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RESEARCH ARTICLE

Effect of wetland extent on seasonal abundance and behaviour of Red-naped Ibis *Pseudibis papillosa* in the semi-arid Dungarpur district, Rajasthan, India

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Abstract Freshwater wetlands in tropical countries experience considerable year-round change of conditions due to strong seasonality and high human pressure, providing potentially challenging conditions for resident waterbird species. An additional source of variation is temperature that is exacerbated seasonally especially in arid areas. In this study, we explored density, flocking and habitat use of Red-naped Ibis *Pseudibis papillosa* in the semi-arid district Dungarpur, Rajasthan, to understand how ibises used areas with differing extents of wetlands in three seasons between March 2021 and January 2022. The highest densities of the ibis were in areas with the most wetlands in all seasons. Behavioural parameters (flock sizes, habitat use) did not much vary seasonally. Wetlands were used more than other habitat types throughout the year notwithstanding landscape-scale wetland extent. Red-naped Ibis showed scale-dependence during the driest season pointing to the important role of the largest wetlands but used wetlands of all sizes in other seasons showing why conservation of wetlands of all sizes on arid landscapes appear essential to safeguard resident waterbird species. These findings underscore the importance of arid and semi-arid areas to sustain waterbird populations while also showing the need for field studies to help update existing assumptions regarding wetland conservation and ecological requirements of resident waterbird species.

Keywords Behaviour, density, flock size, habitat use, wetland extent.

Introduction

Freshwater wetlands are ecologically important habitats providing critical foraging and nesting habitat for many taxa, especially waterbirds (Ma *et al*. 2010). However, these habitats occur patchily across landscapes, especially in tropical and sub-tropical countries where high human densities, urbanization, intensive agricultural practices, and global climate change can limit their persistence (Ma *et al*. 2010; Davidson 2014; Wang *et al*. 2018; Ramirez *et al*. 2018). Additionally, and especially in semi-arid and arid areas of tropical countries, seasonal water levels in wetlands undergo substantial changes (Lopez *et al*. 2020). Conditions vary from high precipitation in one season, when water depth disallows several wading waterbirds from using wetlands (Sundar 2004; Skagen *et al*. 2008), to extreme dryness in another season (Ma *et al*. 2010; Sundar and Kittur 2013). These conditions of wetlands being relatively sparse alongside experiencing significant seasonal variations pose potential challenges for resident waterbird species. Some mechanisms used by large

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waterbirds to cope with these changes are local movements, behavioural variations such as changing foraging times in different seasons, varying flock sizes and changing habitat use ostensibly to match with differences in resources (Sundar 2006; Viana *et al*. 2013; Wells *et al*. 2013; Ghimire *et al*. 2021).

Another aspect of wetlands on tropical and sub-tropical landscapes is unequal distribution – a gradient that can vary from areas having many large wetlands to others having very few, smaller wetlands (Sundar and Kittur 2013, 2019; Rawal *et al*. 2021). Focus on wetland protection for waterbirds on human-dominated landscapes (urban and agricultural) has been biased towards large wetlands due to assumptions that few large wetlands would adequately safeguard biodiversity at landscape scales (Kleijin *et al*. 2014). There have been very few studies to test this widespread assumption and the few existing studies on agriculture-dominated areas showed smaller wetlands having a much higher species richness (as in Rio Grande du Sul, South America; Guadagnin and Maltchik 2006) or having the same species richness as larger wetlands (in Uttar Pradesh, India; Sundar and Kittur 2013). Species richness in urban ponds (wetlands < 5 ha) even in crowded mega-cities such as Delhi in India was exceedingly high suggesting that existing assumptions regarding species diversity and wetland sizes require being updated (Rawal *et al*. 2021). Individual waterbird species have been found to vary in their response to landscape level wetland availability with some like Asian Openbills *Anastomus oscitans*, Woolly-necked Storks *Ciconia episcopus,* and Sarus Cranes *Antigone antigone* increasing in abundance in areas with more wetlands, other species like Cattle Egrets *Bubulcus ibis* declined, while many wading bird species did not show scale-dependent wetland use across the landscape instead using all available wetlands similarly (Sundar and Kittur 2012, 2013). Some species like the Glossy Ibis *Plegadis falcinellus* tracked landscape-scale seasonal changes in wetland extent – they preferred areas with intermediate levels of wetlands during the wet seasons but shifted to areas with the most wetlands in the dry season (Sundar and Kittur 2019). These studies are showing the need to maintain wetlands of all sizes on the landscape to benefit both species richness and individual species of waterbirds.

