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Wolf and Vultures Sympatric Presence in Europe: Ecological Benefits and Constraints

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Abstract: The relationship between wolves and vultures is rarely studied in Europe. Some authors report positive interactions, in which vultures benefit from the relationship by scavenging on the leftovers from wolves' prey. More recent studies, however, have highlighted the potential danger to vultures from the man-wolf conflicts and the related use of poison baits as part of these conflicts. Our study examines the probability that, due to these man-wolf conflicts, the sympatric presence of wolves can indeed have a negative effect on populations of vultures in Europe. We compared the spatial distribution and numbers of vultures and wolves on the Iberian Peninsula and the Balkans, and found large disproportions. Depending on the species, numbers of vultures are between 17 and 65 times higher in Iberia than on the Balkans. In turn, on the Balkans, wolves are twice more populous and occupy an area three times larger than in Iberia. In general, in Europe, the conservation of vultures in areas where wolves are present has proven complicated and has rarely ended in success, with vultures surviving or thriving mainly outside areas with high wolf distributions. Conversely, in areas where wolves and vultures are both present, the threat of illegal poisoning must be buffered. A good solution for achieving stability or even a slight increase in vulture populations in these cases is to maintain permanent vulture feeding stations.

Key words: Man-wolf conflict, *Neophron percnopteurs*, *Gyps fulvus*, *Aegypius monachus*, *Gypaetus barbatus*, *Canis lupus*

Introduction

The four European vultures – griffon vulture *Gyps fulvus* (Hablizl, 1783), cinereous vulture *Aegypius monachus* (L., 1766), bearded vulture *Gypaetus barbatus* (L., 1758) and Egyptian vulture *Neophron percnopterus* (L., 1758) – are well studied in Europe, especially with regard to their ecology, diet, feeding behaviour and the threats to their existence. Most of this scientific data have been published from Spain, unsurprisingly given that about 90% of all European vulture populations have lived there in the last few decades (Slotta-Bachmayr et al. 2004, De la Puente et al. 2007, Del Moral 2009a, 2009b, Andevski 2013).

As obligate scavengers, searching by sight from air, the vultures depend on the presence of carcasses within easily accessible open areas, which in many cases translates to leftovers from predators' prey (Cramp & Simmons 1980). In most European cases, this predator is the wolf *Canis lupus* L., 1758 (Boev & Michev 1981, Botev & Peshev 1985), a typical carnivore that feeds primarily on large ungulates but also eats smaller animals, livestock, carrion and human food waste (Boitani & Mech 2003). Globally, the wolf is considered *Least Concern* in the IUCN Red List 2014. The legal status in the European Union is directly specified in

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the Habitats Directive (92/43/EEC). By default, wolf populations are listed in the Habitats Directive under Annexes II and IV. Annex II requires the establishment of Natura 2000 sites for the species, while Annex IV requires strict protection, prohibiting any destruction or damage to the population (but with derogations still possible under Article 16) (Kaczensky et al. 2013).

Vultures are seriously threatened, both in Europe and globally (IUCN Red List 2014). Some studies have highlighted the importance of factors such as human disturbance, poisoning or food availability (Botha et al. 2017). The bearded and the cinereous vultures are listed as *Near Threatened*, the Egyptian vulture as *Endangered* and the griffon vulture as *Least Concern* in the IUCN Red List, while all four species are of conservation interest in their European range and therefore listed in Appendix I of EU Birds Directive 2009/147/EC or countries' Red Data books and subject to a number of conservation initiatives.

