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Short Communication

Foraging efficiency of white stork *Ciconia ciconia* significantly increases in pastures containing cows

Adam Zbyryt[a], Tim H. Sparks[b,c], Piotr Tryjanowski[b,d,*]

[a] The Polish Society for Bird Protection (PTOP), Ciepła 17, PL-15-471, Białystok, Poland
[b] Institute of Zoology, Poznań University of Life Sciences, Wojska Polskiego 71C, PL-60-625, Poznań, Poland
[c] Museum of Zoology, University of Cambridge, Downing Street, Cambridge, CB2 3EJ, UK
[d] Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Kamýcká 129, 165 00, Prague 6, Czech Republic

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ABSTRACT

Recent changes in agriculture have had a very strong impact on avian populations, but detailed mechanistic explanations are scarce. Some proposed solutions to avian declines can be complicated because responses are not linear. For example, abandoning pasture management can be detrimental to many open-nesting birds, but also to some others, because livestock perform ecosystem engineering, changing sward height and creating micro-habitats for invertebrates, as well as for insectivorous mammals. Both these features affect the foraging efficiency of birds, for example white stork *Ciconia ciconia*. We studied the foraging activities of storks in the presence and absence of grazing cows, and we show that in extensive farmland in NE Poland, the presence of cows has a highly significant effect on stork foraging efficiency (in our study area mainly catching insects), which may be crucial to improving breeding success. Our results may also be important from a practical point of view. In white stork recovery projects where supplementary food is offered to storks (e.g. chicken and fish provided on feeding platforms) we believe that establishing extensive cattle pastoralism would be better from an ecological as well as from an aesthetical viewpoint.

1. Introduction

Due to agriculture intensification, farmland birds are one of the most declining bird groups across Europe (Inger et al., 2015). One example of this intensification is change in dairy milk farms; currently cows are more often kept indoors than on traditional pastures (Buckingham and Peach, 2005; Gaworski, 2016). This trend is also evident in regions with less intensive agriculture, such as central Europe (Chabuz et al., 2012; Gaworski, 2016).

Grazing cows prevent secondary succession and create habitats for open nesting bird species (Mastrangelo and Gavin, 2012), they increase numbers of invertebrates and small mammals which, in turn, are prey for many foraging birds. Furthermore, bird foraging is generally more efficient in shorter grass associated with grazing animals (Tóth et al., 2018). Taking all these factors together, it has been confirmed that grazing cattle have a positive effect on birds, including breeding population size and chick production of the white stork *Ciconia ciconia* (Tryjanowski et al., 2005). The white stork is an icon of European nature conservation, and in western and northern Europe, where the population of this species collapsed, recently established reintroduction programmes have focused on factors important for the recovery of storks (Olsson and Rogers, 2009; Hilgartner et al., 2014). The crucial factor for success is access to foraging habitat (Alonso et al., 1994; Olsson and Bolin, 2014) and this has even been confirmed experimentally (Hilgartner et al., 2014). However, traditionally, grass was not cut especially for storks to allow them to establish rich foraging places nor was supplementary food (even, for example, fish and chicken) provided for them. The white stork is simply a species linked to traditional farmland management and obtained food mainly from meadows and grazing pastures under extensive livestock production (Tryjanowski et al., 2005; Kosicki et al., 2006). It was previously suggested that storks can positively benefit from livestock, such as sheep, horses and cows (Tryjanowski et al., 2005; Chabuz et al., 2012), but the mechanistic link driving this benefit was not identified. However, according to theoretical suggestions, we may assume that grazing provides modest disturbance which then positively affects at least some species in the ecosystem (Connell, 1978; Sabatier et al., 2015; Battisti et al., 2016). Therefore, during a study in a dense white stork population in NE Poland we asked (1) how foraging efficiency of the white stork differs in pastures and meadows with and without cows?; (2) how foraging

* Corresponding author. Institute of Zoology, Poznań University of Life Sciences, Wojska Polskiego 71C, PL-60-625, Poznań, Poland.
E-mail addresses: piotr.tryjanowski@gmail.com, piotr.tryjanowski@up.poznan.pl (P. Tryjanowski).

