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Effectiveness of road transects and wetland visits for surveying Black-necked Storks *Ephippiorhynchus asiaticus* and Sarus Cranes *Grus antigone* in India

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I surveyed Black-necked Storks *Ephippiorhynchus asiaticus* and Sarus Cranes *Grus antigone* in Etawah and Mainpuri districts, Uttar Pradesh, India, by carrying out counts at five wetlands and along a 105-km road transect each month from December 2000 to February 2002. The results were compared to the known population sizes in the area as determined from spot-mapping of territories. On average, road transects detected 17.9% of Black-necked Storks and 35% of territorial Sarus Crane pairs. Densities and encounter rates from road transect data correlated with known numbers of Black-necked Storks. For Black-necked Storks, pairs were more likely to be detected than families, whereas the converse was true for Sarus Cranes. Wetland sites held only 20.5% of Black-necked Storks and 8.9% of territorial Sarus Crane pairs (although wetlands held 65% of non-breeding cranes). Consequently, wetland counts alone were not found to be effective for surveying these two species. On average, they recorded only 1.3% of all Black-necked Stork pairs. Too few Sarus Crane pairs were reliably identifiable in wetlands to determine their sighting probability. Road transects that pass wetland sites and that are carried out in late winter will provide the most accurate data for both species.

INTRODUCTION

Developing suitable methods to estimate population sizes and monitor numbers of rare or declining species is an important priority in addition to direct interventions to improve the conservation status of such species. In India, waterbirds are presently censused as part of the Asian Waterfowl Census (AWC), in which volunteers count birds at wetlands known to be important as wintering sites for migrating waterfowl. These counts provide estimates of local abundance for both migratory and resident species (Perennou *et al.* 1994, Lopez and Mundkur 1997, Li and Mundkur 2004), and can help determine population changes if sufficient sites are visited consistently each year. Information from these winter counts are used to determine the status and population trends of many resident bird species including Black-necked Stork *Ephippiorhynchus asiaticus* and Sarus Crane *Grus antigone*. The results of the AWC show that both species are apparently declining. For Sarus Cranes, this is supported by counts at individual sites, e.g. at Keoladeo-Ghana National Park (Bharatpur), Rajasthan, numbers declined from 283 in 1983 to 19 in 2004 (K. Kumar verbally 2004). Sarus Cranes have also been censused using road transects in many locations in India, but different studies have presented information differently, making direct comparisons difficult (Choudhury *et al.* 1999, Mukherjee 2000, Sundar *et al.* 2000a,b, Kaur *et al.* 2002). Declines are thought to be driven primarily by deterioration in the condition of wetlands (Gole 1989, Rahmani 1989, Meine and Archibald 1996, BirdLife International 2001). Intensification of agriculture is progressing at an alarming rate, particularly in the Gangetic floodplain (Ramankutty and Foley 1999) where most of the population of Sarus Crane and Black-necked Stork occur outside protected areas (Rahmani 1989, Sundar *et al.* 2000a, Archibald *et al.* 2003, Sundar 2003, Sundar and Choudhury 2003).

The reliability of wetland counts or road transects for estimating population sizes and trends for these two species is unknown. Some characteristics of both species make them amenable to testing the efficiency of survey techniques without marking birds individually. Both are long-lived and strongly territorial, maintaining permanent territories in areas with perennial sources of water (Elliott 1992, Ishtiaq 1998, Maheshwaran 1998, Maheshwaran and Rahmani 2002, Sundar 2003, Sundar and Choudhury 2003). These characteristics, however, may make it difficult to estimate reliably population sizes and trends from counts only at wetland sites, since both species are also found in non-wetland agricultural areas (Mukherjee 2000, Mukherjee *et al.* 2002, Sundar 2003, Sundar and Choudhury 2003).

In this paper, I test the reliability of wetland counts and road transects to monitor populations of both species, and investigate whether there are seasonal variations in the effectiveness of these methods, in order to determine the appropriate season to survey them.

STUDY AREA

I conducted the study along the border of Etawah and Mainpuri districts in Uttar Pradesh, India, in an area of c.50 km^2 bounded by the towns of Etawah, Saiphai, Karhal, Sauj, Kurra, Saman, Sarsai Nawar and Baralokpur. The region consists of a mosaic of natural wetlands and agricultural fields interspersed with human habitation (see Sundar 2003, 2004 for detailed descriptions of the study area). The region experiences three seasons: summer (March to June), monsoon (July to October) and winter (November to February). Five large wetlands are found in the area: Saman Bird Sanctuary (the only protected area), Sauj, and three sites that dried up for 2–5 months each year: Kudaiyya, Kurra and Hasil. All five sites had similar levels of human disturbance. Each site had one resident pair of Black-necked Storks and varying numbers of breeding pairs of Sarus Cranes. All five sites could also be viewed along a 105 km road transect running through Etawah, Saiphai, Kudaiyya, along the Karhal–Kishni road via Gaad to the Etawah–Farrukhabad road, and from Lohia to Takhrau.

