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Ornis Hungarica 2026. 34(1): 231–245.
DOI: 10.2478/orhu-2026-0018

Precarious future in the long-term for the breeding population of Golden Eagles *(Aquila chrysaetos)* monitored in Southeast Bulgaria

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Received: March 28, 2025 – Revised: November 12, 2025 – Accepted: November 13, 2025

Milchev, B. & Menzel, J. 2026. Precarious future in the long-term for the breeding population of Golden Eagles *(Aquila chrysaetos)* monitored in Southeast Bulgaria. – Ornis Hungarica 34(1): 231–245. DOI: 10.2478/orhu-2026-0018

Abstract Long-lived and late-maturing top predators, such as the Golden Eagle *(Aquila chrysaetos),* require long-term studies to collect meaningful data on trends in breeding density and productivity and on the effectiveness of conservation actions under large changes in food supplies and human pressure. The study of a remote population of a maximum of 11 pairs in SE Bulgaria detected changes in breeding density and productivity over three periods between 1988 and 2024. Breeding density gradually decreased from 5.3 to 3.4 pairs/1000 km^2 corresponding to a 36.4% drop in the number of breeding pairs. The population's reproductive performances declined most between 1993 and 2005 and improved between 2012 and 2024 but without reaching levels seen in 1988–1992. These changes corresponded to the loss of previous food sources in the 1990s: a steep decline in livestock carrion during the winter months and a reduction in the main prey, tortoises, during the warmer half of the year leading a major dietary shift in prey sources. The analyzed characteristics of nesting mountain slopes and nest trees can inform management and conservation of the Golden Eagles. The declining population has an uncertain future due to the high mortality of adult eagles and their replacement by subadult mates in 57% of the pairs after 2020. The replacement of subadult mates with new subadults every 2.2 years on average was most likely caused by illegal shooting and poisoning.

Keywords: breeding biology, nest survival, breeding performance, subadult nest occupancy, raptor conservation, Natura 2000 network

Összefoglalás A hosszú életű és későn ivaréretté váló csúcsragadozók, mint például a szirti sas *(Aquila chrysaetos)*, esetében hosszú távú vizsgálatokra van szükség ahhoz, hogy érdemi megállapításokat lehessen tenni a költési sűrűség és a költési sikeresség alakulásáról, valamint a természetvédelmi intézkedések hatékonyságáról, különösen a táplálékkínálatban és az emberi zavarásban bekövetkező jelentős változások esetében. Egy legfeljebb 11 párból álló, délkelet-bulgáriai, elszigetelt szirtisas-populáció vizsgálata során 1988 és 2024 között három időszakban figyeltünk meg változásokat a költési sűrűségben és a költési sikerességben. A költési sűrűség fokozatosan csökkent 5,3-ról 3,4 pár/1000 km^2-re, ami a költő párok számának 36,4%-os csökkenését jelenti. A populáció szaporodási mutatói 1993 és 2005 között romlottak a legnagyobb mértékben, majd 2012 és 2024 között javultak ugyan, de nem érték el az 1988–1992 közötti szinteket. Ezek a változások a korábbi táplálékforrások elvesztésével függtek össze az 1990-es években: a téli hónapokban a háziállatok tetemeinek hirtelen visszaesése, valamint az év melegebb felében a fő zsákmányállatnak számító teknősök számának csökkenése jelentős zsákmányösszetétel-változáshoz vezetett. A fészkelőhelyként szolgáló hegyoldalak és fák jellemzőinek elemzése értékes információt nyújthat a szirti sas állományának kezeléséhez és védelméhez. A csökkenő egyedszámú populáció jövője bizonytalan, mivel 2020 után a párok 57%-ában a felnőtt egyedeket szubadult madarak váltották fel. Ezeket a szubadult példányokat átlagosan 2,2 évente újabb szubadult példányok váltották, amelyet nagy valószínűséggel illegális lelövések és mérgezések okozhattak.

Kulcsszavak: költésbiológia, fészek túlélés, költési siker, szubadult fészekfoglalás, ragadozómadár-védelem, Natura 2000 hálózat

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Introduction

Viable populations of top predators are indicators of the stability of biodiversity and its sustainable use and management in the modern world. Predator roles in the functioning of ecosystems and the ambiguous human attitude towards them have turned them into a flagship of environmental protection (Ritchie & Johnson 2009, Natsukawa & Sergio 2022, Fortuna *et al*. 2024). The Golden Eagle *(Aquila chrysaetos)* is a representative of this group among Palearctic birds of prey, currently considered as having a stabilized population in the IUCN category of "least concern" (Birdlife International 2021). The national Red Data Book (Golemanski 2015) has classified the Bulgarian population of 120–150 pairs as "vulnerable". Angelov (2024) reported a 53% (n=212 pairs) decrease in the population to 93 occupied territories after 2020.

