Conservation measures undertaken to improve the population status of eastern imperial eagle (*Aquila heliaca*) in Bulgaria

Ochránárske opatrenia na zlepšenie stavu populácie orla kráľovského (*Aquila heliaca*) v Bulharsku

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Abstract: This study presents the results of conservation measures undertaken and their impact on the eastern imperial eagle population in Bulgaria. The species is distributed in the south-eastern part of the country, as there is only one known pair in central Bulgaria. During the period 2009–2013, 28 different breeding territories were occupied. The population increased by 20%, as the number of pairs that occupied breeding territories increased from 20 in 2009 to 24 in 2013. In general, the mean values of the breeding parameters of the eastern imperial eagle population for the period 2009–2013 were as follows: productivity (P) 1.03 ± 0.18 ; breeding success (BS) 1.18 ± 0.21 ; and fledgling success (FS) 1.68 ± 0.16 . The annual survival rate of breeders varied from 0.795 to 0.932. The most important factor causing the mortality of immature eagles was electrocution. Shooting and poisoning have become important mortality factors, too. Guarded pairs had a higher mean breeding success (1.32 ± 0.88) than non-guarded pairs (1.06 ± 0.91). As a whole, 39% of all artificial nests installed in the period 2009–2013 were occupied by birds of different species. During the period 2008–2013, a total of 23 juvenile eastern imperial eagles were tagged with satellite/GPS transmitters. In addition, 608 hazardous electric poles in the territories of seven pairs were insulated. Supplementary feed was provided for 14 pairs once a week during the autumn–winter seasons (October – March). A total of 483 supplementary feedings took place, 450 of which also included monitoring in order to record the effectiveness of this activity.

Abstrakt: Štúdia prezentuje výsledky ochranných opatrení a ich vplyv na populáciu orla kráľovského v Bulharsku. Druh sa vyskytuje v juhovýchodnej časti krajiny, v centrálnom Bulharsku je známy len jeden pár. V období 2009–2013 bolo obsadených 28 rôznych hniezdnych teritórií. Populácia narástla o 20 %, počet párov s hniezdnyimi teritóriami sa zvýšil z 20 v roku 2009 na 24 v roku 2013. Stredné hodnoty parametrov hniezdenia orlov kráľovských boli v období 2009–2013 nasledovné: produktivita (P) $1,03 \pm 0,18$; hniezdna úspešnosť (BS) $1,18 \pm 0,21$, úspešnosť vyletenia mláďat (FS) $1,68 \pm 0,16$. Ročná miera prežitia hniezdiacich jedincov bola 0,795–0,932. Najdôležitejším faktorom, spôsobujúcim mortalitu mladých orlov boli usmrtenia po zásahu elektrickým prúdom spoločne s nelegálnymi odstrelmi a otravami. Strážené páry mali vyššiu hniezdnu úspešnosť ($1,32 \pm 0,88$) ako nestrážené páry ($1,06 \pm 0,91$). Celkom bolo obsadených vtákmi rôznych druhov 39 % umelých hniezd inštalovaných v období 2009–2013. V období 2008–2013 bolo celkom 23 mladých orlov kráľovských označených satelitnými vysielačkami s GPS jednotkou. V teritóriách siedmich párov bolo izolovaných 608 nebezpečných stĺpov elektrického vedenia. V jesennom a zimnom období (október až marec) sa raz za týždeň realizovalo prikrmovanie 14 párov orlov. Celkom sa zrealizovalo 483 prikrmovaní, na 450 z nich bolo súčasťou sledovanie efektivity tejto činnosti.

Key words: population dynamics, conservation measures

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Introduction

The eastern imperial eagle (EIE) (*Aquila heliaca*) is a Palearctic species (Voous 1960), nesting from Central Europe, the Balkans, Central Asia, and South Siberia to China and Mongolia (BirdLife 2013). Breeding EIEs in Bulgaria are part of the Thracian meta-population of the species, estimated at 60–75 pairs (Demerdzhiev et al. 2011a, b). Since the year 2000, following a drastic population decline during the second half of the 20th century, the population of the EIE in Bulgaria has been increasing. The national population was estimated at 20–25 pairs in 2002 (Stoychev et al. 2004) and 25–30 pairs in 2008 (Demerdzhiev et al. 2011b). In 2013, the number of known occupied territories increased to 24. In 2001–2013, a total of 32 different breeding territories were occupied, mostly in south-eastern Bulgaria. The disappearance of the mountain population of the species recorded in previous periods of study (Stoychev et al. 2004, Demerdzhiev et al. 2011 b) continued in this period. However, between 2009 and 2013 only one EIE pair was known to have bred in mountainous areas. The conservation of the EIE in Bulgaria was supported by the LIFE + project “Save the raptors” in the period 2009–2013. This project aimed at increasing and monitoring the population in Bulgaria, monitoring and insulating dangerous 22 kV power lines, mapping European souslik (*Spermophilus citellus*) colonies, guarding nests and breeding pairs, purchasing land for protection of foraging and nesting sites, monitoring the migration routes and the wintering grounds of juveniles using satellite telemetry, building and installing artificial nests, restoring the EIE nesting habitat by creating plots of riparian forests, providing supplementary winter feeding to increase survivorship, providing supplementary spring and summer feeding to increase breeding success and developing agri-environmental schemes to improve the quality of the species’ habitat.

