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Is the Wolf Presence Beneficial to Vultures in Europe?

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1. Abstract

Relationship between wolf and vultures is rarely studied in Europe. Some authors report positive interaction between wolf as a predator and vultures as scavengers benefiting to feed on predator's preys' leftovers. Some most recent studies, however, highlight the danger of Man-wolf conflict and the consequent use of poison baits, as a great threat for vultures.

Vultures and wolves followed a dramatic decline in last two centuries in Europe. Poison baits use is a major factor for their decline. Vultures are recently only found patchily in Southern Europe, where they previously have been abundant. Conservation measures are underway across Europe and it is still unclear why the Iberian Peninsula vulture populations are increasing and huge, while the ones on Balkan Peninsula are small and still declining, despite generally common features and the conservation measures applied. The research presented here is based on literature study, reviews and personal observations.

Results first show that the most common reason for vultures poisoning on Balkans is the use of poison baits to kill wolves. Secondly, the comparison of vultures and wolf populations show that Iberia harbors between 17 and 65 times more vultures from the four species than Balkans, where in turn there are two times more wolves on three folds bigger area of occupancy. Thirdly, we found strong, positive correlation thus a huge overlaps between the four European vultures breeding territories and the area free of wolf's presence in Europe. Fourthly, we conclude that maintaining permanent feeding sites for vultures in regions of sympatric presence with wolf is an irreplaceable conservation tool.

Conservation of both wolves and vultures in sympatric presence is a complicated and up to now hardly proven working in Europe. Priorities in conservation of threatened species should be set up and any relationship between different conservation dependent groups taken in mind.

***Keywords*:** Man/wolf conflict, poison baits, *Neophron percnopteurs*, *Gyps fulvus*, *Aegypius monachus*, *Gypatus barbatus*, Iberian Peninsula, Balkan Peninsula, conservation, feeding sites,

2. Introduction

The four European vultures - Griffon Vulture *Gyps fulvus* Hablizl, 1783, Black Vulture *Aegypius monachus* Linnaeus, 1766, Bearded Vulture *Gypaetus barbatus* Linnaeus, 1758, and Egyptian Vulture *Neophron percnopterus* Linnaeus, 1758, diets, ecology, feeding behavior and threats are well studied in Europe. Most of the scientific data comes from Spain, where about 90% of all four species on the continent are found in the last few decades (Slotta- Bachmayr et al. 2004, De la Puente et al. 2007, Del Moral 2009a, Del Moral 2009b, Andevski 2013).

As obligate scavengers, searching by sight from the air, the vultures depend on carcass appearance in accessible open areas, which in many cases are naturally made available by predators (Cramp & Simmons 1980). In Europe the most useful predator for the vultures is the Wolf *Canis lupus* Linnaeus, 1758, (Boev & Michev 1980, Michev 1985). It is a typical predator that feeds primarily on large ungulates, though it also eats smaller animals, livestock, carrion, and garbage (Boitani 2004). The wolf is one of the world's best known and well researched animals, with probably more books written about it than any other wildlife species. It has a long history of association with humans, having been despised and hunted in most pastoral communities due to its attacks on

livestock, while conversely being respected in some agrarian and hunter-gatherer societies (Mech & Boitani 2003).

Globally the Wolf is considered *Least Concern* in the IUCN Red List 2014. The legal status in the European Union countries is directly specified in the Habitats Directive (92/43/EEC). By default wolf populations are listed 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 in Europe and Globally (IUCN Red list 2014). Some studies have highlighted the importance of factors such as human disturbance (Gavashelishvili et al. 2006), poisoning (Donazar et al. 2002a, Green 2006), or food availability (Thiollay 2006). The *G. barbatus* and *A. monachus* are listed as *Near Threatened* and the *N. percnopterus* is listed as *Endangered* in the IUCN Red List, the *G. fulvus* is considered *Least Concern* and the four species are of conservation interest in their European range. All are listed in Appendix I of EU Birds Directive 2009/147/EC or countries' Red Data books (except the Griffon Vulture in Spain and Portugal) and a number of conservation programs are underway.

The relationship between the wolf and vultures is rarely studied in Europe. Some authors from Bulgaria report positive interaction between wolf as a predator and the vultures as scavengers benefiting to feed on the predator's preys' leftovers (Boev 1978, Michev and Boev 1980, Michev 1985, Angelov et al. 2005). Some most recent studies however highlight the danger of the Man-wolf conflict and the consequent use of poison baits, which appears to be a great threat for the vultures (Sakoulis 2001, Lopez 2001, Xirouchakis & Tsiakiris 2009, Andevski 2013 and Demerdzhiev et al. 2014, Stoynov et.al. 2014). In Greece a direct relationship has been detected between the appearance of the wolf and the reduction in the Black Vultures and Griffon Vultures as a result of the bait used by farmers to control wolves and feral dogs (Sakoulis, 2001).

The vultures never settled to breed outside latitude North 50° in Europe and experienced a dramatic decline in the late XIX and early and mid XX Century. Vultures are recently only found patchily in Southern Europe and Mediterranean, where they previously have been abundant (Choisy & Terrasse 2007).

The wolf has also undergone a dramatic decline during the same period and some authors present the poison baits use to control predators as a major factor for the species decline (Lopez 2001, Boitani 2004, Chapron et al. 2014). The same is true for the vultures, although the last may have not been targeted (IUCN Red List 2014 and the references therein).

We were working for more than 20 years on conservation of the vultures in Bulgaria and FYROM and we were always excited about the success of vulture conservation in Spain and France (e.g. increase in number and re-introductions). We thus tried to understand why we on the Balkans are not so successful in this, despite the long-term and enormous efforts applied. Just recently published study of Chapron et al. (2014) about the large predators populations return in Europe focused our attention on the fact that the recovery of the *C. lupus* may has been the reason for the simultaneous decline of some vulture species in certain places on the continent. Such statement we found also in several Greek authors' publications (Sakoulis 2001, Xirouchakis & Tsiakiris 2009) that are generally supporting the idea that the decline of vultures in Greece and the complete extirpation of *G. fulvus* and *G. barbatus* from the mainland is attributed to the wolf return from late 1980-ies and the consequent increase of illegal poison baits use by livestock breeders and game keepers.

There is therefore an urgent need to analyze the effect of Wolf reappearance and population and range expansion in Europe and related effects on vulture populations.

This study examines the probability that the Wolf presence affects negatively the vulture populations in modern Europe, based on human/wolf conflict and consequent illegal use of poison baits. We used GIS to visualize and determine the most actual distribution of the four species of vultures and Wolf in Europe and we tested their sympatric presence by constructing simple mathematical models with the support of data available from published sources verified by authors. The main objectives of this study are:

1) to investigate which variables determine the frequency of poisoning episodes, involving vultures in Bulgaria, FYROM and Greece; 2) to examine the area of sympatric presence of each of the vultures species with Wolf, based on precise and most up to date data for their distribution in Europe; 3) to test whether vulture feeding sites availability and operation may avoid poisoning and affect population dynamics over time; 4) Compare model Egyptian, Griffon and populations' trends in areas with complete and permanent Wolf presence and area free of

Wolf; 5) Compare population dynamics of wolf and vultures as well as livestock as a main food source for vultures in model areas; 6) to discuss how these variables explain the spatial distribution of vultures species within the wolf range and their temporal fluctuations, and which conservation measures are to be applied.

In addition, we discus on advantages, disadvantages and implications for conservation of the vultures in the areas of sympatric presence with wolf in modern Europe.

We speculate on eventual effect of human/wolf conflict and consequent illegal use of poisoned baits on populations of vultures in Europe if the wolf receives higher protection and the positive trend of its population development continues.

3. Material and Methods

The study presented here is based on literature survey, analyzes of published data and also on personal observations and data collected by the authors. Discussions with other vulture and wolf experts and conservationists were also provided.

Study area and the literature survey methods

The vultures *G. fulvus*, *A. monachus*, *G. barbatus*, *N. percnopterus* and wolf populations' number and distribution in Europe were studied based on maps produced from most recent and detailed researches. We paid much attention on comparison of Iberian and Balkan Peninsulas, which have similar size, climatic and geographic features and still harbor wolf and vulture populations.

For the wolf a comprehensive study including most of Europe was published in 2013 (Kaczensky *et al.*, 2013), where the species population numbers and distribution by country was presented in 10x10 km EEA cells grid. In this report two categories of presence were used by the authors- "*sporadic presence*" and "*permanent presence*". We consider that for the vultures only the permanent wolf presence is a reason for constant conflict with man, which results in poison baits use affecting vulture populations. Thus we analyzed only permanent presence distribution of wolf.

For the vultures we used the last available data from the national censuses of the four species in Spain (De la Puente, Moreno-Opo & Del Moral 2007; Del Moral 2009a; Del Moral 2009b) or general maps of BirdLife International species factsheet in case of the *G. barbatus*. We used the data for the Griffon Vulture in Europe presented in the species Action Plan (Slotta-Bachmayr, Bögel & Camiña 2004) and compiled data for the vultures on Balkan Peninsula (Andevski 2013).

