Research Article

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Habitat Viability and Threats Assessment for the Reintroduction of the Bearded Vulture *Gypaetus barbatus* (L., 1758) (Accipitridae) in Bulgaria

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Abstract: The availability of areas for reintroducing the bearded vulture in Bulgaria *Gypaetus barbatus* was assessed. There were eight historical and potential breeding sites in the country that were chosen for the assessment. Each of them was compared to the other seven as well as to already occupied territories within other countries. The information was gathered at 15 km radius around high-probability nesting cliffs. Nineteen selected variables that have an essential impact on the choice of breeding sites were analysed (food availability, variability of the environment, presence of other vulture species, poisoning threats, etc.). Viability matrix on habitat quality and threats was produced and a scoring system was introduced in order to rank each of the selected areas and their potential for a reintroduction of the Bearded Vulture. Density of power lines, poisoning of wildlife and specific types of habitat quality parameters were determined as the most restrictive variables. Two protected areas – Rila National Park and Central Balkan National Park – were proposed as the best sites for reintroduction of the bearded vulture. Western Balkan Mountain and Eastern Rhodopes were also identified as suitable areas, although they had relatively lower scores. The obtained results showed that the process of reintroduction of the bearded vulture in Bulgaria could be started *immediately in the selected protected areas*. However, an implementation of additional specific management interventions is important as it would allow for further risks prevention and habitat enhancement.

Key words: *Gypaetus barbatus*, habitat assessment, reintroduction, Rila National Park, Central Balkan National Park.

Introduction

The bearded vulture *Gypaetus barbatus* (L., 1758) was a common species in Bulgaria and until the beginning of the 20th Century it was still broadly distributed, especially in the Balkan Mts. (Boetticher 1927, Simeonov 1962). However, by the end of 1950s, it has become extinct in Bulgaria. Since then, there have been rare sightings in the Eastern Rhodopes Mts. and South-western Bulgaria (Stoynov 2007) but breeding birds have not been found (Boev 2015). The European population of bearded vulture has suffered a dramatic decline that led to the complete extinction as nesting species not only from the Balkans but also from Alps, Carpathians, Cyprus and Sicily (Heredia & Heredia 1997). Despite the variety of applied conservation measures and reintroduction programs, the current population of the species tends to decrease and now it is estimated at only 1300-6700 sexually mature individuals (BirdLife International 2015).

Nowadays, the bearded vulture is a protected species listed in Annexes 2 and 3 of the Bulgarian Biodiversity Act. This species is considered as *Near*

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Threatened in the Global IUCN Red List (BirdLife International 2017) and it was included in Annex II of the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) and the Convention on International Trade in Endangered Species (CITES).

The bearded vulture, as a scavenger feeding on small carrion, is one of the most susceptible species to various types of poison baits (Brown 1991). The main cause for the population decline in Bulgaria was the use of poison baits against terrestrial predators (Botev & Peshev 1985, Stoynov 2007), similarly to the situation in other European territories such as the Pyrenees (Antor 1999, Hernandez 2003) and Greece (Xirouchakis et al. 2001). Poisoning has an increased impact on the remained populations in the whole species geographical range while most of other factors related to human activities such as habitat loss, direct persecution and reproductive failure related to human disturbance seem not to have significant impact anymore (Heredia & Heredia 1991).

It could be considered that some of the main prerequisites for an effective reintroduction of the bearded vulture in Bulgaria already exist: (1) the increase of the autochthonous griffon vulture (*Gyps fulvus*) population in Eastern Rhodopes (Demerdzhiev et al. 2014); (2) the successful reintroduction of the griffon vulture in some of the species' historical sites in Bulgaria (Stoev et al. 2016, Stoyanov et al. 2016, Stoynov et al. 2016); (3) the gained experience in the reintroduction of other vulture species; and (4) generally improved environment for vultures that includes better acceptance by the society, new legislation protection of the historical breeding sites and decreased impact of some of the crucial threatening factors from the past (Heredia & Heredia 1991, Hernandez 2003).

