PLOVDIV UNIVERSITY "PAISII HILENDARSKI"
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Emil Sashev Yordanov

Breeding parameters and phenology of the Egyptian vulture (*Neophron percnopterus Linnaeus,* 1758) in Bulgaria

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The PhD thesis contains 144 pages and includes: 5 tables, 32 figures, 4 appendices and 410 literary sources, of which 24 are in Cyrillic and 386 are in Latin.

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The materials related to the defence are available to the interested parties at the Department of Ecology and environmental conservation and in the library of PU "Paisii Hilendarski"

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1. Introduction

Since ancient times, man has been aware of the connection of vultures with life and death. For the ancient Egyptians, vultures were a symbol of purity and parental care, and also a symbol of the eternal cycle of death and rebirth, due to their role in the food chain - their ability to turn "death" (the dead animals they feed on) into life, distinguished by incomparable elegance in their flight. Because of this unique role in ecosystems, they provide specific and significant ecosystem services, such as disease control and mitigation, providing economic benefits, intellectual, spiritual and aesthetic inspiration (Moleón *et al.* 2014, DeVault *et al.* 2016).

Vultures are divided into two groups - New World vultures and Old-World vultures (Ferguson-Lees & Christie 2001). The Egyptian vulture is a medium-sized Old-World vulture and the only representative of the genus *Neophron* (Dement'ev *et al.* 1966, Cramp & Simmons 1990, Donázar *et al.* 2002a). The species is globally endangered, and is declining in almost its entire range. In the Balkans, the species is threatened with extinction, with only 54 pairs left, the majority of pairs are on the territory of Bulgaria (Николов *и кол*. 2022, BirdLife International 2023).

The collection of information on the breeding cycle is an important part of many studies of the population ecology of birds, and often this information is essential to the identification and implementation of effective conservation measures for threatened and declining species (Green 2004). Tracking reproductive parameters and gathering new information about the breeding biology and ecology of the species can provide valuable information about the state of the population and the factors that influence it. This information would be a key tool for the development of conservation strategies and plans, especially for the very threatened and isolated populations of the species, where this knowledge would be extremely useful. The advent of new technologies gives us the opportunity to take a closer look at the life of birds during their reproductive period. Alternative monitoring methods such as trail cameras and cameras in to the nests can significantly contribute to a more accurate study of the reproductive biology of the species. Such methods make it possible to track the change of partners in nesting pairs, the loss of eggs and young, and even the reasons for these gives us an important event in some cases.

Conventional nest monitoring methods require a lot of time and effort to collect accurate information and avoid disturbing the birds. Binocular monitoring from a stationary point at a distance that does not disturb the birds cannot always give accurate information on the number of hatchlings in the nests, necessitating repeated and even third visits to the same territory. Unmanned aerial vehicles (UAVs, below drone) can be a good alternative to the conventional monitoring method, giving much more accurate results in a much shorter time. The use of a drone allows not only direct observation in the nest itself and accurate counting of the number of hatchlings, but also allows checking remote rocks with rock niches suitable for nesting of the species, those with exposures that do not allow direct observation with a binocular.

All these alternative methods may cause disturbance to the nesting birds and their offspring, which may lead to the abandonment of the nest and even a change of territory, therefore there is a need to draw up guidelines and recommendations for their correct use.

And even though the species is very well studied, and researched in many directions, and has even become one of the species for which there are some of the largest conservation projects worldwide, there are still some questions related to its nesting ecology and biology, which are the subject of research in the current work.

2. Aim and objectives of the study

The aim of the present research is to study the breeding parameters and some aspects of the breeding biology and phenology of the Egyptian vulture (*Neophron percnopterus*) in Bulgaria.

To realize our goal, we set the following tasks:

1. Calculation of the main breeding parameters and determination of the number, distribution and trend of the breeding population of the Egyptian vulture in Bulgaria for the period 2017–2022.
2. Testing a conventional and alternative method for monitoring breeding success in the Egyptian vulture using unmanned aerial vehicle - a drone.
3. Investigating the breeding biology and phenology of the species by installing trail cameras in the nests of the species.
4. Establishing of replacement rate in the observed pairs of Egyptian vultures with trail cameras.
5. Establishing the loss of young and eggs and the reasons for these losses.
6. Description, application and guidance in the use of alternative methods for monitoring Egyptian vultures.

3. Materials and methods
3.1. Range of the study

The study covers the autochthonous population of the Egyptian vulture in Bulgaria, whose breeding range covers the Rusenski Lom, Eastern Balkan Mountain and Eastern Rhodopes (ARKUMAREV *et al.* 2018).

3.2. Following population size, population trends and breeding parameters

In order to establish the breeding parameters and the trend of the population of the species in Bulgaria, monitoring was carried out of all known breeding areas of the species in three regions of the country - Eastern Rhodopes, Eastern Balkan Mountain with the surrounding plateaus and Rusenski Lom (ARKUMAREV *et al.* 2018) (Figure 1).

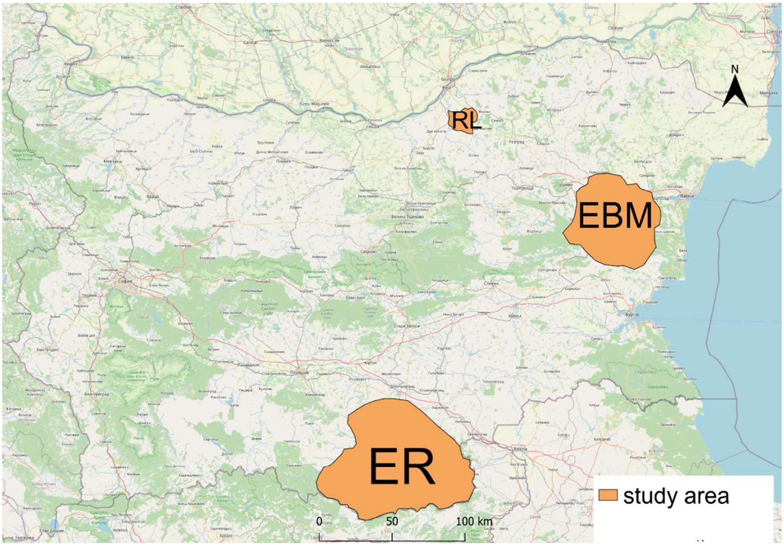

Fig. 1. Map of the study areas – Rusenski Lom (RL), Eastern Balkan Mountain (EBM) and Eastern Rhodopes (ER).

All active nesting areas of the Egyptian vulture in Bulgaria were regularly visited in the period 2017–2022 in order to establish the distribution and numbers of the population of the species in Bulgaria and to calculate the main breeding parameters and population trend of the species. In order to register the active nesting territories, all known territories of the species were visited, making observations from stationary points, and a transect method was also applied to check suitable rocks and neighbouring territories to detect possibly breeding birds in previously unknown territories or historical ones (Bibby *et al*. 1999).

Binoculars with a magnification of 10x50 and a Leica spotting scope with a magnification of 60x were used to monitor the nesting territories of the Egyptian vulture. Data were collected using the mobile application "SmartBirds Pro" (Popgeorgiev *et al*. 2015). Monitoring was carried out during the daylight hours, in to suitable weather conditions and visibility in order to achieve the greatest possible accuracy in reporting breeding parameters (Anderson 2007, Hardey 2009). The observation of the breeding territories and the determination of their status, as well as the search for new nests, was carried out throughout the breeding season of the species from April to September. Searching for breeding areas is more intensive in the pre-laying period, when birds mark and defend their territory, carry nest material and repair their nests (Newton 1979, Cramp & Simmons 1980). At least five visits were made each year (2017–2022) to each territory during the breeding season.