METHODS

To determine the actual number of breeding pairs of Sarus Crane and Black-necked Stork present, spot-mapping of unmarked territorial pairs of both species was carried out from December 1999 to January 2002. During this period, 48 juvenile Sarus Cranes were colour-banded with standard plastic colour bands. Observations of these birds were used to determine territory size (up to 50 ha) and to confirm that it was possible to differentiate at least some pairs by location. For Black-necked Storks, repeated observations of pairs feeding, numbers of chicks with them, and active nests were used to confirm the location and number of pairs (Sundar 2003). Since young Black-necked Storks began to disperse when they were approximately one year of age, birds of at least that age that were not seen for more than a month were considered to have dispersed. For Sarus Cranes, such assumptions could be avoided because the species's smaller territory size ensured that knowledge of the population was always nearly complete. Information on the number and location of single birds, pairs, and families of both species were monitored regularly, giving monthly estimates of the total population. The proportion of birds present in the area that were missed during spot-mapping and omitted from the total was likely to have been negligible.

Black-necked Storks could be differentiated into single birds, adult pairs with no young, and families. Sarus Cranes were present as resident pairs and families, plus flocks of up to 400 non-breeding birds which used larger wetlands to roost and forage (Sundar and Choudhury 2003).

The road transect was undertaken each month from December 2000 to February 2002, once the identity and location of territorial pairs along the route had been identified. Roads are often perceived as sources of disturbance to many bird species, although they are often also used to census bird populations (Sauder *et al.* 1971, Arnold 1994). In the study area, there was no hunting of either species by humans and both species were remarkably tame. Traffic levels on most roads in the study area were low and it was common to see both species along them. Transects were carried out in the first week of each month on non-rainy and non-foggy days. They began within an hour after sunrise (05h00–07h30) and stopped at 10h30. The whole route was covered on two consecutive mornings. A motorbike with an additional observer was driven at 25–40 km/h and all storks and cranes encountered on either side of the road were counted. At wetlands, we stopped for up to five minutes at a spot where the whole wetland was visible, and counted all cranes and storks.

Visibility from the road varied each month owing to growth of crops. The width of each transect was therefore measured at kilometre intervals as the distance to the farthest visible point (up to 1 km) on either side of the road using a Bushnell range finder. These values for both sides were averaged to give a measurement of effective transect width. The population density of both species was then calculated as number of individuals divided by length × effective width of the transect. For Sarus Cranes, density was calculated separately for territorial pairs and non-breeding birds. Encounter rate (birds seen/km) was also calculated for both species, as previous studies have used both density (Gole 1989) and encounter rate (Sundar *et al.* 2000a).

To calculate the effectiveness of road transects, I calculated the percentage of the known number of individuals (Black-necked Storks) or known territorial pairs including families (Sarus Cranes) that was recorded on each transect. The different approach for the two species was because Black-necked Storks are usually seen as single birds (Sundar 2004) whereas Sarus Crane pairs seldom separate. For Sarus Cranes, a subset of resident pairs were reliably identifiable by their location and by colour-banded young. Mean sighting probabilities (mean number of transects on which each pair was seen relative to the total number of transects) were calculated for Sarus Crane pairs with and without young. For some Sarus Crane pairs, sighting probability was compared during months when they were with vs. without young.

Prior to analyses, all data were checked for normality (Kolmogorov-Smirnov one-sample tests) and transformed appropriately when they were not (proportion and sighting probability data were arcsine transformed and other data were log[n+1] transformed). When this failed to normalise the data, non-parametric tests were used on untransformed data. Seasonal differences in monthly densities were compared using a one-way analysis of variance (ANOVA). Linear regression was used to compare the relationship between density (or encounter rate) and the known population each month for Black-necked Storks (but not for Sarus Cranes, as the total population could not be determined each month). Differences in sighting probability of pairs and families were tested using Wilcoxon rank-sum tests; seasonal differences in sighting probability were compared using one-way ANOVAs; difference in sighting probability within pairs owing to breeding status were tested using a paired t-test. Data are presented as mean±SE throughout, both calculated from untransformed data. Statistical tests were carried out using S-PLUS 2000 (MathSoft 1998–1999).