The present study evaluates the opportunities for reintroduction of the bearded vulture in Bulgaria in relation to trophic and spatial capacity, habitat quality and threats in eight potential release areas (Western Balkan, Central Balkan, Eastern Balkan, Pirin, Rila, Eastern Rhodopes and Kraishte). Reasons for the selection of particular site and conservation measures are also discussed.

Materials and Methods

Selection of Areas

Eight historical and potential breeding sites in the country were chosen for the assessment: Western Balkan, Central Balkan, Eastern Balkan, Pirin, Rila,

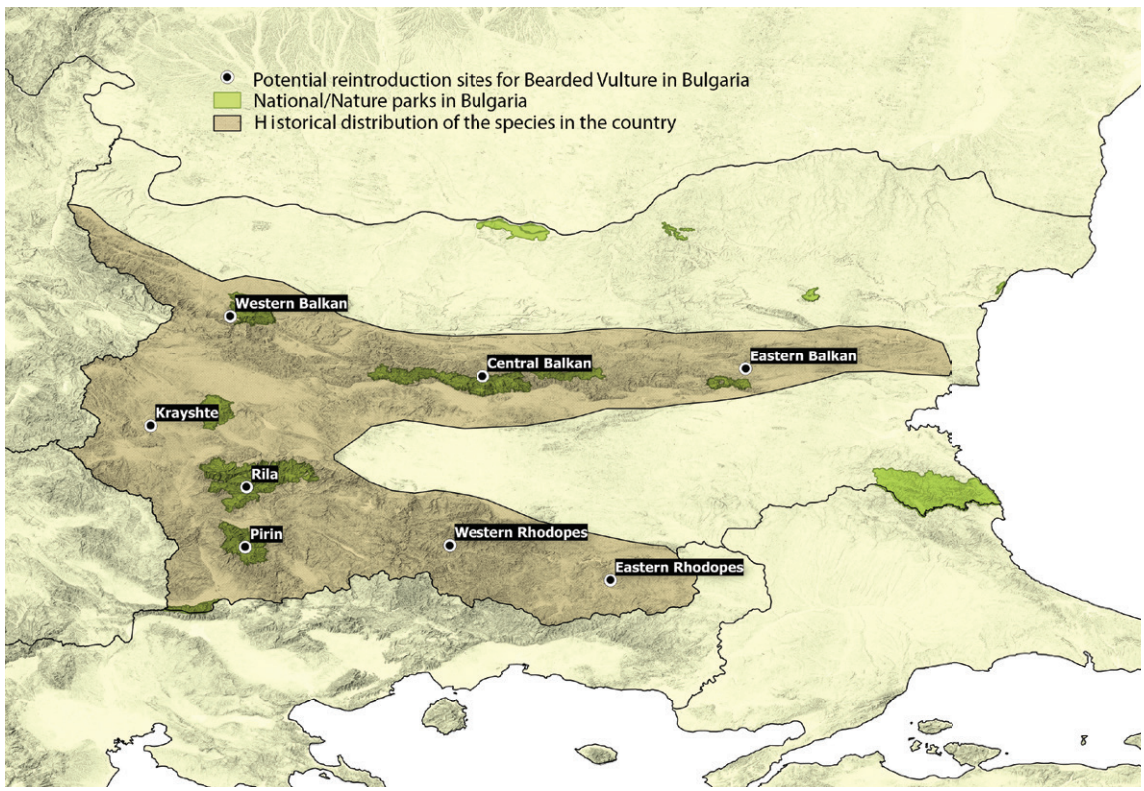

Fig. 1. Map of the eight selected potential release sites (PRS) included in habitat viability and threat assessment of bearded vulture (*Gypaetus barbatus*) and historical distribution of the species in Bulgaria.

Table 1. Environmental variables applied for the assessment of viability for selecting potential release sites (PRS) suitable for reintroduction of bearded vulture in Bulgaria.