Breeding parameters were calculated as follows (Cheylan 1981, Steenhof & Newton 2007):

1. Productivity (number of fledglings/number of occupied territories);
2. Breeding success (number of fledglings/number of laying pairs);
3. Fledgling success (number of fledglings/number of successful pairs);
4. Ratio of laying pairs (number of laying pairs/number of occupied territories and multiplied by 100);
5. Ratio of successful pairs (number of successful pairs/laying pairs and multiplied by 100).

3.3. Testing a methodology for monitoring breeding success in the Egyptian vulture using a drone

The testing of a methodology for establishing the breeding success of the Egyptian vulture was carried out in the period 2019–2022 by means of a drone (drones is a type of UAV) in the Eastern Rhodopes. For each visit to the selected nests for testing the drone methodology, a brief inspection with spotting scope was first performed to count the number of young in the nest, also it was recorded the time for establish the number of young in the nest. A drone flight is then carried out to each of the selected nests to verify the information on the number of young and to record the time taken by the drone inspection and subsequently to compare the time taken by the two methods. For this purpose, a DJI Mavic 2 zoom drone was used, equipped with a 12-megapixel camera (with photo size 4000×3000 and video resolution – 4K: 3840×2160 30p), with 2x optical zoom (24-48mm), a maximum flight speed of 72 km/h (in sport mode) and a flight time of up to 30 minutes (Figure 2).

Fig. 2. DJI Mavic 2 Zoom drone.

All flights were made during the period July – August, when the young are over 30 days old.

3.4. Study of the breeding biology and phenology of the species

To establish the breeding biology and phenology of the species, the behaviour of six pairs of Egyptian vultures was observed, using trail cameras in their nests, during their 22 breeding attempts in the period 2011–2021 in the Eastern Rhodope region. Trail cameras are installed in the nests in late February – early March – before the birds return from their wintering grounds. For the purpose of the research, two models of trail cameras were used - Body Guard with a 30-megapixel camera and MMS function and Scout Guard with a 12-megapixel camera. Before the trail cameras are installed, they are masked as best as possible by covering them with small stones taken from the rocks on which they will be placed, to better blend in with the environment in the nests, to avoid any stress on the birds during of their reproduction. The methodology for installing trail cameras in nests of Egyptian vultures is described in detail in YORDANOV & DOBREV 2021. For the entire period of the study, a total of 208,613 photos were reviewed, within the framework of the dissertation work, 126,175 photos were reviewed. Reviewing the photographs within the dissertation took an average of 14,4 months.

3.5. Establishing the replacement rate of partners in observed pairs with trail cameras

To determine the replacement rate (change of partners in pairs) in the period 2011 and 2021 in the Eastern Rhodope region, six pairs of Egyptian vultures were observed using six trail cameras in six nests. For the purposes of the study, an archive was made with the faces of all the birds from the studied pairs with trail camera. That archive allows the individual recognition of each of the observed birds and, accordingly, the establishment of a possible change of partners in the observed pairs (see appendix 2 of the dissertation work). This archive also allows the identification of dead birds from the pairs.

3.6. Establishing the loss of eggs and young.

In order to determine the loss of eggs and young, in the period 2012–2021 in the Eastern Rhodopes and Eastern Balkan Mountain region, 7 pairs of Egyptian vultures were observed during their 26 breeding attempts, using six trail cameras and one online camera (HikeVision HD) in the nests.

3.7. Statistical data processing

Statistical processing of the data and graphs were done with the program RStudio – 2022.7.1.554 (RSTUDI TEEM 2020). The maps were made with QGIS 3.26.3 (QGIS DEVELOPMENT TEAM 2022). When comparing the breeding parameters, the different population clusters of Rusenski Lom and Eastern Balkan Mountain with the surrounding plateaus are grouped into one data set called Northeast Bulgaria, due to the small number of breeding territories (VELETSKI *et al* 2015г). Data were analysed for normality using the Shapiro-Wilk test. R package "rtrim" was used to track the population trend. 2.1.1, for breeding parameters - Mann-Whitney U-test, for comparing effort – χ2 test, for breeding biology and phenology – χ2 test, Kruskal-Wallis test.

4. Results and Discussion

4.1. Breeding parameters

During the period 2017–2022, 48 breeding territories and 152 breeding attempts of pairs of Egyptian vultures were observed, 114 of which (75% of the cases) being successful and the pairs raised at least one young. On average, 26 ± 3.1 young per year were raised in Bulgaria, or an average of 1.36 young per successful breeding (n=114). On average per year, 84,8% of the pairs laid eggs (n=21,5 ± 1,25 pairs per year), and 88,12% of incubating pairs were successful (Figure 3). 15 unsuccessful breeding attempts were recorded. In 73,3% (n=11) of these unsuccessful attempts the pairs failed at the incubation period and in 26,7% (n=4) failed at the chick rearing period.

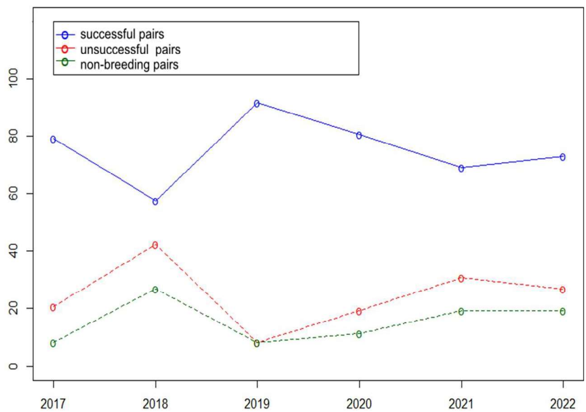

Fig. 3. Annual dynamics of successful, unsuccessful and non-breeding pairs for the period 2017–2022, (values are expressed in percentages).

For the entire study period, the reported values of mean breeding success were 1,22 ± 0.1, mean productivity was 0,98 ± 0,1 and mean fledgling success was 1,37 ± 0,08 (Table 1). Pairs nesting in Northeastern Bulgaria have lower values of breeding parameters. A statistically significant difference was found in productivity ($t = -2,275$, $df = 10$, $p = 0,046$) and mean fledgling success ($t = -3,2383$, $df = 10$, $p = 0.008$) between pairs in the Eastern Rhodopes and pairs nesting in Northeastern Bulgaria (Table 2). For the remaining three parameters, breeding success ($t = -1,92$, $df = 10$, $p = 0.08$), ratio of the successful pairs ($U = 20$, $p = 0,79$) and ratio of the laying pairs ($t = -1,1841$, $df = 10$, $p = 0,2638$) the difference between breeding pairs in the two regions was not statistically significant.