RESULTS

Black-necked Stork

The total population of storks as determined by spot mapping (including pairs, families and young that had dispersed from their natal territories) averaged 52±1 individuals (range: 46–56 individuals) each month. On

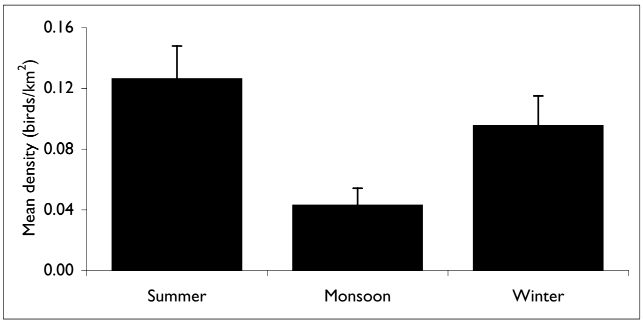

Figure 1. Seasonal differences in the population density of Black-necked Storks *Ephippiorhynchus asiaticus* calculated from monthly road transects. Error bars show 1 SE.

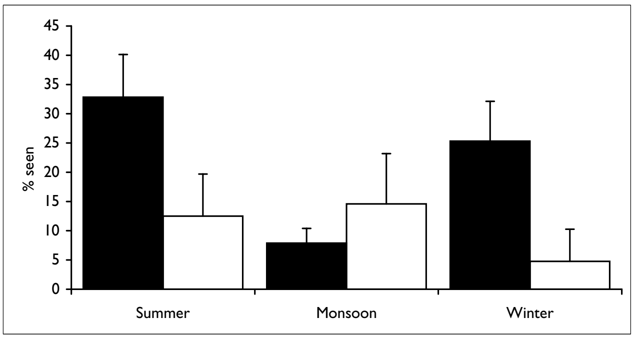

Figure 2. Seasonal differences in the effectiveness of road transects in detecting Black-necked Storks *Ephippiorhynchus asiaticus* as quantified by the mean percentage of known pairs (solid bars) and families (open bars) detected on each transect. Error bars show 1 SE.

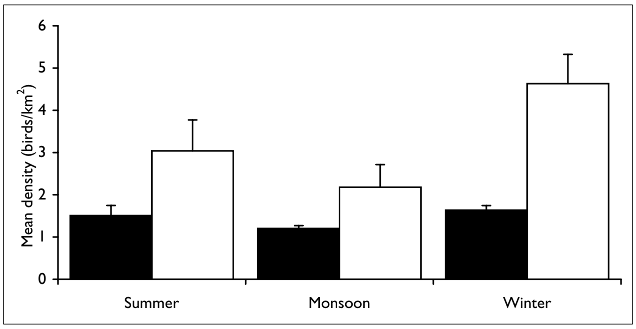

Figure 3. Seasonal differences in the population density of Sarus Cranes *Grus antigone* calculated from monthly road transects. Solid bars show values for resident pairs; open bars show values for all birds including non-breeding individuals. Error bars show 1 SE.

road transects, 17.9±2.6% (range: 2–35%) of the population were recorded on average. The mean density (0.099±0.01 birds/km^2) appeared to be highest in summer and lowest in the monsoon, but these differences were not significant (Fig. 1; one-way ANOVA: $F_{1,13}$=1.71, P=0.21). The monthly estimates of density and encounter rate were significantly positively correlated with the known population size (density: r^2=0.36, P=0.018; encounter rate: r^2=0.37, P=0.016). The mean percentage of pairs (including single adults from known pairs) seen during each transect (mean=33.6±5.8%; range=3.8–68.4%) was significantly higher than the mean percentage of families (mean=9.4±3.6%, range=0–33.33%; Fig. 2; Wilcoxon rank-sum test: Z=3.13, P=0.0017, n=15). There were no significant differences between seasons in the percentage of pairs recorded on transects (Fig. 2; one-way ANOVA: $F_{1,13}$=1.18, P=0.3), nor in the percentage of families recorded on transects (Fig. 2; one-way ANOVA: $F_{1,13}$=1.44, P=0.25), perhaps owing to small sample sizes.

On average, 1.34±0.38% of all Black-necked Storks were recorded during wetland counts. The number of Black-necked Storks found in wetlands averaged 20.5±1.5% (range: 8–25%) of the total population in the area. Four of the five pairs (80%) resident in wetland sites were seen at least once during the 15 wetland counts; on average it took 8.25±0.9 visits (range: 6–10) to first sight these pairs and 13.3±3.7% (range: 0–40%) of the pairs were seen on each transect.

