The effect of NATURA 2000 network on the Eurasian Eagle-owl *(Bubo bubo)* population in Southeast Bulgaria: implications for conservation

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Abstract The effectiveness and efficiency of the NATURA 2000 network for the Eurasian Eagle-owl conservation in SE Bulgaria was assessed by comparing data collected during a long-term study on number of breeding pairs and fledglings before and after network establishment. The NATURA 2000 network and non-protected areas showed similar values of the calculated indices according to the number of occupied localities. However, the pairs in NATURA 2000 sites bred significantly less fledglings after the creation of the network than the pairs in non-protected ones. The Special Protection Areas (SPA) system created specifically for the preservation of birds has the lowest efficiency in respect to Eurasian Eagle-owl protection. Proposals were made after 'gap analysis' for real protection and optimization of the protected-area network to increase the stability of the Eurasian Eagle-owl population in the changing environment.

Keywords: conservation goals, conservation effectiveness, top predator, Special Protection Areas, Special Areas of Conservation

Összefoglalás Délkelet-Bulgária területén hosszú távú vizsgálat alapján elemeztük a NATURA 2000 hálózat hatékonyságát és eredményességét az uhu konzervációbiológiájában, amelyhez számos, a hálózat kijelölése előtti és utáni időszakban gyűjtött költőpár és fióka adatait használtuk fel. A NATURA 2000-es hálózat és a nem védett területek esetén az elfoglalt területek száma szerint számított mutatók hasonlóak voltak. A NATURA 2000-es területeken költő párok a hálózat kijelölése után azonban szignifikánsan kevesebb kirepült fiókát neveltek fel, mint a nem védett területeken fészkelő párok. A kifejezetten a madarak megőrzésére létrehozott SPA rendszer az uhu védelmét tekintve a legkevésbé hatékony. A gap-elemzést követően javaslatot tettünk a védelem hatékonyságának javítására és a védett területek hálózatának optimalizálására annak érdekében, hogy növeljük az uhu populáció stabilitását a változó környezetben.

Kulcsszavak: konzervációs célok, konzerváció hatékonyság, csúcsragadozó, különleges madárvédelmi terület, különleges természetmegőrzési terület

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Introduction

The preservation and sustainable use of wildlife in protected areas are among the largely used global practices (Margules & Pressey 2000, Watson *et al*. 2014, Geldmann *et al*. 2019). The EU's Natura 2000 network is the largest system in the world covering one-fifth of the union land area (European Commission 2021). Its main target is to preserve biodiversity of the continent in the process of accelerated economic development (Trochet & Schmeller 2013, Gantioler *et al*. 2014). Bulgaria designated its Natura 2000 network in time of the accession to EU in 2007 and nowadays it covers 34.9% of the territory of the country. Both groups of sites in the network namely Special Protection Areas (SPA) with 23.1% and Special Areas of Conservation (SAC) with 30.3% designated, respectively, under the EU Birds Directive and the EU Habitats Directive, largely overlap (website of the Ministry of Environment and Water 2021). The existing National Protected Areas network (NPA) as parks and reserves, and smaller protected areas designated according to the national Protected Areas Act served as base for development of Natura 2000 in Bulgaria and most of them were included in SPAs and SACs. The change of the Nature protection legislation in 2002 followed by the creation of national Natura 2000 network in 2007 intend to maintain and restore the conservation status of priority habitats and species.

Top predators are keystones in the conservation strategy as an integral part of biodiversity and their great importance for ecological community dynamics (Sergio *et al*. 2006, 2008, Regos *et al*. 2017). They are usual flagships to promote nature protection, and important for the economic benefits of local communities from nature-friendly management of protected areas (Burgas *et al*. 2014, di Minin & Moilanen 2014). The Eurasian Eagle-owl *(Bubo bubo)* is the largest and strongest nocturnal avian predator, the least concern and increasing European population of which has an unfavorable conservation status in the continent (BirdLife International 2017). The Bulgarian population is stable estimated to 450–550 pairs but depleted from a decline suffered during the last century (BirdLife International 2017). The National Red Data Book included the Eurasian Eagle-owl as an endangered species (Golemanski 2015). The Eurasian Eagle-owl is listed in Annex I of the EU Birds Directive and requires designation of SPAs in Natura 2000 network. Therefore, the status of its population before and after the creation of the national Natura 2000 network is indicative of the effectiveness of the protection-area systems.

The present study assesses the role of the protected-area system with respect to the Eurasian Eagle-owl population in SE Bulgaria through: i) determining the effectiveness and efficiency of the three systems of protected areas according to the breeding distribution; ii) specifying the fledgling effectiveness and fledgling efficiency of the protected-area systems based on the fledgling production. We expect SPAs to be the most effective protected-area system as they have been declared specifically for preservation of birds. We expect the breeding pairs in protected-area systems to produce significantly more fledglings after establishment of the Natura 2000 network in comparison to those in non-protected areas.