The reported values of the breeding parameters in our study are higher compared to the reported values in previous studies for Bulgaria (ARKUMAREV *et al*. 2018) (Figure 4)

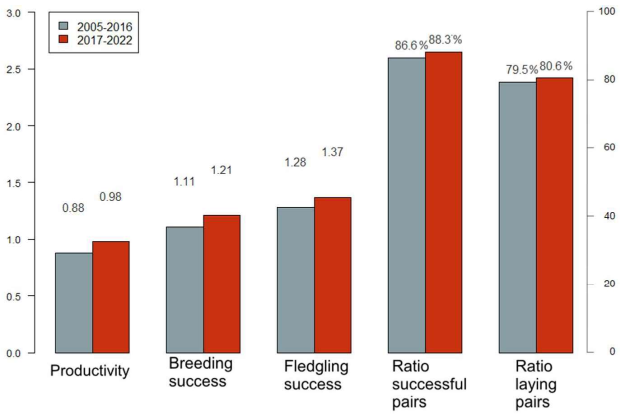

Fig. 4. Comparison of breeding parameters from previous studies of the species for the period 2005–2016 (ARKUMAREV *et al*. 2018) and our study for the period 2017–2022 for the territory of Bulgaria.

The probable reason is that, unlike in the Eastern Rhodopes, where natural food is abundant, in Northeastern Bulgaria it is scarce and difficult to access. This region lacks large and well-functioning feeding grounds, such as in the Eastern Rhodopes, where many pairs feed in such places. Despite the highly varied diet of Egyptian vultures, it is likely that pairs in Northeastern Bulgaria, unlike those in the Eastern Rhodopes, cannot rely on constant food sources and thus may not be able to successfully feed more than one young.

The likely reason for the lower values of breeding parameters may also be due to human disturbance, increased mortality of adults during the breeding season, poaching or nest predation (SARAVIA *et al.* 2016). Cases of illegal shooting and nest robbing are known for this region in the past (SARAVIA *et al.* 2016). During the period of our study, a case of failure of incubating pair was recorded in the area, due to cave climbing training conducted near the pair's nest in 2021 (BSPB unpubl.).

It is a fact that the existence of controlled sources of food (such as feeding grounds or places for individual feeding around the nests) with reliable and constant food positively affects the occupation of the territories (OPPEL *et al.* 2017, TAULER *et al.* 2017). Controlled food sources also support non-territorial birds, which often disperse outside "safe zones", and this dispersal increases the likelihood of mortality from various threats (STAMENOV & DOBREV 2021). Increasing the survival of young and near-adult non-breeding birds will directly contribute to the recruitment of future breeding individuals that could potentially occupy abandoned or new breeding territories (STAMENOV & DOBREV 2021). This, in turn, would have a positive effect on the number of couples. Supplementary feeding combined with nest guarding during the fledgling period is a good strategy to influence population decline on the one hand, and increase productivity on the other (OPPEL *et al.*2016b). Targeted application of these measures in a certain phase of the reproduction of the pairs can have significant benefits for the population (reduced mortality due to accidental poisoning, rescue and taking of young for rearing in rescue centers, etc.) (DOBREV *et al.* 2016b, OPPEL *et al.* 2016b).

4.2. Distribution, number and trend of the population of the species in Bulgaria

For the last 6 years, the spread of the Egyptian vulture in Bulgaria has been preserved in three main territories, the Eastern Rhodope Mountains, the Eastern Balkan Mountain and the Rusenski Lom. The population of the species increased by 7,4% in terms of the number of territories occupied, which increased from 27 in 2017 to 29 in 2022. The number of pairs also increasing by 6,7% – from 24 in 2017 to 26 in 2022. The population growth rate of the Egyptian vulture in Bulgaria for the study period was 1,074 (Figure 5).

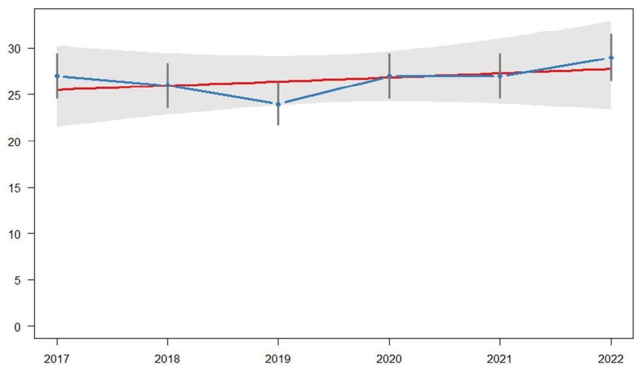

Fig. 5. Population trend of the Egyptian vulture in Bulgaria (2017–2022). The red line represents the population trend, the grey is the 95% confidence interval.

Data on the breeding distribution of the Egyptian vulture in Bulgaria exists since the middle of the 19th century. At the beginning of the 20th century, it was reported as numerous, nesting on rocks all over the country and the number probably reached 300–500 pairs. By 2016, the population of the Egyptian vulture in Bulgaria had shrunk to three main clusters: the Eastern Rhodope Mountains, the Eastern Balkan Mountain and the Rusensky Lom (ARKUMAREV *et al*. 2018). The results of the present study demonstrate that the species has persisted in the same three main breeding regions (Eastern Rhodopes, Eastern Balkan Mountain and Rusenski Lom) and for the first time since systematic monitoring has been conducted, a stabilization of the population numbers has been observed in the last six years. The number of occupied territories in 2022 increased to 29 (in 2017 it was 27), remaining the highest for the period. The number of breeding pairs remained stable throughout the period – an average of 25 ± 0,9 pairs.

Small fluctuations in the number of pairs were observed throughout the study period, with increases and decreases in some areas. The probable reason for these fluctuations is related to various threats that still operate along the migration route and in the breeding grounds (SHOBRAK *et al.* 2020, OPPEL *et al*. 2021a, OPPEL *et al.* 2022). In the last year alone, five individually tagged birds have died in cases of poaching in Bulgaria, electrocution in Turkey and suspected poisoning in Oman and Chad (OPPEL *et al*. 2023). Previous studies of the species for the territory of Bulgaria showed a drastic decrease in its population by 51.8% in the period 2003–2016 (ARKUMAREV *et al*. 2018), as well as in the Balkan Peninsula – a population decrease of 4-8% per year was observed during the period from 2010 to 2013. (VELEVSKI *et al.* 2014, 2015, OPPEL *et al.* 2015).

This stabilization of the population of the Egyptian vulture in Bulgaria is probably due to a large extent to the implementation of many measures to protect the species along its entire migration path, as well as to the releasing of young birds into the wild, bred in a closed restocking program within the framework of a transboundary project "New hope for the Egyptian vulture" (LIFE16 NAT/BG/000874) during the last 5 years. After the implementation of the conservation measures under the project, the survival rate of the young and adult birds has increased. That is a key element for the stabilization of the population of the species, in Bulgaria and in the Balkans (OPPEL *et al*. 2023). Given the low historical levels of the species, survival has been the main constraint on stabilization in past decades as well (Oppel *et al.* 2021c). The annual survival probability of adults is a key demographic parameter that determines the population trajectory of many long-lived species (SAETHER & BAKKE 2000).

The stabilization of the population of the Egyptian vulture in our country could be a key factor for the species in the Balkans, as it turns out to be a source of birds for the nesting areas in our neighbouring countries. Such is the example of a bird tracked with a GPS transmitter – the bird was hatched in the Eastern Rhodopes in 2012, after reaching sexual maturity in 2018, occupied a breeding territory in Greece (DOBREV *et al*. 2021b).