VARIABLES INCLUDED IN THE VIABILITY MATRIX
Threats
Poison. Number of reported poisoning cases /1,000 ha of the PRS including 10 km buffer around the PRS for the last 10 years based on the data from Fund for Wild Flora and Fauna (FWFF) database. This value is converted by a 3x factor since poisoning is the main cause of mortality for vultures. **Power lines**. Density of power lines in the PRS. This is measured as the length of power lines in the entire PRS (m)/extension of the PRS (ha).The value is converted by a 2x factor since this is the second highest cause of mortality for vultures in Bulgaria. **Lead poisoning**. The impact on vultures from this threat is not studied but based on the knowledge from the Alps it is also considered here. The values are calculated as (0) in sites, where hunting is forbidden and (1) where hunting is allowed. Areas where the livestock is likely to be the main food source and where campaign for ban of lead ammunition is on are given with asterisk (*) and they would be reassessed if the final score would depend entirely on this factor. **Cable cars**. Presence of cable cars in and in close proximity of the PRS. The values are presented as (1) if there are cable cars and (0) if absent. **Paved roads**. Density of paved roads inside the PRS, as length of paved roads of the PRS (m)/extension of the PRS (ha). **Unpaved roads**. Density of unpaved roads inside the PRS, as length of unpaved roads of the PRS (m)/extension of the PRS (ha). **Population**. Population density as the number of inhabitants by municipality belonging to the PRS/extension of the PRS (ha). **Outdoor activities**. Number of outdoor activities in each PRS. For example: climbing, biking, trekking, paragliding, hunting, skiing, etc.
Habitat quality
Spatial capacity. Number of potential breeding pairs calculated for each PRS. **Trophic capacity**. Number of potential breeding pairs based on food availability. **Open habitats**. Amount of open habitats in 15 km radius of suitable cliffs. **Cliffs**. Percentage of the PRS with cliffs selected by the model. **Coherence**. The compactness of the suitable habitat, that a viable breeding group (6-9 breeding pairs) may be established at the minimum neighbour distance of 9 km. The best ranked territories receive 2 points, medium ones 1 and the poorest 0. **Villages**. Absence (1), or presence (0) of villages inside the PRS. **Griffon Vulture**. Presence (1), or absence (0) of foraging Griffon Vultures. The best breeding habitats for the Bearded Vulture are not used for breeding by Griffon Vultures. **Egyptian Vulture**. Presence of breeding pairs in the PRS (1), absence (0). **Protected surface**. This variable indicates the extension of protected area that could be used by the Bearded Vulture as foraging area. **Protection**. Degree of protection: only small protected areas, and NATURA 2000 zones (0,5); larger Nature Park and NATURA 2000 zones (1); large National Park and related protected areas and NATURA 2000 zones (2). **Education**. Environmental education about the wildlife and vultures. We evaluated the degree of the viability of the PRS based on the long-term education and/or vulture conservation work in the area (e.g. feeding sites operation, bird watching, reintroduction and the like) – none: (0), some or occasional (1), intensive and long-term (2).

Eastern Rhodopes and Kraishte (Fig. 1). The potential release sites were chosen, based on historical data for the presence of the species (Boev 2015, Stoynov 2007) and by expert assessment of the habitat – topographic irregularity, aptitude, open cliffs, open alpine areas, coherence and spatial capacity. The last was calculated on the basis of the potential area covering 300 km² for a breeding pair. We selected 15-km-radius zones around the high-probability nesting cliffs to analyze the current food base and threats as proposed by Padial et al. (2005).

Selection of Variables for Viability Matrix

Totally, 19 environmental factors – eight types of threats and eleven habitat quality variables – were included in the viability matrix (Table 1). They were chosen on the basis of their importance for the reintroduction of stable population of bearded vulture (Padial et al. 2005).

Loading Capacity

The livestock (ovine, caprine, bovine and equine) census information was gathered from all municipalities belonging to the selected potential release sites (PRS). The numbers of livestock correspond to the year 2016. The data about livestock (Table 2) was provided by Agriculture and Livestock Local Offices from each municipality. Data about wild ungulates was provided by the national parks, nature parks and forestry service administrations.