Material and Methods

The study covered an area of about 10,000 km² in southeastern Bulgaria, 9% of the country (42º 22' 00'' N 27º 00' 00'' E) *(Figure 1)*. The predominant relief is hilly and flat with arable lands, pastures, oasis and riparian deciduous forests with mainly a continental Mediterranean climate (see also Milchev *et al*. 2019). Several low mountains and hills with a height usually up to 300–400 m a.s.l. are located in the southern part near the border with Turkey. Deciduous forests with predominance of oaks (*Quercus* sp.) cover this border area. The forest area decreases from east to west, being replaced by arable land and pastures on flattened ridges and gradual slopes. The depopulation of villages and small towns has been an ongoing process in the region, especially since 1990 due to political changes. The Black Sea coast is much less affected by depopulation because of coastal resort development and tourism growth. The three protected-area systems cover 47.9% of the study area (marine waters are excluded as they are not a habitat of the Eurasian Eagle-owl) *(Figure 1)*. The protected-area network includes mainly the southern state border area and the Black Sea coast.

The Eurasian Eagle-owl is a rock-nesting species in the area and its distribution depends on the available rock complexes with possibility of undisturbed breeding (Milchev *et al*. 2019). The diet is very diverse and with significant temporal changes in the dominant structure both in individual territories (Milchev 2016, Milchev & Spassov 2017) and at the population level (Milchev & Georgiev 2020). Data for breeding distribution and output were collected during the period 2000–2013 and included a 7-year interval before and after the establishment of Natura 2000 network (Milchev *et al*. 2019). This long-term study avoids possibility of misjudgment due to incomplete or short-term occurence of data. Comparisons between the protected and non-protected areas were based on:

(1) number of occupied breeding localities: the least evidences of an occupied rocky complex by Eurasian Eagle-owls were their excrements and food remains;

(2) number of fledglings that reached the age of 45–50 days. Older fledglings are hard to find because they tend to stray from the nest (Penteriani & Delgado 2019);

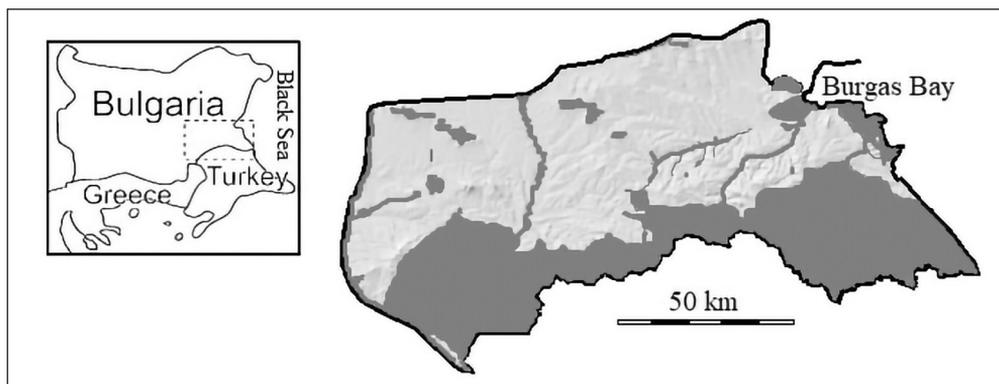(3) fledglings rate: number of fledglings per successful pair.

Figure 1. Study area in SE Bulgaria with marked protected-area network
1. ábra   A mintavételi terület Délkelet-Bulgáriában, jelölve a védett területek hálózatát

The indices of effectiveness, efficiency (Abellán *et al.* 2011), fledgling effectiveness and fledgling efficiency of the three protected-area systems and their combined importance for the breeding popuation of the Earasian Eagle-owl in SE Bulgaria were computed:

(a) Effectiveness index, defined as the proportion of breeding localities included within the system s: Effectiveness = Ns/N, where Ns is the number of localities protected by system s, and N is the total number of localities.

(b) Efficiency index, defined as the proportion of breeding localities included within the system s in relation to the surface of the system: Efficiency = Ns/(N*As), where As is the proportion of land surface of the study area protected by the system s.

(c) Fledgling effectiveness index, defined as the proportion of fledglings of Eurasian Eagle-owl bred within the system s: Fledgling effectiveness = Fs/F, where Fs is the number of fledglings bred within the system s, and F is the total number of fledglings.

(d) Fledgling efficiency index, defined as the proportion of fledglings bred within the system s in relation to the surface of the system: Fledgling efficiency = Fs/(F*As).

Differences between the numbers of occupied breeding territories and fledglings in protected and non-protected areas before and after establishment of Natura 2000 network were calculated with a chi-square test applying Yates' correction. The significance level was $P<0.05$.

