

Density, flock size and habitat preference of Woolly-necked Storks *Ciconia episcopus* in agricultural landscapes of south Asia

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Abstract Crowded agricultural landscapes of the tropics and sub-tropics are assumed to be responsible for the decline of many waterbird species. This includes Woolly-necked Storks, one of the least studied large waterbirds, with no long-term multi-scale information on its ecology. In this study we provide densities, population size, flock size and habitat use of the species in agricultural landscapes across seven districts in lowland Nepal and India using the largest available field data set of Woolly-necked Stork observations ($N = 8,906$ individuals in 3,133 flocks observed seasonally between 2014 and 2019). With this data, we asked whether these metrics showed variation by season and location. Woolly-necked Stork densities fluctuated considerably, both with season in each location and across locations. Estimated population of Woolly-necked Storks in the study area was $1,689 \pm 922$ (SD) which extrapolated to the known distribution range of the species in south Asia provided a coarse population estimate of $2,38,685 \pm 1,24,471$ (SD). Woolly-necked Storks were seen mostly in small flocks of 1-4 birds (86% of flocks) with few extraordinarily large flocks. Flocks were significantly larger in Jhajjar and Kheda districts, in winter, and in fallow fields and wetlands. Most Woolly-necked Storks were observed in agriculture fields (64% of 1,874 observations) with much fewer in wetlands (9%). In three locations where seasonal habitat use was measured, Woolly-necked Storks varied habitat use seasonally in all locations. Of six locations where habitat preference was assessed, storks preferred wetlands in five locations. Results of this study suggest that the largest known global population of this species is resident in agricultural landscapes, and coarse population estimates suggests that the population size of this species was previously underestimated. Results also showed considerable variations in flock size and habitat use with location and season suggesting that Woolly-necked Storks show plasticity in response to changing conditions on agricultural landscapes. These findings will be helpful to revise the species' status assessment and understanding its conservation requirements.

Keywords Agricultural landscapes, lowland Nepal, north India, population estimate.

Introduction

Expanding agriculture in south Asia with conversion of natural habitats and is ranked as one of the most important threats to waterbirds (Sundar and Subramanya 2010). One of the

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species that was recently elevated to the status of "Vulnerable", partly due to assumptions that its forest and undisturbed wetland habitats were being lost to agriculture, is the Woolly-necked Stork *Ciconia episcopus* (BirdLife International 2020). This stork species is one of the least studied large waterbirds globally with a vast majority of information on its ecology constituting anecdotal observations (BirdLife International 2020; Sundar 2020). Until very recently, Woolly-necked Storks

were assumed to need undisturbed areas such as forests with wetlands or large protected wetland reserves. The number of studies documenting behaviour and other ecological aspects of Woolly-necked Storks in south Asia is growing and contrary to existing assumptions, points to the species being widespread, common and resident in agricultural landscapes (Sundar 2006; Pande *et al.* 2007; Katuwal *et al.* 2020; Sundar 2020; Tiwary 2020; Ghimire *et al.* in press). Information on the species' habits in agricultural areas is still piecemeal with existing studies covering a miniscule proportion of its distribution range, and field observations made over relatively short periods of time (Sundar 2006; Pande *et al.* 2007; Ghimire *et al.* in press). Detailed information on ecological aspects of Woolly-necked Storks over multiple years or multiple locations is still missing, and it is not yet clear if they are able to use agricultural areas similarly across their distribution range.

The only existing study conducted over a full year on this species is from Etawah district, Uttar Pradesh, India that showed Woolly-necked Storks to have seasonally varying densities and flock sizes, with the highest of both being recorded during winter months (Sundar 2006). Storks in Etawah used several components of the agricultural landscape including fallow fields, fields with standing crops, irrigation canals, and seasonal grasslands. The storks appeared to respond to seasonal changes in conditions by shifting to different habitats. Behavioural observations in lowland Nepal across two seasons showed Woolly-necked Storks changing time spent foraging in crop fields over seasons with less time spent foraging in winter wheat crops relative to monsoonal rice paddies reflecting higher forage quality of wheat fields (Ghimire *et al.* in press). A shorter study conducted over two seasons in Maharashtra and Karnataka also found the highest flock sizes of Woolly-necked Storks in winter months, with flocks of up to 80 storks seen using unprotected wetlands (Pande *et al.* 2007). All of these studies showed storks commonly using agricultural, unprotected wetlands, and storks in Uttar Pradesh using wetlands proportionally more than available (or preferring this habitat; Sundar 2006). It remains unclear if variations exist in other locations and whether

these storks use agricultural landscapes and unprotected wetlands similarly throughout their distribution range in south Asia.