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efficiency is correlated with the number of cows in a pasture?; and finally (3) how much energy (measured as distance walked by foraging birds) did storks invest for catching food when cows were present and when absent?

2. Data and methods

The study was conducted in late July 2019 in hay meadows and pasture in NE Poland near the border with Lithuania (centred on 54.18°N, 23.14°E, for a description see Solon et al., 2018). The area contains traditional extensive agriculture, including wet meadows and pastures with cows. This region is characterized by the highest density of breeding pairs of white storks in Poland; more than 50 pairs/100 km^2 (authors' own data and Gotkiewicz and Wittbrodt, 2019).

A total of 81 5-min observations of white stork foraging were completed from 41 locations, with more observations from those locations hosting more birds. Each observation period focussed on a single bird and recorded the following: location (GPS coordinates), date, start time, habitat type (hay meadow or pasture), numbers of successful and unsuccessful foraging attempts, prey items, the distance moved by the bird during feeding (6 categories in metres: < 20, 20–50, 51–100, 101–150, 151–200, > 200), broad categories of vegetation height relative to the stork (foot, half leg, full leg or head heights [respectively approximately 3, 30, 70 and above 100 cm], chosen due to pragmatical reasons, but known to influence stork foraging habits – Alonso et al., 1994), and the number of cows grazing in the field, with zero indicating no grazing. In order not to disturb the feeding of storks, observations were carried out from a car using binoculars (Swarovski 8x42). The car was parked at the roadside in such a way that it had as little visible impact as possible to the observed birds (e.g. near a group of trees or bushes). If the stork was disturbed, the observation was discontinued. During observation, foraging was recorded on a dictaphone or digital camera Nikon Coolpix P900 (Nikon Corporation, Tokyo, Japan) with an 83x optical zoom lens, and then transcribed to the field forms. Recordings or photos from the camera were used to accurately identify the type of hunted prey. A stopwatch was used to measure time. In the event that the observed stork temporarily interrupted its foraging (e.g. for feather cleaning, stretching, or a short flight) or temporarily moved out of sight (e.g. behind a cow or hillock), the observation was halted and then resumed when visible foraging continued.

A two sample *t*-test was used to test whether the mean number of foraging attempts differed between observations when cows were present and when absent. Because of the ordinal nature of the height and movement categories these were compared between the cows present/absent groups using Mann Whitney tests, adjusted for ties. The number of successful foraging attempts and the movement category were compared using Spearman's rank correlation. Binary logistic regression was used to model the proportion of successful foraging attempts, relative to cows present/absent and to time of day. Initial exploration of the data suggested that foraging success was not constant and not linear through the day so linear and quadratic components of time of day were fitted. Binary logistic regression was also used to test if the number of cows influenced foraging success within the cows present subgroup. Significant results were classified as those with $p < 0.05$ and all computations were made in MINITAB18.

3. Results

Cows were present for 39 of the 81 (48.1%) observations. Where present their numbers ranged from 2 to 34, with a mean of 12. The number of foraging attempts per 5-min observation varied from 1 to 101 with a mean of 43. There was no significant difference between the mean number of foraging attempts in the presence of cows (mean 43.8) and when cows were absent (mean 43.1) ($t_{79} = -0.16$, $p = 0.877$). In 33 of the observations, vegetation was recorded as the height of the bird's foot, a further 33 at half leg height, 13 at full leg height, and 2 at head height. There was no significant difference in height categories between the cows present/absent groups ($W = 1766$, $p = 0.658$).

A total of 2488 successful foraging attempts were recorded. These were virtually all (99.4%) of insects (orthopterans and beetles). The exceptions were 6 frogs, 5 Roman snails *Helix pomiata*, 4 earthworms and 1 small unidentified rodent.

All but one of the storks foraging in the presence of cows moved less than 50 m during the 5-min observation. Distances moved by storks in the absence of cows were significantly greater ($W = 2468$, $p < 0.001$); the median distance categories were < 20 m in the cows present group and 101–150 m in the cows absent group. Across both groups, there was a negative correlation between distance moved and the number of successful foraging attempts ($r_s = -0.298$, $p = 0.007$). However, there was no significant correlation within the groups when analysed separately (both $p > 0.525$) suggesting that the significant correlation may just be an artefact of the difference between the cows present/absent groups.