The relationship between wolves and vultures is rarely studied in Europe. Some Bulgarian authors have reported positive interactions between the wolf as a predator and the vulture as a scavenger that can benefit from its prey leftovers (Boev 1978, Boev & Michev 1981, Botev & Peshev 1985, Angelov et al. 2005). Conversely, the wolf can locate carcasses to scavenge by observing where vultures congregate and circle over dead animal corpse (M. Kurtev *in litt.*). However, some more recent studies highlight the conservation danger of the man-wolf conflict and the related use of poison baits, which appears to be a great threat for vultures (Sakoulis 2001, Lopez 2001, Xirouchakis & Tsiakiris 2009, Andevski 2013, Demerdzhiev et al. 2014). In Greece, a direct relationship has been detected between the appearance of wolves and the reduction in numbers of cinereous and griffon vultures as a result of poison baits used by farmers to control the wild carnivores and feral dogs (Sakoulis 2001).

The vultures never settled to breed outside latitude North 50° in Europe and experienced a dramatic decline through the late XIX and early- and mid-XX Century. At present, they are patchily distributed in Southern Europe and in the Mediterranean, where once they were abundant. During the same period, wolf populations also suffered a dramatic decline, and some authors have presented the use of poison baits as a major factor in this species' decline (Lopez 2001, Boitani & Mech 2003, Chapron et al. 2014). Although the vultures were not a direct target of these baits, it is certain that the use of poison baits contributed to their decline, as well (IUCN Red List 2014 and the references therein).

In 25 years of modern vultures conservation in the Balkans, its success has hardly proven comparable to the results from Spain and France (where a significant increase in numbers and range occurred). Investigating the factors behind that difference, we researched and compared the history of food availability for the last 30 years and the quality of nesting sites and habitat, but none of these factors were clearly linked to the large disproportion of vulture populations in Iberia and on the Balkans.

The general maps presented in the report of Chapron et al. (2014) and their data about the populations and trends of large predators returning to Europe focused our attention to the fact that the wolf in the Iberian Peninsula is found outside the large vultures' distribution range. We initiated the current study having in mind the above information but also the following:

Poisoning, in general, is the single most important mortality factor for vultures (Botha et al. 2017);

The Greek authors Sakoulis (2000 and 2001) and Xirouchakis & Tsiakiris (2009) have stated that the decline of vultures in Greece and the complete extirpation of griffon and bearded vultures from the mainland can be attributed to the wolf's return from the late 1980s and the consequent increase of illegal poison baits used by livestock breeders;

The Bulgarian study of Parvanov et al. (2018) found the main reason for the poisoning of vultures in Bulgaria, Greece and FYR of Macedonia was the poison in baits targeting the wolf, among several others variables tested.

The present study examines the possible correlation between the presence of wolves and modern European trends in vulture populations, based on man-wolf conflicts and related illegal use of poison baits. We visualize the most current distribution of the four species of vultures and of wolf populations in Europe and calculate the level of their sympatric presence. Data from published sources were used and the following objectives were set: (1) to examine the extent of sympatric presence of each vultures species with wolf, based on precise and most up to date data for their distribution in Europe; (2) to test whether feeding sites' availability and operation is related to the vultures' presence and persistence in the Balkans; (3) to discuss how these variables explain the spatial distribution of vulture species within the wolf range and their temporal fluctuations, and which conservation measures should be applied.

Materials and Methods

The study presented here is based on the analysis of published literature. We reviewed 56 scientific papers on vultures and wolves in Europe, released in the period 1978-2018.

Study area

The vultures and wolf population numbers and distribution in Europe were studied based on maps produced from most recent and detailed studies. Special attention was paid to the comparison between the Iberian and Balkan Peninsulas, which have similar sizes and climatic and geographic features and both still harbour populations of these species. More detailed analyzes were done for the griffon vulture on the Balkan Peninsula, where it is the only vulture species with an increasing, albeit still unstable, population.

Question 1. Do vultures and wolves co-exist in modern Europe?

In the case of the wolf, a comprehensive study including most of Europe was published by Kaczensky et al. (2013), where the species population numbers and distribution by country was presented in a 10x10 km EEA cells grid. In this report, the authors categorize wolves' presence as either "*sporadic"* or "*permanent"*. We consider that only the permanent wolf presence is a reason for constant conflict with man affecting vulture populations. Thus, we analyzed only the permanent presence distribution of wolves.

