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Main mortality factors for the Eastern Imperial Eagle (*Aquila heliaca* Savigny, 1809) in Bulgaria

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Abstract The Eastern Imperial Eagle is a globally threatened species, represented with not more than 35–40 pairs in Bulgaria. As a facultative scavenger feeding on carcasses and parts of dead domestic and wild animals, this species is extremely vulnerable to poisonous baits and toxic agents, intentionally or accidentally set up in its food. The present study identified electrocution and poisoning as the main mortality factors for the eagles in Bulgaria. We analysed a total of 56 cases among which 44 cases were related to the mortality of non-territorial eagles in different age classes, and we found 12 dead or distressed territorial birds recorded between 1992–2019. The main mortality factor was electrocution, accounted for 30.4% of fatalities. The poisoning was the cause of mortality in 12.5% of the non-territorial and 10.7% of the breeding birds. Some of the cases were laboratory confirmed as intoxication, while the others, based on the history, clinical symptoms and field evidence, indicated poisoning. The most commonly used toxic agents were anticholinesterase's inhibitors. As a result of a timely therapy applied to the live birds found in distress with symptoms of poisoning, six eagles were successfully treated and released back in the wild. We found that mortality of eagles depended on the age of birds, breeding or dispersal grounds, while season had no significant effect.

Keywords: mortality factors, raptors, population, poisonous baits, electrocution, floaters

Összefoglalás A parlagi sas egy világszerte veszélyeztetett madárfaj, amelynek bulgáriai állománya nem haladja meg a 35–40 párat. A faj részlegesen dögöt is fogyaszt, így a szándékos vagy véletlen mérgezések jelentősen veszélyeztetik. Jelenlegi vizsgálatunk alapján az áramütés és a mérgezés bizonyult a legjelentősebb halálozási oknak a parlagi sasok között Bulgáriában. Összesen 44 különböző korú, nem költő madarat és 12 territoriális madarat találtunk elpusztulva vagy legyengülve 1992–2019 között. A legfontosabb megkerülési ok az áramütés volt, amely az esetek 30,4%-át tette ki. Mérgezés következtében a nem költő madarak 12,5%-a, míg a territoriális madarak 10,7%-a került meg. A mérgezéses esetek egy részét laboratóriumi vizsgálatok igazolták, míg más esetekben a terepi körülmények alapján lehetett arra következtetni. A leggyakoribb méreganyagok a kolinészteráz-gátló vegyületek voltak. Az életben talált madarak közül hat példányt sikerült gyógyultan szabadon engedni a gyors állatorvosi beavatkozásoknak köszönhetően. Eredményeink azt mutatták, hogy a sasok halálozását a madarak kora, valamint költő vagy diszperziós területen való előfordulásuk befolyásolta. Az évszakoknak nem volt szignifikáns hatása.

Kulcsszavak: halálozási ok, ragadozómadár, populáció, mérgezett csalétek, áramütés, nem költő madarak

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Introduction

Human activities are severely affecting raptor populations, bringing some of them to the brink of extinction (Donàzar *et al.* 2016, McClure *et al.* 2018). Electrocution and poisoning were identified as main mortality factors for many threatened species (Gonzalez *et al.* 2007, Smart *et al.* 2010, Demerdzhiev 2014, Dwyer *et al.* 2015, Demeter *et al*. 2018).

The Eastern Imperial Eagle *(Aquila heliaca)*, hereafter EIE, is a long-lived, large-size territorial raptor whose distribution range spans throughout the forest steppe zone of Eurasia (Thiollay 1994). It extends to Austria to the west, through Ukraine, Kazakhstan, and Russia to the east, and the Balkans and Asia Minor to the south (Ferguson-Lees & Christie 2001). The adult birds of the Pannonian population and the Balkans are resident, while the immatures disperse at different distances (Gradev *et al.* 2011, Horváth *et al.* 2011, Vili *et al.* 2013, Stoychev *et al.* 2014). The last population estimates show that the global population of the species might exceed 10,000 mature individuals (BirdLife International 2020), whereas the European population of the EIE is estimated at 1800–2200 pairs during the period of 2000–2010 (Demerdzhiev *et al.* 2011a). The EIE is classified as vulnerable by IUCN (with decreasing population) (BirdLife International 2019). Currently, the species is legally protected under the terms of Directive 2009/147/EC on the conservation of wild birds (Anonymous 2009), Appendix 1 of CITES, (Anonymous 2019) and Appendix 2 of the Bonn and Bern Conventions (Anonymous 1979). The main reasons for the decreasing population included: habitat loss and degradation along with high adult mortality due to persecution and hazardous powerlines, nest robbing, and prey depletion (BirdLife International 2020).

