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Special Section

Red-naped Ibis ecology

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AIMS AND SCOPE

SIS Conservation (*SISC*) is short for "*Stork, Ibis and Spoonbill Conservation*" and is a peer-reviewed publication of the IUCN SSC Stork, Ibis and Spoonbill Specialist Group (SIS-SG). *SISC* publishes original content on the ecology and conservation of both wild and captive populations of SIS species and Shoebills worldwide, with the aim of disseminating information to assist in the management and conservation of SIS populations and their habitats worldwide.

We invite anyone, including people who are not members of the SIS-SG, to submit manuscripts.

All enquiries, including but not limited to, ideas for special issues, special sections, participation as an Editor, submission of original papers, short notes, essays or letters, should be emailed to sis.conservation@gmail.com.

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Back cover photo: © Devendra Shrimali. Red-naped Ibis *Pseudibis papillosa* foraging in Udaipur, India.

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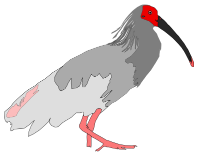

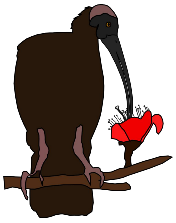

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EDITORIAL

Do the ibis have it?

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In conceiving *SIS Conservation*, we imagined being able to give somewhat equal attention to Storks, Ibises and Spoonbills (SIS). We were, nonetheless, aware that some species have had enormous research and conservation attention. The vast majority of literature on storks, for example, focus on White Storks *Ciconia ciconia* (Gula *et al*. 2023). One of our goals was therefore to try and get attention on the habits and conservation status of poorly studied SIS species. We therefore actively invited submissions to Special Issues or Special Sections that focussed on poorly studied SIS species. With only four issues published (including this one), we have some indications of where our efforts have reached.

Issue 1 focussed on the Glossy Ibis *Plegadis falcinellus* and was the first monograph-like compilation of information on the species (Santoro 2019). Despite having a pan-global distribution, and being a species whose distribution range is expanding, research attention on Glossy Ibises has been relatively sparse. Out of the 24 papers published in SIS Conservation, 13 have been cited at least once for a total of 38 citations (as on 24 March 2024; scholar.google.com).

Contrast these metrics with Issue 2 that featured a Special Section on the ecology and conservation of the Woolly-necked Stork *C. episcopus* (which was not split into two separate species at the time; Sundar 2020). This was the first time that this species received so much research attention. The new information helped disprove several assumptions regarding the species' habitat use and status resulting in the eventual downlisting of the species from an incorrect "Threatened" status to a more realistic "Near-threatened" (Sundar 2020; Gula *et al*. 2023). The Special Section featured 10 papers that have since been cited 86 times.

The Special Section of Issue 3 focused on another well-studied species, the Black Stork *C. nigra* and featured six papers (Cano-Alonso 2021). These papers have been cited twice so far, perhaps an indication of the availability of more detailed papers published in more conventional journals.

This new Issue 4 features a Special Section on the ecology of the poorly studied Red-naped Ibis *Pseudibis papillosa*. Accepted papers were uploaded immediately as online-first contributions. Publication of the full issue was delayed due to several reasons, but was completed and uploaded in March 2024 (Tiwary and Sundar 2022). Eight of the nine papers in the Special Section had been uploaded by then and have been cited 12 times. The Red-naped Ibis is a very common and widespread species across south Asia, and the publication of Issue 4 will hopefully spur new research attention. Prior to the publication of this issue, the Red-naped Ibis was one the least studied waterbirds in the world – an unenviable status that now stands a little altered.

SIS Conservation is helping draw some attention to poorly studied ibis species, while also inviting new work on other SIS species. Apart from the Special Issues and Special Sections focused on ibis species, the four issues of the publication feature additional papers on ibises included in the general

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section. Overall, though, there is still a lot to be done and many species poorly studied and understood ibis species remain. The ibis, it appears, may not have it yet.

This issue also features two important articles. The Opinion article provides a timeline and important learnings from the project in Japan to restore the Crested Ibis *Nipponia nippon* (Okahisa 2022). The project is an excellent example of scientists carefully studying local conditions and the focal species to develop understanding pertinent to the area where the restoration was carried out. The project also stands out for the deliberate use of robust science to guide the restoration efforts with intermittent analyses used to make necessary changes. In the second article, Gula and Mungole (2022) provide the first estimates of foraging success of the poorly studied Saddle-billed Stork *Ephippiorhynchus senegalensis* using 255 minutes of field observations in western Zambia. The storks preyed on fish and invertebrates with a prey capture rate of 0.3 per minute. The study adds to the natural history of the Saddle-billed Stork from an area where studies on SIS species are rare but urgently needed.

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OPINION

Lessons learnt from the successful reintroduction of Crested Ibis *Nipponia nippon*

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Figure 1. One of the successfully reintroduced adult Crested Ibis *Nipponia nippon* on Sado Island. (Photo by Yuji Okahisa).

History of Crested Ibis in Japan

Crested Ibis *Nipponia nippon* (Figure 1), is widely known as one of the bird species that became extinct in Japan during the initial wildlife conservation efforts (Yamashina and Nakanishi 1983). Crested Ibis, however, is no longer extinct as it was successfully reintroduced.

Crested Ibis was distributed over a wide area of Far East Asia, from southeastern Russia, the Korean Peninsula, China, Taiwan, and western Hokkaido, to Okinawa in Japan until the 19th century (Yamashina and Nakanishi 1983; Birdlife International 2001; Li *et al*. 2009; Park *et al*. 2010). Currently, wild populations are only in Yangxian, China. Reintroduction programs are ongoing at Sado Island in Japan, Changnyeong in South Korea, and six other locations in China (Su and Kawai 2015; Yoon and Choi 2018).

In Japan, Crested Ibis mainly bred in the eastern part of Japan and wintered over a wider area of Japan (Figure 2). In the past, records indicated that the ibises were captured for the use of their feathers and artificially introduced into western Japan in the late 1600s and early1700s (Ishikawa Prefectural Museum of History 2010; Kaji 2018). Unfortunately, after the ban on hunting was lifted

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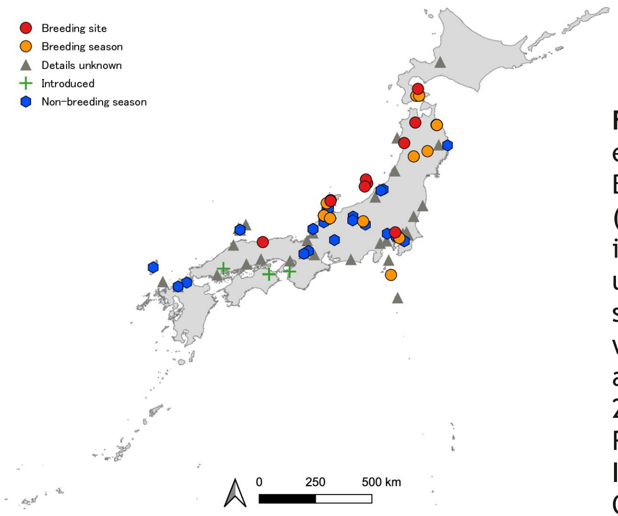

Figure 2. Records of Japanese Crested Ibis before extinction. (Breeding site: records of nests or breeding; Breeding season: records of ibis in the breeding season (from April to June); Non-breeding season: records of ibis in the non-breeding season (from July to March); Details unknown: no detailed information available of the sightings; Introduced: introduced in the Edo period. Data were collected from the following publications: Yamashina and Nakanishi 1983; Takahashi 1995; Birdlife International 2001; Ishikawa Prefectural Museum of History 2010; Kanto Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism 2010; Kaji 2018; Okamura 2019.)

in 1868, the ibis population declined rapidly (Yamashina and Nakanishi 1983). Large numbers of ibis were killed and exported to Europe where their feathers were used to make feather brooms, feather caps, etc. (Uchida 1915; 1933; Forestry Agency 1969). As a result of unsustainable hunting, the ibis was believed to have gone extinct around 1925 (Nakamura 1925). After that, small populations were found surviving on Sado Island and Noto Peninsula, and conservation efforts were initiated in the 1920s (Yamashina and Nakanishi 1983). However, conservation activities were interrupted and halted by the Pacific War and only resumed after the end of the war. Since 1946, feeding, restrictions on human access to nesting forests, construction of completely pesticide-free paddy fields to increase prey species, predator control, and rescue of injured individuals, have been implemented by both local residents and the national government (Niigata Prefectural Board of Education 1974; Niigata Prefecture 2000). In addition, the government bought and nationalized the nesting forest to make it a protected area (Niigata Prefectural Board of Education 1974; Niigata Prefecture 2000). In 1940s, Japan had no laws for the conservation of endangered wildlife. The Ministry of the Environment was established in 1971 whilst the Crested Ibis conservation project was underway. The conservation and propagation project attracted Japanese national attention as being the first modern endangered species conservation activity in Japan. However, the Japanese wild Crested Ibis population declined owing to breeding abandonment due to observation pressure by photographers and TV stations, accidental shots and capture by steel traps, predation by invasive Japanese Martens *Martes melampus*, and agrochemicals (Niigata Prefecture 2000; Okahisa 2022). The population became extinct in the wild when all five birds living on Sado Island were captured for captive breeding in 1981 (Niigata Prefecture 2000). Unfortunately, initial attempts at captive breeding were unsuccessful, and the Japanese population became extinct in 2003 (Nagata and Yamagishi, 2013). The failure to protect the Crested Ibis demonstrated the difficulty of protecting endangered species and the fragility of nature.

Seven Crested Ibis were discovered in China in 1981. One of them was transported to Japan for captive breeding, which was the first exchange between the Japanese and Chinese captive populations (Liu 1981; Tan 1989; Niigata Prefecture 2000). Since 1999, Crested Ibises obtained from China were successfully bred in captivity on Sado Island, with the captive population growing steadily. Once the captive population reached 100, the reintroduction of Crested Ibis to areas within their known distribution range was started on Sado Island in 2008 (Nagata and Yamagishi 2013). To date, 26 releases have resulted in a total of 446 wild-living Crested Ibises.

Status of the reintroduced population

Monitoring of the reintroduced ibis is being performed by 'Team Ibis', which comprises the Ministry of the Environment (Japan), Niigata University, and local volunteers. In addition, an integrated population model and population viability analysis framework with roost count, mark-resight data, and reproductive performance was implemented to assess survival, reproductive success, population size, number of mature individuals, and population projection (Okahisa and Nagata 2022). The combination of close monitoring with the help of citizens and scientists, and a scientific approach that incorporated robust population modelling provided detailed information on the restoration project.

Our models detected that the released ibises had high annual survival rates (mean of 13 years: 0.566) during the first year after release, which improved after one year (0.865). The first successful breeding in the wild occurred in 2012, four years after the birds were released. Wild-hatched individuals had higher survival rates than released individuals (0.757 for juveniles and 0.899 for adults). Furthermore, the reproductive success rate of pairs including wild-hatched individuals was estimated to be higher than that of pairs of released individuals (released–released pair: 0.245; released–wild pair: 0.377; wild-wild pair: 0.350). The estimated reproductive success rate of the Sado Island population was lower than that of the wild populations in China (0.676; Ding 2004). The lower reproductive success rate observed was of concern, however, a high survival rate of successfully hatched ibises was recorded. The population size continued to increase over time through continuous release and breeding in the wild (Figure 3).

Although the population size of the ibis steadily increased, one challenge was to estimate the number of mature individuals, according to the IUCN definition. The IUCN states that "the number of mature individuals is the number of individuals capable of reproduction. Reintroduced individuals must have produced viable offspring before they are counted as mature individuals" (IUCN 2012). However, in an increasing population, the number of mature individuals in the field could not be counted. Thus, the number of mature individuals was estimated using an integrated population model. The results showed that in June 2021, the population reached 457 individuals with a total of 261 mature individuals (Okahisa and Nagata 2022).

The extinction probability for the next five generations was less than 0.01%, even if the release of birds was halted, indicating that the population had achieved self-sustaining viability. Our assessment led to the downgrading of the species from "Extinct in the Wild" to "Endangered" on the Red List of the Ministry of the Environment in January 2019 (Ministry of the Environment 2019). Thus, the conservation of the Crested Ibis, which has been ongoing since the 1920s, can be considered a success. Exceedingly few restoration programmes involving large waterbird population restoration have similarly undertaken robust statistical approaches to monitoring restored populations, and the Crested Ibis project's learning can be of use to other

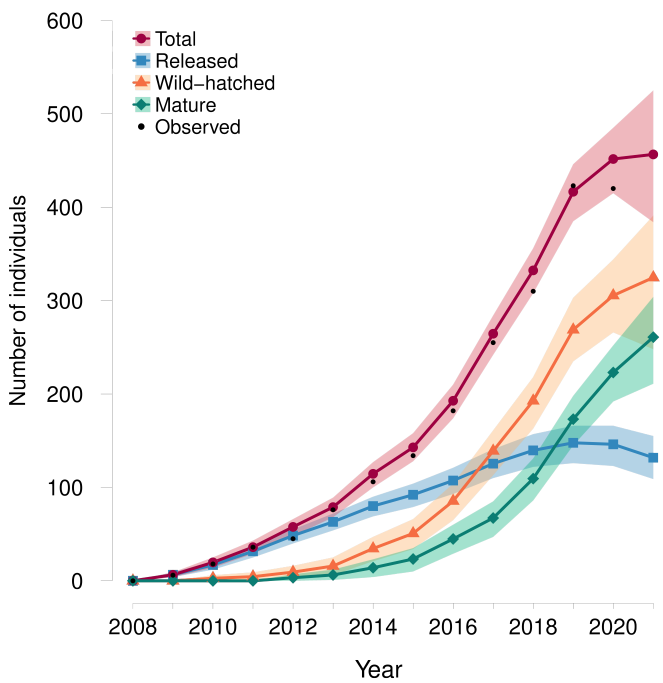

Figure 3. Population size from an integrated population model of the reintroduced Crested Ibis population on Sado Island, measured every June from 2008 to 2021. Posterior means and 95% Bayesian credible intervals are shown (from Okahisa and Nagata 2022).

projects as well.

Key factors of successful Crested Ibis reintroduction

There are two main factors behind the successful reintroduction of Crested Ibis. The first factor was the establishment of successful captive breeding techniques with trained scientists from within Japan and China. Various improvements in captive breeding were performed, especially regarding the establishment of chick-rearing techniques. In captivity, parent ibises exhibit abnormal behavior such as excessive stripping of the eggshell at the time of hatching (Xi *et al*. 2003; Ding 2004). Thus, temporary hand-rearing of chicks was carried out prior to and after hatching, in order to reduce embryo mortality (Okahisa *et al*. 2022). However, hand-rearing chicks for more than two days after hatching impacted their reproduction after release (Figure 4; Okahisa *et al*. 2022). Therefore, an appropriate rearing method was needed to mitigate malimprinting in captivity and to prevent the death of embryos caused by parental egg peeling. Thus, the offspring were hand-reared on the day of hatching and then the hand-reared nestlings were placed in the nests of their biological parents or foster parents so that they could be raised by them. To ensure the parents accepted the hand-reared nestlings, the eggs were replaced with dummy eggs made of clay or unfertilized eggs. After at least two weeks of incubation, the dummy eggs were replaced with nestlings. This resulted in increased fostering rates by the parents and reduced the effects of hand rearing (Okahisa *et al*. 2022). These techniques are currently being implemented and incorporated in seven breeding facilities across the country (Niigata Prefecture and Ministry of the Environment 2018). These techniques are unique to the Crested Ibis and this restoration programme showed the very high value of developing suitable methods for each species independently with careful experimentation rather than imposing methods developed elsewhere on other species.

The second important factor was habitat restoration. Crested Ibis forages in wetlands and as there are few natural wetlands in Japan, rice paddies were utilized as their main foraging environment. On Sado Island, the local inhabitants promoted ibis-friendly agriculture (Usio *et al*. 2014). This initiative spread rapidly from 2008 onwards thanks to the cooperation of local residents, Japan Agricultural Cooperatives, and Sado city based on two aspects: the desire to support the reintroduction of Crested Ibis, and the brand strategy of Sado rice (Watanabe 2012). The initiative involved halving the use of pesticides and chemical fertilizers, installing paddy fishways, creating ditches and biotopes, and flooding paddy fields during the winter (Figure 5). The implementation of the conservation measures increased the number of organisms that ibises fed

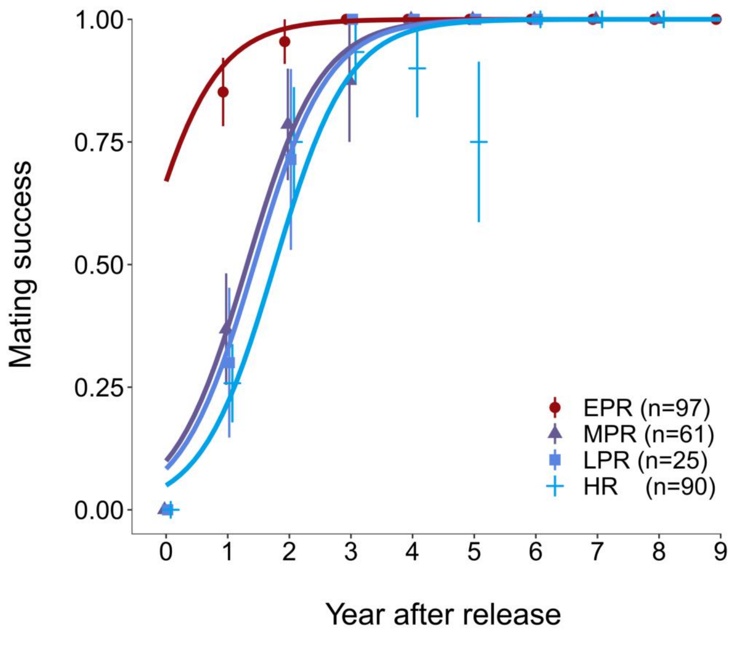

Figure 4. Pair formation rate of male Crested Ibis according to rearing methods. Dots and error bars show the observed mating success and standard error, respectively. (Regression curves were derived from the generalized linear mixed model. EPR: early parent-rearing (parent-rearing began before the chicks' eyes had opened); MPR: middle parent-rearing (parent-rearing began after the chicks' eyes had opened but before they were six days old when the eyesight is fully developed); LPR: late parent-rearing (parent-rearing began when the chicks were seven days old or older); HR: hand-rearing (no regular parent-rearing); from Okahisa *et al*. 2022).

Figure 5. Biodiversity-enhancing practices of the ibis friendly-rice farming (Toki to kurasu sato dukuri rice certification initiative) on the Sado Island. Fishway (top-left, photo by Yuji Okahisa), ibis feeding in the rice fields (top-right, photo by Yuji Okahisa), two ibises feeding in a diversion ditch (bottom-left, photo by Ministry of the Environment, Japan), and ibis benefitting from winter flooding (bottom-right, photo by Ministry of the Environment, Japan).

on, which is a major factor in promoting the high survival rate of Crested Ibis (Usio *et al*. 2014). An advantage for the farmers aiding the conservation was that growing 'Crested Ibis certified rice' could be sold at higher prices and the farmers received subsidies, thereby substantially increasing their income (Kuwabara 2015). These efforts are continuously improving, moving towards a stronger link for living in harmony with nature. The efforts included voluntary initiatives by residents, such as the ban on neonicotinoid pesticides in 2012 and the ban on herbicides in ridges in 2016. The reestablishment of the Crested Ibis through 100 years of continuous conservation programs has become a source of pride in the region (Honda 2015) and is a model that could be implemented globally. Thus, the successful reintroduction of Crested Ibis was driven by the cooperation of residents, researchers, and government officials, who all worked together to ensure successful captive breeding and habitat restoration.

Next steps for our programme

What should be the next steps since the reintroduction of Crested Ibis on Sado Island has been successful? Firstly, the lessons learnt from the history of ibis conservation must be evaluated. According to the IUCN guidelines (IUCN/SSC 2013), the main objectives of reintroductions are to improve the conservation status of the target species and to restore natural ecosystem functions or processes. Restoration of Crested Ibis population in Japan is a clear achievement for the conservation of this species. However, the knowledge on how the restoration of the ibis restored natural ecosystem functions or processes is limited. It is known that the Crested Ibis-specific mite, *Freyanopterolichus nipponiae*, was also conserved in our program (Waki and Shimano 2020). The symbiotic beetle, *Anthracophora rusticola*, was found in nests of the ibis (Kishimoto-Yamada 2019), suggesting that this species is likely to increase in number with an increase in ibises. Other ecosystem functions that the ibis may influence include increasing nutrient dynamics, invertebrate control, and prey for raptors. Further research is needed to understand the significance of ecosystem restoration by the ibis.

In addition, social benefit such as the revitalizing local culture and communities, and the educational effects of using the ibis for environmental learning and awareness-raising should also be evaluated. For example, a questionnaire survey of tourists on Sado Island demonstrated that the success of the Japanese Crested Ibis increased tourism, bringing an annual economic profit of approximately 4.45 billion yen to the region (Okahisa 2022). These economic benefits support local culture and communities. Furthermore, Crested Ibis is a symbol of nature conservation in Japan and stands as a global symbol for the utility of traditional farming such as Japanese rice farming as an important habitat for an endangered species. For this reason, it has featured in numerous textbooks, news items and various other media. This may have led to an increased awareness of nature conservation even among urban residents. The economic and educational effects of the Crested Ibis should also be evaluated from a broader perspective.

Secondly, the knowledge gained from this reintroduction project needs to be shared with other regions and could be applied to other endangered species. The Ministry of the Environment is currently working on a manual describing our efforts to restore the habitat of the ibis, will plans to expand its initiatives to mainland Japan. In the future, ibis-friendly farming may become more active even on the mainland and improve the environment so that Crested Ibises can disperse and settle there. Such an ibis-friendly environment is likely to be suitable for other endangered species, including Oriental White Stork *Ciconia boyciana*. There are other projects evaluating the comprehensive conservation of endangered species. For example, Japanese specialists, including myself, cooperated in the captive breeding and reinforcement program for the White-bellied Heron *Ardea insignis* in the Kingdom of Bhutan. I believe that our experience with the Crested Ibis reintroduction program will be helpful for successful conservation and restoration of many more species globally.

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SHORT COMMUNICATION

Foraging of Saddle-billed Storks *Ephippiorhynchus senegalensis* during the dry season in western Zambia

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Abstract The Saddle-billed Stork *Ephippiorhynchus senegalensis* has been described as a generalist carnivore yet no field study has quantified its diet and foraging ecology. We conducted a brief study in western Zambia on foraging of Saddle-billed Storks using focal animal sampling to address this knowledge gap. From 14 observation periods totaling 255 min, we found storks averaged 8.3 foraging attempts per minute that resulted in 0.3 prey captures per minute. Tactile foraging accounted for 71% of successes and 29% were from visual foraging. Storks primarily captured small (≤10 cm) fish and invertebrates in shallow (~17.5 cm) water. Despite the limitations of our small sample, this study is the first to quantify Saddle-billed Stork foraging. Future work should investigate the influence of seasonality and human activity on foraging ecology in this highly dynamic system..

Keywords Africa, diet, *Ephippiorhynchus senegalensis*, Liuwa Plain, prey, wetland.

Introduction

Diet and foraging behaviour are important life history components that contribute to an understanding of habitat requirements and therefore conservation threats (Depkin et al. 2005; Lantz *et al*. 2011). The Saddle-billed Stork *Ephippiorhynchus senegalensis* (hereafter, Saddlebill) occurs in a variety of wetland and savanna habitats throughout its sub-Saharan African range (Hancock *et al*. 1992). The Saddlebill has been described as a generalist carnivore based on a diversity of prey taken in disparate incidental sightings (e.g., Pienaar 1969; Broadley 1974; Randall 1994; Rockingham-Gill 1997). Although the foraging behaviour and diet of the closely related Black-necked Stork *E. asiaticus* has been studied in India and Australia (Dorfman et al. 2001; Maheswaran and Rahmani 2002), no field research has quantified foraging by Saddlebills. We undertook a brief field study on foraging of Saddlebills in a highly seasonal pan system in western Zambia to describe characteristics of foraging and prey capture.

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Methods

We collected foraging observation data on Saddlebills in Liuwa Plain National Park in Western Province, Zambia, between 20 July and 4 August 2021 (Figure 1). This study area has been described elsewhere (see Gula *et al*. 2021). Briefly, the park is characterised by highly seasonal hydrology in which the plain becomes inundated during the wet season (November–April) and then subsequently dries out during the dry season (May–October). As water recedes during the dry season, a network of ephemeral pans remains where fish, frogs, and aquatic invertebrates become concentrated. Characteristics of pans vary from shallow, sandy depressions that dry rapidly to deep basins with thick mats of floating vegetation that hold water throughout the dry season (pers. obs.; Figure 2a). Approximately

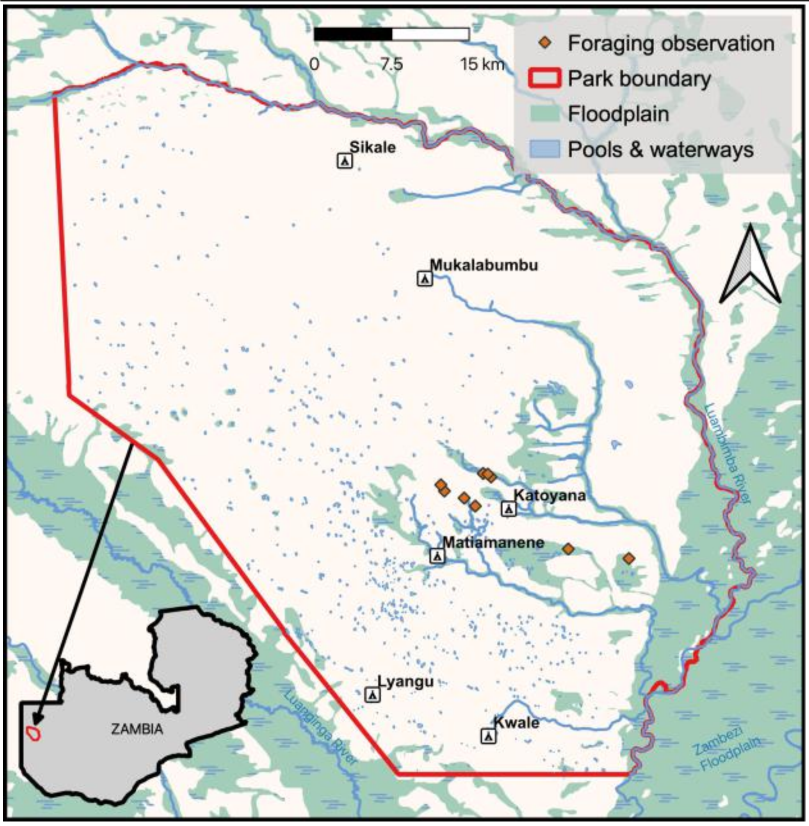

Figure 1. Locations of foraging observation sites in Liuwa Plain National Park, Zambia, in July-August 2021.

10,000 people live within the park and strongly rely on fishing these pans for subsistence, using a variety of fishing techniques depending on the season, including weir construction, gill nets, and active spearing.

Foraging observations took place between 0600 h and 1200 h when Saddlebills are most active at pans. Observations were largely opportunistic because fieldwork was not specifically focused on foraging. Nonetheless, when time allowed we followed an observation protocol similar to Maheswaran and Rahmani (2002) using focal animal sampling for recording foraging. Sexual dimorphism (females with yellow irises) and unique bill patterns (see Gula *et al*. 2021) ensured observations were collected from the focal stork if it was in a pair or a group (e.g., Figure 2c). Observations were made by a consistent observer (JG) using 10 x 42 binoculars while sitting in a vehicle.

A single foraging observation period was between 15 and 30 min, and each was subdivided into 5-min foraging bouts, which allowed for easier data capture in case an observation was interrupted. When a foraging observation period commenced, start time, location, and sex of the focal stork were recorded. Characteristics of the pan were noted but not measured in any way. A digital stopwatch was used to help divide observations into the 5-min bout periods. A hand tally counter was used by the observer to record the number of foraging attempts, which were defined as a chase, a lung, or a bill probe. Both successful and unsuccessful attempts were included in this estimate. Within a bout period, the observer verbally reported details of each foraging success (i.e., prey capture) of the focal stork to the person recording data (AM) to allow for continuous data collection on attempts.

