

# Comparison of avian diversity between managed and unmanaged wetlands in Patna, Bihar, India

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**Abstract** We compared the bird diversity of a managed (Rajdhani Jalashay) and an unmanaged wetland (Mustafapur) in Patna, Bihar, India. We recorded bird species by using point counts and fixed-route monitoring. At Rajdhani Jalashay, a total of 73 species were recorded, of which 15 species were winter visitors. Two species were in the Near-threatened category: Ferruginous Duck (*Aythya nyroca*) and Alexandrine Parakeet (*Psittacula eupatria*), while the others were of least concern. At Mustafapur wetland, 67 species were recorded with 11 species as winter visitors. Simpson’s species diversity index was 0.78 at Rajdhani Jalashay, and 0.81 at Mustafapur wetland. The number of species of waders was 17 at Mustafapur wetland and 11 at Rajdhani Jalashay. The total number of Lesser Whistling-duck (*Dendrocygna javanica*), a resident bird was almost double (526) at Mustafapur wetland than that at Rajdhani Jalashay (234). The nitrate level was twice higher and the phosphate level was four times higher at Mustafapur wetland than those at Rajdhani Jalashay. The difference in species number and composition between the two wetlands may be attributed to the eutrophication resulting from high nitrate and phosphate levels at Mustafapur wetland. Unfortunately, the Mustafapur wetland is under threat due to human influences. The protection and sustainable management of natural wetlands is required for saving the biodiversity of the area.

Keywords: wetland management, conservation, avian diversity, eutrophication

**Összefoglalás** Jelen tanulmányban a madárvilág sokféleségét hasonlítottuk össze a kezelt (Rajdhani Jalashay) és a nem kezelt vizes élőhelyek (Mustafapur) között, az indiai Patnában (Bihar). A madárfajokat pontszámlálással és rögzített útvonalon történő megfigyeléssel jegyeztük fel. A Rajdhani Jalashayban összesen 73 fajt figyeltünk meg, amelyek közül 15 faj téli vendég volt. A cigányréce (*Aythya nyroca*) és a Nagy Sándor-papagáj (*Psittacula eupatria*) a mérsékelt fenyegetett természetvédelmi kategóriába tartozott. A Mustafapur vizes élőhelyen 67 fajt jegyeztünk fel, amelyek közül 11 faj téli vendég volt. A Simpson-féle faji diverzitási index a Rajdhani Jalashayban 0,78, míg a Mustafapur vizes élőhelyen 0,81 volt. A Mustafapur vizes élőhelyen 17, míg a Rajdhani Jalashayban 11 partimadár faj volt jelen. A bengáli füttyölőlúd (*Dendrocygna javanica*) össz-egyedszáma a Mustafapur vizes élőhelyen majdnem kétszerese (526) volt a Rajdhani Jalashay 234 egyedéhez viszonyítva. A Mustafapur vizes élőhelyen a nitrát szintje kétszer, a foszfát szintje pedig négyszer magasabbnak bizonyult a Rajdhani Jalashayhoz képest. A két vizes élőhelytípus közötti fajösszetétel és fajszámbeli különbség a Mustafapur vizes élőhely magas nitrát- és foszfátszintje miatt bekövetkezett eutrofizációnak tulajdonítható. Sajnos a Mustafapur vizes élőhelyet a fokozott emberi tevékenység miatt veszély fenyegeti. A természetes vizes élőhelyek védelme és fenntartható kezelése szükséges a biológiai sokféleség megmentéséhez a vizsgált területeken.

Kulcsszavak: vizes élőhely kezelés, természetvédelem, madárfajok sokfélesége, eutrofizáció

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## Introduction

Urbanization has resulted in more and more natural land being replaced by buildings and roads (Ferenc *et al.* 2014) and has led to biodiversity loss (Grimm *et al.* 2008). Birds form an important indicator group of urban ecosystem health (Yang *et al.* 2020). Therefore, studying bird diversity is important for conservation and management activities in urban ecosystems (Wang *et al.* 2013). Wetlands increase biodiversity in urban areas by acting as networks of fragmented habitat to facilitate the movement of species in the environments (Blicharska *et al.* 2016, Hill *et al.* 2021, Krivtsov *et al.* 2022, Richardson *et al.* 2023). Unfortunately, more than 50% of wetlands around the world have been lost due to urbanization (Martin Jean 2006, Bhagyanathan & Dhayanithy 2023). According to Wetlands International (WI) South Asia, nearly 30% of the natural wetlands in India have been lost in the last three decades. Similarly, 70% of Bihar's wetlands including Patna have been lost in the last few decades. The loss and degradation of wetlands has negatively affected the waterbirds. Maintenance of parks including small waterbodies may help to protect biodiversity in urban ecosystems (Hagen *et al.* 2017). Artificial wetlands or waterbodies managed by humans can provide alternative or complementary habitats for waterbirds (Connor & Gabor 2006). Rajdhani Jalashay (a managed waterbody) of Patna, Bihar, India is one such waterbody. This study was conducted in Rajdhani Jalashay to document the avifaunal diversity that would serve as baseline data for upcoming studies as no comprehensive study on the ecology of this area has been done so far. For comparison, an unmanaged wetland called Mustafapur was also included in the study.

## Methods

Rajdhani Jalashay (25.602583°N and 85.118781°E) is located in the center of Patna city, Bihar, India (*Figure 1*). It is managed by the Government of Bihar and was established in 2019. The area of Rajdhani Jalashay is 0.03 km<sup>2</sup> and the perimeter is 744 m. This waterbody has an elliptical geometry and is surrounded by a gravel pathway. It has well-defined boundaries and is under tight security. This waterbody is recharged with groundwater with the help of a waterpump. Mustafapur wetland (25.59341°N and 85.040778°E) is located around 10 km away from Rajdhani Jalashay (*Figure 1*). Mustafapur wetland has an area of 0.14 km<sup>2</sup> and a perimeter of 1.71 km. This waterbody is recharged with rainwater. The survey was conducted between November 2021 and January 2022. The average temperature was around 18–25 °C with the lowest dip recorded as 7 °C.