In Bulgaria, the EIE was widespread by the end of the 19th century and considered a sacred bird among the native folk (Hristovich 1890). However, in the mid of the 20th century, the EIE population decreased significantly, becoming one of the rarest Bulgarian birds (Patev 1950). During the next decades, the number of breeding pairs declined due to the rapid changes in land use pattern and the agricultural landscape system, together with the massive use of poisonous agents (Petrov *et al.* 1996). As the species reached near extinction till the'90s, the combined efforts of NGOs, supported by the local institutions were intensified (Nikolova 2010), thus resulting in slowly restoration of the population in Bulgaria. Since 2000, the population of the species gradually increased reaching 25–30 pairs in the first decade (Demerdzhiev *et al.* 2011b) and 35–40 pairs nowadays (authors' data). The EIE is distributed mainly in the south-eastern part of Bulgaria (Demerdzhiev *et al.* 2014a).

Recent studies on the species diet showed that it mainly foraged with medium size mammals, birds and reptiles (Marin *et al.* 2004, Katzner *et al.* 2006, Horváth *et al.* 2010, Demerdzhiev *et al.* 2014b, Horváth *et al.* 2018a). However, the EIE is an opportunistic species, therefore taking advantage of the most abundant prey in the occupied territory (Kovács e*t al.* 2005). Because of their prey species, eagles became subject to hunting and poaching (Horváth *et al.* 2018b). Similarly, because the eagles are hunting farm animals (Meyburg & Kirwan 2020) conflicts between human and nature may arise (Duriez *et al.* 2019).

At Balkans level, the most common threats to the species population include electrocution (Stoychev *et al.* 2014), the use of poisonous baits (used mainly to fight livestock predators) (Pantović & Andevski 2018).

Any action against the species welfare is treated as environmental or wildlife crime according to the Bulgarian jurisdiction, as EIE appeared to be protected species under the terms of the Biodiversity Act (Anonymous 2002). Furthermore, specific provisions by the national legislation are foreseen whenever cruelty towards vertebrate animals occurs (Kirov *et al.* 2019), resulting in fine or imprisonment.

The study aimed to summarize and analyse the main causes of incidents among the EIE in Bulgaria: non-human related and human-related causes. Based on the obtained results, we also proposed specific conservation measures to be undertaken to mitigate the identified threats.

Material and methods

Study area

The survey was primarily accomplished in Bulgaria, although the dataset of some birds, which were marked in Bulgaria, but found dead outside the territory of the country, was also included.

Study period and data procedures

Fifty-six cases of injured or dead EIEs were investigated in the period 1992–2019, retrieved by the Green Balkans Wildlife Rehabilitation and Breeding Center (WRBC) and Bulgarian Society for the Protection of Birds (BSPB) species database. The database information included (1) the regular species monitoring scheme within the breeding territories to record the EIE's breeding rates, (2) the surveys of hazardous electric power lines within species home range and (3) intensive monitoring of satellite- or radio-tagged birds. The study covered only incidents with fledged birds and nest mortality cases were excluded from the analysis. The identified factors were compared with the age of birds, season and period. Regarding EIE distribution in age groups, floaters were initially defined as birds prevented from breeding by territoriality or other spacing behaviours (Brown 1969, Newton 1992). If resource availability limits the number of breeders, and territory competition makes some individuals become floaters when all suitable breeding habitats are occupied. Floaters are individuals able to enter the reproductive population as breeders when a breeding site or potential mate becomes available (Penteriani *et al.* 2005, 2006, 2008).

The cases of birds found alive or distressed were analysed by the database of WRBC, where the birds were sent for therapy and rehabilitation. Dead birds were processed according to the status of the corpses. The corpses suitable for analysis (not decomposed) were sent either to WRBC for X-ray and necropsy, or directly to laboratory for toxicological analysis. Several laboratories were chosen with regards to location proximity or capacity for certain analytical methods. Laboratory findings indicated presence of substances - anticholinesterase's inhibitors. Particular pesticides were not determined as the methodology was able to detect only the group mechanism of action. In cases where the birds' corpses did not allow further analysis due to high rate of decomposition, the cause of death was estimated based on evidence found around the bird in the field. We checked each location in the field to verify the condition of the GPS-tagged eagles.

