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ORIGINAL PAPER

# Studying the demographic drivers of an increasing Imperial Eagle population to inform conservation management

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**Abstract** Assessing whether conservation management actions are effective requires a good understanding of the demographic parameters that contribute to the population growth rate. Among the key demographic parameters influencing a population, immigration is one of the most difficult to measure empirically but may mask or accentuate the effects of conservation measures. We use an integrated population model to assess whether a population increase of a large raptor species can be explained by high fecundity and survival resulting from local conservation measures, or whether immigration may have contributed to population growth. We monitored the Eastern Imperial Eagle (*Aquila heliaca*) population in Bulgaria from 1998 to 2014, and tracked juveniles using satellite transmitters to estimate survival probability over the first three years of life. We used intensive territory monitoring of breeding birds to estimate survival probabilities and fecundity of birds older than 3 years. The Imperial Eagle population in Bulgaria increased by about 11 % per year between 1998 and 2014 ($\lambda = 1.111$, 95 % credible interval 1.076–1.156). While local conservation measures have succeeded in reducing nest loss and the mortality of adults (adult survival = 0.924; 0.887–0.955), high mortality of juveniles during their first year of life resulted in only 12 % of fledglings surviving to adult age. Based on these survival probabilities and the estimated fecundity of breeding pairs in Bulgaria (1.063; 0.932–1.203), some immigration may have contributed to the population growth in Bulgaria. Because the integrated population model accounts for all the uncertainty associated with disparate data sources, the estimated immigration rate was too

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imprecise (0.143–2.862 young birds per breeding pair) to quantify the relative importance of immigration. Future conservation measures for Imperial Eagles need to focus on improving the survival of juvenile birds, particularly the reduction of electrocution risk in Eastern Europe and the Middle East.

**Keywords** Bulgaria · Bird of prey · Integrated population model · Bayesian · WinBUGS · Multi-state model

## Introduction

Efficient conservation requires a good understanding of the ecology of the target species and the demographic factors affecting their populations. The key demographic processes recruitment, survival, emigration and immigration that determine population dynamics can, however, be difficult to estimate, especially in long-lived species with delayed maturity (Katzner et al. 2007, 2011; Margalida et al. 2011). Many large raptor species exhibit long life-spans and delayed maturity, and their population dynamics are of great interest to understand the causes of population declines evident in many populations (Thiollay 2006; Virani et al. 2011; Ogada et al. 2012).

Conservation management for raptors often targets breeding productivity and reduction in direct mortality factors (Richardson and Miller 1997; González et al. 2006a; Ferrer et al. 2013). Whether such management measures actually yield effective conservation of the target population requires an understanding of the various demographic parameters that influence the abundance of a population (Ferrer and Hiraldo 1991; Ferrer and Penteriani 2007; Soutullo et al. 2008). Demographic models have been used to improve the understanding of population dynamics and the development of conservation strategies for several raptor species (Katzner et al. 2006; Soutullo et al. 2008; Ortega et al. 2009), but estimating the abundance and survival of cryptic immature age classes remains a formidable challenge (Katzner et al. 2011; Margalida et al. 2011). Movement of individuals between populations is known for several raptor species (Ortega et al. 2009), and this immigration may mask conditions inherent in the target population and potentially lead to erroneous conclusions about the effectiveness of management (Katzner et al. 2006; Schaub et al. 2010; Altwegg et al. 2014). Assessing the effectiveness of raptor conservation management therefore requires approaches that can explicitly account for immigration.

Immigration was not included in earlier raptor population models because no feasible approach existed at that time (Katzner et al. 2006), but recent advances in integrated population modelling facilitate the estimation of immigration in a unified analysis that combines population count data and data on several demographic parameters (Besbeas et al. 2002; Abadi et al. 2010b; Schaub et al. 2013). Integrated population models have been used recently to estimate immigration in a stable (Schaub et al. 2010) and an increasing raptor species (Altwegg et al. 2014). Here we use an integrated population model in a strongly increasing population of the Eastern Imperial Eagle (*Aquila heliaca*) to specifically determine whether the population increase could be explained by conservation management or whether immigration may have contributed to the increase of the population.