A majority of these studies have been conducted on landscapes where rice is a dominant crop in at least one season. Flooded rice and artificial structures such as canals built to sustain rice cultivation, can provide either suitable conditions for waterbirds, or at least some buffering from declining or deteriorating wetlands under certain conditions (Guadagnin and Maltchik 2006; Sundar and Kittur 2012, 2013; Kittur and Sundar 2021). However, when landscapes are more arid with drier crops, responses of waterbirds to unequal wetland distribution, and especially whether they show seasonally different responses, is poorly understood. Waterbirds can potentially show widely varying responses ranging from very strong scale-dependence favouring areas with more wetlands, to using any wetland that is available on the arid landscape thereby showing no scale-dependence. The conservation implications of these two extreme possibilities are greatly different with the former underscoring existing assumptions of the importance of maintaining large (or more) wetlands in an area, and with the latter pattern indicating the need to retain all available wetlands including smaller ones on the landscape. To address this question, we assessed landscape scale distribution and habits of the Red-naped Ibis *Pseudibis papillosa*, an endemic ibis species of the Indian subcontinent (Ali and Ripley 2007; Hancock *et al*. 2011), in the semi-arid district of Dungarpur in southern Rajasthan, India. Red-naped Ibis ecology is very poorly studied with existing descriptions based almost entirely on anecdotal observations. The species is described as using a variety of habitats such as cattle carcass dumping sites, urban areas, drier margins of wetlands, paddy fields, grasslands, and crop fields (usually fallow fields; Ali and Ripley 2007; Soni 2008; Hancock *et al*. 2011). Consequently, the Red-naped Ibis is commonly described as a waterbird that prefers dry uplands rather than wetlands. Recent studies have found the Red-naped Ibis to be uncommon on multi-cropped farmlands in the relatively wet areas of lowland Nepal and the Gangetic floodplains of India (Sundar and Kittur 2012; Katuwal and Quan 2022). In an arid urban area of Rajasthan, India, Red-naped Ibis showed strong variations in

seasonal abundance and habitat use (Soni 2008). However, in contrast to assumed ecology of the species, in a semi-arid location in western India, Red-naped Ibis preferentially used areas dominated by wetlands relative to areas dominant with agriculture throughout the year, but recent study showed that fallow fields are mostly used by the species in this area in all seasons (Ameta *et al.* 2022). They showed a strong preference for wetland habitats (used more relative to available) at multiple spatial scales (landscape and foraging habitat) throughout the year, and flock sizes were much larger during the wet monsoon season likely reflecting newly fledged young (Ameta *et al.* 2022). While these new studies show Red-naped Ibis to be associated positively with wetlands, there is no understanding of whether Red-naped Ibis exhibit scale-dependent use of landscapes based on varied wetland densities, and whether their behaviours change seasonally in response to conditions on arid and semi-arid landscapes. Hence, we developed an *a-priori* field design choosing areas with three different wetland extents across Dungarpur district and our objectives were to document seasonal density, flocking and habitat preference of Red-naped Ibis in a semi-arid condition.