In this paper, using the world's largest field data set on Woolly-necked Storks collated between 2014 and 2019 simultaneously from seven different agricultural landscapes in lowland Nepal and India, we detail several aspects of the species' ecology. The agricultural landscapes we covered included the Gangetic floodplains in lowland Nepal and Uttar Pradesh in India where Woolly-necked Storks and other large waterbird species occur in relatively high numbers despite the high human population of the region (Sundar 2006; Sundar *et al.* 2019; Ghimire *et al.* in press). We also include information from additional agricultural landscapes in the Indian states of Haryana and Gujarat from where information on large waterbirds is sparse. All the areas we explored had agriculture as the major land use, but differed in the crops planted seasonally, had differing proportions of major seasonal crops, and varying human densities (Table 1). All the seven landscapes experienced dramatic seasonal variations in conditions due to a combination of cropping patterns and weather conditions. Collectively, therefore, the data offers a unique view of how one species – the Woolly-necked Stork – fares in different locations all of which are dominated by agriculture, but are disparate with respect to important aspects such as crops and human densities that are known to impact large waterbirds at landscape scales (Sundar and Kittur 2012). We focus on three ecological aspects of the stork that have been documented in previous studies namely density, flock size, and habitat preference. Specifically, we ask if these three ecological aspects varied with location, and whether measures of these three aspects showed variations across years and seasons reflecting altering conditions on the landscape.

Despite a near-total absence of robust field studies with which to derive an informed assessment, their population size across south and south-east Asia is estimated to be 25,000 (Wetlands International 2020). It is not clear how this estimate was reached but was likely biased by the growing number of reports of threats to the species in south-east Asia where it is severely threatened by hunting and habitat loss (BirdLife International 2020). In this



paper, using seasonal densities, we compute population estimates of Woolly-necked Storks at each location. As a crude exercise, and being aware of the potential to over-estimate the population using simple density estimates (e.g. Blanco *et al.* 2012; 2014) we extrapolate measured density estimates to the species' south Asian distribution range to obtain the first evidence-based population estimate for the species in south Asia.

Study area

Woolly-necked Storks were surveyed in six districts in India and one in lowland Nepal. Five districts in India were covered nearly completely (Anand, Etawah, Jhajjar, Kheda, Rohtak), one was covered in part along with a part of the adjoining district (Unnao-Rae Bareli in Uttar Pradesh), and a part of the neighbouring districts of Rupandehi and Kapilavastu were covered in lowland Nepal (see Figure 1). We refer to the Unnao-Rae Bareli landscape as "Unnao" and the Rupandehi-Kapilavastu landscape as "Rupandehi" in this paper. Several characteristics of the focal districts are presented in Table 1. All districts were predominantly agricultural (72 – 89% of area under agriculture), with three seasonal crops cultivated over the year. Major crops in these districts were rice

during the rainy season or the monsoon (July-October), wheat and mustard during the winter (November–February), and varied crops such as vegetables and pulses in few fields during the summer (March–June) with many fields remaining fallow due to the summer heat. These landscapes also supported extremely high human densities of between 520 to 680 people/km² (Table 1). Along with agriculture and scattered towns/villages, these landscapes also hosted several types of wetlands including large perennial reservoirs, seasonal marshes, small scattered ponds used for fish farming, village ponds used to graze livestock, and water from all these wetlands were used for irrigation. A number of natural resources such as fish and lotus stems were manually extracted from wetlands by local people. Anand district in Gujarat also had coastal wetlands but we did not survey these since Woolly-necked Storks were never observed using coastal areas. Most of the landscapes also had streams and rivers flowing through them or on the edges and supported patches of scrub forests and grasslands along the river and scattered across the countryside. All of the focal districts experienced very wet monsoons and the countryside experienced flooding during this season. Summer was the driest and hottest period and all of the seasonal wetlands dried out. Patches of the landscapes were, however, still wet during the summer due to leakages from extensive networks of irrigation canals. These canals provided habitats to storks and other birds practically throughout the year and also added to the

Table 1. Characteristics of the seven districts surveyed for Woolly-necked Storks in lowland Nepal and India. Statistics are taken from Government of India and Government of Nepal websites including from departments relating to national census, agriculture and weather (Indian National Census 2011). We used total area under crops to list the primary crops grown in each district. Climate statistics were downloaded in 2018 and relate to the period 1995-2015. Survey effort lists the cumulative total km traversed for surveys from which data have been used in this paper.