Materials and Methods

Study areas

The studies were carried out in a low-mountain area of Sakar with rounded hilltops and the relatively open river valleys of the Maritsa and Tundzha tributaries, near the Bulgarian-Turkish border. The terrain elevation ranges between 50 and 856 m above sea level. The lower parts of the Sakar territory are occupied by farmland, which has replaced forests of downy oak (*Quercus pubescens* Willd.) and virgilian oak (*Quercus virgiliana*

Ten.). Dispersed xerothermal grass associations, dominated by dichantium (*Dichantium ischaemum* L.), bulbous bluegrass (*Poa bulbosa* L.) etc., and, more rarely, meso-xerothermal vegetation cover about 15% of the area (Bondev 1991). The shrubs of Jerusalem thorn (*Paliurus spina-christi* L.), mixed with jasmine (*Jasminum fruticans* L.), in combination with the xerothermal grass formations, provide suitable habitats for various bird species. Many of the riverbeds and valleys in Sakar are still fringed by old trees of white poplar (*Populus alba* L.), willow (*Salix* sp.), etc., which provide nesting conditions for birds of prey. The neighbouring Derwent Heights is a low-mountain hilly area with a mosaic of different habitats, located to the east of the Tundzha River. The state border between Bulgaria and Turkey passes along their main ridge. Their elevation is between 120 and 550 m. About 20% of the territory of the Derwent Heights is covered by mixed deciduous forests of oak, most often Turkey oak (*Quercus cerris* L.) and Hungarian oak (*Quercus frainetto* Ten.), in places mixed with oriental hornbeam (*Carpinus orientalis* L.) and Mediterranean elements. The forest massifs are interspersed with open areas, overgrown with shrubs of Jerusalem thorn and jasmine (Bondev 1991). The hills are divided by many small rivulet valleys with typical vegetation. Agricultural land also occupies the low parts and the flat areas around the hills. The western Strandzha is located in south-eastern Bulgaria. It covers the western parts of the Strandzha Mts. Its territory includes several types of habitats, the biggest area being occupied by farmland, pastures and shrubs. The broad-leaved forests are represented by Turkey oak and Hungarian oak forests with Mediterranean elements. Woodlands alternate with open arable lands, pastures, grass formations, vineyards and orchards. The upper streams of the catchment areas of the Sredetska and Fakyiska Rivers are situated in the territory of the western Strandzha. The Tundzha river valley includes the middle and the lower reaches of the Tundzha River in the Sliven field and the adjacent Svetiilyski Hills, Manastirski Hills and Bakadzhitsite Hills. The natural vegetation consists of forests, mainly formed by downy oak, virgilian oak, Turkey oak and Hungarian oak. These ecosystems occupy patches within arable land. There are also small areas of forests and scrublands of oriental hornbeam, Jerusalem thorn with xerothermal grasslands etc. (Galabov 1982). The vegetation in the Sredna Gora Mts. consists mainly of forests of common beech (*Fagus sylvatica* L.), sessile oak (*Quercus petraea*

Matt.) and common hornbeam (*Carpinus betulus* L.) (Galabov 1982). The artificial plantations of European black pine (*Pinus nigra* Arnold.) and Scots pine (*Pinus sylvestris* L.) cover significant areas. Shrub and grass formations are less abundant.

Monitoring of the population

During the breeding period (February – August), occupied nests were monitored twice or three times per month. During the autumn and winter period, the breeding territory of each pair was visited at least once a month. Occupied territories, breeding pairs and population breeding parameters were recorded on an annual basis. The recorded data also included the adult survival rate. For estimates of the annual mortality of breeders (adult and sub-adult) we used the territory occupancy of birds that could be aged based on plumage characteristics. We assumed that territorial birds had survived if a bird of the same sex with progressively more mature plumage was observed in the same territory one year later. If an immature or adult bird of a given sex had been replaced by a bird in earlier or later plumage, we recorded the previous territory-holder as ‘unobserved’. This approach relies on the critical assumption of high breeding-territory fidelity in EIEs, an assumption we consider realistic because EIEs are extremely site faithful to breeding territories. From individual turnover observations we constructed encounter histories for each territorial bird and estimated annual survival probabilities. A new partner was considered to have replaced a dead mate (replacement) (Ferrer 2001). However, since it is difficult to record the replacement of a partner by an individual of the same age by visual observation, this method is not as precise as DNA monitoring (Rudnick et al. 2005). Breeding EIEs found dead during the study period were also reported. The identification of plumage was according to Forsman (2005). We estimated the productivity (number of fledglings per occupied territory), the breeding success (number of fledglings per breeding pair) and the fledgling success (number of fledglings per successful pair) for the period 2009–2013, including 107 breeding attempts. We also estimated the value of the success rate (frequency of breeding attempts with at least one fledged chick).

Satellite telemetry

Satellite telemetry was used to identify temporary settlement areas and to collect information about juveniles’ movements and migration. The satellite telemetry enabled the identification of the major factors that cause

mortality of juvenile and immature EIEs. During the period 2008–2013, a total of 23 juvenile EIEs were tagged with satellite / GPS transmitters.

