Journal of Ornithology (2024) 165:551–555
https://doi.org/10.1007/s10336-023-02143-y

SHORT COMMUNICATION

White stork *Ciconia ciconia* nests as an attractant to birds and bats

Piotr Tryjanowski[1,2,3] · **Łukasz Jankowiak**[4] · **Łukasz Myczko**[1] · **Peter Mikula**[2,3,5] · **Andrzej Łuczak**[6]

Received: 15 October 2023 / Revised: 21 November 2023 / Accepted: 21 December 2023 / Published online: 25 January 2024

Abstract

White storks (*Ciconia ciconia*), an emblematic bird of high conservation interest, build massive nests which are also important breeding sites for other birds. However, their role as a potential source of food for foraging birds and bats is unexplored. In this study, we counted insectivorous aerially foraging birds (swallows, martins, and swifts), sparrows, and bats foraging around 51 pairs of white storks' nest and control sites in Poland. The number of birds was significantly higher near active white stork nests than control sites, but this effect was invisible for bats. White storks provide important benefits to the conservation of co-occurring species.

Keywords Animal coexistence · Farmland · Foraging habitats · Nest structure · Umbrella species · White stork

Zusammenfassung

Nester des Weißstorchs *Ciconia ciconia* sind attraktiv für Vögel und Fledermäuse.

Der Weißstorch (Ciconia ciconia), ein emblematischer Vogel von hohem Naturschutzinteresse, baut riesige Nester, die auch für andere Vögel wichtige Brutplätze sind. Ihre Rolle als potenzielle Nahrungsquelle für futtersuchende Vögel und Fledermäuse ist jedoch unerforscht. In dieser Studie haben wir insektenfressende, die in der Luft jagende Vögel (Schwalben, Mauersegler), Sperlinge und Fledermäuse in der Nähe von 51 Paaren von Weißstorchnestern und Kontrollstandorten in Polen gezählt. Die Zahl der Vögel war in der Nähe aktiver Weißstorchnester deutlich höher als an Kontrollstandorten; bei Fledermäusen war dieser Effekt jedoch nicht sichtbar. Weißstörche leisten einen wichtigen Beitrag zum Erhalt von gemeinsam vorkommenden Arten.

Introduction

Large animals have important and irreplaceable functions in ecosystems (Malhi et al. 2016). Large animals often exert strong top-down control on ecosystem structure (Estes et al. 2011). They may act as an umbrella species, i.e., their persistence also conserves co-occurring species, and their presence may be associated with increased local biodiversity (Branton and Richardson 2011). Besides well-described effects of large mammals on habitat structure and biodiversity by creating suitable microhabitat environment for other organisms (Smith et al. 2016), nests of large birds can also act as microhabitat biodiversity hotspots, providing numerous organisms shelter, food, and opportunities for breeding (Kosicki et al. 2007; Whelan et al. 2008; Maciorowski et al. 2021). However, this aspect of large animals' functioning in ecosystems is still largely unexplored.

The white storks (*Ciconia ciconia*) are emblematic farmland birds in Europe, often receiving considerable public

---

Communicated by F. Bairlein.

✉ Piotr Tryjanowski
piotr.tryjanowski@gmail.com

[1] Department of Zoology, Poznań University of Life Sciences, Wojska Polskiego 71C, 60-625 Poznan, Poland

[2] TUM School of Life Sciences, Ecoclimatology, Technical University of Munich, 85354 Freising, Germany

[3] Institute for Advanced Study, Technical University of Munich, 85748 Garching, Germany

[4] Institute of Biology, University of Szczecin, Wąska 13, 71-415 Szczecin, Poland

[5] Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Kamýcká 129, 16500 Prague, Czech Republic