Study area

We conducted the study in the Dungarpur district (area 3,770 km^2) of southern Rajasthan, India (Figure 1). The district has a human population of over 13,88,900 people, 70 % of whom are tribal with the primary occupation of agriculture and animal husbandry (Census of India 2011). Dungarpur is among the least developed districts with 93 % of the people living in rural areas. The district has a hilly landscape (see Figure 2) that supports tributaries of the Mahi River which runs along the district's northern boundary, while the Som River serves as the district's primary south-eastern boundary with Udaipur. Two primary water storage areas created to combat severe aridity in the district are the Som Kamla reservoir on the Som River and the Kadana Dam on the Mahi River. Several wetlands are scattered across the district located beside agriculture, scrubland, valleys of hills, and cities (Figure 2c; pers. obs.). The district experiences distinct seasonality with three easily recognizable seasons based on temperature and precipitation: summer (March-June), monsoon (July-October), and winter (November-February). The temperature ranges from a maximum of ~ 45° C in the summer to a minimum of ~ 5°C during winter. The district experienced 877.6 mm of rainfall in 2020 (Monsoon Report Rajasthan 2020). The primary land use of the district is agriculture (with 35% being cultivated and 10% fallow), with the rest of the district being dominated by mixed forests (16 %), uncultivated lands (14 %; cultivated waste, permanent pasture, scattered agroforestry), and rocky, barren areas (Statistical Abstract 2012). Wetlands of a large variety of sizes are scattered across the landscape and used

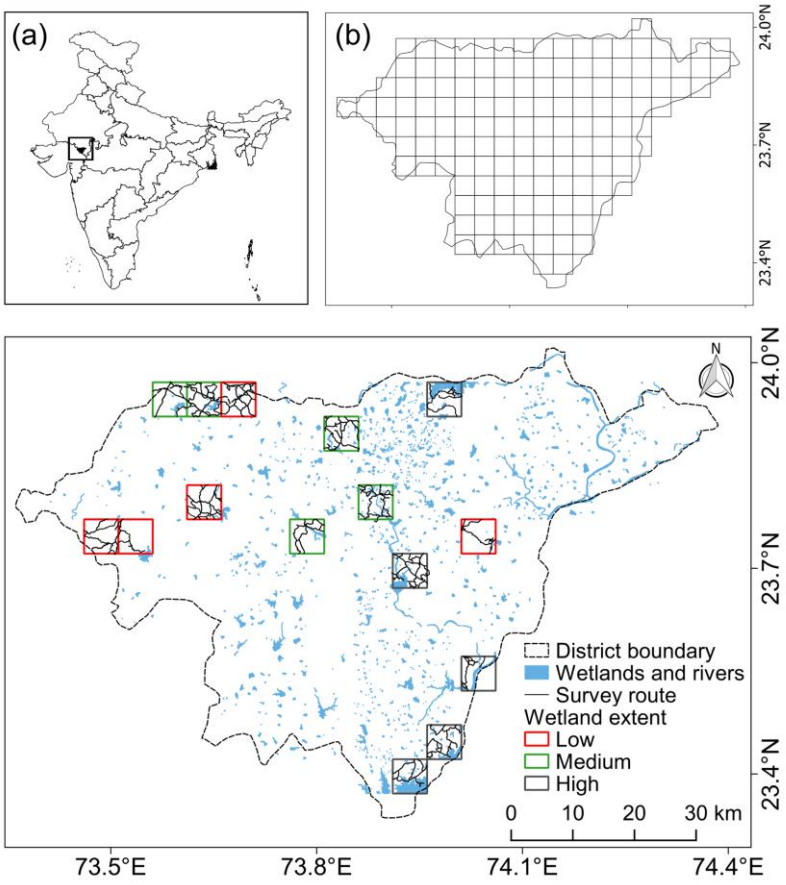

Figure 1. Location of Dungapur district in India (a). The district area was divided into a squares with 5 × 5 km (b), and 15 squares with three different wetland extents (low, medium and high) were randomly selected to study Red-naped Ibis (c). Sampling effort (roads traversed) in each square are also shown.