District	Size (km ²)	Human population	Primary crops	Climate (min-max temperature in °C; average rainfall)	Survey effort (km)
Anand	3,204	20,90,000	Rice, wheat, tobacco, banana	21-33°C; 882 mm	27,838
Etawah	2,331	13,39,870	Rice, corn, wheat, potato	7-43°C; 930 mm	40,593
Jhajjar	1,834	9,57,000	Rice, cotton, wheat, millet	9-45°C; 290 mm	55,268
Kheda	3,959	22,98,900	Rice, millet, wheat, pulses	20-34°C; 830 mm	22,781
Rohtak	1,668	10,58,700	Rice, millet, wheat, sugarcane	2-45°C; 580 mm	54,213
Rupandehi	1,360	8,80,200	Rice, wheat, mustard, sugarcane	12-44°C; 530 mm	43,211
Unnao	4,589	31,10,590	Rice, corn, wheat, vegetables	8-44°C; 850 mm	18,165



hydrological complexity of the landscape.

Methods

Field surveys

In each district, one observer traversed the road network of the district once in each season ensuring complete coverage by using overlaid grids of 5'x5' (approximately 10x10 km) and covering similar lengths of road in each grid. Due to a limited road network in all districts, some roads had to be covered more than once to allow access to all of the grids. Observers carried hand-held GPS units that recorded the survey routes providing a measure of effort for all districts in all seasons. All sightings of Woolly-necked Storks were noted with details of location and number of birds. Starting from winter 2016-2017, observers were trained to also collect data on the habitat in which storks were observed. Habitats were categorised broadly into five types: standing crop, fallow fields (fields after crops had been harvested or uncultivated crop fields), wetlands (lakes, ponds, marshes, and for this manuscript, also included sightings in canals and rivers), trees, and other (included sightings in all other habitats including on artificial structures as well as flying birds).

Habitat availability

To obtain a measure of habitat availability in each district, cloud-free Landsat 8 imageries taken between October and November 2016 were procured (U.S. Geological Survey 2016). Imageries were classified into broad classes (wetlands, habitation, agriculture, trees, scrub and open) using unsupervised classification (Iso-data clustering), to assign pixels into the above classes using ERDAS Imagine version 9.1 (Hexagon Geospatial 2006). Area of Interest (AOI) polygons created by onscreen digitization using Google Earth images were used to reclassify incorrectly classified pixels to the correct classes. Additional details of the classification process are given elsewhere (Sundar *et al.* 2019). Imageries were classified at 30 x 30 m resolution. The overall classification accuracy of the districts varied between 92 and 96%. To match with field observations, the 'wetland' class included natural and artificial ponds, lakes and other water bodies, rivers and canals. However, we clumped standing crop and fallow fields into one 'agriculture' class due to difficulties in assessing their accuracy. For the purpose of this paper habitation, scrub and open classes were merged into the 'other' class. The class 'tree' included orchards, forests and scattered tree patches.

Data analyses

Throughout this document, we present results as average \pm SD. We also present numbers using the south Asian convention of 2,2,3 digit grouping where a million is written as "10,00,000".

A majority of the storks were counted within 150 m on either side of the roads in all the districts, and we use this measure as the transect width. Length of survey (in km) recorded in GPS units multiplied by the transect width provided the area surveyed. Density was computed as storks/ km² each season at each location. We used non-parametric ANOVA tests to test if density varied by season and location, and whether density varied by season within each location. Non-parametric tests freed us from the strict requirements of data distributions and heteroscedacity required for the use of parametric tests. For permutation tests, we used function 'aovp' in R-package 'lmPerm' (Wheeler and Torchiano 2016).

Density computations were conservative as they included all land uses that were traversed using the road network in each district without biasing effort to cover or avoid certain habitats. Additionally, we did not measure and correct for potential variability of detection due to habitat or observer. We estimated populations of Woolly-necked storks for each district using seasonal densities and total area covered. We averaged densities across seasons to arrive at a mean density and the standard deviation (SD) to represent variation in stork numbers in each district. Though we include information over 15 seasons for some locations, densities were computed in all locations for only seven of these seasons due to logistical reasons (see Figure 1). Densities were averaged across all locations only from these seven seasons. We calculated the total area of the distribution range of Woolly-necked Storks in south Asia as 21,62,359 km² using the map provided by BirdLife International (2020). Extrapolations were made for seven seasons separately and an average and SD population estimate of Woolly-necked Storks in south Asia was obtained from these. Despite being coarse, we consider this estimate to be conservative for two reasons. First, estimated densities were for entire districts including towns and villages where Woolly-necked Storks are extremely rare (personal observations). Second, while Woolly-necked Storks are well distributed across the entire distribution range drawn by BirdLife International (2020), they also occur beyond this range (see Gula *et al.* 2020) suggesting that the distribution range we used was itself an underestimate. The extrapolated population estimate, however, should be treated as preliminary since such estimates can frequently have a very wide range and can also be over-estimates (Blanco *et al.* 2012; 2014).