We reviewed 54 scientific papers on vultures in Europe, published in the period 1980-2015 and originating from various countries in Europe. These papers were written in five languages: 32 in English, three in Italian, seven in French, eight in Bulgarian, one in Ukrainian. These were 37 papers published in scientific journals, five in books and monographs, seven reported at conferences or symposia, and six project reports.

Unless details for the home range and the breeding and foraging territory is known, these common rules were followed: colonies of *G. fulvus* and *A. monachus* were buffered by 30 km and single pairs of *G. barbatus* and *N. percnopterus* were buffered by 10 km, as to include the home range. This way a colony of Griffon or Black Vulture shown as spot on the map includes 25 cells of 10x10 km EEA in a badge. Similarly a breeding pair of Egyptian or Bearded Vulture is provided as 9 cells of 10x10 km EEA in a badge.

We used GIS to visualize the distribution of the studied species. Populations' and distribution maps of the *C. lupus* and the four species of vultures in Europe were overlaid and 10x10 km EEA cells of sympatric presence counted. Then they were compared with the number of cells with certain vulture species presence in free of wolf areas. The mismatch and matches were analyzed.

Relationship was searched between the number of 10x10 km EEA cells occupied by breeding Griffon/Black/Egyptian/Bearded Vulture and the number of cells without *C. lupus* presence within the Griffon/Black/Egyptian/Bearded vultures' range, when the cells with sympatric presence with wolf were taken out. Because of the non-parametric data used, a Spearman's correlation coefficient (Spearman 1904) was computed to assess the relationship.

Reasons and effect of vulture poisoning in model territories

We analyzed data for 96 poison cases in Bulgaria, Greece and FYROM in the period 1990-2015, from published sources or reported in the frame of several vulture conservation projects. The data was divided in four groups by species affected - "*G.fulvus*", "*N. percnopterus*", "other birds of prey", "other animals" and four groups by reason of poison baits setting - "targeting wolves", "targeting dogs and cats", "other animals", "pesticides in agriculture". A 3D column chart was created in MS Excel and the data was analysed using Fisher's exact test (2X2). It was divided in two groups by species affected - "Vultures" *and* "other animals" and two

groups by reason of poison baits setting - "targeting wolves", "targeting other animals- dogs, cats, pests, etc.

Based on recent study findings, we also directly compared the growing rate of the best known to us increasing colonies of *G. fulvus* in Massif Central in France (free of wolf) and Eastern Rodopi in Bulgaria (100% co-existence with *C. lupus*) using data from publications by Terrasse 2006, Sarrazin 2013 and Demerdzhiev *et al*. 2014.

Feeding sites as buffers to poisoning of vultures in wolf range

We collected data and analyzed the conservation efforts through establishment and maintenance of feeding sites for the vultures on Balkans and checked if this could be the reason for survival of certain vulture species in sympatric presence with wolf. Fifty eight *G. fulvus* colonies from Balkans were analyzed with 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, fluctuates – 1, stable – 2 and increasing – 3.

A chi-square test of independence and a Fisher exact test were performed to examine the relation between the trend of Balkans' Griffon Vulture colonies, the wolf presence and the vultures' supplementary feeding.

Relation between livestock abundance and wolf reappearance/population growth with Vulture's population trends in Bulgaria, Greece and FYR of Macedonia

We collected data from official sources for livestock (cattle, horses, sheep, goats and pigs) for the Balkan countries in which more than one species of vultures have survived to date – Bulgaria, Greece and FYR of Macedonia. It was then than set up in a scatter plot with Wolf population and Griffon and Egyptian Vultures populations. Dynamics of the numbers were presented through scatter plot using MS Excel by linear regression model.

Statistical analyzes

For meaningful values of W ($p < 0.05$), H_0 is rejected and to prove normality of distribution, the value of W must not be significant ($p > 0.05$). When the data were not normally distributed, they were transformed by the function log (x+1) (Fowler & Cohen 1992). Results with $p<0.05$ [$\alpha = 5\%$] were considered significant.
We implemented statistical analyses with „R" (R Core Team, 2012).

4. Results

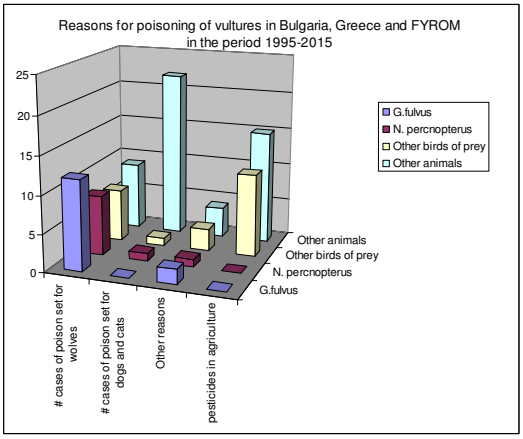
The results are divided into four sections: 1. Presents the Reasons for poisoning of vultures in Bulgaria, Greece and FYROM; 2. Presents the numbers and range sizes of the four vulture species and the wolf on Balkans and Iberian Peninsula; 3. Review of overlaid distribution maps of wolf and vultures in Europe; 4. Review of the state of vulture communities supported by feeding sites compared to non- supported ones in sympatric presence with wolf on Balkans; 5. Comparison of growth rate of two *G. fulvus* colonies in Eastern Rodopi in Bulgaria and Massif Central in France, based on the presence and lack of wolf accordingly; 6. Comparison of dynamics of livestock as food source for vultures, wolf and vultures populations in model territories in Bulgaria, Greece and FYROM.

Reasons for poisoning of vultures in Bulgaria, Greece and FYROM

We found that although the most poisoned animals are affected by poison set for dogs and cats (n=22), and the most birds of prey (other then vultures) are poisoned by pesticides in the agriculture (n=11), the primary cause of poisoning vultures (n=20 ; *G.fulvus* 12 cases and *N. percnopterus* 8 cases) is based on the attempts of poisoning wolves.

Results showed a significant difference between the two groups of poisoning cases with and without vultures affected in terms of poisoning targets (wolves Vs. other animals- cats, dogs, pigs, pests, etc.) ($P<0,001$). So that in 20 (83.3%) cases with Griffon vultures or/and Egyptian vultures poisoned in Bulgaria, Greece and FYR of Macedonia the bait was targeting wolves. Only 4 (16.7%) cases with vultures causalities were happened as a result of targeting other animals.

Figure 1. *Reasons for poisoning of vultures and other animals (number of cases) in Bulgaria, Greece and FYR of Macedonia in the period 1995-2015*



In Bulgaria, Greece and FYR of Macedonia the vultures get mainly poisoned in cases when the bait is targeting wolves. This might be attributed to the fact that wolves are killing prey frequently in relatively small area accessible for vultures on regular basis. The vultures then get used to this more or less predictable source of food and become poisoned, when a shepherd puts poison, using as bait the carcass of the next animal killed by wolves in revenge to losses incurred and as prevention of future depredation.

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

Table. 1. *Numbers of vultures and wolves on Balkan and Iberian Peninsulas*

Species/Region	Iberian Peninsula (*breeding pairs*)	Balkan Peninsula (*breeding pairs*)
G. fulvus	25 000*	600*
A. monachus	1 845 ¶	28*
G. barbatus	120 §	6-7*
N. percnopterus	1500 ‡	80*
C. lupus (ind.)	2200-2500†	3950-5000†

*(Andevski 2013)

¶ (BirdLife International 2013)

§ (BirdLife International 2014)

‡ (BirdLife International 2004)

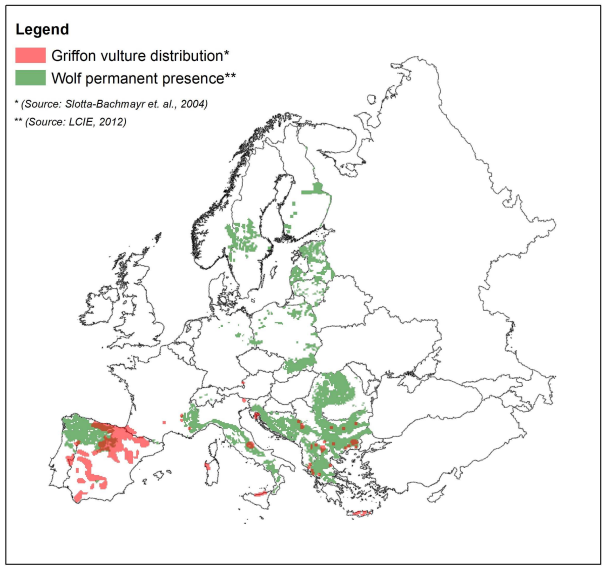
† (Kaczensky et al. 2013)

The wolf population on Balkan Peninsula is not only larger in numbers than the one on Iberian Peninsula, but also occupies about 3 fold bigger territory. The number of occupied cells in the 10x10 km EEA grid are 3.314 on Balkans and 1.203 on Iberian Peninsula (having in mind that Kosovo and Montenegro are not included, because of lack of data) (Kaczensky et al., 2013). In Spain, the Iberian wolf population covers some 120,000 km^2. More than 90% of wolves however are concentrated in three autonomous regions in NW part of the country: Castilla y León, Galicia and Asturias, while on Balkans they are evenly distributed on the entire territory.