The Eastern Imperial Eagle (hereafter 'Imperial Eagle') is a large species nesting from Central Europe, the Balkans, Central Asia, and South Siberia to China and Mongolia.

While the European population is considered stable (Demerdzhiev et al. 2011b), the species is classified as globally vulnerable and decreasing (BirdLife International 2014). Conservation measures to protect nests from human disturbance and persecution, as well as measures to reduce mortality on breeding grounds have been implemented to conserve the species (Kovács et al. 2008; Danko et al. 2011; Demerdzhiev et al. 2011a; Stoychev et al. 2013), and since 2000 the population in several countries of eastern Europe has been increasing (Karyakin et al. 2006; Danko et al. 2011; Demerdzhiev et al. 2011a; Horváth et al. 2011). Here we focus on the Imperial Eagle population in Bulgaria, which is part of a larger meta-population, and is connected with eagles breeding in the European part of Turkey and the population of the species in Asia Minor.

In this study, we use population and nest monitoring data from 1998 to 2014 in combination with survival data of satellite-tracked juvenile Imperial Eagles to construct an integrated population model aiming at a better understanding of the demographic drivers of the recent population increase of Imperial Eagles in Bulgaria. Because the Bulgarian population forms part of a meta-population, immigration may have contributed to the recent population growth and we specifically incorporated immigration as a parameter in our population model. We further assess the viability of the Imperial Eagle population in Bulgaria over the next 10 years and identify important conservation challenges that require future management.

## Methods

### Study area and field data collection

Imperial Eagle territories in Bulgaria are clustered in the Sredna Gora mountains (E 24°27′40″ N 42°36′28″), the Sakar mountains (E 26°19′00″ N 42°02′00″), the Dervent Heights (E 26°45′54″ N 41°58′52″), the Western Strandzha mountains (E 27°1′1.2″ N 42°9′0″), the Tundzha river valley (E 26°30′0″ N 42°28′59.88″), and the Eastern Rhodopes (E 25°52′1.2″ N 41°37′58.8″). We inspected 125 10 $\times$ 10 km UTM grid squares in the areas harboring breeding Imperial Eagles every year or every 2 years in areas without previously occupied territories. Systematic studies were carried out every year to minimize the risk of overlooking occupied territories, but single territories may have been missed in mountainous areas especially prior to 2002 (Stoychev et al. 2004; Demerdzhiev et al. 2011a). We searched for territories and nests between February and May, when trees were not in full leaf and nests were visible, and used the eagles' behaviour to locate their nests. During the breeding period (February–August) we monitored occupied nests once or twice per month until chicks fledged. A territory was considered occupied if we regularly observed a pair of adult or pre-adult birds and found an old nest, or if we observed territory defence, nest building, or other reproductive activity. We considered pairs that laid eggs and started incubating as breeding pairs (Katzner et al. 2006). This intensive monitoring yielded an annual number of breeding pairs and fledglings.

### Conservation management

First direct conservation measures to protect Imperial Eagles in Bulgaria were implemented in the 1990s (Petrov and Stoychev 2002). Active conservation management that included permanent nest guarding and supplementary feeding was initiated in 2001 and intensified after 2004 (Stoychev et al. 2004; Demerdzhiev et al. 2011a; 2014). Between

2001 and 2014, 94 nests were guarded during the breeding season—18 in the period 2001–2004 and 76 in the period 2005–2014. Supplementary feeding can be a successful conservation strategy for raptors (Ferrer and Penteriani 2007; Cortés-Avizanda et al. 2010; Margalida et al. 2014), and we provided supplementary food for 36 breeding pairs once every 5 days during the breeding season (April–July). In the period 2009–2014, supplementary feeding was also provided once a week during the autumn and winter (October–March) for 14 Imperial Eagle pairs. Since 2009, a total of 561 power pylons were insulated in seven territories to reduce mortality of adult and juvenile Imperial Eagles. In addition, an intensive awareness raising campaign was implemented among local stakeholders in all known territories in order to prevent shooting, poisoning and cutting of nesting trees. Other direct conservation measures implemented include the removal and relocation of nests built on unstable trees or in disturbed sites that cannot be guarded, restriction of agricultural and forestry activities close to nests, construction of artificial nests, and captive rehabilitation of nestlings ($n < 10$) that had fallen out of nests (Demerdzhiev et al. 2014).