Both flock size and habitat use of waterbirds can vary due to time of day. In this study, field surveys in all the seven districts extended across the day and we do not consider time of day in analyses. It will be useful to conduct additional studies of Woolly-necked Storks to assess the importance of time of day on these two metrics. Woolly-necked Storks were considered to be in a single flock when multiple birds foraged together, or when they used a single wetland. We computed average (\pm SD) flock sizes seasonally for each district. Flock



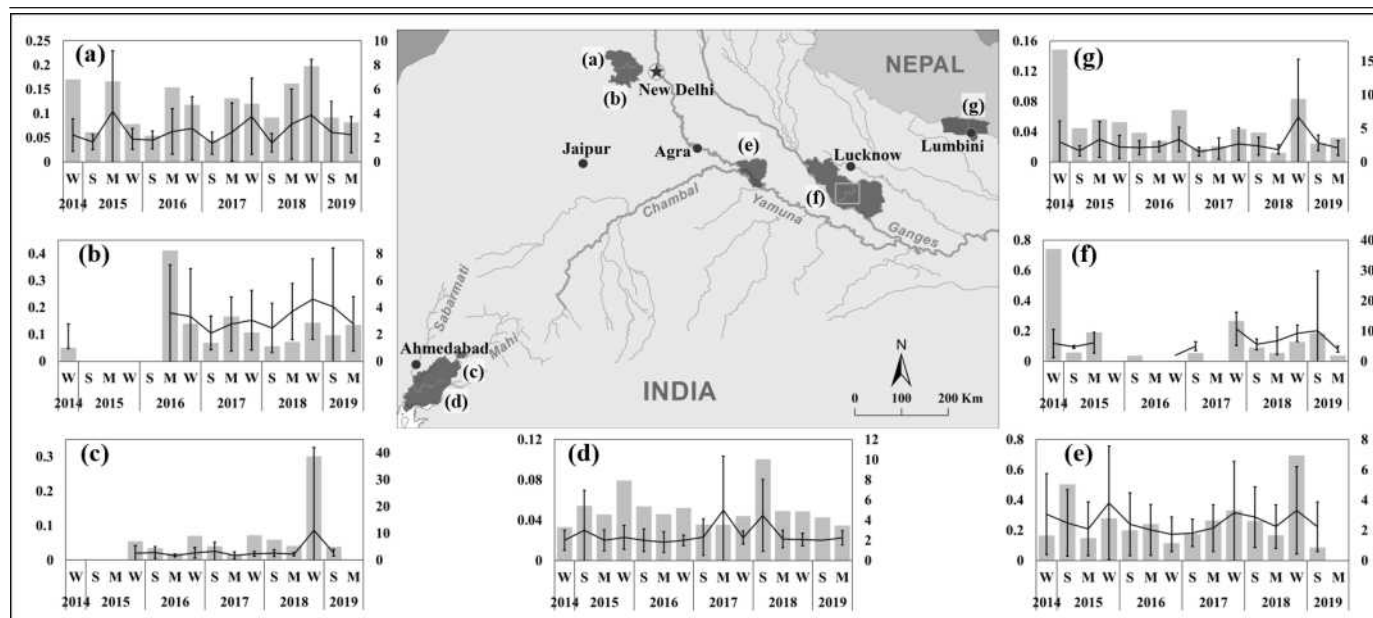


Figure 1. The map shows the locations of the focal districts (dark grey polygons) in lowland Nepal and India. Graphs show measured seasonal densities (bars relate to primary y-axis; M - monsoon, S - summer, W - winter) and flock sizes (average \pm SD; lines relate to secondary y-axis) of Woolly-necked Storks in each district. Missing data signifies periods when field work was discontinued. Districts are: (a) Rohtak, (b) Jhajjar, (c) Kheda, (d) Anand, (e) Etawah, (f) Unnao and (g) Rupandehi.

size distributions were skewed towards smaller flocks, so we employed non-parametric permutation ANOVAs with R-package ‘lmPerm’ to test for differences in mean flock sizes. We tested for differences individually between locations, season, and year and for two-way interactions between these three aspects. Using a smaller data set (see Methods above) we also assessed if flock sizes varied between habitat types, and tested for two-way interactions between habitat and season, and habitat and location to understand if flocks varied solely due to habitat or whether additional variables also influenced flock sizes of Woolly-necked Storks in different habitats. For all tests of flock sizes with habitat, two unusually large flocks were removed from the data prior to the analyses.