Overlaying distribution maps of wolf and vultures in Europe;

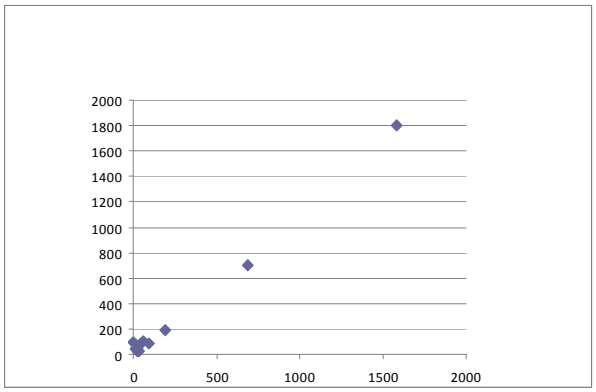
Griffon Vulture/Wolf

Figure 2. *Griffon Vulture and 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*



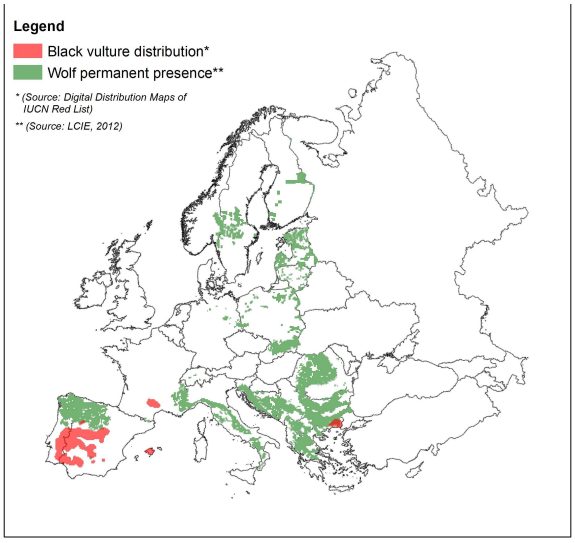
There was a positive correlation between the two variables, r = 0.679, n = 14, p = 0.0075. Scatterplot summarizes the results (Figure 3). Overall, there was a strong, positive correlation thus a huge overlaps between the territory of *G. fulvus* breeding and the area free of wolf's presence in Griffon Vulture range in Europe.

Figure 3. *Number of 10x10 km EEA cells occupied by breeding G. fulvus vs. Number of 10X10 km EEA cells without wolf presence within the G. fulvus breeding range in Europe*



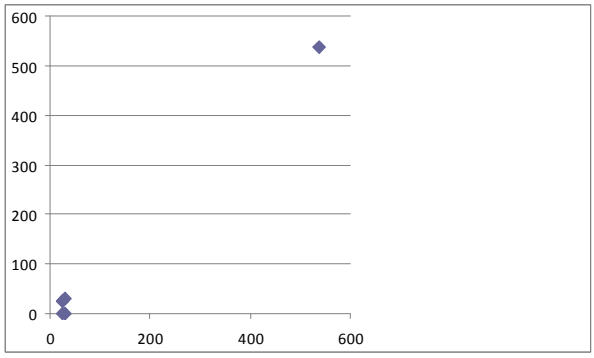
Black Vulture / Wolf

Figure 4. *Eurasian Black Vulture and Wolf distribution in Europe – the wolf range is compiled by Guillaume Chapron (Kaczensky et al., 2013), the Black Vulture range is according to BirdLife International 2013*



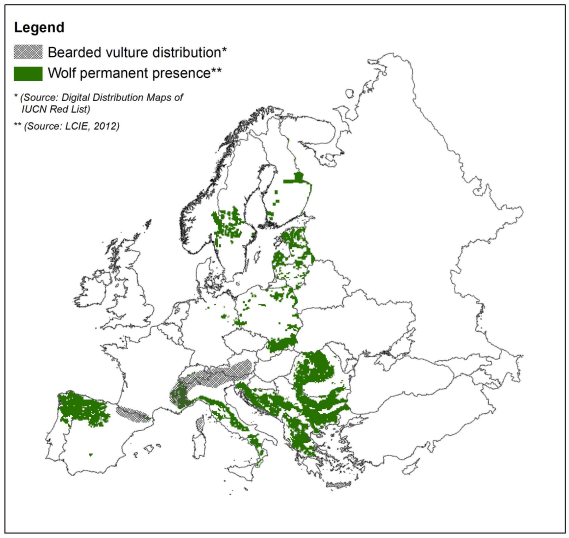
There was a positive correlation between the two variables, r=0.74, n=6, p=0.08. Scatterplot summarizes the results (Figure 5). Overall, there was a strong, positive correlation thus a huge overlaps between the territory of *A. monachus* breeding and the area free of wolf's presence in *A. monachus* range in Europe.

Figure 5. *Number of 10x10 km EEA cells occupied by breeding A. monachus vs. Number of 10X10 km EEA cells without wolf presence within the A. monachus breeding range in Europe*



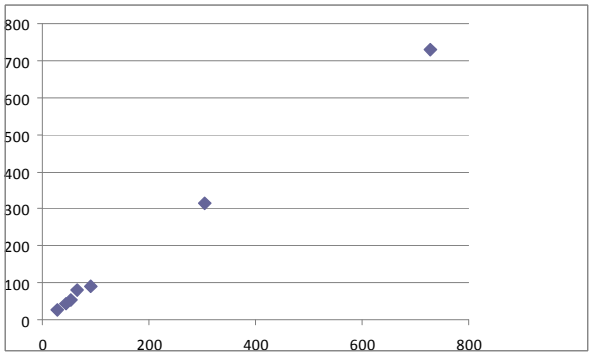
Bearded Vulture/Wolf

Figure 6. *Bearded Vulture and Wolf distribution in Europe – the wolf range is compiled by Guillaume Chapron (Kaczensky et al., 2013), the Bearded Vulture range is according to BirdLife International 2014.*



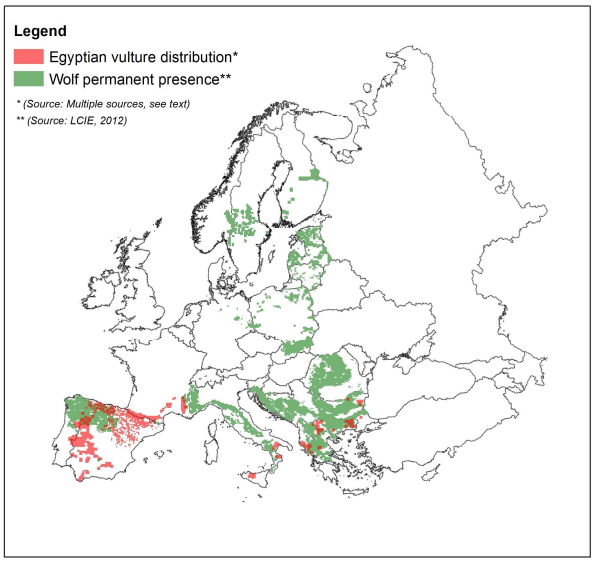
There was a strong, positive correlation between the two variables, thus a huge overlaps between the *G. barbatus* breeding territory and the area free of wolf's presence in Europe, r=1, n=7, p=0.0003. Scatterplot (Figure 7) summarizes the results

Figure 7. *Number of 10x10 km EEA cells occupied by breeding G. barbatus vs. Number of 10X10 km EEA cells without wolf presence within the G. barbatus breeding range in Europe*



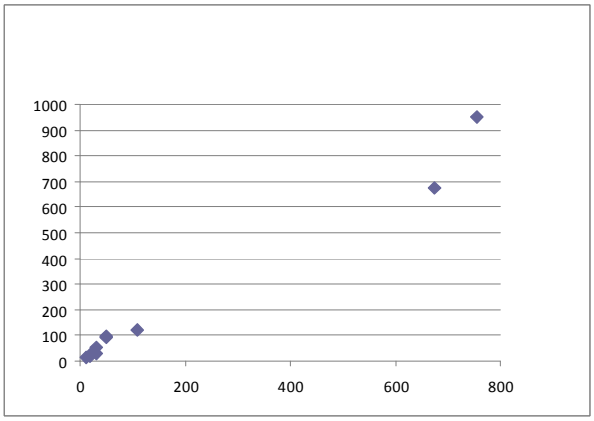
Egyptian Vulture/ Wolf

Figure 8. *Egyptian Vulture and Wolf distribution in Europe – the wolf range is compiled by Guillaume Chapron (Kaczensky et al., 2013), the Egyptian Vulture range is according to Velevski et al. 2014, Del Moral 2009, Andreoti & Leonardi 2009, LPO 2012*



There is a strong, positive correlation thus a huge overlaps between the Egyptian Vulture breeding territory and the area free of wolf's presence in Europe, r=0.97, n=10, p<0.001. Scatterplot (Figure 9) summarizes the results.