## Satellite tracking

Between 2008 and 2014, we equipped 24 juveniles with satellite transmitters at the age of 55–60 days just before the juveniles left the nest. We used solar-powered 70 g GPS transmitters produced by Microwave Telemetry (www.microwavetelemetry.com) that were fixed to the birds' backs using a Teflon ribbon harness ($n = 21$) or a plastic-coated metal harness ($n = 3$). The entire transmitter equipment did not exceed 3 % of the juveniles' body mass as recommended by Kenward (2001), in order to minimize the effects on birds' behaviour. The devices recorded the geographic location of the bird daily over a period of up to 4 years. When a tag indicated mortality of a bird, a field team searched for the carcass in the area of the last recorded location to establish the likely cause of mortality. In addition, we used data received from three birds marked with radio transmitters in 2007 and 2008 which returned to Bulgaria in 2010 (Gradev et al. 2011). Two of these birds subsequently started to breed.

## Estimation of demographic parameters and population growth rate

We used an integrated population model (Besbeas et al. 2002; Brooks et al. 2004; Schaub and Abadi 2011) to estimate demographic parameters and population growth rate of the Imperial Eagle population in Bulgaria. An integrated population model provides a joint analytical framework to estimate both annual abundance data and demographic parameters simultaneously in a single model, which generally leads to more precise parameter estimates (Abadi et al. 2010a). In addition, an integrated population model facilitates the estimation of parameters for which no empirical data exist, such as immigration, while accounting for all sources of uncertainty (Abadi et al. 2010b; Schaub et al. 2010; Schaub and Abadi 2011). Our integrated population model used a similar approach for estimating productivity and immigration probabilities as the model developed by Schaub et al. (2010). Briefly, we used a hierarchical state-space model (De Valpine 2003; Clark and Bjørnstad 2004; Kéry and Schaub 2012) to describe the population trajectory of Imperial Eagles using the annual census data of breeding birds. The annual abundance of Imperial Eagles depends on demographic parameters such as productivity, survival of juveniles and adults, and immigration. To estimate productivity, we used the annual number of fledglings corrected for the annual number of observed pairs in a GLM with a Poisson error distribution. Although fecundity may decrease at higher population size due to density-dependent effects (Ferrer and Donazar 1996; Carrete et al. 2006), the population size of Imperial Eagles in Bulgaria was too low during our study period for such effects (Demerdzhiev et al. 2014) and we did not incorporate density-dependence in our model.

To estimate survival, we used the satellite tracking data of fledglings, and the replacement of territorial adults. We used known-fate capture-recapture methods to estimate monthly survival probability of satellite-tagged birds between fledging and 3 years of age (Murray 2006). We assumed that monthly survival during the first winter (up to 6 months of age) was lower than subsequent survival (Katzner et al. 2006), and incorporated this temporal structure into survival models. If the satellite tags failed or fell off while the bird was still alive, we censored the data for the respective bird at the last month in which the tag was working. Annual survival was estimated by multiplying the respective monthly survival estimates over the first, second and third year of life (Powell 2007). The attachment of satellite transmitters to smaller raptors has reduced survival probability of birds (Steenhof et al. 2006; Peniche et al. 2011), and it is therefore possible that our estimates of juvenile survival probability may be lower than those of unmarked birds. However, other studies on large eagles using a similar backpack harness design found no evidence of reduced survival for marked individuals (Buehler et al. 1991; Bowman et al. 1995; McIntyre et al. 2006), and we therefore assumed that any tag-related mortality was negligible.

