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Breeding performance and population trend of the Egyptian Vulture *Neophron percnopterus* in Bulgaria: conservation implications

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The Egyptian Vulture (*Neophron percnopterus)* has been classified as 'Endangered' due to rapid population declines across its range. Thus, exhaustive studies on its demography may serve as an important stepping stones for successful conservation programs. Breeding performance is one of the main components of the demography of a raptor population. Evaluating reproductive rates is easier than other demographic parameters, while remaining a very useful metric to identify factors driving raptor population trends. Here we present the breeding performance of the species' population in Bulgaria as a result of a long-term monitoring (2005–2016). The studied population shows high breeding performance, based on a breeding success (1.11 ± 0.13 fledglings / laying pairs), productivity (0.88 ± 0.1 fledglings / occupied territories) and fledgling success (1.2 ± 0.1 fledglings / successful pairs), all among the highest recorded in Europe. Pairs breeding in territories with high occupancy rate produced 88% of the fledglings. However, over the last 14 years the Egyptian Vulture population in Bulgaria has declined with 51.7%. We discuss the causes underlying these results and recommend the implementation of conservation measures on a larger scale in order to secure the survival of the species in the country.

1. Introduction

Vultures, as obligate or opportunistic scavengers, have a keystone role for the ecosystems' health (Buechley & Şekercioğlu 2016, DeVault *et al.* 2016). Currently, they are the most threatened guild of birds in the world due to anthropogenic factors (Botha *et al.* 2017). The Egyptian Vulture (*Neophron percnopterus*) is a species of highest conservation concern, distributed throughout the Palearctic, Afrotropical and western Indohimalayan geographic regions and is a long-distance migrant across most of its range (Botha *et al.* 2017). The species is listed as Endangered in the IUCN Red List owing to a recent and extremely rapid population decline in India (>90% in the last decade), Europe (50–79% over the last three generations), and Africa (BirdLife International 2017). The global population is estimated at 18,000–57,000 individuals (12,000–38,000 mature individuals) with 3,000–4,700 breeding pairs in Europe (Botha *et al.* 2017). On the Balkan Peninsula, the Egyptian Vulture is considered extinct as a breeder from Croatia, Romania, Bosnia and

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Herzegovina, Montenegro, and Serbia. While less than 70 pairs in total still persist in Bulgaria, FYR of Macedonia, Greece, Albania and European Turkey, there is an estimated annual population decline of 4–8% during the last three decades (Velevski *et al.* 2015). In Bulgaria, currently holding 40% of the Balkan population, the species was common and widespread in the beginning of the XXth century (Patev 1950), while in the middle of the century it had already gone extinct or declined in most of the country (Arabadzhiev 1962, Michev 1968). In 2013, only 26 breeding pairs were present in 1 core area with 19 pairs in the Eastern Rhodopes and in 1 isolated cluster with 7 pairs in Northeastern Bulgaria (Velevski *et al.* 2015).

Although the main threats for the species in the country were studied and identified (poisoning, electrocution, poaching; Nikolov *et al.* 2016, Saravia *et al.* 2016, Kret *et al.* 2016), and some data exist on survival rate (Oppel *et al.* 2015, 2017) and breeding performance (Baumgart 1991, Kurtev *et al.* 2008, Oppel *et al.* 2017), a better understanding of the demographic parameters of the species in the country is required for the successful implementation of long-term conservation strategies. Reproductive rates are easier to be evaluated than other demographic parameters, while still providing useful insight for factors driving raptor population trends (Steenhof & Newton 2007).

The main factors influencing a raptor's breeding success are the availability and quality of food and breeding sites, the weather conditions, inter- and intraspecific competition, human influences, the age and experience of the partners (Newton 1979, Zuberogoitia *et al.* 2008, Cortez-Avizanda *et al.* 2009). The appropriate composition of all factors, except the last one, determines the quality of the breeding territory and influences the breeding performance especially in raptors showing strong territory fidelity as predicted by the site-dependent population regulation hypothesis (Newton 1991, Franklin *et al*. 2000, Sergio & Newton 2003). Territory quality could be assessed using the occupancy rate as a proxy because territories which have been occupied for longer periods are considered more productive (Rodenhouse *et al.* 1997, Sergio & Newton 2003).

Here we present data on the breeding performance of the Egyptian Vulture in Bulgaria collected over 12 years (2005–2016). We analyze the difference of breeding parameters between territories of high and low quality and compare the two main breeding clusters. Furthermore, we compare our results with similar studies on the breeding performance of the species across Europe. We evaluate the population trend of the Egyptian Vulture in Bulgaria over 14 years (2003–2016). We aim to determine whether the breeding performance might explain the observed rapid population decline. We discuss our findings in the context of other limiting factors to ensure a more holistic management approach for the species.

