Areas of avian richness across an urban-rural setting: A case study of selected water-bodies from Pune, Maharashtra, India

Pankaj Koparde & Ninad Raote

Pankaj Koparde, 07, Radhika Apartment, Anandnagar, Sinhgad Road, Pune 411051, Pune District, Maharashtra, India. E-mail: *pankajkoparde@gmail.com* [Corresponding author].
Ninad Raote, Vrindawan Bungalow, Plot No. 35, Sudarshan Nagar, Chinchwad 411033, Pune District, Maharashtra, India.

Abstract

Species diversity and distribution vary across space, and time, and are influenced by habitat quality. Therefore, to conserve species, it becomes imperative to document them, and the possible threats to the habitats they frequent. Wetland birds can be considered as a good model system as indicator taxa for habitat disturbance studies, as they are more sensitive to landscape modifications and habitat disturbance than most terrestrial birds. To find species-rich wetlands within Pune, India, we compared three sites situated across an urban–rural setting, based on bird species assemblages. Bird species were recorded during 2009-2013, and secondary data was mined from various virtual participatory online fora. A total of 177 species were recorded, 73 were wetland-associated and included four that are globally threatened. Cluster analysis on the localities, based on species-assemblages, revealed two major clusters, Pashan Lake and Khadakwasla, and Kawadi, with a cophenetic correlation coefficient of 0.89. The wetland-species exclusivity and habitat threats were found highest for Kawadi, emphasizing the need of conservation efforts at the site. Our work updates species occurrence data for these three sites, discusses threats to the bird species, and provides a baseline for conservation action.

Introduction

Urbanization leads to land-use change. This affects bird species assemblages (McKinney 2008). Habitat sensitive taxa, and habitat specialists are likely to be affected by a change in land-use. A study by Blair (1996), on avifauna along an urban gradient, showed that native species dominate in forested areas, whereas invasive, and exotic species dominate the human-modified landscape. Sandstrom *et al.* (2006) observed that urban green space might influence species richness. The causal relationship of urbanization also applies to wetland birds. Whited *et al.* (2000) revealed that urban regions showed low species richness but species composition did not correspond to landscape variables. Species composition, and species richness are liable to change with respect to multiple environmental, and habitat variables. Indian inland freshwater wetlands are highly dependent on the monsoon; however many urban wetlands also receive a substantial amount of untreated and/or partly treated wastewater (Bassi *et al.* 2014). Despite most of the urban wetlands being highly polluted, they support numerous wetland bird species. Wetland connectivity, within a landscape, may allow local movements of species for foraging, and breeding (Amezaga *et al.* 2002), resulting in a virtual increase in the number of species. Therefore, long-term studies on wetland birds and their habitat covariates are necessary to enable the evaluation of wetlands with high species richness. Many migratory species from northern Asia spend the northern winter in India (Ali & Ripley 1987; Berthold 2001). Most of the wetland bird censuses conducted in India, such as the Asian Waterbird Census, and heronry census (Urfi *et al.* 2005), are focused on the resident, winter migratory diurnal birds, or a specific group of birds, underestimating nocturnal wetland-associated birds such

as night herons (*Nycticorax*), bitterns (*Ixobrychus*), and fish owls (*Ketupa*). To compensate for such missing data, online fora such as well curated social media groups on wildlife, and portals such as the India Biodiversity Portal (IBP 2015), iNaturalist (iNaturalist 2015), and eBird (eBird 2015), data of which are in the public domain, and are cross-validated by users are emerging as a reliable secondary data source. Such data sources often contain species of rare occurrences. These sources can also be used for adding and/or updating knowledge on regional avifauna.

We present results of a multi-year (2009–2013) study in-and-around Pune, India, where we compare bird species assemblages and attributes of habitat disturbance at three sites situated across an urban–rural setting. This paper also discusses local threats to wetland birds.