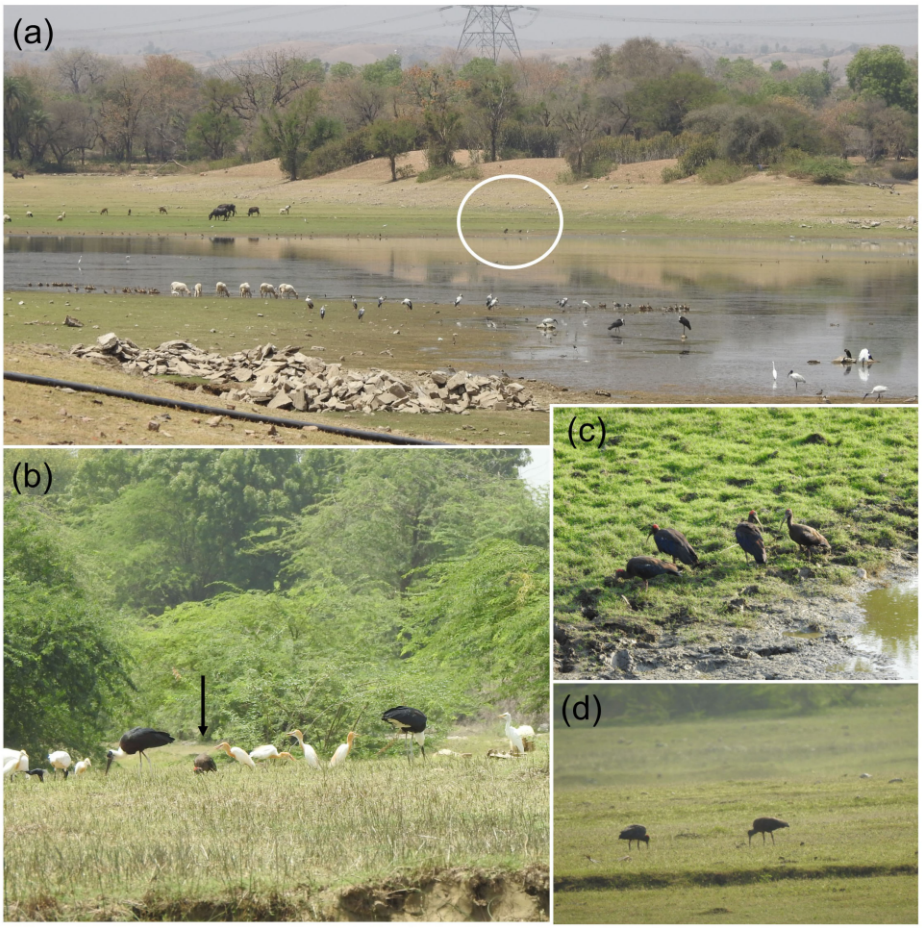

Figure 2. Observations of Red-naped Ibis using different habitats in Dungarpur district, Rajasthan. Two ibis sitting on the bank of a large wetland (a; inside white circle); single ibis foraging with other waterbirds in a fallow agriculture field (b; marked with arrow); a flock of four ibis foraging at the edge of a wetland (c); and two ibis foraging in an open area (d). (Photograph credits: Krishna Asawra).

year-round by both humans and domestic livestock for a variety of purposes (Figures 1, 2). The district is part of Rajasthan's "humid southern plain" climatic zone (Hussain 2015). Farming is carried out as both rain-fed and irrigated crops, and with most farmers practising a mixed form of farming that includes crops, vegetables, fruit orchards, dairy, and poultry (pers. obs.). Maize *Zea mays*, Wheat *Triticum* spp., Rice *Oryza sativa*, and small millets such as Sorghum *Sorghum* sp., Pearl Millet *Cenchrus americanus*, Finger Millet *Eleusine coracana* and Little Millet *Panicum sumatrense* are the main cereal crops (Khatik and Bhimawat 2017), while Sugarcane *Saccharum officinarum* and Cotton *Gossypium* spp. are also grown commercially in many areas (Rao and Singh 2018). Few ecological studies have been conducted on birds of Dungarpur district, though the few existing surveys highlight a diverse waterbird assemblage, including large waterbird species of conservation importance such as the Painted Stork *Mycteria leucocephala* and Black-headed Ibis *Threskiornis melanocephalus* (Sharma and Tehsin 1994; Koli *et al*. 2013).

