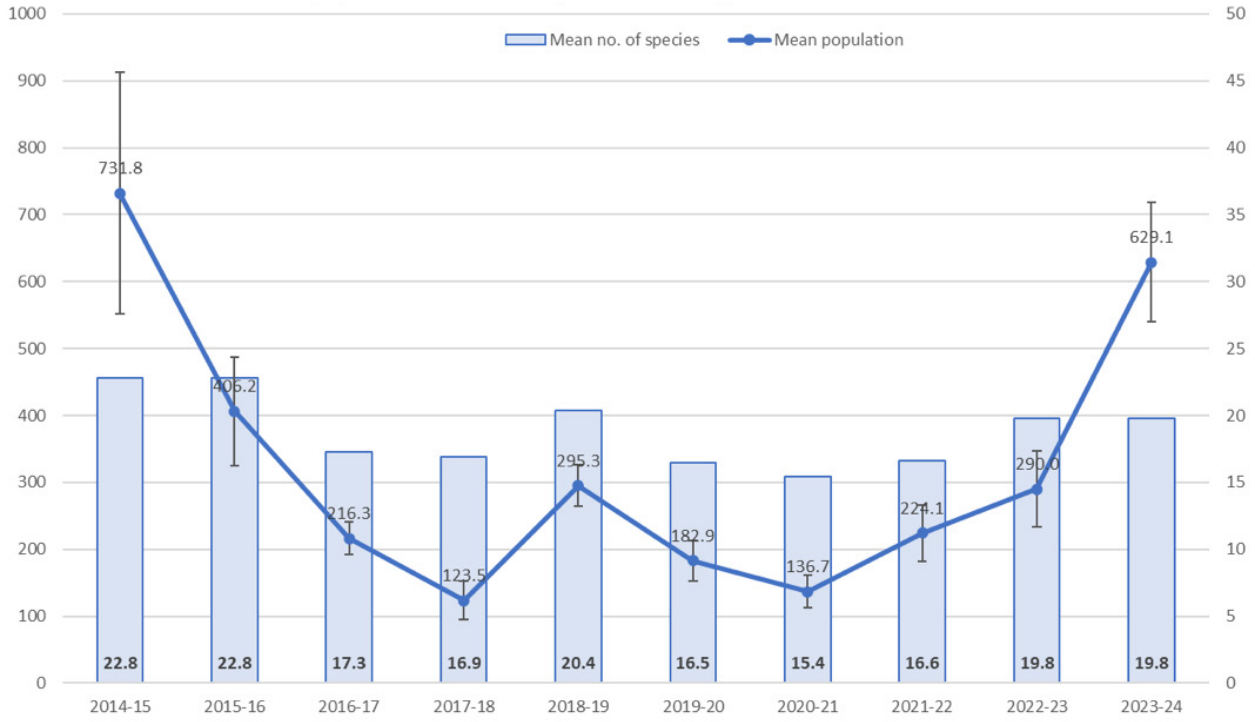


Image 2. Overall waterbird population trend and waterbird species diversity over the decade.

Table 4. Summary of waterbirds of Perur Lake.

Status	Total number of species & their %		Number of species by distribution status				
			Abundant	Common	Fairly common	Uncommon	Rare
Resident	14	27.5%	1	4	5	4	0
Local migrant	14	27.5%	0	2	5	6	1
Winter migrant	13	25.5%	0	0	2	8	3
Uncertain	10	19.5%	0	0	0	0	10
Total	**51**	**100%**	**1**	**6**	**12**	**18**	**14**
% by distribution status			**2%**	**12%**	**24%**	**35%**	**27%**