The tree species found in the Rajdhani Jalashay were *Saraca asoca*, *Mangifera indica*, *Bombax ceiba*, *Ficus religiosa*, *Ficus benghalensis*, *Senna sophora*, *Delonix regia*, *Cassia fistula* and *Adiantum* sp. Birds can be seen roosting on these trees preferably on *Bombax ceiba*. Herbaceous vegetation included species like, *Setaria faberi*, *Ageratum conyzoids*, *Amaranthus spinosus*, *Lantana camara*, *Solanum nigrum*, *Euphorbia prostrata*, *Parthenium hyterophorus* and *Cynodon dactylon*. Aquatic flora included species such as *Eichornia crassipes*, *Lemna minor*, *Azolla* sp. and *Hydrilla*. *Lemna minor* and *Azolla* sp., also known

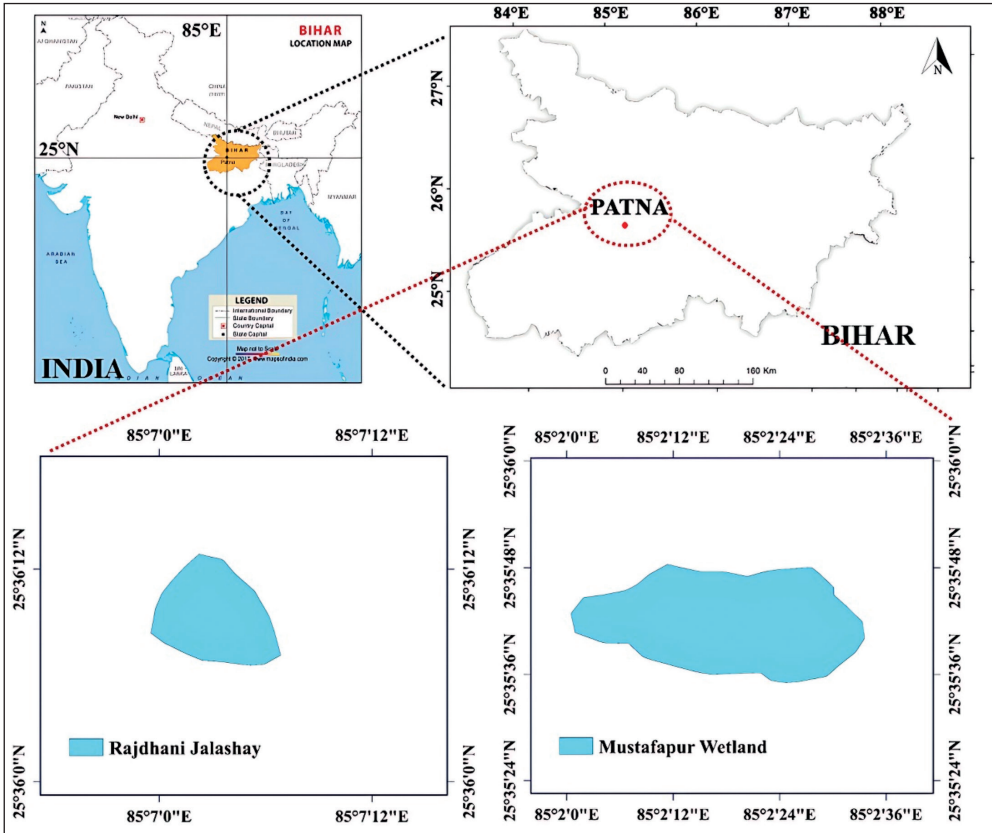


Figure 1. Map of the study area  
1. ábra A vizsgálati terület térképe

as duckweeds are food source for most of the waterbirds. Rajdhani Jalashay supports both migratory and resident birds.

The tree species found in the Mustafapur wetland were *Ficus racemosa* and *Ficus religiosa*. Herbaceous vegetation includes *Cymbopogon martinii*, *Brachiara mutica*, *Pennisetum purpureum*, *Imperata cylindrica*, *Hymenachne amplexicaulis*, *Setaria viridis*, *Arundo donax*, *Phragmites karka*, *Phragmites australis*, *Typha domingensis* and *Actinoscirpus grossus*. Aquatic flora includes *Pistia stratiotes*, *Eichhornia crassipes*, *Nymphaea micrantha*, *Vallisneria natans*, *Spirodela polyrhiza*, *Limnocharis flava*, *Hydrilla verticillata*, *Monochoria vaginalis*, *Azolla pinnata*, *Ottelia alismoides*, *Salvinia natans*, *Eclipta prostrata*, *Lemna minor*, *Alternanthera philoxeroides*, *Elodea najas*, *Polygonum plebeium*, *Enydra fluctuans* and *Marsilea minuta*.

Bird species were recorded by using point count method and fixed route monitoring. In this method we walked along a 360° arc around the study area in both clockwise and anti-clockwise directions. The survey was conducted weekly between 7.30 am and 10.00 am. Birds were identified by direct sightings with the help of a field guide (Ali & Ripley 1983).

Water samples were collected in triplicates from four sites of both the wetlands during the post-monsoon season of 2022 following the standard protocols (APHA, 2012). Nitrate was estimated using Phenyl Disulphonic Acid method by spectrophotometric analysis (Trivedi & Goel 1986). Phosphate was determined using Stannous Chloride method by spectrophotometric analysis (APHA, 2012).