The capture mode was recorded as either visual or tactile upon each foraging success. A visual capture was defined as a success when the stork watched the water without a submerged bill and struck the prey or chased and caught it. A tactile success was when a stork caught prey while probing with its bill in the water. The prey type was recorded as invertebrate, fish, herptile, or unknown. Fish size was visually estimated in relation to the bill–which is about 30 cm in length (Hancock *et al*. 1992)–as either small (≤10 cm), medium (10-20 cm), or large (>20 cm). Water depth where a foraging success occurred was visually estimated as ¼, ½ (pink tibiotarsus joint), ¾, or the full leg length of the stork. We assumed that the average depth at the tibiotarsus joint was 35 cm based on a measurement of a dead captive Saddlebill (D. Ialeggio, Philadelphia Zoo, pers. comm.). The end time of each observation was recorded. Finally, focal individuals were identified using unique bill patterns.

Foraging bouts for an individual observation period were pooled to summarise foraging metrics. Given different lengths of observation periods, raw data on attempts and successes were converted to rates. Foraging rate was estimated as the number of attempts per minute of observation. Similarly, success rate was estimated as the number of successful prey captures per minute of observation. We only report summary statistics due to a limited sample size. Finally, we report anecdotal observations related to foraging.

Results

We recorded foraging observations on 11 unique Saddlebill individuals (4 males, 6 females, 1 unknown subadult) during 14 separate observation

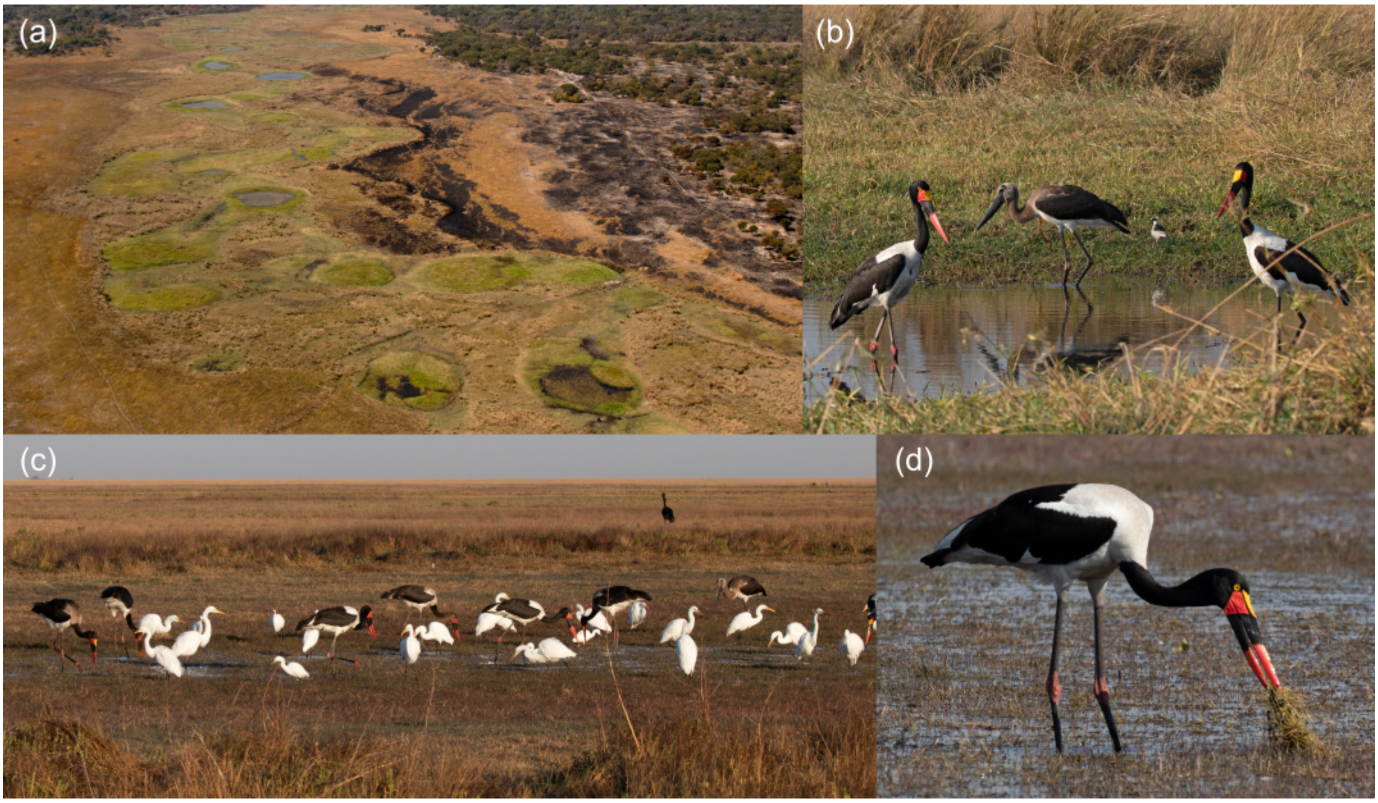

Figure 2. (a) An example of a network of vegetated pools where some Saddle-billed Stork foraging observations were conducted in Liuwa Plain National Park, Zambia. (b) A family group of Saddle-billed Storks foraging in one of the pools along the drying stream in Figure 2a. (c) A concentration of foraging Saddle-billed Storks and egrets at another foraging observation site. (d) Saddle-billed Storks primarily used tactile foraging, which regularly caused them to capture fish in tangles of aquatic vegetation.

periods totaling 255 min of observation. Storks in 13 observations foraged along the margins of shallow pools with submerged vegetation mats and one foraged among floating pond weed. Mean foraging rates of observations of males and females were 6.8 and 10.7 attempts per minute, respectively, for a total mean of 8.3 attempts per minute. Mean success rate for both sexes was 0.3 prey captures per minute. Tactile foraging accounted for 71% of successes and 29% were from visual foraging. Forty-four percent of prey captured were fish, 20% were invertebrates (snails and aquatic beetles), and 36% were unknown prey items (Figure 3). No large (>20 cm) fish were observed being captured, and 89% of captured fish were classified as small (≤10 cm). Ninety percent of successes were in a water depth less than or equal to ~17.5 cm (half the tarsus; e.g., Figure 2d)). No successes were recorded in water deeper than the tibiotarsus joint (35 cm).

On 13 occasions we observed adults from three different pairs feeding their fledged young (estimated to be 2–3 months old). The male fed the young in 77% of these instances. In two cases, the young were foraging (or attempting to) in the same area as their father (e.g., Figure 2b), all the while emitting whistle-like begging calls characteristic of chicks in the nest. Only three of these observations were while collecting foraging data, and in each case the male captured the same number of fish as juveniles he had to feed before going to them. The juveniles were never more than 200 m from the male's foraging site when he went to feed them.

Discussion

Although with the caveat of small sample size, ours is the first study to quantify foraging of the Saddlebill anywhere in its range. Our limited sample did not allow for statistical analyses, but overall we found Saddlebills captured mostly small fish and invertebrates, the latter of which probably accounted for the majority of the unknown prey items given their small size and difficulty in identifying from a distance. Storks also were most successful in shallow water, which probably influenced the size of prey captured. While our findings are only a brief glimpse into Saddlebill foraging ecology, we must acknowledge that they likely are not representative of the species' ecology elsewhere given that Liuwa's aquatic system is unique. Therefore, comparative research is required in other types of wetlands in the species' range.

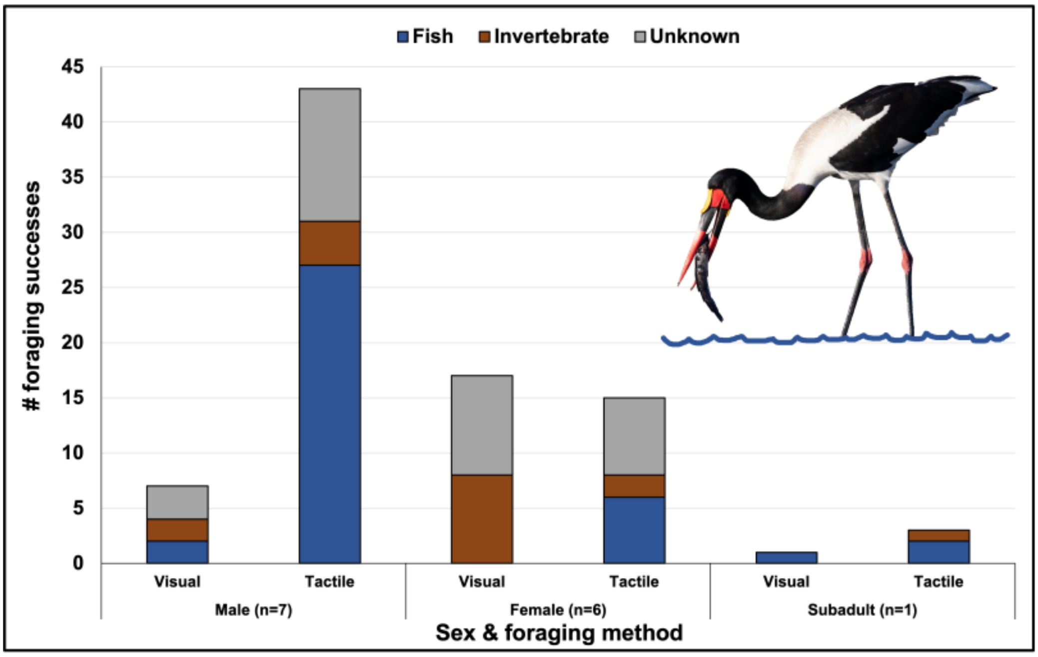

Figure 3. Results from foraging observations on Saddle-billed Storks in Liuwa Plain National Park, Zambia, in July-August 2021. (Photograph by Jonah Gula.)

We found Saddlebills using visual foraging in a greater proportion of observations than a study on the Black-necked Stork, which almost exclusively used tactile foraging (Maheswaran and Rahmani 2002). Whereas foraging success rates in that study did not differ appreciably from our study on Saddlebills, Black-necked Storks overall preferred deeper water (>30 cm) and were least successful in shallow water (15 cm). Like our limited observations, Maheswaran and Rahmani (2002) also observed male Black-necked Storks feeding fledged young more frequently than females did, which resulted in a greater foraging rate for males. Unfortunately, our limited sample size and repeated observations on the same provisioning males did not allow for appropriate comparison between the sexes.

Aquatic invertebrates, especially snails, are an important component of Saddlebill diet in Liuwa, which has not been described previously for the species, although it has been for the Black-necked Stork (Sundar 2011). Our finding that Saddlebills mainly catch fish that are ≤10 cm is similar to what was found with Black-necked Storks in India (Maheswaran and Rahmani 2002, 2008). However, we collected data in the early half of the dry season when large fish may still take refuge in deep parts of pools prior to water recession. A longer field study considering seasonal differences would be beneficial to identify how Saddlebill foraging and prey varies with changing water conditions. We expect that storks would have greater success later in the dry season as water levels recede and fish become more concentrated, which is also similar to what was observed with the Black-necked Stork (Maheswaran and Rahmani 2008). Surprisingly, we did not observe any captures of frogs or snakes, which may also be a result of the seasonal timing of our work.

The prevalence and seasonality of fishing by people who live in the park has the potential to influence Saddlebill foraging behaviour and success and should also be considered in future research. Anecdotally, we have observed that Saddlebills are more sensitive to disturbance by fishermen than other wading birds at pans in Liuwa. Other species, such as Grey Herons *Ardea cinerea* and Great Egrets *A. alba*, may temporarily be displaced from a pan when fishermen arrive to set or check nets, but they readily return, perhaps to take advantage of fish scraps or disturbance that could enhance their foraging success. Saddlebills, on the other hand, are easily spooked by people on foot and may not return to a given pan that day if fishermen remain active there. We also observed Saddlebills foraging around fishing weirs, which could be advantageous by helping corral fish. Therefore, it is possible that seasonality and fishing activity and technique (e.g., greater benefit of weirs in the early dry season when water levels are still high) could have interacting effects on Saddlebill foraging.

Beyond contributing basic life history information, this brief study highlights the need for a more in-depth understanding of Saddlebill foraging ecology. The dynamic hydrology of Liuwa and its large population of fishermen makes the park an ideal setting to investigate multiple environmental and anthropogenic factors that have the potential to influence foraging of Saddlebills and other waterbirds. We recommend a robust a priori approach to such a study that will both enhance our ecological understanding of specific species as well as bolster habitat management in light of increasing human pressure on wetlands.

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SPECIAL SECTION EDITORIAL

Spotlight on the Red-naped Ibis *Pseudibis papillosa*

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Abstract The Red-naped Ibis *Pseudibis papillosa* is an endemic large waterbird of south Asia and is one of the least studied bird species in the world. We collate published information on the habits of this species using available literature and build the most updated account of Red-naped Ibis ecology. Some behaviours such as nesting on artificial structures are recent. Others such as using a diversity of habitat for foraging and nesting singly remain consistent over time. A review of photographs available online also underscored the ability of the species to use a variety of habitats. Submissions to the Special Section added substantially to existing understanding on the species' ecology providing many novel insights into Red-naped Ibis ecology. More wetlands on the landscape attracted more ibises who also showed considerable plasticity in habitat use, flock size and abundance depending on location and rainfall. The first field-based robust estimate of Red-naped Ibis population size has been developed (17,45,340 – 25,41,460). Papers also described several novel behaviours of Red-naped Ibis in varied urban conditions. These include the first record of nectar feeding in ibises, regular colonial nesting in a village, predating on pigeons and their eggs, feeding on food waste in small towns, and fishing. Several important ecological aspects remain unstudied, but the Red-naped Ibis is beginning not to be one of the least-studied waterbirds of the world.

Keywords Agricultural habitats, breeding biology, habitat use, literature review, online photographs, *Pseudibis papillosa*, Red-naped Ibis.

Introduction

Majority of the extant ibis species of the world occur in Africa and Asia, but most of these remain poorly studied with their ecological needs and habits described largely by natural history anecdotes (Hancock *et al*. 1992; Ali and Ripley 2007). The Red-naped Ibis *Pseudibis papillosa* is one such ibis species that is endemic to South Asia making it an automatic focus of the IUCN SSC Stork Ibis and Spoonbill Specialist Group (SIS-SG) that aims to improve the knowledge base for all SIS species in the world. The inclusion of the attractive species in the logo of the SIS-SG by one of us (KSGS) was deliberate to help draw attention to this very poorly understood endemic species. The Red-naped Ibis has a striking appearance and is easily observed in open landscapes (Figure 1). In this Special Section Editorial, we lay out what is known about the species in published literature (until 2020), compile information on habitat use using freely available photographs online, and briefly summarize the papers published in this Special Section. We listed publications using the Latin name and common names of the species as keywords on the site scholar.google.com, and also used the extensive referencing provided along with the species account on Wikipedia (https://en.wikipedia.org/wiki/Red-naped_ibis). With this review, we provide the most updated account of the habits and requirements of the Red-naped Ibis.

Article history

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Figure 1. Adult Red-naped Ibis *Pseudibis papillosa* using different habitats across the Indian subcontinent. (Top left: stubble field; top right: flooded grassland; middle left: freshly ploughed agriculture field; middle right: garbage dump with dead animals; bottom: flock in newly-harvested field. Photographs by K. S. Gopi Sundar.)

Existing research

Taxonomy and common names

The Red-naped Ibis has enjoyed a relatively stable taxonomic position since its description by Temminck in 1824 as a species of the genera Ibis. Early descriptions based on morphology and behaviour saw some changes such as the shifting of the species to the genera Inocotis by Richenback, and eventually to Pseudibis by Hodson (Oberholser 1922). Using nuclear and mitochondrial DNA, the species fits phylogenetically within the subfamily Threskiornithinae alongside several other ibis genera (Ramirez *et al*. 2013). The Red-naped Ibis was thought to be one of two subspecies along with the White-shouldered Ibis *Pseudibis davidsoni* due to morphological similarities (Holyoak 1970) but was subsequently recognized as a separate species.

The common English name of the species has seen many more changes. British hunters referred to the species variously as “king ibis”, “black curlew” and “king curlew”, though more formal literature referred to the species almost uniformly as “Black Ibis” or “Indian Ibis” or “Indian Black Ibis” for a long time (Blandford 1898, Baker 1929, Whistler 1949, Hancock *et al*. 1992, Ali and Ripley 2007). Red-naped Ibis ate a large number of grasshoppers and crickets in indigo fields earning them the moniker “planter’s friend” (Inglis 1903). The change of the common name to “Red-naped Ibis” does not seem essential or necessary. No other species of ibis was being confused with “Black

Ibis" despite the presence of other dark-coloured ibis species such as the Glossy Ibis *Plegadis falcinellus*. The other widely used name "Indian Ibis" was certainly a misnomer since the species occurs in other South Asian countries. Red-naped Ibis is easily recognized by people and has many names across South Asia including *Anril* (Tamil), *Buza* (Hindi), *Kala Buza* (Hindi), *Kālakantak* (Sanskrit), *Karánkal* (Telugu), and *Nella kankanum* (Telugu; (Blandford 1898, Inglis 1903, Dave 1985, Krishnan 1986). A more comprehensive list is needed and will require both field work and a more thorough literature review.

Ecology

The first detailed ecological assessment on the species was a compilation of observations of various people from across the Indian subcontinent on its breeding habits (Hume 1890). The summary noted that the nesting period of the species varied with location, pairs reused nests in subsequent years, some pairs shared nests with other birds especially raptors, ibises nested only on trees, nests were normally single with only one record of a colony of 4-5 nests together, and that the clutch size was 3-4 (Hume 1890). Information from Hume (1890) has been repeated in subsequent treatises of birds of the region. There have been a few recent observations of Red-naped Ibis nesting on power lines and other artificial structures (Ali *et al*. 2013, Sangha 2013), and on trees in villages and towns (Hancock *et al*. 1992; Ali and Ripley 2007). More detailed work on breeding ecology has shown Red-naped Ibis to be relatively cosmopolitan in locating its nest. Red-naped Ibis always nested singly either on *Eucalyptus* in agricultural areas (Rajesh and Kumar 2019), or on trees (primarily *Azadirachta indica* and *Ficus religiosa*) in and around a small city (Soni *et al*. 2011), or beside village ponds in arid areas (Nair and Vyas 2003). The habit of Red-naped Ibises nesting on artificial structures is relatively recent but most nests observed have been located on trees. An unusual instance of nepotism (helper birds assisting breeding adults to raise chicks) was observed during a drought, leading to improved breeding success (Soni *et al*. 2008).

Research interest in the Red-naped Ibis' ecology seems to have peaked between 1980 and 1990 when several graduate dissertations and theses were published on the habits of the species. We were unable to access these dissertations and theses, and the work does not appear to be converted into papers in peer-reviewed journals. Nevertheless, going by the titles, the focus of the studies started out with behaviour, expanding into multiple aspects of ecology of Red-naped Ibis including foraging, feeding, and nesting biology (Salimkumar 1982, Sheshukumar 1984, Lathigara 1989, Vyas 1996, Chavda 1997). It would be of great value to peruse these studies in detail to understand the ecology of the species in an area (Saurashtra, Rajkot, India) from where additional studies have not emerged since. Another very detailed study that followed was conducted in Rajasthan with chapters subsequently published as separate papers that we have cited in this review (Soni 2008).

Diet of the Red-naped Ibis was compiled fairly early as including crustaceans (prawns, crabs), insects (beetles, crickets, grasshoppers), scorpions, and carrion (Jerdon 1864). The ibis' behaviour of eating large numbers of crickets in indigo fields earned them the moniker "planter's friend" (Inglis 1903). Stomach contents of two adults that were shot revealed several frogs and several smaller insects that were likely part of the frogs' diet (Mason 1911). More recent studies have largely substantiated early observations of the species' diet and foraging behaviour. Studies noted that Red-naped Ibis fed on several arthropod pests of agricultural crops, frequently foraging in flocks, leading to a suggestion that they protect crops in arid areas (Soni and Sharma 2007, Rajesh and Kumar 2017). Adult birds have been observed feeding on carrion (Khan 2015). Foraging was observed in a wide range of habitats throughout the year in and around a small city of Rajasthan, including a wastewater site, a garbage dumping site, agriculture fields and sand dunes (Soni *et al*. 2010). Like other ibises, the Red-naped Ibises have been observed preying on frogs that they removed from crab holes (Johnson 2003).

Several additional aspects of Red-naped Ibis have been documented in publications. There is a single description of nocturnal calling (Shekhawat and Bhatnagar 2015). DDT levels have been recorded in the blood of Red-naped Ibis (19 ng/ mL; Dhananjayan and Muralidharan 2010). Growth rates of different body parts have been studied using chicks taken from the wild, and showed that toes, legs and tarsus had the fastest growth (Soni *et al*. 2009).

Several studies have recorded the presence of multiple parasitic taxa on Red-naped Ibis suggesting that focused work is needed to understand host-parasite relationships of the species. Two new species of trematodes, *Strigea pseudibis* and *Diplostomum ardeiformium*, have been described from captive-held Red-naped Ibis that died in the Berlin Zoo (Odening 1962). A new nematode species, *Belanisakis ibidis*, was discovered in the small intestine of Red-naped Ibis (Inglis 1954). The bird lice *Ibdidoecus dennelli* has been recorded on the feathers of Red-naped Ibis (Tandan 1958).

Summarized species accounts

Many publications, usually books, include species accounts that are meant to summarize known information. Many of these accounts detail ecological details of all bird species in a region and usually have brief accounts without properly referencing the provenance of the information provided. Species accounts also accompany bird identification guides whose focus is not ecology. We did not review such species accounts.

The most useful summaries were detailed species treatises that either covered all the birds of a region (Ali and Ripley 2007) or focused on specific taxonomic groups (Hancock *et al*. 1992). These summaries synthesized both published literature and included observations from the field providing the most thoughtful accounts that were very informative especially for poorly studied species. Ali and Ripley (2007) provided one of the earliest thorough literature reviews while also including novel information such as morphometric measurements of both eggs and adults of Red-naped Ibis. Authors agreed on past descriptions of Red-naped Ibis' habitat requirements, feeding habits, and breeding ecology. Hancock *et al*. (1992) incorporated the information in Ali and Ripley (2007), added new published literature and included several personal observations from authors' field trips to India. Their summary provided novel descriptions of several behaviours including courtship, new locations of small breeding colonies and high nest site fidelity despite harassment by crows. Hancock *et al*. (1992) also noted the species' ability to use a variety of habitats for foraging, andd nesting close to human habitation.

Red-naped Ibis ecology and conservation status have also been covered in two widely used global-scale publications. The first was the account in the "Birds of the World" series of books. (del Hoyo *et al*. 1992). Perhaps due to the scale of the effort, species accounts are very brief, and therefore lack novel information and do not include a thorough literature review. The account, however, did provides a list of counts at different wetlands based on volunteer enterprises which it uses to provide the first status assessments for the species. Authors state that the species may be severely affected due to wetland conversion and agricultural expansion. This statement is not substantiated and is in contrast to the description of the habits of the species which shows the ability of the species to use upland and other non-wetland habitats. The same information is repeated in the "The Cornell Lab of Ornithology: Birds of the World" accounts that accompanies the portal www.ebird.org. The second global-scale species account is the Red List species status assessment (BirdLife International 2016). The literature review in the status assessment is exceedingly brief and an ecological description is absent. The Appendix of the status account does very poorly to reflect the known ecology of the species at the time of publication of the account, but accurately reflects the absence of any usable population related information. The account nonetheless provides a confident status for the species as "Least Concern", while also indicating the population trend to be declining. Confident assertions of the negative impact of agriculture, designation of species status and descriptions of population trends despite absence of information are unfortunately common for many SIS species leading to incorrect understanding of many species (Gula *et al*. 2023). Summaries describing Red-naped Ibis in ecology and status have greatly declined in quality and reliability in global-scale publications .

Habitat use as informed by photographs available online

We summarized habitat use by Red-naped Ibis using freely available photographs of the species online, that also had information on the broad location (state, country) where the photograph was taken (see Sundar *et al*. 2019 and Sundar 2020 for methods). Photographs were primarily sourced from ebird.org (N = 2,617), Facebook (N = 871), Oriental Images (N = 222), Flickr (N = 77) and Wikicommons (N = 64). At the scale of countries, Red-naped Ibis records were available largely from India. However, the available records for other countries were adequate to see that the species used wetlands relatively sparsely in all countries across South Asia (Figure 2). Within India, at the scale of the state, Red-naped Ibis used wetlands rarely in all states instead using agriculture, forest, and open areas much more (Figure 2). These findings using photographs available online broadly match existing description of the species as being a species that mostly forages in upland dry areas with sparse use of wetlands, and these habits do not appear to have changed for over a century (Jerdon 1864; Blandford 1890; Inglis 1903, 1954; Baker 1929; Whistler 1949; Hancock *et al*. 1992; Ali and Ripley 2007).

Papers in the Special Section

We started soliciting for manuscripts to be considered for the Special Section in early 2022, but these trickled in through mid-2023 resulting in the delayed production of this issue of *SIS Conservation*. Collectively, the papers provide several unique insights into Red-naped Ibis ecology and conservation requirements.

Four nuanced contributions provided information based on relatively large-scale surveys across different agricultural landscapes in Nepal and India. Katuwal and Quan (2022) continued their impressive and important contributions from the farmlands of lowland Nepal. They recorded ibises to be widespread, detailed novel aspects such as flock size variations in different seasons, and preliminary insights into the breeding ecology of the species in Nepal. Ameta *et al*. (2022) use an *a-priori* field design to ask if Red-naped Ibises were indeed "waterbirds", and whether the species uses habitats differently when using landscapes that have different dominant land uses (agriculture and wetlands) in a semi-arid landscape of Rajasthan, India. They showed ibises responding positively to

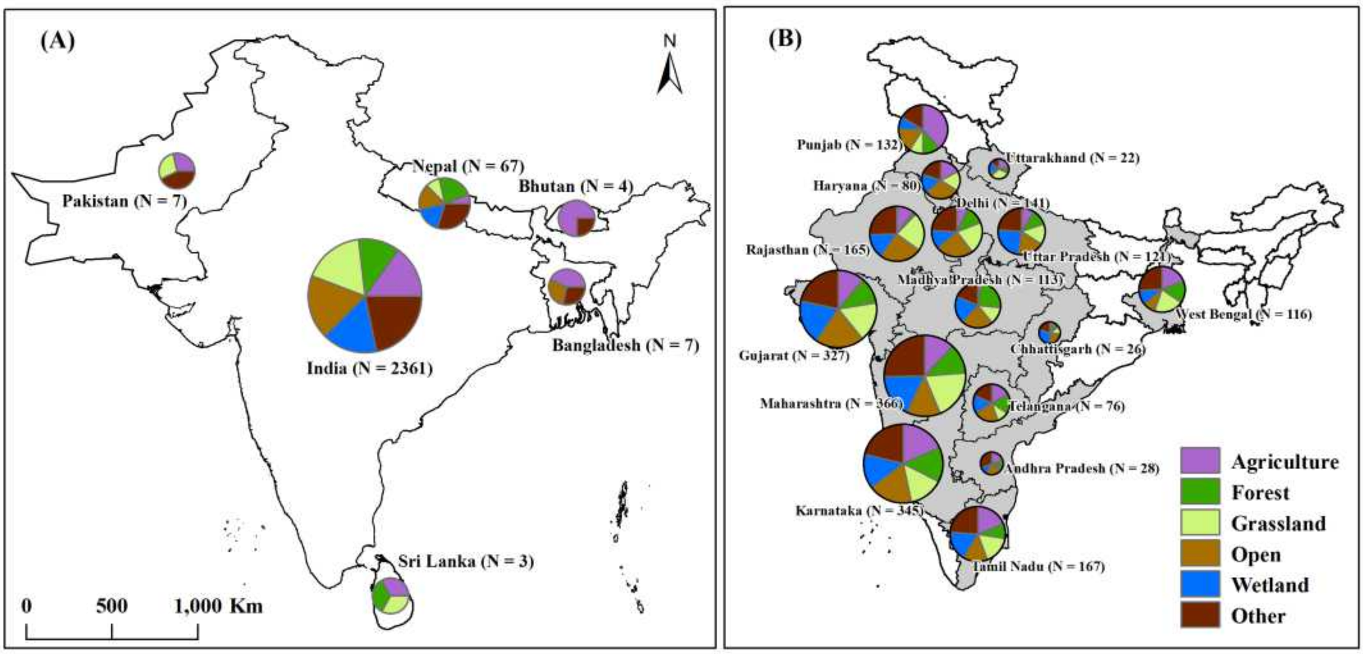

Figure 1. Red-naped Ibis habitat use at the scale of country in South Asian countries (A) and Indian states (B) as determined using photographs available online. (Maps by Swati Kittur.)

landscape-scale availability of wetlands being more numerous in areas with more wetlands and foraged preferentially (used more than availability) in wetland habitats, though the vast majority of observations were in fallow lands and crop fields. They also show that ibises varied greatly in all aspects of ecology such as flock size, habitat use and abundance in different seasons irrespective of the dominant land use. Asawra *et al*. (2022) also focused on habitat use, flock size and abundance, but asked if these aspects of Red-naped Ibis varied when different amounts of wetlands occurred on another semi-arid landscape of southern Rajasthan. They demonstrated Red-naped Ibis showing scale-dependent use of the landscape in the driest season when many more ibises used areas with more wetlands. Other aspects (habitat use, flock size) did not vary much seasonally but ibises in Dungarpur district mostly used wetlands for foraging. Kittur and Sundar (2022) analysed a gigantic data set collected over 2014-2021 across nine districts in Nepal and India. They demonstrated that Red-naped Ibis ecology (habitat use, abundance) varied seasonally and locally, but density was highest during the winter in all the areas. Density was also negatively correlated with rainfall. They extrapolated average seasonal density to the known distribution range of the Red-naped Ibis and obtained the first field-based population estimate for the species at ~20,81,860 (95% CI: 17,45,340 – 25,41,260). This estimate is coarse but varied considerably from the existing guesstimate of ~10,000. This work underscored the high variation that local populations of Red-naped Ibis showcase, but the reasons for these fluctuations are not yet understood. These four papers provide the first landscape-scale understanding of how some aspects of Red-naped Ibis are similar across locations but highlight location-specific differences that are caused by local conditions, especially availability and distribution of wetlands on the landscape.