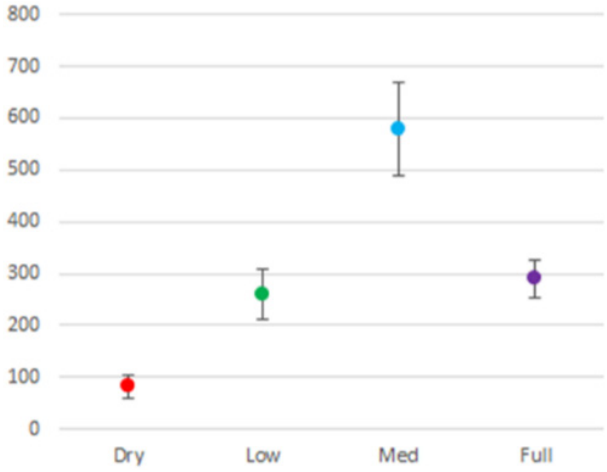


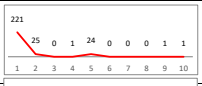
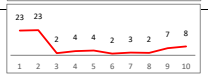
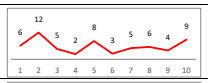
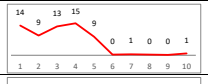
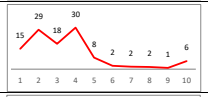
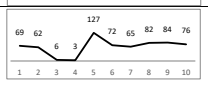
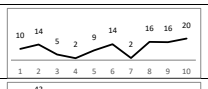
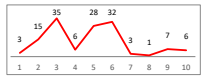
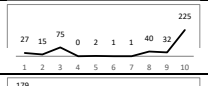
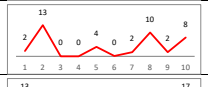
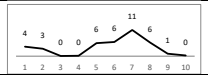
Image 3. Mean count of waterbirds based on water levels.

ducks and shorebirds are highly affected waterbirds with a population decline of above 85%.

DISCUSSION

The decadal study emphasizes the importance of monitoring common waterbirds. Their population levels and breeding status are good and reliable indicators of biodiversity and ecosystem health of wetlands (Gregory et al. 2003; Whelan et al. 2008; Gregory & Van Strien 2010; Parameswaran et al. 2023a; Byju et al. 2024b). The steep increase in the waterbird population during the tenth year is primarily due to the irruption in the

Table 5. Population trend of 10 waterbird guilds and seven individual waterbird species; their comparison with trend assessments from SoIB 2023, IUCN 2025-2.