Identification and insulation of dangerous electricity poles

The surveyed power lines were studied in seven Special Protection Areas (SPAs, namely – Sakar (BG0002021), Zapadna Strandzha (BG0002066), Kamensky Bair (BG0002059), Sinite Kamany-Grebenetz (BG0002058), Derventski Heights (BG0002026) and adjacent areas. The study was carried out in two periods. The first period lasted from September 2004 through December 2004 (Demerdzhiev et al. 2009) and the second from February 2008 through January 2010. The total number of inspected power poles of various types was 2,116. The survey established 297 victims of 46 different taxa, including 11 orders. To evaluate the efficiency of the insulators, 535 insulated poles were inspected again once a month during the period September–November 2012. The inspections were carried out by walking along the power lines. The period between the inspections was no less than 20 days and no more than 30 days. The inspections were performed by the transect method (Bibby et al. 1999) counting the remains of victims within an area of 20 m on either side of each power-supply line.

Purchase of land to conserve key nesting sites and foraging areas

Key nesting sites and foraging areas were identified and purchased. The proper management of the purchased plots guarantees sustainability of the habitat as well as improvement of the habitat quality.

Nest guarding

During the period 2009–2013, within the “Save the raptors” LIFE07 NAT/BG/000068 project, 31 breeding attempts were guarded throughout the entire breeding period by volunteers of BSPB. The guards were situated at a distance of 300–400 m from the nests, depending on the terrain, covering a perimeter within a radius of 1 km around the nests. The nest guarding was implemented on a daily basis and lasted from the beginning of the incubation period (March) till the successful fledging of the chicks. The nests were guarded from 7:00 am to sunset. The guards kept detailed diaries, recording the weather conditions, the behaviour of the eagles, as well as their response to different kinds of disturbance. If

there were disturbers impeding incubation or chick rearing, the guards would undertake the necessary steps to eliminate any disturbance.

Construction and installation of artificial nests

A total of 36 artificial wooden platforms were installed in suitable territories to attract new pairs of EIEs. In addition, three more nests were built in territories occupied by EIE pairs in order to support the breeding pairs whose nests had fallen or had been located in unsuitable places. The trees were identified taking into account several important factors – the availability of food resources, minimal human disturbance, lack of dangerous electric poles, etc. The territories where artificial nests were installed were located adjacent to areas harbouring breeding EIEs. The selection of these territories was based on the availability of sousliks, as the density

of souslik colonies was also taken into consideration (ind. / ha). Artificial nests were also installed in territories where EIE floaters had been observed.

Provision of supplementary winter and summer feeding

In the period 2009–2013, supplementary feeding was provided for 14 EIE pairs once a week during the autumn-winter seasons (October–March). A total of 483 supplementary feedings took place, 450 of which also included monitoring in order to record the effectiveness of this activity. Slaughterhouse offal and carcasses which had undergone veterinary inspection were used for the supplementary feedings. Quantities of 50 to 80 kg were provided during each supplementary feeding. Ten supplementary feeding sites were used. Supplementary feedings were provided for 22 breeding pairs of EIE once every five days during the breeding season (April–July). A total of 528 supplementary fee-

Fig. 1. Breeding distribution of eastern imperial eagle in Bulgaria between 2009 and 2013 (black square – two pairs; black circle – one pair).

Obr. 1. Hniezdne rozšírenie orlov kráľovských v Bulharsku v rokoch 2009 až 2013 (čierny štvorec – dva páry, čierny krúžok – jeden pár).

dings took place, and the effectiveness of each supplementary feeding was recorded. The food provided included pieces of beef or liver taken from animals that had died as a result of overeating or injury in the area of the Sakar SPA and the Zapadna Strandzha SPA. Each animal used for supplementary feeding had undergone a veterinary inspection. The supplementary feeding provided pieces of 500 g to 1 kg, while quantities of 3–4 kg were provided during each supplementary feeding. The places where the meat was left were deliberately set in areas near the nest (300–400 m), with no nearby roads, power-supply grid or risk of disturbance. The provision of the supplementary feeding was carried out with consideration of the natural features of the terrain, with the meat being left in clearly visible open places where birds could perch undisturbed.

Statistical analysis

The statistical processing of data was carried out using the program Statistica for Windows, Release 7.0 (Statsoft 2004). The data was analysed for normal distribution through the Shapiro-Wilk test (Shapiro et al. 1968). Results with $p < 0.05$ were considered significant. The non-parametric Mann-Whitney U-test was used when comparing or seeking correlations between different variables.

Results

Occupied territories and breeding pairs

During the period 2009–2013, 28 different breeding territories were occupied (Fig. 1). Most of them were in the south-eastern part of the country. The species bred in 22 UTM squares. Sixteen of these squares harboured one pair each, and the other six harboured two pairs each. The area harbouring the greatest number of nests ($n=11$) was the Tundzha river valley. The area with the second greatest number of nests ($n=10$) was the Sakar Mts., and the neighbouring hilly region of the Dervent Heights – western Strandzha, was the third most

important region with 5–6 confirmed breeding pairs recorded. Only one breeding pair was recorded in the western part of the country, in the Sredna Gora Mts. The population increased by 20%, as the number of pairs that occupied breeding territories increased from 20 in 2009 to 24 in 2013.

Of all 28 occupied territories, 18 were situated within SPAs. The network of SPAs covered almost 65% of the territories occupied by EIE pairs in the period 2009–2013. During the study period, 5 territories were lost, as 3 of these territories were situated within SPAs. Newly formed pairs were recorded in 10 territories, 3 of which were recorded within SPAs. Of the newly formed pairs ($n=17$) recorded during the period 2009–2013, 71% ($n=12$) were immature pairs, 17% ($n=3$) were mixed pairs, and 12% ($n=2$) were adult pairs. In general, adult pairs prevailed during the period 2009–2013 with an increasingly higher percentage.