4.3. Test methodology for monitoring nesting success in the Egyptian vulture using a drone

For a period of 4 years (2019–2022), 14 flights were made to 14 different active nests of Egyptian vultures (53,8% of active nests in the country). The average flight distance to an occupied nest is 768,6±349,8 m (max 1552,6 m, min 160,4 m), and the average distance from the drone to the nest niches when establishing the number of young is 7,3±1 .8 m. The total number of chicks detected by drone was 18, while the number of chicks detected by spotting scope monitoring was 10. The mean time per nest to detect the number of chicks by drone was 0,15 hours (2,27±0, 05 hours in total for all nests), and the average time per nest to determine the number of young with a spotting scope was 1,35 hours (24,46±1,25 hours in total for all nests). In our results, have significant difference in the time to establish the number of chicks observed between two methods ($\chi 2$ = 14,906, $p < 0,001$) – drone monitoring and spotting scope monitoring (Figure 7).

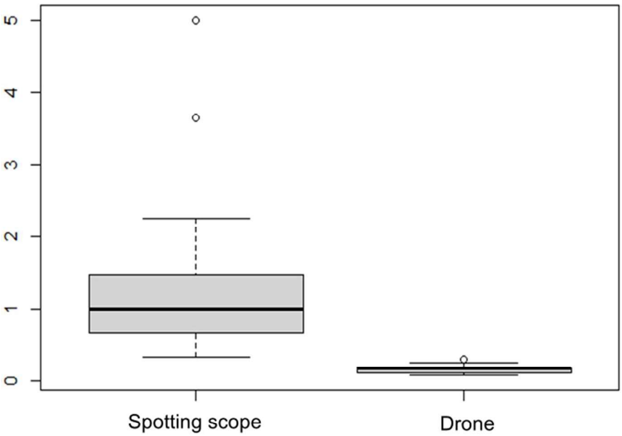

Fig. 7. The time to establish the number of young in the nests for both methods. – observation with a spotting scope and observation with a drone during the chick rearing period.

Using a drone to determine the number of young in the nests takes significantly less time than the traditional monitoring method, these results are also corresponded with other studies conducted with birds of prey (GALLEGO & SARASOLA 2021, JUNDA *et al*. 2015, WEISSENSTEINER *et al*. 2015).

In the results of the present study, a significant difference was observed in the number of chicks detected by the two methods, 8 more chicks were detected with the drone than with the spotting scope. This can be explained by the fact that the observations with spotting scope are made from levels lower than the level of the nests, also from great distances. Very often the nests are filled up with a lot of nest material, branches, wool, etc., which makes establishing the exact number of young in the nest even more difficult and time-consuming.

In order to count the exact number of young with a spotting scope, a second visit to the nests is required, and in some territories even a third visit (BSPB unpub.). The use of a drone makes it possible to avoid repeated visits to the breeding areas during the rearing of the young, which in turn leads to saving time and financial resources. The drone model used in the present study has 2x optical zoom. Thats allows to observe directly into nest niches from a distance. The average distance between the drone and the nest niches for establishing number of young was 7,35±1.85 m, the closest at 5 m and the farthest at 10 m. The greater distance from the nest niche when observed by drone reduced the risk of stress on the young. When the drone approaches the nest, the response of the young is to lie down in the nest niche and remain motionless.

No other responses, expressing extreme stress, such as attempts to leave the nest were observed. In three of the nests, the parents returned while the drone was in front of the nest niche. Due to the noise from the propellers of the drone, the adult birds flew in a circle around the cliff with the nest at a great distance from the drone (about 50-80 m). In all three cases, 15 minutes after the drone was returned to the home point, the birds entered the nest niches. The same reaction was reported in another study with four species of birds of prey (JUNDA *et al.* 2016).

During the same period, 7 old territories, where the species was found in the past, were flown and checked. Also, its historical nests were photographed. 2 more potential territories were flown, in which there are convenient cliffs with suitable rock niches for nesting of the species (Figure 8).

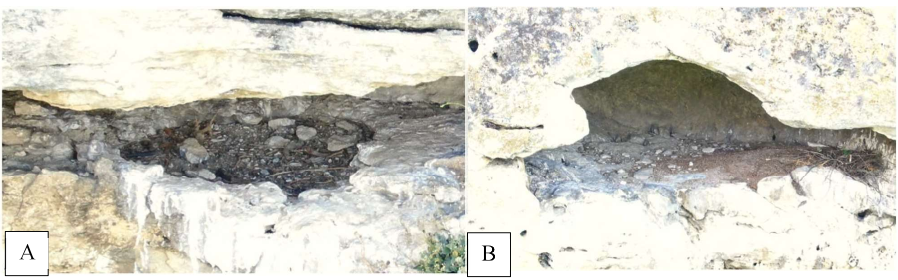

Fig. 8. **A** – Old nest, unused from years, **B** – potential nest niche.

The use of drones allows for the inspection of remote cliffs and those with exposures that do not allow direct observation with a spotting scope. With this type of cliffs, it is necessary to search for a point with good visibility to the cliff exposure and potential nest niches. That sometimes takes considerable amount of time and effort, as many times requires climbing opposite slopes or cliffs and driving on detours (Pers. comm.).

Drones provide the opportunity to monitor nests from a greater distance, more efficiently, safer, saving time and giving much more accurate results than the traditional monitoring method (CHABOT *et al*. 2015, GRENZDORFFER 2013, HODGSON *et al*. 2016). The results of the present study support these facts. Despite all these advantages of drones in the monitoring of birds of prey, it is necessary to strictly follow criteria and rules regarding their use. That will avoid any disturbance to the birds during the incubation period, because leaving the nest during this period will cause the eggs to cool down (see chapter Description, application and guidance of alternative methods for monitoring Egyptian vultures using trail cameras and drone).

4.4. Breeding biology and phenology

4.4.1. Phenology

The earliest recorded date of arrival of adults from wintering grounds is March 17, the latest is April 24. For the entire period (2011–2021), two exceptions were observed. In 55% (n = 11) of observed cases, the male bird returned before the female, in 35% (n = 7) the female returned before the male, and in only two cases (10%) male and female birds return at the same time. The earliest date of start incubation (laying of the first egg) was recorded on March 31, and the latest on May 6. The earliest laying of the second egg was recorded on April 5, and the latest on May 11. Hatching of the first young was recorded on May 20 at the earliest and June 6 at the latest. The hatching of the second chick was recorded on May 17 at the earliest and June 10 at the latest. The first flight of the first hatchling was done on 6 August at the earliest and was reported on 26 August at the latest. The first flight of the second young was recorded as early as August 16 and as late as September 1. Like many other migratory birds, the Egyptian vulture optimizes its spring migration and migrates faster in the spring than in the fall. The strong desire for rapid migration arises due to competition for the order of arrival at the breeding grounds (NILSSON *et al.* 2013). That provides it with the opportunity to return as early as possible and occupy its breeding grounds before other species. In the present study, the earliest recorded date of nest occupation was March 17 and the latest arrival of an adult at the nest was May. 26. Adult Egyptian vultures in the Balkans return from their wintering grounds in a wide range of times and as early as mid-March (PHIPPS *et al.* 2019), and this is also confirmed in the present study.