Sno	Guild Name / Species Name	Population change in % (1st Y vs Last Y)	Population change 1st 5Y vs last 5Y in % (CI Lower bound, CI upper bound)	Trend of the mean population	Annual change in population (%) with SE at Perur Lake	Trend of other assessments		
						Status of Indian Birds 2023 - Current Annual Trend (in % with CI)	Status of Indian Birds 2023 - Current Annual Trend	IUCN 2025-2(Current Global trend)
G-I	Winter Migrant Ducks (Garganey, Northern Pintail and Northern Shoveler)	-99.51%	-99.10% (-185.29%, -12.92%)		Guild : -9.9% ± 3.7% Garganey : -9.9% ± 2.8% N. Shoveler : -10.0% ± 2.1% N. Pintail : -10.0% ± 1.6%	Garganey : -5.72% (-6.84,-4.6)% N. Shoveler: -7.03% (-8.02,-6.04)% N. Pintail : -7.09% (-8.23,-5.95)%	Garganey : Rapid decline N. Shoveler : Rapid decline N. Pintail : Rapid decline	Garganey : Decreasing N. Shoveler : Decreasing N. Pintail : Decreasing
G-II	Rails (Grey-headed Swamphen, Common Moorhen, White-breasted Waterhen)	-61.03%	-61.03% (-106.38%, -15.69%)		Guild : -6.3% ± 1.6% GH. Swamphen: -5.57% ± 1.4% C. Moorhen : -7.04% ± 0.9% WB. Waterhen : -8.41% ± 0.6%	GH. Swamphen: +1.13% (-1.16, 3.42)% C. Moorhen : +1.04% (-0.5, 2.57)% WB. Waterhen : +5.45% (2.52, 8.39)%	GH. Swamphen : Stable C. Moorhen : Stable WB. Waterhen: Inconclusive	GH. Swamphen : Unknown C. Moorhen: Decreasing WB. Waterhen: Unknown
G-III	Resident and Local Migrant Shorebirds (Red-wattled Lapwing, Black-winged Stilt)	+47.16%	-24.39% (-70.94%, +22.14%)		Guild : 4.7% ± 1.5% RW. Lapwing : 9.09% ± 1.1% BW. Stilt : 1.22% ± 1.3%	RW. Lapwing : +1.77% (0.46, 3.07)% BW. Stilt : -2.38% (-3.97,-0.8)%	RW. Lapwing & BW. Stilt: Trend Inconclusive	RW. Lapwing : Unknown BW. Stilt : Stable
G-IV	Small Shorebirds (Little Stint, Little Ringed Plover)	-93.89%	-96.18% (-146.76%, -45.60%)		Guild : -9.4% ± 1.8% L. Stint : -9.43% ± 1.2% LR. Plover : -9.37% ± 1.4%	L. Stint : -4.29% (-5.48,-3.09)% LR. Plover : -4.62% (-5.60,-3.63)%	L. Stint : Rapid decline LR. Plover: Rapid decline	L. Stint : Increasing LR. Plover: Decreasing
G-V	Winter Migrant Shorebirds (Common Sandpiper, Wood Sandpiper, Green Sandpiper, Common Greenshank)	-60%	-86.30% (-122.68%, -49.93%)		Guild : -5.9% ± 1.9% C. Sandpiper : -6.91% ± 1.1% W. Sandpiper : -8.91% ± 1.5% G. Sandpiper : -9.26% ± 0.6% C. Greenshank : 12.93% ± 0.9%	C. Sandpiper : -3.66% (-4.64,-2.69)% W. Sandpiper: -2.92% (-4.11,-1.73)% G. Sandpiper : -0.97% (-2.31,+0.36)% C. Greenshank : -4.46% (-5.58,-3.33)%	C. Sandpiper : Decline W. Sandpiper: Decline G. Sandpiper : Stable C. Greenshank : Rapid decline	C. Sandpiper : Stable W. Sandpiper: Unknown G. Sandpiper : Stable C. Greenshank : Stable