For the vultures, we used the last available data from the national censuses of the four species in Spain (De la Puente et al. 2007, Del Moral 2009a, 2009b) or general maps of BirdLife International species factsheet in case of the bearded vulture. We used data for the griffon vulture in Europe presented in the species Action Plan by Slotta-Bachmayr et al. (2004) and compiled data for the vultures on Balkan Peninsula by Andevski (2013).

Other than in cases where we had explicit details for the home range and the breeding and foraging territory of vultures, we abided by these common rules: colonies of griffon and cinereous vultures were buffered by 30 km and single pairs of bearded and Egyptian vultures were buffered by 10 km, so as to include their home range. In this way, a colony of griffon or cinereous vultures shown as a point on the map actually translated to 25 cells of 10x10 km EEA in a batch. Similarly, a breeding pair of Egyptian or bearded vulture is provided as 9 cells of 10x10 km EEA in a batch.

We used GIS (QGIS) software to visualize the distribution of the studied species. Populations' and distribution maps of the wolf and the four species of vultures in Europe were overlaid and 10x10 km EEA cells of sympatric presence were counted.

The null hypothesis (H0) was that in recent years vultures have been largely found in areas where the wolf exists in Europe. The H1 was that vultures are not found in areas of wolf presence. We looked for a relationship between the number of 10x10 km EEA cells occupied by breeding griffon/cinereous/Egyptian/bearded vultures and the number of cells where wolves were not present within their range, after excluding the cells with wolves-vultures sympatric presence were excluded. Because of the non-parametric data used, a Spearman's correlation coefficient (Spearman 1904) was computed to assess the relationship.

Question 2. Are vultures found on the Balkans only where feeding sites operate?

We collected and analyzed data pertaining to the establishment and maintenance of feeding sites for the vultures on the Balkans and tested if this conservation measure could have aided the survival of certain vulture species in sympatric presence with wolves. Fifty-eight griffon vulture colonies from the Balkans were analyzed using the following variables: a) Presence of wolves: no – 0, yes – 1; b) Vulture feeding site operation: no – 0, sporadic – 1 and permanent – 2; c) Trend of the colony: decreasing – 0, fluctuating – 1, stable – 2 and increasing – 3.

A chi-square test of independence and a Fisher exact test were performed to examine the relationship between the trends of Balkan' griffon vulture colonies, wolf presence, and the supplementary feeding of vultures.

The results from the statistical tests were considered significant at $P<0.05$.

Results

Numbers of vultures and numbers and range size of wolf populations on the Balkans and the Iberian Peninsula

The wolf population on the Balkan Peninsula is twice larger in numbers and occupies about a three-fold larger territory compared to the Iberian Peninsula. The number of occupied cells in the 10x10 km EEA grid are 3,314 on the Balkans and 1,203 in Iberia (Kosovo and Montenegro were not included, due to a lack of data). In Spain, the Iberian wolf population covers some 120,000 km^2, but more than 90% of wolves are concentrated in three autonomous regions in the NW part of the country: Castilla y León, Galicia and Asturias. On the Balkans, however, the wolves are much more evenly distributed on the entire territory.

Table 1. Number of vultures and wolves in the Balkan and Iberian Peninsulas

Species/Region	Iberian Peninsula	Balkan Peninsula	
Gyps fulvus	25,000 [1]	600 [1]	Number of breeding pairs
Aegypius monachus	1,845 [2]	28 [1]	
Gypaetus barbatus	120 [3]	6-7 [1]	
Neophron percnopterus	1,500 [4]	80 [1]	
Canis lupus	2,200-2,500 [5]	3,950-5,000 [5]	Number of individuals

1 – Andevski (2013); 2 – BirdLife International (2013); 3 – BirdLife International (2014); 4 –BirdLife International (2004); 5 – Kaczensky et al. (2013).

Table 2. Correlation between the vulture breeding territories (number of 10x10 km grid cells occupied by the species) and the area without wolf presence (number of 10x10 km grid cells) in certain European countries.