4.4.2. Nest building

The results of the present study show that nest building activity (which includes: bringing nest material and arranging the nest) starts 15,1 ± 7,7 days before the laying of the first egg. The construction of the nest is mainly carried out in the morning hours (in 49,6% of cases). The contribution of the male to the delivery of nest material to the nest was greater than that the female ($\chi2 = 2,5$, $p < 0,05$), also the contribution of the male to the arranging of the nest was greater ($\chi2 = 4$, $p = 0,045$). Each pair delivered an average of 21,4 ± 18,4 items (nest material) per breeding season. The nest material used is mainly branches and wool, birds deliver the nest material to the nest in their beaks. The results of the present study show that the male Egyptian vulture plays a major role in bringing nest material and arranging the nest, which is correspond with other studies and also for other vulture species (MARGALIDA & BERTRAN 2000, MORANT ETXEBARRIA *et al*. 2019). Nest building has traditionally been seen as a result of the advantages of natural selection, but it has also been associated with courtship and pair formation. Male birds taking over most of the nest-building activities is also a demonstration of their reproductive abilities (MARGALIDA & BERTRAN 2000). Nest building can be an energy consuming process and only individuals in good physical condition can build large nests (ZAHAVI 1987).

The use of different nest material in the present study supports the theory that wool is mostly used for insulation material. Materials such as various branches, twigs and roots are used to strengthen and reinforce the nest structure (ORTA *et al.* 2020). The reported differences in the percentage content of the nest material compared to other studies of the species can be explained by the fact that the material composition of the nest can vary depending on the available material in the breeding territory of the species (WIMBERGER 1984).

4.4.3. Copulation

For the entire period of the study, 74 copulations were recorded in the nests. The daily frequency of copulations at the nest was high (> 2 copulations per day), with most copulations occurring in the morning or afternoon hours (Figure 21). Copulation was first recorded in the nest on average 7,1 ± 1,9 days before start of the Incubation and was observed three times after the first egg was laid.

As a territorial bird, the Egyptian vulture begins to copulate after returning to the breeding territory, and as with other birds of prey, copulations are frequent and over a long period of time (NEGRO *et al*. 1992). Although the Egyptian vulture is thought to copulate outside the nest, the present study supports recent findings that this also occurs very frequently in the nest (DONÁZAR *et al.* 1994, DOBREV *et al*. 2021a). The observed copulations, after the laying date and therefore outside the fertile period of the Egyptian vulture, can be explained by the fact that, apart from fertilization, copulations also play a major role in strengthening the pair bond (BIRKHEAD et al. 1987, NEGRO & GRANDE 2001, DOBREV *et al.* 2021a). The reported high frequency of copulation, inside and outside of the nest, may be explained by the male's attempts to ensure paternity and dilute the sperm of possible competitors, as copulations of the female with other males are possible (BIRKHEAD *et al.* 1987, DONÁZAR *et al.* 1994). The present study confirms that the species copulates actively in the nest, with the largest peak observed in the afternoon to dusk, supporting the sperm competition hypothesis in which the male bird should be more likely to copulate late in the day to be able to dilute the sperm of possible competitors, which would provide him with paternity (BIRKHEAD *et al* 1987, BIRKHEAD *et al*. 1988). On the one hand, this behavior will in all probability guarantee the fertilization of the eggs, and on the other hand, it will also guarantee the paternity of the male bird of the pair.

6.4.4. Incubation

The laying interval between the first and the second egg was 6 ± 0,49 days, with the largest observed difference being 9 days and the smallest 4 days. Incubation of each egg lasted 41,8 ± 0,25 days. Both parents put almost equal effort into incubation (7,14 ± 0,13 hours per day for the female and 5,87 ± 0.12 for the male) throughout the period ($\chi 2$ = 0,125, p = 0,72). The female invested slightly more effort in night incubation than the male ($\chi 2$ = 11,139, p < 0,05), with the female observed in 58,31% of the last pictures before dark and the first picture early in the morning the next day. The number of shifts between male and female for incubation (136,81 ± 95,11 times averaged over the entire incubation period) remained almost the same across years (H = 5,67 df = 7, p = 0,57). The total number of shifts for the entire period of the survey for all breeding pairs was 2189. A total of 78,90% (n = 1727) of shifts were made within the nest and only 21,10% (n = 462) were made outside the nest. The results of the present study show that in most cases incubation begins between April 18 and 23, with the incubation period lasting 41,8 days, which is also consistent with other studies on the species (CRAMP & SIMMONS 1980, ARKUMAREV *et al*. 2018). The Egyptian vulture is a species that usually lays two eggs (BROWN & AMADON 1968, CRAMP & SIMMONS 1980, NAOROJI 2006), of which at least one young usually hatch. The results in the present study support the above findings. For the entire study period, all pairs that reached the incubation stage laid two eggs per season, and in just one case only one egg was laid. Incubation in raptors is thought to be done mainly by the female birds (NEWTON 1979). The results of the present study show that male and female birds exert almost equal effort in incubation – 54,88% ± 0,13 for the female and 45,11% ± 0,12 for the male bird, the difference in their effort being very small and statistically not significant ($\chi 2 = 0,125$, $p = 0,72$).

4.4.5. Raising the young

Over the entire study period, couples delivered food a total of 816 times, and in 751 of the deliveries, the size of the food item delivered could be identified. Of all food supplies (n = 816), 638 food items were successfully identified by the trail cameras, "soft tissue" – 65%, "bones and soft tissue" accounted – 13% and unidentified food items accounted – 22%. The identified taxa accounted for 10% of the food delivered to the nest, with four classes (Figure 9) and 19 species identified.

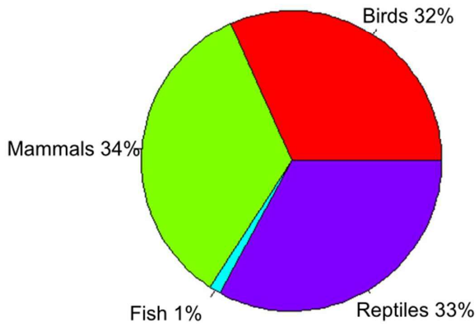

Fig. 9. Percentage of classes identified from the food delivered to the nest. The graph shows that mammals make up the largest percentage of the Egyptian vulture's diet.

The results of the present study show that food supplies are distributed almost equally between the partners of the couples ($\chi 2 = 1,32$, $p = 0,25$), and during the chick rearing period, chicks were fed with equal frequency by the male and female ($\chi 2 = 1,35$, $p = 0,24$).

The development and application of new technologies create opportunities for better disclosure of such details (YORDANOV & DOBREV 2021). The results of the present study show that most of the food items (65%) are soft tissues that will not be found later in the nest and thus the proportion of this type of food will be underestimated or remain unknown (DOBREV *et al.* 2016). Tracking changes in diet may prove to be a key factor for the species, as changes in diet and health status could affect the demographic parameters of some bird species (RESANO-MAYOR *et al.*, 2014). The results of the present study show that most of the food items that birds bring to the nest are the size of vultures' heads (46%) or larger (42%). Egyptian vultures feed on parts of dead animals that they find or visit landfills as well as other food sources. All this requires mobility and well-adapted eating habits during the chick rearing period. Given the presence of competitors for feeding sites, the Egyptian vulture should be able to easily collect and carry a sufficient amount of food to the nest. These facts could explain the results of the present study showing that most deliveries to the nests are made with medium or large food items. The differences in the percentage composition of the diet of the species with other studies (HIDALGO *et al*. 2005) can be explained by the fact that the lower availability of a certain type of food may force individuals to consume one of the two larger and more diverse groups of animals or those that are readily available locally (DOBREV *et al*. 2016).