The other papers in the Special Section varied in their focus and provided several unique insights into Red-naped Ibis ecology. Tere (2022) provided the only existing nuanced account of Red-naped Ibis behaviour when they breed colonially. Observations over two years showed two colonies to be increasing despite being located on trees inside a village. Red-naped Ibis nesting behaviour and breeding success were similar to the habits of comparable large waterbird species nesting in rural areas of south Asia. The rarity of colonial breeding of Red-naped Ibis is inexplicable, though may increase as more birds fledge from these two colonies. Juvvadi (2022) surveyed a rural landscape in Telangana state from where ecological research on birds has been sparse. He provided insights into the perching, roosting, and nesting of the species on transmission pylons and communication towers in an area with few trees highlighting the ability of Red-naped Ibis to use such artificial structures when trees are sparse.

Charan *et al*. (2022) used *ad-hoc* observations over two years to build a picture of the natural history of Red-naped Ibis in two small towns of Rajasthan, Dhariawad and Sikar. The paper uncovered several erstwhile unknown habits of the ibis such as hunting adults Rock Pigeons *Columba livia* and predating on their eggs, feeding on bone marrow of dead cattle, feeding on dead rats and left over food inside a town, scavenging on roadkill, and fishing. In both towns, all observed nests of the Red-naped Ibis were on artificial structures such as cell-phone towers, electricity pillion towers and light poles despite the presence of many large trees in the towns. These observations show that the Red-naped Ibis is capable of becoming fully urban and developing novel feeding habits when human persecution is absent. Finally, Sinha (2022) described the first known instance of ibis feeding on nectar beside a busy road in a mega-city, Delhi. Both juvenile and adult birds were observed feeding on nectar suggesting that this behaviour is likely learnt and is likely to become more common. This observation further underscored the behavioural plasticity of urban-dwelling Red-naped Ibis.

Epilogue

The literature review in this editorial and the papers included in the Special Section have helped highlight four main aspects of Red-naped Ibis ecology. First, the species shows major behavioural plasticity that aids in exploiting resources from unnatural conditions in a variety of urban spaces, and on agricultural landscapes. Second, landscape-scale studies showed how wetlands on the landscape attracted the species, though most ibises prefered to forage in dry habitats such as farmlands. Third, the species displayed strong seasonal and locational variations in abundance due to rainfall and wetland availability suggesting that monitoring its population will be challenging. Undertaking population size estimations and long-term trends that based on counts made only at wetlands should be avoided. Based on the newly estimated population size, increasing observations of the species in urban areas and farmed landscapes, and the plasticity in habits, the Red-naped Ibis' global status appears secure. Finally, some habits of Red-naped Ibis such as the use of diverse habitats for foraging, breeding singly and rarely in colonies, and using human-modified areas appear not to have changed in over a century. Increased focus on urban dwelling Red-naped Ibis have helped discover several novel behaviours.

A large proportion of observations and studies on Red-naped Ibis are from arid and semi-arid regions of India, primarily from Gujarat and Rajasthan states, though some multi-year investigations in wetter areas such as the floodplains of Uttar Pradesh and Nepal are available. Studies covering the rest of the range of the species in south Asia, especially from wetter areas, will be useful to better understand the species' habits. Several ecological aspects such as population genetics, movement ecology, more focused studies on parasites, and survival have not yet been covered by studies, and are needed. Behavioural studies that focus on foraging efficiency, diet of the species in different locations, inter- and intra-species interactions, and mechanisms that allow Red-naped Ibis to live sympatrically with other ibis and waterbird species are also needed. The species appears to be recognized by people across south Asia suggesting that studies based in sociology and anthropology will be greatly rewarding.

We are now armed with a lot of new information that are helping to show the species to be among the most abundant waterbirds in the Indian subcontinent. With the publication of this issue of *SIS Conservation*, the Red-naped Ibis begins to leap out of the list of the least studied waterbirds of the world.

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We are grateful to all the authors who responded enthusiastically to our calls to consider submitting their observation for the Special Section on Red-naped Ibis. We also thank the reviewers who provide rapid yet sound feedback that greatly improved submitted manuscripts. The careful documentation of freely available online photographs was a gigantic chore managed by NT, and we thank the following people for collating this information: Nandini Pathak, Poornima Madan, Alma Ali and Gyanshikha Hazarika. We remain in awe of the photographers who continually and generously contribute their creations for free use in scientific and other outputs. We gratefully acknowledge the various editors on Wikipedia for creating the most detailed account of the Red-naped Ibis that is continually updated. Wikipedia pages are not citable for various reasons, but some like the page on Red-naped Ibis provided freely-viewable information of high quality. KSGS thanks Sai Anurag Nandagiri for developing the stunning artwork that adorns the front cover of this issue. Anurag deftly used photographs to create an image that evokes an artist's field sketch book, and generously donated the image for use by SIS Conservation. We thank S. Kittur for creating the maps used in this editorial. An earlier draft benefited from the comments and suggestions made by L. S. Cano-Alonso and S. Kittur.

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RESEARCH ARTICLE

Status of the Red-naped Ibis *Pseudibis papillosa* in agricultural landscapes of Nepal

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Abstract The Red-naped Ibis *Pseudibis papillosa* is one of the least-studied large South Asian wading birds. The species is categorized as a fairly common species in Nepal but there has not been a careful assessment to estimate its population, understand population trends, the species' habitat requirements and conservation status in Nepal. In this study, we provide novel empirical information on Red-naped Ibis use of lowland Nepal's agricultural landscapes with an intent to develop a preliminary assessment of its status. In 2018, we established 100 transects of 500-m length each in agricultural landscapes of four districts and these were monitored seasonally until 2022 for a total of 875 transects. Red-naped Ibis were sighted in 137 transects with more sightings in Kapilvastu (34% of transects) and during the monsoon (36%), while the least sightings were in the Sarlahi district (12%) and during the summer (30%). Flock sizes ranged from 1 to 17. In 2022, 14 nests were discovered in eight districts, the majority of which were outside protected areas (57%) with Red-naped Ibises mostly nesting in forests (36%). Most nests were located on *Bombax ceiba* (50%) and *Shorea robusta* (29%), and the mean height of nesting trees was 20.28 meters. Our research suggests that Red-naped Ibis are widespread and resident, but not abundant on Nepal's agricultural lands.

Keywords *Bombax ceiba*, habitat loss, nesting site, seasonal variation, *Shorea robusta*, waterbird.

Introduction

Agricultural landscapes provide feeding, roosting, and nesting habitat for diverse bird communities throughout the year (Sundar and Subramanya 2010; Muñoz-Sáez *et al*. 2017; Li *et al*. 2020). However, contemporary intensified agricultural practices, rapid land-use changes, agrochemicals, hunting, and lack of nesting trees could be placing farmland birds in jeopardy (Mitra *et al*. 2011; Stanton *et al*. 2018; Katuwal *et al*. 2021). South Asian agricultural landscapes have retained considerable bird diversity (Sundar and Kittur 2012; Katuwal *et al*. 2022a), with conducive conditions for foraging and breeding (Sundar *et al*. 2016; Ghimire *et al*. 2021). These agricultural landscapes, especially those that support traditional agroforestry, have the largest known breeding populations of several large waterbirds including storks and cranes (Koju *et al*. 2019; Kittur and Sundar 2021; Katuwal *et al*. 2022b). Despite growing work on how large waterbirds use South Asian agricultural areas, the ability of several species to survive on these landscapes is still poorly known, especially resident ibis species.

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Red-naped Ibis *Pseudibis papillosa* (Figure 1) is endemic to South Asia, breeding primarily in India, Nepal, and Pakistan, and perhaps in Bangladesh and Myanmar, with a non-breeding population probably present in China (Matheu *et al*. 2020;

Figure 1. A flock of Red-naped Ibis in paddy field in Sarlahi district, Nepal.

BirdLife International 2022). It is found both within and outside of protected areas, primarily in drier environments such as open fields and dry cultivated land, as well as near urban and village garbage sites (Soni *et al*. 2010a; Inskipp *et al*. 2016). In addition to inhabiting riverbanks, grasslands, and sometimes poultry farms, this species mostly consumes frogs, snakes, small fish, earthworms, many insects and scavenges on cattle carcasses (Soni *et al*. 2010a; Rajesh and Kumar 2017; BirdLife International 2022). The flock size ranges largely from 1 to 10 with larger flocks of about 30 being uncommon (Inskipp *et al*. 2016; Rajesh and Kumar 2017; Matheu *et al*. 2020). The breeding period starts mostly from March to October (Matheu *et al*. 2020). The colony size is often solitary or forms sporadic tiny colonies mostly in large trees such as *Bombax ceiba*, *Ficus religiosa* and sometimes on man-made structures like electricity pylons, and communication towers (Sangha 2013; Inskipp *et al*. 2016; Matheu *et al*. 2020). The vast majority of this information is anecdotal, and this species of ibis is among the least studied large waterbirds in the world.

The Red-naped Ibis is the most abundant and widespread of the three ibis species present in lowland Nepal (elevation mostly below 300 m; Inskipp *et al*. 2016). It has been documented from the Suklaphanta National Park in the west to the Mai valley in the east (Inskipp *et al*. 2016). It is classified as Least Concern and considered to be "fairly common" in Nepal (Inskipp *et al*. 2016). However, despite these vague descriptions, and an absence of field data that could be used to assess its population, the species is believed to be diminishing, and the factors that are listed for these declines are habitat loss and degradation, illegal hunting, and agrochemicals (Inskipp *et al*. 2016; BirdLife International 2022). No systematic field assessment has been conducted to examine the habitat needs and conservation status of the Red-naped Ibis and it is likely that available information, including suggestions of population declines, are not accurate. Therefore, we set out to understand the seasonal use of agricultural landscapes by Red-naped Ibis in lowland Nepal, which is the northern-most portion of its distribution range. We provide novel field information based on a systematic multi-year, multi-site survey, thereby developing the first evidence-based information that can be used to assess the status and habitat requirements of the species in Nepal.

Study area

We conducted this research in the lowlands of Nepal, where the terrain is flat and largely suited to agriculture (< 300 m elevation; Figure 2). Rice *Oryza sativa* was grown throughout this region during the monsoon (June to September), but crops vary seasonally with farmers growing Maize *Zea mays* during the summer (March to

May) and growing multiple crops (Wheat *Triticum aestivum*, various vegetables) during winter (November to February) months (Katuwal *et al*. 2022a). Sugarcane *Saccharum officinarum* is planted in some locations, whereas some people leave their land fallow after rice or winter crop harvest until the monsoon. Seven protected areas exist in lowland Nepal, however, our study covered only three of them (Bardia National Park, Chitwan National Park, Koshi Tappu Wildlife Reserve, and their buffer zones; Figure 2). For management purposes, these protected areas are divided into the core region and the buffer zone, the latter zone consisting of forests, human settlements, and agricultural fields.

Methods

We selected Sunsari, Sarlahi, Chitwan, and Kapilvastu districts of Nepal for the Farmland Bird Survey Program (FBSPN; Figure 2). FBSPN was initiated in 2018 with 116 transects (farmland = 100, forest = 8 and river = 8). To survey farmland birds, we selected 28 - 30 non-overlapping squares in each district from a 2x2 km grid that was overlaid over the entire study area (see Katuwal *et al*. 2022a). For bird surveys, we used a 500-meter transect inside each grid. Each transect was surveyed during the summer, the monsoon, and the winter. Due to national rules that prevented travel to combat the spread of COVID-19, we did not conduct surveys in 2020, and resumed monitoring from December 2021 for a total of 875 transects. However, beginning in 2021, we surveyed only farm transects because forest and river transects were few and our objectives of establishing differences in bird community composition between farmland, forest, and river habitats had been met (see Katuwal *et al*. 2022a). In this study, we exclusively utilized data from 100 farmland transects. Between April 2018 and August 2022, each transect was visited approximately 12 times. However, we merged two trips done during the same season in 2018 (see Katuwal *et al*. 2022a), resulting in a total of three visits each season (summer, monsoon, and winter).

In addition, we opportunistically documented nests of this species from March to September 2022 (Figure 2). The first nest was observed in March, but we are unable to definitively state whether the nesting season commenced then since the species is known to start nesting much earlier (Matheu *et al*. 2020). We recorded the GPS coordinates of the nesting tree as well as the tree's species name and height. We could not monitor nests with repeated visits and therefore do not provide any information related to breeding success and related aspects.

Results

We recorded Red-naped Ibis in 62 (Kapilvastu = 19, Sunsari = 17, Chitwan = 16, and Sarlahi = 10) of 100 farmland transects (Figure 2). However, we observed Red-naped Ibis only 137 times out of 875 total transects conducted between 2018 and 2022. The highest number of sightings was recorded in Kapilvastu (*N* = 47, 34 % of transects with Red-

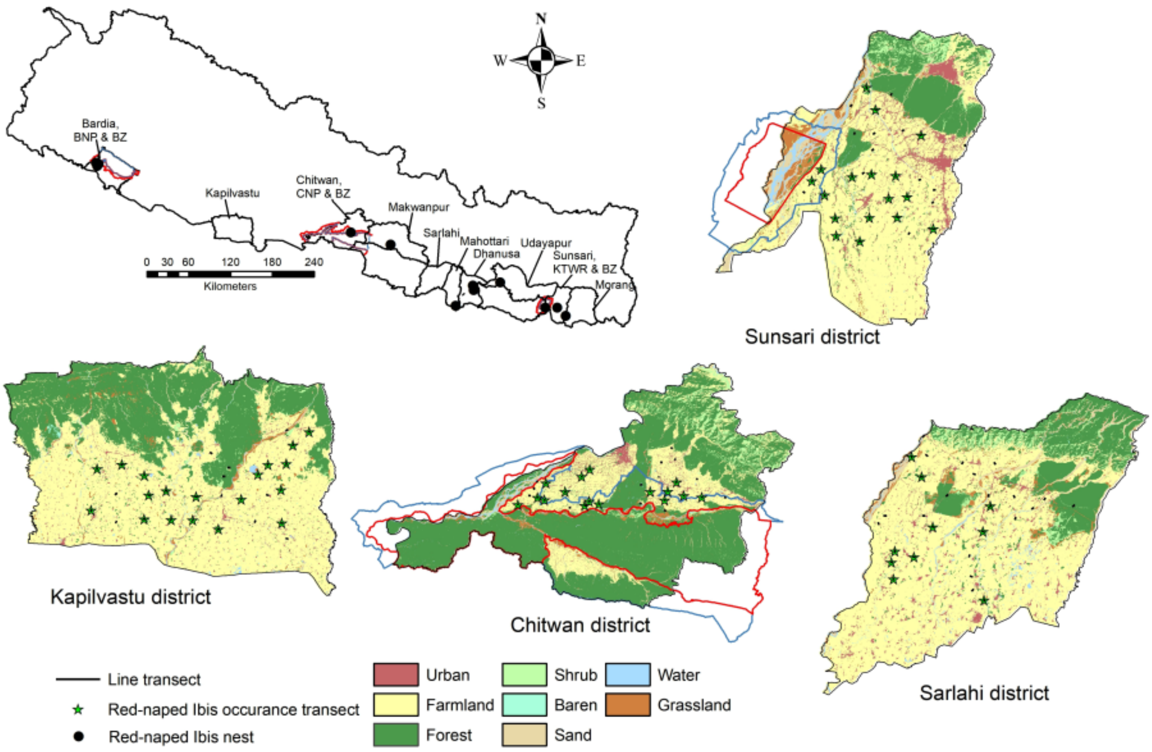

Figure 2. Red-naped Ibis nesting and transect occurrences in Nepal. In 2018, we established 116 transects (Farmland = 100, River = 8, and Forest = 8) in four districts (Kapilvastu, Chitwan, Sarlahi, and Sunsari) for the Farmland Bird Survey Program from 2018 to 2022. We only used farmland transects for this study. Eight land use classes generated from satellite images are also displayed. (BNP: Bardia National Park, CNP: Chitwan National Park, KTWR: Koshi Tappu Wildlife Reserve, and BZ: Buffer Zones.)

naped Ibis), followed by Chitwan ($N = 41$, 30 %), Sunsari ($N = 33$, 24 %), and Sarlahi ($N = 16$, 12 %). Seasonally, Red-naped Ibis were seen in slightly more transects during the monsoon ($N = 49$, 36 %) compared to winter ($N = 47$, 34 %), and summer ($N = 41$, 30 %). Red-naped Ibis flock size within transect ranged from 1 to 17 ibises; 6 % ($N = 8$) of flock size was ≥ 10, 14 % ($N = 19$) of flock size was from 5 to 9, while the majority of flocks ($N = 110$, 80 %) were with 1 to 4 ibises.

In 2022, we discovered 14 nests across eight districts (Bardia = 4, Chitwan = 1, Makwanpur = 2, Mahottari = 1, Dhanusa =2, Udayapur = 1, Sunsari =2, and Morang =1; Figure 2). We discovered more nests outside protected areas ($N = 8$, 57 %) with the rest of the nests located in both core and buffer areas of protected areas (Figure 2). The majority of nests were constructed on trees in forests ($N = 5$, 36%), followed by farmlands ($N = 4$, 29 %), human habitations ($N = 4$, 29 %), and one in shrublands/ grasslands. Most nests were on *Bombax ceiba* ($N = 7$, 50 %) and *Shorea robusta* ($N = 4$, 29 %), while *Terminalia* spp., *Breonia chinensis*, and *Haldina cordifolia* were less frequently used (each with one nest). The mean (± SD) height of nesting trees was 20.28 (± 7.17) m.

Discussion

We discovered Red-naped Ibis to be uncommon on lowland Nepal's agricultural landscapes in contrast to existing literature that suggests that the species is "fairly common" (Inskipp *et al*. 2016). Our surveys were conducted on relatively wet agricultural fields, and it is likely that more Red-naped Ibis occur in areas that have other open fields, as observed in semi-arid parts of western India (Ameta *et al*. 2022; Asawra *et al*. 2022). It is also possible that Red-naped Ibis use drier habitats such as riverbanks and urbanized settings such as dumping grounds, that are frequently cited as a habitat of this species, and in western Nepal, which we did not survey.

In Kapilvastu, Chitwan, and Sunsari districts, we observed Red-naped Ibis in relatively more transects. This could be because these regions have extensive agricultural lands that are used to grow paddy during the monsoon season and farmers typically leave their land fallow after harvesting rice, creating habitats that may be favorable for these birds. In Sarlahi, in contrast, dominant annual crops were sugarcane and maize, and these crops might offer the species less food and foraging grounds. According to Inskipp *et al*. (2016), the species' entire population in Nepal is still unknown, and our study is insufficient to estimate the species' total population in the country. To ascertain ibis' status across Nepal, future investigations require to collect standard metrics such as density to enable estimation of population sizes, and additional related information such as habitat preference.

The seasonal differences in number of transects with Red-naped Ibis were insignificant suggesting that the species is a resident of lowland Nepal. The very similar numbers in all three seasons are also suggestive that breeding pairs may be territorial, though this aspect will require specific study to confirm. A slightly higher number of transects with Red-naped Ibis during the monsoon than winter could be suggestive of its preference for wet farm soils relative to drier agricultural lands. During the summer, they may be at the nest leading to the small decline we observed during this season. In Rajasthan, Red-naped Ibis displayed distinct seasonal fluctuations in abundance with the lowest numbers during the summer, but the seasons with the highest numbers varied with location (summer in Churu city, Soni *et al*. 2009; monsoon in Dungarpur district, Asawra *et al*. 2022; winter in Udaipur district, Ameta *et al*. 2022). These studies suggest that local conditions such as levels of urbanization, agricultural crops grown, irrigation systems, distribution and size of wetlands on the landscape and prevalence of uncultivated fields contribute to seasonal variations in Red-naped Ibis abundance. Therefore, we urge a comprehensive investigation of the factors determining the presence of the species in Nepal.

There has been only one detailed study of the breeding ecology of the Red-naped Ibis which was conducted in a small Indian city (see Soni *et al*. 2010b). We observed its breeding season from March to September, which matches existing information. However, our study should be considered preliminary and detailed information is needed before we can be sure of the nesting season. Most Red-naped Ibis nests were located on trees that were in forests, farmland, and human settlements. Like Red-naped Ibis, other large waterbird species also construct nests on trees in environments dominated by humans such as cities and farmlands (Soni *et al*. 2010b; Karki and Thapa

2013; Koju *et al*. 2019; Ghimire *et al*. 2021; Kittur and Sundar 2021; Katuwal *et al*. 2022b). As a result, their protection and conservation are contingent on the views of the farmers who own these lands (Katuwal *et al*. 2021). In our study sites, most Red-naped Ibis nests were built on *B. ceiba* and *S. robusta*, though we are unable to make any assessment of preferred tree species. Previous studies on other large waterbirds have demonstrated the preference of several South Asian waterbird species to use these two tree species for nesting (Sundar *et al*. 2016; Koju *et al*. 2019; Bhattarai *et al*. 2021; Katuwal *et al*. 2022b). Tall trees are preferred for breeding by waterbirds, but such trees are not common on the agricultural lands of lowland Nepal (Koju *et al*. 2019; Katuwal *et al*. 2022b). Potentially due to paucity of nest trees, Red-naped Ibis were observed constructing nests on electricity pylons in some locations of Rajasthan, India (Ali *et al*. 2013; Sangha 2013). In other locations, they used only trees for nesting with nests located on *Ficus religiosa*, and *Azadirachta indica* (Soni *et al*. 2010b). More recent observations in two small cities of Rajasthan showed Red-naped Ibis entirely nesting on artificial structures despite abundant availability of tall trees (Charan *et al*. 2022). These studies and anecdotal observations are suggesting that Red-naped Ibis may have varied nesting habits depending on location and may not be limited by trees in contrast with other resident large waterbirds in south Asia that nest entirely or largely on trees (Kittur and Sundar 2021; Katuwal *et al*. 2022b). In this paper, we are unable to report on breeding success, but our descriptive data provides previously unknown nuances to the breeding ecology of the Red-naped Ibis.

The Red-naped Ibis appears suitable as a focal species to understand how human modified landscapes are utilized by large waterbirds and appear to use forests similarly for nesting relative to trees on agricultural areas. Such species that show versatility in using varied conditions could be flagships to understand impacts of different human activities. Our paper, and the other papers in this issue of *SIS Conservation*, has systematically collected multi-season, multi-location information on the habits of this endemic ibis from several areas across South Asia enhancing known information on the species' habits substantially. We suggest that the Red-naped Ibis be considered as a species for long-term study given its apparently plastic behaviour, and its occurrence in countries that appear to have landscape and cultural conditions that are similar. Such work may help provide detailed understanding of how to retain large waterbirds on human-modified landscapes in densely populated areas where creation of protected areas may be very challenging.

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RESEARCH ARTICLE

Is the Red-naped Ibis *Pseudibis papillosa* a "waterbird"? Distribution, abundance and habitat use in landscapes with two different dominant land uses in Udaipur district, Rajasthan, India

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Abstract Wetland and agricultural landscapes provide prime habitats for a variety of waterbirds. In tropical and sub-tropical areas, such landscapes experience considerable variation due to seasonal changes in water availability and crops. We asked how the Red-naped Ibis *Pseudibis papillosa*, an endemic and poorly studied waterbird that is assumed to not be closely tied to wetlands, coped with seasonal changes in a semi-arid region of India. We hypothesized that ibises respond differently to seasonal changes when the dominant land use varied (wetlands versus agriculture). We documented Red-naped Ibis abundance (as encounter rate), flocking and habitat use across three seasons in Udaipur district, Rajasthan, India. We used an *a-priori* field design that allowed coverage of focal areas that were dominant in either wetlands or agriculture. In all three seasons, wetland-dominated areas had magnitudes more ibises relative to agriculture-dominated areas. Ibises showed strong seasonal variation in encounter rates, flock size, and habitat use in both landscapes. Red-naped Ibis preferred wetland habitats throughout the year, though a majority were sighted in fallow fields with none using fields with standing crop in either landscape. Our findings suggest that Red-naped Ibis are closely associated with wetlands and that seasonal variations in landscape conditions, especially occurrence of fallow fields, cause ibises to change some of their habits. Existing literature on the species' habits require being updated. Similar careful studies conducted in a variety of conditions are essential to understand if coping mechanisms of Red-naped Ibis vary with crop type and local climate.

Keywords Agricultural and wetland landscapes, encounter rate, habitat selection, north-west India, Rajasthan.

Introduction

Agricultural fields are studied globally to understand waterbird ecology and distribution with the vast majority of studies based in developed countries. Agrarian lands have been viewed as a primary waterbird habitat under certain conditions, especially low human presence (Czech and Parsons 2002; Pierluissi 2010). However, studies of waterbirds in agricultural areas in both temperate and tropical countries have reported substantial populations of waterbirds such as herons, cranes, and storks reliant on human-dominated landscapes, notwithstanding natural wetlands being greatly reduced by a burgeoning human population and expanding cultivation (Kushlan and Hafner 2000; Sundar and Subramanya 2010; Sundar 2011; Kittur and Sundar 2020; Kittur and Sundar 2021). In tropical areas with rice as the principal crop, the landscape experiences significant seasonal changes in conditions related to water availability and primary

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crop cultivated. How waterbirds use such crop fields and how resident species cope with these seasonal changes is being increasingly documented (González -Solis *et al*. 1996; Marques and Vicente 1999). In countries such as India where rice is a dominant crop, there are substantial areas that are arid and rocky with rice cultivation restricted to a few patches, such as in southern Rajasthan (Koli *et al*. 2019). While several waterbirds have been documented using such landscapes, there is limited understanding of how resident waterbirds fare in such landscapes without rice and with seasonal variations in conditions.