About 7.5% of the national Golden Eagle population (10 pairs out of 130–140 pairs) inhabited the most south-eastern corner of Bulgaria in the late 1980s (Miltschew & Georgiewa 1992). The pairs lived in an atypical landscape for the country, the heavily forested and rock-poor Strandzha Mountains. The eyries were found exclusively on mature oaks within a vast hunting territory of up to 170 km^2. Conservation of this population has been challenging given the lack of experience in protecting pairs breeding outside of rocky habitats and the absence of data on pair fidelity to nesting slopes and trees. Monitoring the population aimed to: (i) include occupied nesting slopes in protected areas in accordance with national legislation for assessing effectiveness of conservation measures regionally; (ii) threefold expansion of the study area in SE Bulgaria to map the Golden Eagle distribution in an adjacent poorly known area; and (iii) detect changes in population size and breeding performance during significant socio-economic changes as Bulgarian transitioned to democracy after 1990 and amended environmental legislation to conform to EU norms post-2007.

Material and Methods

Study area

Southeast Bulgaria encompasses 10,000 km^2 in a strip 60–80 km wide along the entire Bulgarian-Turkish border. The relief is more strongly folded near the border, where the low Strandzha Mountains, Derventski Hills and Sakar Mountains with their forested ridges up to 300–400 m high alternate from east to west. A less hilly landscape comprised mostly open areas with arable lands, pastures and meadows lies to the north. Hot, dry summers, mild winters and annual rainfall of 600–800 mm characterize the continental-Mediterranean climate in the region (see also Milchev & Georgiev 2014). Golden Eagles nested only in the southeasternmost and forested part of this territory of about 2,075 km^2 in Strandzha Mountains (Miltschew & Georgiewa 1992) *(Figures 1, 2)*. The area is distinguished from the rest of the territory mainly by the steep slopes with deeply incised ravines with rounded ridges. This rugged landscape has oriental beech *(Fagus* *orientalis)* below a belt of the predominant oak *(Quercus* spp.) forests in the Strandzha Mountains. Afforestation with non-native Austrian pine *(Pinus nigra)* and Scots pine *(Pinus sylvestris)* took place more intensively in the mid-1950s. Open habitats often lie abandoned now with little-used arable land and pastures on flatter areas of ridges and slopes. The Strandzha Nature Park (1,161 km^2) in the southern half of the territory was established in 1995, when forests made up 72% of its area. Natural regeneration of open habitats had increased the forest area to 78% in 2008, of which 6.5% were coniferous plantations (Bondev 1991, Strandzha Nature Park 2024). Malko Tarnovo District (747 km^2) in the central part averaged 3.4 people/km^2 with 41% of population more than 60 years old (National Statistical Institute 2024). Forestry and logging have remained the only stable economic activity in recent decades. Raising livestock was the main source of residents' livelihoods but suffered a catastrophic decline beginning in 1991–1992 after the restoration of private property and the deepening economic crisis at the time in Bulgaria. The number of domestic ungulates (cows, sheep, goats and pigs) decreased by 54% (n=28,283 individuals) between 1988 and 1995 and by another 45% in the following five years (Milchev *et al*. 2012). Livestock farming now remains an underdeveloped livelihood. The state has leased numerous hunting concessions for game management in

Figure 1. A) View of the species' suitable breeding area in the Strandzha Mountains; B) a Golden Eagle nest; C) an eaglet at about 7.5 weeks of age (02.07.2023)

1. ábra A) A faj megfelelő költőhelye a Strandzha hegységben; B) szirtisas-fészek; C) 7,5 hetes szirtisas fióka (2023.07.02)