G-VI	Cormorants & Darter (Little Cormorant, Indian Cormorant, Great Cormorant & Oriental Darter)	+10.06%	+32.42% (-18.01%, +82.84%)		Guild : 1.0% ± 4.2% L. Cormorant : -4.21% ± 3.4% I. Cormorant : 140% ± 2.3% G. Cormorant : 135.83% ± 1.0% O. Darter : 0.26% ± 1.9%	L. Cormorant : +0.23% (-1.07, +1.53)% I. Cormorant : -2.27% (-3.46,-1.09)% G. Cormorant : -0.34% (-1.73,+1.06)% O. Darter : +0.20% (-1.26, +1.66)%	L. Cormorant : Stable I. Cormorant :Inconclusive G. Cormorant : Stable O. Darter : Stable	L. Cormorant : Unknown I. Cormorant :Unknown G. Cormorant : Increasing O. Darter : Increasing
G-VII	Large Herons (Grey Heron, Purple Heron)	+90.24%	+85.27% (+42.54%, +128%)		Guild : 9.0% ± 1.5% G. Heron : 18.16% ± 1.5% P. Heron : -5.74% ± 0.7%	G. Heron : -2.14% (-3.85,-0.44)% P. Heron : -0.28% (-1.60,+1.05)%	G. Heron : Inconclusive P. Heron : Stable	G. Heron : Unknown P. Heron : Decreasing
G-VIII	White Egrets (Little Egret, Intermediate Egret, Great Egret)	-38.56%	-35.43% (-86.43%, +15.56%)		Guild : -3.9% ± 2.6% L. Egret : -5.0% ± 2.3% I. Egret : 4.87% ± 1.2% G. Egret : -5.93% ± 0.9%	L. Egret : -1.98% (-3.04,-0.93)% I. Egret : -1.59% (-3.08,-0.1)% G. Egret : -1.37% (-2.64,-0.11)%	L. Egret, I. Egret & G. Egret: Trend Inconclusive	L. Egret : Stable I. Egret : Decreasing G. Egret : Stable
G-IX	Small Herons & Cattle-Egret (Indian Pond Heron, Black-crowned Night-Heron, Eastern Cattle-Egret)	-71%	-38.65% (-64.68%, -12.62%)		Guild : -7.0% ± 1.9% IP. Heron : -6.5% ± 1.7% BCN. Heron : -8.57% ± 0.7% EC-Egret : -8.49% ± 1.3%	IP. Heron : -0.8% (-1.89,-0.28)% BCN. Heron : +0.15% (-1.75, +2.04)% EC-Egret : -0.76% (-1.86,-0.34)%	IP. Heron : Stable BCN. Heron : Stable EC-Egret : Stable	IP. Heron : Unknown BCN. Heron : Unknown EC-Egret : Stable
G-X	(Black-headed Ibis, Eurasian Spoonbill, Painted Stork, Spot-billed Pelican)	+76.92%	-43.99% (-116.74%, +28.75%)		Guild : 7.7% ± 2.6% BH. Ibis : 250% ± 0.8% E. Spoonbill : -10.0% ± 0.9% P. Stork : 4.83% ± 2.0% SB. Pelican : -10.0% ± 1.6%	BH. Ibis : +0.86% (-0.61, +2.34)% E. Spoonbill : -6.84% (-7.77,-5.92)% P. Stork : -3.18% (-4.59,-1.76)% SB. Pelican : -10% ± 1.6%	BH. Ibis : Stable E. Spoonbill: Rapid Decline P. Stork : Decline SB. Pelican : Rapid Decline	BH. Ibis : Increasing E. Spoonbill: Increasing P. Stork : Increasing SB. Pelican : Decreasing
S-1	Indian Spot-billed Duck	+216.84%	+46.01% (-21.34%, +113.36%)		+21.7% ± 3.3%	-0.69% (-1.95, +0.56)%	Stable	Unknown
S-2	Asian Openbill	+718.74%	+154.28% (-12.22%, +320.79%)		+71.9% ± 3.8%	-2.19% (-3.34,-1.03)%	Trend Inconclusive	Increasing
S-3	Eurasian Coot	-62.85%	-52.10% (-126.47%, +22.26%)		-6.3% ± 3.2%	-3.54% (-4.57,-2.51)%	Decline	Increasing
S-4	Lesser Whistling Duck	-73%	+12.51% (-112.58%, +137.60%)		-7.3% ± 1.9%	+0.39% (-1.52,+2.3)%	Stable	Decreasing
S-5	Glossy Ibis	+259.11%	-4.22% (-110.26%, +101.81%)		+25.9% ± 1.6%	0% (-2.2, +2.21)%	Stable	Stable
S-6	Little Grebe	+30.00%	-3.71% (-88.54%, +81.11%)		+3.0% ± 1.4%	-1.5% (-2.72,-0.28)%	Trend Inconclusive	Unknown
S-7	Whiskered Tern	-93.87%	+62.23% (-103.5%, +227.95%)		-9.4% ± 1.7%	-5.47% (-6.43,-4.52)%	Rapid decline	Unknown