[6] ENINA, Napoleońska 19, 61-671 Poznań, Poland

attention and support from conservation scientists and organizations (Kronenberg et al. 2017; Elliott et al. 2020). White storks are also used as indicator species in biodiversity, and ecological monitoring and assessments (Goutner and Furness 1998; Tobolka et al. 2012). They build large nests (up to 2 m in height and 1.5 m in diameter, and 250 kg in weight; Tryjanowski et al. 2009; Zbyryt et al. 2021) that are used repeatedly even over decades and that may also be relatively often used by other birds, such as sparrows *Passer* spp., Pied Wagtails *Motacilla alba*, Wood Pigeons *Columba palumbus*, and Starlings *Sturnus vulgaris*, for nesting (Indykiewicz 1998; Kosicki et al. 2007). Moreover, white storks are highly opportunistic feeders, bringing to nest and nestlings everything from large invertebrates to vertebrates, including rodents, amphibians, and snakes (Elliott et al. 2020). Remnants of prey, defecated droppings from nestlings over the nest edge, and minerals brought to the nest by parents affect physiochemical characteristic of the nest (Błońska et al. 2021). Nest inferior is humid and provides also organic material as a potential source of energy for assemblages of fungi and arthropods typical for soil (Błońska et al. 2021). Moreover, nests may attract also invertebrates, such as white stork parasites, spiders, or flying insects, hiding in the nests or feeding on organic material (Whelan et al. 2008; Mammeria et al. 2014) which may in turn attract other animals feeding on this type of prey. However, in contrast to the use large birds' nests as a substrate for nesting for other birds, we are not aware of a study focusing on diversity of vertebrates using stork nests as a source of food.

In this study, we counted birds foraging around white stork nests in Poland and divided them according to their foraging habits and behavior into two categories: (1) insectivorous aerially foraging birds (Barn Swallows *Hirundo rustica*, House Martins *Delichon urbicum*, and Swifts *Apus apus*) and (2) sparrows (House Sparrow *Passer domesticus* and Eurasian Tree Sparrow *P. montanus*) which collect food also from the nest surface and interior. Moreover, we also recorded bats that foraged close to the white stork nests. We specifically tested whether active white stork nests with chicks attract higher numbers of foraging birds and bats than empty stork nests or control sites containing only a pylon without stork nest.

Methods

Fieldwork took place between June 19th and 23rd of 2022. Data were collected in farmland areas located in Wielkopolska region (Poland), a typical breeding habitat for white stork in Poland (Tobolka et al. 2012; Kwieciński et al. 2016). To make data sampling efficient, we randomly selected White Storks' nests located only on electricity pylons, which are the most common nesting places in Poland for decades (Tryjanowski et al. 2009). Altogether, we have selected 51 paired sets: each stork nest was paired with a control site with pylon (but without nest) no closer than 250 m from the paired nest. Two types of sites with pylons were considered—those with and without nearby lamps. The paired set always included the same type of site, i.e., if the nest was built on a pylon with a lamp, the control point also included a pylon with a lamp. We also checked the status of the nest, whether it was active (with chicks) or empty.

Bird counts were performed in the evening from 17:30 until 20:30, while bat counts were conducted at night from 21:30 to 01:00. Bird counts were conducted by observing the space (25 m, with stork nest as a center) around each nest for 10 min. The observer stood about ~ 25 m from the nest, with good visibility on the nest, and recorded birds flying around the nest. We counted number of Barn Swallows *Hirundo rustica*, House Martins *Delichon urbicum*, and Swifts *Apus apus* (hereafter "insectivorous birds"), and House (*Passer domesticus*) and Eurasian Tree Sparrows (*P. montanus*) (hereafter "sparrows") around each nest and control point within the 25 m radius around and 5 m above the nest/control point. Once—21 June 2022—we observed Black Redstart *Phoenicurus ochruros* male collecting insects from stork nest, but due to the single observation and specific behavior of this bird species, this observation was excluded from further analyses.

At each nest and control site, at night following bird count, we estimated also number of bats passes using Bat Recorder (Mini-batcorder 1.0 ecoObs) for 10 min. The analyses of bat activity recordings were conducted using ecoObs software (bcAnalyze 2.0, batIdent 1.5 and bcAdmin 4, ecoObs GmbH), all recordings were additionally checked by by manual vetting. One individual of the *Myotis* genus, potentially *M. daubentonii* or *M. nattereri,* was identified only to the genus level due to the high similarity between conspecific sonograms (Parsons and Jones 2000). Because we recorded bats only during 12 counting sessions, we analyzed bat occurrence only as a binomial variable (present or absent). To reduce the potential impact of personal experience on identification abilities, all paired sets—nest and control—were sampled by the same experienced observers (P. T. and L. M. and A. L.).