2. Material and methods

2.1. Study area

The study was conducted in the regions of the Eastern Rhodopes (the core area of the Egyptian Vulture breeding population on the Balkans), Rusenski Lom, and Eastern Balkan Mountain along with the surrounding plateaus (forming two separate clusters with 2–6 occupied territories each) (Velevski *et al.* 2015, Fig. 1). The three regions are at least 60 km away from each other which is twice the maximum foraging distance of breeding Egyptian Vultures (López-López *et al.* 2014).

The Eastern Rhodopes region is characterized by open lands, pastures, hills, cliffs and cliff complexes and sparse vegetation. The climate is continental-Mediterranean with hot summers and mild winters. The Eastern Balkan Mountain and the surrounding plateaus are characterized by transitional continental climate. The relief is mountainous in the southern part with open pastures and deciduous forests, and flatter with rocky plateaus and predominantly arable lands in the northern part. The relief in Rusenski Lom is similar, with huge plateau river valleys, dense shrub vegetation and high cliff complexes. The percentage of pastures is lower in comparison to the other regions and the landscape is dominated by arable lands (Kopralev *et al.* 2002).

2.2. Data collection

All active Egyptian Vulture breeding territories in Bulgaria were regularly monitored during 14 consecutive years (2003–2016) to establish the popu-

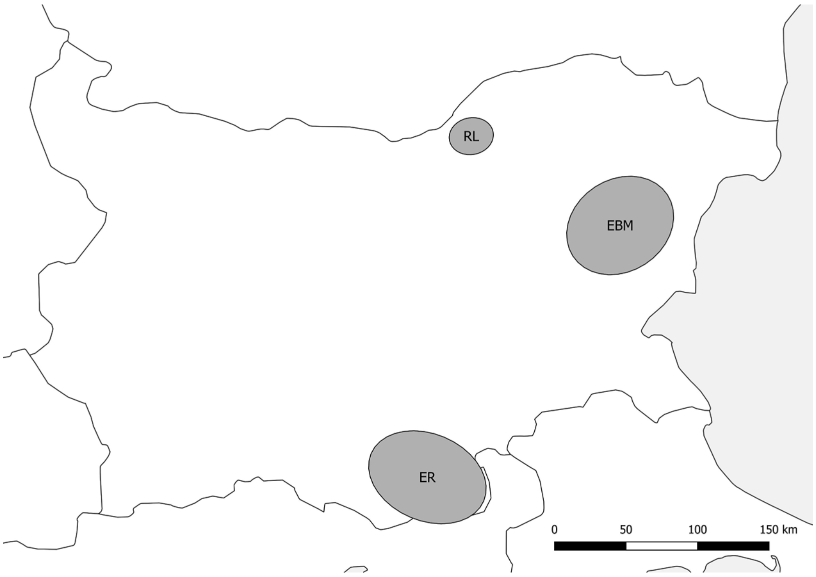

Fig. 1. Map of the Egyptian Vulture study areas in Bulgaria. RL – Rusenski Lom, EBM – Eastern Balkan Mountain with surrounding plateaus, ER – Eastern Rhodopes.

lation trend. For the last 12 years (2005–2016) the monitoring on the reproductive output was more intense and detailed allowing us to estimate the breeding performance of the species. A territory was defined as occupied by a pair when courtship behavior, display, or nest building were observed (Steenhof & Newton 2007).

The turnover rate of the adults within pairs was not calculated as only few adults had rings, making individual identification impossible. All territories occupied by single birds were excluded from the dataset. At least four visits to each territory were conducted during the breeding season. The first visit took place in late March / early April to determine which territories are occupied by pairs; the second visit was conducted in May to confirm in which territories incubation has started; the third visit was conducted in June to inspect the number of hatchlings; and the last visit was in July/August to confirm the number of fledglings. All observations were made from stationary points located at distance greater than the mean maximal alert distance of the species (605 m) in order to avoid disturbance (Zuberogoitia *et al.* 2008).

In cases when the characteristics of the breeding cliff did not allow direct view of the nest, quick inspections from a shorter distance were made. To avoid disturbance, we did not check for the number of eggs and hatchlings, and therefore we are unable to calculate the clutch size and brood reduction in the early stages of the post-incubation period. The start of incubation for a pair was considered as a breeding attempt regardless of the outcome. We calculated the following breeding parameters over regions and years (Cheylan 1981, Steenhof & Newton 2007): (i) productivity (number of fledglings divided by the number of occupied territories); (ii) breeding success (number of fledglings divided by the number of laying pairs); (iii) fledgling success (number of fledglings divided by the number of successful pairs); (iv) percentage of laying pairs (number of laying pairs divided by the number of occupied territories and multiplied by 100); and (v) percentage of successful pairs (number of successful pairs divided by the number of laying pairs and multiplied by 100). A pair was categorized as successful when it had raised at least one fledgling until the age of the first flight or the nestling has reached 80% of the average age of first flight (Steenhof & Newton 2007), which is estimated as 75 days (Donázar & Ceballos 1990).