The initial binary logistic regression model (AIC = 3901.51, deviance $R^2 = 72.4\%$, $p < 0.001$) revealed highly significant differences between the cows present/absent categories ($\chi^2 = 276.6$, $p < 0.001$, Fig. 1) and both linear ($\chi^2 = 4.85$, $p = 0.028$) and quadratic ($\chi^2 = 5.76$, $p = 0.016$) time of day components (Fig. 2). The odds ratio for cows present relative to cows absent was 3.95 indicating foraging was nearly three times more likely to be successful when cows were present. The fitted time of day component suggested foraging success reached a minimum at about 13:45 h.

Adding an interaction between linear time of day and cows present/absent significantly improved the model (AIC = 3893.74, deviance $R^2 = 74.4\%$, $p < 0.001$) but further adding an interaction with quadratic time of day did not (AIC = 3895.56, deviance $R^2 = 74.5\%$, $p < 0.001$). A non-linear relationship with time of day was evident for both of the cows present and cows absent groups, with the minimum success rate later in the day in the cows present group.

A binary logistic regression of only the cows present data revealed that foraging success was positively associated with that the number of cows in this subset with an odds ratio of 1.018 (AIC = 1430.57, deviance $R^2 = 7.1\%$, $p = 0.015$).

4. Discussion

We have clearly shown that the presence of grazing cows positively affected the foraging efficiency of white storks in NE Poland. The high numbers of livestock raised outdoors in this region, compared to many other parts of the country which have changed mainly to an indoor dairy system (Gaworski, 2016; Chodkiewicz and Stypiński, 2017), may partially explain the very high density of white storks in this region, in comparison to Polish, as well as, to other populations in the eastern part of the species range (Tryjanowski et al., 2005; Vaitkuviene and Dagys, 2015; Gotkiewicz and Wittbrodt, 2019). A positive association with the presence of cattle has already been described for many bird species, from small passerines to wading birds and egrets (Dinsmore, 1973; Buckingham and Peach, 2005; Chabuz et al., 2012; Chodkiewicz and Stypiński, 2017; Tóth et al., 2018), and has been linked mainly to better access to food and greater food availability, mainly invertebrates. White storks catch insects (Kosicki et al., 2006; Kwieciński et al., 2017) which were their dominant food in the study area. However, prey were mainly large beetles and orthopterans, not the flying insects normally associated with cows and which, for example, are important for foraging yellow wagtails *Motacilla flava* (Källander, 1993) and barn swallows *Hirundo rustica* (Møller, 2001). These bird species forage close to cows or, like egrets and many other birds in Africa, actually sit on the cows body (Mikula et al., 2018). In contrast, white storks use a different foraging strategy and collect food mainly from grassy areas. Because there were not significant differences in vegetation height or in the number of attempts between the cow present/absent categories, other