Breeding parameters

The mean value of productivity, breeding success and fledgling success for the period 2009–2013, which included 107 breeding attempts, was estimated (Tab. 1). In general, the mean values of the breeding parameters of the EIE population for the period 2009–2013 were as follows: productivity (P) 1.03 ± 0.18 ; breeding success (BS) 1.18 ± 0.21 ; and fledgling success (FS) 1.68 ± 0.16 . The dynamics of the breeding parameters over the years was also monitored (Fig. 2).

During the period 2000–2009, $56.58\% \pm 11.38$ of the pairs, on average, had two chicks each. During the subsequent period (2009–2013), this percentage was higher, with $68.24 \pm 15.83\%$ of the pairs, on average, hatching two chicks each. The mean proportion of three-chick broods was slightly lower in the recent study period than in the previous one (2000–2009: $8.86 \pm 10.09\%$ vs. 2009–2013: $7.95 \pm 5.9\%$), and, in parallel, the frequency of one-chick broods decreased (2000–2009: $34.55 \pm 13.07\%$ vs. 2009–2013: $23.81 \pm 11.46\%$). In this study period the mean annual success rate was similar to

Tab. 1. Descriptive statistics of breeding parameters (P – productivity, BS – breeding success, FS – fledgling success, SD – standard deviation, SE – standard error)

Tab. 1. Opisná charakteristika hniezdných parametrov (P – produktivita, BS – hniezdná úspešnosť, FS – úspešnosť vyletenia, SD – štandardná odchýlka, SE – štandardná chyba)

variable premenná	n	mean priemer	confidence -95% interval spo ahlivosti	confidence +95%	min.	max.	variance rozptyl	SD	SE
P	5	1.03	0.81	1.26	0.74	1.19	0.03	0.18	0.08
BS	5	1.18	0.92	1.44	0.89	1.47	0.04	0.21	0.09
FS	5	1.68	1.49	1.88	1.54	1.90	0.03	0.16	0.07

that of the previous period (2000–2009: 64.5% vs. 2009–2013: 67.3%).

The highest values of breeding success (1.52 ± 0.87) were reported from the western Strandzha-Dervent Heights, where 21 breeding attempts were recorded. The success rate was also higher, $80.9 \pm 40.2\%$. High values of breeding parameters were observed in the region of northern Sakar ($n=15$ breeding attempts). The mean breeding success there was 1.33 ± 0.82 , and the mean success rate was $80 \pm 41.4\%$. A significant change in the values of the breeding parameters was recorded in the region of southern Sakar ($n=26$ breeding attempts), where the mean breeding success (1.23 ± 0.99) and the success rate ($69.2 \pm 47.1\%$) showed a significant increase compared with the previous study period (2000–2009: mean breeding success, 0.81; success rate, 48.69%) (Demerdzhiev et al. 2011b). In the Sredna Gora Mts. the lone breeding pair had both low breeding success (1.2 ± 1.1) and success rate ($60.0 \pm 54.5\%$). The lowest breeding success (0.76 ± 0.72) and success rate ($60 \pm 50\%$) were recorded for pairs ($n=25$ breeding attempts) nesting in the Tundzha river valley.

The annual survival rate of breeders varied from 0.795 to 0.932. As a whole, the survival rate of breeders $\pm$ SD for the period 2009–2013 was 0.847 ± 0.054 . The survival rates of breeders were found to be independent of the sex of the birds. The survival rate of breeders decreased compared with the previous study period (2000–2009; 0.954 ± 0.039), which was an indicator of higher mortality. The annual replacement of breeders increased over the years (Fig. 3).

In the period 2009–2013, replacement of breeders was recorded mostly in territories outside of SPAs

(Fig. 4). Between 2000 and 2013, replacement was recorded in 53.13% of the identified territories harbouring breeding EIEs, and in 29.41% both partners in the pair were replaced. Four breeding territories accounted for 48% of the replacement cases.

Causes of mortality

Brood mortality was accurately surveyed between 1994 and 2013, including 112 breeding failures and mortality of approximately 60 broods and 52 chicks (Tab. 2). During the first two study periods disturbances were among the major factors causing brood loss. Infertility was also one of the main reasons for breeding failure. In cases of brood abandonment, infertility was proven through egg analysis. A new threat recorded during the last period was nest robbing (eggs and chicks). The main reason for the loss of chicks during the three study periods was the insufficient food availability, resulting in starvation or sibling aggression, sometimes leading to cannibalism. The last period was also marked by an increased number of chicks lost as a result of stormy weather or dropping from the nest. There was only one recorded case of a chick poisoned in the nest for the three study periods. The mortality of juvenile and immature birds was recorded in the period 1992–2013, including 25 individuals (Fig. 5).

The most important factor causing mortality among immature birds was electrocution. Shooting and poisoning had also become important mortality factors. Between 1994 and 2013, only three cases of mortality of breeding birds were identified. One eagle was killed and two others were poisoned. All of these cases were recorded in the Zapadna Strandzha SPA and the neighbouring Dervent Heights SPA.

Fig. 2. Dynamics of the breeding parameters in the period 2009–2013 (circles – productivity, squares – breeding success, triangles – fledgling success).