An increasing number of studies in South Asia have showcased the high value of agricultural landscapes that retain a mosaic of crop fields and wetlands for waterbird populations, including several globally threatened species (Sundar 2006; Sundar and Kittur 2013; Sundar *et al*. 2015; Frank *et al*. 2021, Kittur and Sundar 2021; Ghimire *et al*. 2022). Community-managed wetlands maintained within agricultural landscapes primarily for human and livestock use, and to water crops, also support considerable bird diversity despite heavy human use and complicated hydrology (Sundar *et al*. 2015; Sundar and Kittur 2013). Waterbirds responses to season and location, however, varies depending on the landscape, cropping pattern and the species.

In a rice-dominated landscape, the flock sizes of territorial Black-necked Stork *Ephippiorhynchus asiaticus* did not vary across seasons or habitats, and storks used both natural (wetlands) and artificial (agriculture fields, irrigation canals) habitats to a varying degree (Sundar 2004). Contrary to the above pattern, flock sizes and densities of gregarious species such as the Black-headed Ibis *Threskiornis melanocephalus*, Painted Stork *Mycteria leucocephala* and Woolly-necked Stork *Ciconia episcopus* were significantly higher after nesting likely due to immature fledged birds' aggregating with adults (Sundar 2006). The extent of available wetlands affected Asian Openbill *Anastomus oscitans* flock size and habitat use across seasons possibly due to its specific food habits (freshwater snails) and the varied availability of this food in fields and wetlands seasonally (Sundar 2006). In a multi-scale, multi-year study across several landscapes where rice was the dominant crop in one season, Woolly-necked Storks showed considerable complexity in densities and habitat use with both metrics varying seasonally and across locations (Kittur and Sundar 2020). The majority of the storks used agricultural fields (in proportion to their availability) while preferring (used more relative to availability) wetlands in most landscapes (Kittur and Sundar 2020). In a two-year landscape-scale survey across southern Rajasthan where rice is rare, Black-headed Ibis, a flocking species, was observed using multiple habitats but did not vary habitat use seasonally (Chaudhury and Koli 2018). Black headed Ibises predominantly used wetlands while occasionally using other habitats such as crop fields, sewage lines and garbage disposal sites (Chaudhury and Koli 2018). In yet another study in the rice-dominant landscape of Gujarat, India, Glossy Ibises *Plegadis falcinellus* showed strong scale dependant habitat use with preference for areas with intermediate levels of wetlands (50-100 ha of wetlands in grids of size 10 ×10 km) but changed preference to areas with the most wetlands during the dry summer season (Sundar and Kittur 2019). In another Indian state, Haryana, a district where the majority of wetlands have been illegally converted to fishponds, reduction of water levels caused by irrigation for surrounding crop fields improved the use of such wetlands by few waterbirds (Sundar *et al*. 2015). These studies collectively show that while agricultural landscapes provide excellent habitats for waterbirds overall, the variation in habitat use and population densities with seasons is species-specific.

One large waterbird species that is widely distributed across the Indian subcontinent is the poorly studied Red-naped Ibis *Pseudibis papillosa* (Ali and Ripley 2007). Available observations suggest that it is a species less dependent on wetlands relative to other sympatric ibis species and is thought to be a habitat generalist. It has been observed foraging in a wide range of habitats such as drier margins of wetlands, grasslands, paddy fields, fallow crop fields, open sewage channels, garbage dump sites, and sand dunes (Ali and Ripley 2007; Soni 2008; Hancock *et al*. 2011). Systematically collected empirical information on the species is rare and biased towards agricultural landscapes dominated by rice in at least one season. Two such studies found that Red-naped Ibises use these landscapes in small numbers (Sundar and Kittur 2013; Katuwal and Quan 2022). Red-naped Ibises in lowland Nepal mostly nest on trees in forested areas seemingly avoiding agricultural areas for breeding (Katuwal and Quan 2022). Red-naped Ibises were common, widespread residents in one city in Rajasthan, India – Churu – but showed strong seasonal changes in abundance, used different foraging sites and preferred nesting on trees within the city (Soni 2008).

There is no systematically collected empirical information on how Red-naped Ibises cope with seasonal changes in relatively arid agricultural landscapes where rice is not the dominating crop. We designed a study across Udaipur district to understand the habits of this species, particularly abundance, flocking habits, and habitat use across a full year. Udaipur was ideal for this study since rice is rare as a crop across the district. The region is semi-arid, and much rockier relative to the areas where majority of waterbird studies have been carried out globally (Koli *et al*. 2019). In settings such as these, where wetlands and agriculture are sparser on the landscape relative to areas cultivated with rice, and where seasonal variations are much starker, we asked how Red-naped Ibises would respond to seasonal changes? Given existing assumptions regarding Red-naped Ibises not being a wetland bird (Hancock *et al*. 2011), would responses be similar in areas where wetlands were more common relative to areas dominant with agriculture? We hypothesized that Red-naped Ibises would: (1) use wetland-dominated and agriculture-dominated landscapes differently with variations apparent in metrics such as abundance and flock sizes; (2) show less seasonal variation of population metrics in wetland-dominated landscapes relative to agriculture-dominated landscapes; and (3) not show a strong preference for wetlands as foraging habitat, notwithstanding whether the landscape was dominated by wetlands or agriculture. Landscape scale studies with an *a-priori* design stratifying a landscape based on dominant land uses relevant to waterbird ecology are rare and have previously been developed across the Gangetic flood plains where areas with different amounts of rice grown were identified and sampled (Sundar and Kittur 2013). This study is the first where the *a-priori* stratification includes two major land uses – wetlands and agriculture.

Study area

Udaipur district (~13,419 km^2) is located in the southern part of the state of Rajasthan, India (Figure 1a). The Aravalli Mountain range dominates the western and south-western parts of the district providing rocky relief to the geography leading to considerably low water availability relative to the wetter, flatter northern and eastern parts of the district (personal observations). The north-eastern parts of the district have extensive fertile plains that are utilized for agriculture (Figure 1c). Both artificial and natural wetlands are interspersed across the district providing potentially high-quality habitat for wetland dependent fauna (Chaudhury and Koli 2018; Koli *et al*. 2019). Specific studies documenting the kinds of wetlands and how they are managed are not available for the region. The human population of the district is 26.33 million, out of which ~55 % are tribal who primarily depend on agriculture and animal husbandry for their livelihood (Census India 2011).

The district experiences three distinct seasons namely monsoon (or rainy season; July - October), winter (November-February) and summer (March - June) that are differentiated by distinct temperature and precipitation profiles. Average annual rainfall is ~772 mm and temperature ranges from 1º - 25º C in winter to 26º - 48º C in summer (averaged for 2016 - 2020; data from Water Resources, Government of Rajasthan 2016-2020). Cropping is also distinctly seasonal with each growing season having local names such as Kharif (June - September), Rabi (October - February), and Zayad (March - June; Jat *et al*. 2004). The primary Kharif crops include Maize *Zea mays*, Jowar *Sorghum bicolor*, and Urad dal *Vigna mungoi*, whereas the Rabi crops are Wheat *Triticum aestivum*, Barley *Hordeum vulgare*, and Mustard *Brassica juncea*. During the summer, the primary Zayad cultivated crops are Watermelon *Citrullus lanatus*, multiple vegetables, and fodder crops such as Alfalfa *Medicago sativa*, Berseem Grass *Trifolium alexandrinum*, and Great Millet *Sorghum bicolor*. 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

Field design

We developed a land use map of Udaipur district using satellite imagery that was used to identify the two focal strata – areas dominating in wetlands or agriculture. Three western tehsils of the district, namely Gogunda, Kotra and Jhadol, were entirely hilly and inaccessible, and were excluded from our study (Figure 1b). Four Sentinel-2 (Level-2A; https://scihub.copernicus.eu) images of 10 x 10 m resolution with the least cloud cover (two images dated 19 December 2019 and two dated 29 December 2019) were downloaded and clipped using the shape file of study area (shaded part of Figure 1b). All images were classified separately into four broad land classes, namely agriculture (agriculture fields with crops), built-up (included buildings and roads), water (included seasonal and permanent lakes, ponds, and rivers), and other (a mix of various other land uses that had considerable overlaps in spectral signature including tree patches, scrubland and open areas that included fallow fields) using the 'Maximum likelihood' algorithm in Semi-automatic Classification Plugin (SCP; Congedo 2021) in QGIS freeware (ver. 3.10 'A Coruña'; QGIS Development Team 2019). Some misclassified regions were identified and corrected manually by using Google map as a references layer. For this, the Serval Plugin (https://www.lutraconsulting.co.uk/blog/2016/09/05/serval/) and Edit Raster tool in the post processing menu of SCP were used. The classified and cleaned images were then mosaicked to form a single raster image. The overall accuracy of the classified imagery was 90 % (Kappa = 0.86).

The focal study area was overlaid with a grid of hexagonal units (shape chosen to reduce edge effects) with each side measuring 1.96 km providing an area of 10 km^2 per hexagon. We calculated the area of each land class category in each hexagon and selected 20 grids having the most wetland area (range 1.64 - 8.71 km^2/ hexagon) as "wetland hexagons" and 20 hexagons with the most agriculture area (range 1.25 - 2.50 km^2/ hexagon) as "agriculture hexagons" for field surveys (Figure 1c, d).

Field surveys

We surveyed focal hexagons from 1 July 2021 to 30 May 2022 covering each hexagon once every season on days without rain and fog. Surveys started at sunrise and ended before 1100 h. For surveying hexagons, we used the network of metalled roads which ensured that coverage remained nearly the same in all three seasons. All available motorable roads in each hexagon were traversed. We searched for Red-naped Ibises, driving on a motorbike at *c*. 20 km/ hr. and a hand-held GPS was used to record tracks (to calculate transect length in km) and bird locations. All individuals of Red-naped Ibises visible within *c*. 300 m on either side of the road were counted. At large wetlands, we used vantage points to scan for ibises with 10 × 50 binoculars. Whenever ibises were sighted, we noted the following: location of sighting (latitude - longitude), number of individuals, number of adults and younger birds (identified by duller red coloration on the head; see Figure 2), and broad habitat category that ibis were using (agriculture, built-up, wetland, and others).

Analysis

We present summary metrics as average ± SD throughout the paper. Abundance of Red-naped Ibis

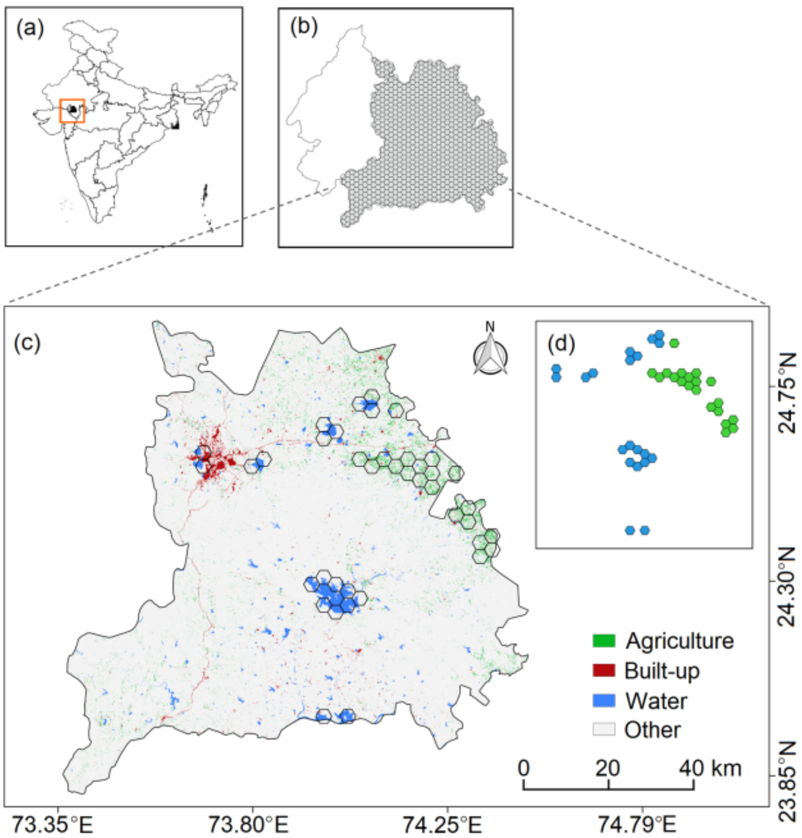

Figure 1. Location of Udaipur district in India (a), and the grid with hexagonal units of 10 km^2 used to overlay the district prior to selecting study locations (b). Major land uses across Udaipur district with focal hexagons (c) chosen as wetland ("water") and agriculture hexagons are shown (d).

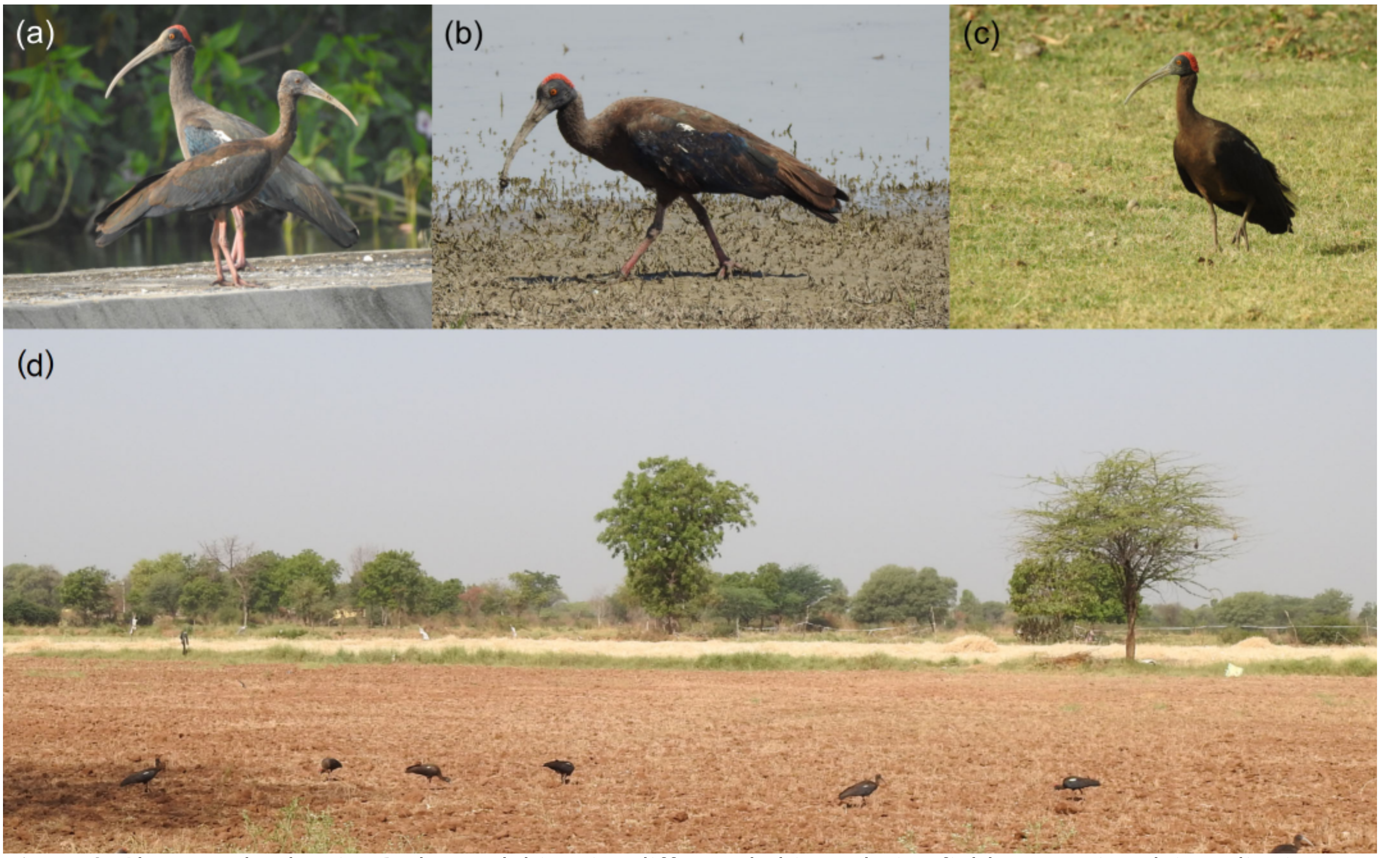

Figure 2. Photographs showing Red-naped Ibis using different habitats during field surveys in Udaipur district, Rajasthan. (a) An adult (behind) and a juvenile (in front) are standing on a cemented dyke beside a wetland; (b) an adult ibis foraging in the muddy shore of a wetland; (c) an adult ibis resting in an open grassland; and (d) an ibis flock foraging in a fallow agricultural field. Field surveys were carried out between July 2021 and May 2022. (All photographs by Hitesh Ameta.)

was estimated per hexagon as encounter rate (ibises counted/ transect length in km) for each season, as road transects were unequally distributed. We used the non-parametric permutational multivariate analysis of variance (PERMANOVA) test to assess if there were differences in flock sizes between wetland-dominated and agriculture-dominated landscapes in each season. Two-way interactions were tested between hexagon type and seasons to understand if encounter rate varied solely due to dominant land use or seasons. This test was carried out using the R-package 'lmPerm' with function 'aovp' (Wheeler and Torchiano 2016). The non-parametric test freed us from the assumption of normal data distributions. We used Fisher's exact test in R environment to test if Red-naped Ibis sightings using individual habitat types varied across strata and seasons.

To understand if Red-naped Ibises showed preference or avoidance of individual habitat types, we employed the use-availability framework (Manly *et al.* 2004). We calculated proportions sightings of Red-naped Ibises in different habitats as "use" of each habitat and proportion of each habitat type from satellite images as "available" (Manly *et al.* 2004). Sightings in each season were contrasted against a one-time measure of habitat availability. We used function 'widesI' in R-packages 'adehabitatHR', 'adehabitatHS', 'adehabitatLT' and 'adehabitatMA' (Calenge 2006). The test provides log-likelihood χ^2 (or the 'Khi2L') value testing the hypothesis that all available habitats were used randomly and provided selection ratios that compared use versus availability for each habitat. This allowed an assessment of whether each habitat was used more than available (preferred), or less than available (avoided), or used in proportion to availability. All statistical results were considered significant at $p < 0.05$ level.

Results

A total of 2,362 km (878 km in the monsoon season; 746 km in winter; 739 km in summer) were surveyed. The highest number of Red-naped Ibis were recorded in winter (N = 296; 291 adults and 5 juvenile) with intermediate numbers during the monsoon (N = 124; 102 adults, 22 juveniles), and the lowest count during the summer (N = 102 adults, no juveniles).

Encounter rate

Many more Red-naped Ibis were found in wetland hexagons in all the three seasons (monsoon: N = 74; winter: N = 179; summer: N = 114) relative to agriculture hexagons (monsoon: N = 28; winter: N = 39; summer: N = 10). Encounter rates (ibis seen per km in each hexagon) were magnitudes higher in wetland hexagons ($p < 0.001$) especially during

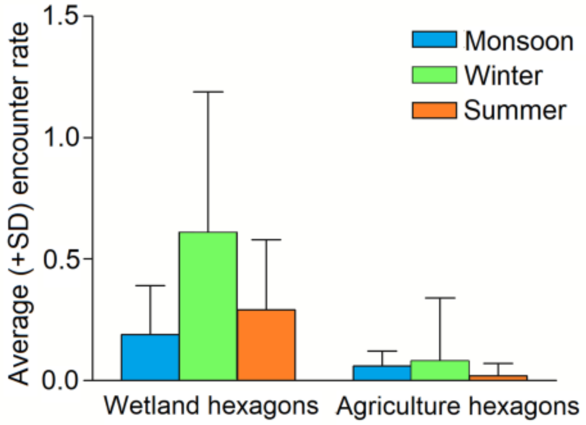

Figure 3. Seasonal encounter rates (birds seen per km in individual hexagons) of Red-naped Ibis in wetland and agriculture hexagons in Udaipur district, Rajasthan. Field surveys were carried out from July 2021 to May 2022.

the winter ($p < 0.001$; Figures 3 and 4).

Flock size

The mean flock size, combined across all hexagons, of Red-naped Ibis was magnitudes larger during the winter ($N = 46$, 6.43 ± 11.39 SD; range: 1 - 61 individuals) compared to the much smaller flock sizes during the summer ($N = 41$, 3.02 ± 3.09 SD; range: 1 - 15 individuals) and monsoon ($N = 52$, 1.96 ± 1.52 SD; range: 1 - 8 individuals). Most flocks comprised of < 5 ibises with flocks of > 10 ibises being rare and only two observations of flocks with > 50 ibises (Figure 5). Both number of flocks and sizes of individual flocks differed significantly between agricultural and wetland hexagons (Figure 5). Differences were the highest during the winter ($p < 0.0001$) and summer ($p = 0.02$). Flock sizes were similar in hexagons with the two dominant land uses during the monsoon despite many more ibises counted during this season relative to summer ($p = 0.42$).

Foraging habitats

Red-naped Ibises were recorded most in the category of mixed land uses ("other", 49.23 % of total sightings– 37.3 %, 93.3 %, and 75.6 % of sightings during the monsoon, winter and summer respectively). Of the remaining sightings, the majority were observed using wetland edges (48.27 %; Figure 2b) and in built-up areas (2.49 %). Ibises were never observed using fields with standing crop. Use of different land use categories varied significantly across seasons (combining all hexagons: $p < 0.001$), and within hexagons with the two dominating land uses (agriculture: $p = 0.002$; wetland: $p = 0.005$; Figure 6).

Considering all land use types together, Red-naped Ibises displayed very strong non-random use of categories in all seasons in both hexagon types ($p < 0.05$), except during the monsoon in wetland

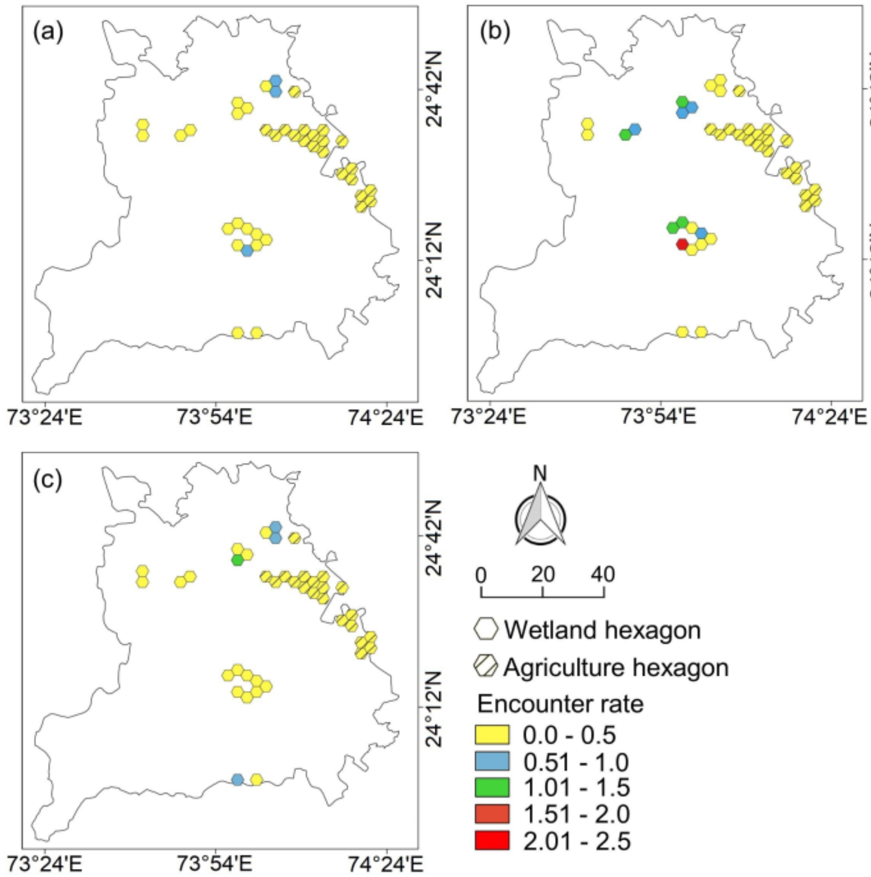

Figure 4. Encounter rates of Red-naped Ibis in wetland (without diagonal lines) and agriculture (with diagonal lines) hexagons recorded during monsoon (a), winter (b) and summer (c) in Udaipur district, Rajasthan.

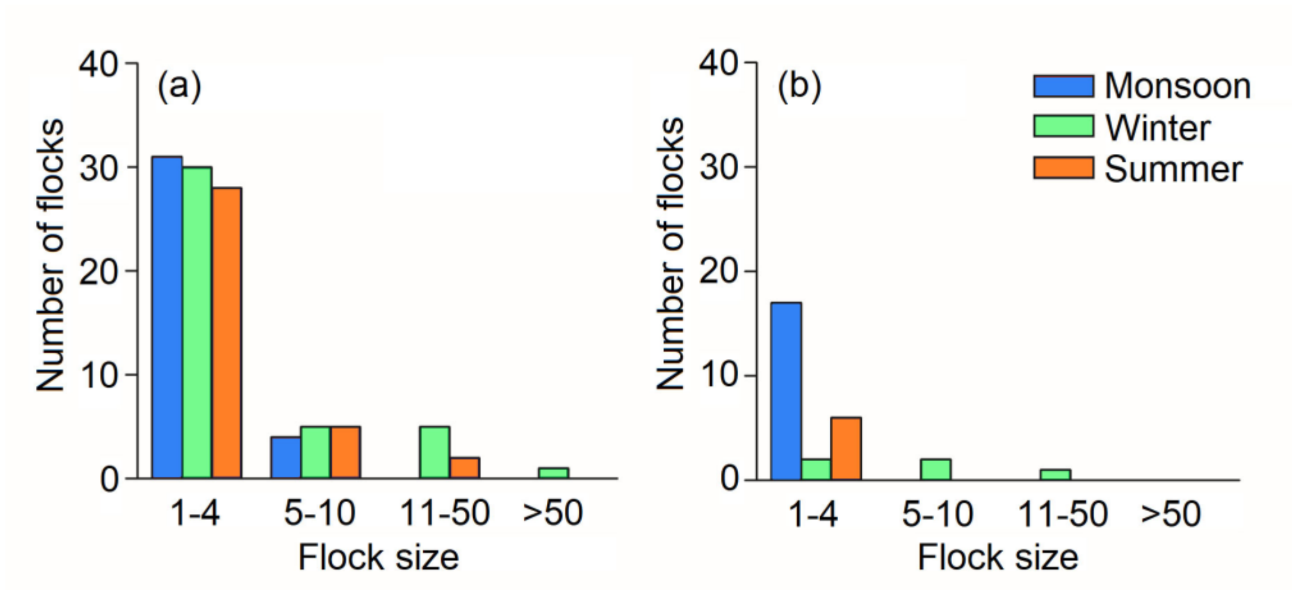

Figure 5. Flock sizes of Red-naped Ibis in wetland (a) and agriculture (b) hexagons, in three seasons in Udaipur district, Rajasthan from July 2021 to May 2022.

hexagons (χ^2 = 3.89, p = 0.27). Notwithstanding dominant land use, Red-naped Ibises strongly preferred wetlands (used more relative to availability) in all seasons (Figure 6). Built-up areas were preferred in wetland hexagons only during the monsoon, but otherwise built-up areas were used much less relative to availability (Figure 6). The category “other” was largely used less relative to availability (Figure 6).

Discussion

Our study is the first to investigate Red-naped Ibis density, flocking and habitat use across seasons and landscape scales using an *a-priori* field design, that stratified the study area based on two dominant land uses – wetlands and agriculture. Red-naped Ibis varied seasonally in both abundance related (encounter rate) and behaviour related (flock size and habitat use) metrics, both across the full sample and between hexagons with dominant land uses. The species was mostly seen in small flocks with large aggregations being rare. Contrary to descriptions in the majority of available literature, Red-naped Ibis were strongly and positively associated with wetlands, notwithstanding the dominant land use.