Statistical analyses were performed using generalized linear mixed models (GLMM). We ran two separate Poisson models, using either number of insectivorous birds or number of sparrows counted near each nest or control point as a response variable. To account for the fact that each pair (nest site vs control) is dependent on the site (51 different sites), we introduced a random intercept and a random slope into the model. Each site can have a different baseline level (intercept) of response variable, and pairs from different sites can vary in its responses (slope) using the syntax "(Pair | Site ID)". We used point type (nest—active: chicks present;

nest—empty: no White Storks at the nest; control: no white stork nest) and the lighting/working lamp presence (yes or no) as predictors. For bats, we used the same predictors, but because the response variable was scored as binomial (due to many zeros during bat counts), we employed a GLMM with the binomial distribution. We used only random intercept of Site ID in the models because convergence issue.

We also used Poisson mixed model with the same random model structure to compare association between abundance of insectivorous birds and sparrows (response variables), respectively, with bats (predictor). However, in both cases, we detected over-dispersion. Hence, we used negative binomial distribution. Bat abundance was treated as a continuous variable.

We estimated the significance of association between response and predictor variables using the likelihood ratio test (LRT), which compares the full model to a reduced model where the target variable has been dropped. The model comparison was made according to AIC (Akaike information criterion), and computation was performed using the "drop1" function. Post hoc comparisons (Sidak tests) were performed using package "emmeans" (Lenth 2020) and mixed models were done using package "lme4" (Bates et al. 2014). All statistical analyses were conducted using R 4.3.1 software (R Development Core Team 2022).

Results

Altogether, we observed 424 individuals of insectivorous birds, with 337 barn swallows (79.5% of all insectivorous birds), 61 common house martins (14.4%), and 26 common swifts (6.1%). We also observed 225 sparrow individuals, including 198 house sparrows (88%) and 27 Eurasian tree sparrows (12%).

Additionally, we observed a total of 194 bats, including 118 Common Noctules (*Nyctalus noctula*; 60.8% of all bats), 23 Serotine Bats (*Eptesicus serotinus*; 11.9%), 35 Common Pipistrelles (*Pipistrellus pipistrellus*; 18%), 11 Nathusius's Pipistrelles (*Pipistrellus nathusii*; 5.7%), five Soprano Pipistrelles (*Pipistrellus pygmaeus*; 2.6%), one Northern Bat (*Eptesicus nilssonii*; 0.5%), and one *Myotis* sp. (0.5%).

Abundance of insectivorous birds was positively related with abundance bats (Fig. 1B; *df* = 1, LRT = 6.112, *p* = 0.013). Similarly, we found a positive association between sparrows' abundance and bats (Fig. 1A; *df* = 1, LRT = 6.406, *p* = 0.011).

In insectivorous birds, we found that the number of observed birds significantly differed between point type (*df* = 2, LRT = 7.394, *p* = 0.025) (Table S1). The post hoc comparison revealed a significantly higher bird numbers in counting points with the stork nests with chicks than in the control group (*p* = 0.031) (Fig. 1B). However, there was no difference between the control points and the points with empty nests (*p* = 0.877), nor between the empty nests and nests with chicks (*p* = 0.087). We found no significant association between number of observed birds and lamp status (*df* = 1, LRT = 0.463, *p* = 0.496).

In sparrows, we found that the significant effect of point type on number of observed sparrows (*df* = 2, LRT = 73.752, *p* < 0.001) (Table S2). We revealed a difference between the control group and the nests with chicks (*p* = 0.002) (Fig. 1C) but also between the control group and the empty nests (*p* = 0.004). However, there was no difference between the