The trophic loading capacity was calculated using the following equation: Trophic capacity (pairs) = ((n+N)*2/100)*7*20/100/350, where "n" is the number of livestock and "N" is the number of wild ungulates. The applied formula was based on the following criteria: (1) the bearded vulture can consume up to 7 kg from each medium-sized ungulate carcass (Clouet 1984, Canut at al 1987); (2) the annual requirements of a breeding pair are 350 kg (Hiraldo

et al. 1979); (3) we assumed a livestock mortality rate of 2%; (4) we considered that only 20% of the available biomass will be accessible for the bearded vulture (Margalida et al. 2007).

The spatial capacity was evaluated using the information related to the distribution of the most suitable cliffs and the mean distance between breeding pairs, estimated to be at least 9 km (Donazar et al. 1993, Gavashelishvili & McGrady 2006) in the elevation range of 700–2310 metres (Gavashelishvili & McGrady 2006).

Environmental Viability Matrix

The crucial factors influencing the distribution, productivity, mortality and conservation of the bearded vulture are already known (Donázar et al. 1993, Báguena et al. 2004, Hirzel et al. 2004, Padial et al. 2005) and they were applied in the environmental viability matrix (Table 3). The comparison of the selected eight PRS was done after transformation of the original values of the included variables to 0 and 1. Some of the variables were weighted two or three times in relation to their implication to the mortality and conservation of the species. Threat index is equal to the sum of threats and receives only negative values. The habitat quality index represents the sum of all variables positively affecting the survival of the bearded vulture and it always has a positive value. The viability index is the difference between the "Habitat quality" index and "Threat" index.

Results

Among the studied PRS, Central Balkan Mts. and Rila Mts. showed the highest values for habitat quality index and the lowest values for threat index (Table 3). These two PRS received equal viability index (9.2) that was significantly higher than viability index of the other six potential areas. The lowest threat index is due to the absence of some of the main threat factors such as lead poisoning, paved and unpaved roads. Although these two areas do not have extremely high spatial capacity and the best trophic capacity, they have a relatively high value of habitat quality because the existence of more open habitats, better coherence and a much higher degree of protection (Table 2).

Eastern Rhodopes and Western Balkan Mts. are the second group of important areas with suitable conditions and relatively high viability index (5.4). The habitat quality of Eastern Rhodopes is similar to that of the previous two PRS but the threat index had significantly higher absolute values (-8.1) due to the high density of power lines, lead poisoning and the presence of paved and unpaved roads (Table 3).

Pirin, Eastern Balkan Mts. and Western Rhodopes Mts. could be considered as the next group of PRS that had lower viability index in comparison to the previous four areas. In all these three cases, the observed threat index was almost equal to the habitat quality index and the viability index was close to zero. Pirin Mts. could be distinguished from the other two areas in this group by the highest risk of vulture poisoning events.

Kraishte had the lowest viability index (-8.4) that was due to the extremely high threat index, low spatial and trophic capacity and the absence of coherence and other vulture species (Tables 2 and 3).

Discussion

The food preferences of the bearded vulture in the Pyrenees were well studied and it was found that the essential part of the food came from carcasses of sheep and goats (Heredia & Margalida 2001). This assumption is not fully applicable in the viability matrix for the Bulgarian territories and could lead to incorrect conclusions because although the numbers of sheep and goats exceed those of cattle and horses several times, the biomass of the latter type of food is significantly higher. For this reason, the number and biomass of cattle and horses were also included in the calculation of the trophic capacity. This additional food source for bearded vulture should not be underestimated because cattle and horses are bred free-ranging in alpine pastures in Bulgaria during the summer (cattle and horses) and year-round (horses), and their carcasses will be frequently and easy available. In addition, it has to be noted that the trophic diversity probably is considerably higher than has been herein assumed because the exclusion of many food sources such as juveniles, wild boar, roe deer and red deer; wolf kills and hunting offal remains that could be an important part of vultures meal (Margalida & Bertran 2000, Margalida et al. 2003).

The highest trophic capacity was observed in the Eastern Balkan Mts. but it did not correspond to the spatial capacity of this region, which was relatively low (Table 2). Actually, as a rule, the trophic capacity of the environment was considerably higher than the spatial capacity of the environment in all PRS.