Results

The number of occupied breeding territories of Eurasian Eagle-owls increased slightly in both protected and non-protected areas after formation of Natura 2000 network in 2007 and the change was insignificant ($\chi^2=0.0003$, $df=1$, $P>0.05$) *(Table 1)*. The effectiveness index of the total protected-area network did not exceed the index for the non-protected area *(Table 1)*. SACs were the most effective system with 95% of protected localities included (n=21 localities). There was a cumulative effect of the three protected-area systems, which

Table 1. Effectiveness and efficiency of the protected area network in SE Bulgaria for the protection of the local Eurasian Eagle-owl *(Bubo bubo)* population

1. táblázat Délkelet-Bulgária ökológiai hálózatainak eredményessége és hatékonysága a lokális uhu *(Bubo bubo)* populáció védelmében

Area	Occupied localities		Area km²	As	Effectiveness	Efficiency
	before 2007	since 2007				
NPA	11 (30.6%)	9 (21.4%)	1238.9	0.12	0.21	1.79
SPA	13 (36.1%)	12 (28.6%)	3683.0	0.37	0.29	0.77
SAC	19 (52.8%)	20 (47.6%)	4142.5	0.41	0.48	1.15
Protected combined	19 (52.8%)	21 (50.0%)	4789.2	0.48	0.50	1.04
Non-protected	17 (47.2%)	21 (50.0%)	5210.8	0.52	0.50	0.96
TOTAL	36	42	10000			

Table 2. Breeding performances, fledgling effectiveness and efficiency indices of the Eurasian Eagle-owl *(Bubo bubo)* population in SE Bulgaria before and after establishment ot Natura 2000 network in 2007

2. táblázat Az uhu *(Bubo bubo)* populáció szaporodási teljesítménye, a kirepülés eredményességi és hatékonysági indexe Délkelet-Bulgáriában a Natura 2000 hálózat 2007-es kialakítása előtt és után

Area	Fledglings		Fledgling rate		Fledgling effectiveness	Fledgling efficiency
	before 2007	since 2007	before 2007	since 2007		
NPA	41 (25.9%)	26 (15.0%)	2.2	1.7	0.15	1.25
SPA	48 (30.4%)	46 (26.6%)	2.1	1.8	0.27	0.72
SAC	76 (48.1%)	56 (32.4%)	2.1	1.9	0.32	0.79
Protected combined	76 (48.1%)	62 (35.8%)	2.1	1.9	0.36	0.75
Non-protected	82 (51.9%)	111 (64.2%)	2.0	1.8	0.64	1.23
Total	158	173	2.1	1.8		

alone are less effective. However, it did not apply to the network efficiency. NPAs were the most efficient system in comparison to SPAs, which proved to be the least efficient system for the target species.

There was a significant association between raised fledglings and particular protected status of the breeding localities ($\chi^2=4.62$, $df=1$, $P<0.05$). Young Eurasian Eagle-owls fledged less frequently in the Natura 2000 network after its establishment *(Table 2)*. Pairs in the non-protected area raised 64.2% of all fledglings (n=173) for the same period. The fledgling rate of the population decreased from 2.1 to 1.8 fledglings after the establishment of the Natura 2000 network. The decrease affected the breeding pairs equally in both protected and non-protected areas.

The indices for fledgling effectiveness and fledgling efficiency of the protected-area network were about twice lower compared to their values for the non-protected area *(Table 2)*. The fledgling efficiency index in NPAs stood out with a very high value among the three protected-area systems and was the only one to reach the value of the index in non-protected areas. No cumulative effect was found in the value of the efficiency index from the superimposition of the three systems of protected areas.

Discussion

Protected-area networks are part of the natural environment and are subject to constant change mainly due to human activities, both positive and negative. The EU's Natura 2000 network is crucial for reducing losses in environmental and landscape diversity, with changes remaining greater in surrounding non-protected areas (Kubacka & Smaga 2019). Changes in SPAs and SACs have already been reported in Bulgaria (Nikolov *et al.* 2014), but without any alteration in the Eurasian Eagle-owl population and without taking into

account the effectiveness of the protected area in comparison to the surrounding non-protected area. The effectiveness and efficiency of the protected-area network for Eurasian Eagle-owl population in SE Bulgaria proved to be similar to those of the non-protected area. SPAs must have been the most effective and efficient protected-area system for the species. However, the efficiency index placed NPAs as the most efficient among the three systems according to the land surface and number of localities of the target species. The reason for this is primarily that 5 localities (56%, n=9) have been included in the NPA system at the author's suggestions to protect areas with high biodiversity and breeding localities of threatened birds (Milchev & Georgiev 2014).