Obr. 2. Dynamika hniezdnych parametrov v období 2009–2013 (krúžky – produktivita, štvorčeky – hniezdna úspešnosť, trojuholníky – úspešnosť vyletenia).

Fig. 3. Replacement of breeding birds between 2000 and 2013 (y axis – values [%], linear regression equation $y=1.141x-2281$, $R^2=0.4754$).

Obr. 3. Výmena hniezdiacich vtákov v období 2000–2013 (os y – hodnoty [%], rovnica lineárnej regresie $y=1.141x-2281$, $R^2=0.4754$).

Nest guarding

During the period 2009–2013, within the “Save the raptors” LIFE07 NAT/BG/000068 project, 31 breeding attempts were guarded throughout the entire breeding period by volunteers of BSPB. Two more nests were guarded from the hatching of the chicks till their fledging. In addition, during the same period, 20 breeding attempts were guarded by volunteers of the Green Balkans Federation and the Bulgarian Academy of Science (G. Gradev, T. Michev, pers. comm.).

The difference between the breeding success of the guarded and that of the non-guarded pairs recorded in the period 2009–2013 was not statistically significant ($Z=1.25$, $p=0.2$). However, the guarded pairs had a higher mean breeding success 1.32 ± 0.88 than the non-guarded pairs 1.06 ± 0.91 . The recorded mean success rate of the guarded pairs was $77.3\pm42.4\%$, while that of the non-guarded pairs was $64.6\pm48.3\%$.

Construction and installation of artificial nests

As a whole, 39% of all artificial nests installed in the period 2009–2013 were occupied by birds as follows, EIE – three newly formed pairs, long-legged buzzard (*Buteo rufinus*) – seven nests, common buzzard (*Buteo buteo*) – one nest, hobby (*Falco subbuteo*) – one nest and black stork (*Ciconia nigra*) – two nests.

Provision of winter and summer supplementary feeding

Different numbers of EIEs fed in 50% ($n=223$) of the implemented winter supplementary feedings. No less than 45 EIEs of different ages visited the supplementary

feeding sites. The most numerous group was that of the adult birds (51%) from the pairs breeding in the region. Birds in immature plumage were represented mostly by immature individuals (2–3 years of age) (22%), follow-

Fig. 4. Replacement of breeding birds within the SPA (squares) and outside the SPA (triangles).

Obr. 4. Výmena hniezdiacich vtákov vnútri (štvorčeky) a mimo (trojuholníky) územia SPA.

Fig. 5. Cause of death of juvenile and immature individuals of eastern imperial eagles between 1992 and 2013.

Obr. 5. Príčiny úmrtí mladých a imaturných jedincov orlov kráľovských v období 1992–2013.

Tab. 2. Brood mortality of eggs and chicks between 1994–2013
Tab. 2. Mortalita vajec a mláďat v období 1994–2013

factors of mortality / faktory mortality	1994–2002		2003–2008		2009–2013	
	eggs / vajcia	chicks / mlá atá	eggs / vajcia	chicks / mlá atá	eggs / vajcia	chicks / mlá atá
infertility / neplodnosť	8; 44%	11; 47%	6; 32%			
disturbance / vyrušovanie	8; 44%	7; 31%	1; 5%			
storm / búrka	3; 16%	1; 5%	3; 11%			
bad weather conditions / nepriaznivé počasie	1; 4%					
cutting of nest trees / výrub hniezdných stromov	1; 4%					
poisoning / otravy	1; 5%					
nest robbing / vykrádanie hniezd	2; 25%	1; 4%	5; 26%	2; 8%		
unknown factors / neznáme faktory	2; 12%	1; 12%	2; 9%	7; 37%	6; 32%	6; 23%
starvation / hladovanie	3; 38%	3; 16%	5; 19%			
cainism / kainizmus	2; 25%	4; 21%	2; 8%			
dropping from the nest / vypadnutie z hniezda	1; 5 %	6; 23%				
predation / predácia	2; 8%					

ed by juvenile (16%) and sub-adult eagles (4–5 years of age) (11%). Two of the supplementary feeding sites (Sakar and Kamenski bair) were visited by two of the birds tagged with satellite/GPS transmitters. In addition to the EIE, nine more species of birds of prey also visited the supplementary feeding sites, golden eagle (*Aquila chrysaetos*), booted eagle (*Aquila pennata*), black kite (*Milvus migrans*), common buzzard (*Buteo buteo*), rough-legged buzzard (*Buteo lagopus*), long-legged buzzard (*Buteo rufinus*), northern goshawk (*Accipiter gentilis*), peregrine falcon (*Falco peregrinus*), and hen harrier (*Circus cyaneus*).

There was no statistically significant difference between the breeding success of the supplementary-fed pairs and those for which no supplementary feeding was provided ($Z=0.79$, $p=0.43$). Supplementary-fed pairs that did not use the provided food were not included in the analysis. However, the birds taking from the supplementary food had a higher mean breeding success 1.53 ± 0.62 compared with those for which no supplementary feeding was provided 1.33 ± 0.87 .

Satellite telemetry

The satellite telemetry enabled the identification of the following temporary settlement areas, harbouring concentrations of EIEs.