Because the survival estimation based on satellite telemetry covered only the period between fledging and tag failure, we were only able to estimate survival for the juvenile (first year of life), second, and third-year birds from these data. To estimate the annual survival probability of older immature and adult birds, we used the territory occupancy of birds that could be aged based on plumage characteristics to be in their third or fourth year. 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 1 year later (Roth and Amrhein 2010; Hernández-Matías et al. 2011). Similarly, we assumed that territorial adults had survived if a bird of the same sex with similar plumage was observed 1 year later. If an immature or adult bird of a given sex had been replaced by a bird in earlier plumage, we recorded the previous territory-holder as 'unobserved'. This approach relies on the critical assumption of high breeding territory fidelity in Imperial Eagles, an assumption we consider realistic because Imperial Eagles are site faithful to breeding territories (del Hoyo et al. 1994; Rudnick et al. 2005). Some birds may occasionally abandon and switch territories (Ferrer and Bisson 2003; Vili et al. 2013), which would result in underestimated survival probabilities, but given our results (see below) we consider such events negligible. From individual turnover observations we constructed encounter histories for each territorial bird and estimated annual survival probabilities for different age classes using an age-structured multi-state model where each state represented an age class (Kéry and Schaub 2012).

The integrated population model that combined the different data sets was based on an age-structured matrix population model developed by Katzner et al. (2006) for the same species. We considered six different age classes, and assumed that all adult birds (5 years and older) would attempt to reproduce (Katzner et al. 2006). However, some younger birds also attempt to breed, especially when populations are small and below carrying capacity (Ferrer et al. 2004; Demerdzhiev et al. 2011a; Horal 2011). We therefore included two parameters in the integrated population model to estimate the proportion of 3 and 4 year old birds that breed in a given year, which effectively allowed for a flexible age at first breeding. We further assumed an equal sex ratio at fledging to incorporate the estimated annual productivity into our female-based population model. The number of birds in each age class was estimated for each year based on a Poisson process and the survival probability of birds from the previous year (Abadi et al. 2010b). Because Imperial Eagles are mostly site-faithful as adults, we assumed that dispersal occurred in early life-history stages. We therefore estimated the number of immigrants by allowing immigrants to enter the immature life-history stages, and we defined immigration rate as the number of 1-year old immigrated females per breeding pair in Bulgaria in the previous year (Schaub et al. 2010). This formulation allows a direct assessment whether population growth rate is mostly dependent on local productivity or immigration.

We also used the population growth rate estimated with the integrated population model to assess the probability of population decline and extinction in Bulgaria over the next 10 years. For that purpose, we included a 10-year projection in the model run (Kéry and Schaub 2012; Oppel et al. 2014) and estimated the probability of a population decline occurring as the proportion of simulations that yielded a future population size smaller than the population size recorded in 2014. We used a Bayesian framework for inference and parameter estimation because it provided more flexibility and allowed for the incorporation of existing information to inform prior distributions for demographic parameters (Wade 2000; Brooks et al. 2004; Schaub et al. 2007). Specifically, we used diffuse priors (0–1) for the poorly known survival probabilities during the first three years of life, but curtailed priors of survival probabilities of older individuals to values (0.5–1) consistent with previous studies (Katzner et al. 2006; Ortega et al. 2009). The prior for immigration rate was uninformative and allowed for immigration to explain from nothing to all of the population growth in Bulgaria. We fitted the integrated population model in program WinBUGS (Lunn et al. 2000) called from R 3.1.0 (R Development Core Team 2014) via the package 'R2WinBUGS' (Sturtz et al. 2005). We ran three Markov chains each with 750,000 iterations and discarded the first 250,000 iterations. From the remaining iterations we only used every 5th iteration for inference, and we tested for convergence using the Gelman–Rubin diagnostic (Brooks and Gelman 1998). We present posterior estimates of parameters with 95 % credible intervals.