Although all PRS included in our study have a relatively good potential to host breeding pairs of bearded vulture in the future, having in mind the limited availability of birds for release, the effective selection based on objective criteria was an essential

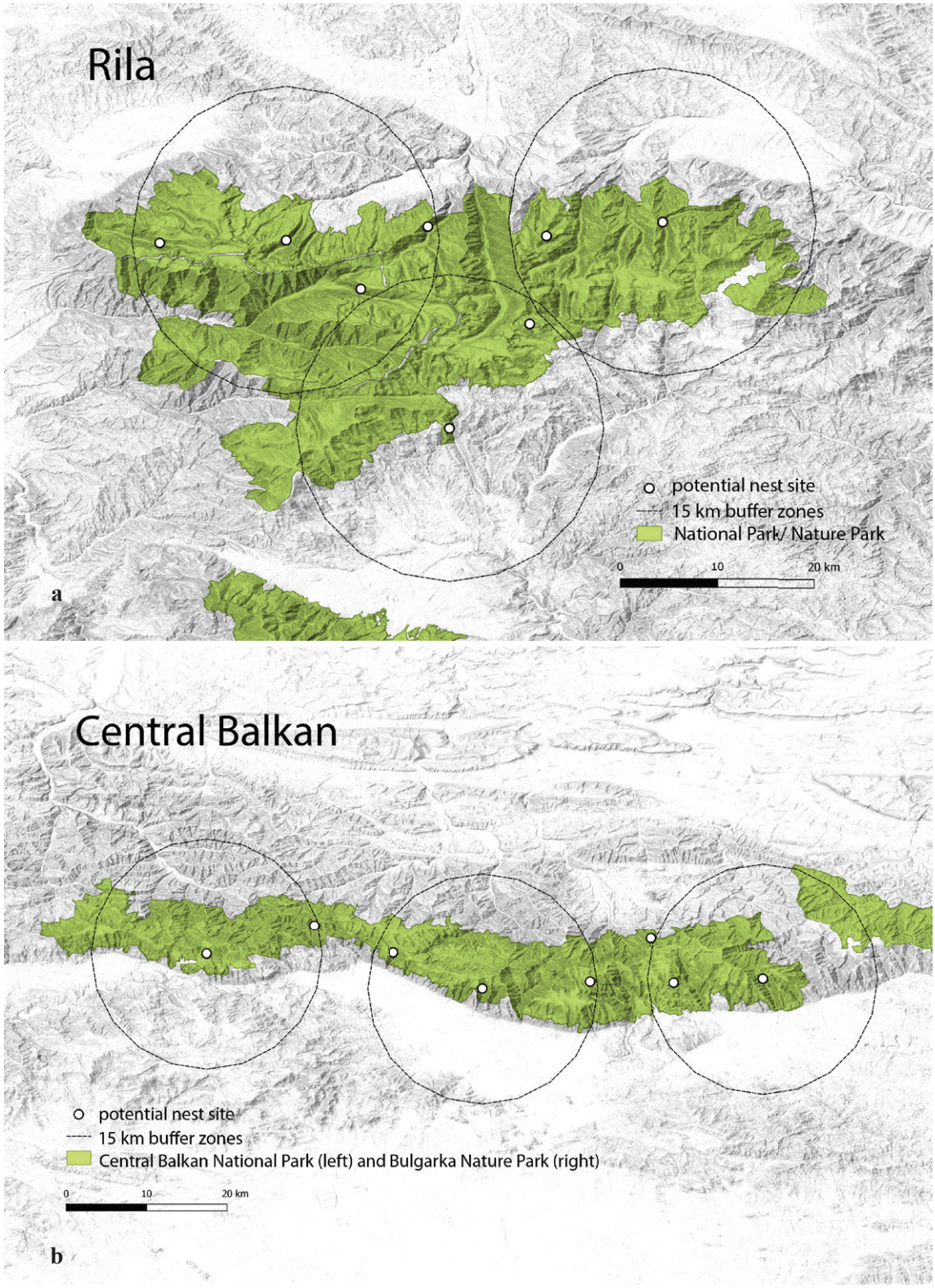

Fig. 2. Potential bearded vulture nesting sites and 15-km buffer zones in (**a**) Rila National Park and (**b**) Central Balkan National Park.