Figure 9. *Number of 10x10 km EEA cells occupied by breeding N. percnopterus vs. Number of 10X10 km EEA cells without wolf presence within the N. percnopterus breeding range in Europe*



Analysis of feeding site statistics on the Balkan Peninsula

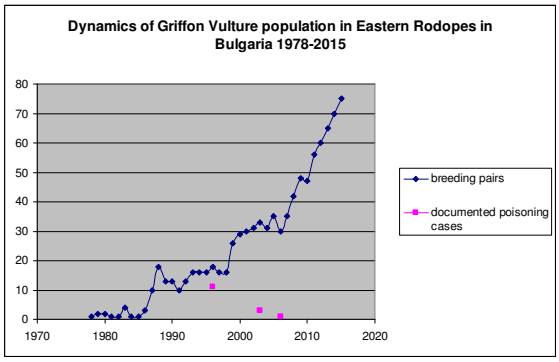
The relation between the positive trend of Balkans' Griffon Vulture colonies with sympatric presence of wolf and the supplementary feeding was found to be significant with the chi-square test of independence, X^2 (12, N = 58) = 65.8, p <0.01, as well as with the Fisher's exact test p <0.001.

It can be concluded that in areas of sympatric presence of *G. fulvus* 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 restaurants.

Comparison of Griffon and Black Vulture population increase in model territories within and outside wolf range.

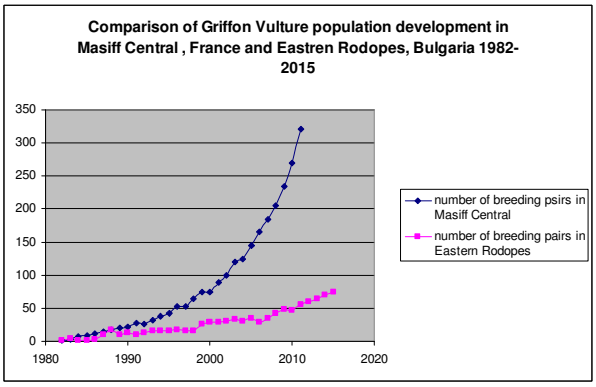
The dynamics of the breeding pairs numbers of the colonies of Griffon Vultures in Massif Central in France, found outside the wolf range and the colonies in Eastern Rodopi in Bulgaria, that are entirely within the wolf range and documented poisoning events were compared.

Figure 10. *Dynamics of Griffon Vulture population in Eastern Rodopi, Bulgaria and documented poisoning events 1978-2015*



It is seen that the population number of Griffon Vulture in Eastern Rodopi decreases in each of the three documented poisoning events. Most probably the other few declines were also related with poisoning episodes, which remained unnoticed accordingly.

Figure 11. *Dynamics of Griffon Vulture populations in Eastern Rodopi, Bulgaria (within wolf range) and Masiff Central, France (outside wolf range) 1982-2015*



It can be concluded that in areas of sympatric presence of *G. fulvus* and wolf (Eastern Rodopi in Bulgaria) the dynamics of the population is biased by the poisoning episodes, while the free of wolf area of Massif Central in France facilitates three times higher increase for the same period in absence of large and repeated poisoning events.

Comparison of the situation with livestock, Griffon and Egyptian vulture and wolf in Bulgaria, Greece and FYR of Macedonia.

Figure 12a. *Dynamics of Livestock, Wolf and Griffon Vulture numbers in Eastern Rodopi, Bulgaria 1979- 2011*

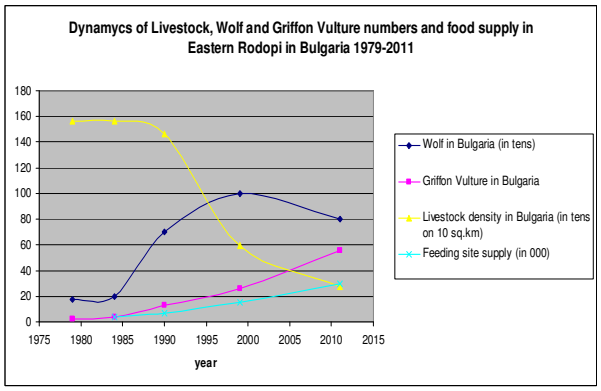
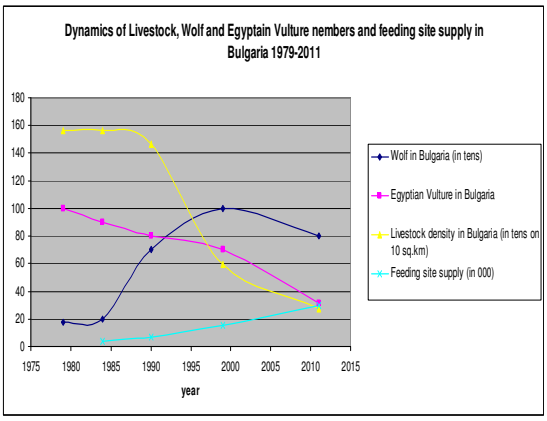


Figure 12b. *Dynamics of Livestock, Wolf and Egyptian Vulture numbers in Eastern Rodopi, Bulgaria 1979-2011*



In Bulgaria we see that the wolf population has increased from 1980-ies, the livestock number dropped down catastrophically (7 fold) after 1990 and the Griffon Vulture (Fig. 12a) however is constantly increasing, most probably based on permanent feeding sites operation in Eastern Rodopi which quantity supply increases in time and buffers the possible negative effects from food base decline and wolf increase. The Egyptian Vulture (Fig. 12b) is however in decline, may be because very small part of the population is outside the wolf range, while the feeding sites in Eastern Rodopi may serve to only part of the breeding pairs nuclei, but still enough to ensure their survival to date.

Figure 13a. *Dynamics of Livestock, Wolf and Griffon Vulture numbers in Greece 1979-2011*

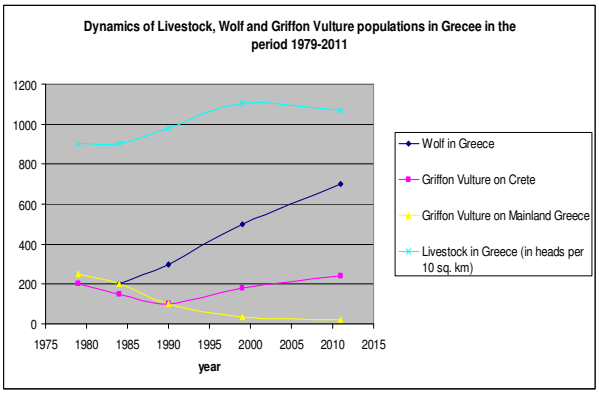
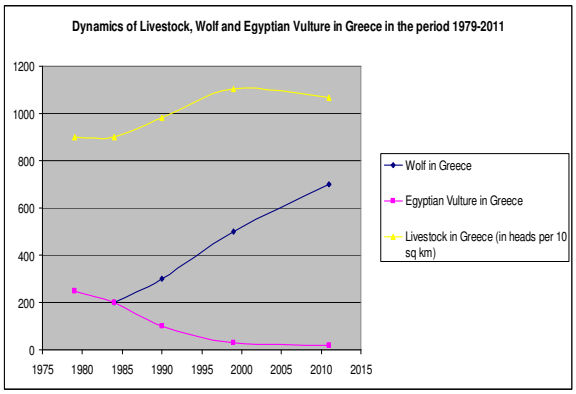


Figure 13b. *Dynamics of Livestock, Wolf and Egyptian Vulture numbers in Greece 1979-2011*



In Greece the food availability in the period was constant or even with slight increase after the country joined EU in the 1980-ies. However the Griffon Vulture (Fig. 13a) population and range contraction on mainland is in synchrony with the increase of the wolf. The population on Crete, in absence of wolf remained stable.

The Egyptian Vulture (Fig. 13b) also responded to wolf increase in the country and subsequent illegal use of poisoned baits and declined rapidly after 1990-ies and now is on the verge of extinction. Here too should be worth mentioning the Dadia Forest National Park, where the last compact nucleus of breeding pairs is found to date, based again on permanent vulture feeding site operation.

