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LETTER TO THE EDITOR

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Individual tracking reveals first breeding of Oriental Storks at age 2 years in the wild

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Abstract

In this study, we report the first ever documented instances of attempted and successful reproduction (rearing two offspring) of Oriental Storks (*Ciconia boyciana*) at age 2 years in a wild population in the middle Heilongjiang-Amur River Basin in Russia, using a combination of GPS-GSM tracking, DNA sex identification and field verification.

Keywords: *Ciconia ciconia*, First breeding age, Telemetry

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Studies show that age at maturity is an important life history trait, which influences bird population dynamics (Sæther et al. 2005). Oriental Storks (*Ciconia boyciana*) were typically observed to first start breeding at 3 or 4 years of age in Russia (Andronov et al. 2011). However, based on ringing information, one male ringed as a chick was recorded breeding at 2 years of age at Xingkai Lake National Nature Reserve, China, in 1990 (Wang and Yang 1995). In the equivalent species breeding in Europe, White Storks (*Ciconia ciconia*) were documented as breeding first between one and five years of age (Tortosa et al. 2002), although average age of first breeding age varied between populations and years, ranging from 2.7 to 4.5 (Tortosa et al. 2002). A decrease in the age of first breeding has been noted in some populations, especially in those that are increasing or those with access to good feeding opportunities (Bairlein 1991).

Previously, information on age at first breeding has been collected from long term ringing of chicks as nestlings followed up by resighting the same birds as adults at their own nest sites in subsequent years (Barbraud et al. 1999). While this approach combines the advantages of low cost of rings and large sample size, the disadvantages include its labour intensiveness and the reliance on individuals returning to the monitored parts of the natal area (because an unknown number of individuals may not return to the same study area to start breeding). Technological improvements now enable us to track individual birds in ways that have provided us with valuable insight into many aspects of avian biology (López-López 2016). Here, using GPS/GSM telemetry devices, we reveal new information on the age of first breeding of Oriental Storks breeding in southeast Siberia.

This study was carried out in the middle Heilongjiang-Amur River Basin, mainly in Berezovsky (50.56° N, 127.75° E) and Amursky Wildlife Refuges (49.62° N, 128.29° E) in Amurskaya province, Bastak Nature Reserve (48.87° N, 133.01° E) in the Jewish Autonomous Region, and Khanka Nature Reserve (44.92° N, 132.80° E) in Primorsky province of Russia.

Oriental Storks's nests were located and examined from helicopters or using drones, then age of chicks was determined by site visits allowing individuals to be captured before fledgling. We marked individuals with both a plastic color band and metal ring on tibiotarsus and then attached solar powered GPS-GSM backpack tracker (model OrniTrack-50, Ornitela, Lithuania) to each chick in each study site (For details nest site information, please refer to Additional file 1: Table S1). Devices recorded their latitude and longitude every 10–20 min. Feather

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samples were pulled to derive blood traces for subsequent DNA analysis to determine sex of each individual.

We downloaded movement data from all marked individuals and manually inspected their traces to determine whether storks conspicuously began to remain within one restricted area of the summering area, regularly returning to the same point, which would indicate that that individual was building a nest, subsequently visiting these locations for verification of a nesting attempt. Natal dispersal (movement between the places of birth and first breeding) distance was calculated using the "distHaversine" function of the R package "geosphere" (Chernetsov et al. 2006; Hijmans 2019), which calculates the shortest distances using the great circle-distance method to quantify horizontal distance (Hijmans 2019).

We individually marked and tracked 41 Oriental Storks in 2018 of which two showed distinct signs of nesting in May 2020. DNA sex identification showed that they are both male and field inspections confirmed that both of them successfully built nests. Of these, no egg was laid in the nest of the stork tagged with tracker 180467, but the pair including the male with tracker 180458 successfully incubated 4 eggs and fledged 2 chicks in August 2020. The natal dispersal distance of 180467 and 180458 were 388.91 km (natal nest site: 48.87° N, 133.01° E; new built nest site: 50.73° N, 128.43° E) and 86.83 km (natal nest site: 49.63° N, 128.30° E; new built nest site: 50.41° N, 128.31° E), respectively. This is the first solid evidence that male Oriental Storks can successfully reproduce at age 2 years in the wild population. The body weight is 4260.13 ± 82.32 g (Mean ± SE, range 3295.00–5235.00 g; $N = 39$), 180467 and 180458 were 4200 g and 3580 g, respectively. The body length is 915.05 ± 16.77 cm (732.00–1150.00 cm; $N = 37$), 180467 and 180458 were 893.00 cm and 1000.00 cm, respectively. The tarsus length is 257.89 ± 4.71 cm (191.00–302.00 cm; $N = 37$), 180467 and 180458 were 268.00 cm and 270.00 cm, respectively. The previous account of a two-year-old male associated with a nest also had a clutch size of four; however, no details were provided to confirm whether eggs were fertilized or if and how many chicks fledged successfully (Wang and Yang 1995).

Oriental Storks differ from White Storks behaviorally, ecologically, and morphologically (being c. 40% heavier Luthin 1987; Fan et al. 2020). The age of first breeding found in this study is earlier than that previously reported (Andronov et al. 2011) and seems to make the Oriental Stork more like White Stork in this trait (which can breed in their second summer Tortosa et al. 2002).