We used the data collected in 2012–2016 when an intensive and nation-wide nest-guarding programme was applied (Oppel *et al*. 2016a) to present the breeding phenology of the species. During the nest-guarding programme selected nests were observed throughout the breeding season and exact dates of start of incubation, hatching and fledging were recorded.

2.3. Data analyses

We estimated the occupancy rate index (OR, range: 0–1) for every territory occupied at least once during the study period and monitored for at least 5 consecutive years. OR was estimated as the ratio of the number of years in which the territory was occupied by a pair and the number of years when the territory was monitored (Sara & Di Vittorio 2003). We considered territories with high occupancy rate (HOR) when OR > 0.6. Territories with OR < 0.6 were classified as territories with low occupancy rate (LOR) (Sergio & Newton 2003).

When comparing the breeding parameters among the different population clusters we grouped Rusenski Lom and the Eastern Balkan Mountain with surrounding plateaus into one dataset named Northeastern Bulgaria due to the small number of breeding territories (Veletski *et al* 2015). Breeding parameters of the pairs breeding in the different regions and those in HOR vs LOR territories were compared with the Mann-Whitney U-test. A non-parametric test was applied because data did not approach the normal distribution even after transformation (Krebs 1999). The statistical significance was set at $p < 0.05$ ($\alpha = 5\%$). Means are presented ± Standard Deviation (SD). Descriptive statistics were used to present the mean duration of the fledgling period and the breeding phenology of the species (Newton 1979). Only the events (i.e. incubation, hatching and fledging) with the exact date recorded were considered in this analysis. The statistical processing of the data was carried out using the program Statistica for Windows, Release 7.0 (StatSoft 2004). The population trend was calculated using the R package "rtrim" v. 1.0.1 in R 3.3.1 (Bogaart *et al*. 2016, R Core Team 2016)

3. Results

3.1. Breeding performance and phenology

We monitored 47 Egyptian Vulture breeding territories for up to twelve years, resulting in 277 breeding attempts. In 8 territories (17%) no breeding attempt was registered. For the rest of the territories 14.4% of the breeding attempts were unsuccessful and in 85.6% of the cases fledglings were successfully raised. In average 25.6 fledglings were raised annually in Bulgaria during the study period (n = 308 fledglings in total) or 1.3 fledglings per successful breeding (n = 237), with 1 and 2 raised fledglings respectively in 70% and 30% of the cases. The breeding success was 1.11 ± 0.13 fledglings / laying pairs, productivity was 0.88 ± 0.1 fledglings / occupied territories and fledgling success was 1.28 ± 0.1 fledglings / successful pairs (Fig. 2a). Annually, incubation started in 79.5% ± 6.7 of the territories (Fig. 2b). Moreover, 20.5% ± 6.4 of the pairs did not start breeding and 68.7 ± 6.2% of the pairs were successful (Fig. 2c).

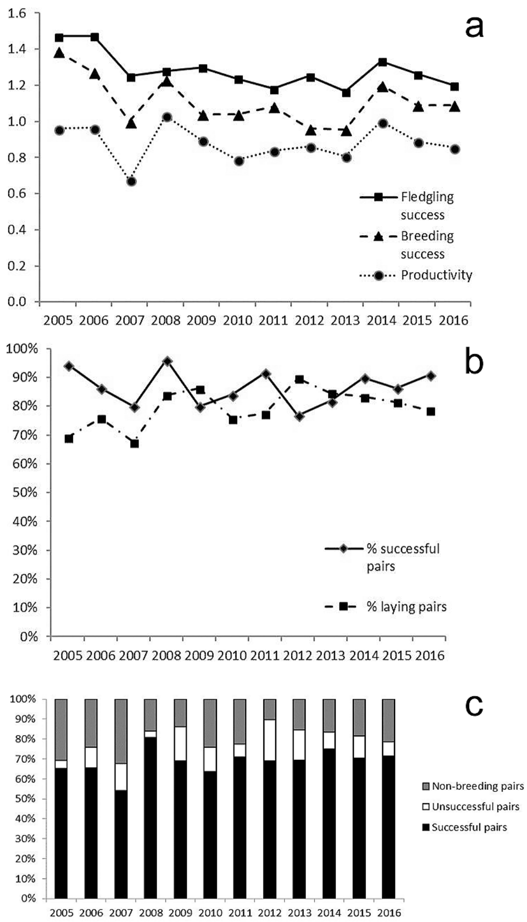

Fig. 2. Breeding performance of the Egyptian Vulture in Bulgaria (2005–2016). (a) fledgling success, breeding success and productivity per years, (b) percentage of successful pairs and percentage of laying pairs per years, (c) percentage of non-breeding, unsuccessful and successful pairs.