4.5. Establishing the replacement rate of partners in observed pairs with trail cameras

Over the entire study period (2011–2022), partner change was detected in 33,33% of the observed pairs with trail camera (n = 2). In both cases, the change is of the female bird of the pairs. In the first case, the reason for the change of partner in the pair was poisoning of the female bird and the young with a poisonous bait against predators in 2020. In the second breeding season (2021), the nest is again occupied by the old male, but with a new female bird. The second recorded case of partner change is again from 2021, the likely cause being decease of the female bird during migration or on the wintering grounds. The Egyptian vulture is a monogamous species that adheres to the same nesting territory and maintains long-lasting bonds with its mates (CRAMP & SIMMONS 1980).

The installation of trail cameras in the nests of Egyptian vultures allowed us to identify each adult bird from the following nests individually and create an archive of all birds from the studied pairs (Dissertation Appendix 2). While the difference in facial skin coloration allows us to distinguish male from female individuals well (NEWTON & OLSEN 1990, CLARK & SCHMITT 1998), there is another facial marker that allows Egyptian vultures to be recognized strictly individually. These are black spots around the eyes or the so-called black mask (LEVY 1990, MERETSKY 1995, RODRIGUEA 2013) (Figure 10).

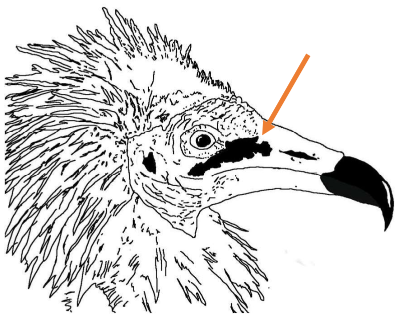

Fig. 10. Black mask – an individual mark for recognizing the individuals in the following pairs with trail cameras (Drawing – Emil Yordanov).

For the Eurasian goshawk (*Accipiter gentilis*) and the Eurasian sparrowhawk (*Accipiter nisus*) it is known that if the female dies, the male will remain in his territory and the female will be replaced by a new female, inasmuch as if the male bird of the pair dies, the nest will be abandoned. This is explained by the fact that one of the biological functions of the male is to hold the nest and the territory, inasmuch as the female bird will go in search of a new male if the "holder of the given territory" dies (OGBURN 1938). It is very likely that this is also true of Egyptian vultures. In the two observed cases in our study, the male birds maintained their territory as the female bird was replaced. In some studies, for long-lived birds, reuniting pairs have better productivity than those pairs that have changed partners (Rowley 1983, Clum 1995, Fowler 1995). Our research supports this fact. The couples which switched partners in the two cases we observed were unsuccessful in the first year with their new partner. Over the entire period of the present study, no mate exchange was observed between the fowling pairs with trail camera.

4.6. Loss of eggs and young

4.6.1. Egg loss

For the entire period of the study (2012 – 2021) in 90,9% of the cases the pairs laid 2 eggs each, and a total of 42 eggs were laid, of which 35 (83,3%) hatched, and 4 (9,5%) were registered unhatched eggs in three different nests. 3 cases were also recorded in two different nests where it is not clear whether there was a loss of an egg or a chick due to a failure in the monitoring system. In all observed cases of egg loss, pairs incubated the eggs intensively, partners took regular shifts and did not leave eggs uncovered for long periods (mean 0,07 ± 0,03 min per bird shift). The Egyptian vulture is a species that usually lays two eggs (DONÁZAR 1993, MARGALIDA *et al.* 2012, BROWN & AMADON 1968, CRAMP & SIMMONS 1980, NAOROJI 2006). The results of the present study confirm these studies, with observed pairs laying two eggs per breeding season. An exception was observed in only one case in which the female bird of the pair laid only one egg; this was also one of the cases of egg loss.

The first two cases of egg loss were recorded in one of the monitored nests with trail cameras, with both of the pair's eggs not hatching on the expected dates, the pair continuing to incubate them intensively for an average of 50,5 days. From the trail camera photos in the nest, it is clearly visible that the incubation characteristics of the pair do not differ from the incubation characteristics of successful pairs (DOBREV *et al.* 2021), in all probability the pair's eggs were not fertilized.

At the third egg loss, the male bird appears in the nest for the first time 2,5 days before the first egg is laid. The second egg hatches after 42 days of incubation, the first egg remains in the nest and the pair continues to incubate it for 76 days. The couple is experienced and has always raised two chicks. Data from previous years show that the male bird of the pair usually returns from migration to its breeding territory on average 12,3 ± 6,6 days before the first egg is laid. After the male's arrival, copulations in the pair's nest began on average 7,1 ± 1,9 days before the first egg was laid. Given the late arrival of the male bird in the case we observed (2,5 days before the female laid the first egg), the first egg most probably did not hatch because it was unfertilized. The last case of egg loss is also the only recorded case of laying only one egg. In that case, the male bird of the pair first appears in the nest 23 days after the first egg is laid. It is possible that the female bird has not had contact with another male and the egg is unfertilized, because three hours after laying the egg, she pulls it out on the sides of the nest hole and breaks it with its beak. The female bird does not lay a second egg even after the arrival of the male.

4.6.2. Loss of young

For the entire study period, 35 chicks were hatched, 88,5% of which (n = 31) were reared and successfully left the nest. 4 cases of dead young (11,4%) were registered in three different nests. In all four recorded cases, the loss is of the second chick. In those 4 cases the cause of the lost is:

- in 1 case, the cause remains unknown due to a failure in the monitoring system;
- in 1 case, the probable cause is illness, malformation or genetic disease;
- in 1 case, the cause was poisoning as a result of poisonous bait for predators brought to the nest by the adult birds;
- 1 case of Cainism.

The chicks age difference in the nests with losses is on averaged 5,5 ± 0,4 days, in the case of the poisoned chick there was no reported difference because the first egg of the pair did not hatch (one of the cases of egg loss).

The hatching interval in Egyptian vultures varies from three to eight days, and when the age difference between the young is large, the smaller one is more likely to die due to competition with the bigger one sibling (MENDELSSOHN & LESHEM 1983). For the entire period of the present study, one case of manifested aggression – cainism was reported, which led to the death of the second chick, the reported difference between the chicks in this case was 6 days. Except for the case of cainism, no antagonism was observed between chicks in the remaining nests monitored with trail cameras. Aalthough the largest observed differences between two chicks were 9 days and 8 days. It is believed that if the second young survive between 7 and 14 days, then it can be expected to successfully reach fledging age (DONAZÁR & CEBALLOS 1989).

The results of the present study support this claim. As in three of the observed cases of chick losses, the second chick did not survive to day 14 of hatching, whereas all chicks that survived the first two weeks of hatching successfully reached the age of fledgling.

In the first case of chick loss, a monitoring system failure occurred four days after the second chick hatched. After repairing the damage, only one chick was found in the nest. From the photographs reviewed from the first four days of life of the second chick, no aggression was detected by the older chick. Both chicks are lively and are being fed regularly by both parents. The reasons for the loss of the second young remain unknown.

In the second case of chick loss, the second chick is visibly with a much smaller body size for a hatchling of its age. At every meal, the parents tried to feed him, but in most cases, it did not accept the food from the parents. Considering the fact that it is very inactive and does not take food in most cases, it is most likely that the cause of its death was a disease, malformation or other health problem that could not be detected and investigated by the trail camera.

In the third case of loss, the adult birds brought a piece of meat to feed the young, about an hour later the young died, it was subsequently found to be a poisonous bait for predators. Three days after the death of the young, the adult female bird returns to the nest and feeds on the carcass of the young, thereby poisoning her. This is also one of the registered cases of changing partners in the present study (see chapter 4 of the dissertation and YORDANOV *et al.* 2021).