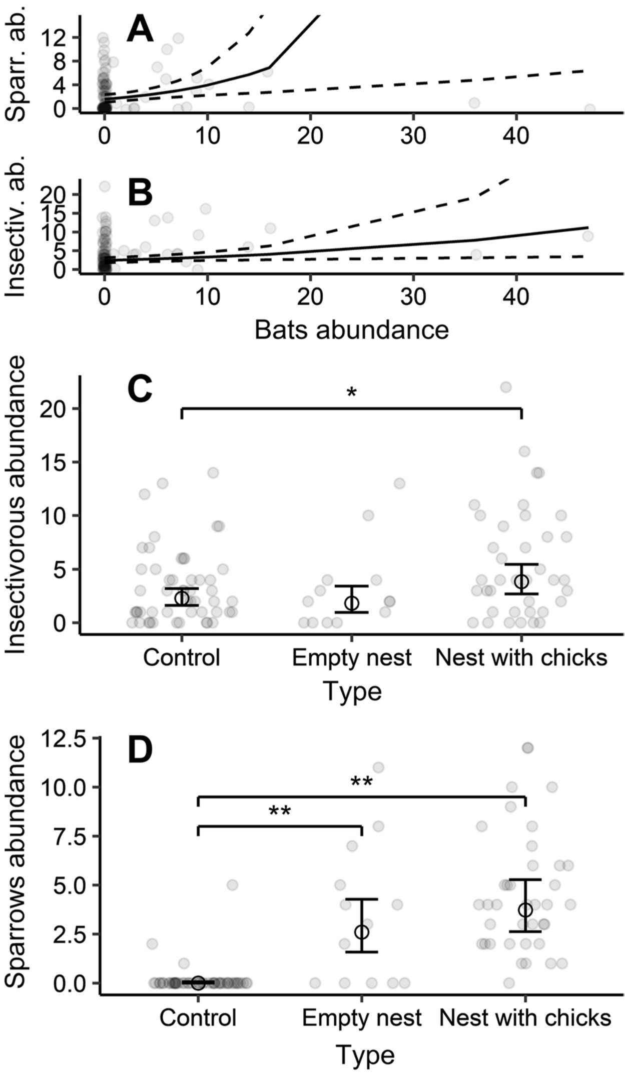

Fig. 1 **A** indicates significant ($p < 0.05$) relation between the number of observed insectivorous birds and bats and **B** relationship between the number of observed sparrows and bats. Number of observed insectivorous birds (**C**) and sparrows (**D**) near different types of count sites (control site without stork nest; site with empty stork nest; site with active stork nest). Asterisks indicate significant differences between site categories (*$p < 0.05$, **$p < 0.01$) and comparisons were made using the post hoc Sidak test. The points represent raw data

empty nests and nests with chicks ($p = 0.457$). We again found no significant association between number of observed birds and lamp status ($df = 1$, LRT = 0.200, $p = 0.655$).

In bats, we did not find a significant effect of nest type nor lamp status on the number of observed bat individuals ($df = 2$, LRT = 0.154, $p = 0.926$ and $df = 1$, LRT = 1.477, $p = 0.224$, respectively) (Table S3).

Discussion

Our results indicate that the nest of White Storks serve not only as breeding sites for some bird species (Kosicki et al. 2007; Zbyryt et al. 2017) or habitat for insects and other invertebrates (Zbyryt and Oleksa 2018; Błońska et al. 2021) but may represent also important source of food for other vertebrates. We found that even empty white stork nests attracted numerous smaller birds to forage in their proximity. However, we found no preference of bats to forage near white stork nests. Our study supports a hypothesis that the nests of large birds play an important role as biodiversity hotspots on a small spatial scale and are attractive places for many other species (Maciorowski et al. 2021; Lõhmus et al. 2021).

We found that active nests of White Storks attracted significantly higher numbers of insectivorous aerially feeding birds and sparrows than control points without any nest. However, we found that empty and active nests attracted similar amounts of these birds. Moreover, we showed that bird and bat abundances were correlated across sites, although the effect of white stork nest presence was more evident in birds than bats. Note, however, that the direction of nest effect presence was same in both animal groups. The mechanistic explanation is straightforward: birds and bats feeding on insects and other invertebrates search and concentrate near places with higher abundance of they prey than in surrounding environment, similarly to their foraging behavior near livestock (Møller 2001; Downs and Sanderson 2010; Orłowski and Karg 2013). Besides invertebrate species that develop in the nest lining (Jerzak et al. 2006; Zbyryt and Oleksa 2018), there are also species that utilize the nest's waste and food remnants (Gilbert et al. 2015; Błońska et al. 2021), as well as insects that parasitize on nestlings (Mammeria et al. 2014). All of these insect groups can serve as a food source for insect-eating birds and bats and attract them. Positive correlation between abundance of bats and birds may also suggest the presence of rich and/or abundant flying insects around storks' nests and little competition between two groups of insectivores, presumably because of temporal mismatch in the main foraging activity as well as differences in the resources used (Shields and Bildstein 1979).

Previous studies suggested that artificial light from streetlamps and other sources has affected the foraging behavior of both birds and bats (Rydell 1992; Lebbin et al. 2007; Dwyer et al. 2013). However, we did not find any significant effect of street lamps on number of foraging birds and bats. In birds, the lack of effect is probably linked to the fact that observations were performed during the daylight whereas the lack of effect in bats may be related to the relatively small sample size. Moreover, other factors such as foraging habitat structure could be more important than the presence of lamps (Lesiński et al. 2000).