Encounter rate

Significant differences in encounter rates of Red-naped Ibis across hexagons and seasons suggest local movements likely due to changing foraging conditions seasonally. The caveat to this explanation is that activity of ibises was not recorded for each sighting. Assuming that all habitats were used similarly is not ideal, and future studies to parse apart habitats used for different activities will be useful. Responses of ibises, however, varied with dominant land use as indicated by encounter rates. Highest encounter rates everywhere were during the winter. However, the season with the lowest encounter rate varied between dominant land uses: monsoon in wetland hexagons, and summer in agriculture hexagons. This variation in encounter rates suggests that seasonal conditions differed as a function of dominant land use causing ibis movements in different seasons. It is also possible that breeding preferences of Red-naped Ibis varied by dominant land use, and that low encounter rates during the monsoon in wetland hexagons reflect increased activity at the nest. In north India, the breeding season for this species is thought to be March to October (summer and monsoon seasons –Ali and Ripley 2007). The addition of fledged juveniles following breeding likely contributed to higher encounter rates of Red-naped Ibis during the winter. Soni (2008) counted Red-naped Ibis at roosting sites in an arid area of Rajasthan, and found higher numbers during the winter. The two studies suggest that, most Red-naped Ibis can be counted during the winter notwithstanding the method used.

Flock size

Red-naped Ibis mostly occurred as small flocks, matching descriptions in existing literature and more recent work where the species is described to occur largely as solitary birds, pairs, or in small family groups (Ali and Ripley 2007; Soni 2008;

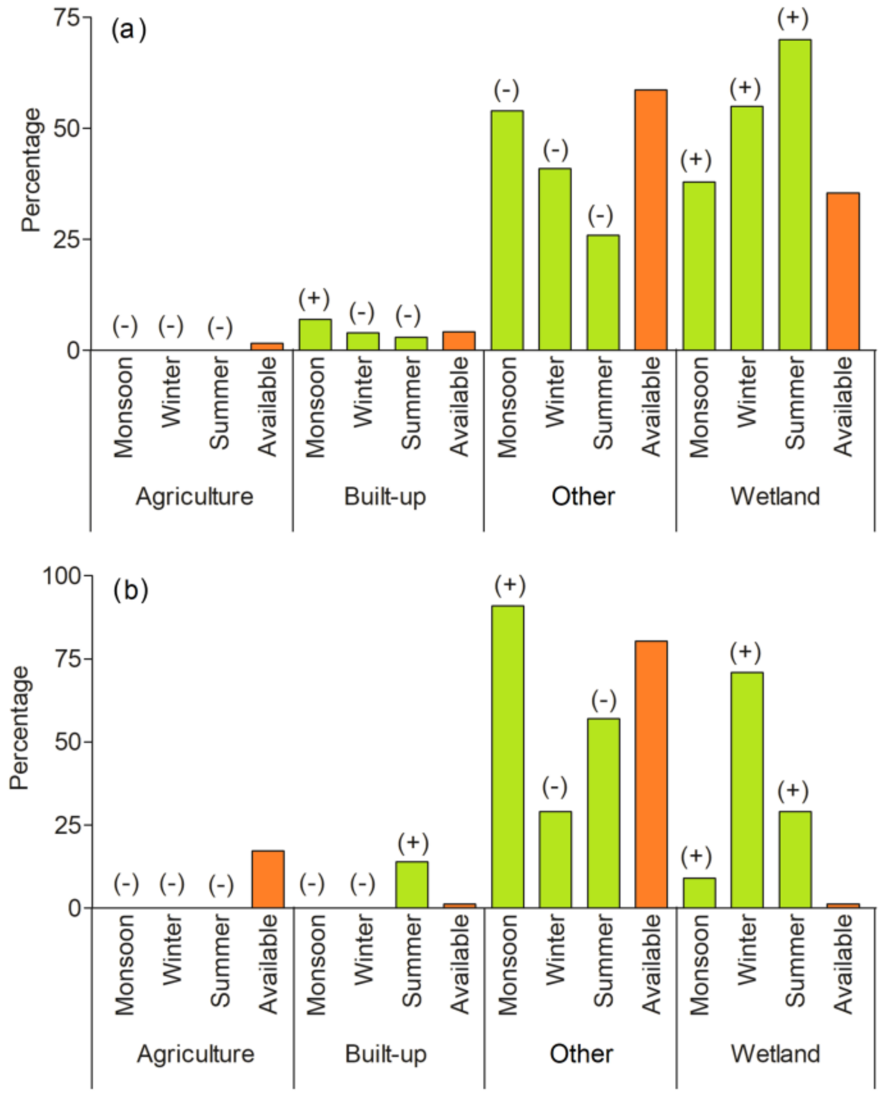

Figure 6. Habitat use (green bars) by Red-naped Ibis and available habitat (orange bars) over three seasonal surveys in wetland-dominated (a) and agriculture-dominated (b) hexagons in Udaipur district, Rajasthan. Symbols show preference (used more relative to availability; +) and avoidance (used less relative to availability; -) of a particular habitat.

Katuwal and Quan 2022). Larger flocks with > 50 birds were rarely observed; the only sighting was during the winter in a wetland hexagon. Flock sizes varied significantly in two of three seasons due to dominant land uses (winter and summer; much larger flocks in wetland hexagons; Figure 5). This suggests that this relatively easy to measure metric is related to landscape quality but requires to be used with the caveat that flock sizes during the monsoon are likely to be similar everywhere. Previous studies have shown that Asian Openbill, Black-headed Ibis and Woolly-necked Stork flock sizes have identical variations with season (Sundar 2006; Pande *et al*. 2007; Kittur and Sundar 2020). Monsoon is a season with the highest agricultural activity in Udaipur district due to widespread availability of water and may provide additional foraging ground for the species leading to its spreading out and small flock sizes everywhere. Bigger flock sizes during the winter (particularly in wetland-dominated hexagons; Figure 5) are suggestive of newly-fledged younger Red-naped Ibis flocking in areas with more wetlands, like with other large waterbird species (Sundar 2006; Kittur and Sundar 2021).

Land use preference

Contrary to existing literature and our hypotheses, encounter rates were far higher in wetland-dominated hexagons in all the seasons (Figures 3 and 4). Wetlands were also the most preferred habitat in all seasons in both hexagon types, and there was not a single observation of ibis in agricultural fields with standing crop (Figure 6). This finding suggests that Red-naped Ibis avoid crops in semi-arid areas such as Udaipur district. Most Red-naped Ibis were, however, seen in fallow fields (see Figure 2d). It seems likely that along with wetlands, open areas and especially fallow agricultural fields, are important for supporting Red-naped Ibis in semi-arid landscapes. Future work requires to undertake analyses related to land use more carefully and ensure that fallow agricultural land is a distinct category of land use prior to analyses relating to preference-avoidance of habitats. The importance of fallow fields as foraging habitats has been demonstrated for a variety of waterbird species in other studies across diverse agricultural landscapes (Sundar 2006; Tscharntke *et al*. 2011; Sundar and Kittur 2012; Toivonen *et al*. 2015). That Red-naped Ibis used fallow fields but not fields with standing crop suggests that their avoidance of fields is associated with the crops grown and not agriculture *per se*. We suspect that standing crops such as millets and maize offered physical resistance to foraging ibises, but this aspect of ibis-agriculture interaction is clearly intriguing and worthy of specific research attention. The relationship of Red-naped Ibis with built-up areas was more complex, with ibises preferring such areas in few seasons. But this seasonal preference was not similar across areas with differing dominant land uses (Figure 6). This finding is analogous to observed varying seasonal abundances of Red-naped Ibis within a small city in an arid part of Rajasthan (Soni 2008). In Udaipur, Red-naped Ibis used built-up areas much more in wetland hexagons during the monsoon, which is the primary breeding season for the species suggestive of the species relying on urban trees for breeding as in Churu, Rajasthan (Soni 2008). Why Red-naped Ibis preferred built-up areas in agricultural hexagons during the summer, and whether they entirely avoid trees found outside urban areas on the larger landscapes for breeding, are questions that are worthy of future research.

Conclusions

Our findings show how Red-naped Ibis in semi-arid rocky regions of India interacted with different dominant land use and changed their behaviours seasonally. To fully understand species such as this ibis, studies will require to cover diverse landscapes – with rice, without rice, and other settings. We also show that Udaipur district supports a relatively large and resident population of Red-naped Ibis suggesting that areas dominated by non-rice crops also support waterbirds. Previous work in this region showed the significant importance of wetlands and urban areas in supporting a diverse assemblage and substantial abundance of foraging and roosting waterbird species (Chaudhury and Koli 2018; Koli *et al*. 2019). This work on Red-naped Ibis underscores those findings while additionally suggesting that fallow crop lands may be additionally beneficial to sustain waterbirds. Our work adds important nuance to understanding Red-naped Ibis ecology while showcasing that this species may use somewhat different but related strategies to live alongside humans in different parts of south Asia. We underscore many recent calls to cover additional human-modified and human-dominated areas in regions such as south Asia to help uncover potentially novel settings where large waterbirds are not deterred by, but instead cope with sharp seasonal changes on the landscape accentuated by human activity.

Acknowledgments

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RESEARCH ARTICLE

Observations of colonially-nesting Red-naped Ibis *Pseudibis papillosa* at Amla, Gujarat: nest tree preference and breeding success

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Abstract Colonial breeding is uncommon in Red-naped Ibis *Pseudibis papillosa* with only a few records available from India and Nepal. There are no detailed descriptions of such sites and there is no understanding of conditions under which this species could nest colonially. The species was observed nesting colonially on a regular basis at Amla village of Vadodara district of Gujarat state, India. In this study, I provide detailed documentation of characteristics of nesting sites, a comparison with available trees, document nest location at colonies, and other characteristics of the landscape around the colonial nesting site. The colony was observed for two years (2021 and 2022) with weekly surveys during the nesting period. A total of 12 nests in 2021 and 20 nests in 2022 was recorded. Red-naped Ibis selected two species of trees, *Ficus benghalesis* and *Tamarindus indica*, both of which had large canopies, high diameter, and were protected by local cultures. The ibises nested in a village that had a water source and was surrounded by agricultural fields. Nest success (proportion of nests with at least one chick fledging) was 95% during 2022. Colonially-nesting Red-naped Ibis used cues similar to that used by other large waterbirds in south Asia, such as nesting in a village, preferring few tree species and nesting on the tallest available trees. These conditions occur across the distribution range of this species, and the rarity of colonial breeding in this species is, as yet, inexplicable.

Keywords Colonial nesting, nesting trees, *Pseudibis papillosa*, Red-naped Ibis.

Introduction

The advantage of breeding colonially to waterbirds has remained a topic of great interest among researchers. Food acquisition, predation avoidance, availability of mates and social stimulations are some of the factors that are thought to support colonial breeding in birds (Kopachena 1991; Wagner 1993; Richner and Heeb 1996; Baxter and Fairweather 1998). Habitat selection (selection of a limited number of favourable breeding sites relative to available foraging areas) and sexual selection are considered as important factors, other than food fidelity and reduced predation in evolution of colonial behaviour of birds (Burger 1981; Brown *et al*. 1990; Richner and Heep, 1996; Boulinier and Danchin 1997; Danchin *et al*. 1998; Danchin and Wagner 1999). The distribution and size of waterbird colonies are governed by the availability of suitable nesting sites and habitat composition around nesting sites (Parasharya and Naik 1990; Fasola and Alieri 1992; Kelly *et al*. 1993; Sach *et al*. 2007).

The Red-naped Ibis *Pseudibis papillosa* is widely distributed across the Indian subcontinents (Ali and Ripley 1987). It breeds largely as a solitary nester from March to November varying in different localities and in different years, on trees and artificial structures such as electricity pillion towers, cell phone towers, public lighting poles,

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and temple flag poles (Whistler and Kinnear 1949; Dodia and Parasharya 1986; Soni 2008; Sangha 2013; Ali *et al*. 2013; Rajesh and Kumar 2019). Colonial breeding is uncommon in Red-naped Ibis with only a few records available from Indian subcontinent. Two pairs nesting on Palmyra palms *Borassus flabellifer* was reported in ICRISAT campus, Patancheru, Medak district, Andhra Pradesh, India (Sangha 2013). A small colony of 3-5 pairs of birds nesting together on the same tree was recorded from Sind, Pakistan (Baker 1935). Hancock *et al*. (1992) recorded two pairs nesting on the same tree in Nepal terai. Existing observations were made over short visits, and it is not known if colonies of Red-naped Ibis are reused over multiple years, similar to the habits of other colonially nesting large waterbirds in the Indian subcontinent. The waterbirds are known to use the same nesting site regularly, for example, Painted Stork *Mycteria leucocephala* in Delhi Zoo (Desai 1971; Meganathan and Urfi 2009, Urfi 2010), Black-necked stork *Ephippiorhynchus asiaticus* in Etawah and Mainpuri districts, Uttar Pradesh (Sundar 2003), Asian Open-bill Stork *Anastomus oscitans* at Nandankanan wildlife sanctuary in Orissa (Mohapatra *et al*. 2019) and many waterbird species at Bhitarkanika mangroves, Orissa, India (Gopi and Pandav 2011).

In 2021, I discovered a site in Vadodara district, Gujarat, in western India where Red-naped Ibis were nesting colonially (Tere 2021). After initial documentation of this phenomenon at this site, I continued visiting the site for another year to document in detail several aspects of the nesting site, nest locations and breeding success to develop an understanding of conditions at colonies in this species. There are no previous detailed descriptions of Red-naped Ibis colonies, and in this study, I provide details gathered over two years.

Study area

Vadodara is a semi-arid district located in central Gujarat in western India (Figure 1). It covers an area of 7,794 km^2 and receives annual precipitation of 83 cm on average (World Weatheronline 2022). Amla village (N 22^0 10' 32.63"; E 73^0 04' 27.20") is located in Padra tehsil of Vadodara district in Gujarat, about 15 km southwest to Vadodara city (see Figure 1). Beside the village, there were two waterbodies, one smaller one (W1) measuring 0.01 Km^2 and a larger one (W2) measuring ~1 Km^2. Agriculture fields and scattered large trees surrounded W1 and W2.

Methods

Site survey

Amla village was surveyed once weekly between 0800 – 1200 h during the active nesting period from April to August, and monthly during the rest of the months in 2021 and 2022. Surveys covered the village on foot to

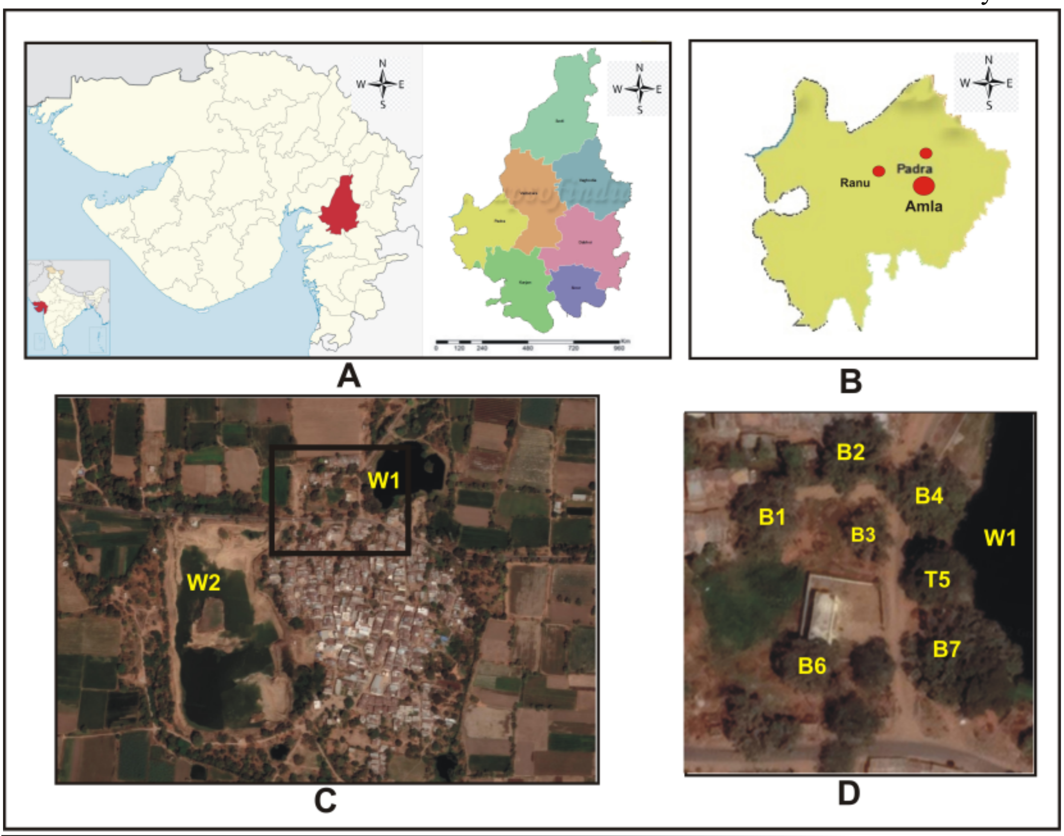

Figure 1. Maps showing the location of Vadodara district in Gujarat state, India (A), the location of Amla village in Padra tehsil of Vadodara district (B), photograph of Amla village showing location of nesting site of Red-naped Ibis (C) and close-up photograph showing location of nesting trees (D; source of photographs: Google Pro Earth). Letters indicate location of nest trees of two species (B - Banyan; T - Tamarind; No. 1 to 7 - numbers given to individual trees with nests). W1 and W2 are the two primary water bodies around Amla.

locate all nests of Red-naped Ibis, and villagers were also questioned to ensure that nests were not missed. If more than one nest occurred on a tree, or on trees with contiguous canopies, it was considered a “colony”. In 2021, I also surveyed the area around the village up to 2 km to locate any nesting ibis.

Nests and nesting activity

Total numbers of nests on each tree were counted by walking around nest trees. The heights at which nests were located were measured to the nearest m using a Blume-Leiss altimeter. Distance between neighbouring nests was either estimated visually or by plotting the locations on ground and measured by measuring tape. GPS locations were obtained from the photographs taken using a Sony HX400 camera. Observations on nest initiation, hatching and fledging of chicks was recorded weekly during 2022. Nest success was calculated as the percentage of nests that successfully hatched at least one egg.

Tree morphometry

For each nest tree, species identity, height (to the nearest m using an altimeter), diameter at breast height (DBH; in cm, using a measuring tape), canopy cover (in m^2 using measurements from the trunk in eight cardinal directions), and distance to the nearest neighbouring nesting tree (in m, using a measuring tape, or using Google Earth for trees much further away) were measured. To understand if ibises were preferentially selecting trees for size, the same measurements were taken for all trees ≥ 10 m height found within an area of 0.01 Km^2 that encompassed nest trees. To understand selection of tree species, total numbers of available tree species were recorded by conducting six transects of 500 m each in peripheral area surrounding the nesting site.

Data analyses

To understand whether the selection of trees by ibises does exist for nesting or it occurs randomly, I performed F-tests to compare canopy, DBH and height of (i) trees with nests (TN) and trees without nest (TWN) and (ii) trees with colony and trees with single nests. All tests were performed by using R programme 4.2.1.

Results

Site survey, nests and nesting activities

Colonial nesting of Red-naped Ibises occurred both years. A total of 12 nest in 2021 (two colonies of three and eight nests each) and 20 in 2022 (three separate colonies of three, six and eight nests on each) were observed. In 2021, both colonies were on Banyan trees *Ficus benghalensis*, while in 2022, the Red-naped Ibis added a colony on a Tamarind tree *Tamarindus indicus*. Banyan-1 and Tamarind-5 had maximum nests (Table 1). The nests were built between 8 and 21 m from the ground, with most of the nests located between 14 and 16 m height from the ground. The distance between the adjacent nests on the same tree varied from 1 to 8 m.

Table 1. Details of trees on which colonial and single nesting of Red-naped Ibis was observed during 2021 and 2022 on Banyan (B) and Tamarind (T) trees at Amla, Gujarat. (TH - height of tree in m; No. 1 to 7- numbers of nesting trees).

No.	Trees	Presence of livestock	No. of nests	
			2021	2022
Trees with colonies				
1	B1	√	8	8
2	B2	√	3	3
3	T5	√	0	6
Trees with single nests				
4	B3	√	1	1
5	B4	-	0	1
6	B6	√	0	1
7	B7	√	0	1
Total Nests			**12**	**20**

A pair was observed on Banyan 1 when the site was visited in late February 2022, but nest building was first observed in March. The nesting was asynchronous with the earliest nesting pairs starting nest construction in March 2022 with additional nests started in April and May 2022. Only one pair abandoned the nest, and the rest of the pairs continued with all fledging chicks successfully. Eggs or hatchlings could not be monitored due to height of nests. The chicks were observed in a few nests, but others were blocked by leaves. However, it was possible to observe the fledged young ones as they came out of nests and occupied branches near nest. The nest success was 95 % in 2022. No other solitary or colonial nests of Red-naped Ibis were found within 1 km area around Amla, but a few birds were nesting solitarily in Ranu and Goriyad villages that were further away.

Tree species and morphometry

All the nesting trees were within 0.01 Km^2 area, beside and within human habitation, and located near W1 (Figure 1). Except for one Banyan tree, all other nest trees were used by villagers to tie livestock under the shade (Figure 2). A total of 184 available trees with ≥ 10 m height of 21 species were enumerated (Appendix 1). The ibises preferentially nested on only two tree species –

Figure 2. Photographs showing Banyan tree with nests of Red-naped Ibis on the top and cattle in its shade (A); Banyan tree with nests on the uppermost canopy (B), nest building activity by adult Red-naped Ibis (C) and an adult incubating in the nest (D) at Amla village, Gujarat. (All photographs by Anika Tere.)

Banyan and Tamarind. The mean distance between nest trees was 26 m (± 4 SD). The trees selected for nesting had larger DBH and canopy cover. There was a significant difference between the canopies of TN and TWN (F =11.9, p = 0.0083 < 0.05), however, the canopy of trees with colony and single nests did not differ. Among the TWN, a single Banayan tree had higher DBH and was excluded for F test. Comparison of DBH of rest of TWN with TN showed a significant difference (F = 08.04, p = 0.037 < 0.05). There was no difference in height of TN and TWN and trees with colony and with single nests (Table 2).

Discussion

The Red-naped Ibis nested for two successive years and showed colonial nesting behaviour in both years. Site fidelity of colonial nesting Red-naped Ibis was not known before since past observations were based on short visits in one year (Tere 2021). This colony is located inside a village with nest trees used to shade livestock and is apparently expanding. This is strongly suggestive that Red-naped Ibis benefit from tolerant attitudes of people in rural India. Such tolerance and a high occurrence of colonially-nesting large waterbirds in human-dominated areas such as villages, cities and agricultural areas in south Asia is well known (Sundar *et al*. 2015; Roshnath *et al*. 2019). With this note, we can now add Red-naped Ibis to the list of species that nest successfully under such conditions. Past observations of colonially-nesting ibises were also in urban areas (campus of educational institution; Sangha 2013) and on a tree amid agriculture (Hancock *et al*. 1992).

The number of Red-naped Ibis colonies and single nests increased over the two years of observations. Villagers indicated that the colony has been active for many years, but it is not clear why the growth has increased so much during the study. While the conditions leading to the formation of the colony are not possible to determine, it may be possible to unravel the reasons for colony growth. The pattern of increasing sizes of existing colonies and additional single nests suggests that potential mechanisms at work, singly or in combination, without these being mutually exclusive. These possible mechanisms are: (i) existing colonies are attracting new adult breeders; (ii) adults from nearby areas are coalescing to this site that appears to be safe and leading to relatively high breeding success; and (iii) young birds fledged in previous years are returning with partners (Greenwood and Harvey 1976; Harvey *et al*. 1979; Greenwood and Harvey 1982; Warkentin *et al*. 1991; Fernández-Cruz and Campos 1993; Mckilligan *et al*. 1993;

Table 2. Morphometrics of trees at Amla village, Gujarat. (DH - Distance from house; DW - Distance from Water body-1; TH - Tree height; TC - Tree canopy area; DBH - Diameter at breast height).

No.	Tree species	DH (m)	DW (m)	TH (m)	TC (m^2)	DBH (m)
Trees with Red-naped Ibis nests: colonies						
1	Banyan (B1)	9.85	56.45	17	421.57	6.56
2	Banyan (B2)	8.20	36.55	17	364.3	4.96
3	Tamarind (T5)	9.60	7.34	23	261.01	9.45
Trees with Red-naped Ibis nests: single nests						
4	Banyan (B3)	8.90	26.12	15	160.19	3.63
5	Banyan (B4)	8.65	07.15	15	353.35	6.49
6	Banyan (B6)	8.15	48.63	16	229.05	3.78
7	Banyan (B7)	35.18	6.37	21	748.03	6.48
	Mean	**12.65**	**1.05**	**17.71**	**362.5**	**5.91**
Trees without nests						
1	Tamarind	36.18	6.4	22	235.22	3.2
2	Neem	33.29	33.87	21	160.51	2
3	Neem	11.6	44.88	20	141.68	4
4	Banyan	24.56	69.28	16	279.74	4.58
5	Neem	8.34	55.13	15	120.65	3.80
6	Neem	8.21	110.63	20	195.16	3
7	Neem	3.25	87.51	22	179.79	3
	Mean	**17.91**	**58.24**	**19.43**	**187.54**	**3.37**

Fasola *et al*. 2002; Vergara *et al*. 2006; Mashiko and Toquenaga 2022). Progression of nesting of Red-naped Ibis was asynchronous, which is similar to other large waterbirds in south Asia (Wittenberger and Hunt Jr. 1985; Urfi *et al*., 2007; Suryavanshi and Sundar 2019).

Previous observations on nesting Red-naped Ibises have recorded nests on tree species such as Peepal *F. religiosa*, Neem *Azadirachta indica*, Nilgiri *Eucalyptus* sp., Palmyra palm, Sheeshum *Dalbergia sissoo* and Khejri *Prosopis cineraria* (Baker 1935; Nair and Vyas 2003; Dookia 2004; Soni *et al*. 2010; Sangha 2013; Rajesh and Kumar 2019). In Amla, however, Red-naped Ibises preferentially nested on only Banyan and Tamarind trees despite 19 other tree species being present. They also preferred taller and bigger trees with large canopies, which is identical to choices shown by other colonially nesting waterbirds in south Asia (Gadhavi and Soni 2002; Roshnath and Sinu 2017a; Koju *et al*. 2019). These features of trees are thought to be selected to minimize predation risk and increase shading (Morse 1980).

Amla village is surrounded by agricultural fields and freshwater bodies – both of which are known foraging habitats of Red-naped Ibises (Ameta *et al*. 2022; Asawra *et al*. 2022; Katuwal and Quan 2022). Several studies have suggested that colony locations are tied to proximity to foraging sites that enhance foraging efficiency while provisioning chicks (Tere 2004; Roshnath and Sinu 2017b; Koju *et al*. 2019). It may therefore be that, along with other conditions that waterbirds prefer, such as the absence of disturbance by humans, presence of trees of preferred dimensions, and additionally, potentially predators being dissuaded by the presence of humans, have created the perfect conditions for Red-naped Ibises to nest colonially at Amla. The presence of cattle in vicinity of nesting trees may have additional benefits such as increased insect availability. However, all these conditions appear to exist in many other locations across their distribution range allowing many other waterbird species to nest (Subramanya 1996; Gopi and Pandav 2007; Chaudhury and Koli 2018; Roshnath and Sashikumar 2019; Trivedi and Parasharya 2019; Gohel 2021). It is therefore not clear why colonial nesting of Red-naped Ibis is so rare. Continuing to monitor the apparently growing colony at Amla promises to provide additional understanding and nuances that, at the least, can contribute to understanding breeding biology in the only known location where Red-naped Ibises are displaying high fidelity for nesting colonially.

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Appendix 1. Available trees around the sites that colonially-nesting Red-naped Ibis used in Amla village, Gujarat. (Only trees ≥10 m height.)