Species	*N*	*r*	*P*
Gyps fulvus	14	0.68	0.0075*
Aegypius monachus	6	0.74	0.08
Gypaetus barbatus	7	1.00	0.0003*
Neophron percnopterus	10	0.97	<0.001*

* Correlation is significant at 0.01 level (2-tailed). N – number of cases (European countries, included in the study where the species occurs nowadays), r – Spearman correlation coefficient, P – probability

Checking the sympatric presence of wolf and vultures in Europe

See Table 2 and Fig. 1.

Analysis of feeding site statistics on the Balkan Peninsula

The relationship between supplementary feeding and the positive trend of Balkan griffon vulture colonies with sympatric presence of wolves was found to be significant with the chi-square test of independence, X^2 (12, N = 58) = 65.8, P <0.01, and also with the Fisher's exact test P <0.001.

Discussion

In Bulgaria, Greece and the FYR of Macedonia, the vultures are mainly poisoned in cases when the bait targets wolves (Parvanov et al. 2018). This could be attributed to the fact that wolves kill prey on a regular basis in relatively small areas that are accessible for vultures. The birds tend to adapt to this predictable source of food and become easily killed when a shepherd illegally puts poison in the carcass of an animal killed by wolves in an attempt to avenge the losses incurred and prevent new depredations.

Additionally, Andevski (2013) claims that the main cause for the decline of vultures in the Balkan region and the current limiting factors for their recovery is the use of poison against wild predators that come into conflict with human activities (mainly livestock farming and hunting). Our study provides additional support to this concept and also to the data of Sakoulis (2001) and Xirouchakis & Tsiakiris (2009) that the wolf presence, or reappearance after decades of absence, is clearly linked to the vultures' decline and misfortune in this particular territory.

In terms of worldwide distribution, the wolf reached its lowest point in the 1960s. The recovery of this species in the seventies was a result of increasing environmental awareness and the implementation of environmental conservation laws (Lopez 2001). At present, the wolf is the second most abundant large carnivore species in Europe, with an estimated total number of over 12,000 individuals, with most populations increasing or stable during recent years (Chapron et al. 2014). According to the Chapron et al. (2014), the wolf population on the Balkans increased up to 5 fold in number and range from 1970-ies to 2014.

In the same period, the last bearded vultures became extinct from the mainland Balkans, along with many of the griffon and cinereous vultures, and the same process continues rapidly in the last decades with the Egyptian vulture (Andevski 2013, Velevski et al. 2014).

The use of poison for wolf control is a commonly used local method employed by shepherds to reduce depredation events, but it can not be considered a major threat to the wolf species itself (Iliopoulos 2000, Sakoulis 2001). On the other hand, the extinction of vultures in Central Greece in the 1990s was attributed to the re-establishment of wolf packs and the related increasing illegal use of poisoned baits. The anticipated result for wolf extermination by poison baits never occurred, but the detrimental effects of this illegal practice on other wildlife species, such as vultures, became obvious only a few years later (Sakoulis 2001).

Our results show that colonies of griffon and cinereous vultures and nuclei of bearded and Egyptian vultures breeding pairs survived on the Balkans only outside the wolf range. In areas of co-existence with