Figure 14a. *Dynamics of Livestock, Wolf and Griffon Vulture numbers in FYR of Macedonia1979-2014*

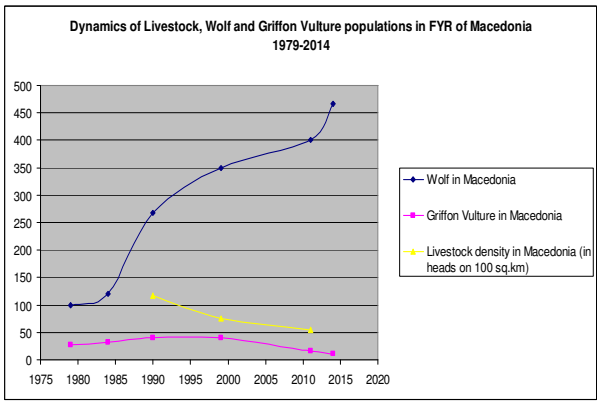
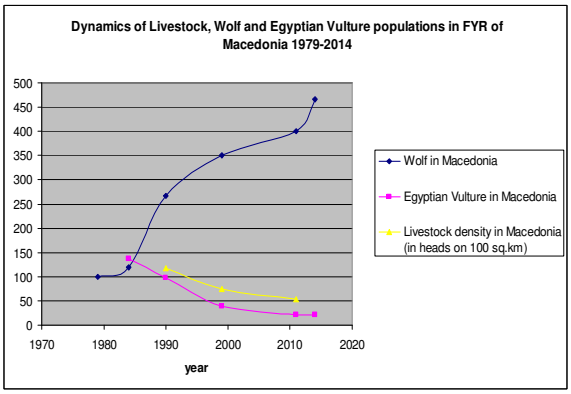


Figure 14b. *Dynamics of Livestock, Wolf and Egyptian Vulture numbers in FYR of Macedonia 1979-2014*



In FYR of Macedonia the livestock declined after 1990 (but still not that much as in Bulgaria), the wolf number increased in number and range, and the combination led to population decline of both Griffon and Egyptian Vultures. The reason that these species are not fully extirpated by poisoning, so far, could be found in sporadic feeding site operation in the core vulture area Tikvesh, but mainly in appearance of five rubbish dumps (Stip, Sveti Nikole, Veles, Negotino, Kavadartsi), where slaughter offal is disposed on permanent basis.

5. Discussion

In terms of worldwide distribution, the wolf reached its lowest point in the sixties. The recovery of the wolf occurred in the seventies as a result of a very much greater environmental awareness and the introduction of environmental conservation laws (Lopez 2001). The Wolf population has recovered in Europe and it is the second most abundant large carnivore species, with an estimated total number larger than 12,000 individuals. Most populations have been increasing or stable during recent years (Chapron et al. 2014). According to the same study the wolf population on Balkans increased up to 5 fold in number and range from 1970-ies to 2014.

In this period the last Bearded Vultures have extinct from the mainland Balkans and this has happened with the Griffon and Black Vultures from many places and the same process continues rapidly in last decades with the Egyptian Vulture (Grubac 1998, Hallman 2001, Xirouchakis & Tsiakiris 2005, Sakoulis 2001, Iankov 2007, Velevski et al. 2014).

The use of poison for Wolf control is a common local method used by shepherds to reduce

depredation events, but it can not be considered a major threat to the species itself (Iliopoulos 2000, Sakoulis 2001). But the extinction of vultures in Central Greece in 1990-ies is attributed to the re-establishment of Wolf packs and the related increased illegal use of poisoned baits. So, the anticipated result from the use of poisoned baits, that is the extermination of the Wolf, is not achieved, but the detrimental effects of their use on other wildlife species, such as vultures, become obvious only few years later (Sakoulis 2001).

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) (Andevski 2013).

Our results show that colonies of Griffon Vulture and Black Vulture and nuclei of breeding pairs of Bearded and Egyptian vultures survived only outside the wolf range on the Balkans. In areas of co-existence with wolf, certain species of vultures survived only, where intensive and continuous feeding site operation is in place or alternatively – slaughterhouses' dumpsites (the case in FYR of Macedonia).

Our study supports the concept of Sakoulis (2001), Xirouchakis & Tsiakiris (2009), that the wolf presence or reappearance, after some decades of absence, is a reason for poison baits use and this is the primary reason for vultures mortality in Bulgaria, Greece and FYR of Macedonia in the period 1995-2015.

The maps of recent distribution of wolf and vultures in Europe present an antagonistic distribution of vultures and wolf. Within the range of vultures in Southern Europe one could see that the vultures are absent were the wolf is present. The largest vultures' populations are flourishing or at least survived in modern Europe, where the wolf is absent (most of Spain, France, Portugal and some Mediterranean Islands – Mallorca, Corsica, Sardinia, Cres, Crete and Cyprus). The numbers of the large European vultures on Iberian Peninsula are 40 fold larger than on the Balkan Peninsula with almost equal size and geomorphologic and climatic characteristics. The number and range of wolf on the two peninsulas are 3 to 1 in favor to Balkans. This fact to larger extend may provide the answer why the vulture conservation is so successful on Iberian Peninsula and Southern France compared to the Balkans.

About 98% of the Griffon Vulture population in Europe is found in Spain, France and Portugal and about 95% of it is outside the wolf range on the continent. In Spain very small part of the Griffon Vulture population overlaps with wolf distribution and where it is so (Central North Spain), the wolf and Griffon Vulture populations both have a low density. It will be interesting to see further research on this topic with detailed spatial and temporal distribution of vultures and wolf on Iberian Peninsula. One may speculate that the colonies of Griffon Vulture and the nuclei of Egyptian Vultures in the area of their co-existence with wolf in Spain may be not stable and may serve as "population sinks". Their survival and relative stability for the last decades may be attributed to the supply with floaters from the other areas of the Peninsula that most probably serve as "population sources". Further research on this topic would be in important input.

On the Balkans the only healthy subpopulation of Griffon Vulture, which survived to date without special and intensive conservation action is found on Crete Island in Greece. Here lives about half of the Balkan population (240 pairs) in complete absence of wolf. Other large subpopulation (≈130 pairs) of Griffon Vulture on the Balkans is found on Croatian Cres and Krk Islands, again in absence of wolf. The others few remaining colonies on the Balkans, which fall partly or entirely within the wolf range (Serbia, Bulgaria, FYR of Macedonia, Evros in Greece) are under permanent and long-term conservation efforts (feeding sites, public awareness, education etc.) of State institutions and local NGOs. Only in FYR of Macedonia the conservation efforts are not so intensive. But there, slaughterhouse offal is deposed at open dumpsites, which are playing the role of vulture feeding sites. This is no longer possible in Greece and Bulgaria due to EU sanitary requirements. The future accession of FYR of Macedonia to EU may result in closing these slaughterhouse dumpsites and will negatively affect the remnant Griffon and mostly Egyptian Vulture population in the country.

The colonies of Griffon Vulture in Eastern Rodopi in Bulgaria (100% co-existence with wolf) and the reintroduced one in Massif Central in France (totally outside the wolf range), both starting with 2-4 pairs in 1983-1984 reached 65 pairs and over 340 pairs accordingly in 2012. Although the two colonies show long-term increase, the reasons for the lower success of the Bulgarian colony may be attributed to the several documented poisoning episodes targeting wolves (with up to 11 birds poisoned), and may be some more such remained unnoticed.

The comparison of Bulgaria, Greece and FYR of Macedonia in terms of livestock, wolves and Griffon Vulture population dynamics for the period 1970-2012, provides the following results: 1. the abundance of

livestock remains stable in Greece, dramatically decreases in Bulgaria and moderately decreases in FYROM. The wolf increases with the same intensity in the three countries. The Griffon Vulture declines in mainland Greece, keeps stable in Crete, and moderately declines in FYROM, while despite the dramatic decline of livestock in Bulgaria the species follows a constant increase. These facts are attributed to wolf reappearance in the three countries, which leads to poison baits use and vultures decline. On Crete because of the lack of wolves the Griffon Vultures keeps stable, while in Bulgaria the problem of poisoning is buffered by feeding sites operation.

The Eurasian Black Vulture is probably very much affected by Man-Wolf conflict in Europe, because it is a species in close relationship with the wolf (Michev 1985). It readily feeds on wolves prey's leftovers – a fact hardly noticed and reported in Spain, because the two species are not found together for the last few decades. The principle cause for the Black Vulture being more affected by poison, in comparison with other more abundant species and which are being poisoned to the same extent is their alimentary habits. The Black Vulture specializes in feeding on medium and small carrion so that it is exposed to consuming foxes, cats, badgers and all kinds of carrion of predator, which are precisely those targeted by poisoned bait (Sanchez 2001). This to larger extent is valid for wolf kills and related poison baits use consequences, also because the Black Vulture readily lands to feed in open forest habitats, where the wolf preys are found, especially if the wolf is still around (authors own obs.).

Healthy populations of *A. monachus* 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 former two areas - successfully reintroduced). The Black 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 operation and 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 keep the colony alive. Each group of birds that does attempt to disperse outside this area is most probably getting poisoned (D. Vasilakis – pers. comm.).