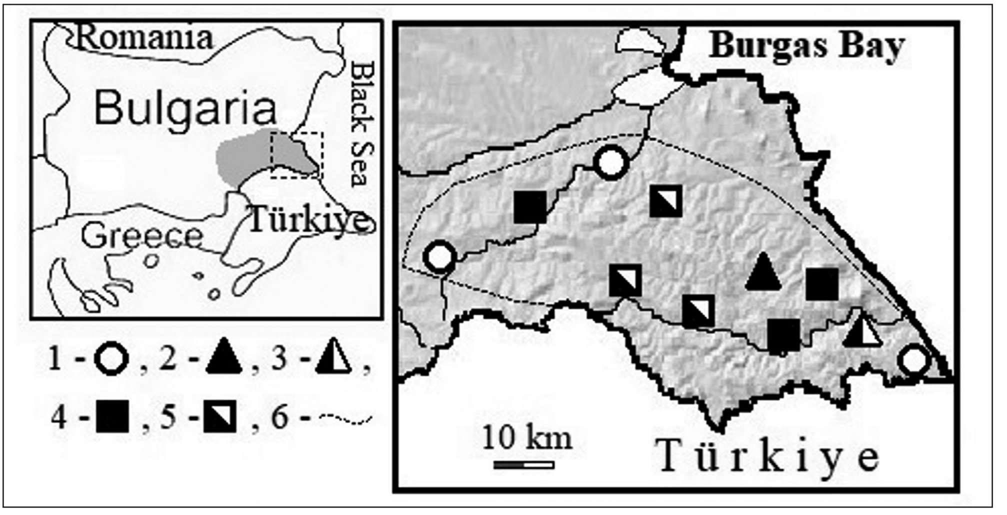

Figure 2. Breeding distribution of the Golden Eagle in SE Bulgaria between 1988 and 2024: 1 – historical breeding territory; 2 – periodically occupied territory; 3 – periodically occupied territory with a subadult mate; 4 – permanently occupied territory; 5 – permanently occupied territory with a subadult mate; 6 – boundary of the species' suitable breeding area

2. ábra Szirti sasok kötési területe Délkelet-Bulgáriában 1988 és 2024 között: 1 – korábban ismert territórium; 2 – időszakosan foglalt territórium; 3 – időszakosan foglalt territórium szubadult példánnyal; 4 – állandóan foglalt territórium; 5 – állandóan foglalt territórium szubadult példánnyal; 6 – a faj számára alkalmas költőterület határa

the Strandzha Mountains since 2008, which include breeding territories of Golden Eagle. The resort and tourist complexes along the Black Sea coast are a popular summer tourist destination outside the species' suitable breeding area.

Data collection

The work of Miltschew and Georgiewa (1992) on the breeding distribution and fecundity of Golden Eagles in the Strandzha Mountains in 1987–1990 was the basis for this long-standing research. The other two-thirds of SE Bulgaria were mapped in 1994–1995 during surveys focused mainly on Eurasian Eagle-Owl *(Bubo bubo)* (Milchev *et al*. 2019) and Egyptian Vulture *(Neophron percnopterus)* (Milchev & Georgiev 2014). Breeding data were collected with minimal disturbance to the eagles during 3–4 annual visits to occupied territories with established breeding until 2005 with careful precautions taken so that: 1) an incubating eagle could be seen without disturbance from at least of 300 m in 9 nests on four territories before the oak leafing in April; 2) observations from a location with extensive visibility in April – early May could establish whether the pairs started breeding (joint activities of the pair during this period indicated failure to breed or a failed clutch); and 3) the number and age of the eaglets was determined in late June – early July, when they were more than 45 days old as observed upslope from nest trees (during this period, we entered one nest in case of unsuccessful breeding to gather data on the size of two unsuccessful clutches); and 4) a visit in late August – early September helped to determine whether the young birds successfully left the nests. Territories without observed individuals were visited annually until the last known nest fell. We subsequently checked for re-occupation at 1–2-year intervals, mainly in spring and autumn. We visited our known nests to record the duration of their use only once during the period 2006–2011. The monitoring of the population resumed using the above-described scheme with repeated searches for occupied territories and new nests in 2012–2024.

Remnant eggshells at nest sites were collected and deposited in the National Museum of Natural History in Sofia. Determining the age of the eaglets followed published descriptions and photos (Hoechlin 1976, Glutz von Blotzheim *et al*. 1989, Driscoll 2010) *(Figure 1)*. The start of egg-laying was calculated by subtracting 44 days for incubation (43–45 days after Glutz von Blotzheim *et al*. 1989, Watson 2010). Feathers from moulting pairs were collected under the nests and from feeding and resting places within a radius of about 200 m from eyries. A subadult partner was proven according to primaries, secondaries, their coverts and rectrices. Dimensions of these feathers proved the sex of the partners in a pair (Hansen & Synnatzchke 2015). The feathers were deposited in the collection of the Museum Alexander König in Bonn, Germany. Visual sex determination based on the size difference of partners during a joint flight was possible only twice.