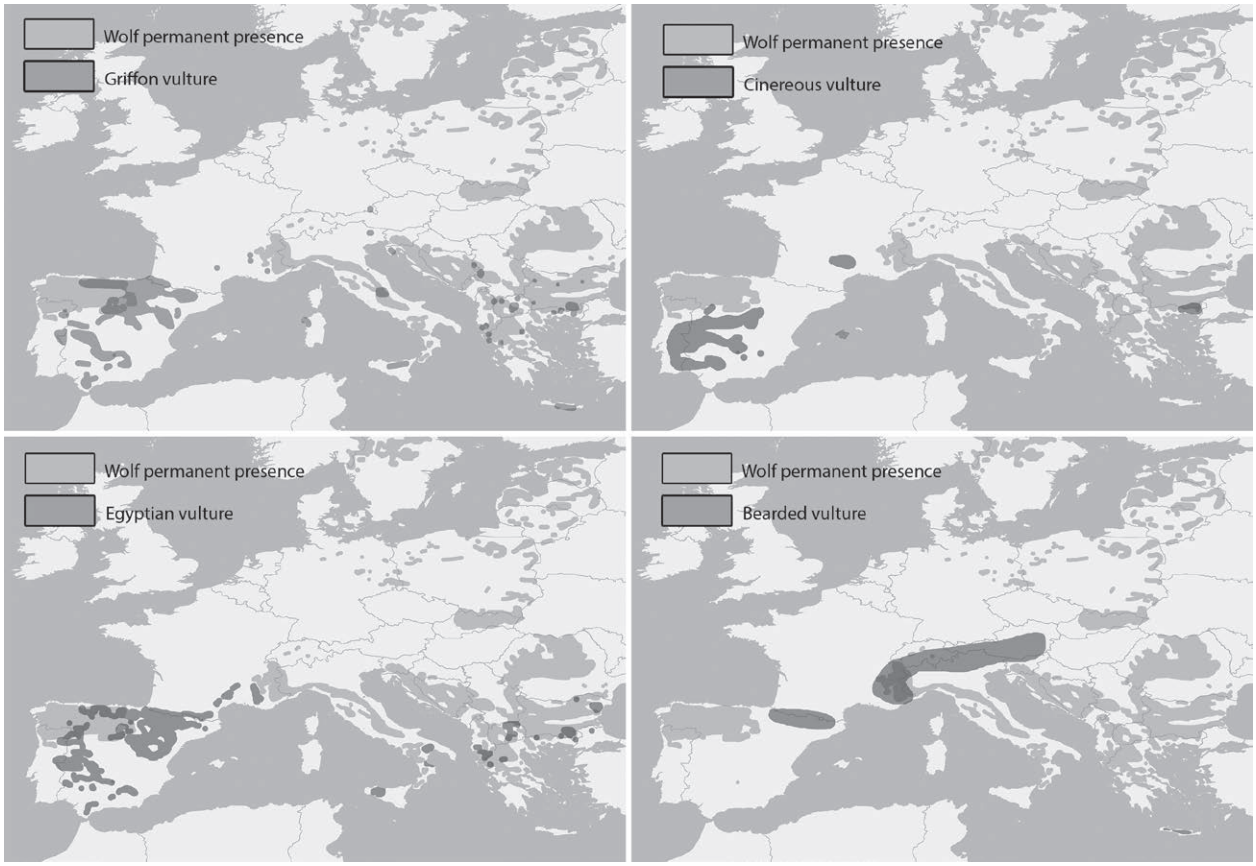

Fig. 1. The four European vulture species and the wolf distribution in Europe – wolf range is compiled by Guillaume Chapron (Kaczensky et al. 2013), the griffon vulture range is compiled by Slotta Bachmayr et al. (2004) with additions from the authors, the cinereous, bearded and Egyptian vultures distributions are according to IUCN Red List (2014).

wolves, certain species of vultures survived only where intensive and continuous feeding site operation has been in place, or alternatively, in the case of the FYR of Macedonia, where slaughterhouses' dumpsites were freely accessible for vultures.

Our study rejects the H0 and is in disagreement with the theoretical statement of Boev (1978), Boev & Michev (1980) and Botev & Peshev (1985) that the vultures need the wolf's predatory activity to ensure in a natural way the availability of leftovers for scavengers. Although this theoretical situation might hold true without the man-wolf conflict and the related poison use, the recent overlap in wolves and vultures' distributions in Europe has proven to be significantly antagonistic. In Southern Europe, vultures are observably absent wherever the wolf is present. In modern Europe as a whole, the largest vulture populations flourish or at least survive, where the wolf is absent (for example, in most of Spain, France, Portugal and some Mediterranean Islands, including Mallorca, Corsica, Sardinia, Cres Island (Croatia), Crete (Greece) and Cyprus. The numbers of the large European vultures on the Iberian Peninsula are 40 fold larger in total than on the Balkan Peninsula despite their almost equally sized areas and geomorphologic and climatic similarities. Meanwhile, the number and range of wolves on the two peninsulas are 3 to 1 in favor of the Balkans.