Natural wetlands fill during the monsoon and are used to water crops in the other seasons, though the majority of them dry up at the end of winter resulting in a rapid and significant reduction of wetlands during summer. The larger reservoirs have some water throughout the year and are used for various purposes including fish rearing (personal observations).

Methods

Study design

The district area was divided into a 5×5 km grid (N = 128 squares). Each individual wetland was traced as a polygon using the February 2020 image on Google Earth Pro (ver. 7.3.4.8642). All polygons were converted into shapefiles for use in the QGIS freeware platform (ver. 3.1.0; QGIS Development Team 2020). The wetland area in each square was calculated using QGIS software and ranged from 0.002 to 7.73 km^2 with over 73 % of squares having < 1 km^2 of wetlands. Based on the wetland extent in squares, we stratified squares into three categories (low: < 0.1 km^2 of wetlands; medium: 0.1 – 0.3 km^2; high: > 3 km^2). We randomly selected five squares of each stratum to study Red-naped Ibis' seasonal responses to wetland distribution (see Figure 1).

Field methods

Field surveys were conducted in 15 focal squares in random order using roads that were traversed using a motorcycle driven at a speed of c. 20 km/ hr between March 2021 and January 2022. Wetland areas falling out of the district boundary were not visited. Survey routes were recorded using mobile application LOCUS and effort (km) was quantified in each square. Large wetlands that were beside road routes and those can not be scanned from a vintage point, were surveyed on foot to enumerate all Red-naped Ibis using the wetland and its edge. Each square was surveyed once per season, and ibis seen within a width of ~ 200 m on either side of transects were enumerated. Habitats in which Red-naped Ibis were sighted were recorded in the following

categories: fallow fields (open agriculture fields without crops), garbage sites, open uncultivated areas, and wetlands (either in water or on wet soil immediately beside the wetland; see Figure 2a). To add to the natural history information on Red-naped Ibis, we also documented the number of juveniles and sub-adult birds seen with adults using morphological differences (young of the year did not have the bright red papillose head that adults did; Ali and Ripley 2007).

Analysis

We used the metric density for Red-naped Ibis which is controlled for effort that varied due to field condition. Density (birds km^{-2}) was estimated for each focal square using a transect width of 400 m and presented as mean (± SD). Our sample sizes (five replicates per strata) were very small, and close presence of few grids also shows dependency of observations; hence results should be considered preliminary. Due to small sample sizes, we did not conduct any statistical analyses.

Results

A total of 1,436 km was traversed in search of Red-naped Ibises (5.3 - 55.2 km per square; 566 km in summer, 437 km in monsoon, and 433 km in winter). A total of 426 ibises (418 adults and 8 juveniles) were counted, including 171 in the summer (3 juveniles), 202 (one juvenile) in the monsoon and 53 (4 juveniles) in the winter.

Density

Higher densities of Red-naped Ibis were recorded in squares with the higher wetland extent (Figure 3). Seasonal variations were apparent with monsoon densities being three times the winter density (mean ± SD density; monsoon: 1.06 ± 1.39, summer: 0.69 ± 0.93, and winter: 0.31 ± 0.34; see Figure 3). Using season-wise average density and coarsely extrapolating to the entire district, the Red-naped Ibis population in Dungarpur district varied seasonally between 1,169 and 3,996 birds.

Flock size

Flock sizes did not vary due to wetland extent in any of the three seasons; most flocks were small (1 - 4 individuals), with larger flocks observed almost entirely in medium and high-wetland squares (Figure 4).