Breeding productivity measures followed Driscoll (2010) and Watson (2010) based on observations of pairs at nests inspected annually: 1) Nesting success: the percentage of occupied breeding territories by pairs producing young; 2) Productivity: the number of young produced per occupied breeding territory; 3) Fledgling rate: the number of young produced per active nest (a nest in which eggs have been laid); and 4) Mean brood size: the number of young produced per successful nest. Pairs dropped out of breeding accounts after moving to an area without visibility to the new nest or to a site close to installations at the international border. Breeding data were classified by years into three periods according to potential food supply (Watson 2010, Milchev 2022): 1) 1988–1992 (5-year period) – stable number of tortoises (*Testudo* spp.) as the main prey during the warm half of the year and of domestic ungulates as a source of carrion during the winter period; 2) 1993–2005 (13-year period) – decreasing number of tortoises with a gradual shift of Golden Eagles to a new main prey, the Northern White-breasted Hedgehog *(Erinaceus roumanicus)*, and sharply decreasing number of domestic ungulates; and 3) 2012–2024 (13-year period) – hedgehogs were the main prey during the warm half of the year, and the number of domestic ungulates was constantly low, due to mandatory disposal of their carcasses by incinerator or burial. The national nature protection legislation aligns with that of the EU and the European Ecological Network Natura 2000 which began in the interval between the second and third period.

Human-induced nest losses are distributed according to IUCN (2022) categories. Evidence of illegal immigrants at sites included discarded plastic bottles, food wrappers, etc. which marked the paths and resting places after people crossed into Bulgaria. The Turkish inscriptions on the trash clearly distinguished them from trash of local residents.

Spearman's rank correlation measured the association between elevation of the nest site and distance of the nest tree from the Black Sea shoreline. The same test calculated the statistical significance of the correlation of the number of failed clutches in a nest to its distance to a settlement or a livestock farm. Differences in annual nesting success between the three study periods were calculated using the Kruskal–Wallis test. The different clutch frequency according to the date of initial egg-laying during the three periods was tested using a chi-square test. All means were arithmetic means ± standard deviations. The tests were considered two-tailed and statistically significant at $p < 0.05$. The analyses were implemented with PAST 3.01 software (Hammer *et al.* 2001)

Results

Distribution of the breeding population and recruitment by subadult eagles

Golden Eagles inhabited 11 breeding territories, of which six territories (54.5%) were permanently occupied *(Figure 2)*. Two territories (18.2%) were periodically occupied by pairs for 4 and 7 years. Three historical territories (27.3%) remained unoccupied during the third period. The pair in the easternmost territory near the seacoast disappeared first, probably in 1993–1994. The westernmost breeding territory remained uninhabited after 2007. The northernmost territory was the only one newly occupied and inhabited during the 14-year period from 1993 on. Breeding density decreased from 5.3 to 4.8 pairs/1000 km^2 in the 1990s to fluctuating between 3.4–3.9 pairs/1000 km^2 after 2012, corresponding to a 36.4% decrease in the number of breeding pairs to seven at present days.

A subadult partner has been present in eagle pairs in four of eight territories since 2018: three territories with a subadult male and one with a subadult female *(Table 1, Figure 2)*. At least six replacements of subadult partners occurred over the same period (2.2±1.0 years, range 1–3). The replacement was with an adult partner in one case and only for one breeding

Table 1. Golden Eagle pairs with a subadult mate in SE Bulgaria
1. táblázat Szirtisas-párok szubadult példányokkal Délkelet-Bulgáriában

Breeding territory	Year; subadult partner; breeding data
Westernmost permanent territory	2018; subadult ♂ and adult ♀; without breeding attempt. 2019; subadult ♂ and adult ♀; successful breeding. 2021; new subadult and adult; unknown sex; without breeding attempt 2024; new subadult ♂ and adult ♀; without breeding attempt
Southernmost permanent territory	2020; subadult ♂ and adult ♀; without breeding attempt. 2021; new adult ♂ and adult ♀; successful breeding. 2023; new subadult ♂ and adult ♀; successful breeding. 2024 subadult ♂ and adult ♀; unsuccessful breeding attempt.
Northernmost permanent territory	2022; subadult ♂ and adult ♀; successful breeding. 2023; subadult ♂ and adult ♀; successful breeding. 2024; new subadult ♂ and adult ♀; unsuccessful breeding attempt.
Eastern periodically occupied territory	2018–2019; single subadult; unknown sex; first occupation of the territory since 1994. 2020–2022; subadult with adult; unknown sex; without breeding attempt. 2024; new subadult ♀ and adult ♂; unknown breeding success.

season. Pairs in the other three territories have included a new subadult partner during the next 3–7 years after the appearance of the first subadult.