6.6.3. Cainism

The Egyptian vulture is not an obligate cainist, but there are cases of killing the second young by the first young through direct aggression or by taking advantage during feeding (BIRDLIFE ISRAEL 2021, BROWN *et al*. 1982), however these cases are not frequently encountered (KUMAR *et al*. 2020, REDONDO *et al*. 2019, YORDANOV *et al*. 2021). The present study supports this fact. For the entire period of the study, one case of cainism was observed, and this is the first registered case for Bulgaria. Aggression between nestlings may not be related to food abundance or scarcity (O'CONNOR 1978, PARKER & MOCK 1987, ANDERSON 1990, RODRIGUEZ-GIRONES 1996), like in some obligate cainist species (SIMMONS 1988, MOCK *et al. 1990*). Nestlings may exhibit aggressive behavior even when food is not a limiting factor (STINSON 1979, FORBES 1991, FORBES & YDENBERG 1992). The present study supports this fact. In our observed case, probably the abundance of the food is not a limiting factor. The data shows that, both young are fed regularly by the pair, which confirmed the abundance of the food resource in the area. In the present study, the occurrence of aggression was observed, which increased over time regardless of the fact that the food delivered did not decrease, and the frequency of meals increased over time. In many cases in the bearded vulture, adults did not intervene when older young showed aggression towards younger ones (MARGALIDA *et al*. 2004). In the case we observed, when an adult bird is present in the nest, the young are separated, with the adult bird standing between them to limit contact between them. In some cases, they try to separate them by giving food into the beak of the bigger chick, but it does not take it, instead it continues to show aggression towards the smaller one.

This fact testifies that the aggression is not caused by hunger or lack of food. Sometimes adult birds use branches that they place between the young to separate them in case of aggression. The pair is experienced and has been breeding in the territory for more than ten years. In the observed case in the present study makes clear, the experience of the pair in rearing the young is not always crucial for the survival of the second young in the presence of antagonistic behavior by the bigger chick.

4.7. Description, application and guidance of alternative methods for monitoring Egyptian vultures using trail cameras and drone

4.7.1. Trail camera

The development and application of new technologies provide opportunities for more detailed observation from a closer distance of the breeding behavior of birds. The use of trail cameras and video cameras to monitor nests is a very good method to better understand different aspects of birds breeding biology. This method can help to more accurately establish the date of arrival of the birds, the dates of laying eggs, and the hatching dates of the young. Trail cameras are a good tool for establishing the amount of food delivered and the rate of copulation in the nest over the years. The present study shows that trail cameras can be used effectively to accurately ascertain clutch size, hatchling rate, loss of eggs and young, and in some cases even reveal young loss events. However, it should be bear in mind that installing trail cameras in Egyptian vulture nests can be a real challenge and if not done correctly, trail cameras can cause disturbance to breeding birds, leading to nest abandonment and shifting of territory. Experience so far shows that there are ways to avoid disturbance. Some of the practices that were used in the present study in installing the trail cameras are described here.

Trail cameras should be installed before the start of the breeding season, they should be masked as best as possible with natural materials, such as stones, dry leaves and moss (Figure 11).

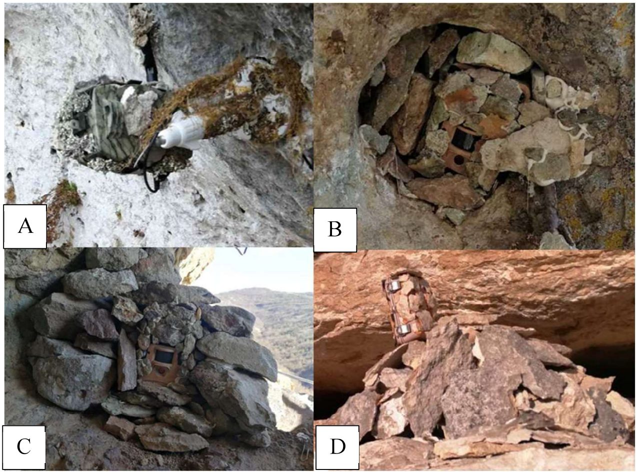

Fig. 11. Correctly installed and masked trail cameras. **A -** mounted on a stand outside the nest, **B** – mounted in a natural hole in the nest, **C** – covered with a pyramid of stones and **D** – mounted on a stand covered with a pyramid of stones in the nest.

Another very important aspect is the size of the nest niche, if it is small (e.g. height > 1m, depth > 1m, width > 1m) and there is no convenient place for the birds to land such as a platform (rock terrace), trail cameras should not be installed in such a type of nest niche. It is recommended to use rechargeable UPS batteries. One UPS battery lasts one season for a simple trail camera, for a trail camera with MMS function it is recommended to connect two UPS batteries connected in parallel. The use of rechargeable batteries prevent of additional waste each season, from changing ordinary batteries.

6.7.2. Drone

Slowly but effectively, drones are used ecological research, as a tool that saves time and gives much more accurate information (GRENZDÖRFFER 2013, CHABOT *et al*. 2015, HODGSON *et al*. 2016). However, their incorrect use, can have a negative effect, especially when monitoring birds of prey and especially Egyptian vultures. This, in turn, can lead to both disturbing the breeding birds and compromising their reproduction, and damage to the drone. If the practices listed below are followed, the negative effect can be avoided and the stress on the adult birds and nestlings can be minimized.

When monitoring with drone, flights should be made with caution and done as quickly as possible to reduce stress on the birds. The drone pilot must be experienced in flying long distances, without direct visibility of the drone and orientation only on the camera of the drone. It is recommended that, in addition to the drone pilot, there is also another human "observer" who watches with binoculars or a spotting scope for attempted attacks on the drone by birds flying around or the adult birds of the studied nests. If any sign of aggressive behavior or attempted attack is observed, the drone must immediately return to the point from which it took off. If the adult birds of the studied pair appear in the territory or an adult bird was disturbed and leaves the nest, the drone should move far away from the nest and return home. After the drone is retracted, it is recommended that, observers remain and ensure that the adult birds land on the nest. It is not recommended to use a drone for establishing of the clutch size (the number of eggs in the nest) because the adult birds will leave the nest, which in turn will cause the eggs to cool. It is recommended to use a drone only during the chick rearing period – July – August (for the Egyptian vulture on the territory of Bulgaria), when the young are more than 14 days old. During this period, the adult birds spend more time outside looking for food, so the probability that only the young are in the nest is greater.