Sl. no.	Tree species	No.	Sl. no.	Tree species	No.
	Family Moraceae			**Family Caesalpiniaceae**	
1	Banyan *Ficus benghalensis*	6	12	Ashoka *Saraca asoca*	1
2	Peeple *Ficus religiosa*	2	13	Tamarind *Tamarindus indica*	13
3	*Ficus* sp.	1	14	Yellow flame *Peltoforum pterocarpum*	8
	Family Mimosaceae			**Family Fabaceae**	
4	Gorasamli *Pithecellobium dulce*	10	15	Karanjhi *Pongmia pinnala*	9
5	Babul *Acacia nilotica*	15	16	Shirish *Albizia lebbeck*	1
	Family Boraginaceae			**Family Myrtaceae**	
6	Gunda big *Cordia dichotoma*	2	17	Jambu *Syzygium cumini*	9
7	Gundi *Cordera gharaf*	1	18	Nilgiri *Eucalyptus tereticornis*	10
	Family Meliaceae			**Family Ulmaceae**	
8	Neem *Azadirachta indica*	45	19	Jungle cork *Holopteria indigrifolia*	3
	Family Anacardiaceae			**Family Sapotaceae**	
9	Mango *Mangifera indica*	29	20	Mahudo *Madhuca indica*	1
	Family Rutaceae			**Family Combretaceae**	
10	Wood apple *Limonia acidissima*	9	21	Arjun Adad *Terminalia arjuna*	1
	Unidentified species				
11	Unidentified 1	8		**Total**	**184**

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RESEARCH ARTICLE

Nesting substrates of Red-Naped Ibis *Pseudibis papillosa* in human dominated landscapes of Telangana, India

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Abstract Artificial structures such as power lines and communication towers have negative impacts on birds, posing risks of collisions and electrocutions, but also provide substrates for perching, roosting and nesting. In this note I present incidental sightings of Red-naped Ibis *Pseudibis papillosa* using transmission pylons and communication towers for roosting and nesting in rural Telangana, India. Between 1 November 2020 and 27 November 2022, 512 surveys were carried out in 56 locations covering a total of 2,870 Km. A total of 129 observations of Red-naped Ibis were recorded during the study period. The highest count ($N = 33$) recorded on a single survey was along the rural road (60 km); majority ($N = 29$) were roosting on transmission pylons and very few ($N = 4$) on communication towers, with flock size ranging from three to ten birds. Ten active nests were recorded - six on communication towers, one on a pylon, one on a *Borassus flabellifer* Palm and two on a cliff. On one of the communication towers, active nests of a pair of ibis and a pair of Red-necked Falcons *Falco chicquera* that were using an older ibis nest were recorded. The surveyed part of rural Telangana had very few trees. Here, transmission pylons and communication towers appear to be providing nesting substrates to the Red-naped Ibis whose nests, in turn, appear to be supporting raptors like the Red-necked Falcon that do not build nests. These novel observations show Red-naped Ibis to be very adaptable to human presence and actively breeding even on landscapes with few trees.

Keywords Artificial structures, modified landscapes, nests, raptors, Red-naped Ibis, road, roosting.

Introduction

Despite rapid land-use changes, South Asian agricultural landscapes have retained considerable bird diversity (Sundar and Kittur 2012; Katuwal *et al*. 2022), with conducive conditions for foraging and breeding (Sundar *et al*. 2016; Ghimire *et al*. 2021). However, contemporary intensified agricultural practices, rapid land use changes, extensive use of agrochemicals, illegal hunting, and reduction of nesting trees could be placing farmland birds in jeopardy (Mitra *et al*. 2011; Stanton *et al*. 2018; Katuwal *et al*. 2021). Birds nesting on man-made utility structures has been well documented all over the world; in some parts of the world the availability of utility structures has resulted in some species flourishing due to an unlimited potential for nesting (Harness 2008). Birds that build stick nests may find areas on electricity transmission and distribution structures suitable for nesting sites (APLIC 2006). In Europe, the White Stork *Ciconia ciconia* commonly nests on transmission and distribution towers (Janss 1998). Double-crested Cormorants *Phalacrocorax auritus* and Great Blue Herons *Ardea herodias* have been recorded nesting on steel-lattice

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transmission towers along the Great Salt Lake in Utah, USA (APLIC 2006). In Telangana Woolly-necked Storks *C. episcopus* have been seen using communication towers for nesting in busy towns (pers. obs.). In a north Indian agricultural landscape with traditional agroforestry, the Woolly-necked Stork rarely used artificial structures with most nests located on trees (Kittur and Sundar 2021). Large nests of birds on such landscapes are reused by birds such as some raptor species that do not build nests of their own. Prairie Falcons *Falco mexicanus* have been documented using Common Raven *Corvus corax* nests (DeLong and Steenhof 2004). Woolly-necked Stork nests have become the most common nesting substrate for Dusky Eagle-owls *Bubo coromandus* in north India (Sundar *et al*. 2021). Bhatt (2023) has recorded Red-necked Falcons *Falco chicquera* nesting on empty nests of House Crows *Corvus splendens* and Red-naped Ibis *Pseudibis papillosa* in Gujarat, India. While a few studies are emerging on waterbird use of artificial structures in south Asia and reuse of waterbird nests by raptors, studies so far have covered very few areas, and several resident waterbird species remain unstudied.

The Red-naped Ibis, though a widely distributed species across the Indian subcontinent, is poorly studied with the majority of information on its ecology being anecdotal (Ali and Ripley 1992). The species is found both within and outside of protected areas, and is thought to primarily use drier environments such as open fields and dry cultivated land, drier margins of wetlands, grass-lands, paddy fields, fallow crop fields, open sewage channels, as well as near urban and village garbage dump sites and sand dunes (Hancock *et al*. 1992; Ali and Ripley 2007; Soni 2008; Soni *et al*. 2010a; Inskipp *et al*. 2016). However, recent studies are recording the positive association of Red-naped Ibis with wetlands especially in semi-arid areas (Ameta *et al*. 2022; Asawra *et al*. 2022). Records of this species using man-made structures are few. Ali *et al*. (2013) documented a nest on a 110 kV transmission pylon in agricultural land along a national highway in Gujarat. Charan *et al*. (2022) observed Red-naped Ibis nesting on tall light poles, and cell phone towers in two cities of Rajasthan. Bhatt (2023) has observed 12 Red-naped Ibis nests on transmission pylons near perennial waterbodies and irrigation canals. The majority of observations of Red-naped Ibis nesting on electricity pylons and communication towers are anecdotal (Sanga 2013), and the frequency to which such structures are used for nesting on landscapes differing in number of trees and human presence is poorly understood. For example, one systematic study in a small city, Churu, Rajasthan, India, recorded Red-naped Ibis using only trees (Soni *et al*. 2010b). In treeless regions, power line structures have increased the availability of nesting sites for many species of raptors (Harness 2008) and large waterbirds (Janss 1998; APLIC 2006). Is the Red-naped Ibis similarly influenced, or does it entirely avoid artificial structures when trees are rare or absent on the landscape? There is no work on this species from Telangana and work on nesting is restricted to one study in Rajasthan (Soni *et al*. 2010b) and a few notes on its use of artificial towers (Ali *et al*. 2013; Charan *et al*. 2022). In this note, I present observations of Red-naped Ibises nesting and roosting along a road close to Hyderabad city in Telangana state, India over a two year period.

Study area

The study focused on two routes, a motorable rural road (60 km) and on walkable paths in Vasalamarri village ending at the surveyed rural road (Figure 1). All observations were made while driving along the rural road and at an open scrub habitat with grassland and paddy fields in Vasaalamarri village. The rural road passed through two districts, Medchal-Malkajgiri and Yadadri Bhuvanagiri District, and the other surveyed location is part of Yadadri Bhuvanagiri District. The survey route passed North East from the city of Hyderabad, between the municipality of Thumkunta (Medchal-Malkajgiri District) and the village Vasalamarri (Yadadri Bhuvanagiri District). The habitat and land use across surveyed locations were a mix of semi-urban areas with small towns, villages, man-made water bodies including village tanks, low hills with dense mixed scrub and rocky outcrops, fallow lands with open scrub, grassland, and meadows. Agricultural fields were common with mostly paddy *Oryza sativa* grown during both the Kharif (June-November) and Rabi (November-March) seasons. The area also has orchards of Mango *Mangifera indica*. Power lines (132 kV, 220 kV, 400 kV and 800 kV) crisscrossed the landscape, while communication towers were limited to small towns, villages and other built-up areas.

Methods

All records of Red-naped Ibis were made during

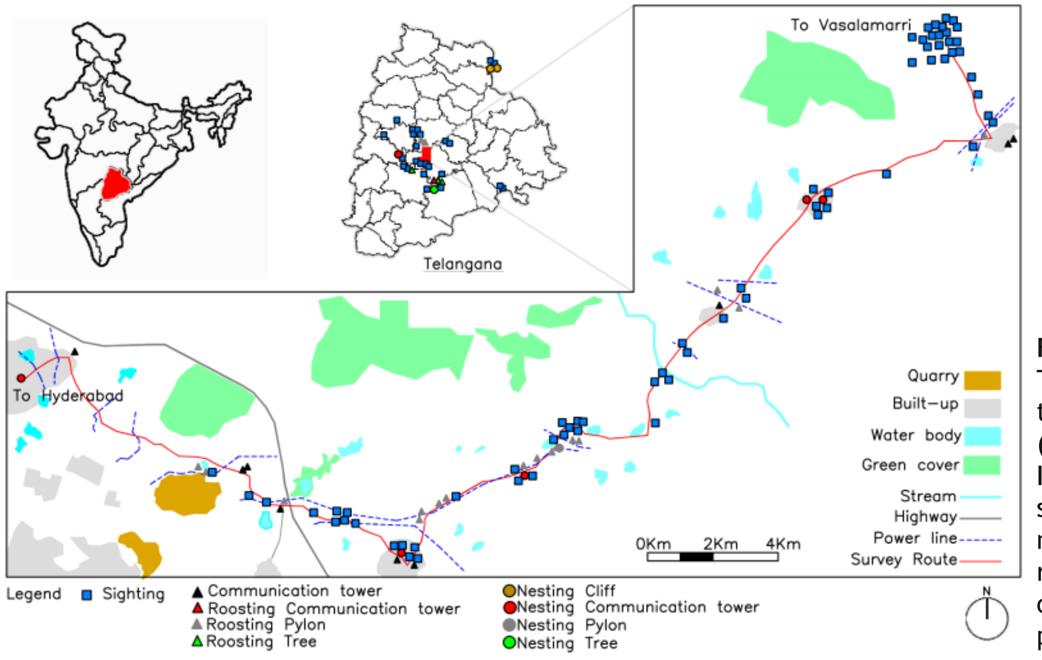

Figure 1. Location of Telangana in India with the map of Telangana (insets) and Red-naped Ibis sightings. The surveyed routes with the major land uses along the routes where Ibis observations are also provided.

surveys for ongoing studies on birds of the region between 1 November 2020 and 27 November 2022. Ibis were observed and recorded while driving a jeep on the road, or on foot while covering areas without motorable roads. Surveys were conducted in the mornings before 1000 h and evenings (between 1600 h - 1830 h). Road surveys were conducted by driving in a car at 40 Km/ hr, while foot and stationary surveys were carried out on walkable paths in the study area. All ibis seen or heard were recorded and other details like locations, number of birds, nest locations and habitat types were also noted. Two locations, a rural road and a location at the end of this road, together formed the most frequently surveyed areas (see Figure 1). While the road was surveyed by car, the other rural location was surveyed on foot. Survey effort were not similar across months. Nests were considered as active when either adult birds were seen carrying nesting material to the nest or when at least one adult bird was seen sitting in the nest or when mating was observed next to nests. Only locations of nests were recorded and it was not possible to carry out more detailed observations related to breeding biology.

Results

Between 1 November 2020 and 27 November 2022 a total of 512 surveys were carried out in 56 locations, covering a total of 2,870 Km. Red-naped Ibis were encountered on 96 surveys with a total of 129 observations. Of the 2,870 Km surveyed 287 Km were surveyed on foot and 2,583 Km were covered by road surveys.

The rural road was the most frequently surveyed road (*N* = 55; 1,362 Km; Figure 1). Of 96 encounters of Red-naped Ibis, 36 were along the rural road with a total of 68 observations. More than half (*N* = 38) of these observations were on power lines and communications towers which included nesting observations (Figure 2). The rural location in Vasaalamarri village was the most surveyed location by foot (*N* = 144; 78 Km) with 24 encounters; 16 of these observations were of ibises foraging or flying over paddy fields and grassland mosaic. No nests were observed in this location. Roosting was observed on transmission pylons (*N* = 18 encounters), trees (*N* = 3 encounters) and communication towers (*N* = 2 encounters). The highest count recorded on a single survey was 33 birds along the rural road in the month of August. Of these, 29 were seen roosting, spread out in groups ranging from 3 -10 on four different 220 kV pylons on the same line. Two pairs were seen roosting on two communication towers with nests. The highest number (*N* = 16) of ibises recorded roosting together was on a 400 kV pylon beside a small waterbody in July along the rural road.

All recorded nesting observations were between the months of March and September. Ten active nests were found with most on communication towers (*N* = 6; Figure 2 and Figure 3), and only one on a 220 kV transmission pylon (*N* = 1; Figure 2), *Borassus flabellifer* Palm (*N* =1) and a cliff (*N* = 2; Figure 1). Five of the six communication tower nests were along the rural road and one was along a national highway. The communication tower nest along the national highway (NH 65) had an active nest of a Red-naped Ibis, with an almost fully-fledged nestling in the nest. On the same tower, below the ibis nest was a pair of Red-necked Falcons *Falco chicquera* with chicks in an old nest of a Red-naped Ibis (Figure 3). Five of the

Figure 2. Photographs showing communication towers and a 220 kV transmission pylon (bottom right) with active Red-naped Ibis nests in Telangana. The photographs are deliberately wide-angle to facilitate a view of the larger countryside. (Photographs by Pranay Juvvadi.)

six nests on communication towers were in small towns and villages. The nest on the transmission pylon was along a small water body and surrounded by paddy fields. All recorded nests except the cliff nests were on private lands. The nest on the palm tree was in a dense area of palms along a small seasonal pond surrounded by paddy fields. Both the cliff nests were recorded on the Palarapugutta. Peddavaagu, a tributary of Pranahita river, flows along the cliff.

Discussion

Red-naped Ibis has previously been recorded nesting on trees like *Ficus religiosa*, and *Azadirachta indica* (Soni *et al*. 2010a), *Bombax ceiba* and *Shorea robusta* (Katuwal and Quan 2022) and *B. flabellifer* (pers. obs). They have also been recorded nesting of power line structures (Ali *et al*. 2013; Sangha 2013) and in some places nesting entirely on artificial structures despite abundant availability of tall trees (Charan *et al*. 2022). These observations suggest that this species uses a diversity of nesting substrates and may not be limited by trees in contrast to other resident large waterbirds in south Asia that nest entirely or largely on trees (Kittur and Sundar 2021; Katuwal *et al*. 2022). The records presented in this paper indicate that power line and communication structures are frequently used nesting sites of this species in areas like Telangana where large trees are rare on the landscape. It is easy to assume with the present information that a lack of suitable natural nesting substrates in combination with the increased availability of artificial structures is a major reason. But it seems more complicated. Soni *et al*. (2009) have observed all nests on trees in the city in Churu, but recent observations by Charan *et al*. (2022) found all nests on artificial structures in Dhariawad and Sikar cities even though trees were plentiful. These two studies from the semi-arid and arid areas of Rajasthan seem to suggest that use of artificial structures for nesting by Red-naped Ibis may be a recent behaviour, though this is difficult to confirm. Some plausible reasons for use of artificial structures could be the height advantage along with the sturdy lattice-steel of these structures, which probably provide protection against ground-based predators and reduced disturbance by people relative to the shorter trees. The ability to easily sight ibises and their nests on power lines and communication towers along roadsides probably also biases observations toward finding nests on these structures, but these observations do show that these birds can readily use manmade structures for nesting and roosting (Figure 3). To determine if this behaviour is influenced by the lack of suitable natural substrates alone or if there are other factors involved needs more carefully conducted studies. The results in this study also indicate that Red-naped Ibis preferred communication towers to transmission pylons for nesting, while they preferred transmission pylons for roosting. It was also observed that not all communication towers available were used for nesting and similarly not all transmission towers were preferred for roosting. It can be inferred that there are other factors that determine how and why they choose certain structures and over others in the same landscape. The two active Ibis nests recorded on a cliff were located 20 meters apart; one pair was seen bringing sticks in their beaks and the other pair was on the nest calling. There were at least 4 other birds on the ledges of the same cliff with lots of vocalisations (T. Singh & H. Vardhan pers. comm., 2022).

In human dominated and modified landscapes, with more records of Red-naped Ibis using utility structures, a long-term study on the breeding success and other detailed parameters on nest sites will help to understand whether this species is getting habituated to human structures in these densely populated areas. Studies like this should go in conjunction with the need to sensitise the utility staff of power and communication companies, as the current maintenance practices involves complete removal of nests from these structures. Bhatt (2023) has observed indiscriminate removal of Red-naped Ibis and House Crow nests from transmission pylons by utility companies in Gujarat, India as part of maintenance works. This not only impacts these species, but Bhatt (2023) has observed a dearth of nests for other species like the Red-necked Falcons that depended on empty nests of ibises and crows. Having an avian protection plan integrated into the utility maintenance routine and managing bird nests on these structures will not only solve operational concerns, but will also result in improved breeding of several bird species that may be used to obtain positive publicity for the utility companies.

Bird interactions with utility structures like power lines and communications towers and the impacts they cause on bird populations in human dominated landscapes is relatively poorly studied in India, and observations are steadily increasing covering both additional species and landscapes. While utility infrastructure like power lines can have negative impacts on bird populations from electrocutions and collisions, they also have created novel opportunities for birds to perch, roost and nest. One of the most frequently observed bird species building nests and nesting on power line structures and communication towers in

Figure 3. Red-naped Ibis nest with a fully fledged chick (top left) and a Red-necked Falcon nest on the same com-munication tower (top right) in Sangareddy, Telangana. Adult Red-naped Ibis in nest on a communication tower (bottom left) and Ibis roosting on an 800 kV transmission pylon (bottom right). (Photographs by Pranay Juvvadi.)

rural Telangana is the House Crow and Red-naped Ibis. The association between Red-necked Falcon and Red-naped Ibis recorded in this paper, where the former using disused nests of the latter is probably more common than expected. After crows, the Red-naped Ibis nests are probably the most available nests for the falcon species. This has also been recorded by Bhatt (2023) in Gujarat, India, where empty nests of both House Crow and Red-naped Ibis nests on transmission pylons and trees were the major nest sites for Red-necked Falcons. Such reuse of ibis nests by the Red-necked Falcon was observed once before in Telangana when a pair of falcons successfully used an ibis nest atop a *B. flabellifer Palm* (pers. obs.). The relationship of Red-naped Ibis with built-up areas and artificial structures, and the utility of ibis nests for additional species, seems complex and worthy of future research.

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SHORT COMMUNICATION

Natural history and behavioural observations of Red-naped ibis *Pseudibis papillosa* in Dhariawad and Sikar cities, Rajasthan

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Abstract The Red-naped Ibis *Pseudibis papillosa* is among the least studied waterbirds of the Indian subcontinent. With the intention to increase knowledge on the birds' habits, we assembled observations in and around two differently sized cities – the smaller Dhariawad (Pratapgarh district) and larger Sikar (Sikar district) – of Rajasthan between 2021-2022. In both cities, ibises used busy marketplaces to forage and roost. Feeding observations included some known habits such as feeding on earthworms and feeding on carcasses. Novel feeding habits included catching fish, predation of birds' eggs and adult Rock Pigeons *Columba livia*, scavenging on roadkill especially feeding on the bone marrow of recently killed cattle, and feeding on waste (dead rats and left-over foods) that house owners disposed on roadsides. Red-naped Ibis in both cities nested and roosted almost entirely on artificial structures (mobile phone towers, high-tension pillion towers, light poles) despite the presence of abundant trees at both locations. Our observations add a number of novel habits of the Red-naped Ibis. Though entirely anecdotal, the observations point to Red-naped Ibis showing considerable plasticity in habits in urban areas when persecution by people is absent. Observing poorly understood resident species such as the Red-naped Ibis, especially in small cities, offers opportunities to add knowledge to the habits of such species and how they interact with varying levels of urbanisation.

Keywords Artificial roost and nest site, catching fish, predating on birds, scavenging, urban birds.

Introduction

The Red-naped Ibis *Pseudibis papillosa* is a species endemic to the Indian subcontinent that has been very poorly studied (Ali and Ripley 2007; Hancock *et al*. 1992). The entirety of understanding of the species' habits is based on anecdotal observations despite the commonness of the species across the subcontinent. Such natural history observations are useful to develop early ideas of species requirements, traits, habits, and other associated ecological aspects, especially for poorly studied species.

In this note, we compile observations on Red-naped Ibis made between 2021 and 2022 in and around two differently sized cities: the smaller Dhariawad city (Pratapgarh district) and the larger Sikar city (Sikar district) of Rajasthan in north-western India. These two cities have greatly disparate conditions with Dhariawad located in the wettest part of the state and Sikar in one of the driest parts of the state (pers. obs.). Red-naped Ibis have colonised both cities and are among the most

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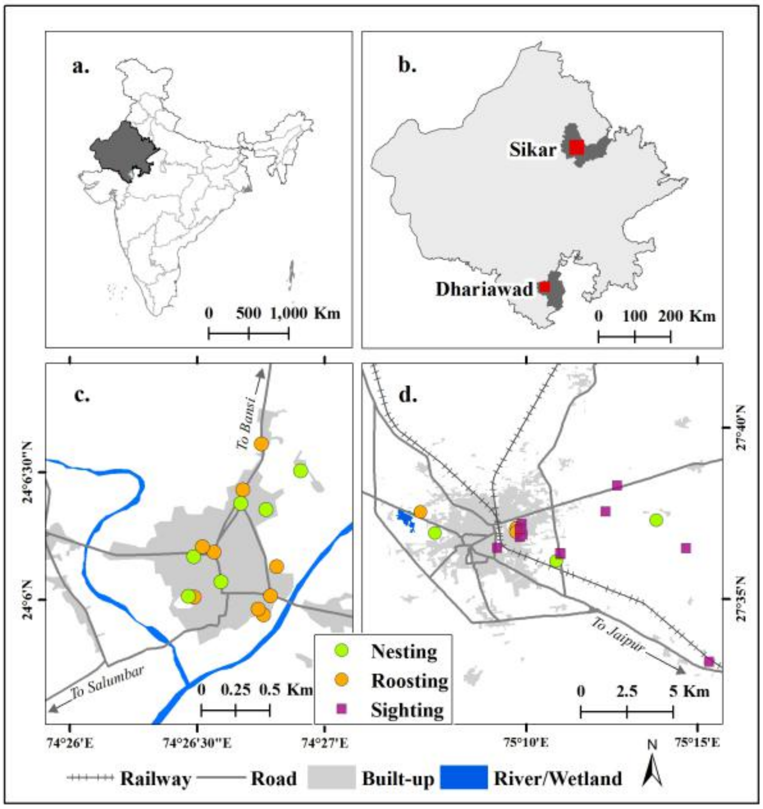

Figure 1. Map showing the location of Rajasthan (a) and the two focal cities, Dhariawad and Sikar, in Rajasthan (b). Detailed maps show nest and roost locations in each city (c: Dhariawad; d: Sikar), and include the locations of the various observations made in and around Sikar city. City maps are simplified to show only major features.

common bird species observed in both cities (pers. obs.). We provide observations on feeding and breeding, with few notes on other ecological aspects. Finally, we discuss our observations in relation to information available in existing literature, including papers published in this issue of *SIS Conservation*.

Study Area

There have not been any studies previously in the two focal cities (see Figure 1 for locations), and we therefore base the majority of the descriptions on personal observations, and sources such as Wikipedia which are not directly citable. Dhariawad city, located in Pratapgarh district (known as the greenest district of Rajasthan state), is a small town surrounded by large arid scrublands and extensive rainfed farmlands amid the Aravalli Mountains. The major crops are Maize *Zea mays*, Wheat *Triticum aestivum*, Soya Bean *Glycine max* and Opium *Papaver somniferum*. The city is called the "river city" of Pratapgarh district as it is situated between five rivers leading to its name in the local Rajasthani language ("dariya" meaning rivers, "wad" meaning between; information from local villagers). The largest dam in the state, Jakham, is located 32 km from the city which also has one seasonal and two perennial rivers. The town has a population of just over 11,300 people (Census of India 2011). Climatic variables were available from the nearest large city, Udaipur, and their averages are recorded between 1981-2010. Temperatures varied between 32º C (high) and 17.6º C (low), with an annual mean rainfall of 674 mm. Sikar city, in stark contrast, is located within the area broadly described as the Thar desert, the most lowland arid area of the Indian subcontinent. The region has a single large water body situated in the adjoining Jhunjhunu district known as Kot dam situated around 30 km from Sikar city. The dam is surrounded by the Aravali hills without any irrigation utility. The surrounding area of the dam consists of sparse tree growth spread over a large area, in an otherwise arid landscape, especially of Sheesham *Dalbergia sissoo*, Neem *Azadirachta indica*, Bargad *Ficus bengalensis* and Peepal *Ficus religiosa*. Sikar city had a population of over 2,37,500 people (Census of India 2011). Temperatures varied between 44.9º C and 1º C, with an annual mean rainfall of 358 mm. Both cities experienced very strong seasonality due to temperature and precipitation patterns. The severity of conditions including heat (much hotter and longer summers in Sikar) and rainfall (much more in Dhariawad) provide contrasting environments for Red-naped Ibises.

Methods

Observations on Red-naped Ibis were initiated in September 2021 continuing until end of October 2022. Opportunistic observations were made throughout. We also interviewed farmers, other villagers and business owners who were observed to be noticing behaviour of the ibises. Most observations in Dhariawad city were made inside the town, while observations were made in and around Sikar city (see Figure 1).

Results

Habitat use and nesting

In Dhariawad city, Red-naped Ibis were observed as single birds (rarely), pairs (mostly) or small groups of 3-5 that were likely family groups. No large flocks were sighted in the city during the entire observation period. Ibises were observed foraging in rivers, fallow agricultural fields, beside wetlands, and rarely, in the marketplace. Several roosting sites were located, and all of these were on poles erected to provide light in markets (see Figure 2). Roosts had only pairs except for one roost that had six ibises. Ibises were observed on 15 artificial structures of three types (mobile towers, light poles, temple flagpoles) out of which five were used for nesting, all within a radius of approximately 1 km from the town centre (Figure 1). The ibises used four mobile towers and two light poles (see Figure 2) for nesting over two consecutive nesting seasons. Two juveniles fledged from each nest every season and all nests were reused for two consecutive seasons. Two additional nesting sites were initiated but no eggs seemed to have been laid, and both were abandoned. Despite considerable tree cover in and around the city (pers. obs.), no nest was observed on trees.

Figure 2. Red-naped Ibis nesting atop public light poles in Dhariawad city. The photographs show proximity to busy marketplaces (above, and below-right) and rooftops from where residents watch the ibises frequently (below-left). (Photographs by Pradeep Sharma and Mahendra Singh.)

In Sikar city, a total of 54 Red-naped Ibis were observed with 11 juveniles in ten visits. A flock of 27 ibises was seen feeding on a cattle carcass near the city. A single flock of at least 200 ibises was additionally counted in the periphery of the city during winter 2021 spread out over a mobile phone tower nearby the carcass dump. Red-naped Ibises were also seen in pairs and small flocks of < 5 birds foraging in wheat and vegetable fields, nurseries where plants and trees were grown for sale, garbage dumps, and along highways. Three active nests, all of them on artificial structures (two on powerline towers, one on a mobile phone tower) were located, and at least one juvenile fledged from each nest.

Feeding

In Dhariawad town, Red-naped Ibis were observed feeding on unidentified insects (including Coleoptera grubs), frogs and unidentified worms (very likely earthworms) in freshly tilled agricultural fields just prior to the monsoon season. Red-naped Ibis were frequently observed feeding on livestock carcasses and at a garbage dump situated beside a river. An adult Red-naped Ibis was observed predating nests of Rock Pigeons *Columba livia* located on air conditioners outside windows in a busy part of the city. Pigeon juveniles were killed using both the beak and the feet and taken to a nest atop a light pole to be fed to ibis nestlings. Residents whose rooftop allowed close observations of the nest described such hunting of pigeons as common. One Red-naped Ibis was seen flying to the nest on a light pole with an unidentified snake measuring < 0.5 m, which was fed to its nestlings.