We computed both seasonal and aggregate habitat use by Woolly-necked Storks using a smaller data set starting from the winter of 2016-2017. Each observation was used as a data point and not each stork since individual birds in a flock are not independent. Seasonal habitat use was constructed for three districts where we obtained over 400 individual records of habitat use. We used Fisher’s exact tests (R Core Team 2019) to test if number of observations of Woolly-necked Storks using individual habitat types varied across seasons.

Using the habitat data from field surveys and land cover data from classified imageries we applied the use-availability framework of Manly *et al.* (2004) to understand if Woolly-necked Storks exercised habitat preference and avoidance. For this analyses, we aggregated all stork sightings in each district and contrasted these against a one-time measure of habitat availability. We used function ‘widesl’ in R-package “adehabitat” (Calenge 2006) which uses measurements

of habitat use and availability to estimate preference at the population level without requiring data from marked animals. The method also requires each observation to be independent and therefore we used number of observations and not the number of storks sighted in each habitat. The algorithm computes the Manly selectivity measure allowing tests of habitat use at two scales. The first scale is for the overall data set estimated using log-likelihood χ^2 (or the ‘Khi2L’ statistic of “adehabitat”) to test the hypothesis that all habitats were used randomly. Next, selection ratios (use/ available) were estimated for each habitat and differences between the ratios were tested using pairwise Bonferroni tests. These allowed a formal assessment of whether each habitat was preferred (used more relative to availability), avoided (used less relative to availability) or used in proportion to availability (Manly *et al.* 2004).

Results

This study includes monitoring across 15 seasons from winter 2014 to monsoon 2019. However due to logistical reasons surveys in some seasons could not be carried out in some of the districts (see seasons with missing values in Figure 1). A total of 8,906 Woolly-necked Storks were observed in 3,133 flocks, with habitat use noted for 1,874 observations.

Density and population estimates

Woolly-necked Stork density varied widely seasonally in each location and across locations (Figure 1, Appendix). The overall average density



was $0.12 (\pm 0.13)$ storks/km². Density was significantly different with location ($p < 0.001$) and season ($p = 0.01$). However, at each location, density did not vary significantly with season ($p = 0.46$). The estimated population of Woolly-necked Storks cumulatively in the seven districts was $1,689 \pm 922$ (SD). The lowest estimated population was in the relatively small area covered in lowland Nepal with 30 ± 22 Woolly-necked Storks. The largest populations were estimated in Etawah (522 ± 368) and Unnao (303 ± 464) districts, but with considerable seasonal variations in estimated numbers. The districts in Haryana also had fairly high estimated populations of Woolly-necked Storks with Rohtak (192 ± 79) having more estimated storks than Jhajjar (179 ± 194) district. Districts closer to the coast had intermediate estimated populations with Kheda (161 ± 239) having a slightly higher number of storks compared to Anand (150 ± 53) district. Extrapolated to the distribution range in south Asia, the species' population estimate was $2,38,685 \pm 1,24,471$ (SD) across south Asia.

Flock size

Woolly-necked Storks were usually seen in small flocks of 1 to 4 birds (86%) and only 2.5% of flocks were more than 10 birds. Average flock size

pooled across all the areas and all seasons was 2.8 ± 3.5 (SD). Seasonal averages for each location are detailed in the Appendix. Two unusually large flocks were observed during systematic surveys: 66 (Unnao, summer 2019) and 114 (Kheda, winter 2018-19). Another large flock of 120 storks was sighted in Etawah district in December 2014 (winter) during an ad-hoc visit. Flock sizes showed significant differences across years, seasons and landscapes ($p < 0.001$; Figure 1). Flock sizes were also significantly different across seasons within a year ($p < 0.001$) and across landscapes each year ($p < 0.001$). Finally, in each landscape they also showed significant seasonal variation ($p < 0.001$). Seasonal average and SD for flock sizes are shown as lines in Figure 1. Flock sizes were also significantly different across habitat types with the largest flocks observed in fallow fields and wetlands ($p < 0.001$).