Altogether, we have demonstrated that white stork nests with its local invertebrate fauna may be attractive foraging location for other vertebrates, particularly insectivorous birds. This study brings another evidence that White Storks, but presumably also other large birds, may act as umbrella species important to co-occurring organisms in unexpected and complex ways. The protection of White Storks and their nests is important for other species, not only those directly using the nests but also for those foraging in their vicinity (Kosicki et al. 2007; Zbyryt et al. 2017; Kronenberg et al. 2017). Hence, the monitoring of changes in species composition and abundance of organisms associated with the white stork can be used as an indicator of environmental changes (Tobolka et al. 2012; Kronenberg et al. 2017).

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10336-023-02143-y.

Acknowledgements We thank to Marcin Tobółka for information on nest positions in the study area, and Martyna Fratczak with help in the field. PT and PM were supported by IAS TUM—Hans Fisher Senior Fellowship.

Funding Open Access funding enabled and organized by Projekt DEAL.

References

Bates D, Maechler M, Bolker B, Walker S (2014) lme4: linear mixed-effects models using Eigen and S4. R package version 1.1–7. http://CRAN.R-project.org/package=lme4. Accessed 12 Oct 2023

Błońska E, Lasota J, Jankowiak R et al (2021) Biological and physicochemical properties of the nests of White Stork Ciconia ciconia reveal soil entirely formed, modified and maintained by birds.

Sci Total Environ 763:143020. https://doi.org/10.1016/J.SCITOTENV.2020.143020

Branton M, Richardson JS (2011) Assessing the value of the umbrella-species concept for conservation planning with meta-analysis. Conserv Biol 25:9–20. https://doi.org/10.1111/J.1523-1739.2010.01606.X

Downs NC, Sanderson LJ (2010) Do bats forage over cattle dung or over cattle? Acta Chiropt 12:349–358. https://doi.org/10.3161/150811010X537936

Dwyer RG, Bearhop S, Campbell HA, Bryant DM (2013) Shedding light on light: benefits of anthropogenic illumination to a nocturnally foraging shorebird. J Anim Ecol 82:478–485. https://doi.org/10.1111/1365-2656.12012

Elliott A, Garcia EFJ, Boesman PFD (2020) White stork (*Ciconia ciconia*), version 1.0. In: del Hoyo J, Elliott A, Sargatal J et al (eds) Birds of the world. Cornell Lab of Ornithology, Ithaca

Estes JA, Terborgh J, Brashares JS et al (2011) Trophic downgrading of planet earth. Science 333:301–306. https://doi.org/10.1126/SCIENCE.1205106/SUPPL_FILE/ESTES.SOM.PDF

Gilbert NI, Correia RA, Silva JP et al (2015) Are white storks addicted to junk food? Impacts of landfill use on the movement and behaviour of resident white storks (*Ciconia ciconia*) from a partially migratory population. Mov Ecol 4:1–13. https://doi.org/10.1186/S40462-016-0070-0/TABLES/2

Goutner V, Furness RW (1998) Feathers of white stork *Ciconia ciconia* chicks in North-Eastern Greece, as indicators of geographical variation in mercury contamination. Toxicol Environ Chem 67:379–390. https://doi.org/10.1080/02772249809358629

Indykiewicz P (1998) Breeding of house sparrows *Passer domesticus*, tree sparrow *P. montanus*, and starling *Sturnus vulgaris* in the white stork *Ciconia ciconia* nests. Notatki Ornitol 39:97–104

Jerzak L, Bocheński M, Czechowski P (2006) Unusual feeding behaviour of the White Stork *Ciconia ciconia* in the Kłopot colony (W Poland). In: Sparks T, Tryjanowski P, Jerzak L (eds) The White Stork in Poland: studies in biology, ecology and conservation. Bogucki Wydawnictwo Naukowe, Poznan, pp 203–207

Kosicki JZ, Sparks TH, Tryjanowski P (2007) House sparrows benefit from the conservation of white storks. Naturwissenschaften 94:412–415. https://doi.org/10.1007/S00114-006-0207-X/FIGURES/2

Kronenberg J, Andersson E, Tryjanowski P (2017) Connecting the social and the ecological in the focal species concept: case study of White Stork. Nat Conserv 22:79–105. https://doi.org/10.3897/NATURECONSERVATION.22.12055