The Bearded Vulture is very much related to wolf kills leftovers as this way it has an access to the preferred food – bones of medium sized mammals. Probably because of the same reason as mentioned above (for Black Vulture) the species is almost extirpated from Europe, during the mass poisoning campaigns against predators in 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 at 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 is successfully restored in Alps (in absence and current reappearance but still in low numbers and density of wolf). The last few remnant birds 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 *G. barbatus* in Andalucía were reported by Vulture Conservation Foundation. It is worth mentioning that the region is now free of wolves – less than 10 animals in Sierra Morena (Kazciensky 2013). In the same time an attempt for reintroduction of Bearded Vulture in the "Picos the Europa" National Park, Asturias, failed due to permanent man/wolf conflict and consequent poison baits use.

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 1970-ies, when the wolf was almost extirpated. Probably the poisoning that generally took place in the winter months did not affected the Egyptian Vulture, because as a migrant species it is in this season in Africa. However *N. percnopterus* is now declining rapidly in most of its range. Again this species is doing nowadays better in areas outside the wolf range. The only surviving pairs within the wolf range on the Balkans are found in Eastern Rodopi shared between Bulgaria and Greece (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 few pairs survives as well as a small population in Albania (Velevski *et al*. 2014) both outside the wolf range.

The comparison of Bulgaria, Greece and FYR of Macedonia in terms of livestock, wolves and Egyptian Vulture population dynamics for the period 1970-2012, provides the following results: 1. the abundance of livestock remains stable in Greece, dramatically decreases in Bulgaria and moderately decreases in FYROM. The wolf increases with the same intensity in the three countries. The Egyptian Vulture declines in Greece,

FYROM and Bulgaria with the same intensity despite the huge difference in livestock availability. These facts are attributed to wolf reappearance in the three countries, which leads to poison baits use and related vultures decline. The decline is slower in some nuclei, which are outside the wolf range and where feeding sites operate (Eastern Rodopi in Bulgaria and Greece). With the case of FYROM the open access slaughterhouses dumpsites are buffering the poison baits use, and compared to Bulgaria and Greece the situation seems to be better, because the permanent sources of predictable food are evenly distributed to larger area.

Wolf and Vultures Co-existence

Advantages

A. Wolf kills are important for vultures, because they are frequently available even in areas with lower livestock/wild ungulates density, which otherwise should be bigger to support vulture colony through only non-predation mortality. In equal other circumstances, the vultures prefer wolf kills instead of any other carcass (authors pers. obs.).

B. Wolf kills are attractive food source for vultures, because they are fresh, opened, and usually found away from people.

C. Wolf chew and break bones at carcasses thus providing small fragments to the benefit of vultures to ingest calcium.

D. Wolf and vultures found in same areas increase their conservation value.

E. Wolf and vultures sympatric presence in an area is a prerequisite for more interesting eco-tourist product.

Disadvantages

F. The wolf conflicts with livestock and game owners are a common reason for poison baits use as revenge from the affected entities. Our study shows that about 84% of the vultures poisoned in Bulgaria, Greece and FYROM died from poison targeting wolves, which were most frequently set up in wolf kills leftovers (usually medium to large ungulates). Also our observations show that wolf kills were always preferred by any other carcass available for the vultures in same other circumstances. Thus the poisoning of vultures in wolf areas is more frequent, compared to areas without wolfs and thus without conflict.

G. The wolf presence in certain area leads to lower livestock density, because of depredation prevention and loss minimization actions (e.g. increased need of labor as herdsmen, keeping of smaller herds to be better guarded, raising of guarding dogs, which compete with the vultures for food, etc.) (Stoynov *et al*. 2014), which leads to less food available for vultures.

Priorities in conservation

In Southern Europe, wolf extermination was not as complete as in Northern Europe, due to greater cultural tolerance of the species. Wolf populations only began declining in the Iberian Peninsula in the early 19th-century, and was reduced by a half of its original size by 1900. Wolf bounties were regularly paid in Italy as late as 1950. Wolves were exterminated in the Alps by 1800, and numbered only 100 by 1973, inhabiting only 3–5% of their former Italian range (Mech and Boitani 2004). Nowadays the wolf is the second most abundant large carnivore species in Europe with about 12 000 individuals and expanding population and range (Chapron *et al*. 2014).

The majority of the specialists propose managing the wolf by a zoning designed to reduce conflicts with human activities. But the rejection of hunting and controlling the wolf by one section of society and the appearance of extremely radical groups may make its legal management difficult and encourage illegal alternatives (Lopez, 2001).

The wolf is a sympathetic animal for most of the nature lovers and general public living in cities or outside of the wolf range, but it is hated from the people that encounter permanent interactions with it – livestock breeders, game managers, etc. Conservation actions targeting wolves, based on increased legal protection will generally be accepted negatively from the former groups and could lead to increase of poison use to control the predator. Conservation of vultures is a matter of man-wolf conflict management or buffering the impact of poison use through complex of measures as vultures feeding sites maintenance, compensation and prevention schemes. Priorities in conservation of threatened species should be set up and any relationship between different conservation dependent groups taken in mind. Precise planning of different species populations' conservation is thus necessary.

If the wolf population in Southern and Mediterranean Europe is getting restored and continues to expand, without taking away the conflict, this could lead to the extinction of the vultures. On the Iberian Peninsula almost all vultures and other scavenger birds (Iberian Imperial Eagle *Aquila adalberti*, Red Kite

Milvus milvus, Black Kite *Milvus migrans*) live outside wolf territories. On the Balkans the survival of the last vultures is the result of permanent and long-lasting conservation efforts. Conservation measures for the wolf, like the ban of wolf hunting, would be accepted negatively from all people who are in conflict with the wolf. If the only legal measure to persecute the wolf will be banned, the risk on the use of illegal measures, like poison baits, will increase with a dramatic ending for the vultures.

6. Conclusions

Finally, we can conclude that to protect the vultures within the wolf range in Europe, a complex of legislation adaptation and conservation actions are needed. Some of the most important are the following:

- Any future wolf conservation and management planning should take in mind the vultures' poisoning issue.
- Implementation of a complex of measures targeting the man-wolf conflict on the Balkans- 1. Restocking and reintroductions of wild ungulates (Fallow deer, Red Deer, Chamois, Alpine Ibex etc.) as an alternative food base for wolves and/or vultures; 2. Adaptation of the livestock management practices as improving the night corrals, shifting from sheep and goats to cattle (Stoynov et al. 2014), introduction of fenced ranches; 3. Massive introduction of the livestock insurance;
- Feeding sites for vultures should be considered 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.
- Creation of source populations of vultures outside (but not far away) the wolf range could support remnant populations within the wolf range.
- Reintroductions of vultures within the wolf range have lower probability of success, unless intensive and permanent feeding site(s) operation is secured to buffer expected poisoning episodes' impact.
- The vultures' populations are probably overestimated in Southwestern and Central Asia, having in mind the wolf presence and related poison issues there.
- Intensifying the monitoring of wolf population on Iberian Peninsula and prevention of expanding its range, which will be a great threat for the European and (for some species) Global stronghold of vultures.
- Providing of precise research, site by site on the relationship of wolf and vultures is necessary to increase knowledge and direct measures for successful conservation especially in areas of co-existence.

7. Acknowledgements

We are grateful to Rufford Small Grants, Whitley Fund for Nature, Bioparc Zoo de Doue, Friends of Vienna Zoo, Black Vulture Conservation Foundation, Frankfurt Zoological Society, DBU, EAZA and "Life for Kresna Gorge" project supported by LIFE+ financial instrument of EU for the financial support of the Compensation programme for livestock depredation of Fund for Wild Flora and Fauna for the period 2003 – 2015, in which most of the data was collected.

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ANNEXES

Figure 2. Griffon Vulture and 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