Female White Storks (median 177 km, $n = 19$) bred significantly farther from their natal sites than males (median 15 km, $n = 25$) (Chernetsov et al. 2006). Unfortunately, while we lack data on female Oriental Storks, in these two cases, natal dispersal distance of male Oriental Storks appear greater than those of White Storks in Poland. Given such large scale natal dispersal, searching for nesting birds carrying rings to determine age at first breeding of individuals is likely to be highly ineffective at monitoring true age of first breeding in this population. It is evident that GPS-GSM tracking offers a far more effective method to monitor this parameter in Oriental Storks than traditional means using ringing and resighting, the results of which are likely to be highly biased because of the limited extent of the study area and the number of visited nests.

Numbers of Oriental Storks wintering at Poyang Lake in China were significantly positively correlated with monthly average maximum temperature (Miao et al. 2013), perhaps suggesting that the species prefers high temperatures. Air temperature and precipitation indirectly affect availability of potential food resources, as White Storks were less active in cold and wet weather compared to warm and dry weather in Polish breeding area (Kosicki 2010). In the middle Heilongjiang-Amur River Basin, the mean annual temperature increased significantly, while the annual precipitation has not changed significantly from 1950 to 2010 (Yu et al. 2013). While the frequency of extreme precipitation events did not change significantly, the frequency of extremely low temperature events has also decreased from 1953 to 1995 (Yu et al. 2013). Poor breeding conditions have been observed in other long-lived bird species to lead to individuals delaying maturation (Fjelldal et al. 2020) and Black-legged Kittiwake (*Rissa tridactyla*) chicks from food-supplemented nests initiated reproduction at younger ages when compared with those recruited from control nests (Vincenzi et al. 2013). Such favorable environmental conditions could potentially promote earlier attainment of suitable body condition and even sexual maturation in Oriental Storks. However, based on such small sample sizes and the implementation of new telemetry methods, we should be prudent about concluding too much from these results as real evidence of a change in age of first breeding in this population compared to earlier years.

In Korea, one female Oriental Stork fed ad libitum in captivity was observed to start to breed at age 3 years, but abandoned its chicks (Cheong et al. 2006). In Shanghai Zoological Park, China, of 119 followed individuals, one male and one female were observed to start to breed at 2 years of age (Wu 2013). In Japan, captive population storks usually start breeding when they are four years old; however, a male of 2 years old in a reintroduced wild population (16 individuals in total) subject to artificial feeding and nest-tower arrangement succeeded in fledging a chick (Ezaki and Ohsako 2012). The on-set of sexual maturity in storks seems to vary between populations in captivity in different regions, but these observations tend to support the hypothesis that the availability of a good and predictable food supply potentially contributes to the explanation for the earlier start of reproduction.

Since the beginning of the twenty-first century, the Oriental Stork has expanded its breeding area southward dramatically. The species is now occur as summer residents and can be found breeding around Poyang Lake, Wuchang Lake and the Yellow River Delta which used to be their wintering areas or stopover sites (He et al. 2008; Chen et al. 2010; Xue et al. 2010). The species is also increasingly selecting power-line poles, artificial poles and pylons as their nest-sites (Chen et al. 2010, 2020).

Poaching and habitat loss has been put forward as the main reason for the decline in global abundance of the Oriental Stork (Murata 1997). Besides the degradation of wetlands on the breeding areas, wintering areas and stopover sites (Wei et al. 2016; Zheng et al. 2016; Sun et al. 2020), nest-site loss may also be one of the principal forms of "habitat" loss restricting expansion in the breeding population size. Oriental Storks prefer tall natural trees with broad, dense canopies that can support their huge nests (Wang and Li 2006). Widespread deforestation since the middle of the twentieth century makes such trees extremely rare in area close to wetlands in Northeast China (Zheng et al. 2016). Just as the abundance of cavity-nesting bird species can be limited well below potential carrying capacity by lack of natural holes in young even aged tree stands (Wiebe 2011), Oriental Storks may suffer from a similar limitation by lack of suitable nest sites despite an abundance of suitable feeding habitats on the wetlands. The rapid uptake and successful use of artificial nest sites following their provision supported a major increase in breeding Oriental Stork abundance at Honghe National Nature Reserve (Li 1995; Zhu et al. 2008), a case that provides evidence that the number of breeding pairs was limited by availability of nest-sites, indicating that, at least at local scales, nest-sites may be limited. In Russia, the provision of artificial nest platforms also led to their rapid uptake, followed by an increase in local abundance in most refuges and reserves of the region (Averin and Panin 2011; Sasin 2011).

Despite limited sample size, the use of new technology in this case was critical to our ability to confirm the early attempt at reproduction in these two individuals, which provides new insights into the population dynamics of this species. The recent increase of Oriental Storks populations is thought to be partly explained by the effect of prohibition wetland reclamation and construction of artificial nests (Zheng et al. 2016). However, ultimate driver of recent changes in abundance remains poorly known. Through our use of tracking devices, we have the ability to track the age of first breeding of other individuals from the same cohort over many years to derive a frequency distribution of age at first breeding, which over time will also give insights into any changes in this parameter and potential reasons for such change. We must become more innovative in the ways in which we integrate such developing remote sensing and technologies into our regular monitoring of long term population dynamics of critical and threatened species.

Supplementary Information

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Additional file 1: Table S1. Natal nest site of tagged Oriental Stork in 2018 at the middle Heilongjiang-Amur River Basin.

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Authors' contributions

AS and QZ conceived this study. AS and QZ wrote the paper. AS, ASe, ZB and QZ performed the experiments, analyzed the data, did the fieldwork. All authors contributed critically to the drafts and revised the drafts. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated during and/or analysed during the current study are not publicly available due to the fact that Oriental Storks in this flyway are highly threatened by illegal hunting, but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The Federal Service for Technical and Export Control and The Coordination Council of the Directors of Nature Reserves of southern Far East of Russia (No.332) approved the attachments of the transmitters and field methods used in this study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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