Shannon-Weiner Diversity Index (Shannon, 1948), Evenness index, Effective Number of species (ENS), Simpson's diversity index (Simpson, 1949), and Relative abundance were calculated to understand the difference in avifaunal diversity between the two wetlands.

### Relative Abundance

Relative abundance of avian species was determined by using encounter rates that give crude ordinal scales of abundance (abundant, common, frequent, uncommon and rare) (Bibby *et al.* 1992) (Table 1).

Student's t test and Kolmogorov-Smirnov tests were used for statistical comparisons in GraphPad Prism v9.0. Kolmogorov-Smirnov (non-parametric) test was used to compare the abundance data between the two sites.

## Results

At Rajdhani Jalashay, a total of 73 species were recorded of which 14 species were winter visitors and one was a summer visitor. The recorded species were classified into 16 orders and 33 families. The most dominant order was Passeriformes followed by Anseriformes (Table 2). The most dominant family was Anatidae. *Dendrocygna javanica* was observed to be the most abundant species. Two species Alexandrine Parakeet (*Psittacula eupatria*) and Ferruginous Duck (*Aythya nyroca*) were Near threatened. Four species Western Marsh Harrier (*Circus aeruginosus*), Booted Eagle (*Hieraaetus pennatus*), Crested Honey-buzzard (*Pernis ptilorhynchus*) and Eurasian Wigeon (*Mareca penelope*) were recorded for the first time in Rajdhani Jalashay. At Mustafapur wetland, 67 species were recorded with 11 species as winter visitors. No summer visitor was found. The recorded species were classified into 15 orders and 29 families. The most dominant order was Passeriformes followed by Anseriformes (Table 3). The most dominant bird families were Anatidae along with Ardeidae. *Dendrocygna javanica* was observed to be the most abundant species. Figure 2 represents a comparative assessment of waterbird abundance in both the wetlands. The Mustafapur wetland had a higher species richness

Table 1. Classification of bird species based on abundance score

1. táblázat A madárfajok osztályozása egyedsűrűségi mutatóik alapján

Abundance score	Local Occurance Rate (L.O.R)	Acronym
0–0.2	Rare	R
0.21–0.40	Uncommon	UC
0.41–0.80	Frequent	F
0.81–5.0	Common	C
>5	Abundant	A

Table 2. Status and relative abundance of bird species in Rajdhani Jalashay (RJ)

2. táblázat A madárfajok természetvédelmi és vonulási besorolása, valamint relatív egyedsűrűség kategóriája Rajdhani Jalashay területén

Order	Family	Species	IUCN status	Migratory status	R.A	L.O.R
<b>Anseriformes</b> (9 sp)	Anatidae (9 sp)	Cotton Pygmy-goose ( <i>Nettapus coromandelianus</i> )	LC	WM	0.2	R
		Lesser Whistling-duck ( <i>Dendrocygna javanica</i> )	LC	R	45.7	A
		Knob-billed Duck ( <i>Sarkidiornis melanotos</i> )	LC	R	0.39	UC
		Ferruginous Duck ( <i>Aythya nyroca</i> )	<b>NT</b>	<b>WM</b>	<b>0.2</b>	R
		Red-crested Pochard ( <i>Netta rufina</i> )	LC	WM	0.2	R
		Garganey ( <i>Anas querquedula</i> )	LC	WM	2.15	C
		Northern Shoveler ( <i>Anas clypeata</i> )	LC	WM	1.37	C
		Eurasian Wigeon ( <i>Anas penelope</i> )	LC	WM	0.2	R
		Gadwall ( <i>Anas strepera</i> )	LC	WM	2.34	C
<b>Apodiformes</b> (1 sp)	Apodidae (1 sp)	Asian Palm Swift ( <i>Cypsiurus balasiensis</i> )	LC	R	0.2	R
<b>Cuculiformes</b> (3 sp)	Cuculidae (3 sp)	Common Hawk Cuckoo ( <i>Hierococcyx varius</i> )	LC	R	0.39	UC
		Asian Koel ( <i>Eudynamis scolopaceus</i> )	LC	R	2.15	C
		Greater Coucal ( <i>Centropus sinensis</i> )	LC	R	0.59	F
<b>Columbiformes</b> (4 sp)	Columbidae (4 sp)	Spotted Dove ( <i>Spilopelia chinensis</i> )	LC	R	0.78	F
		Eurasian Collared Dove ( <i>Streptopelia decaocto</i> )	LC	R	0.39	UC
		Yellow-footed Green Pigeon ( <i>Treron phoenicoptera</i> )	LC	R	1.56	C
		Feral Pigeon ( <i>Columba livia</i> )	LC	R	0.59	F
<b>Gruiformes</b> (3 sp)	Rallidae (3 sp)	Common Moorhen ( <i>Gallinula chloropus</i> )	LC	R	1.17	C
		White-breasted Waterhen ( <i>Amaurornis phoenicurus</i> )	LC	R	0.98	C
		Eurasian Coot ( <i>Fulica atra</i> )	LC	R	1.56	C
<b>Podicipediformes</b> (1 sp)	Podicipedidae (1 sp)	Little Grebe ( <i>Tachybaptus ruficollis</i> )	LC	R	0.78	F
<b>Charadriiformes</b> (3 sp)	Charadriidae (1 sp)	Red-wattled Lapwing ( <i>Vanellus indicus</i> )	LC	R	0.39	UC
	Scolopacidae (1 sp)	Common Sandpiper ( <i>Actitis hypoleucos</i> )	LC	WM	0.59	F
	Jacanidae (1 sp)	Bronze-winged Jacana ( <i>Metopidius indicus</i> )	LC	R	0.78	F