The causes of incidents were classified in two main groups: non-human related reasons, such as intraspecific aggression or windstorm, and human-related activities, such as poisoning, electrocution, shooting and collision with power lines or traffic.

Statistical procedures

To examine the correlation of the incidents due to the age, individuals were categorized as juveniles (the period from fledging to the end of the first winter), immatures (from their second to fifth plumage) and adults (after their fifth plumage) (Forsman 2005). The fluctuation in the number of incidents was investigated in relation to the eagle's reproductive cycle: (1) breeding, i.e. laying and incubation (during spring), (2) chick-rearing period (in summer), (3) post-fledgling period (autumn), and (4) pre-laying period (during winter season) (Kovács *et al.* 2005). Analysis of the temporal variation in the incident cases was divided into three periods: (1) till 2006, the period before the acquisition of Bulgaria in the European Union; 2) 2007–2013, Bulgaria being accepted as a member state in the EU, implementation of the EU legislation and period of active conservation measures for the species with increase in the population numbers, (3) 2014–2019, the period of population stagnation and increase in the threats for the species.

The data were processed with IBM SPSS Statistics (SPSS-Inc., 2019, SPSS Reference Guide 26 SPSS, Chicago, USA) using descriptive statistics with frequency distribution tables. The correlation between different variables was investigated with the Pearson correlation coefficient. All categorical data were organized in 2×2 contingency table. As within the table there were cells with expected count less than 5, the Fisher exact test was applied. Significance of results was presented with the exact P-value (2-tail), known in SPSS as Exact Sig (2-sided).

Results

Main mortality factors

We registered 56 cases of incidents with EIE in Bulgaria within the study period. The majority of all analysed birds were found dead (n = 45, 80.40%) and the rest of the eagles were found alive (n = 11, 19.60%). It was possible to determine the cause of death for 76.90% (n = 43) of the individuals (those found dead at discovery and those that died during therapy at WRBC). Electrocution (30.40%, n = 17 cases) and poisoning (19.60%, n = 11 cases) were the most frequent causes of mortality. Of the remaining causes, only shooting (n = 7 cases, 12.50%), collision with power lines (n = 3 cases, 5.40%) and mortality due to collision with vehicle (n = 2 cases, 3.60%) were particularly frequent.

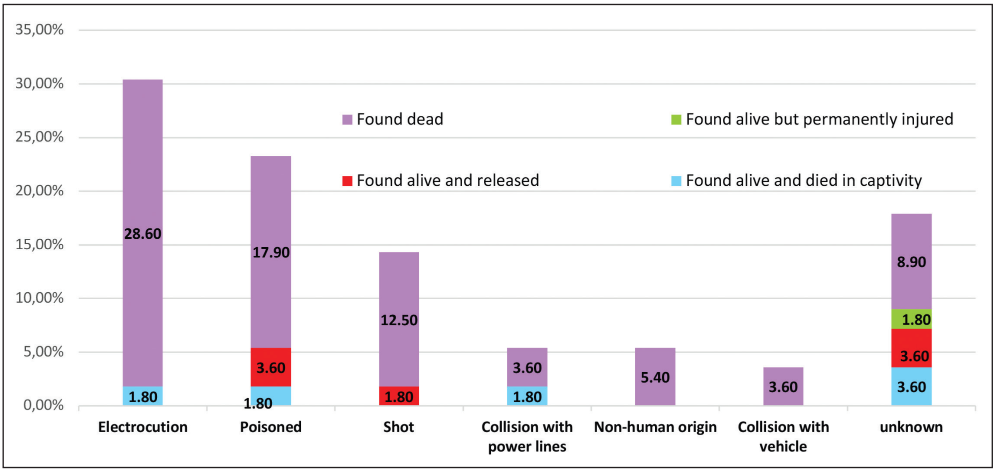

Figure 1. Causes of mortality or injury among Eastern Imperial Eagles in Bulgaria according to the status at discovery and outcome of the injury