Table 1. Egyptian Vulture mean breeding parameters by regions and nationally (2005–2016). Breeding parameters which differ statistically (Mann-Whitney U-test) between the two regions (Eastern Rhodopes and Northeastern Bulgaria) are marked with a *.

Breeding parameters	Regional scale		Nationally
	Eastern Rhodopes	Northeastern Bulgaria	Bulgaria
Breeding success	1.11 ± 0.10	1.09 ± 0.30	1.11 ± 0.13
Productivity*	0.84 ± 0.12	0.97 ± 0.28	0.88 ± 0.10
Fledgling success*	1.24 ± 0.09	1.38 ± 0.20	1.28 ± 0.10
Percentage of successful pairs*	89.5 ± 6.8%	78.3 ± 13.2%	86.6 ± 6.2%
Percentage of laying pairs*	76.1 ± 8.2%	88.2 ± 13%	79.5 ± 6.7%

Pairs breeding in the core area (Eastern Rhodopes) in general had lower values of their breeding parameters, except for the percentage of successful pairs and breeding success (Table 1). The productivity, fledgling success and percentage of laying pairs in Northeastern Bulgaria were significantly higher than those in Eastern Rhodopes ($U = 37$, $U = 38$ and $U = 30$, $p < 0.05$). However, the percentage of successful pairs in Eastern Rhodopes was significantly higher than that in Northeastern Bulgaria ($U = 31.5$, $p < 0.05$). Still, the breeding success of the pairs in the two regions was similar.

The start of incubation was recorded between 11th of April and 20th of May ($n = 41$ cases), but in most cases (71%), the event took place between 16th and 25th April. Hatching events were recorded between 23th of May and 1st of July, but in most of the cases (77%; $n = 35$) chicks appeared between 27th May and 5th of June. Fledglings started their first flights between 1st of August and 8th of September, but in 64% of the cases ($n = 73$) this event took place between 11th and 20th August. Therefore, the fledging age in Bulgaria is 77 ± 5.6 days (Fig. 3).

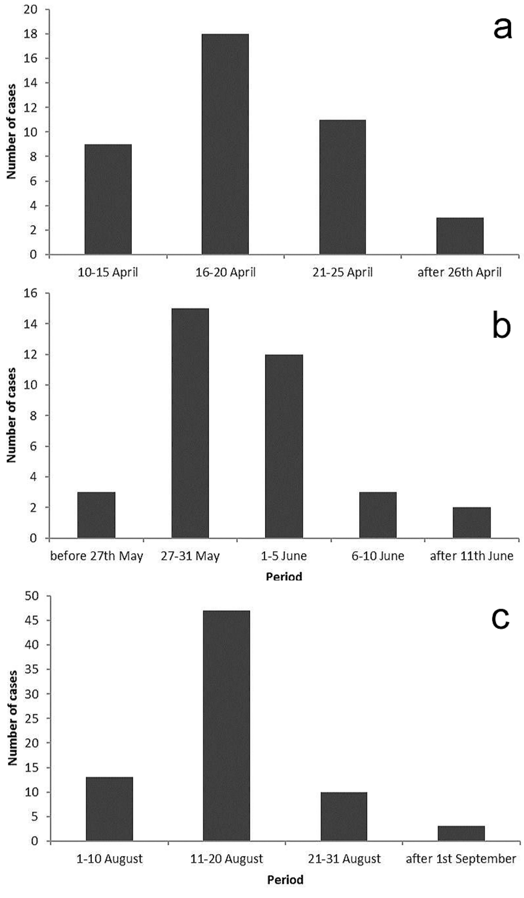

Fig. 3. Breeding phenology of the Egyptian Vulture in Bulgaria (2012–2016): a) start of incubation; b) hatching; c) the first flight of fledglings.

3.2. Occupancy rate and breeding performance

Out of the 47 breeding territories we monitored, 57.4% ($n = 27$) were with HOR and 42.6% ($n = 20$) with LOR. Pairs breeding in territories with HOR had higher values of the breeding parameters than those in territories with LOR (Table 2). Moreover, 88% ($n = 271$) of the fledglings were raised in territories with HOR. In the Eastern Balkan Mountain with surrounding plateaus 75% of the Egyptian Vulture territories were with HOR; this percentage was slightly lower in the Eastern Rhodopes (62.5%), and very low in Rusenski Lom (14.3%).