Order	Family	Species	IUCN status	Migratory status	R.A	L.O.R
<b>Ciconiiformes</b> (1 sp)	Ciconiidae (1 sp)	Asian Openbill Stork ( <i>Anastomus oscitans</i> )	LC	R	0.2	R
<b>Suliformes</b> (2 sp)	Phalacrocoracidae (2 sp)	Little Black Cormorant ( <i>Phalacrocorax sulcirostris</i> )	LC	R	0.98	C
		Indian Cormorant ( <i>Phalacrocorax fuscicollis</i> )	LC	R	0.39	UC
<b>Pelecaniformes</b> (5 sp)	Ardeidae (5 sp)	Cattle Egret ( <i>Bubulcus ibis</i> )	LC	R	0.78	F
		Little Egret ( <i>Egretta garzetta</i> )	LC	R	0.59	F
		Purple Heron ( <i>Ardea purpurea</i> )	LC	R	0.2	R
		Indian Pond Heron ( <i>Ardeola grayii</i> )	LC	R	1.56	C
		Black-crowned Night Heron ( <i>Nycticorax nycticorax</i> )	LC	R	0.2	R
<b>Accipitriformes</b> (5 sp)	Accipitridae (5 sp)	Black Kite ( <i>Milvus migrans</i> )	LC	R	0.78	F
		Shikra ( <i>Accipiter badius</i> )	LC	R	0.39	UC
		Crested Honey Buzzard ( <i>Pernis ptilorhynchus</i> )	LC	R	0.2	R
		Booted Eagle ( <i>Hieraaetus pennatus</i> )	LC	WM	0.2	R
		Western Marsh Harrier ( <i>Circus aeruginosus</i> )	LC	WM	0.2	R
<b>Bucerotiformes</b> (1 sp)	Bucerotidae (1 sp)	Indian Grey Hornbill ( <i>Ocyrceros birostris</i> )	LC	R	0.78	F
<b>Coraciiformes</b> (3 sp)	Alcedinidae (1 sp)	White-throated Kingfisher ( <i>Halcyon smyrnensis</i> )	LC	R	0.39	UC
	Meropidae (1 sp)	Asian Green Bee-eater ( <i>Merops orientalis</i> )	LC	R	0.2	R
	Coraciidae (1 sp)	Indian Roller ( <i>Coracias benghalensis</i> )	LC	R	0.2	R
<b>Piciformes</b> (3 sp)	Picidae (1 sp)	Black-rumped Flameback ( <i>Dinopium benghalense</i> )	LC	R	0.98	C
	Megalaimidae (2 sp)	Coppersmith Barbet ( <i>Megalaima haemacephala</i> )	LC	R	0.98	C
		Brown-headed Barbet ( <i>Megalaima zeylanica</i> )	LC	R	0.78	F
<b>Psittaciformes</b> (3 sp)	Psittaculidae (3 sp)	Rose-ringed Parakeet ( <i>Psittacula krameri</i> )	LC	R	0.59	F
		Plum-headed Parakeet ( <i>Psittacula cyanocephala</i> )	LC	R	0.98	C
		Alexandrine Parakeet ( <i>Psittacula eupatria</i> )	<b>NT</b>	<b>R</b>	<b>0.39</b>	UC

Order	Family	Species	IUCN status	Migratory status	R.A	L.O.R
<b>Passeriformes (26 sp)</b>	Sturnidae (4 sp)	Common Myna ( <i>Acridotheres tristis</i> )	LC	R	1.37	C
		Indian Pied Myna ( <i>Gracupica contra</i> )	LC	R	1.17	C
		Brahminy Starling ( <i>Sturnia pagodarum</i> )	LC	R	0.39	UC
		Rosy Starling ( <i>Pastor roseus</i> )	LC	R	0.39	UC
	Oriolidae (2 sp)	Golden Oriole ( <i>Oriolus oriolus</i> )	LC	R	1.17	C
		Black-hooded Oriole ( <i>Oriolus xanthornus</i> )	LC	R	0.78	F
	Corvidae (3 sp)	Rufous Treepie ( <i>Dendrocitta vagabunda</i> )	LC	R	0.98	C
		Large-billed Crow ( <i>Corvus macrorhynchos</i> )	LC	R	1.76	C
		House Crow ( <i>Corvus splendens</i> )	LC	R	2.15	C
	Hirundinidae (1 sp)	Barn Swallow ( <i>Hirundo rustica</i> )	LC	WM	0.2	R
	Turdidae (1 sp)	Orange-headed Thrush ( <i>Geokichla citrina</i> )	LC	R	0.39	UC
	Leiothrichidae (1 sp)	Jungle Babbler ( <i>Turdoides striata</i> )	LC	R	3.71	C
	Dicruridae(1 sp)	Black Drongo ( <i>Dicrurus macrocercus</i> )	LC	R	0.59	F
	Muscicapidae (7 sp)	Verditer Flycatcher ( <i>Eumyias thalassinus</i> )	LC	R	0.39	UC
		Asian Brown Flycatcher ( <i>Muscicapa dauurica</i> )	LC	WM	0.39	UC
		Oriental Magpie Robin ( <i>Copsychus saularis</i> )	LC	R	0.78	F
		Black Redstart ( <i>Phoenicurus ochruros</i> )	LC	R	0.2	R
		Taiga Flycatcher ( <i>Ficedula albicilla</i> )	LC	WM	0.39	UC
		Pale-chinned Blue Flycatcher ( <i>Cyornis poliogenys</i> )	LC	R	0.2	R
		Brown Rock Chat ( <i>Cercomela fusca</i> )	LC	R	0.2	R
	Motacillidae (2 sp)	White Browed Wagtail ( <i>Motacilla maderaspatensis</i> )	LC	R	0.39	UC
		White Wagtail ( <i>Motacilla alba</i> )	LC	WM	0.59	F
	Pyconotidae (1 sp)	Red-vented Bulbul ( <i>Pycnonotus cafer</i> )	LC	R	1.17	C
	Cisticolidae(1 sp)	Common Tailorbird ( <i>Orthotomus sutorius</i> )	LC	R	0.78	F
	Phylloscopidae (1 sp)	Greenish Warbler ( <i>Phylloscopus trochiloides</i> )	LC	WM	0.59	F
	Nectariniidae (1 sp)	Purple Sunbird ( <i>Cinnyris asiaticus</i> )	LC	R	0.39	UC