Materials & methods

Study area

Pune is situated on the eastern edge of the northern Western Ghats in Maharashtra. Three wetlands, namely, Khadakwasla Reservoir, Kawadi, and Pashan Lake, situated in and around the city (Fig. 1), were selected for the study. These wetlands also set up a system of wetlands over an urbanization as well as pollution gradient. Khadakwasla Dam, built across the Mula River, is located *c.* 15 km south of Pune city. A large part of the reservoir has a water depth of more than five meters. The reservoir is surrounded by agriculture, scrubland, and human-modified landscape; birds use its shallow margins. It falls in a rural area, and is the least polluted of the three wetlands.

Pashan Lake is a small reservoir located along the Ram River in the Pashan suburb of Pune. It is surrounded by scrubland, and a human-dominated landscape. The Ram River flows into the
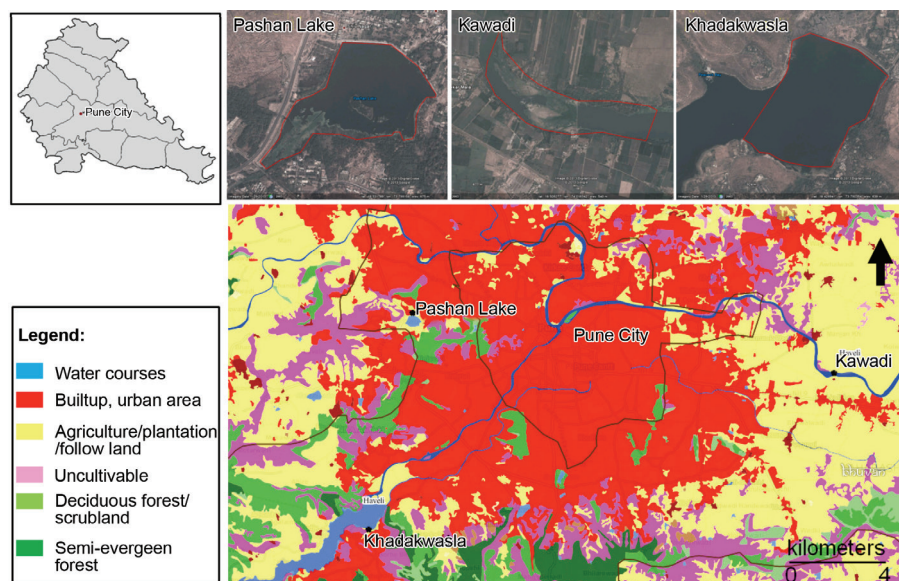
Fig. 1. Map of the study area of wetlands in and around Pune. The map on the bottom right is superimposed on land-use map in Bhuvan Portal (http://bhuvan.nrsc.gov.in) with Pune city limits outlined in black. The inset map on the top left indicates Pune district. The three maps along the top are from Google Earth and indicate the boundaries of the three wetland sites, Pashan Lake, Kawadi and Khadakwasla.

The presence of solid waste, in a water body, was measured by observing the number of rubbish piles, garbage bags, floating polystyrene, and other solid waste material. The growth of *Echhornia* species was measured by gauging the approximate area of the water body the plant covered. Water turbidity was measured visually. Water was collected in a clear glass flask and allowed to stand for five minutes to allow the debris to settle. Water turbidity was then scored on an ordinal scale of 0–10. The number of bird photographers was recorded at each locality. The modal value of photographers across samples was used as a measure of disturbance to birds. Apart from photographers, cattle-grazing was an anthropogenic disturbance. Cattle-grazing was occasional and localised only in certain part of the wetland; therefore we did not consider it as a disturbance factor.

Mutha River, which converges with the Mula River in Pune, after passing through a variety of land-uses. The lake lies in a highly urbanised area, and is moderately polluted. Kawadi is situated *c.* 25 km east of Pune, on the Pune–Solapur highway, amidst agriculture (especially sugarcane and other cash crop plants), and scrubland, and is formed by a small bund (approximately 100 m in length) across the Mula-Mutha River, which has created a small shallow reservoir. It is in a sparsely urbanised area, and is heavily polluted with industrial effluents, and domestic sewage waste carried by the Mula–Mutha River.