numbers of the two waterbirds, which are Indian Spot-billed Duck *Anas poecilorhyncha* (560% increase) and Asian Openbill *Anastomus oscitans* (700% increase). The possible explanation for this increase is due to the favourable water level condition over two-thirds of the period during the tenth year, i.e., either medium or low (Parameswaran et al. 2023a, 2025; Byju et al. 2025d). When these two birds mentioned above are removed from consideration, then the population decline of the rest of the waterbirds is 61.5% over the decade.

The winter migrants, which comprise exclusively of ducks and shorebirds, have declined the most in Perur Lake. This is also the trend nationally in India, according to SoIB (Table 5). The rate of decline is noticeably larger in

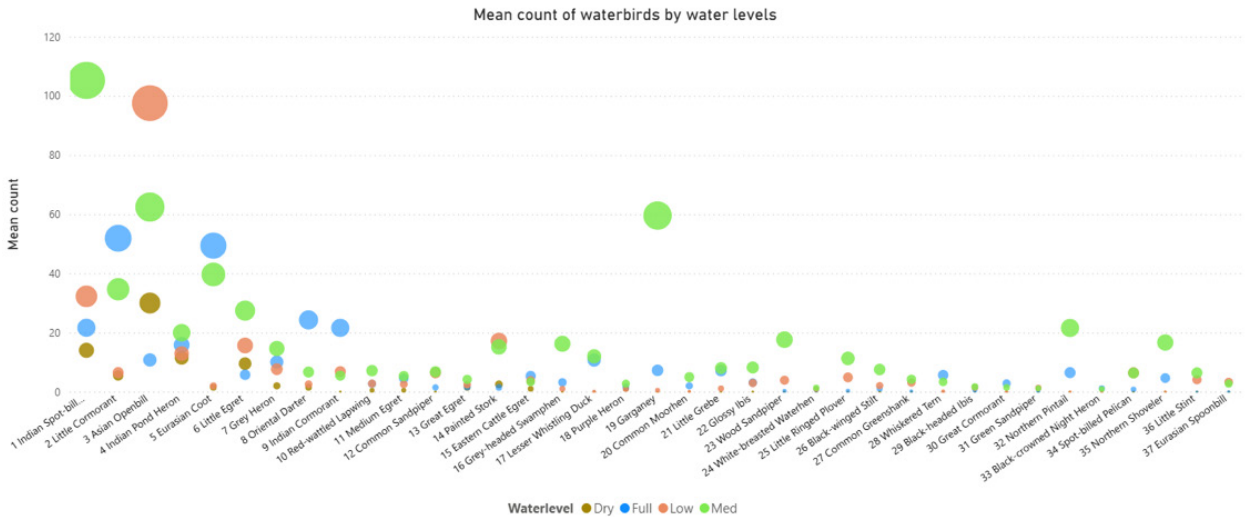


Image 4. Mean counts of individual waterbird species by water levels.