Table 2. Comparison of the mean Egyptian Vulture breeding parameters in territories with high occupancy rate (HOR) and territories with low occupancy rate (LOR). All breeding parameters statistically (Mann-Whitney U test) different between HOR and LOR are marked with a *.

Breeding parameter	HOR (*n* = 27)	LOR (*n* = 20)
Breeding success*	1.08 ± 0.3	0.59 ± 0.6
Productivity*	0.94 ± 0.4	0.5 ± 0.5
Fledgling success*	1.24 ± 0.3	0.7 ± 0.7
Percentage of successful pairs*	83 ± 21%	46 ± 45%
Percentage of laying pairs*	84 ± 23%	49 ± 45%

3.3. Population trend

The Egyptian Vulture population in Bulgaria decreased by 51.7% in terms of numbers of occupied territories (from 58 to 28) between 2003–2016. The population has declined by 5.8% per year with annual growth rate 0.943 (Fig. 4). The annual growth rates were similar in Eastern Rhodopes (0.965) and Eastern Balkan Mountain with surrounding plateaus (0.976) and lower in Rusenski Lom (0.842) where the number of occupied territories decreased with 17.2% per year. The decrease was significantly lower in Eastern Rhodopes (3.56% per year) and lowest in Eastern Balkan mountain with surrounding plateaus (2.4% per year) (Fig. 5).

4. Discussion

Our results show high values of the breeding parameters of the Egyptian Vulture in Bulgaria. The breeding success is one of the highest in Europe (Table 3). Studies from other parts of the Balkan Peninsula have recorded lower breeding success – 0.93 and 0.87 respectively in FYR of Macedonia (Grubač *et al.* 2014) and Greece (LIFE10 NAT/BG/000152, unpubl. data). However, the recorded productivity is similar to the mean in Europe (0.89 juveniles/pair; Iñigo *et al.* 2008). The percentage of successful pairs is the highest reported. It is ca. 10% higher than the one recorded in Italy (Liberatori & Penteriani 2001) and in France (Constantin *et al.* 2016). The observed breeding phenology is similar to the one reported from other parts of Europe (Donázar & Ceballos 1990, Cramp & Simmons 1980). The breeding performance of the Egyptian Vulture in Bulgaria presented in this study is similar or even higher when compared to stable or slightly increasing populations in Europe e.g., France, Catalonia and the Cantabrian Mountains in Spain (Mateo-Tomas *et al.* 2010, Kobierzycki 2012, Tauler *et al.* 2015 Constantin *et al.* 2016).

Thus, the observed rapid population decline in Bulgaria (Velevski *et al.* 2015) could not be explained by the breeding performance and seems to be related to high mortality in both adults (Velevski *et al.* 2014, Saravia *et al.* 2016) and juveniles (Oppel *et al.* 2015). This conclusion is in ac-

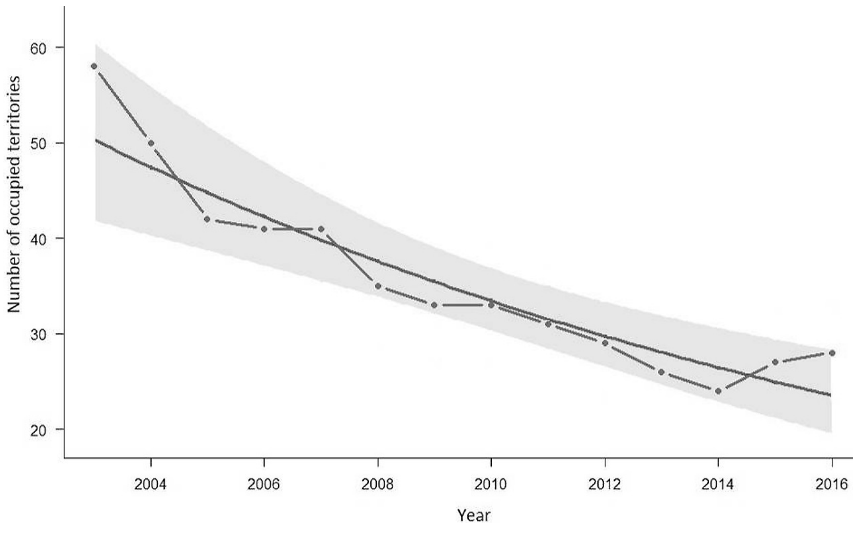

Fig. 4. Trend of the Egyptian Vulture population in Bulgaria (2003–2016). Solid line represents the trend, with 95% confidence band in grey, dots indicate the number of occupied territories per year.