1. ábra Parlagi sasok pusztulási vagy sérülési okai Bulgáriában a megtalálási állapot és a sérülés kimenetele alapján

The eagles found alive after the incidents were sent to the WRBC for therapy. Results showed that 10.70% (n = 6) of the birds survived the therapy and were consequently released (only one bird was left for aviary keeping due to its permanent disabilities). There were no significant differences between the cause of the incident and the final outcome from the injury (exact P = 0.26). The subject for the traumatic injury in all of the cases was analysed and for the most of the incidents was associated with human-related activities (n = 43, 76.80%), and only small share of the birds (n = 3, 5.40%) had suffered from non-human related reasons (intraspecific aggression and windstorm). In 17.90% of the cases (n = 10) the cause of injury remained unknown (for both alive and dead specimens) *(Figure 1)*. No significant differences were found between the cause of incident and the health status of the bird at discovery (exact P = 0.14).

Age related mortality

There were significant differences in the cause of death between age classes (exact P = 0.01). Incidents at different age stages appeared to be significantly influenced by the cause for the mortality.

The main factor for casualties in juvenile EIE was electrocution (n = 7, 12.50%), followed by poisoning (n = 3, 5.40%). However, unknown causes accounted for seven birds (n = 7, 12.50%). Immature eagles were mainly affected by electrocution, followed by shooting and poisoning. The main cause for incidents in adult birds was poisoning, followed by electrocution and causes from non-human origin.

We found that 46.2% (n = 6) of all registered poisoning incidents were diagnosed as such based on the case history and clinical symptoms of the birds. The rest 53.8% (n = 7) of the poison samples were confirmed to contain anticholinesterase's inhibitors, suggesting the use of pesticides.

Table 1. Causes of mortality or injury among Eastern Imperial Eagles in Bulgaria according to the different variables studied

1. táblázat Parlagi sasok pusztulási vagy sérülési okai Bulgáriában az egyes vizsgált változók alapján

	Electrocution	Poisoned	Shot	Collision with power lines	Non-human origin	Collision with vehicle	Unknown	Total
Age								
juvenile	7	3	0	1	1	0	7	**19**
immature	8	5	7	2	0	1	3	**26**
adult	2	5	1	0	2	1	0	**11**
Season								
spring	1	3	2	2	1	1	1	**11**
summer	8	4	0	0	0	1	3	**16**
autumn	4	2	1	0	0	0	4	**11**
winter	4	4	5	1	2	0	2	**18**
Period								
until 2006	0	4	2	1	1	0	4	**12**
2007–2013	8	3	4	0	0	0	5	**20**
2014–2019	9	6	2	2	2	2	1	**24**
Territorial/Floaters								
Floaters	15	7	5	3	2	2	10	**44**
Territorial	2	6	3	0	1	0	0	**12**
Tagged/Non-tagged								
Transmitter-tagged	8	7	3	0	0	2	3	**23**
Non tagged	9	6	5	3	3	0	7	**33**
Country								
Bulgaria	13	12	8	3	3	2	7	**48**
Turkey	3	1	0	0	0	0	2	**6**
Syria	1	0	0	0	0	0	0	**1**
Sudan	0	0	0	0	0	0	1	1
Total	17	13	8	3	3	2	10	56

Season-related mortality

The maximum number of incidents occurred during winter and summer *(Table 1)*. No significant differences were found between the cause of death and seasonality (exact P = 0.18). The majority of the traumas (detected in live and dead birds at discovery) in juveniles and immatures were recorded in the autumn season. On the contrary, we registered the majority of incidents with adult birds in the summer.

Temporal changes in mortality

The study found a relationship between the period of the registered casualties and the main causes identified as factors for the incidents (exact P = 0.04) *(Table 2)*. A statistically significant difference was determined between the period 2007–2013 and the increase of electrocution traumas in EIE.

Mortality in breeding and dispersal areas

The territorial dependence appeared to be an important factor related to circumstances for fatal incidents for the EIE (exact P = 0.07). Floaters were affected with a significantly higher rate by electrocution injuries than territorial ones.

Tagging-devices were found to play no important role in the traumatic injuries (exact P = 0.25). However, a slight increase in the number of electrocution casualties was found for the group of the non-tagged EIE.