Data collection

We used the point count method for sampling bird diversity (Magurran 2004). Each point count sample covered an area of 50 m diameter, and lasted 20 min. Point counts were carried out from 0700 to 1000 hrs. Each locality was sampled at two different points on each visit. All the localities were visited at least twice during the northern winter season (November–February) during 2009–2013. A species was marked present if it was sighted at least twice in different samples. Birds were identified using field guides (Grimmett *et al.* 2011; Rasmussen & Anderton 2012). Birds flying overhead were noted down separately. Species other than wetland birds were recorded opportunistically in and around point count stations. Secondary data was collected from multiple online data sources including the Facebook pages of Birds of Pune (FBBP 2013), Birds of Maharashtra (FBBM 2013), India Nature Watch (2013), Flickr (2013), Orkut Pune Birders (Orkut PB 2013), and Tigerland (2013). The IUCN Red List of Threatened Species (IUCN 2015) was used to assign threat status to the species. Disturbance factors to the habitat, and to birds, were measured semi-quantitatively on each site visit using an ordinal scale of 0–10, ten being the highest rank for the category, when attributes such as solid waste disposal, growth of *Echhornia* species, water turbidity, and numbers of photographers were recorded. The modal value of the habitat, and bird disturbance factors, were summarized across samples.

Data Analysis

We drew species saturation curves for each site to judge if our sampling efforts for species richness were adequate (Magurran 2004). We repeated the sampling till the species saturation curve reached an asymptote. We used PAST v2.17b (Hammer *et al.* 2001) for cluster analysis. We used a Bray-Curtis distance algorithm to construct a dendrogram based on species composition. Depending on the presence of the species in all the localities, we categorized the species into three groups: widespread (present at all the localities), less widespread (present at any two localities), and localised (present at a single locality).

Results

1. Species richness and distribution based on point count data

A total of 177 bird species were recorded during the study belonging to 64 families and 133 genera. Of these, 73 species were wetland associated. 69 species were recorded during point counts, all of which were wetland associated. These include four threatened species: Common Pochard *Aythya ferina* (Vulnerable), Painted Stork *Mycteria leucocephala* (Near–Threatened=NT), Black-headed Ibis *Threskiornis melanocephalus* (NT), and Oriental Darter *Anhinga melanogaster* (NT). Table 1 provides a list of birds observed at the point count stations. The highest number of species was recorded at Kawadi (59), followed by Pashan Lake (50), and Khadakwasla (43). The maximum number of localized species was found at Kawadi (14), followed by Khadakwasla (2), and Pashan Lake (2) (Fig. 2).

2. Species records from secondary data

From various online sources, we retrieved 53 entries for birds from the three localities. Among these, 48 records were from Kawadi, while the remaining were from Pashan Lake. Only five records out of 53 were not common to the primary data. Table 2 summarises

Table 1. Bird species recorded during point counts around Pune, 2009–2013.