Habitat use

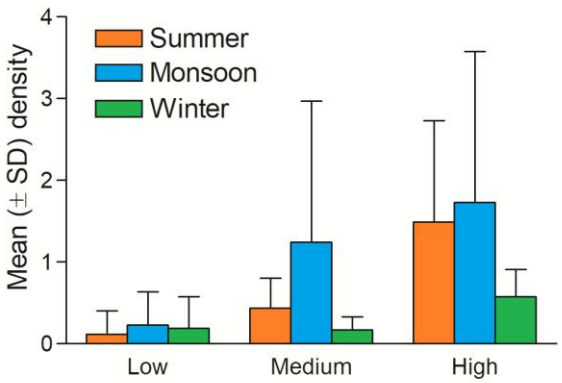

Figure 3. Red-naped Ibis seasonal density (birds per sq. km) in 5 x 5 km squares across three strata with differing wetland extent recorded in Dungarpur district, Rajasthan, India from March 2021 to January 2022.

Most Red-naped Ibises were observed foraging in wetlands, particularly in summer and many more individuals used wetlands in areas with higher wetland extent (Figure 5). Similar number of ibises were observed using the next-most frequented habitat type, fallow fields, in all three strata. Garbage sites and open areas were rarely used by Red-naped Ibis in Dungarpur (Figure 5).

Discussion

Our study highlights a preliminary status of density, flocking and habitat use of Red-naped Ibis due to varying wetland extents using an *a-priori* field design with low sample sizes in southern most district of Rajasthan state. Red-naped Ibis are resident in Dungarpur, but it is not immediately clear why so few juveniles were observed during our study. The results were likely influenced by low sample sizes. A larger sample of focal isolated squares with seasonal mapping of satellite imageries for water area may yield improved results.

Density

Densities varied much more seasonally than they did across strata, leading to wide seasonal variation in the estimated population sizes of Red-naped Ibis (Figure 3). Wetland distribution is likely affected the most during the summer when smaller and shallow wetlands dry. Observations of most ibis during the summer in squares with the most wetland extent (Figure 3), and most observations of ibises using wetlands in summer (Figure 5), suggests that Red-naped Ibis will be influenced by wetland declines at multiple spatial scales.

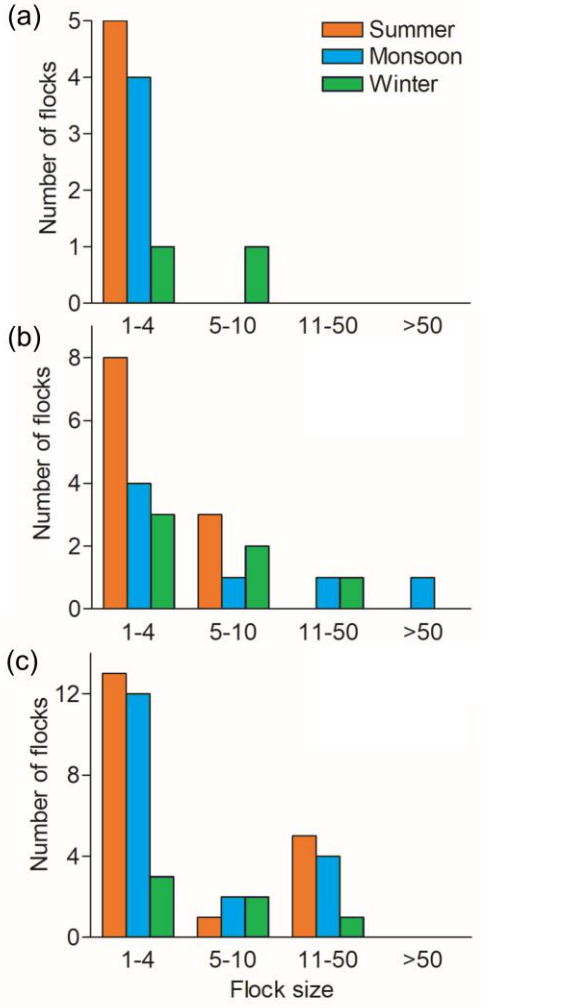

Figure 4. Red-naped Ibis flock sizes during three seasonal surveys in three strata differentiated based on wetland extent (a: low; b: medium; c: high) in Dungarpur district, Rajasthan, India.