## Results

We monitored 245 breeding attempts during the period 1998–2014 and recorded an increase from 12 breeding birds in 1998 to 52 breeding birds in 2014 (Fig. 1). The integrated population model indicated that the Imperial Eagle population in Bulgaria increased substantially between 1998 and 2014 ($\lambda = 1.111$, Table 1). The mean estimated fecundity of the breeding pairs in Bulgaria was slightly higher and estimated with much more precision than the immigration rate (Table 1).

Of the 27 tracked juveniles, 25 provided more than 6 months of data, and 17 (68 %) of these survived the first 6 months, but only 11 (50 % of 22 birds) survived the first year. Consequently, the estimated survival of juveniles was low (Table 1), increased in the second year, and then declined in the third year (Table 1). However, because most satellite-tracked birds did not provide data in their third year, there was very high uncertainty around the third year survival estimate (Table 1). Similarly, survival probability of the first age class informed by territorial birds (survival between the third and fourth year) was relatively imprecise and may have been affected by emigration from initially acquired territories (Table 1). Fifth year and adult survival for the study period were >0.9 (Table 1). Overall, the probability to survive from fledging to adulthood (5 years) was 0.12, and the Imperial Eagle super-population (including the source

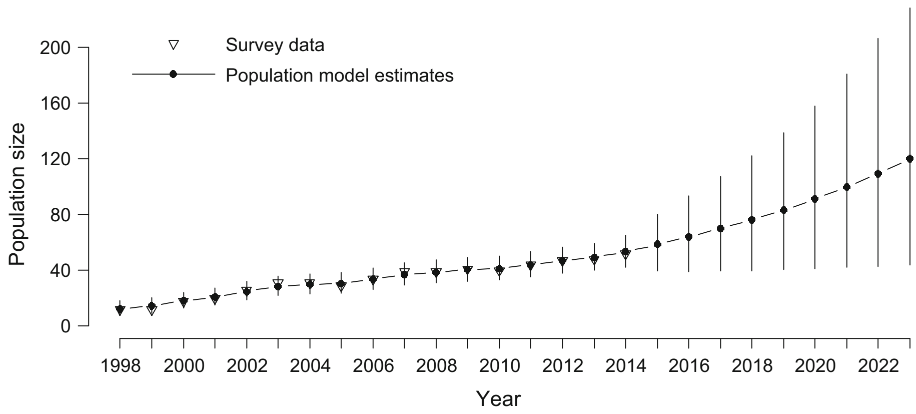


**Fig. 1** Observed and estimated population size of Eastern Imperial Eagles in Bulgaria (number of breeding individuals) between 1998 and 2014. Estimates were based on an integrated population model taking survey, fecundity, and survival data into account

**Table 1** Mean estimates (±95 % credible interval) of demographic parameters of the Eastern Imperial Eagle population in Bulgaria between 1998 and 2014 estimated with an integrated population model

| | Mean estimate | Lower credible limit | Upper credible limit |
|---|---|---|---|
| Juvenile survival | 0.500 | 0.340 | 0.662 |
| Immature survival [1–2] | 0.723 | 0.506 | 0.896 |
| Immature survival [2–3] | 0.541 | 0.168 | 0.906 |
| Immature survival [3–4] | 0.617 | 0.504 | 0.842 |
| Immature survival [4–5] | 0.907 | 0.781 | 0.985 |
| Adult survival | 0.924 | 0.887 | 0.955 |
| Breeding probability [3 y] | 0.294 | 0.017 | 0.581 |
| Breeding probability [4 y] | 0.458 | 0.122 | 0.781 |
| Immigration rate | 0.848 | 0.143 | 2.862 |
| Mean fecundity | 1.063 | 0.932 | 1.203 |
| Population growth rate | 1.111 | 1.076 | 1.156 |

Immature survival is given as the probability to survive from fledging to the age of 1 year (juvenile survival), from age 1 to 2 years old [1–2], and for each immature stage until birds are considered adult (5 years of age and older). Breeding probability is given for birds in their third and fourth year, older birds are assumed to breed every year. Immigration rate is expressed as the number of immature birds per breeding pair, and is thus directly comparable to fecundity

population of immigrants) therefore has to produce at least 9 fledglings per year to ensure that at least one of these fledglings reaches adult age.