About 98% of the griffon vulture population in Europe is found in Spain, France and Portugal, and about 95% of it lies outside the wolf range on the continent. In Spain, only a small part of the griffon and Egyptian vulture populations overlap with wolf distribution (in Central North and NW Spain), while the bearded and cinereous vulture populations fall entirely outside the wolf range. It will be interesting to see further research on this topic with detailed spatial and temporal distribution of vultures and wolves and ecological factors on the Iberian Peninsula.

To date on the Balkans, the only healthy subpopulation of griffon vultures that has survived without special and intensive conservation efforts is found on Crete Island in Greece. About half of the species' Balkan population (240 pairs) inhabits Crete, in complete absence of the wolf. Other large subpopulations (≈100 pairs) of griffon vultures on the Balkans are found on the Croatian Cres and Krk Islands, again in absence of the wolf. The others

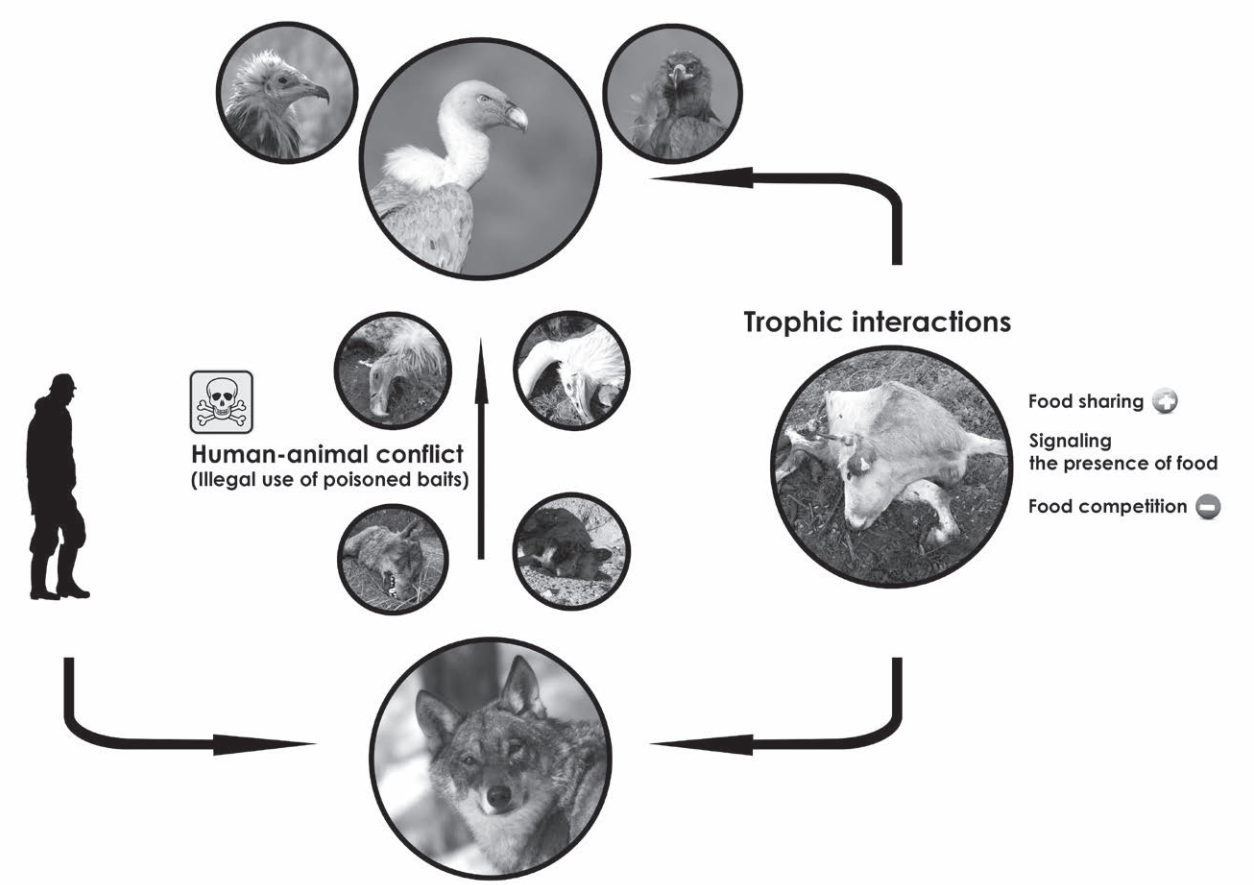

Fig. 2. Wolf and vultures coexistence: ecological benefits and constraints.

- *The main benefits from species coexistence are the positive trophic interactions*. Wolf kills are important and preferable food sources for vultures. One of the main reasons for this is because they are frequently available. Especially in areas with lower livestock and wild ungulates density, this source of food for the vultures could be very important. Another reason is because they are fresh, opened, and usually found away from people. In addition, the broken and chewed bones by the grey wolf provide small fragments which are good calcium source for vultures. The wolf is able to see vultures from a large distance when they fly and congregate above the animal carcass and they usually approach it to scavenge.
- *The main constraints from species coexistence are food resource competition and human-animal conflict consequences.* Searching from the sky in large groups the vultures usually find the carcasses first and can eliminate available meat shortly, thus competing the wolf for food resources. The wolf conflicts with livestock and game owners are common reasons for poisoning events that usually affect vultures. A study shows that the poison used to kill grey wolf was the primary cause of 60% of all registered vulture poisoning events in the southern Balkan Peninsula during the last 36 years (Parvanov et al. 2018).