Habitat use and preference

In all locations, most of the Woolly-necked Stork observations were in agriculture fields (64% of observations were in standing crop and fallow fields; Figure 2), and very few were seen in wetlands at each location (9% of total observations). The aggregated data did not show significant variations in habitat use across different

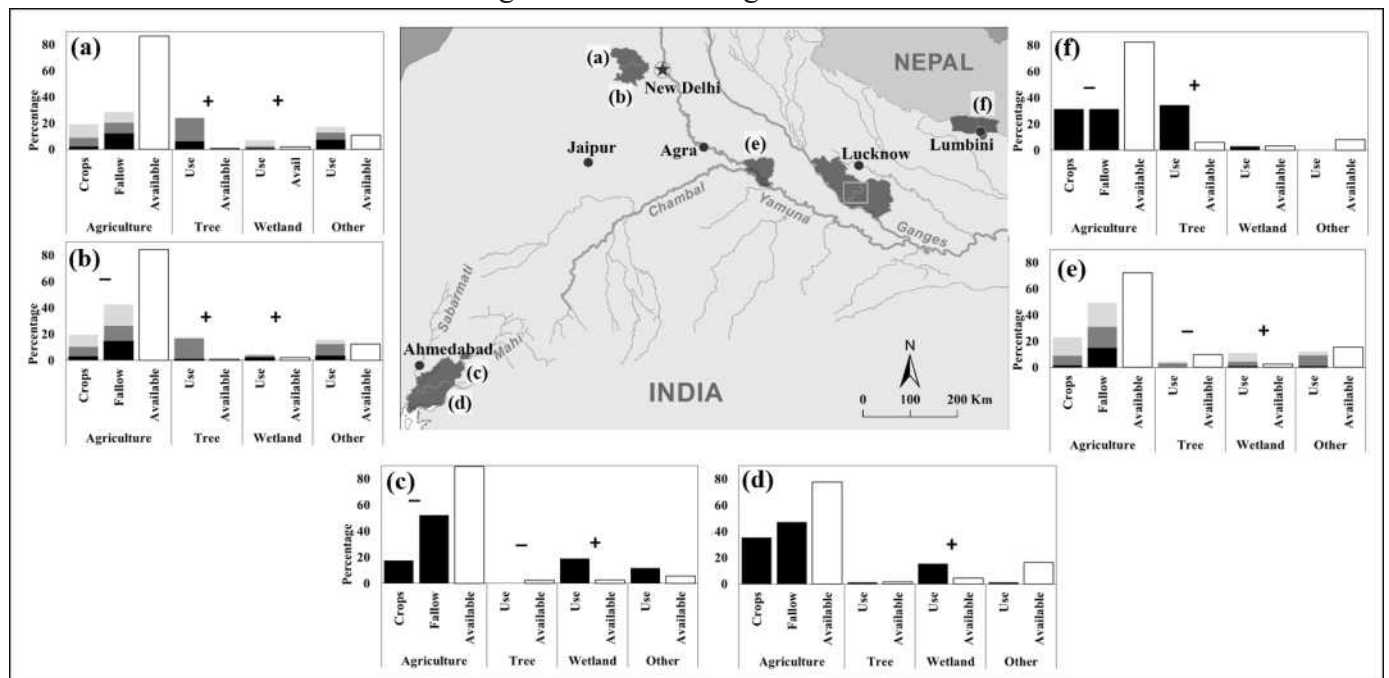


Figure 2. Graphs show habitat use (coloured bars) by Woolly-necked Storks and available habitat (white bars) in districts (dark polygons in map) surveyed over multiple seasons. Symbols indicate whether a particular habitat type was preferred (+) or avoided (-) using a use-availability framework. When habitats were used in proportion to their availability, no sign is provided. For three districts with > 400 observations each of storks using habitats, proportional contribution of habitat use in each of three seasons (black: summer; dark-grey: monsoon; light-grey: winter) are shown as stacked bars. Districts are: (a) Rohtak, (b) Jhajjar, (c) Kheda, (d) Anand, (e) Etawah and (f) Rupandehi.



locations ($p = 0.48$) but showed significant seasonal variations ($p < 0.001$) in habitat use. In the three districts with > 400 observations each of habitat use (Etawah, Jhajjar, Rohtak), Woolly-necked Storks used significantly different habitats seasonally in each of the three districts (Figure 2; $p < 0.001$).

Agricultural fields were the dominant land use in all surveyed districts, with wetlands and trees being relatively rare (see Figure 2). Woolly-necked Storks preferred wetlands in nearly all the locations and avoided agriculture in three districts, using them in proportion to availability in the other districts (Figure 2). Trees were strongly preferred in three districts (mostly used during the monsoon), avoided in two and used in proportion to availability in the remaining district (Figure 2).