Conservation management in Bulgaria was intensified from 2004 onwards and focused on increasing productivity by protective measures in breeding territories. The breeding success of guarded nests (1.26 ± 0.89 fledglings/pair; $n = 94$) was significantly higher compared with the breeding success of unguarded nests (0.93 ± 0.90; $n = 120$, $Z = 2.380$, $p = 0.017$). The number of fledglings per breeding pair (fecundity) ranged from 0.66 (in 2003) to 1.47 (in 2013) and increased significantly between 1998 and 2003 (mean 0.87, 95 % confidence interval 0.69–1.05) and 2004–2014 (1.12; 0.99–1.26; $F = 5.91$, $p = 0.028$).

Assuming that all demographic parameters would vary around means estimated for 1998–2014 for the next 10 years, the projected population growth rate from 2014 to 2023 was 1.09 (1.004–1.166) and the probability of a population decline was 2.1 % (Fig. 1).

## Discussion

Eastern Imperial Eagle populations have increased over the past 15 years throughout eastern Europe (Demerdzhiev et al. 2011b; Horváth et al. 2011) and southern Russia and Kazakhstan (Karyakin et al. 2006, 2011). Conservation management for the species in Bulgaria led to an increase in fecundity and likely contributed to the relatively high adult survival that we estimated, but juvenile survival was too low to facilitate a population increase of the magnitude observed for a similar species in Spain (Ortega et al. 2009). Our integrated population model, which allowed us to estimate survival probability for all age classes and immigration rate, therefore revealed that severe conservation challenges remain that cause high mortality in juvenile eagles and that the population in Bulgaria benefitted to some extent from immigration of Imperial Eagles from adjacent regions.

The adult survival of Eastern Imperial Eagles in Bulgaria is similar to estimates from Kazakhstan (Katzner 2003), and for Spanish Imperial Eagles (*Aquila adalberti*) (Ferrer and Calderón 1990; Ferrer et al. 2013). However, the survival of juveniles was relatively low compared to the pre-adult survival rate estimated for Spanish Imperial Eagles (0.561; Ferrer and Calderón 1990; Ortega et al. 2009). A substantial part (at least 50 %) of the juvenile mortality was caused by electrocution on power lines (Stoychev et al. 2014), a well-known threat for many raptor species including imperial eagles (Ferrer and Hiraldo 1992; Lehman et al. 2007; Angelov et al. 2013). Our results highlight the need to increase the efforts to minimise the risk of electrocution, poisoning, and shooting of eagles on the Balkan peninsula, in Turkey, and the Middle East. Modification of dangerous electricity pylons, promotion of public awareness, and active involvement of private landowners in eagle conservation is needed (López-López et al. 2011).

Estimating survival of large, long-lived, and rare birds is a considerable challenge because the sample size of birds that can be individually marked is generally low. Low sample sizes especially in the third year after fledging, when many transmitters had failed and young individuals had died, led to highly imprecise survival estimates for this age class in our model. Likewise, the estimation of survival from territorial adults aged 4 years and older was limited by the small number of birds occupying territories at the age of 4 years. In addition, some individuals may move between territories if the first acquired territory is suboptimal (Ferrer and Bisson 2003; Vili et al. 2013), which may bias our sub-adult and adult survival estimates. Conversely, the undetected replacement of adult birds by floaters, which appears to be substantial in Hungary (Vili et al. 2013), could bias our survival estimates in the opposite direction. Overall, given that survival of adults and 5 year old birds estimated with our model were broadly similar to estimates obtained elsewhere, we are confident that the bias in survival estimates is relatively small.