Table 2. Ratio of Eastern Imperial Eagle specimens found dead or injured in Bulgaria in relation to the Bulgarian breeding population. Data till 2014 were retrieved from Demerdzhiev, 2015. After 2015 we used unpublished authors data and field observations

2. táblázat Az elpusztultan vagy sérülten megtalált parlagi sasok száma Bulgáriában az országos költő állomány nagyságához viszonyítva

Year	Population size (n) (Number of nesting pairs x 2)	Number of specimens found (n)	Ratio of incidents vs. population size (%)
1992	4	1	25.00
1993	4	1	25.00
1998	12	1	8.33
2001	20	1	5.00
2004	30	7	23.33
2005	28	1	3.57
2008	38	2	5.26
2009	40	3	7.50
2010	36	4	11.11
2011	44	5	11.36
2012	46	5	10.87
2013	50	1	2.00
2014	52	10	19.23
2015	56	5	8.93
2016	56	2	3.57
2017	56	5	8.93
2018	58	1	1.72
2019	62	1	1.61

Discussion

The sustainability of the ecological food systems is highly dependent on the sustainability of the scavenger and raptor populations for maintaining the environmental balance. Unfortunately, growing evidence shows a negative change in the apex scavenger populations worldwide (O'Bryan *et al.* 2019), which become vulnerable with other predatory species due to violent human activities (Santangeli *et al.* 2019). Human disturbance, bad weather or a combination of both were identified as factors causing chick mortality in the threatened EIE in Austria (Wichmann 2011). Although our study did not include mortality at this early stage (chick growing) in the estimations, we found that 71.5% of the mortality cases of the EIE from Bulgaria were also result from human interventions, with the other 5.4% caused by intraspecific aggression and extreme weather. Similar results were found for the threatened

Spanish Imperial Eagle *(Aquila adalberti)*, as well, with the illegal use of poisonous baits and veterinary drugs as main causes for mortality (Ferrer *et al.* 2013, Margalida *et al.* 2017).

The protection of EIE in Bulgaria was directly addressed for the first time in the 1990s (Petrov & Stoychev 2002). The systematic conservation activities, implemented since 2000, have led to increase in the number of pairs and occupied territories. This positive trend appeared to be a consequence as well from both better protection of breeding grounds and some immigration of eagles from adjacent regions (Demerdzhiev *et al.* 2015). The observations on the status of the Bulgarian populations of EIE improved till 2014 (Demerdzhiev *et al.* 2011b, Demerdzhiev *et al.* 2014a, Demerdzhiev *et al.* 2015).

Despite the success of the conservation efforts and the implementation of the European legislation on wildlife protection and regulation on pesticide use in Bulgaria since 2007 (Anonymous 2009, Nikolova *et al.* 2015), our results indicated non-significant decrease in the number of incidents and total mortality rates in eagles. Our data confirmed the previous findings that the most important factor causing the mortality of immature eagles was electrocution (Stoychev *et al.* 2014), accompanied by shooting and poisoning too (Demerdzhiev *et al.* 2014a).

The natal dispersal of EIEs was found to be the most threatened period, as high mortality rates were revealed for the first calendar year birds (Demerdzhiev *et al.* 2015), that increased further for the second and third calendar years (Stoychev *et al.* 2014), while we found significant decrease mortality rates in adults. The main factor for fatal casualties in juvenile eagles was electrocution, followed by unknown causes and poisoning. For the immatures key mortality factor was electrocution, accompanied by shooting and poisoning. Likewise, the main causes for trauma injuries in juvenile and immature eagles from the Bulgarian population were identified by other studies as well (Stoychev *et al.* 2014).

We speculate that adult eagles appeared to be less likely to die from electrocution due to their life experience. By occupying a certain area, they learned to avoid electric poles and landed on trees instead. At the same time, we rarely registered shot adult EIE in their breeding territories as a result of successful long-term awareness raising work. Immature birds that visited different areas within their dispersal period (very often outside Bulgaria) could be shot due to misunderstanding or intentionally, so the work with hunters at these places should be intensified. Poisoning appeared as a threat of equal intensity for all age groups, with the juveniles and immatures being poisoned in the dispersal areas and the adults in the nesting areas. We could assume also that most of the unknown causes of death were probably due to poisoning, however, the late discovery of the body or its remains, prevented us to confirm the cause of dead.