In Sikar city, Red-naped Ibises were observed eating several animal carcasses dumped by city municipal workers at a main garbage dump site. These included a snake, several unidentified birds, and rodents. One flock of 22 Red-naped Ibis feeding at a carcass dump included five juveniles. The carcasses were of mostly cattle with few dog carcasses. Ibises fed on small meat pieces and skin parts. Two ibises were observed inserting their beaks into the bones of cattle that had died after a collision with vehicles on the highway. The ibises were apparently feeding on bone marrow. In a plant nursery, a Red-naped Ibis adult was observed catching and swallowing 28 earthworms in one minute. Several ibises were seen catching fish from the shallow waters of a reservoir. At a dam, one of a flock of three Red-naped Ibises caught a fish in shallow waters and tried to fly off with it. The fish slipped out onto the shore and the ibis swallowed the fish only after it stopped moving. Inside the city, Red-naped Ibis were observed feeding on a dead mouse that was thrown out of a house, and on leftover food thrown after a social event. Four juvenile Red-naped Ibis were observed to feed on carcasses of Grey-headed Swamphens *Porphyrio poliocephalus*, Lesser whistling Duck *Dendrocygna javanica*, Red-wattled Lapwing *Vanellus indicus*, and Black-winged Stilt *Himantopus himantopus* around a municipal sewage outflow. Ibises were observed flying towards living birds of these species apparently for hunting, but none of these attacks resulted in a kill during observations. One ibis was observed feeding on a roadkill snake of an unidentified species. Around mobile phone towers in the city, where the ibis roosted, three separate observations were made of adult ibises attacking Rock Pigeons that were either feeding on grains, on the ground or flying. Two of these attacks resulted in kills, and ibises flew away with the dead pigeons. Farmers reported that Red-naped Ibises feed extensively on white grubs, a prominent pest of local crops.

Discussion

Our observations collectively support some existing observations of Red-naped Ibis feeding behaviour but add considerably to the known feeding and breeding habits of the species. While insects, frogs and reptiles are known to occur in the species' diet, its habit of catching fish appears to be novel (Hancock *et al*. 1992; Ali and Ripley 2007). Additional novel feeding habits included predating Rock Pigeon nests, hunting adult pigeons, eating bird carcasses and roadkill, and some novel food items of a uniquely urban origin (dead rodents being thrown out of a house, and leftover foods) from people inside the cities. Reaching into bone cavities, presumably for bone marrow, is also a previously undescribed feeding behaviour suggestive of ibises getting habituated to feeding on road kills of large domestic animals. A more careful systematic study of the dietary habits of Red-naped Ibis will likely yield newer dietary items. Designing such a study to include ibis populations inside cities can assist to understand their reliance on foods found in urban areas and the extent to which they appear habituated to humans.

A previous study of the breeding biology of Red-naped Ibis in another city of Rajasthan, Churu, showed the ibises to nest only on trees (Soni 2008). Our observations of nests in both cities were entirely on artificial structures, including previously unknown ones such as temple flagpoles. There was no scarcity of potential nest trees in either focal city (pers. obs.) and it is not clear why Red-naped Ibises appear to have shifted nesting to entirely artificial structures. In other parts of the country, Red-naped Ibis have been observed building nests on artificial structures, both in areas where trees were rare or absent (Parasharya and Naik 1990; Juvvadi 2022) and at other times, when trees did not appear to be limiting (Ali *et al*. 2013; Sangha 2013; Rajesh and Kumar 2019). A careful study of nesting ecology of Red-naped Ibis in varied settings, and over multiple years, will be required to understand whether the species is shifting nesting habits and becoming more reliant on artificial structures.

Roosting Red-naped Ibis have previously been observed using artificial structures (Dodia and Parasharya 1986), but large roosts such as the one we report appear to be rare. It is likely that the large ibis roost near Sikar city is formed by birds attracted to the carcass dump site nearby. Such carcass dump sites are found near all cities in Rajasthan suggesting that more careful observations in and around cities may help discover many more roosting sites with high numbers of Red-naped Ibis.

Collectively, our observations suggest that Red-naped Ibis are acclimatized to cities of varied sizes in Rajasthan. People in Rajasthan do not persecute ibises, and many appear to be closely watching the habits of these birds on a regular basis. While farmers were previously known to be aware of ibises' feeding habits (Ali and Ripley 2007; Hancock *et al*. 1992), our interactions with residents of the two focal cities suggested that the ibises are being observed closely by many people. These people were aware of habits, such as ibises predating pigeon nests, feeding on white grubs and snake kills, that does not find any mention in available literature. There appears to be great value in employing common resident waterbirds such as Red-naped Ibis as long-term study subjects to understand how waterbirds interact with urban areas and people.

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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

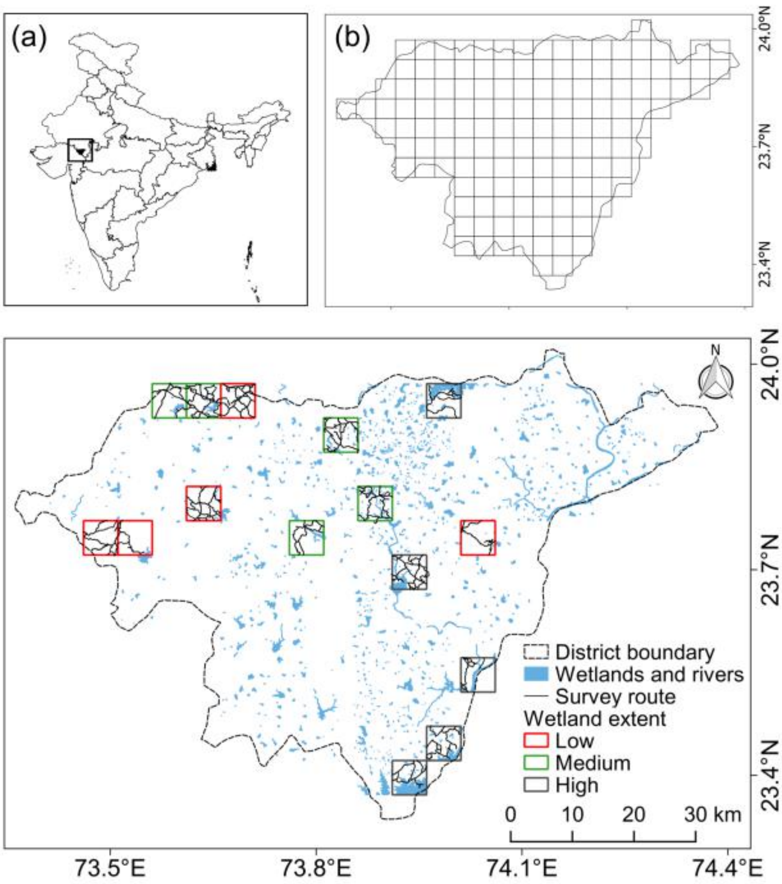

Figure 1. Location of Dungapur district in India (a). The district area was divided into a squares with 5 × 5 km (b), and 15 squares with three different wetland extents (low, medium and high) were randomly selected to study Red-naped Ibis (c). Sampling effort (roads traversed) in each square are also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

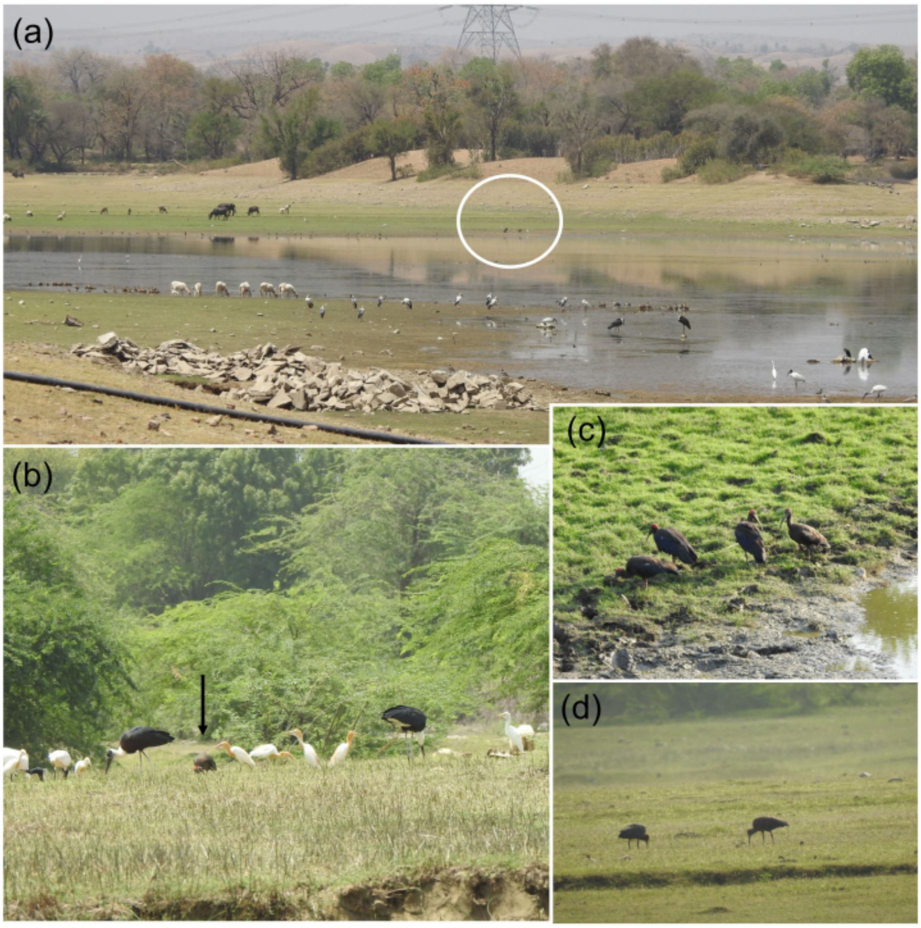

Figure 2. Observations of Red-naped Ibis using different habitats in Dungarpur district, Rajasthan. Two ibis sitting on the bank of a large wetland (a; inside white circle); single ibis foraging with other waterbirds in a fallow agriculture field (b; marked with arrow); a flock of four ibis foraging 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

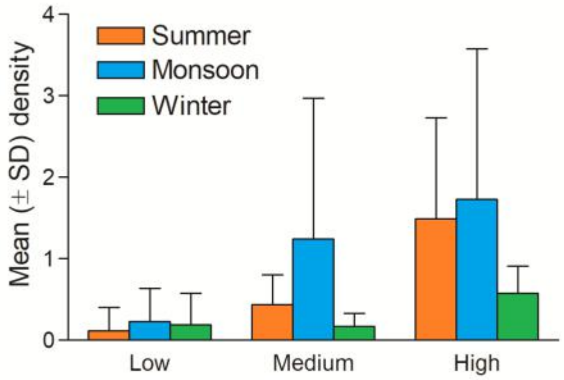

Figure 3. Red-naped Ibis seasonal density (birds per sq. km) in 5 x 5 km squares across three strata with differing wetland extent recorded in Dungarpur district, Rajasthan, India from March 2021 to January 2022.

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.

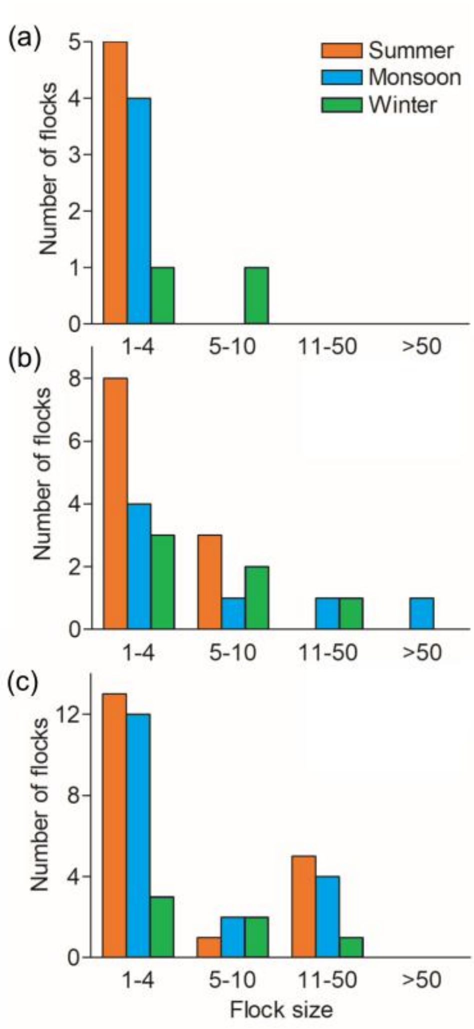

Figure 4. Red-naped Ibis flock sizes during three seasonal surveys in three strata differentiated based on wetland extent (a: low; b: medium; c: high) in Dungarpur district, Rajasthan, India.

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

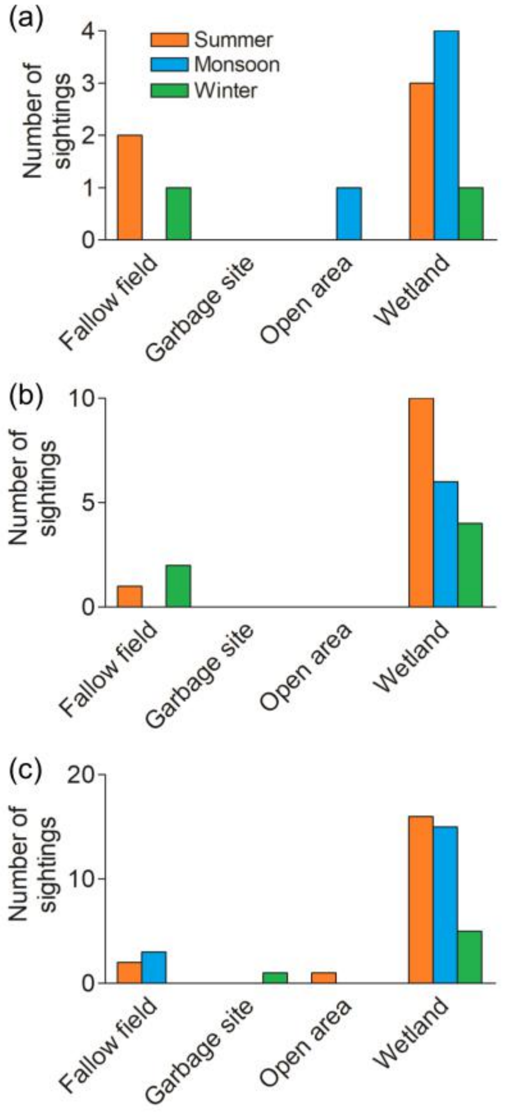

Figure 5. Red-naped Ibis seasonal habitat use in three strata differentiated based on wetland extent (a: low; b: medium; c: high) in Dungarpur district, Rajasthan, India.

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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RESEARCH ARTICLE

Red-naped Ibis *Pseudibis papillosa* density across time and space in south Asian farmlands: the influence of location, season, and rainfall

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Abstract South Asian landscapes are dominated by farmlands, crowded with high human density, experience seasonal changes in crops and retain relatively few wetlands. Nuanced understanding of resident waterbirds' responses to these conditions is increasing in individual locations, but there is sparse understanding of how species respond to conditions across the region. We surveyed five agriculture-dominated landscapes spanning nine districts across South Asia simultaneously over 2014 - 2021 to understand the habits of a poorly studied endemic Red-naped Ibis *Pseudibis papillosa*. We assessed if seasonal variations in density were consistent across locations, and if seasonal densities correlated with rainfall. Red-naped Ibis density varied greatly with location and season, with winter densities being the highest in all locations. Average density of ibis, using seasonal densities across all focal areas, was 0.7 (95% C.I. = 0.57; 0.83) which extrapolates to an estimated 20,81,868 (17,45,340; 25,41,460) Red-naped Ibis across their distribution range. Combined across the full study area, density increased as rainfall declined only during the winter ($p = 0.005$). The same relationship was seen in each district separately as well, with the relationship being statistically significant in only three districts (Kheda, Rohtak and Rupandehi; $p < 0.01$). We provide the first population estimates for Red-naped Ibis, show substantial seasonal fluctuations in density, and complex relationship with rainfall. These findings suggests that tracking population trends for this species will be challenging. Our work provides novel understanding of Red-naped Ibis biology while underscoring the utility of South Asian agricultural landscapes for yet another resident waterbird species.

Keywords Agricultural biodiversity, population estimate, rainfall, South Asia, waterbirds.

Introduction

A global understanding of the relationship between agriculture and waterbird diversity and abundance is currently incomplete and biased by many more studies in North America and Europe (Parejo and Sánchez-Guzmán 1999; Fasola *et al*. 2010; Essian *et al*. 2022). Studies of the value of agricultural areas for birds in other parts of the world are increasing, especially studies that focus on waterbirds living in Asian farmlands (Kim and Koo 2009; Roshnath and Sinu 2017; Frank *et al*. 2021). These studies are finding that many Asian farmlands sustain not only a high species richness of birds but also support substantial and healthy populations of waterbirds despite relatively high human densities and long histories of multiple cropping over the year (Sundar and Kittur 2012; Katuwal *et al*. 2022a,b; Menon and Mohanraj 2022). Contrary to what was previously assumed,

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several waterbird species use south Asian farmlands as primary foraging and breeding habitats and are supported by agriculture rather than suffer deleterious consequences due to farming (Sundar 2004, 2006, 2011; Sundar *et al*. 2016; Koju *et al*. 2019; Katuwal *et al*. 2020; Ghimire *et al*. 2021; Kittur and Sundar 2021). Many of these studies, however, are restricted to single locations making it difficult to understand if waterbirds can thrive on agricultural landscapes across their distribution range. A small but growing number of studies have begun to explore the influence of location on waterbird survival alongside farming, showcasing substantial complexities with species abundance and habitat use varying with location, despite having similar cropping patterns (Sundar and Kittur 2019; Katuwal *et al*. 2020; Kittur and Sundar 2020). These studies are underscoring the need for multi-location studies conducted simultaneously in order to fully comprehend the factors that benefit or deter species survival on agricultural landscapes. Many resident waterbird species outside north America and Europe remain poorly studied making it additionally difficult to know how individual species fare on agricultural landscapes (Gula *et al*. 2022; Marcot *et al*. 2022; Sundar 2022).

One waterbird species that has been very poorly researched is the Red-naped Ibis *Pseudibis papillosa* which is endemic to South Asia (Ali and Ripley 2007; Hancock *et al*. 1992). Species accounts of this ibis species are dominated by anecdotal observations with carefully conducted studies being rare (Soni *et al*. 2009). Based on volunteer winter counts at wetlands, the population of this species is estimated at 10,000 individuals (in Wetlands International 2023, which refers to a much older reference but provides no new revision). However, the majority of existing information shows this species to largely frequent farmlands, urban areas and other drier landscapes away from wetlands suggesting that population estimates based on counts at wetlands are likely severe underestimates (Ali and Ripley 2007; Hancock *et al*. 1992). Most of the existing studies on Red-naped Ibis have been carried out over multiple seasons offering insights into year-long habits of the species. Red-naped Ibis abundance varied greatly across seasons in each location notwithstanding the disparate settings in which studies have been carried out. Locations included an urban area (Churu city of Rajasthan state in India; Soni *et al*. 2009), a landscape influenced by floodplains dominated by farmlands (lowland Nepal; Katuwal and Quan 2022), and two semi-arid and relatively rocky landscapes where agriculture was limited (Udaipur and Dungarpur districts of Rajasthan state in India; Ameta *et al*. 2022; Asawra *et al*. 2022). Outside of urban areas, more Red-naped Ibis frequented areas dominated by wetlands relative to areas with agriculture, but largely used agriculture fields in all areas (Ameta *et al*. 2022). In another semi-arid landscape, Red-naped Ibis abundance was positively correlated with extent of wetlands on the landscape (Asawra *et al*. 2022). These studies suggest that wetland presence at larger spatial scales positively influenced Red-naped Ibis abundance in semi-arid areas, that they use wetlands as foraging habitats relatively rarely, and that they use a variety of habitats including human-dominated cities and farmlands.

Studies describing Red-naped Ibis habits outside of the semi-arid and arid areas of Rajasthan are rare. Ibis responses to seasons on wetter landscapes with seasonally varying crops are known from one study, and abundance on farmlands was the most during the monsoon or rainy season and the least during the summer (Katuwal and Quan 2022). Ibis responses to seasonal rainfall in such wetter areas is unknown. Does Red-naped Ibis density remain similar across seasons in other relatively wet landscapes since availability of wetlands is less varied relative to drier landscapes? Also, on wetter landscapes, do Red-naped Ibis respond positively to rainfall, analogous to increased wetland extent on landscapes? Finally, do these interactions with season and rainfall remain identical across multiple landscapes that have similar cropping patterns? We addressed these questions using a systematic multi-year monitoring framework spread across nine districts in lowland Nepal and north-central India between 2014 and 2021. We also developed population estimates for the species for each surveyed districts and extrapolated estimated densities to the distribution range of the species to obtain a crude, but conservative population estimate for the species.

Study area

We surveyed four landscapes in India (the contiguous Rohtak and Jhajjar districts in Haryana state, the contiguous Anand and Kheda districts in Gujarat state, Etawah district and a part of the contiguous Unnao and Rae Bareli districts in Uttar Pradesh state) and one in Nepal (covering parts of the contiguous Rupandehi and Kapilabastu districts) for Red-naped Ibis (Figure 1). Agriculture was the major land use of all focal districts with seasonally changing crops. The primary crop during the rainy or monsoon season (July to October) was rice *Oryza sativa*, followed by winter (November to February) wheat *Tritium aestivum* along with mustard *Brassica juncea* (though other crops were also planted with patterns differing by district), and most fields left fallow during the hot summer (March to June). The surveyed districts also had relatively high human densities varying from 520 to 680 people/ km^2 (Kittur and Sundar 2020). Additional details relating to district sizes, major crops planted, human population density and weather are provided in Kittur and Sundar (2020).

Methods

Field surveys

Each landscape was surveyed extensively per season between winter 2014 - 2015 and winter 2021 - 2022. One person drove slowly on a motorcycle on existing road networks in each district enumerating all encountered ibises and noting the location using a handheld GPS device (see Figure 1). Number of Red-naped Ibis in each observation was noted and survey effort (km surveyed) was recorded each season as GPS tracks.

Rainfall

Total monthly precipitation data for each of the study districts from 2014 to 2021 was downloaded from NASA Prediction of Worldwide Energy Resources (POWER) website (NASA Langley Research Center, 2022). Seasonal and annual precipitation for the survey period in each district were obtained by summing the monthly precipitation.

Analysis

We estimated Red-naped Ibis density in each district (or landscape where parts of two districts were covered) seasonally. This metric was calculated each season in each district using a conservative effective count width of 150 m on either side of the road (density = ibis counted/ (track length x 0.3 km)) similar to that used for other large waterbird species in the same region (Kittur and Sundar 2020). The entire distribution range for the species was calculated to 30,62,000 km^2 by combining distribution information available on ebird.org and BirdLife International (2022). Range distribution for the species was different in these two sources, so we combined them obtaining a crude and conservative range. Carefully estimated distribution range for Red-naped Ibis based on robust field information is not currently available. We used the average of seasonal densities (and 95 % C.I.) obtained across all focal districts to derive a central population

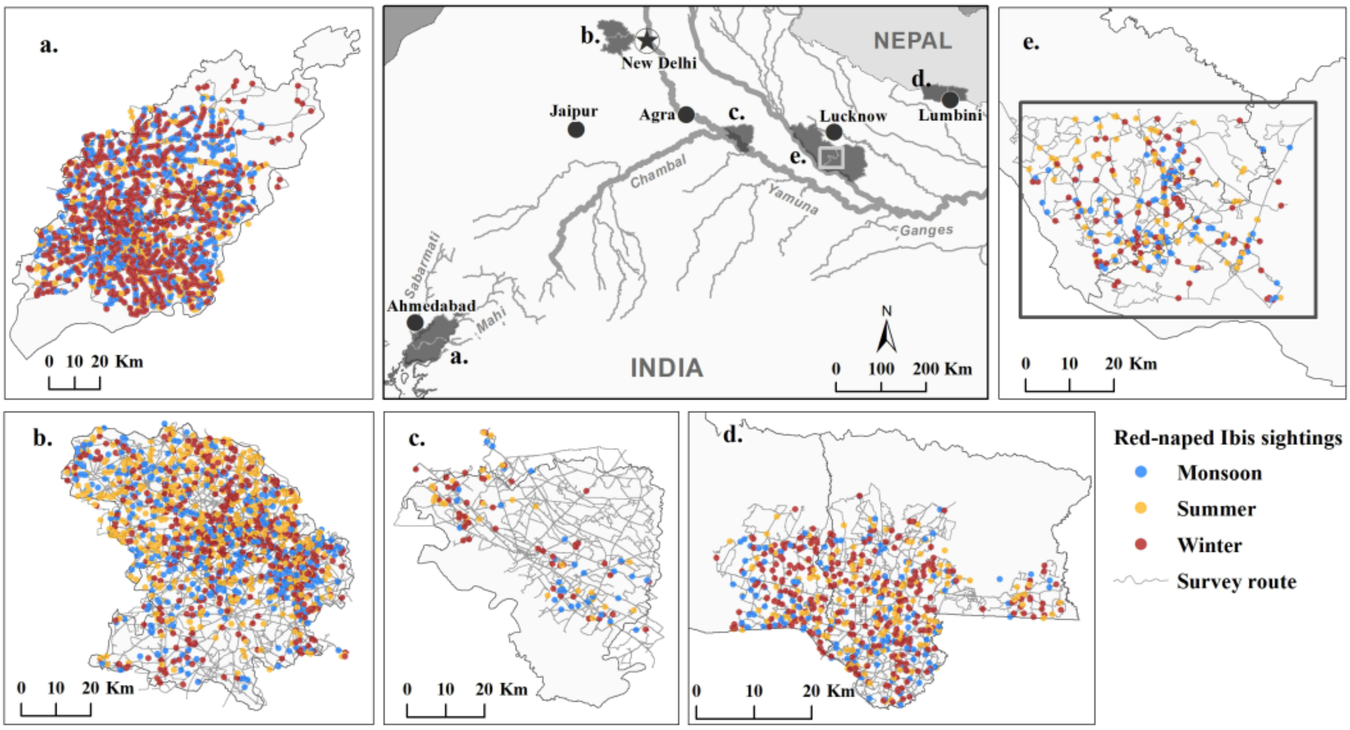

Figure 1. Map showing the districts (center) surveyed in south Asia for Red-naped Ibis from 2014 to 2022, survey routes and season-wise locations of ibises in each of the study locations: Anand and Kheda districts (a), Rohtak and Jhajjar districts (b), Etawah district (c), Rupandehi and Kapilabastu districts in Nepal (d) and Unnao and Rae Bareli districts (e).

estimate for the species across its distribution range. We could not correct for potential detection bias due to individuals conducting the counts or varying crop cover in different seasons. Additionally, surveys were not restricted to mornings and the potential role of time of day in counts due to varying behaviours was not controlled for. Computed population estimates are therefore greatly conservative. Information from these surveys have been analysed previously for other large waterbird species using the same methods (Kittur and Sundar 2020, 2021; Sundar and Kittur 2019). As discussed in previous papers, we are closely aware of and acknowledge the limitations of extrapolating abundance estimates beyond the focal work areas to the full distribution range of the Red-naped Ibis. The estimates of total abundance we present of the species are therefore to be considered coarse but are the first estimates based on multi-year robust field surveys across multiple locations and covering all potential available habitats.