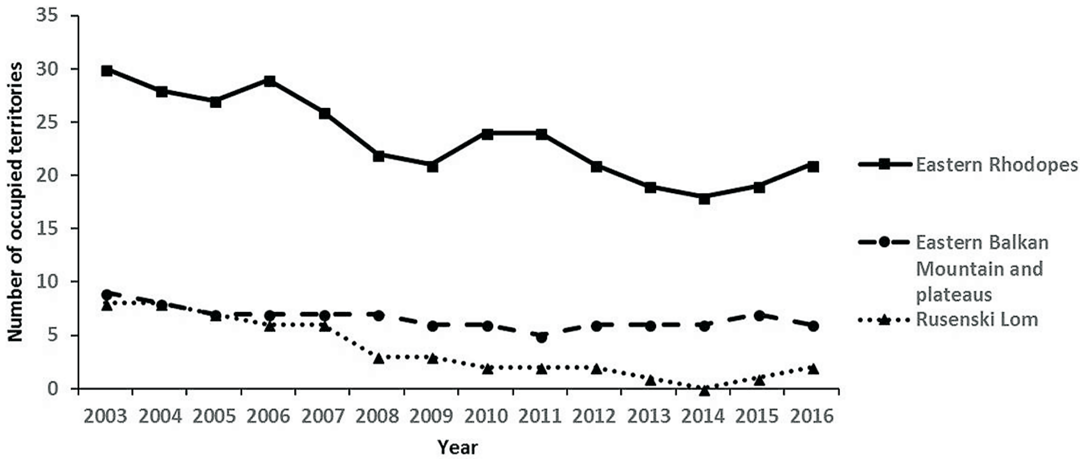

Fig. 5. Changes in the number of occupied Egyptian vulture territories in Bulgaria per breeding clusters (2003–2016).

cordance with other studies which show that mortality is a much more significant factor in the population dynamics of the species than the breeding performance (Grande 2006, Garcia-Ripolles & López-López 2011). Recent Population Viability Analysis for the Egyptian Vulture in FYR of Macedonia, which experience similar decline rates, showed that neither increase nor decrease with 10% in the productivity will lead to substantial changes in the mean number of surviving individuals within a 30 or 50 years period (Velevski *et al.* 2014). However, the combined effect of reduced mortality of individuals and increased productivity shows prolonged survival of the population (Velevski *et al.* 2014).

Amongst the main drivers of reduced productivity in raptors are changes in the availability of food (Newton 1979), but a recent study on the Egyptian Vulture in the Balkans failed to demonstrate a clear relationship between productivity and diet and showed that the diet diversity has not changed significantly in the period 2006–2013

Table 3. Breeding performance of the Egyptian Vulture in Europe.

Country/Region	Year	Productivity	Breeding success	Fledgling success	Reference
Bulgaria	2005–2016	0.88	1.11	1.28	This study
FYR of Macedonia	2006–2011	0.84	0.93	1.19	Grubač *et al.* 2014
Greece	2012–2016	0.49	0.87	0.85	LIFE10 NAT/BG/000152, unpubl. data
Italy	1984–1999		0.99	1.27	Liberatori & Penteriani 2001
Sicily	1980–2002	0.97			Sara & Di Vittorio 2003
France	1999– 2012	0.72	0.86	1.13	Constantin *et al.* 2016
Portugal	1980s	0.86		1.42	Vasconcelos 1987
Spain	2008	0.65	0.88	1.12	Del Moral 2009
Ebro Valley	1999–2005	0.98			Grande 2006
Segovia	2005–2007	0.88	1.08	1.36	WWF/Adena 2008
Castellon	2003–2005	0.91	0.76	1.20	Garcia-Ripolles & López-López 2006
Cantabrian Mountains	2008	1.04	1.10	1.17	Mateo-Tomas *et al.* 2010
Bardenas Reales	1989–2007	0.6			Cortez-Avizanda *et al.* 2009
Catalonia	1988–2012		1.11	1.17	Tauler *et al.* 2015
Navarra	1983–1985	0.81		1.29	Donázar & Ceballos 1988

(Dobrev *et al.* 2016). At the same time the existence of a reliable and predictable food sources such as feeding stations and landfills has a positive effect on the territory occupancy (Oppel *et al.* 2017, Tauler *et al.* 2017) even though it does not have a strong positive effect on the overall breeding performance of this population (Oppel *et al.* 2016a). Providing supplementary food at central feeding stations occasionally might cause unintended outcomes e.g. attraction of nonbreeding birds and increased interference resulting in a reduction of productivity (Carrete *et al.* 2006).