Regarding the Spanish Imperial Eagle, data suggested that electrocution occurred more frequently in autumn and winter (Gonzalez *et al.* 2007). In contrary to these findings, we registered high mortality due to electrocution in summer. Considering the EIE mortality by seasons, it could be pointed out that electrocution was more common in summer for floaters, which used to concentrate in Temporal Settlement Areas such as Sliven field, appeared to be attracted by abundant prey in this season, mostly European Souslik *(Spermophilus citellus),* and due to lack of tall trees they often perched on the poles where got injured. Winter and spring were suggested as the seasons with more frequent poisoning cases of Spanish Imperial Eagles (Thirgood *et al.* 2000), related to the illegal control on other predator species

(Gonzalez *et al.* 2007). For EIE, we found that the highest number of registered poisoning incidents occurred in winter and summer, when EIE become attracted by poisonous baits, which we hypothesized to be intended for wolves and jackals (winter), or when baits for rodents were dispersed (summer). This hypothesis was based only on field observations as we lacked sufficient evidence from toxicological analyses. The shooting incidents were mainly detected in winter, due to the permitted active hunting in this season, which imposed the necessity for more intensive conservation work with hunters during winter. To summarize, the winter period was generally associated with the highest mortality rates among EIE, due to the difficulties in finding food and deteriorating weather conditions and other mortality factors with anthropogenic character occurring then.

Despite the numerous conservation activities undertaken during the second and third periods of the study, the number of EIE found dead increased. In consistence with previous studies, our results showed that till 2006 the fatal cases due to electrocution were 0%, in the period 2007–2013 they increased to 14.30% and in 2014–2019 they reached 16.10%. This contradiction is due to the lack of systematic studies until 2004 on bird mortality caused by the hazardous power grid (Demerdzhiev *et al.* 2009), as well as to more precise method for determining mortality factors by marking eagles with transmitters (Stoychev *et al.* 2014). At the same time, more than 3000 hazardous electric poles in the territories of the Bulgarian population of the species were modified to bird-friendly design to prevent the casualties (Demerdzhiev *et al.* 2014a, authors' data). Explanation of increased mortality due to electrocution in the third period could be found in expansion of the population and colonization of new breeding territories mainly by unexperienced immature birds and also by probably increased number of the floaters, which made the risk of incidents by unsecured poles higher. As a measure for reducing the hazard, the modification of risky electric poles in the new nesting areas and new dispersal sites should be continued. Regarding the poisoning incidents, we found no differences till 2014. During the next few years from 2014–2019, an increase in the number of registered poisoning cases was documented. The role of anthropogenic factors as shooting and human disturbance, which pose a threat for the EIE populations was confirmed as well (Schmidt & Horal 2018), despite the intensive conservative measures in the period 1998–2014 (Demerdzhiev *et al.* 2015).

When compared with the population size, the noted increase in the total number of incidents in the second and third periods was accompanied by a significant increase in the number of the EIE population during the same time. Thus, registered EIE casualties per year represented a small share compared to the total population size *(Table 2)*.

Data for the mortality rates estimations were obtained from both transmitter-tagged and non-tagged birds, as Gonzalez *et al.* (2007) suggested that records of individuals from both groups provided similar information on the frequency of the causes of mortality.

Mortality due to electrocution had been estimated through specific methodology of studying this factor based on regular inspections of hazardous electric poles when the injured eagles were easily found. Data from the 27 satellite-tracked EIE unambiguously proved electrocution as a major factor in floater mortality (Stoychev *et al.* 2014).

It should be noted that certain difference in mortality between territorial birds and floaters existed. The study found that nesting birds died more often from poisoning and less often from electrocution, while in floaters mortality due to electrocution was more frequent than poisoning. The last fact could be explained by the lack of experience of the floaters and probably their wider distribution. Together with young birds, in their dispersal areas, they used to land often on electric poles and become casualties of electrocution. At the same time, the breeding EIE used to stay within the familiar nesting territories, while the floaters explored many different places, thus, increasing the risk to get injured or die from any of the anthropogenic factors.