We used seasonal density estimates to ask whether densities in each district varied by season. We used the non-parametric permutational ANOVA (PERMANOVA) to compare seasonal densities (at 95 % confidence levels) using the R-package 'lmPerm' (Wheeler and Torchiano 2016). We did not conduct similar statistical analyses across districts, instead used boxplots to make visual assessments. To understand if Red-naped Ibis densities were related to seasonal rainfall, we used simple linear regressions and stratified this analysis by season to understand whether relationships were consistent across seasons. Analyses were carried out for the full data set separately, and for each district separately. All analyses were carried out using the freely available R-platform.

As shown in other studies (Ameta *et al*. 2022; Asawra *et al*. 2022), it is possible that Red-naped Ibis abundance varied due to differing amounts of wetlands present. Many more wetlands were formed during the monsoon, with most of these retained during the winter, and several drying during the summer (personal observations). However, we were not able to obtain high resolution wetland maps for each district for each of the seasons. A separate analysis will be needed to assess if wetlands affected Red-naped Ibis abundance, whether these relationships changed with location, and what the relative influence is of wetlands over rainfall at each location

Results

We covered a total of 3,42,092 km of road across the 14,800 km^2 of area (total area of all the surveyed districts) between 2014 and 2022 and obtained 9,440 observations of 54,067 Red-naped Ibis (Figure 1). Except for Etawah district where Red-naped Ibis seemed spatially restricted, they were distributed widely across all the other districts in all three seasons (Figure 1). Ibises were observed using a wide variety of habitats especially fallow fields, periphery of wetlands and grassland patches (Figure 2).

Density across locations and seasons

Red-naped Ibis density was substantially higher in the western most districts, Anand and Kheda, throughout the study (Figure 3). Densities were lower but comparable in all the other locations (Figure 3; Table 1). Winter densities were consistently and significantly higher in all

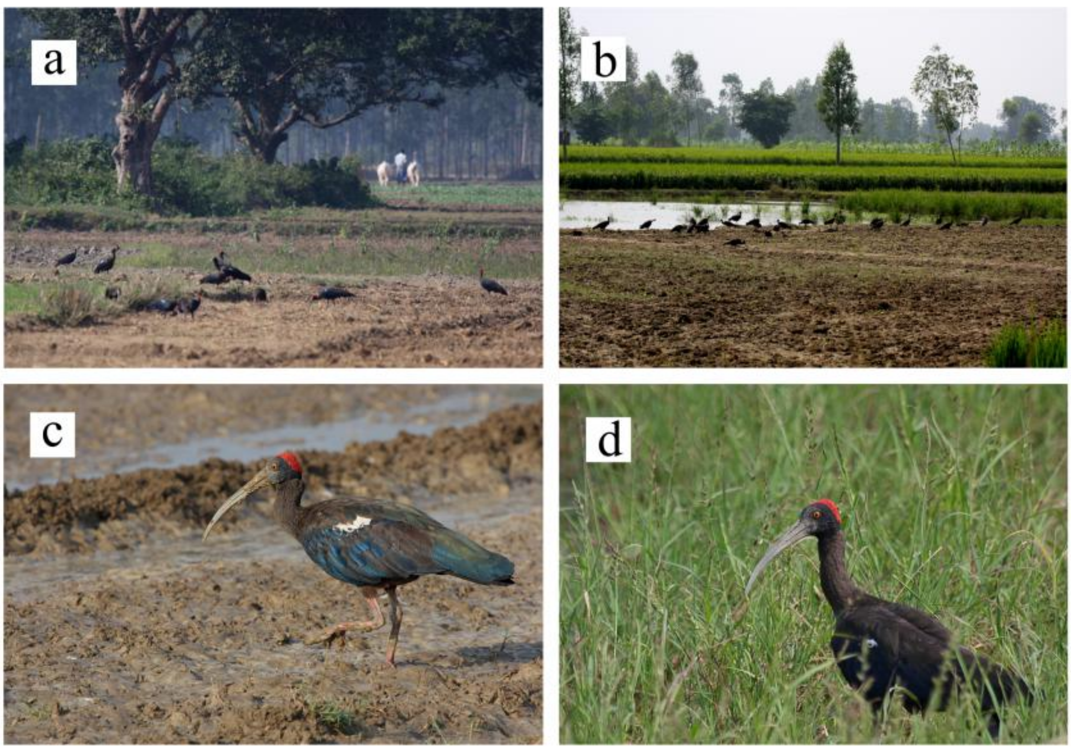

Figure 2. The general landscape and habitats used by Red-naped Ibis in the study area. Images show ibises using croplands interspersed with trees (a); fields and wetland edges (b), flooded fallow fields (c), and grassland patches amid cultivation (d). (All photographs by K. S. Gopi Sundar.).

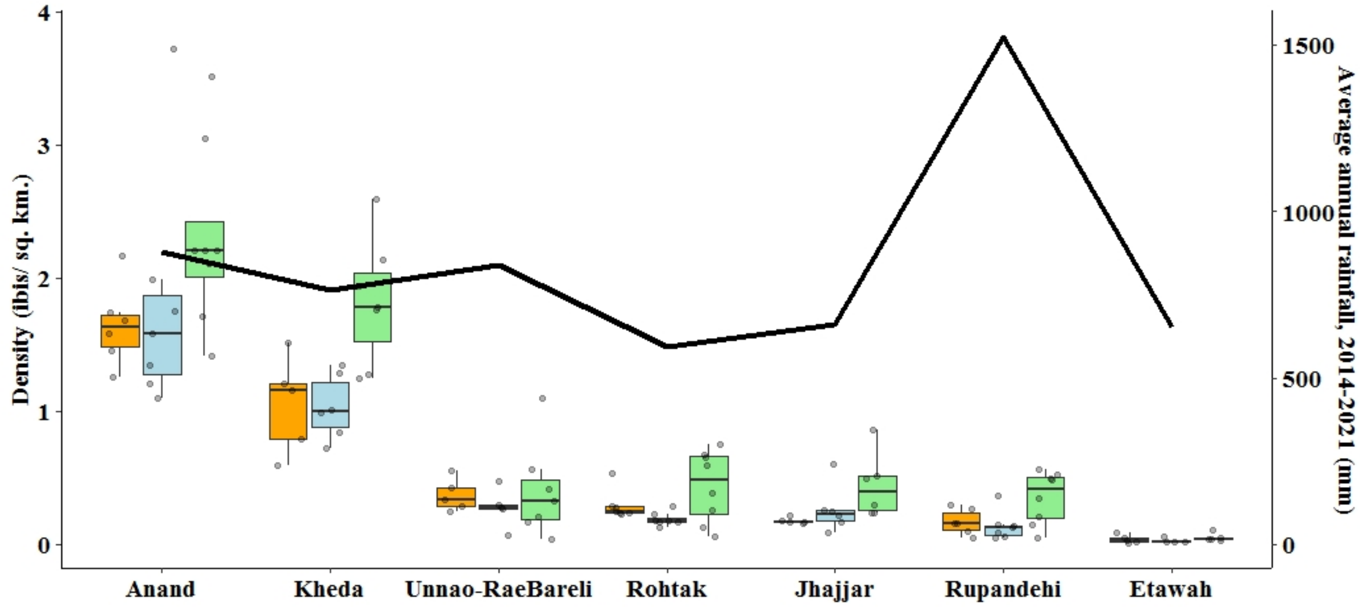

Figure 3. Box plots showing seasonal density of Red-naped Ibis (primary y-axis) and line indicating average annual precipitation (secondary y-axis) in the study districts from 2014 to 2022. The plots show median values (central horizontal line), inter-quartile range of estimates (25% and 75% respectively, lower and higher horizontal lines), and vertical lines that extend to minimum and maximum values. Jittered filled circles are estimated seasonal densities and are included to show spread of the data including outliers. Colours represent different seasons (yellow: summer; blue: monsoon; green: winter). Annual average rainfall recorded during the study period in each location is drawn to illustrate relative rainfall volumes in study sites. ("Rupandehi - Kapilvastu" has been shortened.)

locations ($p < 0.05$; Figure 3) and were similar in the other two seasons in each location (Table 1). Estimated population sizes varied greatly and inconsistently within and between seasons across locations and years (Table 1). Maximum seasonal population estimates were up to 13 times that of the minimum estimate in the same season at some locations underscoring the high degree of variation of ibis numbers even within a season (Table 1). The total population of Red-naped Ibis across the study area was estimated to be 9,053 ± 10,653 SD (range: 1,601 - 19,706). Average density of Red-naped Ibis, combining seasonal densities across all focal districts, was 0.7 (95 % C.I. = 0.57; 0.83). Extrapolating these density estimates to the full distribution range of the Red-naped Ibis provides a population estimate of 20,81,868 (17,45,340; 25,41,460) for the species.

Density and rainfall

For the full data set, Red-naped Ibis density and rainfall showed a negative association during the summer (not statistically significant) and winter (strongly significant; Figure 4). Within each district, the relationship was also negative with statistically significant relationships ($p < 0.005$) in only Kheda ($r^2 = 0.26$), Rohtak ($r^2 = 0.2$) and Rupandehi ($r^2 = 0.24$) districts.

Discussion

We present the largest field data set on Red-naped Ibis collected over multiple years using robust and repeatable field methods across multiple sites in south Asia. The analyses showcase very wide variations in density between and within locations, and also between and within seasons. Monitoring population trends of Red-naped Ibis will be challenging given these observed fluctuations.

Population sizes

We present the first estimates of density and population of Red-naped Ibis in multiple locations across south Asia. We use estimated densities to develop a coarse but conservative population estimate across the species' distribution range. All surveyed locations showed highly variable densities both within and across seasons. Clearly, a multi-season and multi-year monitoring framework will be essential to understand population dynamics of this species in any location. Two previous studies in lowland Nepal and in the Gangetic floodplains of north India used 500 m - 1 km long transects, respectively, to count Red-naped Ibis and found that ibises were uncommon (a low proportion of transects had ibises, Sundar and Kittur 2012; Katuwal and Quan 2022). In this study where we covered entire

Table 1. Estimated population sizes of Red-naped Ibis in focal districts of south Asia.

District	Survey period	Estimated population size (Average ± SD; min-max)		
		Winter	Summer	Monsoon
Anand	2014-22	6,107 ± 1,807; 3,748-9,330	4,368 ± 817; 3,340-5,754	4,807 ± 2,384; 2,908-9,877
Etawah	2014-19	110 ± 63; 66-220	81 ± 65; 13-179	62 ± 42; 35-125
Jhajjar	2016-22	816 ± 445; 438-1,595	325 ± 44; 286-399	485 ± 329; 157-1,112
Kheda	2015-22	5,872 ± 1,534; 4,010-8,384	3,393 ± 1,170; 1,921-4,883	3,334 ± 781; 2,335-4,335
Rohtak	2014-22	729 ± 444; 102-1,257	484 ± 179; 373-881	311 ± 84; 212-470
Rupandehi - Kapilvastu	2014-22	329 ± 184; 45-527	159 ± 90; 46-280	128 ± 102; 42-345
Unnao - Rae Bareli	2014-21	973 ± 853; 94-2,665	886 ± 298; 587-1,332	673 ± 347; 168-1,145

landscapes, Red-naped Ibis densities in lowland Nepal were amongst the lowest of all the locations we covered but varied with location in the Gangetic floodplains (Etawah, Unnao - Rae Bareli; Table 1). We estimated Red-naped Ibis to number in the low hundreds each in lowland Nepal and Etawah and low thousands in Unnao – Rae Bareli (Table 1). The Red-naped Ibis is clearly widely spread out across agricultural landscapes and uses a diversity of habitats including an increasing use of cities and novel foods (Ameta *et al*. 2022; Asawra *et al*. 2022; Charan *et al*. 2022; Sinha 2022). Using relatively small transects to monitor the species appears to be inefficient likely reflecting relatively large territory sizes of breeding pairs, and possibly also local movements. Similar findings have emerged for several other south Asian large waterbirds including Sarus Cranes *Antigone antigone* (Sundar 2005), Black-necked Storks *Ephippiorhynchus asiaticus* (Sundar 2004, 2005), Lesser Adjutants *Leptoptilus javanicus* (Koju *et al*. 2019; Katuwal *et al*. 2022a), and Woolly-necked Storks *Ciconia episcopus* (Kittur and Sundar 2020).

Red-naped Ibis used a large variety of habitats on agricultural landscapes (see Figure 2), and largely used crop fields in semi-arid landscapes of Rajasthan despite being attracted to areas with more wetlands at landscape scales (Ameta *et al*. 2022; Asawra *et al*. 2022). The systematic monitoring in two semi-arid districts of Rajasthan in western India provided Red-naped Ibis densities that when extrapolated to Rajasthan state would number in the tens of thousands. Estimating populations of such a species using counts made only at wetlands cannot provide realistic estimates. The extrapolated population estimate we provide for the Red-naped Ibis underscore the severe underestimation in existing literature, identical to findings for other large waterbird species that largely use agricultural landscapes like the Woolly-necked Stork (Kittur and Sundar 2020). The scale of underestimation for Red-naped Ibis (previously estimated to be 10,000; Wetlands International 2023, and our estimate is 20,81,868) is far higher relative to the underestimate that was made for Woolly-necked Storks (previously estimated to be ~ 30,000, and our revised estimate was 2,38,685; Kittur and Sundar 2020). A major consideration of existing population estimates of large waterbirds in literature appears to be the assumption that agriculture is not conducive to the survival of waterbirds. There is now increasing evidence to the contrary from a number of disparate landscapes and species (Parejo and Sánchez-Guzmán 1999; Fasola *et al*. 2010; Sundar 2006, 2011; Sundar and Kittur 2012; Roshnath and Sinu 2017; Koju *et al*. 2019; Koli *et al*. 2019; Kittur and Sundar 2021; Frank *et al*. 2021; Katuwal *et al*. 2022a,b). Multi-year evaluations on Asian farmlands in some areas are also showing numbers of breeding birds to be increasing or remaining largely unchanged, contrasting sharply with declining trends of birds observed on North American and European farmlands (Lin *et al*. 2023). Moving ahead, ornithological literature requires to avoid providing “guesstimates” of population sizes and avoid incorrect ecological assumptions related to trends of bird populations on farmlands. Avoiding such assumptions will assist in improving evidence-based evaluations and can help highlight species that require scientific attention.

Red-naped Ibis densities in the western most districts, Anand and Kheda, were much higher than the other locations where ibis densities were comparable (Table 1; Figure 3). Anand and Kheda also had very high numbers of a sympatric ibis species, the Glossy Ibis *Plegadis falcinellus* (Sundar and Kittur 2019). However, these two districts had amongst the lowest estimated densities of the Woolly-necked Stork relative to the other surveyed districts (Kittur and Sundar 2020). It appears that different factors influence densities of different large waterbird species in each

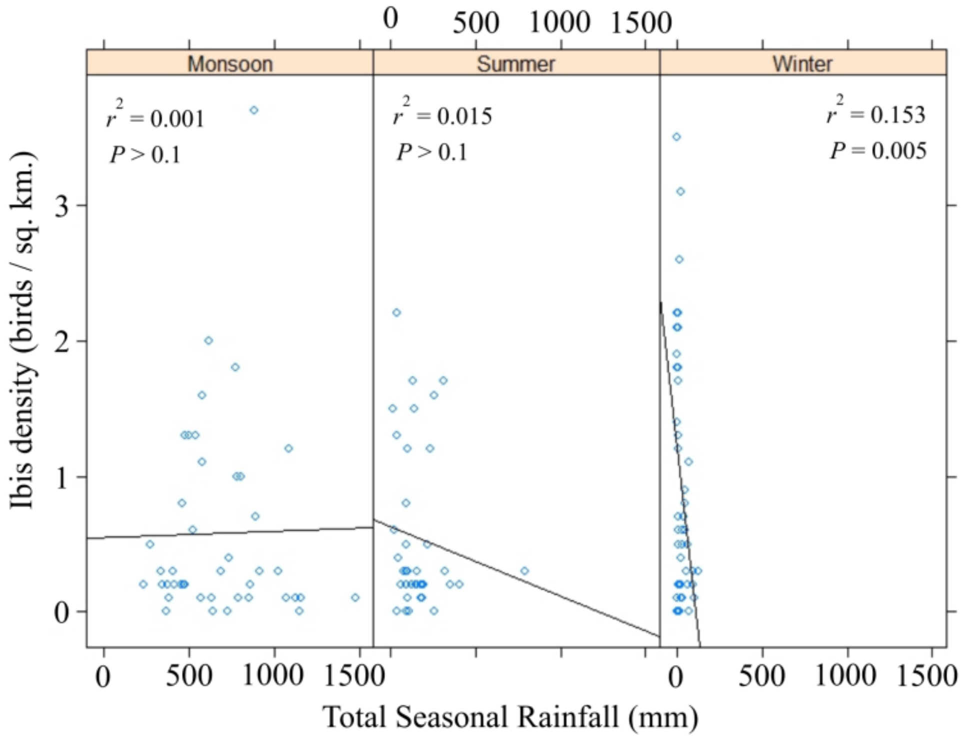

Figure 4. Lattice plots showing relationships between density of Red-naped Ibis and rainfall in three seasons for nine districts of lowland Nepal and north-central India between 2014 and 2022. Dots are seasonal density estimates in districts and simple linear regressions were used to draw lines.

location. Species-specific studies are needed across multiple locations to help locate factors influencing local abundances of waterbird species.

Density and rainfall

The relationship between Red-naped Ibis density and rainfall has not been previously assessed. We show that summer and monsoonal rainfall had no significant influence on seasonal densities in any location, but increased rainfall during the winter was associated with lower densities suggesting local movements in at least three districts (Table 1; Figure 4). Other sympatric large waterbirds also show identical patterns suggesting that seasonal conditions on south Asian farmlands influence habits of several resident species similarly (Sundar 2004, 2006; Sundar and Kittur 2019; Kittur and Sundar 2020; Katuwal *et al*. 2022a). One potential explanation for higher winter densities in all locations is that breeding takes place during the preceding monsoon, and family groups potentially increase local densities during the winter. Red-naped Ibis movements and breeding habits, however, have not been systematically studied anywhere in south Asia. Such studies on resident waterbird species promise to be of great value to understand how waterbirds use farmlands in this region.

Methodological caveats of this study

As briefly described in the Methods section, this study has several methodological shortcomings that bear repetition and discussion. Densities were computed using an effective width of 150 m on either side of the road, which was what we used for other large waterbirds (Kittur and Sundar 2020). Our observations in the field, however, indicated that most Red-naped Ibis sightings were much closer to the road and that an effective width of 150 m on either side of the road provides conservative estimates of density (unpublished information). Additionally, the counts were done without measuring and controlling for detection bias that could vary due to crop height and other aspects related to each location. However, the landscapes had the least crop cover during the summer, but the highest counts were consistently during the winter when the landscape was covered with crops suggesting that a systematic seasonal bias in detection was likely not present or minimal (personal observations). Finally, the distribution range we used to obtain range-wide population estimates combined publicly available information from two sources. The reliability of information from either source is unknown. The combined range was bigger than the range estimated from each source separately. In this study we did not constrain field work to mornings and do not correct for ibis' behaviour (e.g. roosting in trees during the mid-day, personal observations). However, this bias was consistent across all locations, and we suspect that contrasting relative estimates between locations and seasons are still useful to provide an understanding of ibis habits. All estimates were derived without correcting for various biases suggesting that the total population sizes we present are likely to be underestimates. Studies that can incorporate additional methodological nuances such as detection bias can provide improved population estimates.

Conclusions

The Red-naped Ibis is an endemic waterbird species that has not received too much scientific attention. Our work and existing primary literature show that the species is very widely distributed across south Asia, is abundant in most locations, and uses a diverse range of human modified settings. Emerging findings are showcasing complexities related to changes in seasonal densities. The relatively high abundance of the species on human modified areas renders it a useful species to conduct studies that can showcase the idiosyncrasies of south Asian landscapes where people and a few waterbird species appear to live alongside each other. Such work will help provide additional evidence to move away from generic assumptions regarding the supposed inability of waterbirds to survive alongside human presence

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SHORT COMMUNICATION

Nectar in the diet of the Red-naped Ibis *Pseudibis papillosa*

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Abstract I report observations of Red-naped Ibis *Pseudibis papillosa* feeding on the nectar of *Bombax ceiba* in Delhi city. This appears to be the first observation of any ibis species feeding on nectar. Between 2020-2023, one juvenile and two adult Red-naped Ibis were seen seemingly taking nectar from the flowers of *Bombax ceiba* beside a busy road in New Delhi. Spare little has been written on the habits and requirements of the Red-naped Ibis, and my observations support previous observations of this ibis species changing food habits depending on availability. My observations also adds to growing evidence of the importance of cities and urban trees for this species.

Keywords *Bombax ceiba*, Delhi, nectaring.

Introduction

The Red-naped Ibis *Pseudibis papillosa* is a widespread and common waterbird species endemic to south Asia (Ali and Ripley ; Hancock *et al*. 1992). However, it remains one of the least studied waterbird species of the world, though there is now an increasing number of studies and anecdotal observations on its habits that are helping to build a better picture of its requirements (Ameta *et al*. 2022; Juvvadi 2022; Tere 2022). Natural history observations on the behaviour of this species are surprisingly sparse despite the value of such observations to help construct initial understanding of such poorly studies species (e.g. Charan *et al*. 2022; Tere 2022). In this note, I describe a new item in the diet of this species.

Study Area and Methods

Observations were made in the city of Delhi, India in an *ad-hoc* fashion between 2020 and 2023 while documenting the bird species that visited flowers of *Bombax ceiba* – a native, common tree species planted across the city (pers. obs.). The *B. ceiba* in Delhi were observed to flower synchronously once a year in February and March (pers. obs.). This allowed regular monitoring of the same trees over multiple years by planning visits during this flowering period. Delhi is among the largest mega-cities in the world that is rapidly expanding but retains high bird diversity in large part due to the extensive tree cover and other remnant habitats that are retained across the city (Tiwary and Urfi 2016; Rawal *et al*. 2021).

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Results

In March 2020, I discovered a flock of Red-naped Ibis roosting on two *B. ceiba* trees on the side of Africa Avenue, a busy road with heavy traffic flow in South Delhi. On March 18, 2020, I began regular observations of birds visiting the flowers by standing across the road and conducting observation through binoculars and a camera. On March 19, I observed and documented a juvenile Red-naped Ibis (recognized by the absence of bright red on the head; Figure 1) dipping its bill delicately and repeatedly into flowers. The ibis was not destroying the flowers, like a bird seeking insects would likely do. Instead, it was apparently

Figure 1. Juvenile Red-naped Ibis feeding on nectar from *Bombax ceiba* flowers on 19 March 2020 in Delhi. The series of photographs shows the bird gently dipping its bill into the flower rather than tearing into it as insectivores sometimes do. (Photographs taken from a video shot by Neha Sinha.)

feeding on the nectar of the *B. ceiba* flowers. The bill dipping occurred multiple times over 5 seconds and was filmed. The bird poked the flower gently with its bill, then opened its bill inside the flower. It would then repeat probing of the flower, and opening of the bill. At this time, there were a total of five ibises on the tree. Adult ibises kept flying and returning intermittently, while the juvenile ibis remained on the tree feeding on nectar. I observed the birds for forty minutes. Longer observation periods were not possible as the birds were only visible from the side of the road where traffic was a hazard.

On 20 March 2020, I returned to find an adult ibis feeding on nectar from the *B. ceiba* flowers of the same tree (Figure 2). I watched the birds for forty minutes again. I also watched the birds on 21 March 2020 for forty minutes. Eleven ibis were present on the tree but no feeding or nectar taking was observed, potentially because the birds were being mobbed by House Crows *Corvus splendens* (Figure 3). Further observations could not be made in March 2020 because of the global COVID-19 pandemic and the subsequent lockdown in Delhi.

I visited the same trees multiple times in 2021 and 2022 during March. The ibises were not present during all visits, but when present, nectar feeding from flowers was not observed in these years. In 2023, blossoming of *B. ceiba* occurred a little earlier than usual (pers. obs.) and I returned on 24 February 2023 to the same location for additional observations. Seven Red-naped Ibis were on the tree (Figure 4), with two more perched on a streetlamp beside the tree. An adult Red-naped ibis was observed feeding on nectar of *B. ceiba* flowers for about three seconds (Figure 5). Very good photo documentation was not possible because of heavy road traffic.

Figure 2. Adult Red-naped Ibis feeding on nectar from *Bombax ceiba* flowers on 20 March 2020 in Delhi. (Photograph by Neha Sinha.)

Discussion

Nectar has never been observed to be a dietary item of the Red-naped Ibis, or any ibis species (Ali and Ripley ; Hancock *et al*. 1992). Observations on the diet of Red-naped Ibis have been greatly uncommon and every new publication on diet

Figure 3. Eleven Red-naped Ibis roosting on the *Bombax ceiba* tree on 21 March 2020 in Delhi. They were being mobbed by House Crows. (Photograph by Neha Sinha.)

Figure 4. Seven Red-naped Ibis roosting on a *Bombax ceiba* tree on 24 February 2023 in Delhi. There were four birds in the large branch on the extreme right side. (Photograph by Neha Sinha.)

appears to add new dietary items suggesting that this species' habits are far more plastic and variable than previously understood (Charan *et al*. 2022). *B. ceiba* has been common in many parts of Delhi for a long time. The tree has been observed to produce seedlings naturally but has also been a long-favoured horticultural tree for parks and roadsides in Delhi (pers. obs.). It is therefore plausible that the Red-naped Ibis have been taking nectar from this tree species before my observations, though I was unable to find any photographic or literary record of this behaviour. My observation of a juvenile Red-naped Ibis taking nectar for a longer period than adults raises the possibility that younger birds of this species are more adventurous or flexible in their feeding habits. From my observations over four years, it is clear that Red-naped Ibis feed on nectar regularly and that this was not a temporary or a one-time occurrence. Since I visited trees in the same location, and because Red-naped Ibis are likely territorial (K. S. G. Sundar, pers. comm.) and were seen on the same tree, it is possible that I observed the same adults and their young of multiple years. It is, however, likely that this habit will now spread as young ibises disperse, as is common in several waterbird species, and ibis feeding on flowering trees in Delhi may well become common in the near future.

The observation also adds to increasing number of observations of Red-naped Ibis using cities, villages and other human-dominated areas such as farmlands for critical activities such as breeding and feeding (Charan *et al*. 2022; Juvvadi 2022; Katuwal and Quan 2022; Tere 2022). Though broadly described as being a "waterbird", these new observations underscore previous observations that the species can adapt to diverse conditions, including learning to secure a new food source in one of the most populated cities of the world. Given the delicate nature of bill dipping into the flower (see Figure 1), it seems highly possible that the Red-naped Ibis is a novel pollinator of *B. ceiba* and that my observations likely provide a new example of mutualism. Discoveries of such multi-species interactions in heavily crowded urban areas or other human-modified areas such as agricultural landscapes are greatly uncommon. One recently discovered example was that of Woolly-necked Stork *Ciconia episcopus* nests being commensally reused by Dusky Eagle-owls *Ketupa coromanda* in an ancient but intensively farmed landscape in northern India (Sundar *et al*. 2022). The small but growing number of documentations of such multi-species interactions from south Asian urban and farmland landscapes are suggestive of the absence of directed persecution of large waterbirds such as the Red-naped Ibis by people.

Feeding habits of few ibis species around the world have been carefully studied, and none have ever been seeing eating nectar (Hancock *et al*. 1992). *B. ceiba* has been observed being used by the Olive Ibis *Bostrychia olivacea* as a roosting tree, but there are no published records of nectar feeding (Hancock *et al*. 1992). Vegetarian items in ibis diet appears to be generally very rare. Ali and Ripley (2007) reported finding mushy vegetative material in stomachs of Black-headed Ibis *Threskiornis melanocephalus* in India. Soni (2008) reporting Red-naped Ibis feeding on groundnuts *Arachis*

Figure 5. Adult Red-naped Ibis feeding on nectar of *Bombax ceiba* flowers on 24 February 2023 in Delhi. (Photograph by Neha Sinha.)

hypogaea and other crops in India. My observations of Red-naped Ibis feeding on nectar are the only other known instance of ibises feeding on vegetarian items. All existing vegetarian feeding of ibises are currently from India suggesting that increasing observations on ibis behaviour in other locations around the world is likely to add more such examples.

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