Nesting slope and nest tree preferences

Nest trees were located usually in the upper half of wooded slopes (86.7%, n=15 nests) and with north-facing exposures (93.3%, n=15 nests). Twelve nest trees (80%) grew on very steep scree slopes. Two nest trees (13.3%) were by a brook on a gently sloping wooded bank, but their crowns towered above the forest canopy. One nest tree (6.7%) was on a gentle slope at the edge of old-growth forest and a scrub-covered area. The eagle pairs nested on one slope in two territories (28.6%, n=7 territories), and on two slopes in the other breeding territories (71.4%). Pairs used a slope with nest trees for an average of 15±9.5 yr (range 3–29 yr).

The nest trees were most often oaks (80%, n=15 trees), and less commonly European hornbeam *(Carpinus betulus)* (13.3%) and oriental beech (6.7%). The characteristics of Golden Eagle nests (n=15) are summarized in *Table 2.* The elevation of the nest trees sites increased significantly with distance from the Black Sea coast ($r_s = 0.739$, $p < 0.01$). An average of two active nests per breeding territory was found (range 1–4). Constructed nests remained intact on average of 11 years. The shortest-preserved nest was the first one in the newly occupied northernmost territory. The longest-preserved eyrie existed from before the start of the study, i.e. for more than 24 years (one third of the nest fell after collapse of a supporting branch in 2001, while the nest diameter was reduced to 0.9 m, but the pair used it for another 11 years until the oak fell entirely). Another nest structure has existed for 19 years, when the nest tilted and collapsed in its seventh year, and the eagles carried twigs from it to build a new nest 290 m away. However, the structure survived, and the pair returned to build an addition to it after six years and this "recycled" nest is still in use today *(Figure 1)*. Nests collapsed due to the following reasons: supporting branch broke off (25%, n=12), nesting tree fell (25%), the breeding territory was abandoned (16.7%), a large branch from the crown of the same oak above the nest fell into it (8.3%) or from unknown causes (25%).

Table 2. Characteristics of Golden Eagle nests (n = 15) in seven breeding territories of SE Bulgaria between 1988 and 2024.

2. táblázat Szirtisas-fészkek (n = 15) jellemzői hét költő territóriumban Délkelet-Bulgáriában 1988 és 2024 között

Characteristics	Average (min – max)
Number of found nests in a breeding territory	2 (1–4)
Nest longevity (years)	11±7 (2–24)
Distance between consecutive nests in the same breeding territory (m)	816±978 (6–2100, median 230)
Altitude of the nest tree (m)	225±89 (60–360)
Distance to a village (m)	2840±990 (1000–4650)
Distance to a cattle ranch (m)	1565±1176 (160–4000)

Golden Eagles used green twigs from oaks and eight other plant species in the nests during the breeding season; regularly many twigs of oaks and oriental hornbeam *(C. orientalis)* and rarely twigs of Austrian pine, oriental beech, Norway maple *(Acer platanoides)*, field maple *(A. campestre)*, European mistletoe *(Viscum album)*, common ivy *(Hedera helix)*, and Scots pine. One pair first brought an Austrian pine twig to their nest in 1995 and used 9 twigs of this non-native tree in 2001. Several conifer twigs in nests were used annually everywhere since 2003. Golden Eagles brought occasionally green twigs in May–June in years without a breeding attempt or with unsuccessful breeding (six observations). Pairs used the nest in such years as a resting place (two observations) or once during light summer rain.

Changes in breeding performance

Reproductive success of the Golden Eagles has changed over the years: productivity was best before 1992, deteriorated considerably thereafter until 2005, and then improved in the third period, however, without recovering productivity seen before 1992 *(Table 3)*. Golden Eagles disappeared from three breeding territories during the second period, in two of which the pairs raised 33.3% (n=27) of all eaglets by 2005. The proportion of non-breeding and unsuccessful pairs increased 6–7 times then and productivity fell to 0.13 fledgling per occupied breeding territory. Average nesting success was significantly different in the three periods ($K = 9.351$, $df = 2$, $p < 0.01$) and at least the first and second periods were significantly different from each other. The initial date of egg-laying (range February 26 – April 13, median March 21, n=33 clutches) also differed across the three periods, and successful pairs laid eggs later during the second and third periods *(Table 3)*. The frequency of clutches laid in April was significantly higher in the second period

Table 3. Breeding performances of Golden Eagles in SE Bulgaria between 1988 and 2024.
3. táblázat Szirti sasok költési sikere Délkelet-Bulgáriában 1988 és 2024 között