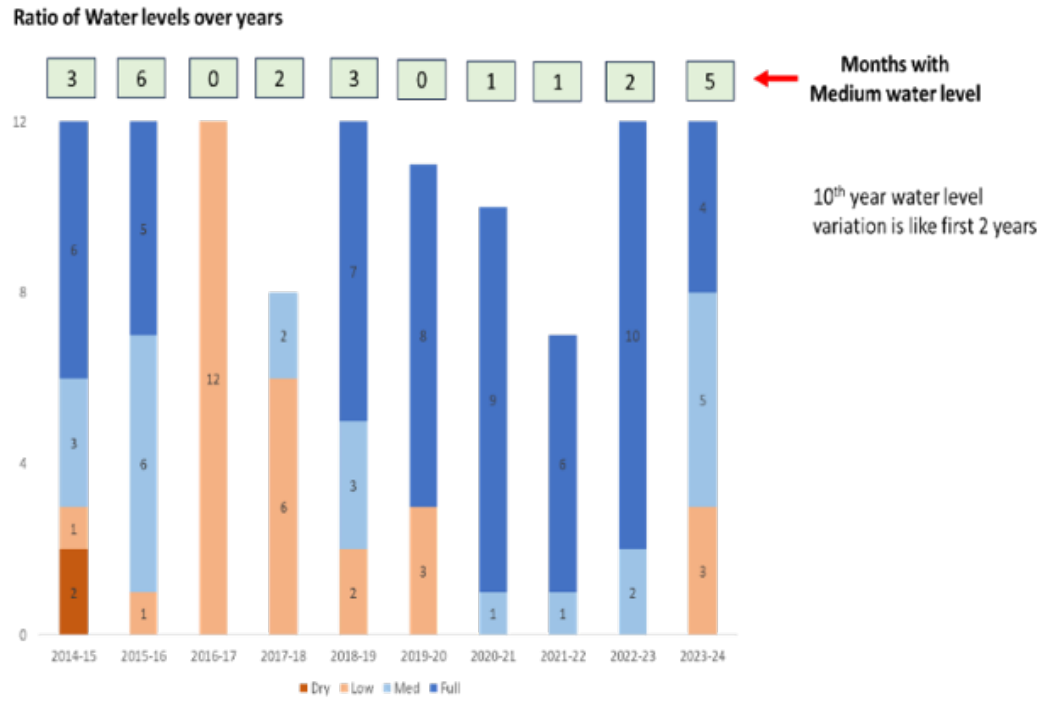


Image 5. Water level variations across the decade.

Perur Lake than national trends; for example, in the case of Garganey *Spatula querquedula*, the highest decline as per SoIB is 6.84% annually, whereas in Perur Lake it is 12.7%. Therefore, local anthropogenic activities have also most likely played a significant role in contributing to this decline (Parameswaran et al. 2023a; Byju et al. 2024a). According to Evans et al. (2008), local factors are more influential than regional ones and, by logical extension, national and international factors.

Table 6. Population decline in waterbirds of Perur Lake.

Guild / Species No.	Status of waterbirds	Total species	Range of population decline in % (1st 5 years vs last 5 years)
Guild I, IV and V	WM	9	86% to 99%
Guild II, X and S-3	R, LM	8	43% to 61%
Guild III, VIII and IX	R, LM	8	24% to 38%
S-5 and S-6	R, LM	2	3% to 4%

Table 7. Negative impact of commercial fishing on waterbirds of the lake.

Period	Number of surveys	Average number of waterbird species per month	Average number of waterbirds per month	Average number of winter ducks, winter shorebirds
May 2014 to Sep 2018 (Before commercial fishing)	49	20	373	92
Oct 2018 to Apr 2024 (Since commercial fishing)	59	18.5	313	11
Decrease	-	7.5%	16%	88%

Table 8. Negative impact of road expansion on waterbirds in the periphery of the lake.

Period	Number of surveys	Average number of waterbird species per month	Average number of waterbirds per month	Average number of rails	Average number of Eurasian Coot	Average number of Little Grebe
Mar 2019 to Feb 2021 (during road expansion)	21	17	177	2	1	0.1
Mar 2021 to Apr 2024 (After road expansion)	33	19	394	6	34	9
Increase in % after cessation of disturbance due to road expansion	-	12%	123%	300%	3400%	8900%

Impact of anthropogenic actions

Anthropogenic actions in Perur Lake can be broadly categorized as follows:

Commercial fishing

The commercial fishing operation was started in October 2018 and is primarily carried out in the eastern part of the wetland, covering approximately 69% of the water spread area, with occasional forays into the western area of the lake (Image 6). This operation was implemented in this core area of the wetland without any safety features for the bird population (Parameswaran et al. 2023a). This has significantly impacted the waterbird population, especially the Guilds I, IV & V comprising winter migrant ducks and shorebirds, and the Guilds III, VIII, IX & X comprising resident and local migrant waterbirds. This is true for birds found in the deeper water (Image 4) as well as those on the margins (Parameswaran et al. 2023a; Byju et al. 2025). The comparison of waterbird population before and after the commercial fishing shows 16% decline in the overall waterbird population and 88% decline in winter migrant ducks and shorebirds (Table 7). These results indicate a strong negative association between commercial fishing activity and the abundance of winter migrant waterbirds. The logical framework supporting this inference, along with the underlying hypotheses, is provided in the supplementary file (Parameswaran et al. 2025). Image 5 shows the annual variation of water level across the decade, indicating the higher water levels in the last five years to aid "Commercial fishing".