For most raptors annual survival probability increases with age and increasing experience (Newton 2010). Our model suggests, however, that survival in the third and fourth years may be lower than in the second year, although the estimates were surrounded by considerable uncertainty and therefore do not permit robust interpretation. However, a similar pattern has been described in other long-lived raptors where survival was lowest for the life stage when young birds first attempt to occupy a breeding territory (Grande et al. 2009). We estimated that about 29 % of three year old birds and 46 % of four year old birds may start a breeding attempt. From that age onwards we estimated survival via territory occupancy, which relies on the assumption of high territorial fidelity. Because sub-adult breeders may exhibit lower fidelity to their breeding territories, our estimates of annual survival probability for 4 year old birds may be confounded by emigration from initial breeding territories and may therefore be an underestimate.

Owing to the considerable uncertainty in survival estimates of the cryptic age classes, the estimate of immigration rate was highly imprecise. Although such poor precision may be undesirable for decision makers, the great advantage of an integrated population model is the appropriate consideration of all sources of uncertainty in a single modelling framework which often leads to more realistic error margins around parameter estimates (Kéry and Schaub 2012; Oppel et al. 2014). Although our estimates of immigration are too imprecise to evaluate what proportion of the population increase in Bulgaria is due to immigration, they provide evidence that the population increase is likely a consequence of both better protection of breeding grounds and some immigration of eagles from adjacent regions. Thus, management of breeding pairs alone may not be sufficient to safeguard a long-lived raptor population, which was previously also found for the Spanish Imperial Eagle population (Ferrer and Hiraldo 1991; Ferrer and Penteriani 2007). For management of the population it is therefore important to identify the potential source population of immigrants. While a few unknown pairs may inhabit mountain habitats in the Balkan or Rhodopes mountains in Bulgaria and may provide immigrants for the known breeding population (Danko et al. 2011; Demerdzhiev et al. 2011a; Horváth et al. 2011), it is unlikely that there are sufficient undetected birds that would account for the documented population increase. However, the breeding Imperial Eagles in Bulgaria are part of the Thracian meta-population of the species, estimated at 60–75 pairs (Demerdzhiev et al. 2011a, b), which is connected to breeding populations in Asia Minor. The breeding populations in central Turkey are only 240–300 km away from the eagles breeding in Thrace and thus within the dispersal range (324 km) of Imperial Eagles (González et al. 2006b; Horvath and Kovacs 2009). Turkey could harbor the third largest population of the species in the world after Russia and Kazakhstan, and genetic analyses of Eastern Imperial Eagle subpopulations suggest that the populations in Thrace (Bulgaria and Turkey) are genetically much more similar to birds from central Turkey than to those in Russia, Kazakhstan, and central Europe (M. Horvath, unpubl. data). It is therefore possible that immigrants from the Turkish part of the Thracian subpopulation and from Asia Minor contribute to the population growth in Bulgaria.

Our results indicate that the probability of extinction of Imperial Eagles in Bulgaria is currently minimal. However, habitat changes or human activities may affect productivity or survival of the species in the future. In this respect it is vital to better understand the relative importance and the source of immigrants supporting the Bulgarian population, and how the source populations may be affected by economic development in Turkey (Sekercioglu et al. 2011). From a conservation perspective, it is extremely important to increase the survival of juvenile and immature Imperial Eagles in order to boost the recovery of the small Bulgarian population. Current work focused on breeding territories and protected areas in the EU Natura 2000 network is important but is insufficient and conservation measures should be expanded to reduce non-natural mortality in areas used by young birds in the first three years of their life, which includes roaming areas in Bulgaria, Turkey, and the Middle East (Demerdzhiev et al. 2014; Stoychev et al. 2014). Increasing both successful breeding and pre-adult and adult survival of Eastern Imperial

Eagles not only in target populations, but also in the populations that may provide the immigrants that contribute to stable or growing populations in Eastern Europe will be the key conservation goal for the immediate future.

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