step in the preparation of the reintroduction program. The analysis of the obtained results showed that PRS in the Central Balkan Mts. and Rila Mts. were the most suitable areas for the intended purpose (Table 3, Fig. 2). Some of the main positive features of these two territories are the absence of paved and unpaved roads. Other studies indicated that bearded vulture avoid areas where road network density is high (Gavashelishvili & McGrady 2006). Road density is directly linked to the regional development

Table 2. Livestock census (year 2016), annual mortality rate, wildlife number (chamois and fallow deer), annual mortality of wildlife, available biomass, trophic and spatial capacity. Abbreviations: WBalk: Westren Balkan Mountains; EBalk: Eastern Balkan Mountains; CBalk: Central Balkan National Park; Rila: Rila National Park and Rilski Manastir Nature Park; Pirin: Pirin National Park and Kresna Gorge; WRhod: Western Rhodopes; ERhod: Eastern Rhodopes; Krai: Kraishte.

PRS	Livestock type	Livestock (n)	Livestock (kg)	Wild ugulates (N)	Wild ungulates (kg)	Biomass (kg)	Trophic capacity (pairs)	Spatial capacity (pairs)
WBalk	Ovine/caprine	49264	9810	100	70	9880	5,65	5
	Bovine	13718						
	Equine	7093						
EBalk	Ovine/caprine	146985	18496	0	0	18496	24.58	4
	Bovine	38897						
	Equine	12318						
CBalk	Ovine/caprine	107752	16578	200	140	16718	12.09	5
	Bovine	31925						
	Equine	11234						
Rila	Ovine/caprine	109129	11998	700	490	12488	12.27	5
	Bovine	31513						
	Equine	12100						
Pirin	Ovine/caprine	96650	16257	500	350	16757	10.73	3
	Bovine	25000						
	Equine	12037						
WRhod	Ovine/caprine	64470	13300	1500	1050	1435	8,20	5
	Bovine	21554						
	Equine	8980						
ERhod	Ovine/caprine	110761	23899	1500	1050	24949	14,24	5
	Bovine	48854						
	Equine	11097						
Krai	Ovine/caprine	44000	8730	0	0	8730	4,98	3
	Bovine	11863						
	Equine	6500						

and consequent disturbance. It could be suggested that the pattern of road distribution and frequency of their use may affect food availability for most of the European vultures. As a consequence, it already has a visible negative effect on bearded vulture breeding success in Spain (Donázar et al. 1993). Central Balkan Mts. and Rila Mts. have also other positive characteristics such as the absence of lead poisoning and smaller impact of power lines.

The future strategy of the reintroduction process of the species would include releases at both selected sites simultaneously. It should be noted that the *weather and climate conditions* in these two PRS differ significantly – mountain sub-Mediterranean climate zone in Rila and mountain continental climate in Central Balkan. Therefore, the simultaneous reintroduction in the selected two areas will overcome the existing risk of unsuccessful acclimatisation of the target species. The reintroduced birds would have an increased chance to interact with the vultures released in the other areas and they might choose to occupy their preferred site.

The Western Balkan Mts. and Eastern Rhodopes Mts. were rated with lower scores but they also could be considered as suitable for the next stage in the future reintroduction program. The Western Balkan Mts. provide perfect limestone cliffs, optimal mean slope (ruggedness) and mid and upper subalpine altitude, while the food base is recently insufficient (Table 2). However, the positive influence of Vrachanski Balkan Nature Park authority and the active support of the local non-governmental organisations (NGO) probably will result in a successful program based on a smooth and well organized bearded vulture food management. Eastern Rhodopes is also considered as one of the most important vulture areas in Bulgaria. It should be taken into account that the Greek part of the mountain was the last place where the bearded vulture disappeared from this part of Balkan Peninsula (Xirouchakis et al. 2001). The estimated trophic status is excellent (Table 2) but the problem is that the area does not represent the recently considered optimal habitat such as alpine and subalpine areas (Gavashelishvili & McGrady 2006). The Eastern Rhodopes are low mountainous and hilly area, with volcanic cliffs. However, the presence of all the other three species of European vultures and the food abundance may attract some of