5. Conclusions

1. The values of all breeding parameters for the period of our study (2017–2022) are greater compared to the reported values in previous studies of the species in Bulgaria;

2. The breeding parameters of the species in Northeastern Bulgaria are lower than those of the species in the Eastern Rhodopes, a statistically significant difference is found in productivity ($t = -2,275$, $df = 10$, $p = 0,046$) and fledgling success ($t = -3,2383$, $df = 10$, $p = 0,008$). It is likely that in Northeastern Bulgaria pairs cannot rely on permanent food sources such as large and well-functioning feeding grounds, and thus may not be able to successfully feed more than one young;

3. The productivity (0,98 ± 0,15) and breeding success (1,21 ± 0,1) of the Egyptian vulture in Bulgaria are among the highest in the Balkans and Europe;

4. The population of the species in Bulgaria increased from 27 to 29 occupied territories, and for the first time in more than 40 years, a stabilization of the population of the species was observed for the period 2017–2022;

5. Using a drone to measure breeding success shows significantly more accurate results than the standard method (observation with spotting scope from a stationary point), saving significantly more time and effort ($\chi2 = 14,906$, $p < 0,001$). Drones can be used widely in establishing the breeding parameters of the species and searching for suitable nest niches, but with

the observance of strict rules, especially during the incubation period and the first three weeks of the life of the young birds;

7. Male birds are usually the first to return from migration to the nesting grounds between March 29 and April 4, and in 45% of cases incubation begins in the period April 18 – April 23;

8. Male Egyptian vultures play a major role in providing nest material and in arranging the nest, putting significantly more effort into these activities than female birds ($\chi2 = 92,5$, $p < 0,05$). Nest building occurs mostly in the morning hours and begins about 15,1 ± 7,7 days before the first egg is laid;

9. The species actively copulates in the nest, thus beginning 7,1 ± 1,9 days before Incubation, and copulations were observed only three times after laying of the first egg. The frequency of copulations increased in the days before laying (from day 3 to 0) and peaked in the afternoon hours, with the largest observed peak being in the afternoon to dusk. That supporting the hypothesis of sperm competition in which the male bird should be more inclined to copulate later in the day in order to dilute the sperm of possible competitors, which would ensure paternity;

10. Both parents put equal effort in incubation throughout the period ($\chi2 = 0,125$, $p = 0,72$), with the female investing slightly more effort in night incubation than the male (in 58,31% of cases). The laying interval between the first and the second egg is 6 ± 0,49 days, and incubation of each egg lasts 41,8 ± 0,25 days. The majority of observed changes between partners during brooding were made in the nest (78,90% of cases);

11. Both parents put equal effort in providing food and feeding the young ($\chi2 = 1,32$, $p = 0,25$);

12. Most supplies of food items are soft tissues (in 65% of cases) that leave no trace in the nest and will not be found later in the nest. And thus, the proportion of this type of food will be underestimated or remain unknown. The largest percentage of the species' diet is mammals (34%), followed by reptiles (33%), birds (32%) and fish (1%);

13. For the period 2011–2021, 2 cases (33,33%) of partner change were found in the observed pairs with trail cameras, and in both cases the change was of the female bird. The reason for the change in one case was death due to poisoned bait, and in the other case – probable reason is death during migration or in the wintering grounds;

14. In 90,9% of the cases the pairs observed with trail cameras lay two eggs per season, only one exception was observed. 4 cases of egg loss were found for the entire study period (2012–2022), and in all four cases the probable cause was unfertilized eggs;

15. In 88,5% of the cases the hatchlings reached the fledging stage, and 4 cases of loss of the young were reported. In each case, the loss was of

the second chick, all died chicks lives less than 14 days. All hatchlings that survive the first two weeks after hatching successfully reach fledging age;

16. Only one case of cainism has been recorded in the Egyptian vulture. The phenomenon occurs regardless of the abundance of the food resource, and is probably due to the principles of natural selection in this phenomenon, which is very common in other species of vultures and birds of prey.

6. Dissertation contributions

6.1. Original contributions

6.1.1. The trend of the population of the species in Bulgaria has been monitored for a period of 6 years, and for the first time a growth in the population of the species and an increase in the number of occupied territories have been recorded;

6.1.2. For the first time, a UAV (drone) was used to determine the nesting success of the species, as an alternative monitoring method;

6.1.3. The breeding biology and phenology of 23,6% of the Egyptian vulture population in Bulgaria was studied using trail cameras, over a period of 10 years;

6.1.4. For the first time, it has been found that both sexes put equal effort into egg incubation during the day. For the first time, night incubation was observed, in which gender asymmetry was observed, and in the majority of cases, female birds incubate the eggs;

6.1.5. For the first time, the change of partners in nesting pairs is tracked using trail cameras;

6.1.6. For the first time, the loss of eggs and young was tracked using trail cameras and a video camera in the nests of the species;

6.1.7. For the first time, a case of cainism is described for the species in Bulgaria.

6.2. Confirmative Contributions

6.2.1. The national population of the Egyptian vulture continues to be concentrated in the Eastern Rhodopes, Rusenski Lom and Eastern Balkan Mountain;

6.2.2. The use of a drone for monitoring allows monitoring from a greater distance, is more efficient, safer, saves time and gives much more accurate results than the traditional monitoring method;

6.2.3. The present study confirms that the species copulates actively on the breeding grounds, with a peak in the afternoon;

6.2.4. Male birds put more effort into building the nest than females, chick rearing (delivery of food to the nest and feeding the young) until they leave the nest is done by both parents;

6.2.5. The Egyptian vulture usually lays two eggs, incubation lasts an average of 41,8 ± 0,25 days, and the difference between the two eggs is usually 6 ± 0,49 days;

6.2.6. The results confirm that the majority of the food resource (65%) is soft tissue.

6.3. Contributions of a scientific and applied nature

8.3.1. A guide has been created for installing trail cameras in Egyptian vultures' nests;

6.3.2. An archive was created with the faces of all the birds from the studied pairs with trail cameras, through which it is possible to establish the change of partners in the tracked pairs; it could also be used for the development of a guide for sexual dimorphism in the species;

6.3.3. An identification guide of the age of hatchlings in Egyptian vulture nests was developed;

6.3.4. Guidelines and recommendations for the proper use of alternative methods for monitoring of Egyptian vultures (trail cameras and drone) are drawn up.

7. Publications on the subject of the dissertation

1. 1. OPPEL S., DOBREV V., ARKUMAREV V., SARAVIA-MULLIN V., BASHMILI K., BINO T., BOUNAS A, CHARDIN A., DOBREV D., DURO K., KAPSALIS E., KRET E., MARCHANT M.-P., NAKEV S., PETROVSKI N., PAPAIOANNOU H., POPGEORGIEV G., SELGJEKAJ L., SKARTSI T., STAMENOV A., STOYCHEV S., TOPI M., VAVYLIS D., VELEVSKI M., VORPSI Z., WESTON J., XEKA E., XHERRI X., **YORDANOV E.** & *&* NIKOLOV S. 2023. Long-term conservation efforts at flyway scale can halt the population decline in a globally endangered migratory raptor. Animal Conservation. 8 p.

2. **YORDANOV E.**, DOBREV V. *&* JAMBON A. 2023. Trail cameras reveal new details of the breeding behaviour of an endangered Egyptian vulture. Acta Zoologica Bulgarica, Suppl. 17 (06).

8. Participation in scientific conferences with materials on the topic of the dissertation work:

1. Participation in the conference "Ecology – a way of thinking 13" with two reports – one " Identifying hatchlings mortality in the Egyptian vulture (Neophron percnopterus) through the means of trail cameras " - on the topic of the dissertation work and the other report on the topic "Use of unmanned aerial vehicles means (drones) in environmental surveys";.

2. Participation in the scientific conference "Ecology - a way of thinking 14" with a report on the topic "Effect of microhabitat type on some climatic factors related to nesting success in the Egyptian vulture";

3. Participation in an international online conference "Natural Forests & Wilderness Conference – present and future conservation and research", with a report "Identifying hatchlings mortality in the Egyptian vulture (*Neophron percnopterus*) through the means of trail cameras";

4. Participation in the international online conference "Egyptian Vulture Online Conference 2022" with two abstracts and two presentations – on the topics: "The use of trail cameras to monitor hatchlings mortality and replacement rate in Egyptian Vulture pairs in Bulgaria" and "Nest guarding during the fledgling period of the Egyptian vulture as a conservation tool".