**Abbreviations:** WM-Winter Migrant, SM-Summer Migrant, R-Resident, IUCN-International Union for Conservation of Nature, LC-Least Concern, NT-Near Threatened, RA-Relative Abundance, L.O.R-Local Occurrence Rate



Table 3. Status and relative abundance of bird species at Mustafapur wetland

3. táblázat A madárfajok természetvédelmi és vonulási besorolása, valamint relatív egyedsűrűség kategóriája Mustafapur területén

Order	Family	Species	IUCN status	Migratory status	R.A	L.O.R
<b>Anseriformes</b> (7 sp)	Anatidae (7 sp)	Gadwall ( <i>Anas strepera</i> )	LC	WM	2.94	C
		Garganey ( <i>Anas querquedula</i> )	LC	WM	1.8	C
		Lesser Whistling-duck ( <i>Dendrocygna javanica</i> )	LC	WM	42.97	A
		Red Crested Pochard ( <i>Netta rufina</i> )	LC	WM	0.33	UC
		Northern Pintail ( <i>Anas acuta</i> )	LC	WM	0.49	F
		Northern Shoveler ( <i>Anas clypeata</i> )	LC	WM	0.49	F
		Eurasian Wigeon ( <i>Mareca penelope</i> )	LC	WM	0.16	R
<b>Apodiformes</b> (1 sp)	Apodidae (1 sp)	Asian Palm-swift ( <i>Cypsiurus balasiensis</i> )	LC	R	0.9	C
<b>Cuculiformes</b> (2 sp)	Cuculidae (2 sp)	Asian Koel ( <i>Eudynamis scolopaceus</i> )	LC	R	0.16	R
		Greater Coucal ( <i>Centropus sinensis</i> )	LC	R	0.49	F
<b>Columbiformes</b> (4 sp)	Columbidae(4 sp)	Eurasian Collared Dove ( <i>Streptopelia decaocto</i> )	LC	R	0.33	UC
		Spotted Dove ( <i>Spilopelia chinensis</i> )	LC	R	0.16	R
		Laughing Dove ( <i>Spilopelia senegalensis</i> )	LC	R	0.65	F
		Rock Pigeon ( <i>Columba livia</i> )	LC	R	0.82	C
<b>Gruiformes</b> (4sp)	Rallidae (4 sp)	Grey-headed Swamphen ( <i>Porphyrio poliocephalus</i> )	LC	R	1.8	C
		Common Moorhen ( <i>Gallinula chloropus</i> )	LC	R	1.23	C
		Common Coot ( <i>Fulica atra</i> )	LC	R	2.45	C
		White-breasted Waterhen ( <i>Amaurornis phoenicurus</i> )	LC	R	1.63	C
<b>Podicipediformes</b> (1 sp)	Podicipedidae (1 sp)	Little Grebe ( <i>Tachybaptus ruficollis</i> )	LC	R	0.98	C



Order	Family	Species	IUCN status	Migratory status	R.A	L.O.R
<b>Charadriiformes</b> (6 sp)	Charadriidae(2 sp)	Red-wattled Lapwing ( <i>Vanellus indicus</i> )	LC	R	1.06	C
		Grey-headed Lapwing ( <i>Vanellus cinereus</i> )	LC	R	1.63	C
	Scolopacidae(2 sp)	Wood Sandpiper ( <i>Tringa glareola</i> )	LC	R	0.08	R
		Common Sandpiper ( <i>Actitis hypoleucos</i> )	LC	WM	0.49	F
	Jacaniidae (2 sp)	( <i>Metopidius indicus</i> )	LC	R	1.96	C
		Pheasant-tailed Jacana ( <i>Hydrophasianus chirurgus</i> )	LC	R	1.47	C
<b>Ciconiiformes</b> (1 sp)	Ciconiidae (1 sp)	Asian Openbill Stork ( <i>Anastomus oscitans</i> )	LC	R	4.98	C
<b>Suliformes</b> (2 sp)	Phalacrocoracidae (2 sp)	Indian Cormorant ( <i>Phalacrocorax fuscicollis</i> )	LC	R	2.94	C
		Little Black Cormorant ( <i>Phalacrocorax sulcirostris</i> )	LC	R	3.27	C
<b>Pelicaniformes</b> (7 sp)	Ardeidae (7 sp)	Cattle Egret ( <i>Bubulcus ibis</i> )	LC	R	0.65	F
		Little Egret ( <i>Egretta garzetta</i> )	LC	R	0.9	C
		Great Egret ( <i>Ardea alba</i> )	LC	R	0.33	UC
		Purple Heron ( <i>Ardea purpurea</i> )	LC	R	0.57	F
		Indian Pond Heron ( <i>Ardeola grayii</i> )	LC	R	0.33	UC
		Black-crowned Night Heron ( <i>Nycticorax nycticorax</i> )	LC	R	0.57	F
		Cinnamon Bittern ( <i>Ixobrychus cinnamomeus</i> )	LC	R	0.74	F
<b>Accipitriformes</b> (3 sp)	Accipitridae(3 sp)	Black Kite ( <i>Milvus migrans</i> )	LC	R	0.82	C
		Western Marsh Harrier ( <i>Circus aeruginosus</i> )	LC	WM	0.08	R
		Shikra ( <i>Accipiter badius</i> )	LC	R	0.25	UC
<b>Coraciiformes</b> (3 sp)	Alcedinidae (1 sp)	White-throated Kingfisher ( <i>Halcyon smymensis</i> )	LC	R	0.41	F
	Meropidae (1 sp)	Asian Green Bee-eater ( <i>Merops orientalis</i> )	LC	R	0.57	F
	Coraciidae (1 sp)	Indian Roller ( <i>Coracias benghalensis</i> )	LC	R	0.25	UC
<b>Piciformes</b> (1 sp)	Megalaimidae (1 sp)	Coppersmith Barbet ( <i>Megalaima haemacephala</i> )	LC	R	0.49	F
<b>Psittaciformes</b> (2 sp)	Psittaculidae (2 sp)	Plum-headed Parakeet ( <i>Psittacula cyanocephala</i> )	LC	R	0.65	F
		Rose-ringed Parakeet ( <i>Psittacula krameri</i> )	LC	R	0.49	F