Table 3. Viability matrix representing all selected potential release areas and their compared values of threat and habitat quality. The viability index is the sum of both habitat quality index and threat index. In parenthesis is the original value of the variables before transformation. Abbreviations: WBalk: Westren Balkan Mountains; EBalk: Eastern Balkan Mountains; CBalk: Central Balkan National Park; Rila: Rila National Park and Rilski Manastir Nature Park; Pirin: Pirin National Park and Kresna Gorge; WRhod: Western Rhodopes; ERhod: Eastern Rhodopes; Krai: Kraishte.

No	Threats	Potential Release areas							
		WBalk	EBalk	CBalk	Rila	Pirin	WRhod	ERhod	Krai
1	Poison	3 (1)	3 (1)	3 (1)	3 (1)	6 (2)	3 (1)	3 (1)	3 (1)
2	Power lines	2 (1)	2 (1)	1 (0.5)	1 (0.5)	2 (1)	1 (0,5)	2 (1)	4 (2)
3	Lead poisoning	1	1*	0	0	1*	1	1*	1
4	Cable cars	0	1	1	1	1	1	0	1
5	Paved roads	0	2	0	0	0	1	1	1
6	Unpaved roads	0.5	1	0	0	0	0	0.5	1
7	Population	0	0	0	0	0	0	0	0
8	Outdoor activities	0.6 (3)	0.8 (4)	0.8 (4)	0.8 (4)	1 (5)	1 (5)	0.6 (3)	1 (5)
Habitat quality									
9	Spatial capacity	1 (5)	0.8 (4)	1 (5)	1 (5)	0.6 (3)	1 (5)	1 (5)	0.6 (3)
10	Trophic capacity	0.5 (5.65)	2 (24.58)	1 (9.55)	1 (7.14)	2 (9.58)	1 (8.20)	2 (14.24)	0.5 (4.98)
11	Open habitats	2 (36 000)	1 (25 000)	1 (20 000)	2 (56 000)	1 (20 000)	1 (20 000)	2 (50 000)	1 (20 000)
12	Cliffs	2	1	2	2	2	2	2	1
13	Coherence	2	0	2	2	1	1	2	0
14	Villages	0	0	1	1	0	0	0	0
15	Griffon Vulture	1	1	1	1	1	0	1	0
16	Egyptian Vulture	0	1	0	0	0	0	1	0
17	Protected surface	1	0	2	2	1	0	0	0
18	Protection	1	1	2	2	2	0.5	0.5	0.5
19	Education	2	2	2	1	2	0	2	0
Indexes									
Threat Index		-7.1	-10.8	-5.8	-5.8	-11	-8	-8.1	-12
Habitat quality index		12.5	9.8	15	15	11.6	6.3	13.5	3.6
Viability Index		5.4	-1	9.2	9.2	0.6	-1.7	5.4	-8.4

the released in Central Balkan and Rila bearded vultures and the species to settle in the area on its own. This will give us a new direction for future releases in the latter area.

Given the current progress of the programs to restore the species in other areas of Europe such as the Hohe Tauern National Park in Austria, the Calfeisental Valley in Switzerland, the Grands Causses in the French Massif Central and Andalusia (Padial et al. 2005, Schwarzenberger et al. 2013) as well as the need to expand the European bearded vulture population to southeast and to facilitate interchange with the population of the species in Asia Minor, the action plan based on the present study seems realistic and feasible.

In conclusion, the analysed data showed that the process of reintroduction of the bearded vulture in Bulgaria could be started *immediately in the first two selected protected areas, i.e. Rila and Central Balkan Mountains*. However, an implementation of additional specific management interventions in these PRS is of crucial importance in order to manage and minimize further risks and to ensure habitat enhancement.

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