No	Common Name	Scientific Name	Kawadi	Pashan	Khadakwasla	Occurrence
1	Lesser Whistling Duck	*Dendrocygna javanica*	–	X		L
2	Ruddy Shelduck	*Tadorna ferruginea*	X	X	X	W
3	Common Pochard*	*Aythya ferina*	–	X	X	LW
4	Tufted Duck	*A. fuligula*	–	X	X	LW
5	Garganey	*Anas querquedula*	X	X	X	W
6	Northern Shoveler	*A. clypeata*	X	X	X	W
7	Gadwall	*A. strepera*	X	X	X	W
8	Eurasian Wigeon	*A. penelope*	–	–	X	L
9	Indian Spot-billed Duck	*A. poecilorhyncha*	X	X	X	W
10	Northern Pintail	*A. acuta*	X	X	–	LW
11	Common Teal	*A. crecca*	X	–	X	LW
12	Comb Duck	*Sarkidiornis melanotos*	–	X	X	L
13	Cotton Teal	*Nettapus coromandelianus*	–	–	X	L
14	Little Grebe	*Tachybaptus ruficollis*	X	X	X	W
15	Indian House Swift	*Apus affinis*	X	–	–	L
16	Brown Crake	*Amaurornis akool*	X	–	–	L
17	White-breasted Waterhen	*A. phoenicurus*	X	X	X	W
18	Purple Swamphen	*Porphyrio porphyrio*	X	X	X	W
19	Common Coot	*Fulica atra*	X	X	X	W
20	Painted Stork*	*Mycteria leucocephala*	X	X	–	LW
21	Asian Openbill	*Anastomus oscitans*	X	X		LW
22	Woolly-necked Stork	*Ciconia episcopus*	X	X	X	W
23	Cinnamon Bittern	*Ixobrychus cinnamomeus*	X	X		LW
24	Black-crowned Night Heron	*Nycticorax nycticorax*	X	X		LW
25	Indian Pond Heron	*Ardeola grayii*	X	X	X	W
26	Cattle Egret	*Bubulcus ibis*	X	X	X	W
27	Grey Heron	*Ardea cinerea*	X	X	X	W
28	Purple Heron	*A. purpurea*	X	X	X	W
29	Great Egret	*A. alba*	–	X	X	LW
30	Intermediate Egret	*Mesophoyx intermedia*	X	X	X	W
31	Little Egret	*Egretta garzetta*	X	X	X	W
32	Black-headed Ibis*	*Threskiornis melanocephalus*	X	X	–	LW
33	Eurasian Spoonbill	*Platalea leucorodia*	X	X	X	W
34	Indian Black Ibis	*Pseudibis papillosa*	X	–	X	LW
35	Glossy ibis	*Plegadis falcinellus*	X	X	X	W
36	Little Cormorant	*Phalacrocorax niger*	X	X	X	W
37	Great Cormorant	*P. carbo*	X	–	–	L
38	Indian Cormorant	*Phalacrocorax fuscicollis*	X	X		LW
39	Oriental Darter*	*Anhinga melanogaster*	–	X	X	LW
40	Black-winged Stilt	*Himantopus himantopus*	X	X	–	LW
41	Common Ringed Plover	*Charadrius hiaticula*	X	–	–	L
42	Little Ringed Plover	*C. dubius*	X	–	–	L
43	Red-wattled Lapwing	*Vanellus indicus*	X	X	X	W
44	Greater Painted-snipe	*Rostratula benghalensis*	–	X	X	LW
45	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	X	X	X	W
46	Bronze-winged Jacana	*Metopidius indicus*	–	X	–	L
47	Ruff	*Philomachus pugnax*	X	–	–	L
48	Temminck's Stint	*Calidris temminckii*	X	–	–	L
49	Little Stint	*C. minuta*	X	–	–	L
50	Common Snipe	*Gallinago gallinago*	X	X	–	LW
51	Common Sandpiper	*Actitis hypoleucos*	X	X	X	W
52	Green Sandpiper	*Tringa ochropus*	X	–	–	L
53	Wood Sandpiper	*T. glareola*	X	X	X	W
54	Little Pratincole	*Glareola lactea*	X	X	–	LW
55	Gull-billed Tern	*Gelochelidon nilotica*	X	–	–	L
56	River Tern	*Sterna aurantia*	X	X	X	W
57	Western Marsh Harrier	*Circus aeruginosus*	X	–	X	LW
58	Common Kingfisher	*Alcedo atthis*	X	X	X	W
59	Pied Kingfisher	*Ceryle rudis*	X	X	X	W
60	White-throated Kingfisher	*Halcyon smyrnensis*	X	X	X	W
61	Paddyfield Pipit	*Anthus rufulus*	X	X	X	W
62	Western Yellow Wagtail	*Motacilla flava*	X	–	–	L
63	Grey Wagtail	*M. cinerea*	X	X	X	W
64	Citrine Wagtail	*M. citreola*	X	–	–	L
65	White-browed wagtail	*M. maderaspatensis*	X	X	X	W
66	White Wagtail	*M. alba*	X	–	–	L
67	Wire-tailed swallow	*Hirundo smithii*	X	X	X	W
68	Barn Swallow	*H. rustica*	X	X	X	W
69	Bank Myna	*Acridotheres ginginianus*	X	–	–	L