Order	Family	Species	IUCN status	Migratory status	R.A	L.O.R
Passeriformes (23 sp)	Costicolidae (5 sp)	Rufescent Prinia ( <i>Prinia rufescens</i> )	LC	R	0.25	UC
		Ashy Prinia ( <i>Prinia socialis</i> )	LC	R	0.41	F
		Plain Prinia ( <i>Prinia inornata</i> )	LC	R	0.82	C
		Common Tailorbird ( <i>Orthotomus sutorius</i> )	LC	R	0.57	F
		Zitting Cisticola ( <i>Cisticola juncidis</i> )	LC	R	0.08	R
	Motacillidae (4 sp)	Citrine Wagtail ( <i>Motacilla citreola</i> )	LC	WM	0.33	UC
		White-browed Wagtail ( <i>Motacilla maderaspatensis</i> )	LC	R	0.74	F
		White Wagtail ( <i>Motacilla alba</i> )	LC	WM	0.65	F
		Rosy Pipit ( <i>Anthus roseatus</i> )	LC	R	0.08	R
	Muscicapidae (2 sp)	Brown Rock Chat ( <i>Cercomela fusca</i> )	LC	R	0.49	F
		Oriental Magpie Robin ( <i>Copsychus saularis</i> )	LC	R	0.33	UC
	Pycnotidae (1 sp)	Red-vented Bulbul ( <i>Pycnonotus cafer</i> )	LC	R	0.49	F
	Nectariniidae (1 sp)	Purple Sunbird ( <i>Cinnyris asiaticus</i> )	LC	R	0.41	F
	Dicruridae (1 sp)	Black Drongo ( <i>Dicrurus macrocercus</i> )	LC	R	0.98	C
	Leiphrichidae (1 sp)	Jungle Babbler ( <i>Turdoides striata</i> )	LC	R	0.82	C
	Hirundinidae (1 sp)	Barn Swallow ( <i>Hirundo rustica</i> )	LC	R	0.9	C
	Corvidae (3 sp)	Large-billed Crow ( <i>Corvus macrorhynchos</i> )	LC	R	0.57	F
		House Crow ( <i>Corvus splendens</i> )	LC	R	0.98	C
		Rufous Treepie ( <i>Dendrocitta vagabunda</i> )	LC	R	0.33	UC
	Sturnidae (3 sp)	Common Myna ( <i>Acridotheres tristis</i> )	LC	R	0.82	C
		Indian Pied Myna ( <i>Gracupica contra</i> )	LC	R	0.65	F
		Bank Myna ( <i>Acridotheres ginginianus</i> )	LC	R	0.98	C
	Passeridae (1 sp)	House Sparrow ( <i>Passer domesticus</i> )	LC	R	0.57	F

**Abbreviations:** WM-Winter Migrant, R-Resident, IUCN-International Union for Conservation of Nature, LC-Least Concern, RA-Relative Abundance, L.O.R-Local Occurrence Rate