Understanding on the nature of poisoning in wildlife is provided by a number of studies on the human-wildlife conflict (Margalida *et al.* 2014, Schmidt & Horal 2018). The unstable coexistence of carnivores and birds of prey with game and livestock, resulting in damages in human property and safety, was stated to be a motive for a hostile attitude towards raptors (Brochet *et al.* 2019, BirdLife International 2020), scavengers (Plaza *et al.* 2019), and use of poisonous baits to control livestock predators like wolves (Petrov *et al.* 1996, Peterson *et al.* 2010). Thus, secondary or malicious animal poisoning was recorded to pose an enormous threat for the stability of the Spanish Imperial Eagle populations with estimation of 54% mortality cases in adult birds since 1990, due to increased use of poison in hunting areas (Ferrer & Penteriani 2008), and illegal practices related to use of poisonous baits in EIE (Horváth *et al.* 2016, Chiaria *et al.* 2017). The fatal incidents with the EIEs in Bulgaria were associated also with the use of poisonous baits against the Grey Wolf *(Canis lupus)* population, but affecting also raptors and scavengers. In fact, data reported no presence of the grey wolf in territories, co-inhabited by the eagle pairs, till 2014 (Anonymous 2013). On the other side, evidences for the presence of several wolf packs were received through field observations (authors' data) after 2014. Indirectly, the role of poisonous baits for wolves as a mortality factor for the eagles was confirmed due to the change in the land use in agriculture (Lazarova & Balieva 2020) and signals from farmers for wolf attacks on their herds.

Reasons behind poisoning in wildlife were investigated in a range of European countries like Belgium, France, Greece, Italy and Spain. Data over a ten-year period reported that deliberate primary or secondary poisonings, mainly in birds, including raptors, were of a concern to all countries. Analysis showed that in poisoning incidents with fatal consequences among the frequently identified agents were metals (particularly lead arising from sporting/hunting activities) and pesticides (mainly anticholinesterases and anticoagulants) (Guitart *et al.* 2010). Poisoning was the most significant mortality factor for EIE in Hungary (Deák *et al.* 2020b). Regarding scavenger species, like vultures, it was found that secondary poisoning due to human-wildlife conflict exposed the birds to the toxic effect of pesticides (Plaza *et al.* 2019) and in long-term resulted in 60% of all registered vulture poisoning events in the southern Balkan Peninsula during the last 36 years. Most frequently used substances in poisonous baits were strychnine, carbamate, and organophosphorus compounds (Parvanov *et al.* 2018). Moreover, highly toxic pesticides were detected in intentional poisoning of domestic animals and wildlife in Spain (aldicarb, carbofuran and strychnine) (Martínez-Haro *et al.* 2008), Italy (insecticides – anticholinesterases, rodenticides, molluscicides and herbicides) (Chiaria *et al.* 2017), Tunisia (carbamates, organophosphates and rodenticides-anticoagulants) (Lahmar *et al.* 2019) and Hungary (carbofuran, brodifacoum, terbufos and diazinon) (Deák *et al.* 2020a). In correspondence with these findings, our results showed that laboratory confirmed intoxications in EIEs from the study were caused by anticholinesterase's inhibitors such as organophosphate and carbamate insecticides.

The extremely high number of poisoning incidents in raptors and scavengers registered worldwide in the last decades redirected the conservation efforts towards improvement of the detection efficiency of poisonous baits. In Europe, poison-and carcass searching dog units were established and joint forces of NGOs, governmental officers, wildlife veterinarians, police and prosecutors were set to improve detection, reporting, investigation and persecution of illegal poisoning in vulnerable species like the EIE (Petrov *et al.* 1996, Horváth *et al.* 2018b).

Conclusion

EIEs are using a larger range and visiting diverse areas during their wanderings, while territorial birds are attached to a specific area, therefore different mortality factors are affecting these two groups, which require different conservation approaches. Among the main mortality causes for the eagles appeared to be electrocution and poisoning, despite the continuous joint efforts of conservation organisations in the last two decades.

Modification of the hazardous electric poles should be considered the main conservation priority in both natal and species dispersal areas. Anti-poisoning actions should be considered at a first priority step in EIE breeding territories and as a second priority in dispersal areas outside Bulgaria. Moreover, international pressure and support on these threats can result in better conservation applicability, especially outside Bulgaria. Least, but importantly not last, it is necessary to intensify the work with local institutions and stakeholders such as hunters, farmers, etc., who have a crucial role in the long-term survival of the EIE in Bulgaria.

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