Kwieciński Z, Morelli F, Antczak M et al (2016) Seasonal changes in avian communities living in an extensively used farmland of Western Poland. Eur J Ecol 2:9–18. https://doi.org/10.1515/EJE-2016-0012

Lebbin DJ, Harvey MG, Lenz TC et al (2007) Nocturnal migrants foraging at night by artificial light. Wilson J Ornithol 119:506–508. https://doi.org/10.1676/06-139.1

Lenth R (2020) emmeans: estimated marginal means, aka least-squares means. R package version 151

Lesiński G, Fuszara E, Kowalski M (2000) Foraging areas and relative density of bats (Chiroptera) in differently human transformed landscapes. Z Saugetierkd 65:129–137

Lõhmus A, Runnel K, Palo A et al (2021) Value of a broken umbrella: abandoned nest sites of the black stork (*Ciconia nigra*) host rich biodiversity. Biodivers Conserv 30:3647–3664. https://doi.org/10.1007/S10531-021-02268-7/FIGURES/3

Maciorowski G, Jankowiak Ł, Sparks TH et al (2021) Biodiversity hotspots at a small scale: the importance of eagles' nests to many other animals. Ecology 102:e03220. https://doi.org/10.1002/ECY.3220

Malhi Y, Doughty CE, Galetti M et al (2016) Megafauna and ecosystem function from the Pleistocene to the Anthropocene. Proc Natl Acad Sci 113:838–846. https://doi.org/10.1073/PNAS.1502540113

Mammeria AB, Bitam I, Boutellis A, Kernif T (2014) First account of arthropods in the nest of the white stork, *Ciconia ciconia*, in Algeria, including the flea *Ctenocephalides felis*. Bull Soc Zool Fr 139:199–213

Møller AP (2001) The effect of dairy farming on barn swallow *Hirundo rustica* abundance, distribution and reproduction. J Appl Ecol 38:378–389. https://doi.org/10.1046/J.1365-2664.2001.00593.X

Orłowski G, Karg J (2013) Diet breadth and overlap in three sympatric aerial insectivorous birds at the same location. Bird Study 60:475–483. https://doi.org/10.1080/00063657.2013.839622

Parsons S, Jones G (2000) Acoustic identification of twelve species of echolocating bat by discriminant function analysis and artificial neural networks. J Exp Biol 203:2641–2656. https://doi.org/10.1242/JEB.203.17.2641

R Development Core Team (2022) A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna

Rydell J (1992) Exploitation of insects around streetlamps by bats in Sweden. Funct Ecol 6:744. https://doi.org/10.2307/2389972

Shields WM, Bildstein KL (1979) Bird versus bats: behavioral interactions at a localized food source. Ecology 60:468–474. https://doi.org/10.2307/1936065

Smith FA, Doughty CE, Malhi Y et al (2016) Megafauna in the Earth system. Ecography 39:99–108. https://doi.org/10.1111/ECOG.02156

Tobolka M, Sparks TH, Tryjanowski P (2012) Does the White Stork *Ciconia ciconia* reflect farmland bird diversity? Ornis Fenn 89:222–228

Tryjanowski P, Kosicki JZ, Kuzniak S, Sparks TH (2009) Long-term changes and breeding success in relation to nesting structures used by the White Stork, *Ciconia ciconia*. Ann Zool Fennici 46:34–38. https://doi.org/10.5735/086.046.0104

Whelan CJ, Wenny DG, Marquis RJ (2008) Ecosystem services provided by birds. Ann N Y Acad Sci 1134:25–60. https://doi.org/10.1196/ANNALS.1439.003

Zbyryt A, Oleksa A (2018) The first observation of obligate saproxylic chafer larvae inside white stork *Ciconia ciconia* nest. J Insect Conserv 22:795–797. https://doi.org/10.1007/S10841-018-0106-4/FIGURES/1

Zbyryt A, Jakubas D, Tobolka M (2017) Factors determining presence of passerines breeding within White Stork *Ciconia ciconia* nests. Sci Nat 104:1–10. https://doi.org/10.1007/S00114-017-1492-2/TABLES/5

Zbyryt A, Dylewski Ł, Neubauer G (2021) Mass of white stork nests predicted from their size: online calculator and implications for conservation. J Nat Conserv 60:125967. https://doi.org/10.1016/J.JNC.2021.125967