The region of the Besaparski Hills (central Bulgaria). The region harbours concentrations of 3 to 6 individuals throughout the year (Demerdzhiev 2011). The European souslik (*Spermophilus citellus*) and the domestic pigeon (*Columba livia* f. *domestica*) represent the main prey species. The major threat is the use of poisonous baits (live pigeons smeared with poison) for birds of prey. Other serious threats include: the ploughing of grasslands and their subsequent conversion into arable land involving significant deterioration of the habitat quality and considerable reduction of the souslik colonies; the hazardous power-supply network; and large-scale quarry opening. Two immature EIEs were found dead, and it was proven that one of the birds had been poisoned.

The region of the Topolchansko pole – Kamenski bair (eastern Bulgaria). The region harbours concentrations of 5 to 14 individuals throughout the year (Demerdzhiev 2011). The area was visited by more than 50% of the birds tagged with satellite/GPS transmitters. The European souslik, the domestic pigeon, the European hare (*Lepus europaeus*) as well as slaughterhouse offal represent the main food base. The major threat is the hazardous power-supply network. Other

serious threats include: use of poisonous substances to control the number of European sousliks; the large-scale ploughing of grasslands and their subsequent conversion into arable land, thus reducing the food availability for the eagles; and illegal shooting. Two immature EIEs were found dead – one electrocuted and one shot.

The region of Malko Sharkovo dam (south-eastern Bulgaria). The region harbours concentrations of three to eight individuals, mostly in winter (Zelev et al. 2009). The main food base includes slaughterhouse offal and voles (*Microtus* sp). The major threats include: the use of poisonous baits for predator control; use of pesticides for rodent control; and the hazardous power supply network.

The region of Dobrudzha (north-eastern Bulgaria and south-eastern Romania). The region harbours concentrations of three to five individuals in spring and summer. The European souslik, voles, the European hare and the common pheasant (*Phasianus colchicus*) represent the main prey species. The threats are related to the hazardous power-supply network, intensification of agriculture as well as possible use of pesticides.

The region lying to the north of the Sea of Marmara, between the towns of Tekirdag and Corlu (European Turkey). The region harbours concentrations of 5 to 12 individuals in winter. Voles and the yellow-legged gull (*Larus michahellis*) represent the main prey species. The threats are related to the use of poisons, illegal shooting and the hazardous power-supply network. Four EIEs were found dead – one shot, one poisoned, and the cause of death of the other two birds remains unknown.

The region of the western Anatolia (Turkey). The region harbours concentrations of four to seven individuals throughout the year. In summer, the region is abundant in Anatolian souslik (*Spermophilus xanthopymnus*). The food base during the winter period has not been identified. The major threats include the hazardous power-supply network, the ploughing of pastures and their afforestation with cedar (*Cedrus* sp.), the opening of large-scale quarries in areas harbouring dense souslik colonies, as well as intensification of farming and agriculture, which presumably involves potential use of pesticides. One electrocuted immature EIE was found dead.

The region of Ankara (Turkey). The region harbours concentrations of three to ten individuals, mostly in winter. The food base has not been identified. The major threat is the hazardous power-supply network. One electrocuted juvenile EIE was found dead.

The results of a total of 20 juvenile EIEs tagged with satellite / GPS transmitters in the period 2008–2012 show that in their first year the birds migrate and winter mostly beyond the borders of Bulgaria. Four of the tagged eagles overwintered in the Arabian Peninsula and the Near East, seven eagles in Anatolia, four eagles in the European part of Turkey, to the north of the coastline of the Sea of Marmara, one EIE overwintered in Sudan, and one individual did not migrate, spending the winter season in the Sakar Mts. During the second winter period, two EIEs did not migrate and overwintered in south-eastern Bulgaria.

Purchase of land to conserve key nesting sites and foraging areas

A total of 14.32 ha of riparian habitats, representing eleven separate plots in the areas of seven settlements (five in the Sakar SPA and two in the Zapadna Strandzha SPA) were purchased. Two of the purchased plots harbour active nests of EIEs. In addition, a total of 59.32 ha of fields with souslik colonies, representing 74 separate plots in the territories of eight breeding pairs and one temporary settlement area, were purchased.

Identification and insulation of dangerous electricity poles

Electrocution victims accounted for 69.02% of all registered deaths ($n=297$) along the studied power lines (Demerdzhiev 2014a). The species with the highest mortality rate due to electrocution were white stork (*Ciconia ciconia*) – 24.39%, common buzzard – 12.68%, hooded crow (*Corvus cornix*) – 9.76%, and magpie (*Pica pica*) – 8.29%. Collision with wires accounted for 30.98% of the registered cases of death ($n=92$) along the 20 kV power-supply network. The species that most often fell victims to collisions with wires were white stork – 21.7% and common buzzard and starling (*Sturnus vulgaris*) with 7.6% each (Demerdzhiev 2014a). All victims were gathered under 144 of all 2,116 studied poles. These 144 power poles, called ‘killer poles’, accounted for 6.8% of all power poles included in the study. In addition, 608 hazardous electric poles in the territories of 7 pairs were insulated. No victims were found under the insulated poles.

Discussion

Population dynamics

During the latest study period (2009–2013), in addition to the population growth, gradual expansion of the dis-

tribution area was also recorded. The increasing population expanded along the Tundzha river valley, occupying new territories. Compared with the previous study period (2000–2009), the number of pairs along the Tundzha River increased more than two-fold. However, the Tundzha river valley and the surrounding areas hold suitable habitats, where floaters seeking unoccupied territories are normally found. The expansion in this region will probably continue in the future. The population of EIE in Sakar and Dervent Heights – western Strandzha is stable, of unchanged abundance and distribution compared with the previous study period. The loss of territories of the mountain eco-type that had begun in the previous study periods continued during the last one as well. Of the birds breeding in the mountains, only one pair was left in the Sredna Gora Mts. The other pair in the Sredna Gora Mts. and the pair in the eastern Rhodopes Mts. had disappeared. The new pairs consisted mainly of birds in immature plumage, occupying vacant territories.