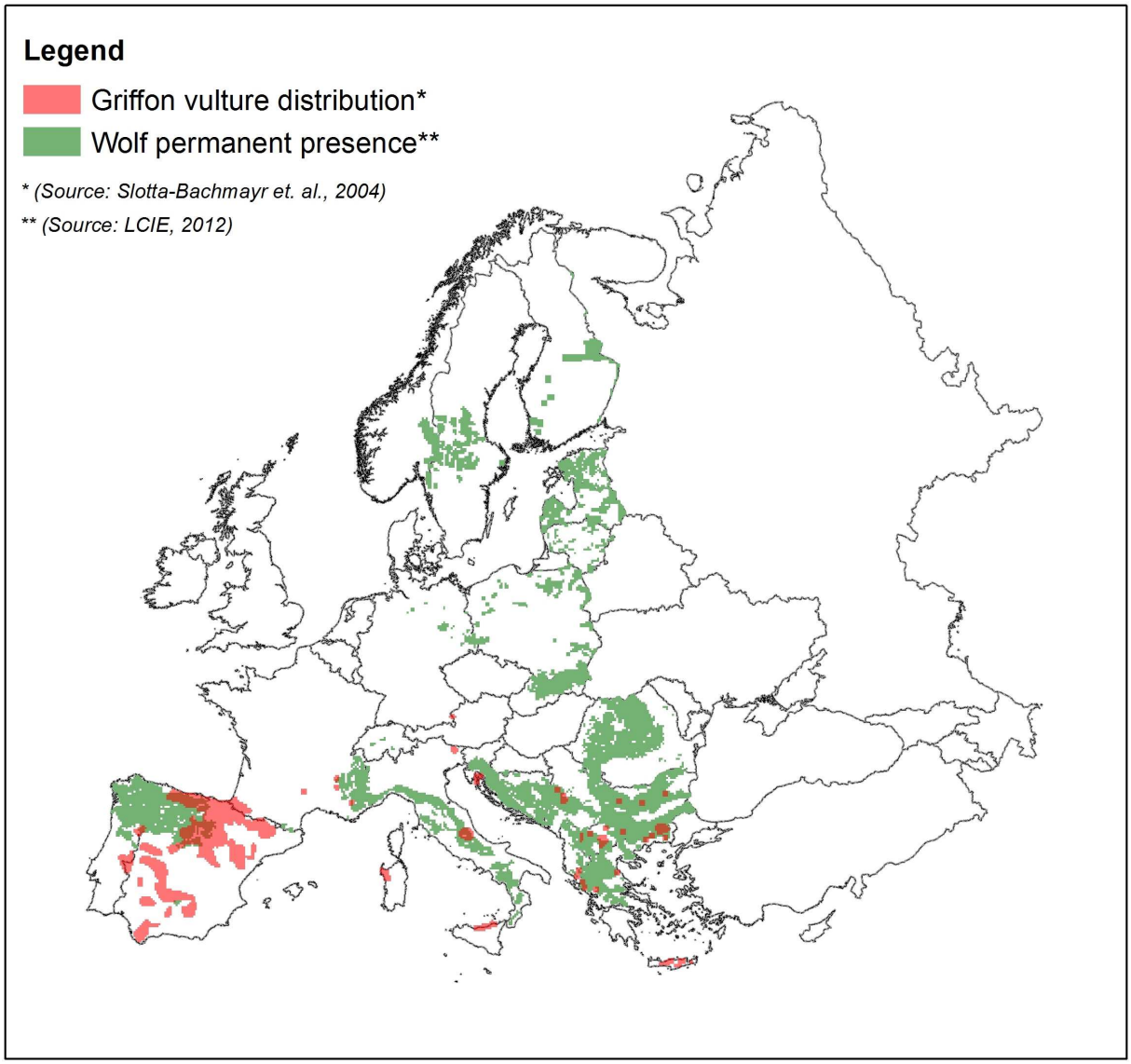

Table 2. Number of 10x10 km EEA cells occupied by breeding G.fulvus, Number of 10X10 km EEA cells without wolf presence within the G.fulvus breeding range and number of 10X10 km EEA cells with sympatric presence of C. lupus and G. fulvus in Europe

Country	Number of 10x10 km EEA cells with sympatric presence of wolf and *G. fulvus*	Number of 10x10 km EEA cells with no wolf presence within the *G. fulvus* breeding range in Europe	Number of 10x10 km EEA cells occupied by breeding *G.fulvus* in Europe
Austria	0	25	25
Bulgaria	93	1	94
Croatia	0	30	30
Cyprus	0	25	25
France	0	191	191
Greece	40	60	100
Crete and Naxos	0	90	90
Italy	38	37	75
Sicily	0	25	25
Sardinia	0	25	25
FYR of Macedonia	31	25	56
Portugal	11	689	700
Serbia	32	14	46
Spain	220	1580	1800
TOTAL	**465**	**2817**	**3282**

Figure 4. Eurasian Black Vulture and Wolf distribution in Europe – the wolf range is compiled by Guillaume Chapron (Kaczensky et al., 2013), the Black Vulture range is according to BirdLife International 2013.

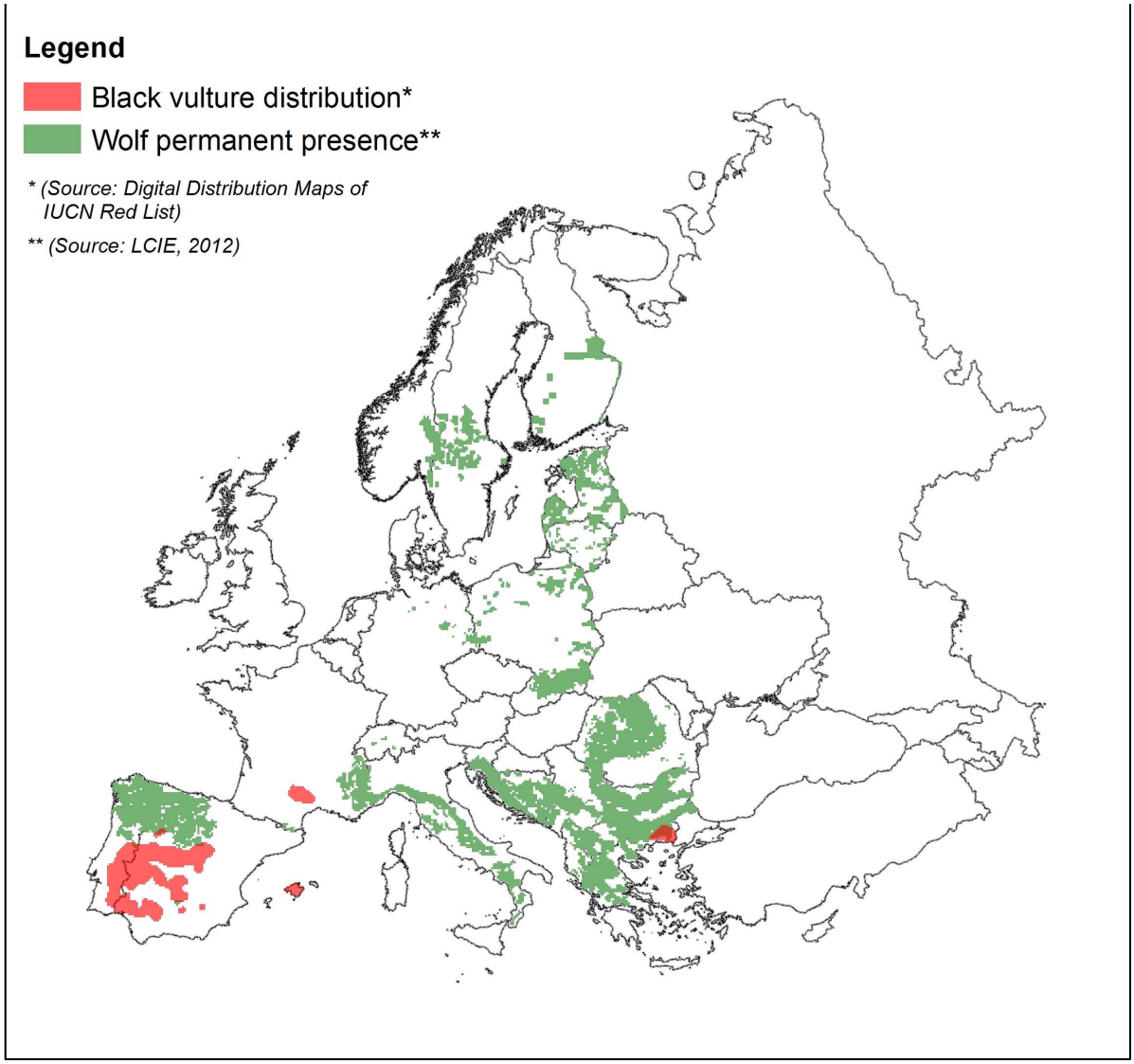

Table 3. Number of 10x10 km EEA cells occupied by breeding A. monachus, number of 10X10 km EEA cells without wolf presence within the A. monachus breeding range and number of 10X10 km EEA cells with sympatric presence of C. lupus and A. monachus in Europe

Country	Number of 10x10 km EEA cells with sympatric presence of *A. monachus* and *C. lupus* in Europe	Number of 10x10 km EEA cells with no wolf presence within the Black Vulture breeding range in Europe	Number of 10x10 km EEA cells occupied by breeding Black Vultures in Europe
Bulgaria	23	1	24
France	0	30	30
Greece	28	1	29
Portugal	0	25	25
Spain	0	537	537
Baleraes	0	25	25
TOTAL	**51**	**619**	**670**

Figure 6. Bearded Vulture and Wolf distribution in Europe – the wolf range is compiled by Guillaume Chapron (Kaczensky et al., 2013), the Bearded Vulture range is according to BirdLife International 2014.