Legend: LW: Low widespread; **W:** Widespread; **L:** Localised. * indicates threatened species listed by IUCN (2015). The nomenclature follows Praveen *et al.* (2016).
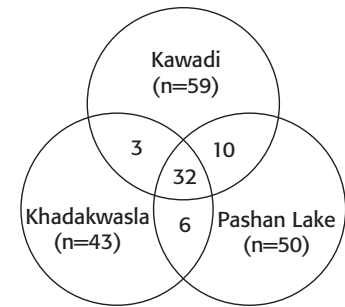

Fig. 2. Relationship among wetlands based on shared species observed at three study sites, Pune, 2009-2013.

the list of species recorded around point count stations, including data in the public domain. The secondary data revealed the presence of Common Shelduck *Tadorna tadorna* at Kawadi, and Pashan Lake (at least one male individual from 2010–2012 each year). Although our sampling was carried out during the day, two nocturnal species, namely, Spotted Owlet *Athene brama*, and Grey Nightjar *Caprimulgus indicus* were observed around the point count stations.

3. Cluster analysis

The cluster analysis revealed two major clusters: one comprising Pashan Lake, and Khadakwasla in a single cluster, and the other comprising Kawadi (Fig. 3). The dendrogram, based on the species composition data, was supported with a cophenetic coefficient of 0.89.
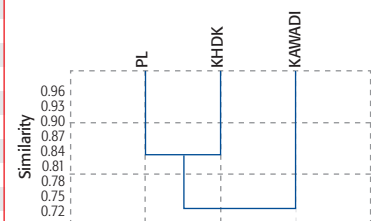

Fig. 3. Cluster analysis based on species composition data using Bray-Curtis distance algorithm. **PL:** Pashan Lake; **KHDK:** Khadakwasla reservoir; **KAWADI:** Kawadi.

4. Disturbance

The potential disturbance score for Kawadi was the highest for all the measured attributes, as summarised in Table 3. On a few occasions, dead fish, and

Table 2. List of bird species observed around point count stations around Pune, 2009-2013 and from secondary data. #species recorded from secondary data.