The breeding success increased by 16.8% compared with the previous study period (2000–2009) (Demerdzhiev et al. 2011b). The mean productivity of the population was also higher (14.4%), and the increase in the mean fledgling success was lower (7.7%). The increase of the breeding parameters was a function of the increased number of cases of two-chick broods. In parallel with the increasing population size, the decrease of the breeding success could be predicted because of density-dependent population regulation (Ferrer 2001, Ferrer & Penteriani 2008). In our case, breeding success also increased with the population size, which is contrary to the density-dependent population regulation hypothesis. The reason is that the population inhabits mainly suitable lowland habitats; therefore, the population is most probably still under-saturated and density-dependent regulation has not yet significantly affected the population parameters.

The breeding parameters recorded in the regions of western Strandzha – Dervent Heights and northern Sakar remained almost unchanged compared with the previous study period (Demerdzhiev et al. 2011b), maintaining their high values. A slight increase was recorded in the Sredna Gora Mts., where during this study period only one EIE pair bred. The significant increase in the breeding success and the success rate of the pairs breeding in southern Sakar was mainly due to the conservation measures undertaken in the region, in particular guarding risky nests during the breeding period, providing supplementary feeding for the pairs during

the spring and the breeding season, as well as applying agri-environmental measures aimed, in general, at improving the habitat quality. The emerging trend of low breeding success and success rate of the pairs breeding in the Tundzha river valley is a result of a number of factors. The EIE population in Bulgaria is increasing mostly in this region, as the newly formed pairs consist of birds in immature plumage of lower breeding potential, which are less experienced in rearing offspring and often breed in unsuitable areas. On the other hand, some of the newly occupied territories along the Tundzha river valley are of poorer quality and lower occupancy rate and produce fewer chicks. Moreover, these territories fall beyond the boundaries of SPAs, the threats there are less explored and studied and the conservation activities are not as efficient as in the other regions.

Obviously, the increase in the replacement rate is a function of the increased mortality over the years. In some territories, the higher replacement rate was probably a result of the smaller volume of conservation efforts made in those areas. The actions undertaken by nature conservation organisations and institutions, aimed mostly at preserving the species within the SPAs, produce good results, and the EIE population within these sites is considerably protected. The increase in the EIE population in Bulgaria has taken place mostly in territories falling beyond the borders of the SPAs, as in many cases the mortality of the species there is high – most probably as a result of the insufficient awareness of the local people or some other reasons. Therefore, the institutions and organizations working for the protection of the species have to make more efforts in these regions in the future, in order to secure the survival of the EIE.

The temporary settlement areas are used by the juvenile birds when they leave their breeding territories, until they establish and occupy their own territories (Ferrer 2001, Penteriani et al. 2005). In certain parts of the temporary settlement areas, offering plenty of food within a relatively small area, the non-breeding eagles form concentrations and can be observed throughout the year. The areas known to harbour bird concentrations in Bulgaria include the Besaparski Hills, the region of Topolchansko pole – Kamenski bair, as well as the Malko Sharkovo dam (Zelev et al. 2009, Demerdzhiev 2011, Stoychev et al. 2012). Of all 20 juvenile EIEs tagged with satellite/GPS transmitters in the period 2008–2012, one individual visited the Besaparski Hills, and 11 birds stayed in the region of Topolchansko pole – Kamenski bair for different periods of time. Satellite

telemetry enabled the identification of major factors that cause mortality of juveniles and immature EIEs, the wintering grounds, as well as previously unknown temporary settlement areas, some of which are of global significance for the species.

Mortality and undertaken conservation efforts

The increasing number of nests guarded during the breeding season in recent years significantly reduced the importance of human disturbance. Infertility, as a factor leading to breeding failure, was mostly due to premature breeding attempts, even at the age of two. Both during this study period and the previous one (Demerdzhiev et al. 2011b), new pairs occupying vacant territories consisted mainly of birds in immature plumage, which, in most cases, had not reached sexual maturity before their first breeding attempts. Nest robbing of eggs and chicks is a new threat recorded in the country. It is still related to a few isolated cases and foreigners' collections abroad. The insufficient food availability can result in starvation, leading to death or sibling aggression. Aggression among siblings depends on the frequency of food supply and the abundance of the major prey species within the territory of the pair (Meyburg & Garzon 1973, Meyburg 1974, 1978, Gonzalez 1991). According to Lack's hypothesis (1954), in the case of a shortage of food resources needed for rearing the whole aerie, premature death of some of the chicks is a kind of mechanism that prevents further loss of resources. Data on EIE cannibalism has been published in different countries (Svehlik & Meyburg 1979, Vasic & Misirlic 2002, Petrov & Stoychev 2002, Horvath et al. 2011, Demerdzhiev 2011). However, sibling aggression is not a significant factor causing mortality of chicks. Adverse weather conditions also lead to the loss of chicks, usually from falling from the nest in high winds. There were even cases when the whole nest was blown down. More than 1/3 of the victims died as a result of electrocution. The undertaken surveys revealed that the 20 kV grid in the country was made up of hazardous power poles putting birds at risk (Stoychev & Karafeizov 2004, Demerdzhiev et al. 2009, Gerdzhikov & Demerdzhiev 2009, Demerdzhiev 2014a). Prior to the introduction of satellite telemetry as a method of studying the threats to immature EIEs, this factor, which causes most of the mortality cases, was unknown. The negative impact of the dangerous power-supply network spreads beyond the borders of the country, causing bird mortality in neighbouring Turkey, where three of the EIEs tagged in