Retaining larger or more wetlands across the district will be most beneficial to ibises during the dry summer months and could help limit variations in seasonal densities that are suggestive of local movements. The highest densities were during the monsoon, when wetland extent was the highest, suggesting that Red-naped Ibis were influenced positively by increasing wetland extent in Dungarpur. Semi-arid landscapes such as Dungarpur district appear to be elegant study systems to understand waterbird-wetland pulsing dynamics with results being pertinent to landscapes that have unprotected wetlands not managed for waterbirds. While seasonal variation in Red-naped Ibis numbers have been documented elsewhere, seasonal patterns are not consistent. Ibis numbers in the semi-arid and neighbouring Udaipur district were the most during the winter (Ameta *et al*. 2022) but were the most during summer in Churu city, Rajasthan (Soni 2008), while being the most during the monsoon in this study. Additional variables such as total rainfall, actual measures of wetland extent in different areas and overall habitat structure (such as crop type, percentage area under crops, level of urbanisation etc.) likely influence Red-naped Ibis abundance causing these variations in seasonal abundance patterns even within semi-arid and arid landscapes. Studies that do not carefully evaluate changes in observed abundance with relation to locally pertinent variables can provide erroneous conclusions with regard to population changes. For studies to be useful in discussions regarding populations of Red-naped Ibis, they need to enumerate at least one year of seasonal variations. The coarse population estimates in this study suggest that there are tens of thousands of Red-naped Ibis in Rajasthan state alone. The strong preferences of Red-naped Ibis to wetlands at multiple spatial scales potentially make it an ideal candidate as a flagship species with which to evaluate status of wetlands.

Flock size

In our study, flock sizes of Red-naped Ibis did not show scale-dependent or seasonal variation suggesting that social behaviours are minimally influenced by water availability. The breeding season for the Red-naped Ibis varies across India, but it has been reported as being from March to October in north India (Ali and Ripley 2007). Ameta *et al*. (2022) found the largest flocks of Red-naped Ibis during the winter in the neighbouring semi-arid Udaipur district suggesting that formation of families likely influenced seasonal flock sizes. The absence of such a clear difference in Dungarpur is likely due to small sample sizes in our study, but we require studies specifically on breeding behaviours to confirm observed trends. The largest flocks in Dungarpur were seen in areas with more wetlands in all seasons. This pattern suggests that resident Red-naped Ibis in areas with few or small wetlands are territorial corresponding to potentially lower food and habitat availability, while areas with larger or more wetlands seemingly accommodate more ibises. This pattern is identical to that observed in Sarus Cranes in western Uttar Pradesh where breeding crane pairs defended small wetlands while larger wetlands were able to accommodate non-breeding cranes providing scale-dependent variations in landscape-scale abundance (Sundar and Kittur 2013). Our study found most Red-naped Ibis in small groups (1 - 4 birds) which is consistent with findings in standardised field