As per Lorenzon et al. (2017), "changes in hydrological fluctuation result in changes to the availability of food, because the prey for these waterbirds are affected by fluvial dynamics". This reference states that out of 21 species analysed, 12 species were negatively affected by rise in water levels in the Parana River in Argentina, which constituted eight shorebirds, one egret, one heron, one ibis, and the last one being Wood Rail, which is a result of loss of floodplains and beaches (mudflats). Similar long-term studies on shorebird population on Manoli Island, located in the Gulf of Mannar, Tamil Nadu, substantiates the studies (Byju et al. 2023). The significant difference is that the water level fluctuations in the Parana River are part of the ebb and flow of the river's ecosystem function, whereas in Perur Lake, they are caused by human action. The higher water level in the core area of Perur Lake makes food inaccessible to many waterbird guilds, especially winter migrant ducks and shorebirds. Globally, the modification of natural systems affects bird species, and the biological resource extraction, such as fishing, alone exceeds 200 species (Lees et al. 2022).

Some examples of waterbirds that prefer various water levels are (1) Asian Openbill *Anastomus oscitans* and Painted Stork *Mycteria leucocephala* for low, (2) Indian Spot-billed Duck *Anas poecilorhyncha* and Wood Sandpiper *Tringa glareola* for medium and (3) Indian Cormorant *Phalacrocorax fuscicollis* and Eurasian Coot *Fulica atra* for full.

Road expansion

From March 2019 onwards, the wetland was

Image 6. Commercial fishing using fixed nets and a coracle. © G. Parameswaran.

Image 7. Building of the containment wall in the wetland for road expansion during the dry season. © G. Parameswaran.

Image 8. The submerged containment wall during the monsoon season. © G. Parameswaran

Image 9. Sand mining in Perur Lake from June–September 2017. © G. Parameswaran

subjected to an encroachment in the form of expansion of the existing road (Images 7 & 8), which was finished in February 2021. This entailed the removal of vegetation and the appropriation of the wetland's area for a two-lane roadway. An estimated 0.1 km^2 (c. 9% of water coverage area) has been encroached for the construction of a containment wall of 1.5m in height along the perimeter of the wetland (Image 7). During this period, the birds that were dependent on the periphery of the wetland, like the Common Moorhen *Gallinula chloropus*, Eurasian Coot *Fulica atra*, Grey-headed Swamphen *Porphyrio poliocephalus* and White-breasted Waterhen *Amaurornis phoenicurus* declined sharply based on our data (Parameswaran et al. 2023a). Since the completion of the road expansion operation, Rails as a guild, Eurasian Coot *Fulica atra* and Little Grebe *Tachybaptus ruficollis* have recovered moderately (Table 8).

Nevertheless, this recovery has not attained the higher levels of the previous years, and it is evident that a road expansion has had a deleterious effect. A similar phenomenon was also noticed during the previous road construction operation from March 2014 to August 2014 (Parameswaran & Sivashankar 2018).

Sandmining

From June 2017 to September 2017, Perur Lake was subjected to sandmining, technically called reclamation (O'Connell 2000), which altered the character of the core area of the wetland. Deep pits and ravines that resulted from this operation altered 69% of the water spread area (Image 9). The topography of the gentle-sloping bowl-shaped wetland that was once hospitable to various waterbird groups like ducks, shorebirds, and egrets, deteriorated significantly (Parameswaran et al. 2023a).

Due to all these disturbances, there is an overall

decrease in waterbird population from May 2014 to April 2024, and the low counts are a result of the superimposition of the above-mentioned anthropogenic actions (Image 1). Waterbirds usually avoid areas with extensive disturbance, choose roosting or foraging sites without them, and generally prefer wetlands with features that maximise the abundance and accessibility of their food (Khan et al. 2016; Lorenzon et al. 2017; Parameswaran et al. 2023a).

The most probable reasons for the decline of the winter migrant waterbird population are sand mining (executed between June–September 2017) and unregulated commercial fishing (from October 2018 and continuing to the present day). Both these anthropogenic disturbances executed in tandem maintained high water levels in the core area of the wetland, covering 69% of the water spread area to facilitate commercial fishing.