On the other hand, long-term monitoring programs have shown that supplementary feedings do improve survival and may therefore facilitate population recovery in the long term (Oro *et al.* 2008, Lieury *et al.* 2015). Thus, conservation measures such as supplementary feedings or nest guarding which aim to increase the survival rate and the reproductive parameters of the population can only be applied as supplemental to initiatives that tackle with major threats resulting in increased mortality of adults and non-breeding birds such as poisoning, electrocution and poaching.

When comparing the breeding performance of the pairs breeding in the two studied regions we found that Egyptian Vultures from Eastern Rhodopes have lower productivity, fledgling success and percentage of laying pairs but higher percentage of successful pairs. These results show that in Eastern Rhodopes proportionally a higher number of pairs does not start incubation but if they do, they are more successful in raising a fledgling. The Eastern Rhodopes are the core of the Egyptian Vulture population on the Balkans where the density is the highest (Velevski *et al.* 2015). This might lead to increased intraspecific competition and lower breeding performance or interspecific competition with other avian scavengers and cliff-nesting species (e.g., Griffon Vultures *Gyps fulvus* and Ravens *Corvus corax*) for breeding sites and food (Carlon 1998, Levy & Segev 1996).

During the study period in this region three new territories were occupied by new pairs which did not breed successfully in the first 3–4 years, likely because these pairs were formed by inexperienced "young" adults (authors' pers. obs.). When the density is high, new pairs are forced to occupy lower quality territories resulting in lower breeding performance, with a decrease in the mean population productivity but an increased variance among the pairs (Brown 1969, Dhondt *et al.* 1992, Ferrer & Donázar 1996). The opposite process might explain the high values of the breeding parameters in Northeastern Bulgaria. The number of occupied territories in this region was continuously decreasing therefore increasing the distance between neighboring territories. The density in this region is low and only the best quality territories which also have high occupancy rates and consequently higher breeding performance were still occupied by the end of our study period.

However, the lower percentage of successful pairs in Northeastern Bulgaria might be due to human induced disturbance, increased mortality of adults during the breeding season, nest robbing or nest predation (Saravia *et al.* 2016). In three territories in this region high turnover of the partners in the pair was recorded probably due to increased mortality (authors' pers. obs.). Cases of shooting and nest robbing are known from this region which may explain the lower percentage of successful pairs (Saravia *et al.* 2016). On the other hand, in Eastern Rhodopes the biggest Griffon Vulture population in Bulgaria is breeding; since both vulture species often breed in the same cliff complexes (Demerdzhiev *et al.* 2014b) this leads to interspecific competition.

Egyptian Vultures breeding close to Griffon Vulture colonies often are exposed to high disturbance and this might cause breeding failure (Carlon 1998). The Raven is common, widespread and with high density in the Eastern Rhodopes but rarer in Rusenski Lom and Eastern Balkan Mountain with surrounding plateaus (Iankov 2007). In general, the earlier breeding species has the advantage in nest site selection (Newton 1979, Collias & Collias 1984). Ravens use the same nesting habitats but start breeding in late February or early March (Madge & Burn 1999) or ca. a month earlier before the arrival of the Egyptian Vultures and compete with the latter species for nesting sites (Nikolov *et al.* 2013). A habitat model shows that the proximity to a Raven's nest has an overall negative influence on the breeding propensity of the Egyptian Vulture (Oppel *et al.* 2017).

Our results confirm that pairs breeding in territories with HOR have higher breeding performance when compared to pairs breeding in territories with LOR. The occupancy rate is a useful metric to define the quality of a territory and the latter might substantially affect the breeding performance of raptor species (Newton 1991, Ferrer & Donázar 1996, Sergio & Newton 2003). On the other hand, the quality of the individuals inhabiting the breeding territories may also have an important influence on the reproductive outcomes. High-quality individuals start breeding and disappear from the breeding population at later ages than low-quality individuals but have higher breeding success (Sanz-Aguilar *et al.* 2016).

High quality territories usually are occupied by more experienced and productive individuals than low quality territories and vice versa (Newton 1989). The low percentage of territories with high occupancy rate in Rusenski Lom might be a result of the gradual isolation of this breeding group. It is the northernmost and most isolated cluster in Eastern Europe. Increasingly isolated clusters with few pairs face higher extinction probability due to demographic, environmental or potentially genetic stochasticity (Velevski *et al.* 2014).

Egyptian Vultures are known for their high natal philopatry (Carrete *et al.* 2007) but conspecific attraction seems to be another important factor affecting the probability of territorial persistence. Isolated territories may stay unoccupied due to absence of conspecifics and in the long-term too many vacant territories in a certain region could result in local extinction (Carrete *et al.* 2007). The high percentage of territories with high occupancy rate in Eastern Balkan Mountain with surrounding plateaus might be explained by the gradual extinction of low quality territories and persistence only of the high quality ones. These territories attract the "surplus" non-breeding adults which are searching for a vacant territory or to replace dead partners in occupied territories and recruit into the breeding population.