No.	Common Name	Scientific Name	Kawadi	Pashan	Khadakwasla
1	Common Shelduck#	*Tadorna tadorna*	X	X	
2	Indian Peafowl	*Pavo cristatus*	X	–	X
3	Jungle Bush Quail	*Perdicula asiatica*	X	–	–
4	Grey Francolin	*Francolinus pondicerianus*	–	–	X
5	Rock Pigeon	*Columba livia*	X	X	X
6	Yellow-legged Green Pigeon	*Treron phoenicopterus*	–	–	X
7	Eurasian Collared-Dove	*Streptopelia decaocto*	X	–	X
8	Laughing Dove	*S. senegalensis*	X	X	X
9	Oriental Turtle Dove	*S. orientalis*	–	–	X
10	Red Collared-Dove	*S. tranquebarica*	–	–	X
11	Spotted Dove	*S. chinensis*	X	X	X
12	Grey Nightjar	*Caprimulgus indicus*	X	–	–
13	Greater Coucal	*Centropus sinensis*	X	X	X
14	Pied Cuckoo	*Clamator jacobinus*	–	–	X
15	Asian Koel	*Eudynamys scolopaceus*	X	X	X
16	Grey-bellied Cuckoo	*Cacomantis passerines*	X	–	–
17	Common Hawk-Cuckoo	*Hierococcyx varius*	X	X	X
18	Indian Cuckoo	*Cuculus micropterus*	X	–	–
19	Common Redshank#	*Tringa totanus*	X	–	–
20	Indian Courser	*Cursorius coromandelicus*	X	–	–
21	Osprey#	*Pandion haliaetus*	X	–	–
22	Black-winged Kite	*Elanus caeruleus*	X	–	X
23	Oriental Honey Buzzard	*Pernis ptilorhynchus*	X	X	X
24	Crested Serpent Eagle	*Spilornis cheela*	–		X
25	Changeable Hawk Eagle	*Nisaetus cirrhatus*	–	X	X
26	Bonelli's Eagle	*Aquila fasciatus*	–	–	X
27	Booted Eagle	*Hieraaetus pennatus*	–	–	X
28	Shikra	*Accipiter badius*	X	X	X
29	Eurasian Sparrowhawk#	*A. nisus*	X		
30	Brahminy Kite	*Haliastur indus*	X	X	X
31	Black Kite	*Milvus migrans*	X	X	X
32	White-eyed Buzzard	*Butastur teesa*	–	–	X
33	Spotted Owlet	*Athene brama*	X	–	–
34	Indian Grey Hornbill	*Ocyceros birostris*	X	X	X
35	Common Hoopoe	*Upupa epops*	X	–	–
36	Brown-fronted Woodpecker	*Dendrocopos auriceps*	X	–	–
37	Coppersmith Barbet	*Psilopogon haemacephala*	X	X	X
38	Green Bee-eater	*Merops orientalis*	X	X	X
39	Indian Roller	*Coracias benghalensis*	X	X	X
40	Common Kestrel	*Falco tinnunculus*		X	X
41	Plum-headed Parakeet	*Psittacula cyanocephala*	X		X
42	Rose-ringed Parakeet	*P. krameri*	X	X	X
43	Small Minivet	*Pericrocotus cinnamomeus*	X	X	X
44	Black-headed Cuckooshrike	*Coracina melanoptera*	–	–	X
45	Indian Golden Oriole	*Oriolus kundoo*	X	X	X
46	Common Woodshrike	*Tephrodornis pondicerianus*	–	–	X
47	Common Iora	*Aegithina tiphia*	X	X	X
48	Black Drongo	*Dicrurus macrocercus*	X	X	X
49	Ashy Drongo	*D. leucophaeus*	X		X
50	White-throated Fantail	*Rhipidura albicollis*	X	X	X
51	Bay Backed Shrike	*Lanius vittatus*	X	–	–
52	Long-tailed Shrike	*L. schach*	X	X	X
53	House Crow	*Corvus splendens*	X	X	X
54	Large-billed Crow	*C. macrorhynchos*	X	X	X
55	India Paradise-Flycatcher	*Terpsiphone paradise*	X	X	–
56	Thick-billed Flowerpecker	*Dicaeum agile*	X	X	X
57	Pale-billed Flowerpecker	*D. erythrorhynchos*	X	X	X
58	Purple-rumped Sunbird	*Leptocoma zeylonica*	X	X	X
59	Purple Sunbird	*Cinnyiris asiaticus*	X	X	X
60	Golden-fronted Leafbird	*Chloropsis aurifrons*	X	–	–
61	Baya Weaver	*Ploceus philippinus*	X	X	–
62	Red Munia	*Amandava amandava*	X	–	–
63	Indian Silverbill	*Euodice malabarica*	X	X	X
64	Scaly-breasted Munia	*Lonchura punctulata*	X	X	X
65	Black-headed Munia	*L. malacca*	X	–	X
66	House Sparrow	*Passer domesticus*	X	–	X
67	Tree Pipit	*Anthus trivialis*	–	–	X
68	Blyth's Pipit#	*A. godlewskii*	X	–	
69	Common Rosefinch	*Carpodacus erythrinus*	X	–	X
70	Grey-necked Bunting	*Emberiza buchanani*	X	–	
71	Cinereous Tit	*Parus cinereus*	X	X	X
72	Rufous-tailed Lark	*Ammomanes phoenicura*	X	–	–
73	Ashy-crowned Sparrow Lark	*Eremopterix griseus*	X	–	–
74	Jungle Prinia	*Prinia sylvatica*	X	X	X
75	Ashy Prinia	*P. socialis*	X	X	X
76	Plain Prinia	*P. inornata*	X	X	X
77	Common Tailorbird	*Orthotomus sutorius*	X	X	X
78	Sykes's Warbler	*Iduna rama*	X	X	

Table 2. List of bird species observed around point count stations around Pune, 2009-2013 and from secondary data. #species recorded from secondary data.