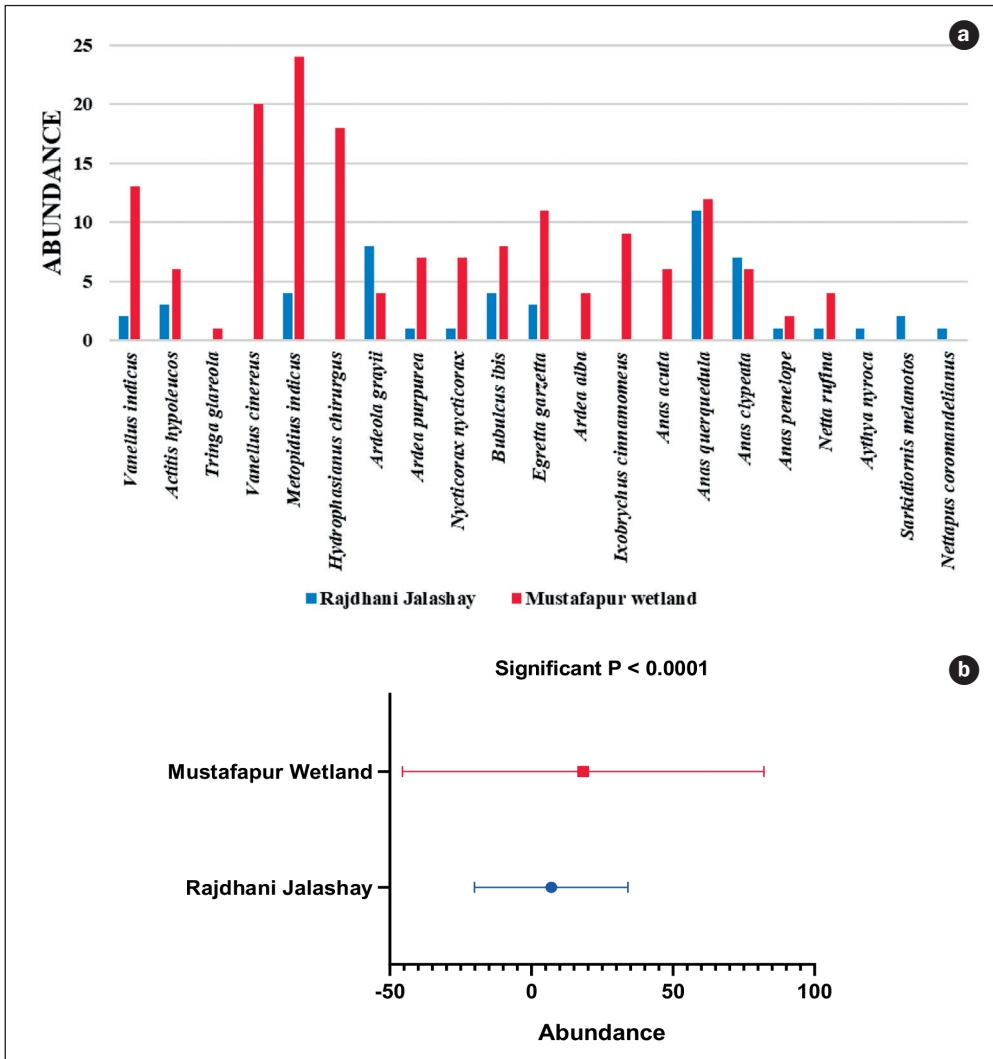


Figure 2. Comparison of abundance of waterbird species between Rajdhani Jalashay and Mustafapur wetland at Patna, Bihar. (a) Comparison of bird count between the two sites; (b) Statistical difference in abundance of birds between the two sites

2. ábra A madárfajok egyedsűrűségének összehasonlítása Rajdhani Jalashay és Mustafapur vizes élőhelyein (Patna, Bihar, India). (a) A két területen leszámlolt madarak összehasonlítása; (b) Statisztikai különbség a két terület madárfajainak egyedsűrűségében

( $n=21$ ) compared to Rajdhani Jalashay ( $n=18$ ) (Kolmogorov-Smirnov  $D=0.4823$ ,  $P < 0.0001$ ). The results indicate a notably higher abundance of most waterbird species in the unmanaged Mustafapur Wetland compared to the managed Rajdhani Jalashay. For instance, the Lesser Whistling-duck (*Dendrocygna javanica*) was 2.2 times more abundant at Mustafapur Wetland, while the Gadwall (*Anas strepera*) exhibited a threefold higher abundance, and the Asian Openbill Stork (*Anastomus oscitans*) was a remarkable 61 times more abundant.