Study period	1988–1992	1993–2005	2012–2024	Recap for 1988 – 2024
Breeding pairs studied	5	6	3	6
Occupations of breeding territories	18	77	34	129
Nesting attempts	17	47	25	89
Nonbreeding pairs (%)	5.6	39.0	26.5	31.0
Failed nests (%)	11.8	76.6	52.0	58.4
Laying date (median)	11 March	29 March	24 March	21 March
Nestlings (total)	17	11	13	41
Fledglings (total)	17	10	12	39
Nesting success (%)	83.3	13.0	35.3	28.7
Productivity	0.94	0.13	0.35	0.30
Fledgling rate	1.00	0.21	0.48	0.44
Mean brood size	1.13	1.00	1.00	1.05

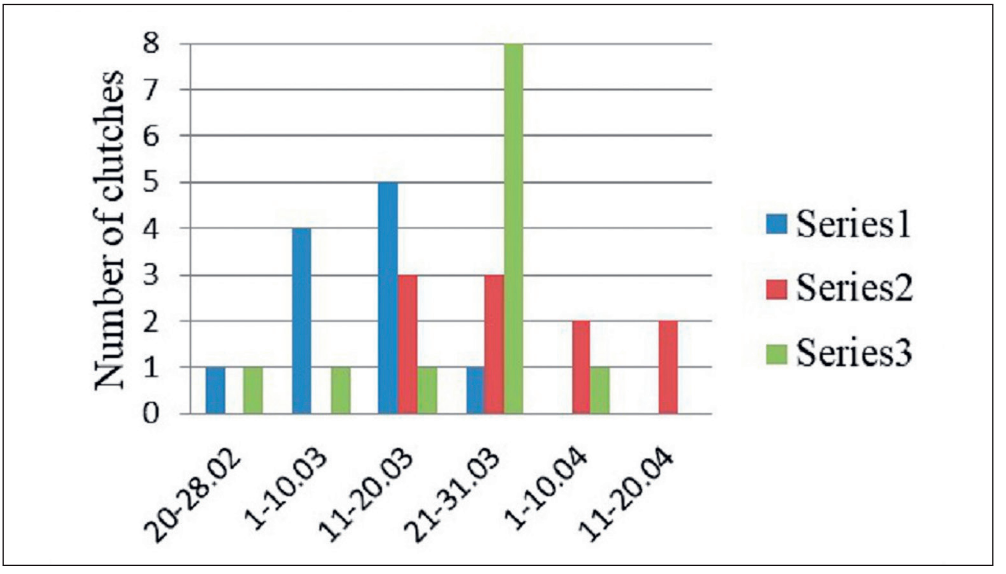

Figure 3. Distribution of successful Golden Eagle clutches in ten-day periods according to egg-laying date in SE Bulgaria

3. ábra A sikeres szirti sas fészekaljak tojásrakási idejének eloszlása tíznapos időszakokban Délkelet-Bulgáriában

compared to the other two periods ($\chi^2 = 21.27$, df = 10, p = 0.019) *(Figure 3)*. The opposite was true for the first period with significantly more frequent clutches laid in the first decade of March. Broods with two eaglets successfully fledged twice (5.3%, n=38 broods) only during the first period.

Causes for breeding failure and protection actions

Intentional or indirect human actions were the most common causes of failed nests (23.5%, n=51) *(Table 4)*. Possible natural causes led to three failed nests (6%). Unintentional negative human actions were three times more frequent than direct actions targeted at destroying active nests. Human activities (83%, n=12) negatively affected breeding in only one of the nests in five territories during 1993–2003. Unintentional disturbance by illegal immigrants in one territory was the only human activity (17%) in 2012–2024. Correlations between the number of failed clutches in the nest and the distance to a settlement ($r_s = -0.389$, $p > 0.05$) or farm ($r_s = -0.476$, $p > 0.05$) were statistically not significant. The majority of nest failures were attributed to unknown causes (70.6%) mostly because concerns for conservation preclude visiting nest trees from January to the last two weeks of June.

Until 1995, five breeding territories and the nesting slopes in four others (81.1%, n=11 territories) were included in protected areas according to national legislation. Only one territory remained outside the Natura 2000 protected network established in Bulgaria in 2007.