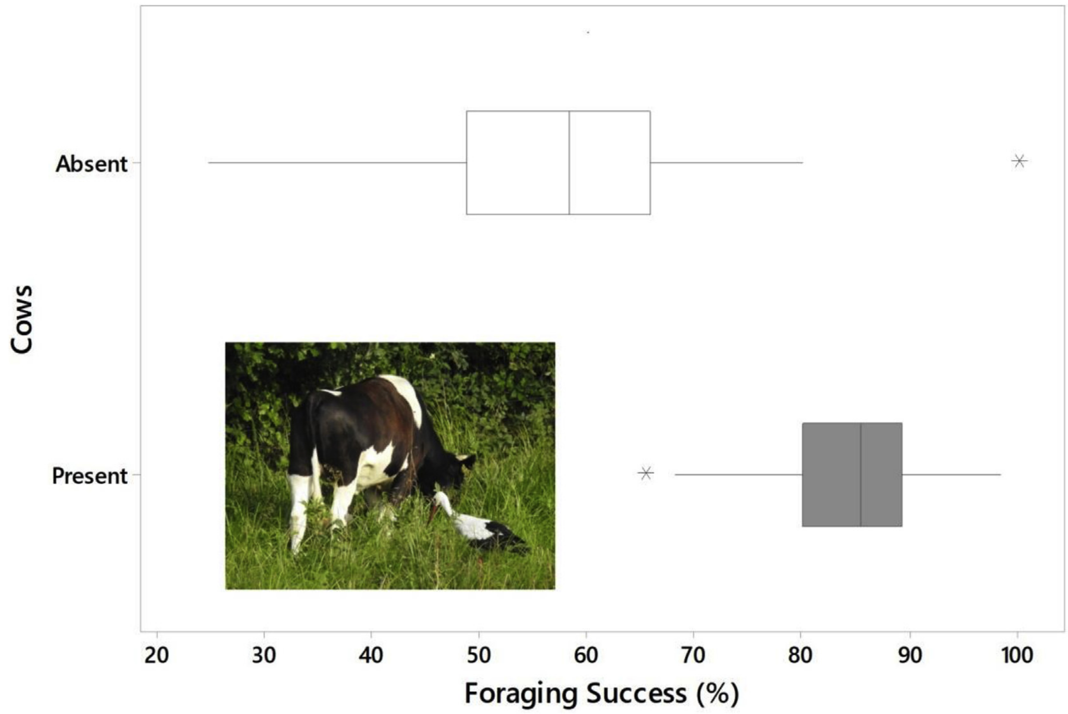

Fig. 1. Boxplots indicating foraging success rates of white stork *Ciconia ciconia* in NE Poland when cows were absent (white background; based on n = 42 timed observations) or present (grey background; n = 39). Success rates were significantly higher when cows were present ($p < 0.001$). The box for each category represents the interquartile range and the central line within the box represents the median. Whiskers extend to extreme values, except where an outlier is indicated by an asterisk.

factors influence white stork foraging efficiency.

The presence of cows improves white stork foraging success rates and they need to move less to achieve that success, thus saving energy (Alonso et al., 1994; Olsson and Bolin, 2014; Kwieciński et al., 2017). A similar phenomenon was demonstrated in the case of cattle egrets *Bubulcus ibis* when they foraged with cows. The number of steps taken by egrets when foraging in the presence of cows was significantly lower and feeding efficiency was much higher than when they were foraging in the absence of cows (Dinsmore, 1973; Paoloni et al., 2018). Moreover, in this kind of extensive pastoralism, increasing the number of cows also improved the success rate of foraging storks. This may be because, when cattle are present, prey insects are disturbed by cattle movements, and/or prey become less cautious of animal movements and thus become more susceptible to storks (Kosicki et al., 2006; Kwieciński et al., 2017). Cows also produce tracks and dung, both very attractive places for crickets and beetles (Gawałek et al., 2014) which in turn are important food items for storks (Kosicki et al., 2006; Kwieciński et al., 2017).

The success rate of storks varies by time of day; with a minimum in the middle of the day, which may be related to activity patterns of stork

