The usefulness of Unmanned Aerial Vehicles (UAV) in white stork censusing

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Research Article

Keywords: Ciconia ciconia, long-term monitoring, colonial breeding, waterbirds, farmland birds

Posted Date: December 29th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2384831/v1

Abstract

Long-term bird monitoring brings vital information on the effects of environmental changes on wildlife. However, covering a large area with direct observations in the field is time-consuming and economically costly. New technologies, such as Unmanned Aerial Vehicles (UAV), are effective and often noninvasive tools successfully used in bird monitoring. However, the stability of the method is essential when handling long-term data in the context of population changes. We examined the efficiency and precision of data collected by UAV and human observers within two distinct populations of the white stork *Ciconia ciconia*, in Poland and Spain, presenting two different nesting patterns, solitary and colonial breeding. In Polish and Spanish populations, the number of fledglings was significantly lower when recorded by human observer than by UAV, i.e. 2.21 vs 2.60, and 1.35 vs 1.55. The mean time needed to record the number of fledglings was significantly longer when using a UAV than by a human observer. The number of detected nests in colonies differed significantly between the human observer and UAV, on average 13.1 vs 7.4, respectively. The difference number of recorded nests was linked with the type of nest substrates, i.e. on trees, the error was higher than in colonies located on human-made structures. The probability of mistake by the observer was significantly lower when recording the number of fledglings in colonial white storks in Spain than in solitary nesting in Poland.

Although UAVs are a helpful tool in bird monitoring, in long-term studies, they must be used with caution and awareness that obtained results might differ from those obtained previously in a long-term monitoring framework.

Introduction

As many bird species are considered good bioindicators (Canterbury et al. 2000; O'Connell et al. 2000; Butchart et al. 2004; Schulze et al. 2004), their long-term population monitoring brings vital information on the effects of global environmental changes, including climate change (Butchart et al. 2004; Virkkala and Lehikoinen 2014; Stephens et al. 2016; Bowler et al. 2019). Long-time series on bird distribution and abundance allow us to predict changes in many species ranges in the future (Doswald et al. 2009; Soultan et al. 2022) or even reproduce them to the past (Thorup et al. 2021). However, there are some limitations when detailed data on density and productivity are unavailable (Van Doren 2022), highlighting the importance of detailed long-term monitoring with constant standardised methodology. Although bird monitoring is now well established in many countries of the Northern Hemisphere, very long-term data on species distribution, abundance, and productivity are scarce. Only a few bird species are monitored on a broad geographical scale using a standardised methodology (Perrins et al. 1991). Among these species is the white stork *Ciconia ciconia*, which has been being monitored in some locations for over 100 years (Bairlein 1991). More importantly, the monitoring is being performed on the entire breeding range under the International White Storks Censuses according to standardised methodology, which enables the assessment of current trends on broad time and geographical scales (Wuczyński et al. 2021). The white stork is an example of an easily recognisable species that does not demand high expertise during censusing, and its monitoring can be performed even by amateurs. However, in some cases recording the exact number of fledglings is difficult even for experienced observers, mainly when the nest is large, brood is numerous, and some fledglings are lying in the middle of the nest. The white stork breeding is very synchronised, and there is a short time window of 1–2 weeks when all necessary data can be collected (Aguirre and Vergara 2009), i.e. when nestlings are not able to fly but developed enough to be considered as fledglings. However, detailed censusing of breeding populations on a large scale is time-consuming and needs a lot of human resources.

A promising solution for bird monitoring is Unmanned Aerial Vehicles (UAV) or unmanned aircraft systems (UAS), which have been used in many environmental studies (reviewed by Nowak et al. 2018). Also, in ornithology, the use of UAV is beneficial when access to breeding colonies is restricted due to natural barriers like water, marshland or mountains (Nowak et al. 2018). Using a UAV might be a reasonable solution to deal with fieldwork constraints and save time for data collection. In the case of the white stork, such a method has no significant behavioural effect on breeding individuals and their offspring (Zbyryt et al. 2020), contrasting to some colonial waterbirds who react intensively and change their behaviour and time budget (Brisson-Curadeau et al. 2017). Moreover, the efficiency of data collecting may differ between species and populations nesting solitary and in colonies. In theory, when visiting a colony, the time needed to record nest occupancy per bird pair may be shorter than in the case of solitary breeding birds. Hence, the use of UAV might be more effective for monitoring colonial birds than territorial ones.