Bulgaria were killed by the hazardous grid. It was found out that threats like shooting and poisonous baits still exist. Another new threat was identified thanks to the satellite telemetry – namely, the use of poisonous baits by pigeon fanciers. This still locally practiced method, using live pigeons smeared with poison and left as live baits in places where raptors can easily catch them, could turn into a serious problem in the future. In the region, where an immature EIE died as a result of the use of such baits, this method practiced by the pigeon fanciers has led to a serious decline in the populations of the long-legged buzzard and the peregrine falcon (*Falco peregrinus*) (Demerdzhiev 2014b). This was probably the reason for the loss of a saker falcon (*Falco cherrug*) pair in that region. In the period 2009–2013, a breeding EIE was recorded dead as a result of poisonous bait used for predator control. The Sakar Mts., the Derwent Heights and the western Strandzha, where most of the EIE population is concentrated, harbour high densities of jackal (*Canis aureus*). Because of the damage jackals cause to the local people and hunters, there are cases of poisonous baits set to control this predator. Yet, thanks to a broad awareness-raising campaign implemented by the nature conservation organisations and institutions on the significance of the EIE for the ecosystems and the damages caused by the poisonous baits, such incidents are rare. Another case of poisonous baits was recorded in this region during the project period, when a beech marten (*Martes foina*) and domestic dogs were found poisoned.

Different EIE pairs show different tolerance towards human presence. Some pairs let farm animals and shepherds approach the nest tree during the incubation period. However, although accustomed to the traditional agricultural activities, EIEs leave the nests in case of a change in the people's behaviour or the emergence of machines making noise. Examples of such disturbance include ploughing under the actual nest in the middle of the incubation period, shepherds shouting and listening to the radio, machines extracting sand and workers collecting stones. Ornithological tourism can be a threat, too, since birds react from a great distance (more than 300 meters) to any objects directed at them and to the emergence of groups of people. The negative impact of human disturbance on the reproductive success of the EIE is particularly visible in some of the studied regions (Demerdzhiev et al. 2011b). The guarding of nests exposed to frequent human disturbance during the breeding period increases the success rate by more than 20% and the breeding success of “risky” pairs by 35% (Demerdzhiev 2011).

In autumn and winter, when the food sources are limited, EIEs often feed on carrion, sometimes even at dumps. Thus, they can come across poisoned animals or poison baits set out against wolves and jackals. The supplementary feeding of the pairs and of immature and juvenile birds supports the eagles during this difficult period, providing easily accessible food, thus increasing their survival rate. This is particularly valid for birds in immature plumage which are not experienced enough and find it difficult to catch their prey when there is snow. Data from satellite telemetry proved that EIEs in their second year do not migrate but overwinter mainly in the south-eastern part of the country, where the supplementary feeding sites are located.

Raptors' ability to secure enough food is a major factor limiting incubation. The good condition of the birds during the winter period is associated with the regular supply of food and has a direct correlation with the clutch size (Newton 1979). It has been proven that the abundance of food resources increases the levels of hormones in the blood, which results in more eggs laid. In 2013, three pairs which regularly fed at the supplementary feeding sites laid three eggs each, and two of them successfully raised their three-chick offspring. The EIE pairs demonstrated a different attitude towards the provided food in the summer season. Some of them took more than 90% of the provided meat; others fed in only half of the cases, while there were pairs that fed accidentally or did not take the food at all. Moreover, the birds changed their behaviour over time. In a year abundant in prey the birds did not take the provided food, while in other years the same birds used to take the meat. Seasonal differences in the behaviour of the birds were also recorded. Birds that did not eat during the summer feedings took the food provided during the winter. During the breeding season, the eagles were recorded feeding on the meat left at the supplementary feeding site as well as taking the provided food to the nest.

In Bulgaria in recent years a number of former nesting sites and dense souslik colonies in semi-natural grassland have declined significantly due to major land-use changes, such as land abandonment or conversion into intensive agricultural areas. The purchase of a mosaic of related nesting and feeding areas for key species such as EIE is seen as essential to prevent the national extinction of the species due to rapid land-use changes. High concentrations of sousliks are particularly important to EIEs. Because EIE show considerable nest-site fidelity, BSPB embarked upon a successful strategy

of buying key plots of land that incorporate nesting and feeding sites.

The insulated electric poles are situated in the territories of seven EIE pairs as follows: four territories in the Sakar SPA, one territory in the Zapadna Strandzha SPA, one territory in the Kamenski bair SPA, and one territory in the Sredna Gora SPA. The insulation of hazardous electric poles provides a long-term solution to the problem related to the electrocution of birds. In the fall of 2013, EVN and BSPB launched implementation of the project "Life for safe grid" funded by the LIFE+ Program of the European Commission. The project provides for burying 45 km of power lines underground in the vicinities of three EIE nests, as well as insulating 2,740 hazardous electric poles in the areas harbouring breeding EIE pairs.

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