few remaining colonies on the Balkans, all of which fall partly or entirely within the wolf range (Serbia, Bulgaria, the FYR of Macedonia, Evros in Greece), are under permanent and long-term conservation efforts (feeding sites, public awareness, education etc.) by state institutions and local NGOs. In the FYR of Macedonia, although conservation efforts are not so regular and intensive, slaughterhouse offal is deposed at open dumpsites that effectively play the role of vulture feeding sites. This is no longer possible in Greece and Bulgaria due to EU sanitary requirements. The future accession of the FYR of Macedonia to the EU may result in closing these slaughterhouse dumpsites and as a result will likely negatively affect the remnant griffon and mostly Egyptian vulture population in the country.

The result for the cinereous vulture's antagonistic relationship with the wolf was nearly significant at P=0.08, which might be attributed to the small data set available. Thus, further and more detailed research on the subject is needed. In all likelihood, the cinereous vulture is highly affected by man-wolf conflicts in Europe, because it is a species with a close relationship to the wolf (Botev & Peshev 1985). It readily feeds on the leftovers from wolves' prey – a fact hardly noticed and reported in Spain, because the

two species have not been found together for the last few decades. The principle cause for the cinereous vulture's higher incidence of being affected by poison, compared to more abundant species exposed to poison to the same extent, lies in its alimentary habits. The cinereous vulture specializes in feeding on medium and small carrion, so that it is more exposed to foxes, cats, badgers and other kinds of predator carrion that are precisely the ones targeted by poisoned bait (Sanchez 2001). This is true to an even larger extent for wolf kills because the cinereous vulture readily lands to feed in open forest habitats where wolves' prey is usually found, especially if the wolf is still around (authors' own observation). Healthy populations of cinereous vulture are nowadays found only outside the wolf's range in Europe: Central to Southwestern Iberian Peninsula, Mallorca, Crimean Peninsula and French Massif Central and Pre-Alps (in the former two areas - successfully reintroduced). The cinereous vulture's only remaining colony on the Balkans (within the wolf range) is found in Dadia Forest National Park in NE Greece. This colony is supported through intensive feeding site operations and a number of other conservation measures. Vasilakis et al. (2005) suggests that the specimens that are attached to the protected area and feed on the poison-free food at the feeding site are those who survive and maintain the colony. Each group of birds that does attempt to disperse outside this area is most probably exposed to poison (Vasilakis *in litt*.).