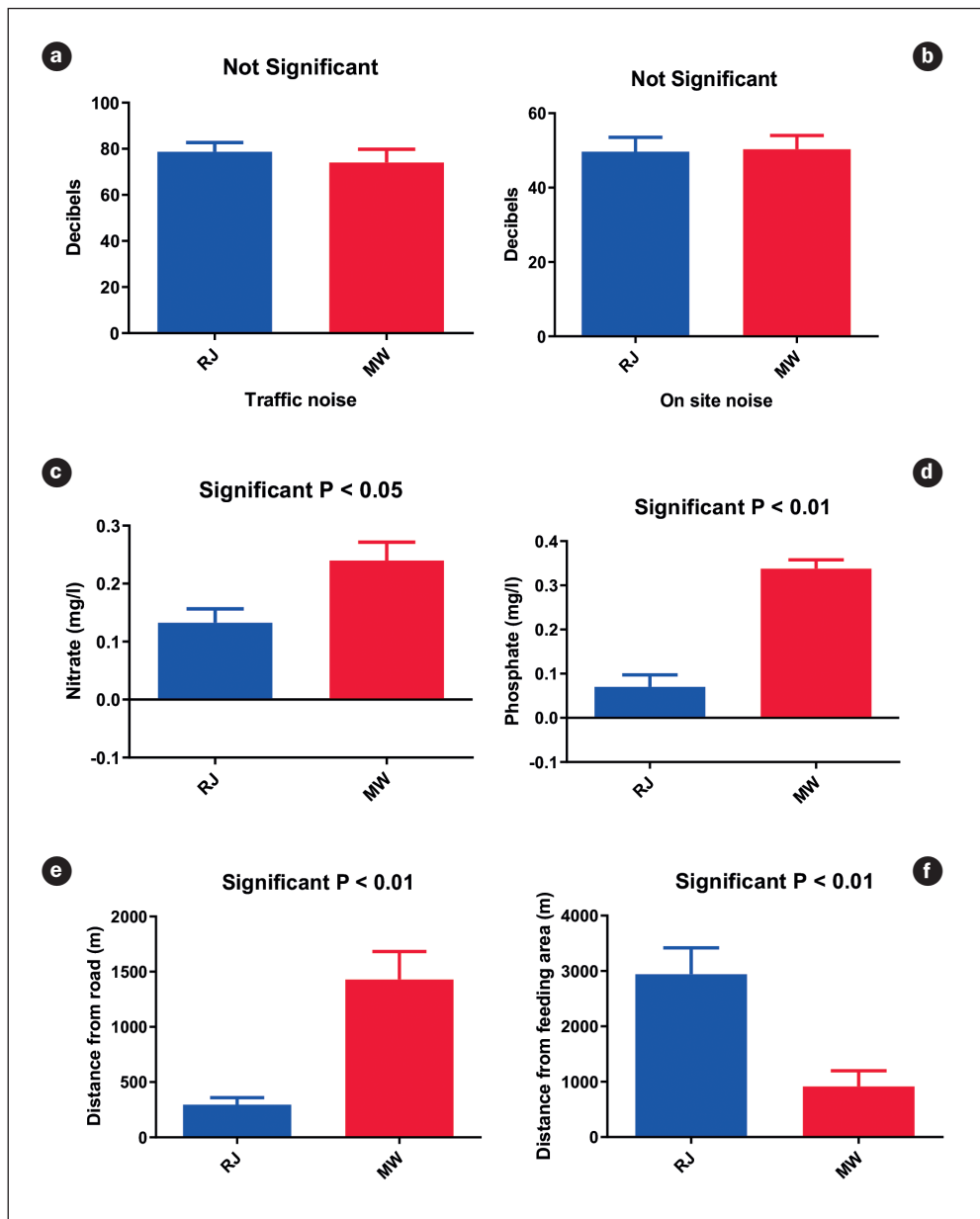


Figure 3. Comparison of Rajdhani Jalashay (RJ) with Mustafapur wetland (MW)

3. ábra A két vizes élőhely Rajdhani Jalashay (RJ) és Mustafapur (MW) tulajdonságainak összehasonlítása

Simpson's diversity index for Rajdhani Jalashay was calculated as 0.78. Shannon-Weiner's diversity index was 2.85. Species evenness of the community was 0.66 and Effective Number of Species (ENS) was 17.32.

Mustafapur wetland showed marginal higher values of the Simpson's diversity index (0.81), Shannon-Weiner's diversity index (2.86), Species evenness (0.69), and Effective Number of Species (17.59).

While the traffic and on-site noise level were non-significantly different between the two wetlands, distance from the road was higher for Mustafapur wetland ( $t=4.343$ ,  $df=14$ ,  $P=0.0007$ ). More importantly, distance from adjoining feeding area was significantly less ( $t=3.641$ ,  $df=14$ ,  $P=0.0027$ ) for Mustafapur wetland (Figure 3). The nitrate level at the unmanaged wetland was found to be twice higher ( $t=2.725$ ,  $df=6$ ,  $P=0.0344$ ), and the phosphate level was four times higher ( $t=7.867$ ,  $df=6$ ,  $P=0.0002$ ) as compared to the managed waterbody (Figure 3).

## Discussion

The number of resident species were greater as compared to migrants at both the wetlands. Resident species contribute the most to the diversity (59%) and density of waterbirds on artificial irrigation tanks (Bellio *et al.* 2009).

Wading birds are highly mobile and respond quickly to changes in habitat quality, thus serving as important indicator species for wetland systems (Beerens *et al.* 2015). Moreover, the total number of Lesser Whistling-duck, a resident bird was almost double (526) at Mustafapur wetland as compared to 234 at Rajdhani Jalashay. Similarly, Adhurya *et al.* (2019) reported high number of the species at Ambuja Wetland, West Bengal having high nutrient load.

The concentration of phosphate varied from 0.01–0.38 mg/l that would promote algal bloom. Higher nitrate and phosphate levels at the unmanaged wetland can be attributed to the inflow of sewage from adjacent residential areas and run-off from nearby crop fields resulting in eutrophication. Eutrophication is often produced by an excess of macronutrients derived from anthropogenic sources, which has been shown to promote growth of aquatic vegetation (O'Hare *et al.* 2018). Rosselli and Stiles (2012) and Murphy and Dinsmore (2018) have also attributed the higher aquatic bird richness and abundance at one of the smallest lakes studied, Colta Lake, to high eutrophication levels, expressed as high values of biochemical demand of oxygen and high concentrations of phosphates and nitrites. However, high levels of eutrophication may also trigger the proliferation of green algae and decline of macrophytes leading to a high-turbidity state of water, in which few species can survive (Scheffer *et al.* 1993). To address the eutrophication and excess nutrient issues in aquatic ecosystems, phytoremediation offers a promising solution (Liu *et al.* 2021). Aquatic plants like duckweeds, water lettuce (*Pistia stratiotes*), and water lilies have demonstrated their ability to combat eutrophication by absorbing and assimilating excess phosphorus and nitrogen (Nahar & Hoque 2021). However, these plants can sometimes grow uncontrollably, potentially covering the water surfaces. To avoid such scenarios, regular monitoring is

essential (Liu *et al.* 2021). Promoting public awareness is the cornerstone for mobilizing support and ensuring effective eutrophication management. Controlled eradication of excess flora when necessary is vital to prevent overgrowth. This integrated approach can effectively reduce eutrophication in the water bodies (Wang *et al.* 2022).

Each species of wetland-dependent bird has a unique and complex set of needs for wetland habitats that makes it difficult to generalize about how loss or degradation of wetlands affects bird populations. Wetland restoration efforts for aquatic birds should focus on protecting and creating habitat to maintain demographic and genetic connectivity and metapopulation viability (Hall & Beissinger 2017). Further, ecosystem-based approach is needed in wetland management with various targets (Ma *et al.* 2010). This requires integrated knowledge of the entire wetland ecosystem (including hydrology, geology, agrology, botany, aquatic biology, landscape ecology, engineering, and ornithology). Wetland restoration has been found to increase bird count and diversity (Proctor *et al.* 2022). Therefore, protection and sustainable management of natural wetlands is required that may help to restore the declining biodiversity especially of avifauna and other aquatic fauna and also support the livelihoods of the local population (Aslam *et al.* 2021).

## Conclusion

This study shows that even in developed urban areas like Patna, certain habitats support significant numbers of bird species. Therefore, perennial flowering plants, fruit trees that provide nesting grounds for bird species, should not be cut and more trees should be planted to attract more birds. For better understanding the ecology of these waterbodies, it is recommended that the physicochemical parameters along with biological parameters of these sites should be monitored on a regular basis.

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