Table 4. Causes for breeding failures of Golden Eagles in SE Bulgaria between 1988 and 2024.
4. táblázat A szirti sasok sikertelen költéseinek okai Délkelet-Bulgáriában 1988 és 2024 között

Causes for breeding failure (number of cases)			Number (%) of failed nests
Possible natural causes		Addle egg in 1-egg clutch (1)	1 (2%)
		Abandoned 2-eggs clutch (1)	1 (2%)
		Dead nestling and fledgling (2)	1 (2%)
Biological resource use	Persecution or control	Logging neighboring trees in order to destroy the nest intentionally (2)	2 (3.9%)
		The nest tree was hit with an axe to drive away the eagles (1)	1 (2%)
	Gathering mushrooms	Unintentional effects (5)	5 (9.8%)
Human intrusions and disturbance	Work and other activities	People spending time in natural environments for reasons other than recreation or military activities (2)	2 (3.9%)
		Human disturbance near the nest tree by illegal immigrants (2)	2 (3.9%)
Unknown reason			36 (70.6%)

Discussion

The Golden Eagle's excellent ability to use updraft air currents for energy-efficient flight contributes to its preference for highly rugged terrain (Driscoll 2010, Ștefănescu & Bălescu 2019, Natsukawa *et al*. 2024, Sidiropoulos *et al*. 2024). In SE Bulgaria, Golden Eagles breed only in the most rugged part of the Strandzha Mountains, designated as the species' suitable breeding area. Single birds or pairs observed only once have been recorded between this area and the nearest breeding territories about 70 km north and about 100 km west (Milchev & Kovachev 1998, our unpub. data). The species has not been reported in the southern Strandzha Mountains in Türkiye (YMBP 2010).

The studied population showed slow but consistent negative changes in the number of pairs and breeding density along with the disappearance of peripheral territories. The declining breeding density to 3.4 pairs/1000 km^2 is among the lowest in Europe (review in Watson 2010) and close to that in some parts of Serbia (Rudić & Rajković 2023), the Mediterranean region (Borlenghi 2017, Fernández-Gil *et al*. 2023) and Sweden (Tjernberg 1985). Other Bulgarian studies have not shown the slow decline in the target population in SE Bulgaria. Golemanski (2015) reported 8 pairs in the western part of Strandzha Mountain, which were double the four pairs there in the present study. A 75% decline in the number of breeding pairs followed in SE Bulgaria according to Angelov (2024), with only two pairs remaining by 2023. The updated data for 2021 in the standard form of Natura Zone "Strandzha" BG0002040 adds to the inconclusiveness. The Zone includes just over half of the species' suitable breeding area, but with 5–7 breeding pairs at a density between 4.3–6 pairs/1000 km^2 (Ministry of Environment and Water 2021). Such striking differences result from formal mapping methods of breeding birds and monitoring protocols (Belichev & Milchev 2010, Milchev 2010, Milchev & Georgiev 2014).

Easy access to the nest and the nest location below prime hunting habitats in open terrain on rounded ridges provides more economical prey transport and appears to driving selection of slope and tree selection for the nest as observed in similar Golden Eagle studies (Haller 1996, Watson 2010). The terrain elevation of nest trees gradually increases with distance from the Black Sea coast. Pairs prefer the southern exposure of nests in the northern areas of the species range, while in the southern parts, they use the northern component (Haller 1996), as in the present study. Golden Eagles usually have several nests in their territory, which they use alternately over the years (Glutz von Blotzheim *et al*. 1989, Watson 2010). Nests in trees are more perishable than those on rocks and are inhabited for up to 30 years at most (Haller 1996). The study population inhabited one nesting slope for decades and used nest trees typically for over a decade.

Bringing fresh green twigs to nests has been described in various species of birds of prey (Newton 1979, Watson 2010). Miltschew and Georgiewa (1992) observed the lack of use of twigs from non-native conifers in Golden Eagle nests, even though these trees were the only source of green twigs until the latter half of April. Pairs used pine branches regularly only since the beginning of this century, when pine plantations reached 45–50 years of age. Most likely, the pine trees in the area have powerful enough branches from this age on for the eagles to land on them and tear off twigs for their nests.

Productivity of 0.94 fledgling per occupied territory in the first study period was among the higher values for a Golden Eagle population (review in Watson 2010). This result confirmed the statement of Miltschew and Georgiewa (1992) that weather conditions met the requirements of the species, serious human disturbance did not occur, and the food supply was sufficient. The complex negative impact of reduced food supply combined with human disturbance may explain sharply deteriorating reproductive performance during the second studied period 1993–2005. The main prey species in the diet of breeding Golden Eagles hibernate during the cold half of the year in SE Bulgaria (Milchev 2022). Data on the winter diet of the Bulgarian population are lacking, but Golden Eagles depend heavily on ungulate carrion in other parts of their range (Haller 1996, Sánchez-Zapata *et al*. 2010, Watson 2010). Socio-economic changes severely depressed livestock farming in the study area in 1992–1993, causing a steep decline in the domestic ungulate population and relocation of the remaining animals from farms once scattered throughout the mountains with extensive pasture grazing to small farms lots clustered around villages. As a result, livestock carcasses available to eagles in winter became scarce, disappearing from failed farms. Insufficient food supply before the breeding season leads to poor energetic condition of pairs, leading to delays in the start of egg laying and an increase in the number of failed breeding attempts (Steenhof *et al*. 1983, 1997, Fernández 1993, Sein & Väli 2024). The study population showed significant differences in these reproductive parameters between the first and second periods. The main prey of breeding pairs, tortoises, gradually decreased during the same period, and Golden Eagles began to replace it with alternate prey (Milchev 2022). This diet shift may have further depressed the fledgling rate. Most human disturbance events occurred during the second period and contributed to the decline in breeding performance and abandonment of at least two territories. Intentional attempts to demolish nests (by felling thinner neighboring trees or hitting the nest tree with an ax) occurred during the diet shift period, when domestic piglets and lambs/goatlings appeared in the diet of the affected pairs (Milchev 2022).