CONCLUSION & RECOMMENDATIONS

Based on the results of the data analysis of the decadal study in Perur Lake, the following conclusions are drawn:

1. Unregulated commercial fishing carried out in the core area of the lake, covering 69% of the water spread area, is most probably the principal reason for the decline of the waterbirds and especially the winter migrants.
2. Disturbances like sandmining in the core area of the wetland have more lasting impacts than the disturbances along the periphery, like road expansion.
3. Even though the impacts caused by road expansion are less than those of commercial fishing and sandmining, it also depresses the population of waterbirds, and it is not an endorsement to use the periphery of the lake as a transportation corridor.

The data in conjunction with the above-mentioned inferences emphasize the urgency of addressing the downward population trend in common waterbirds. It is demonstrated that the anthropogenic disturbances in an urban wetland are detrimental to the waterbirds it supports. While the decline in waterbirds can be correlated with the local disturbances, these threats may have acted in tandem with decline events outside the study area.

Results from the first six years have shown (Parameswaran et al. 2023a) that 12 common birds have declined overall from 43% to 100%. The current decadal study has expanded the scope by using the guild analysis and thereby demonstrated the decline of the waterbirds is more widespread and encompasses 73% of the waterbirds analysed.

Perur Lake was actively considered for the designation as a "bird sanctuary" due to the presence of a large number of migratory and resident birds (Mohanraj et al. 2000; Chandra et al. 2009). The establishment of buffer areas around the lakes could have reduced the anthropogenic pressures and augmented the natural purification processes in these systems, and improved the environmental quality of the wetland (Chandra et al. 2009). The non-implementation of those protective measures promptly has not only resulted in the reduction of bird population due to loss of habitat but also the overall deterioration in the functioning of the ecosystem.

The National Green Tribunal (NGT) took suo-moto cognizance (O.A. No. 84 of 2024, 18 September 2024) of the decline of waterbirds in Perur Lake based on our six-year study (Parameswaran et al. 2023a) and the associated article (Parameswaran et al. 2023b). The judgement instructed the Tamil Nadu government to designate Perur Lake as a wetland, but with no definite timeline.

By contrast, in the case of the Nanjarayan Tank, Tirupur District (11.212° N, 77.362° E), it was transferred from the Public Works Department (PWD) to the Forest Department for conservation, notified as a bird sanctuary (Gazette notification) in 2022, and designated a Ramsar Site in 2024. This represents a successful case of 'Navigating the back loop' (Biggs et al. 2010) where a transformative governance shift, rather than incremental change, helped in resolving existing stakeholder conflicts and integrated ecological conservation with socio-economic benefits.

The latest IPCC (2021) report titled "summary for policy makers", along with the Tamil Nadu wetland mission (2022), has multiple model possibilities for various scenarios for future conservation. From a wetland perspective, they indicate that continued "global warming will disrupt the global hydrological cycle and thereby influence the global monsoon precipitation and the severity of wet and dry events" with a high degree of certainty. The Millennium Ecosystem Assessment (2005b) on wetland and water recommends "wise use of wetlands by maintaining their ecological character for long-term sustainability". Therefore, the administrative institutions were urged whether national, state, or local, to manage the wetlands as responsible stewards rather than enablers for unsustainable resource extraction that seriously disrupts the wetland ecosystem. It is also recommended that the Tamil Nadu Government

follow the successful administrative strategy used for "Nanjarayan tank" and designate Perur Lake as a wetland without any further delay.

Although limited to a single wetland, this study serves as an early warning indicator of progressive ecological degradation, especially in the wetlands of Coimbatore District. The ecological integrity of Perur Lake is best sustained when it functions as a floodplain extension of the Noyyal River riparian corridor supporting a diverse bird population, invertebrates, moderating floods, enabling groundwater recharge, and providing irrigation, rather than being managed as an impounded water storage system prioritizing extractive uses such as commercial fishing (O'Connell 2000).

It is important that coordinated, synchronous monitoring of birds of the adjacent wetlands is necessary to develop a landscape-level understanding of the ecological functions of the Greater Coimbatore wetlands. It is also proposed that the second Saturday of each month can be designated as wetland bird survey days to help with this effort.

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