No.	Common Name	Scientific Name	Kawadi	Pashan	Khadakwasla
79	Blyth's Reed Warbler	*Acrocephalus dumetorum*	X	X	X
80	Paddyfield Warbler	*A. Agricola*	X		
81	Clamorous Reed Warbler	*A. stentoreus*	X	X	X
82	Red-rumped Swallow	*Cecropis daurica*	X	X	X
83	Red-whiskered Bulbul	*Pycnonotus jocosus*	X	X	X
84	Red-vented Bulbul	*P. cafer*	X	X	X
85	Common Chiffchaff	*Phylloscopus collybita*	X		X
86	Greenish Warbler	*Seicercus trochiloides*	X	X	
87	Oriental White Eye	*Zosterops palpebrosus*	X	X	X
88	Lesser Whitethroat	*Curruca curruca*	X	X	
89	Yellow-eyed Babbler	*Chrysomma sinense*	X	X	X
90	Indian Scimitar Babbler	*Pomatorhinus horsfieldii*			X
91	Tawny-bellied Babbler	*Dumetia hyperythra*			X
92	Puff-throated Babbler	*Pellorneum ruficeps*			X
93	Large Grey Babbler	*Argya malcolmi*	X	X	
94	Common Babbler	*A. caudata*	X		
95	Jungle Babbler	*Turdoides striata*			X
96	Brahminy Starling	*Sturnia pagodarum*	X	X	X
97	Common Myna	*Acridotheres tristis*	X	X	X
98	Jungle Myna	*A. fuscus*	X	X	X
99	Indian Robin	*Saxicoloides fulicatus*	X	X	X
100	Oriental Magpie-Robin	*Copsychus saularis*	X	X	X
101	Tickell's Blue Flycatcher	*Cyornis tickelliae*	X	X	X
102	Bluethroat	*Luscinia svecica*	X		
103	Red-breasted Flycatcher	*Ficedula parva*	X		X
104	Black Redstart	*Phoenicurus ochruros*	X		
105	Blue Rock Thrush	*Monticola solitarius*	X		X
106	Siberian Stonechat	*Saxicola maurus*	X	X	X
107	Pied Bushchat	*S. caprata*	X	X	X
108	Orange-headed Thrush	*Zoothera citrina*	X		

The nomenclature follows Praveen *et al.* (2016).

Table 3. Overview of sampling and habitat and bird disturbance attributes of three sites, 2009-2013. Scores are out of ten.

Site	WT	SWD	ESG	PHO	SPRICH	VISITS
Kawadi	8	8	7	6	59	16
Pashan Lake	5	4	3	2	50	13
Khadakwasla	2	1	1	1	43	12

Legend: WT: Water turbidity; **SWD:** Solid waste disposal; **ESG:** *Echhornia* spp. growth; **PHO:** Number of photographers; **SPRICH:** Bird species richness; **VISITS:** Number of visits in 2009–2013.

checkered keelback *Xenochrophis piscator* were observed in the water. The main attributes for potential disturbances at Pashan Lake were solid waste disposal, the grazing of livestock, and the washing of cars. Human interference at the site is intensive, but

a small island in the lake is used as a safe roost site by several species, including three Near-threatened species. At Khadakwasla, the main attributes for potential disturbances were unregulated tourism, including swimming in the lake, and the large numbers of tourists attracted to eateries temporarily erected on the shores of the backwaters, especially during the monsoon season. During our surveys, we found that wetland species tend to aggregate in areas with low human-mediated disturbance, and low human activity such as bird photography.

Discussion

We found that Kawadi (a sparsely urbanised locality, but heavily polluted), which offers both, open lotic, and open lentic systems, had the highest species richness, whereas Khadakwasla (a rural locality, but less polluted) had the lowest. Although we classified the sites based on their locations with respect to the city limits and land-use patterns around them; our results suggest that the bird species richness at a locality could be a function of various factors that could not be easily summarized in our broad categories. Other factors that influence species richness could be the geographical location of these sites, with respect to the city, other nearby wetlands and other habitats, food abundance, and availability, *etc*.