The reduced population improved its reproductive performance during the third period with a stabilization of the breeding diet with hedgehogs as the main prey and in the absence of targeted human disturbance near the nests. However, a new factor limited its reproductive potential by increasing mortality of the breeding partners. This process became apparent around 2020, when the share of subadult eagles in a breeding population started to increase due to unnaturally high mortality of adult mates and insufficient adult floaters to fill the vacancies (Balbontín *et al*. 2003, Ferrer *et al*. 2003, Whitfield *et al*. 2004, Monzóna & Friedenberg 2018). The increased number of subadult eagles in pairs in several other eagle populations was mainly due to human persecution such as illegal shooting and poisonous baits to control carnivore mammals (Whitfield *et al*. 2004, Monzóna & Friedenberg 2018). Several replacements of only a subadult partner in three of the pairs with a new subadult eagle point to illegal shooting as a more likely cause in SE Bulgaria. Reduced food availability and illegal shooting of pairs accompanied the extirpation of breeding Egyptian Vultures in the Strandzha Mountains (Milchev & Georgiev 2014).

National legislation allows creation of a protected area for the nesting slope of a Golden Eagle pair to preserve the habitat and limited forestry activities to the post-breeding season. Implementation of this legal option in Strandzha Mountains has been successful in protecting the long-occupied nesting slopes with nest trees. Bulgarian legislation does not actually provide protection for nests of protected birds such as Golden Eagles from human disturbance in the different categories of protected areas (Milchev & Georgiev 2014, Milchev *et al*. 2019). Therefore, the nest conservation scheme described of Slater *et al*. (2017) is not being applied in the study area. The results of Angelov (2024) on the disappearance of breeding Golden Eagles in Pirin National Park and on the last remaining pair in Rila National Park confirm the inadequacy of current protections. A lack of critical funding at the national level for the network of Bulgarian protected areas fails to provide wildlife rangers to actually guard eagle nests and to limit human-caused disturbance in them.

The Natura 2000 network of protected zones has not resulted in positive outcomes for the Strandzha Mountains eagle population since establishment of the network in 2007. The pair in the northernmost permanent territory had raised 50% (n=12) of the eaglets in the mountain since 2012, but it was outside the Natura network. A subadult mate appeared later in this territory than in the eagle pairs within the network-protected zones. The diet of this pair had a similar structure to that in the other territories (Milchev 2022). Milchev and Georgiev (2021) reported a similar result with no positive outcomes from the Natura network for the Eagle-Owl population as another top predator in SE Bulgaria.

The great concern for the survival of the Strandzha Golden Eagle population turned out to be, as for the national level (Angelov 2024), the historically abnormally high mortality of adult eagles as indicated by the unprecedented number of eagle pairs with a subadult partner. Acceleration of the decline driven by the lower breeding success of pairs with a subadult partner threatens the long-term survival of the breeding population of the Golden

Eagle (Steenhof *et al*. 1983, Pedrini & Sergio 2001, Whitfield *et al*. 2004, McIntyre & Schmidt 2012, Monzóna & Friedenberg 2018). This impending threat requires urgent conservation actions by the competent services in the Ministry of Environment and Water against increased human pressure through illegal shooting and poisoning.

Acknowledgements

We thank U. Georgiewa, A. Kovachev, V. Georgiev, V. Marinov, and P. Arsov for their invaluable assistance in the field. Many thanks to D. Dimitrov for the species identification of some green twigs from the eyries. We sincerely thank G. Kostov for his help in stopping logging near an eyrie in 2018. We are indebted to Dr. J. Weigand for improving the English in this paper. We would like to thank the anonymous reviewers for their valuable comments. The study complies with the current laws in Bulgaria.

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