Where it can, the bearded vulture tends to target wolf kill leftovers as this way it has an access to its preferred food, namely the bones of medium sized mammals. This is probably why the species was almost extirpated from Europe during the mass poisoning campaigns against predators in the early to mid XX Century.

Solitary-nesting scavengers, such as the bearded vulture, which feeds on small carrion, are most susceptible to poisoned baits, even those the size of meatballs (Brown 1991), and thus more prone to extinction. This is very much true for the Egyptian vulture as well.

The bearded vulture in Europe survived outside the current wolf range – the Pyrenees, Corsica and Crete Islands – and was successfully restored in the Alps in the absence and current reappearance but still low numbers and densities of wolves. The last few birds that remained in mainland Greece within the wolf range are no longer present (Sakoulis 2001, Xirouchakis & Tsiakiris 2009). Just recently, promising results for the reintroduction of the bearded vulture in Andalucía were reported by the Vulture Conservation Foundation. It is worth mentioning that the region is now free of wolves – less than 10 animals in Sierra Morena (Kazciensky 2013). At the same time, an attempt for the reintroduction of bearded vultures in the Picos de Europa National Park, Asturias, failed due to the permanent man-wolf conflict and the related use of poison baits (Anonymous 2015).

The Egyptian vulture has survived in Europe largely outside the wolf range, in Spain, Portugal, France, Italy, Menorca and Canaries. On the Balkans, the species was still abundant until the 1970s, when the wolf was almost extirpated. In all likelihood, the poisoning that generally took place in the winter months of those years did not affect the Egyptian vulture because, as a migrant species, it spends the winter season in Africa. However, the Egyptian vulture is now declining rapidly in most of its range. Once again, this species is doing better nowadays in areas outside the wolf range. The only surviving pairs within the wolf range on the Balkans are found in the Eastern Rhodopes shared between Bulgaria and Greece, with both sites well supplied with vulture feeding sites, and FYROM, where the species still benefits from slaughterhouses dumpsites. In NW Bulgaria, a small nucleus of a few pairs survives, as does a small population in Albania (Velevski et al. 2014), both outside the wolf range.

Conclusions

It can be concluded that in areas of sympatric presence of griffon vulture and wolf, an effective solution to buffer the illegal poisoning threat and to achieve stability or even slight increase of the vulture population is to maintain permanent vulture feeding stations.

We can conclude that to protect the vultures within the wolf range in Europe, a low enforcement against poison use and a combination of legislation adaptation and conservation actions are needed. Some of these include:

Any future wolf conservation and management planning should take in mind the poison issue and its effect on vultures.

Implementing a combination of measures targeting the man-wolf conflict on the Balkans, such as: 1. Restocking and reintroducing wild ungulates (fallow deer, red deer, chamois, Alpine ibex, etc.) as an alternative food base for wolves and/or vultures; 2. Adapting livestock management practices by improving the night corrals and shifting from sheep and goats to cattle (Stoynov et al. 2014), as well as introducing fenced ranches; 3. A wide introduction of livestock insurance;

Feeding sites for vultures should be considered an irreplaceable conservation tool within the wolf range.

Continuing the maintenance of the existing feeding sites on Balkans and enlarging the network of feeding sites to provide poison-free food to the vulture populations.

Providing precise research, site by site, on the relationship between wolves and vultures in order to increase the knowledge and the use of direct measures for successful conservation, especially in areas of co-existence.

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