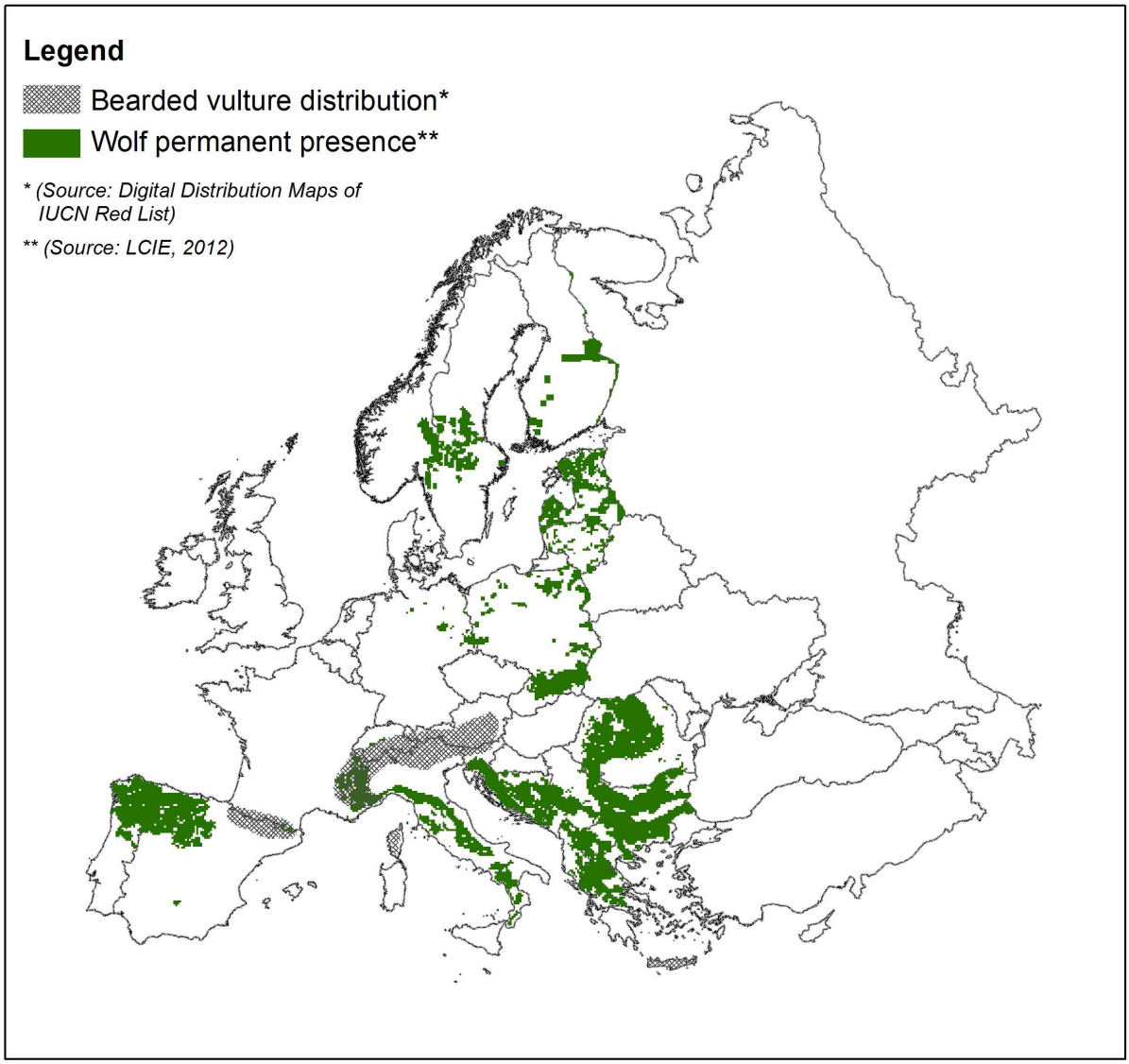

Table 4. Number of 10x10 km EEA cells occupied by breeding G. barbatus, number of 10X10 km EEA cells without C. lupus presence within the G. barbatus breeding range and number of 10X10 km EEA cells with sympatric presence of C. lupus and G. barbatus in Europe

Country	Number of 10x10 km EEA cells with sympatric presence of *C. lupus* and *G. barbatus*	Number of 10x10 km EEA cells free of *C. lupus* within the breeding range of *G. barbatus*	Number of 10x10 EEA cells with breeding Bearded Vultures
Austria	0	27	27
France	10	305	315
Corsica	0	45	45
Greece (Crete)	0	54	54
Italy	16	65	81
Spain	0	729	729
Switzerland	0	90	90
TOTAL	**26**	**1315**	**1341**

Figure 8. Egyptian Vulture and Wolf distribution in Europe – the wolf range is compiled by Guillaume Chapron (Kaczensky et al., 2013), the Egyptian Vulture range is according to Velevski et al. 2014, Del Moral 2009, Andreoti & Leonardi 2009, LPO 2012

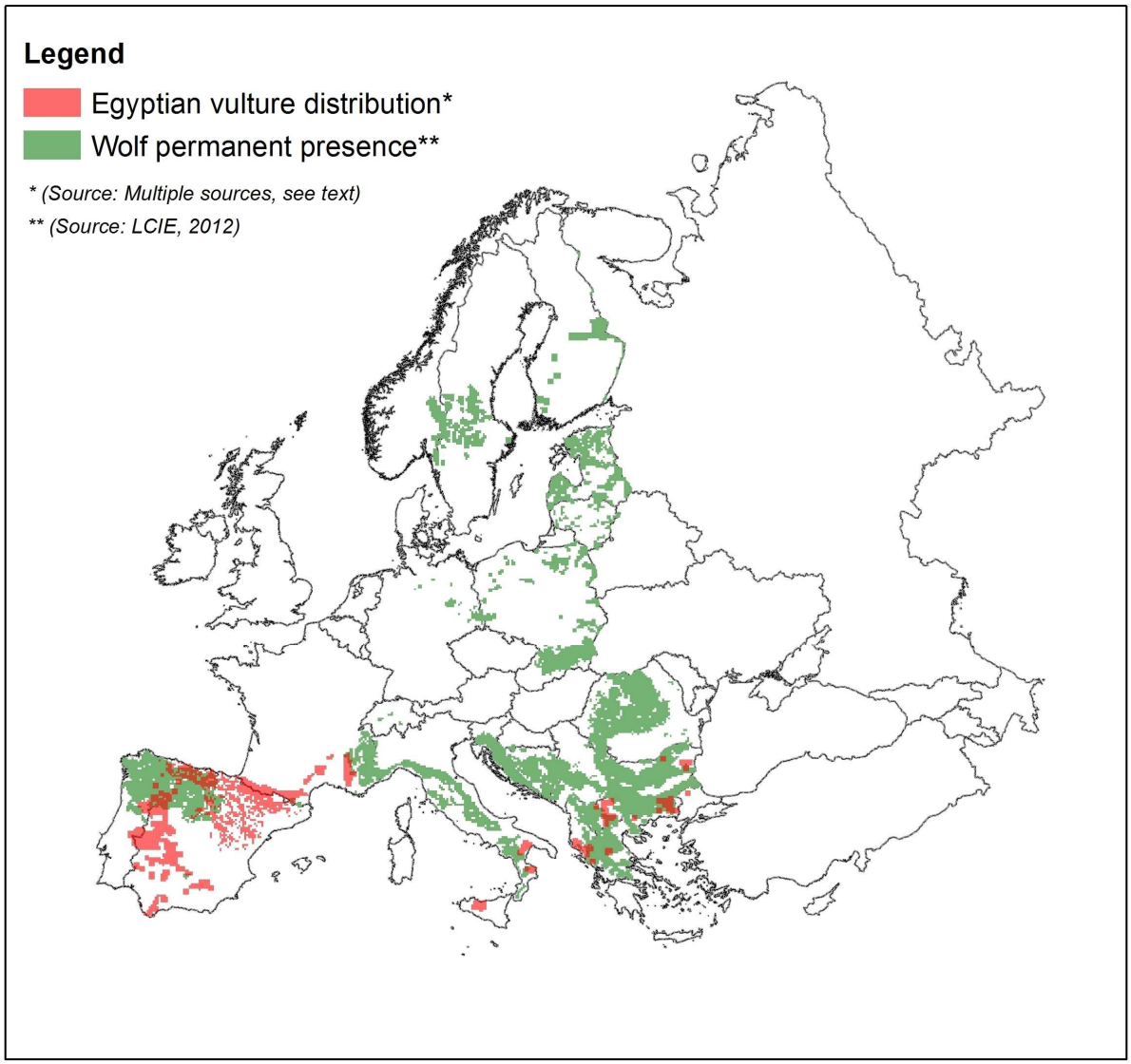

Table 5. Number of 10x10 km EEA cells occupied by breeding N. percnopterus, number of 10X10 km EEA cells without C. lupus presence within the N. percnopterus breeding range and number of 10X10 km EEA cells with sympatric presence of C. lupus and N.percnopterus in Europe

Country	Number of 10x10 km EEA cells with sympatric presence of *N. percnopterus* and *C. lupus* in Europe	Number of 10x10 km EEA cells with no wolf presence within the Egyptian Vulture breeding range in Europe	Number of 10x10 km EEA cells occupied by breeding Egyptian Vultures in Europe
Albania	12	24	36
Bulgaria	48	50	98
France	0	675	675
Greece	40	50	90
Italy	0	30	30
FYR of Macedonia	25	30	55
Portugal	11	109	120
Spain	196	754	950
Baleraes	0	13	13
Canaries	0	20	20
TOTAL	**332**	**1755**	**2087**