However, in long-term studies, more than efficiency, the stability of used methods is crucial. To maintain the stable, standardised conditions of observation, the evidence of whether the new methods affect obtained results is highly needed. Therefore, in this study, we aim to test whether results obtained via the standard observation method by a human observer from the ground differ from data gathered using UAV (i) in terms of the number of detected nests and the number of fledglings. We also tested if the time devoted to obtaining results differed between these two methods (ii). We present the tests within two populations of white storks differing in breeding ecology, i.e. solitary vs colonial nesting, in Poland and Spain.

Methods

Study areas and fieldwork

We conducted the study in two distinguished populations of the white stork differing in ecology and facing different environmental conditions. One, near the town of Augustów in NE Poland (N 53.85, E 22.98), where the population density is high, namely 44 breeding pairs/100 km^2, and the landscape is composed of traditionally managed agricultural lands with a mosaic of grasslands (meadows and pastures), arable fields and woods (Zbyryt et al. 2014). White storks breed here solitary, sometimes forming small aggregations but not colonies. The second population is in the province of Madrid in Central Spain (N 40.42, W 3.70), where the white stork has increased and reached the density of 28 breeding pairs/100km^2. It forms colonies of even over 100 pairs and inhabits semi-natural agricultural environments composed of pastures and agro-forestry lands (López-García et al. 2021; López-García and Aguirre 2022).

In 2019 (between 1th and 2th July), according to the standard methodology of white stork censusing (Wuczyński et al. 2021), we surveyed 57 white stork nests in NE Poland. One experienced observer who knew well the study area (AZ – co-author of this paper) recorded the number of fledglings using binoculars 10x42. In parallel, the UAV operator performed a flight aiming to record the number of fledglings from the height. The time needed to obtain breeding output (the number of fledglings) was also recorded starting from when the observer/UAV operator got off of the car to record the number of fledglings and return to the car (the observer and UAV operator separately). Using a GPS receiver, we also measured the distance between the observer and the observed nest. In 2021 (between the 29th of May and the 12th of June), similar fieldwork was performed in central Spain, Madrid District (by ALG & RGM – co-authors of this paper). The white stork breeds here colonially; hence, the method was adjusted to local conditions, i.e. the time was recorded for the whole colony survey and divided by the number of nests in the colony. If possible (mainly when nests were on buildings), the observations were conducted from a greater distance to avoid disturbance of the breeders in the colony, as colonial, white storks are much timider than solitary ones inhabiting human settlements. In total, 117 nests aggregated in 15 colonies and one solitary nest were surveyed. Recordings obtained by UAV were analysed after the fieldwork, and the time needed for the image processing was also included in the time of UAV observation. Colonial breeding of the white stork in Spain also allowed us to test differences in the number of recorded nests between traditional observation from the ground by a human observer and the UAV.

Statistical Analyses

We used the two-way ANOVA to test the effect between nesting type (solitary vs colonial) and the observation method (UAV vs human observer), including interaction (nest type × observation method) on the time needed for the white stork nest inspection to record the number of fledglings.

We performed paired Welch t-test to compare results obtained by human observer and UAV (no. of fledglings) separately for data collected in Spain (colonies) and Poland (solitary nests). Moreover, we used paired Welch t-test to compare the number of recorded nests in colonies in Spain between the observer and UAV. We used logistic regression to test the probability of making mistakes in the recorded number of fledglings by a human observer in stork colonies in Spain and solitary nests in Poland. We indicated 0 when humans observed a different number of fledglings (always lower) than UAV and 1 when humans observed the same number.

Results

Poland – solitary nests

The mean number of fledglings recorded in the nest by the human observer was 2.21 while by UAV – 2.60, and the numbers differed significantly ($t = 4.3175$, $df = 56$, $p < 0.0001$).

The mean time needed to record the number of fledglings was 29 and 127 seconds (observer and UAV, respectively) and differed significantly ($t = 32.153$, $df = 56$, p-value < 0.0001, Fig. 1).

Spain - Colonies

Mean number of fledglings in a nest was 1.35 and 1.55 (observer and UAV respectively) and the numbers differed significantly ($t = -3.7899$, $df = 117$, $p = 0.0002$). The mean time needed to obtain the number of fledglings was 59 and 322 seconds and differed significantly ($t = -5.1821$, $df = 117$, $p < 0.0001$). Also, the number of detected nests differed significantly between human observer and UAV, i.e. 13.1 and 7.4 respectively ($t = 3.2992$, $df = 15$, $p = 0.005$). However, the difference in the number of recorded nests was linked to the type of nest substrates. In colonies located on trees the error was significantly higher (on average 7.7, range: 0–24 detected pairs) than in colonies located on human-made structures (no differences in detected pairs), i.e. buildings and poles ($t = -3.7468$, $df = 11$, $p = 0.003$, $n = 16$ colonies).