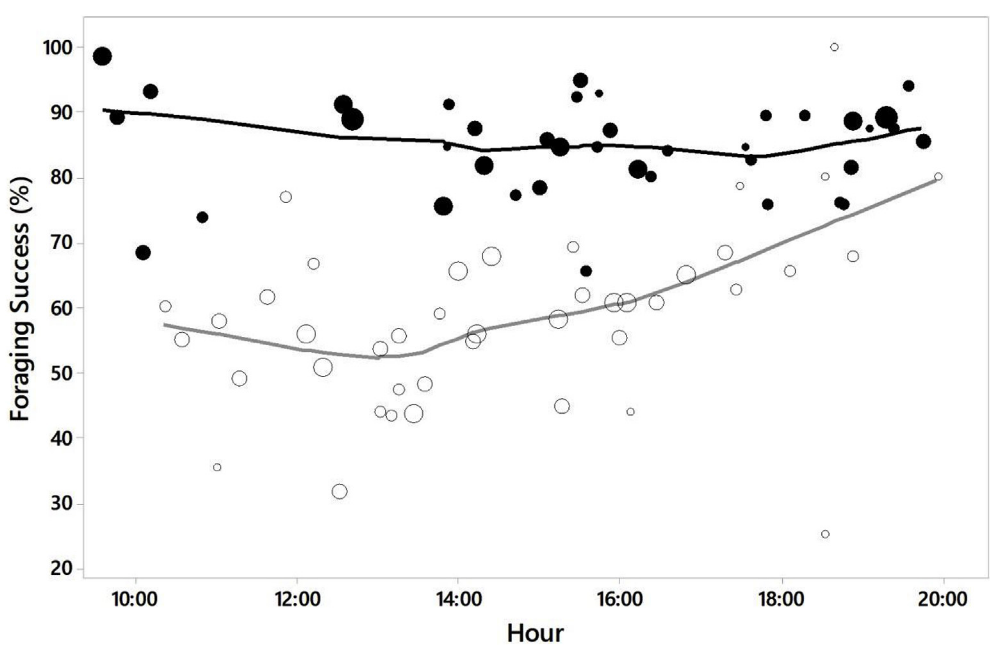

Fig. 2. Foraging success rates of white stork *Ciconia ciconia* in eastern Poland by time of day when cows were absent (open symbols, grey line; n = 42) or present (solid symbols, black line; n = 39). Foraging success varied significantly by time of day ($p < 0.05$), see text for details. Smoothed lines (lowess), unadjusted for number of foraging attempts, shown for each group. Increasing symbol size indicates increasing number of foraging attempts in five range classes (1–20, 21–40, 41–60, 61–80, > 80).

(Alonso et al., 1994; Zolnierowicz et al., 2016; Nyklová-Ondrová et al., 2019) and insect prey (Gawałek et al., 2014; Twardowski et al., 2017) in relation to ambient temperature. However, the success rate reached a minimum later in the day in the case of storks foraging with cows. Chronic food deficiency can cause hunger stress in chicks, which translates into lower body mass, constantly elevated baseline and higher acute stress-induced levels of corticosterone (Kitaysky et al., 2001; De Jong et al., 2002). In the case of the white stork, it has been proved that the stronger response of chicks to acute stress is a good predictor of both lower survival and a lower probability of recruitment to reproductive age (Blas et al., 2007). This shows that foraging storks with cows results in greater hunting success and can have much greater conservation and population implications than would seem to be the case at first glance.

This phenomenon is also very interesting in an evolutionary context. Did storks, known for their plasticity in foraging, learn to forage in the presence of cows when man first domesticated cattle? With the increase in cattle domestication did stork behaviour in relation to cattle spread? Or did they originally forage with grazing herds of wild ruminants in open habitats? We do not know, but knowledge on this issue certainly would allow a better understanding of the strong relationship between the storks and locations where cow breeding occurs (Tryjanowski et al., 2005). The explanation of whether this is an evolutionary legacy or relatively recent behaviour acquired through greater farming with cattle by man, may be sought from observations of foraging storks with large ruminants in Africa on their wintering grounds. Anecdotal literature indicates that such behaviour occurs in the foraging of storks with cape buffalo *Syncerus caffer*, white rhinoceros *Ceratotherium simum*, blue wildebeest *Connochaetes taurinus* and impala *Aepyceros melampus*, where these birds hunt mainly for insects, particularly Orthoptera (Dean and MacDonald, 1981). This indicates that this behaviour in winter in the Southern Hemisphere matches that observed during this study. This suggests that storks already understood the relationship between ruminants and greater hunting efficiency and used it in summer in the Northern Hemisphere with the development of cattle farming by humans.

We confirmed that livestock presence on pasture has a positive effect on the white stork. The regression equation suggested that every additional cow increased the odds of foraging success by 1.8% and this knowledge may be used to better manage white stork foraging patches, for example in the numerous recovery programs of this species in Europe. From an ecological, as well as an aesthetical, point of view a better solution than supplementary feeding is to extensively farm cattle where populations of the white stork exist, for example in areas identified for species recovery programs.

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