Sarus Crane

The total population of cranes each month could not be estimated owing to the difficulties of estimating numbers of mobile non-breeding flocks. A total of 158 pairs defended territories through the study period; none abandoned territories and no new pairs established territories during the study period. Road transects detected 35.1±2.5% of resident pairs on average. The mean density of cranes (3.55±0.47 birds/km^2) differed significantly across seasons (Fig. 3; one-way ANOVA: $F_{1,13}$=4.76, P=0.048), with the highest densities recorded in winter. The density of territorial pairs did not differ significantly across seasons (Fig. 3; one-way ANOVA: $F_{1,13}$=3.05, P=0.104).

Seventy-one territorial pairs were reliably identifiable. Of these, 53 pairs raised young at least once, and 18 pairs did not nest successfully during the study. No territorial pair was seen in all transects. Over 94% of territorial pairs were sighted at least once by the fifth transect, but it took ten transects to see all 71 pairs at least once. The mean sighting probability of crane pairs without young (32±4.4%) was significantly lower than for those with chicks (38±2.7%; Wilcoxon rank-sum test, Z=3.25, P =0.001). This result was supported by within-pair comparisons (paired t-test: t=1.72, df=52, P =0.09, n=53 pairs).

The wetland sites supported 14 territorial pairs of Sarus Cranes (8.9% of the total pairs identified) but only two of these could be reliably differentiated from flocks each month. Flocks were present in four of the five wetland sites, constituting 65.1±6.9% (range: 19-100%) of all non-breeding cranes each month. Total counts of cranes in each wetland site varied widely with season, with the highest counts in winter, although this was not significant (one-way ANOVA: $F_{1,13}$=2.74, P=0.12.

DISCUSSION

Black-necked Stork

Black-necked Storks occurred at low densities in the study area in comparison to Sarus Cranes (mean density=0.099 vs 3.55 birds/ km^2 respectively). For every territorial pair of Black-necked Storks, there were more than five pairs of territorial Sarus Cranes. Furthermore, Black-necked Stork was the rarest large waterbird in the area. On average, densities of Painted Stork *Mycteria leucocephala*, Asian Openbill *Anastomus oscitans*, Woolly-necked Stork *Ciconia episcopus* and Black-headed Ibis *Threskiornis melanocephalus* recorded on 15 transects were respectively 7.9, 5.8, 4.1 and 9.3 times greater than those of Black-necked Stork (unpublished data). In addition, Black-necked Stork pairs were more difficult to detect: their sighting probability on road transects was 17.9% compared to 35% for Sarus Cranes. These results are supported by anecdotal reports (Round *et al.* 1988, Santiapillai *et al.* 1997, Barzen 2003, Thomas and Poole 2003) and empirical evidence (Morton *et al.* 1993, Purcell 1993) from other locations within the species's range. The large territory sizes of Black-necked Storks result in lower densities, and consequently lower detectability compared to Sarus Cranes and other large waterbirds. In addition, the species may be less tolerant of disturbance along roads than Sarus Crane. Extrapolating conservatively and excluding unsuitable habitat, I estimate the population of this species in Etawah and Mainpuri districts to be 200–250 individuals. This equates to at least 20% of the estimated Indian population, highlighting the importance of the area for this species.

Road transects were more effective for monitoring populations of Black-necked Storks than wetland counts, detecting 17.9% of the population on average, compared to 1.3% for wetland counts. This was partly because only 20.5% of the population was resident in wetlands. It required 8–9 visits to a wetland site on average to detect the presence of a pair. However, this may have been because the study began in winter when adult storks are less conspicuous while they attend nests. The sighting probability during wetland counts may have been higher if longer had been spent at each wetland (although each site was small and could be completely censused from the viewpoint selected).

Road transects passing wetland sites are most useful in regions like Uttar Pradesh which retain considerable numbers of natural wetlands. In contrast, in areas such as Gujarat and Rajasthan where the land almost entirely comprises agricultural fields or arid habitats, counts at perennial wetlands in summer when water levels are reduced may be more appropriate than road transects. Observations at Keoladeo-Ghana National Park, Rajasthan (S. Sharma verbally 2003) and in Gujarat (Dave 2004) indicate that Black-necked Stork numbers peak in summer, presumably as birds congregate when wetlands dry out. In Madhya Pradesh, which is nearly completely cultivated with soybean requiring well-drained, non-flooded land, counts in near-permanent wetlands may be the most appropriate method to use.

Black-necked Stork may be less approachable in other areas, perhaps owing to greater human disturbance, and this may bias surveys: further work is needed to investigate this. Recorded densities and encounter rates were lowest during monsoon and winter months when birds attend nests and are less conspicuous (Sundar 2003). Therefore, counts in late winter or summer will be most useful for monitoring this species, and would provide the most accurate data on breeding success.