High quality territories offer better conditions for reproduction. When choosing breeding territory adult non-breeding raptors prefer to occupy a territory in an area which is already inhabited by conspecifics rather than to set up a new territory in a suitable habitat remote from conspecifics (Watson 2010). Egyptian Vulture's first choice of breeding territory is important and they invest in searching for high quality areas which might promote delayed recruitment to the breeding population well beyond sexual maturity, even in the presence of empty territories if they are of low quality (Grande *et al.* 2009, Sanz-Aguilar *et al.* 2016).

The Egyptian Vulture population in Bulgaria has considerably declined over a period of 14 years (2003–2016). During the same study period the species went extinct as a breeder from a large part of its former range e.g., Southeastern, Southwestern and Northwestern Bulgaria (Stoynov *et al.* 2013, Milchev & Georgiev 2014). In 2016, in Rusenski Lom the species is on the brink of extinction with only two occupied territories. The cluster in Eastern Balkan mountain held a stable number of 6–7 occupied territories.

However, if the negative population trend for the species continues, this cluster might face extinction in near future. Population viability analyses of the species in FYR of Macedonia, where the population is similar in size and with similar trend as in Bulgaria, show a high probability of extinction within 25 to 50 years (Velevski *et al.* 2014). The population of the Egyptian Vulture on the Balkan Peninsula has shrunk to only 70 breeding pairs in three main core areas and the negative annual growth rate is similar across its range (Velevski *et al.* 2015). Therefore, a variety of conservation measures has to be applied on a larger geographic scale in order to halt the population decline (Oppel *et al.* 2016).

In conclusion, we have shown that the breeding performance of the Egyptian Vulture in Bulgaria is amongst the highest recorded in Europe. Therefore, the observed rapid population decline could not be explained by suppressed breeding performance and seems to be related to high mortality in the population. Pairs breeding in territories with high occupancy rate have the highest breeding parameters and produce the majority of the fledglings in the population. These are territories with higher quality which hold the most productive individuals. Conservation measures mitigating the main threats such as poisoning, electrocution and poaching should be a priority in these territories in order to secure the survival of the most productive pairs and their fledglings.

Areas and territories with lower percentage of successful pairs (related to higher failure during incubation and chick rearing) should be subject of targeted research and conservation in order to identify and mitigate possible predation, nest robbing or persecution. Reinforcement of the population through restocking might also have positive effect on the population trend but only when it is applied together with measures reducing the mortality (Velevski *et al.* 2014). Supplementary feedings and nest guarding as conservation tools could be applied as additional to the above-listed measures in territories with low occupancy rate where breeding performance of the pairs is unsatisfactory in order to improve the quality of the territory in terms of food availability but also to decrease the probability of disturbance, nest robberies and direct persecution..

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Pikkukorppikotkan lisääntymismenestys ja populaatiotrendit Bulgariassa: suojelunäkökulma

Pikkukorppikotkan uhanalaisluokitus on "vaarantunut", koska sen populaatiot ovat nopeasti vähentyneet koko esiintymisalueellaan. Tehokkaat suojeluohjelmat tarvitsevat onnistuakseen laadukkaita ja perinpohjaisia aineistoja lajin demografiasta, erityisesti lisääntymismenestyksestä. Lisääntymismenestys on helpompi kartoittaa luotettavasti kuin esimerkiksi eloonjäävyys, ja hyvin tärkeä populationkoon muutoksien selittäjä. Pikkukorppikotkan lisääntymismenestystä on seurattu pitkäaikaisseurannassa (2005–2016), joka kattaa koko Bulgarian. Populaatioissa lisääntymismenestys on korkea kaikilla mittareilla koko muihin Eurooppalaisiin populaatiohin verrattuna: poikastuotto (1.11 ± 0.13 lentopoikasta/muniva pari), tuottavuus (0.88 ± 0.1 poikasta /aktiivinen reviiri), ja poikastan lentoonlähtötodennäköisyys (1.2 ± 0.1 lentopoikasta / onnistunut pari). Parit, jotka pesivät aktiivisilla reviireillä tuottivat 88 % lentopoikasista. Kuitenkin pikkukorppikotka on vähentynyt 51,7 % viimeisen 14 vuoden aikana Bulgariassa. Selvitämme näiden tulosten syitä ja esitämme suosituksia laajamittaisille suojelutoimille, jotta lajin säilyvyys voitaisiin taata.

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