Discussion

Measured metrics of Woolly-necked Storks varied greatly with location and season. This suggests that these storks exhibit behavioural plasticity likely in response to changing conditions on agricultural landscapes. Densities varied significantly with location and season, but at each location, seasonal densities were not significantly different despite some variation being apparent (Figure 1, Appendix). This suggests that Woolly-necked Stork population are largely resident with some local or regional movements of birds. These movements do not appear to be consistently in one season since highest measured densities were in winter in some locations (e.g. Etawah; Appendix) and monsoon in others (e.g. Jhajjar). The least number of Woolly-necked Storks were seen in summers and monsoons (see Appendix) suggesting that some local movement may occur in response to water availability. These findings match previous observations in Etawah (Sundar 2006). Overall density in Etawah in this study (average of 0.26 ± 0.16) was lower than the estimated density in 2000-2001 (0.41 ± 0.4 ; from Sundar 2006). This reduction in densities is likely to be related to the coverage of the district, with a lot more area covered during this study relative to the few roads covered in 2000-2001. Findings suggest that metrics such as density and population size estimated over short periods of time are unlikely to provide a reasonable understanding of the local or regional status of Woolly-necked Storks.

Woolly-necked Storks occurred largely in flocks of < 4 birds suggesting that these birds largely occur as pairs or small family groups. Extraordinary sizes of flocks were rare but exceeded a hundred storks foraging together in wetlands and in crop fields. Flock sizes, however, appear to vary substantially across season, year and location suggesting that this metric may not be a suitable representative of landscape quality. Significantly large flocks occurred in both fields and wetlands additionally suggesting that Woolly-necked Storks are versatile foragers on agricultural landscapes. Unusually large flocks occurred in more than one season with the timing suggesting that these can occur in response to fledged chicks (winter flocks) and in response to drying wetlands (summer flocks). Observations therefore match suggestions in previous studies (Sundar 2006; Pande *et al.* 2007), but indicate that Woolly-necked Storks may respond to both and not any one stimuli across its distribution range. One caveat of our study was the inability to factor in time of day in the analyses of flock sizes. Large waterbirds such as storks often aggregate in the afternoons after foraging in the mornings (pers. obs.). However, it is not known if such aggregations occur similarly across seasons and locations for Woolly-necked Storks.

Woolly-necked Storks were mostly observed using agricultural fields in all the districts which is contrary to existing information (BirdLife International 2020). Tree use during the monsoon increased in a few districts matching breeding seasonality of this species. Differences in districts and in seasons could also be due to observer bias, though field associates were usually very careful and were very highly trained. Another potential reason for observed variability in use of different habitats could be detection bias, and a separate measurement of this bias can help with correcting potential errors. Additionally, large waterbirds could use different habitats with time of day – a variable that we have not included in the analysis for this paper. Multi-season multi-location information on habitat use is absent for most bird species in south Asia. For Woolly-necked Storks, our analyses confirms that this species is capable of considerable plasticity in habitat use on agricultural landscapes. Their habit of being resident alongside their ability to be plastic in using disparate habitats in all of the study locations suggests that this species is likely to adjust to similar suitable agricultural areas. This finding is contradictory to many past treatises that suggest



that increase in agriculture is detrimental to Woolly-necked Storks. Our findings offer hope that this is one of the few large waterbird species whose long-term status is likely stable and positive notwithstanding expanding agriculture in south Asia.

Similar multi-year multi-seasonal studies on the Glossy Ibis (*Plegadis falcinellus*) in two of the districts that were included in this study (Anand and Kheda) showed considerable seasonal and annual differences in densities and flock sizes (Sundar and Kittur 2019) suggesting that Woolly-necked storks are not unique in being able to use south Asian agricultural landscapes. Additional studies are needed in south Asian agricultural landscapes and elsewhere to understand if other large waterbirds species are similarly well adjusted to these seasonally changing landscapes.

It is not clear what the past population estimates of 25,000 for Woolly-necked Storks in south and south-east Asia is based on, but this work suggests that it was a severe underestimate. We are aware and acknowledge that our estimate of $2,38,685 \pm 1,24,471$ Woolly-necked Stork is coarse. However, as we have explained in the Methods, this estimate is unlikely to be an over-estimate. The relatively wide bias in the estimate is a consequence of the seasonal and locational variations of stork densities, but are appropriate in the absence of better designed larger-scale studies. The current distribution range of the Woolly-necked Storks in south Asia needs to be expanded (see Gula *et al.* 2020) and improved methods that can explicitly control for potential biases due to observers and time of day are needed. Our population estimate for the species is therefore to be regarded as a conservative and preliminary estimate.