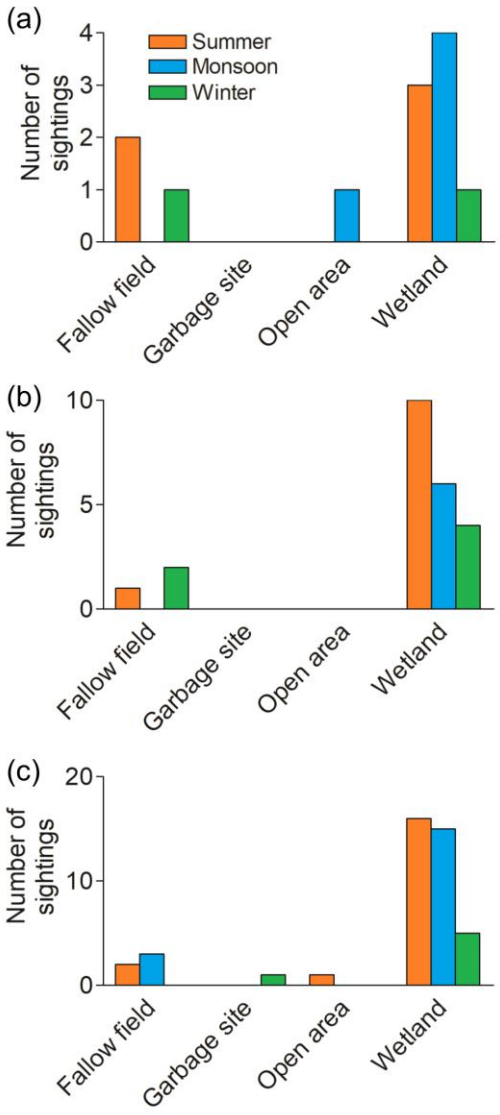

Figure 5. Red-naped Ibis seasonal habitat use in three strata differentiated based on wetland extent (a: low; b: medium; c: high) in Dungarpur district, Rajasthan, India.

studies (Ameta *et al*. 2022; Katuwal and Quan 2022) and general descriptions available in species accounts (Ali and Ripley 2007).

Habitat use

Red-naped Ibis in Dungarpur showed strong positive associations with wetlands at both the scale of habitat use and the landscape. Ameta *et al*. (2022) also showed identical patterns of Red-naped Ibis preferring wetlands at multiple spatial scales, even when the landscape was dominated by agriculture. These findings from carefully designed field studies that asked different questions are not consistent with descriptions in general species accounts that suggest Red-naped Ibis to be a generalist favouring drier uplands, though the species has been described previously as using margins of wetlands (Ali and Ripley 2007; Hancock *et al*. 2011). These systematically conducted landscape-scale studies are also showing Red-naped Ibis to rarely use human-created sites such as garbage dumps, which is cited as an important foraging site for the species in general descriptions (Ali and Ripley 2007; Hancock *et al*. 2011). Red-naped Ibis numbers at garbage dumps and cattle carcass sites can be very high in arid urban areas, where these ibises are also apparently acclimatized to human presence (e.g. Charan *et al*. 2022). These differences in observations appear related to sampling methods such as surveying entire landscapes (as in our study and Ameta *et al*. 2022) versus only around small towns (Charan *et al*. 2022) and cities (Soni 2008; Sinha 2022). Emerging information appears to showcase plastic behaviours of Red-naped Ibis when using disparate conditions varying from semi-arid landscapes to towns of different sizes. Habitat use metrics should therefore be contrasted carefully paying attention to the focal landscape and to the survey methods.

Conclusion

With this study, despite the limitation of small sample sizes, we add important nuance to Red-naped Ibis ecology, especially underscoring the value of wetlands of all sizes in semi-arid landscapes for the well-being of the species. That the species showed strong preference for wetlands at multiple spatial scales, and also showed variations in abundance with season shows the need to move away from existing unsubstantiated species descriptions. We add to the growing number of studies on sub-tropical and tropical landscapes that cover multiple seasons to understand how resident waterbirds cope with changing seasonal conditions. Without exception, these studies are showcasing the high value of South Asian landscapes and unprotected wetlands in supporting considerable populations of a diverse waterbird assemblage. These studies are providing important counterarguments to accumulated evidence of the importance of protected wetlands in developed countries (e.g. Kleijn *et al*. 2014). The availability of more published evidence from developed countries has led to the development of the fallacy that all agricultural areas and unprotected wetlands are detrimental to all waterbird species, which in turn have led to incorrectly developed species assessments for poorly studied species (see also Sundar 2020). Our work adds also to the existing sparse literature that

showcases the importance of arid and semi-arid landscapes to waterbird species in South Asia. A large number of waterbird species in south Asia remain poorly studied, and existing studies cover only few geographies and aspects of ecology, with the vast majority being conducted in wetter landscapes, and covering only one season. Filling these lacunae, especially obtaining important metrics such as breeding success, density of breeding pairs, survival, and movement patterns across multiple locations, is necessary to further assist evidence-based evaluations of species status and importance of unprotected landscapes.

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