Differences in individual productivity among the population of territorial predators have long been known (Newton 1979). The qualities of the breeding territory and nesting site such as food supply, protection from human activities, enemies and competitors, climatic factors, but probably also the individual abilities of the territory owners are driving differences in the productivity among Eurasian Eagle-owl populations (Penteriani & Delgado 2019). Therefore, reproductive output allows to assess whether the protected areas have included the more productive part of the population. Thus, investments in the creation and management of the Natura 2000 network meant to ensure the sustainable state of the Eurasian Eagle-owl population that inhabits them (León-Ortega *et al.* 2017). The more productive part of the population in the protected network could support the population outside the protected areas, which is expected to suffer from more diverse and intensive negative human influences. The results demonstrated just the opposite in SE Bulgaria. The breeding pairs in the Natura 2000 network produced significantly less fledglings after the establishment of the network, while the fledgling rate decreased synchronously in protected and non-protected areas. One reason is that the three protected-area systems did not have actual ranger protection to reduce the primary breeding losses in the study area from destroyed or disturbed nests by people (Milchev *et al*. 2019).

Food supply in the hunting territory usually defines the reproductive output of the Eurasian Eagle-owl (Penteriani & Delgado 2019, Scherzinger & Mebs 2020). The significant increase of superpredation (hunting predatory mammals and birds) in the diet of the study population (Milchev & Georgiev 2020) was an indicator of deteriorating food supply and food stress (Penteriani & Delgado 2019). Reduced fledgling rate of the population corresponded to this pattern in the dietary structure. The Natura 2000 network mainly covers the area along the border with Turkey, which is most affected by depopulation, the decline of livestock, and the abandonment of arable land (Milchev & Georgiev 2020). The diet of the pairs there (see *Clusters 1, 3, 6, 7, Figure 4* in Milchev & Georgiev 2020) included the highest values of superpredation and otherwise rare atypical prey such as many smaller species of open and wood-shrubby habitats after the establishment of the Natura 2000 network. The combined impact of the crucial negative factors leading to breeding losses and poor food supply explain the low efficiency of the Natura 2000 network in the region and the resulting lack of sustainable perspective for the Eurasian Eagle-owl population in SE Bulgaria. A similar combination of factors explained the extinction of Egyptian Vultures *(Neophron percnopterus)* (Milchev & Georgiev 2014) from the region and the local decline of Lesser Spotted Eagles *(Clanga pomarina)* (Demerdzhiev *et al*. 2019).

Implications for conservation

Investments in the creation and management of the Natura 2000 network must ensure the sustainable development of the Eurasian Eagle-owl population. The poor and incommensurate effectiveness and efficiency of the protected-area network indicate the need for urgent changes in several directions after 'gap analysis' (Scott & Schipper 2006).

1) Management gaps:

The NPA system does not provide security for breeding pairs due to the lack of legal and financial capacity for effective protection with rangers. Adequate management and security of the NPA system will improve the productivity of all species sensitive to or benefiting from human presence. These measures will boost the efficiency of the Natura 2000 network, which includes the vast majority of the NPA system.

Breeding pairs in rocky quarries produced similar number of fledglings like in natural rocky complexes (Milchev *et al.* 2019). Environmentally-friendly management in quarries at list in the Natura 2000 network will minimise the breeding losses of the Eurasian Eagle-owl and other threatened bird species nesting there (Milchev *et al.* 2019, Rohrer *et al.* 2020).

2) Ecological gaps:

The protected-area network must be developed and take into account the current data on the status of the target species and habitats. Ecological gaps in the Natura 2000 network with inadequate protection of the rodents Roach's Mouse-tailed Dormouse *(Myomimus roachi)* and Romanian Hamster *(Mesocricetus newtoni)* (Milchev & Georgiev 2012) proved to be very similar to those of the Eurasian Eagle-owl in SE Bulgaria. Only the first rodent species was subsequently removed from the lists of priority species in these SACs, which Milchev and Georgiev (2012) cited as an example of species included in protected areas without proven localities. The protection of both mammals remains unresolved in SE Bulgaria, despite the conclusion of Nedyalkov *et al.* (2018) for adequate habitat presence in the Natura 2000. Apparently, none of the rodent species prefer the protected areas designated for them as it is now the case with Eurasian Eagle-owl. Therefore, given the large area of the Natura 2000 network in Bulgaria, we support the recommendation of Gantioler *et al.* (2014) for optimizing the protected-area network in the member states where its area is well above the EU average. Much better effectiveness and efficiency of the Natura 2000 network for the Eurasian Eagle-owl and other species from the Bird and Habitat Directives will be achieved if the network includes the already preferred parts of SE Bulgaria by the species themselves according to the studies of Milchev and Georgiev (2012), Milchev and Menzel (2017), Chobanov and Milchev (2020).

Acknowledgements

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