Our findings collectively suggest that the Woolly-necked Stork cannot continue to be considered a “Vulnerable” species. The new population estimate and the findings that agricultural landscapes are not necessarily detrimental for the species should both be considered for an update of the species’ status. Our findings also showcase the value of remnant scattered wetlands on south Asian agricultural landscapes for large waterbirds such as Woolly-necked Storks. Woolly-necked storks seem to have complex and varied flocking and habitat use patterns and appear to be an erstwhile-ignored study model to help understand how human-modified landscapes can be useful as

bird habitats.

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Appendix. Density (birds/ km²) and flock size (average ± SD and range) of Woolly-necked Storks in six districts in Nepal and India. Values are average ± SD, along with the range (in parenthesis). Estimates were derived for each season after pooling data across all years of field work for that season at each district. Sample sizes for each district are provided for both metrics below district names (total number of storks encountered for density; total number of flocks for flock sizes).

District	Monsoon	Summer	Winter	Total
Density				
Anand (426)	0.04 ± 0.01 (0.03 to 0.05)	0.06 ± 0.03 (0.04 to 0.1)	0.05 ± 0.02 (0.03 to 0.08)	0.05 ± 0.02 (0.03 to 0.1)
Etawah (3,034)	0.21 ± 0.06 (0.15 to 0.26)	0.25 ± 0.16 (0.09 to 0.5)	0.32 ± 0.23 (0.12 to 0.69)	0.26 ± 0.16 (0.09 to 0.69)
Jhajjar (2,059)	0.2 ± 0.15 (0.07 to 0.41)	0.07 ± 0.02 (0.06 to 0.1)	0.11 ± 0.04 (0.05 to 0.14)	0.13 ± 0.1 (0.05 to 0.41)
Kheda (403)	0.03 ± 0.01 (0.01 to 0.04)	0.04 ± 0.01 (0.03 to 0.06)	0.12 ± 0.12 (0.05 to 0.3)	0.07 ± 0.08 (0.01 to 0.3)
Rohtak (1,843)	0.14 ± 0.03 (0.08 to 0.17)	0.07 ± 0.02 (0.04 to 0.09)	0.14 ± 0.05 (0.08 to 0.2)	0.12 ± 0.05 (0.04 to 0.2)
Rupandehi (540)	0.03 ± 0.02 (0.01 to 0.06)	0.03 ± 0.01 (0.02 to 0.04)	0.08 ± 0.04 (0.04 to 0.15)	0.05 ± 0.03 (0.01 to 0.15)
Unnao (601)	0.1 ± 0.08 (0.04 to 0.19)	0.09 ± 0.06 (0.04 to 0.18)	0.28 ± 0.32 (0 to 0.74)	0.15 ± 0.2 (0 to 0.74)
Flock size				
Anand (181)	2.2 ± 1.7 (1 to 13)	2.7 ± 2.4 (1 to 12)	2.1 ± 0.8 (1 to 5)	2.4 ± 1.8 (1 to 13)
Etawah (1,208)	2.1 ± 1.6 (1 to 16)	2.4 ± 1.9 (1 to 20)	3 ± 3 (1 to 20)	2.5 ± 2.3 (1 to 20)
Jhajjar (641)	3.1 ± 2.6 (1 to 22)	2.9 ± 3 (1 to 24)	3.6 ± 2.9 (1 to 24)	3.2 ± 2.8 (1 to 24)
Kheda (116)	2 ± 0.8 (1 to 4)	2.8 ± 2 (1 to 11)	4.3 ± 14.3 (1 to 114)	3.5 ± 10.5 (1 to 114)
Rohtak (702)	2.8 ± 2.6 (1 to 20)	1.9 ± 1.5 (1 to 18)	3.2 ± 3.3 (1 to 30)	2.6 ± 2.6 (1 to 30)
Rupandehi (201)	2.4 ± 1.6 (1 to 9)	2 ± 1.1 (1 to 5)	3.5 ± 4.3 (1 to 30)	2.7 ± 2.9 (1 to 30)
Unnao (84)	6 ± 3.4 (1 to 17)	7 ± 12.4 (1 to 66)	7.9 ± 5 (2 to 21)	7.2 ± 7.7 (1 to 66)