Comparison Between Colonies And Solitary Nests

We found significant differences in probability of mistake by observer ($F = 6.9958$, $p = 0.009$) when recording the number of fledglings in colonial white stork in Spain (probability ± SE = 0.195 ± 0.0365, 95% CL: 0.133–0.276) and in solitary nesting in Poland (0.386 ± 0.0645, 0.269–0.517, Fig. 2).

Discussion

In this study, we found significant differences in the recorded number of white stork fledglings between the human observer and the UAV. It is not surprising as the access to a nest for humans standing on the ground is much more constrained than for a flying object. However, it is important information that during the long-term censusing of the population, the overall breeding output may be underestimated when only ground checking is performed. In practice, it means that when the observer is counting fledglings standing on the nest, some of them can sit or lay in the nest, invisible to the observer, particularly when the nest is large construction (Vergara et al. 2010; Zbyryt et al. 2021). Moreover, the way of ground survey predicts the probability of making a mistake in recording fledgling numbers, i.e. in colonies, the probability of a mistake was significantly lower than in solitary nests. It is probably due to the different observation angles in these two populations. Solitary nests in Poland are mainly located in villages on electric poles or roofs (Tobolka et al. 2013), so it is sometimes difficult to observe them from a further distance, outside the village, due to rural settlements surrounding the nest constraining the observation. Colonies in Spain are often on tree aggregations far from the settlements. Due to the timid behaviour of nestlings storks, the best solution to observe them is from a distance, which in turn makes the angle of observation more convenient to record the exact number of fledglings, including those sitting or lying in the nest.

On the other hand, when performing long-term monitoring, an additional interview with property holders where the nest is located is a standard action, particularly when brood fails (Janiszewski et al. 2013; Tobolka et al. 2015). Thus, the obtained results can be supplemented and more accurate. What is more, in the case of the white stork, often the monitoring is accompanied by chick banding, i.e. direct visits in the nests. Therefore, data collected on the long-term study sites can be considered relevant for population monitoring. However, the use of UAV monitoring during the time when stork nestlings are hatching would bring much more information when studying breeding biology of the species due to collecting data that human observer cannot record standing on the ground.

The time needed for obtaining the information about the number of fledglings differed significantly between the human observer and the UAV, which contradicts the study on oystercatcher *Haemantopus ostralegus*, where the traditional method of censusing was significantly more time-consuming and, therefore, more costly than UAV. However, the white stork nests close to human settlements, on buildings, and in prominent locations (Tobolka et al. 2013), which facilitates monitoring compared to ground-nesting birds. Hence, in the case of the white stork, using a UAV does not shorten the time needed for a survey and does not necessarily reduce fieldwork costs. Using a UAV in a constrained period (i.e. two weeks for nestling monitoring) in large areas requires several UAVs and the associated qualified personnel. It requires additional permits when flying close to settlements and electricity networks or close to airports or military training areas. Moreover, the use of UAV is often restricted by current laws, with the impossibility of using this system in particular parts of the study area.

Using the data from Spain, where white storks breed mainly in colonies, the recorded colony size was significantly larger when surveyed by the human observer than by UAV. It contrasts with the study on the ground-nesting bird, the black-headed gull *Chroicocephalus ridibundus*, where images obtained from an unmanned aircraft system (UAS) allowed to establish colony size with very high precision (Sarda-Palomera et al. 2012) and results of Oystercatcher studies where a higher number of occupied nests was detected using UAS than by traditional census method (Valle and Scarton 2019). In the case of the white stork, the differences in the assessment were due to the tree canopy coverage that affected the numbers obtained by UAV, which is not a problem during a survey in open space areas such as bar ground, beach or sparsely vegetated habitat. However, using a thermal infrared camera would solve this issue as it was proven an effective tool in at least mammalian studies (Linchant et al. 2015).

Conclusions

Although new technologies offer suitable tools for data collecting during fieldwork, they must be used with caution, particularly in long-term studies focusing on population productivity.

In the case of the white stork, monitoring using a UAV may not necessarily save time and costs. However, it may increase the accuracy of collected data.

Declarations

Acknowledgments

We would like to thank volunteers and amateurs who provide us with observational data on several stork nests locations, which improved the fieldwork.

Funding Statement

The study was supported by the following grants: LIFE financial instrument of the European Community, LIFE15 NAT/PL/000728 awarded to AZ; Narodowa Agencja Wymiany Akademickiej (National Agency for Academic Exchange, Poland), PPI/PRO/2019/1/00040 awarded to LD, ALG, and MT; and Narodowa Agencja Wymiany Akademickiej (National Agency for Academic Exchange, Poland), PPN/BEK/2020/1/00426 awarded to MT.