Aerial surveys for this species have been used in Australia, but it is thought that the numbers recorded were underestimates (Morton *et al.* 1993, Purcell 1993). Using aerial surveys to locate nests during the nesting season, followed by ground surveys, would be worth trying in locations where they occur in relatively high densities.

Sarus Crane

Sarus Crane was the most numerous large waterbird in the area, with densities 4.5, 36, 6.2, 8.6 and 3.9 times respectively higher than for Painted Stork, Black-necked Stork, Asian Openbill, Woolly-necked Stork and Black-headed Ibis (unpublished data). Extrapolating conservatively, the population of Sarus Crane in Etawah and Mainpuri districts is 2,500–3,000 individuals. This equates to c.30% of the estimated global population of *G. a. antigone* (8,000–10,000 individuals: Meine and Archibald 1996), and nearly 10% of the estimated global population for the species (25,000–37,000: Meine and Archibald 1996). This highlights the importance of the area for this globally threatened species.

On average, only 35% of known Sarus Crane pairs were seen during road transects. Road counts may however be useful for determining relative abundance at different sites. As wetland sites supported only 8.9% of breeding pairs, and very few of these were reliably identifiable, wetland counts were also found to be inadequate as a survey technique. As previous estimates of abundance of this species have been largely based on road transects, the totals are likely to be underestimates.

Seasonal differences indicate that winter months are most suitable for surveys. High intra-season variation in totals recorded possibly resulted from disturbance episodes, which are impossible to control since the majority of birds were in private fields and wetlands frequented by humans. Families were more likely to be seen than pairs. This is counterintuitive since one might expect families to be more sensitive to disturbance from traffic than pairs without chicks. However, the small size of territories, and the greater conspicuousness of families may explain this result.

Implications of the study

Waterfowl counts at the scale of the Asian Waterfowl Census are subject to various errors, including individual bias, but it is thought that random counting errors tend to cancel each other out (Li and Mundkur 2004). However, research on such errors has been limited. It appears that for the two species considered here, volunteer counts in wetlands have been inappropriate for estimating total population size or even local abundance. In India, only 19–44 Black-necked Storks and 47–178 Sarus Cranes were counted in five winters during 1997–2001 (Li and Mundkur 2004). These numbers are very low considering the estimates for populations in Etawah and Mainpuri districts alone and considering the numbers of Sarus Cranes recorded in specific counts (1,991–3,315 in three counts during 1999–2001: Choudhury *et al.* 1999, Sundar *et al.* 2000b, Kaur *et al.* 2002). The importance of surveying non-wetland areas was also demonstrated by Kachar *et al.* (1987) for Demoiselle *Grus virgo* and Common Crane *Grus grus* in Gujarat. For both species, counts at wetland sites were highly unpredictable and required additional knowledge to infer population trends from the results. Road transects, however, when used to cover a large enough area, provided much better estimates of abundance (Kachar *et al.* 1987).

Very few previous studies have explored the number of visits required to detect territorial pairs in linear transects. D'Amico and Hemery (2003) estimated the probability of detecting pairs of White-throated Dippers *Cinclus cinclus* to be 63–94%. This higher level of detectability is likely to be a consequence of their conspicuousness in riverine habitats, and smaller territories. Further work with individually marked storks and cranes would allow the determination of optimal transect width and length.

Are the current population estimates for the two species too low? For Black-necked Stork, the present estimate of 1,000 birds in Asia is based on wetland counts. Given that these took place in winter—an inappropriate season to count these birds due to their nesting habits—and that wetlands hold only a small proportion of the population, the total is likely to be an underestimate. However, further information from elsewhere in the species's range is needed. For Sarus Crane, the current estimates are based on a combination of methods including nationwide species-specific counts, and are likely to be more accurate. A long-term, nationwide programme of road counts in areas of different land-use, rainfall intensity and human disturbance is needed.

CONCLUSIONS

Road transects can be very useful for monitoring populations of large waterbirds in areas that retain relatively large wetlands in the landscape. For Black-necked Stork, road transects are effective if they pass major wetlands. For Sarus Crane, road transects are preferable to wetland counts, and are useful for determining parameters such as the proportion of young or of non-breeding birds. Coordinated road transects that include wetlands can be undertaken across very large scales by volunteers who are not necessarily professional biologists. However, rudimentary training for volunteers is important to reduce individual biases (Frederick *et al.* 2003). Counts in February are optimal for these two species. It would be useful to calculate correction factors for both road transects and wetland counts using marked birds. Given the dismal forecast for wetlands in India and concern for the future of these two species, ascertaining their numbers and monitoring them using the most appropriate method is vital.

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