Despite the fact that the Mula-Mutha River at Kawadi is highly polluted by human and industrial waste, as was observed during the study, we recorded high species richness, as well as the highest number of localised species in this locality. The wetland at Kawadi is surrounded by scrubland and agricultural fields (Fig. 1), especially of sugarcane, and other cash crop plants. It is suspected that pesticides and chemical fertilizers from surrounding farmlands drain into the Mula-Mutha River, polluting it, as apparent from the dead fishes and snakes seen in it. The high growth of *Echhornia*, and the disposal of solid waste into the water appear to contribute to its stagnation. The high species richness may reflect the variety of microhabitats such as marshland, pond, river, scrubland, and farmland adjacent to the river, all offering diverse feeding options for different wetland bird species. The water depth at Kawadi is generally shallow, and hence may offer the right foraging options for waterfowl, herons, egrets, and waders. Additionally, downstream of Kawadi, the Mula-Mutha River offers multiple sites for foraging, nesting, and roosting. In addition, further eastwards, the Mula-Mutha River joins the Bheema River (close to Bhigwan), which is another migratory bird hotspot (Bharucha & Gogate 1990; Ebird 2015). These may be the reasons that multiple wetland bird species were found to aggregate in this area despite the river being heavily polluted. On-site disturbance to the birds at Kawadi is negligible, as compared to the other two sites, except, possibly from bird photographers who may disturb flocks of birds. However, based on our observations it is difficult to understand the impact of photographers on the species composition. From secondary data, obtained from bird photographers, we recorded that Common Shelduck was sighted at Kawadi and Pashan Lake. The known southern limit of the species in India is from the north (Rasmussen and Anderton 2012, ebird 2015), and northwest (Grimmett *et al.* 2011, ebird 2015) of Maharashtra during the northern winter.

Although polluted by human and industrial waste, as apparent from our observations of mixing of sewage water with the lake water during the study period, and situated amidst human habitation, Pashan Lake, which is a highly urbanised locality,

retains relatively cleaner water, with a low amount of solid waste, as compared to Kawadi (Table 3). Our observations of species richness and the condition of the lake match that of Parchizadeh (2014); who reported fluctuations in species richness during two years of observations (2010–2012).

Khadakwasla Reservoir is spread across a larger area than the other two sites. It was lowest on the disturbance attributes as well as the species richness (Table 3). Due to its large spread, our sampling may not have adequately recorded its species richness in its entirety, but only that of the point count stations. We observed that the habitat of Khadakwasla is under the threat of unregulated tourism such as picnics, and temporary establishments such as eateries around the reservoir, especially during the monsoon season.

The data that we collected was categorical and hence may not provide insights on the effect of habitat disturbance on species assemblage. Future studies focusing on the collection of continuous data over a span of few years will be necessary to understand if, and how, various disturbance attributes drive species assemblages. Having said this, our data shows mixed results when compared to Whited *et al.* (2000) who have shown that species richness is low in urban areas in a temperate region. A future study that includes habitat, as well as landscape variables will be useful in testing the hypothesis that wetland bird species richness decreases towards more urbanization.

From our observations, we found that species used to aggregate in areas of low disturbance, and possibly away from where humans could reach. Although Kawadi currently supports the highest species richness amongst the studied sites, given the current situation of habitat disturbance it may deteriorate in future. Human access to Pashan Lake needs to be regulated so as to minimise habitat disturbance. Owing to its large area, Khadakwasla Reservoir did not show immediate threats to the avifauna, except through unregulated tourism. The peak tourism season is in the monsoon hence, may not affect winter migratory birds but resident birds. However, this is a speculation based on our observations of how wetland bird species tend to avoid high human activity areas. There could be a potential threat from on-going construction on various private properties around Khadakwasla Reservoir, but this has to be validated with further studies.

The change of land-use into urban space in-and-around Pune city is increasing (Nalavade 2000) and has the potential to lead to further deterioration in the quality of wetland habitats within the city limits (Nalavade *et al.* 2000; Patwardhan *et al.* 2003). Though the current study fails to connect the effect of habitat disturbance to species richness, and assemblage, it provides baseline data for future studies. It also highlights the importance of records in the social media, and in the public domain. Our study highlights the need for immediate conservation action at Kawadi.

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