Conflict of interest

Authors declare no conflict of interest

Author Contribution Statement

MT wrote the main manuscript draft. MT and LD analysed the data and prepared figures. AJG, JIA, RGM, AZ carried out the fieldwork. All authors contributed in conceptualization of the study and reviewed the manuscript.

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Figures

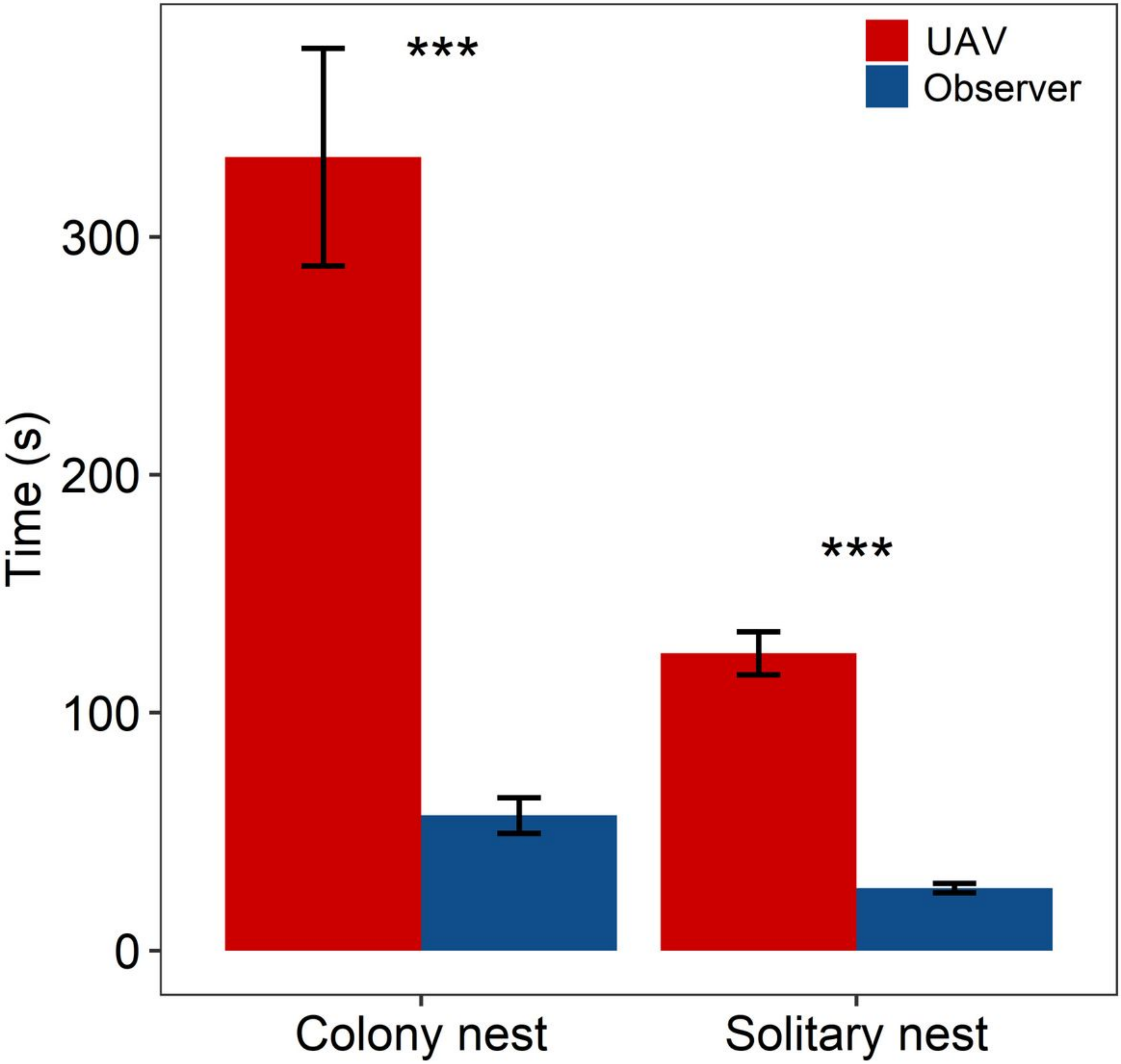

Figure 1

Comparison of time needed by UAV and human observer to record the number of fledglings in the nest in colonial nesting in Spain and solitary nesting white storks in Poland. Whiskers present standard error. Differences are statistically significant (in both cases, $p < 0.0001$).

Figure 2

Comparison of the probability of making a mistake by a human observer and UAV in recording the number of fledglings in colonial nesting in Spain and solitary nesting white storks in Poland. Differences are statistically significant ($p < 0.009$).