

The northern hawk owl *Surnia ulula* invasions in Europe

Invázia krahule hôrnej *Surnia ulula* v Európe

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Abstract: The northern hawk owl is a real irruptive species that respond to irregular changes in the food supply. When prey levels are adequate, it breeds and winters within northern forests. Decreased prey availability can start winter invasions, the timing and magnitude of which are the subject of this study. Mainly the citizen data were extracted from the national bird websites to obtain data on the number of northern hawk owls observed in 2010–22. This paper demonstrates that through citizen data large amounts of information can be collected over wide areas, entire Europe in this case.

From Finland to Poland and Czechia the invasions years were very similar, 2013–14, 2017–18 and 2021–22 but in Sweden and Norway three clear irruption years were a year or two before. In Denmark, the clear invasions years were 2013–14, 2016–17 and 2019–20 but Poland, peak years were not at all as clear as in the other countries. The invasions started earliest in Finland in September and peaked in November. In Estonia and Latvia peaks occurred from November to January. In Poland, irruption peaked a month later in December but continued until April like in Finland, Estonia and Latvia.

The origin of the irrupting owls in the region has been debated. In Norway, authors are convinced that owls originate from Fennoscandia but this paper indicates that mass invasions have to originate from northern Russia. However, only in Denmark there was one Russian northern hawk owl ring recovery.

Further ring recoveries and preferably GPS tagging and satellite tracking of the northern hawk owls are awaited to have a better picture of invasion movements and future conservation needs.

Abstrakt: Krahul'a hôrna je skutočný irruptívny druh, ktorý reaguje na nepravidelné zmeny v ponuke potravy. V čase dostatku koristi, hniezdi a zimuje v severných lesoch. Znížená dostupnosť koristi môže spustiť zimné invázie, ktorých načasovanie a rozsah sú predmetom tejto štúdie. Údaje od občanov o počte pozorovaných krahúľ hôrných v rokoch 2010–22 boli extrahované z národných ornitologických webstránok. Táto práca demonštruje, že prostredníctvom údajov od verejnosti možno zhromaždiť veľké množstvo informácií na rozsiahlych územiach, v tomto prípade celej Európy.

Od Fínska po Poľsko a Česko boli roky invázií veľmi podobné, 2013–14, 2017–18 a 2021–22, no vo Švédsku a Nórsku boli tri jednoznačné roky irupcií o rok či dva skôr. V Dánsku boli jasnými rokmi invázie roky 2013–14, 2016–17 a 2019–20, ale v Poľsku neboli roky vrcholu invázie vôbec také zretelné ako v ostatných krajinách. Vo Fínsku sa invázie začali najskôr v septembri a vrcholili v novembri. V Estónsku a Lotyšsku sa vrcholy vyskytovali od novembra do januára. V Poľsku invázia vrcholila o mesiac neskôr v decembri, ale pokračovala až do apríla podobne ako vo Fínsku, Estónsku a Lotyšsku.

Pôvod prenikajúcich sov v regióne bol predmetom diskusie. V Nórsku sú autori presvedčení, že sovy pochádzajú z Fenoškandinávie, ale táto práca naznačuje, že masových inváziách musia jedince pochádzať zo severného Ruska. Každopádne s ruským krúžkom bola zaznamenaná len jedna krahul'a hôrna v Dánsku.

Na získanie lepšieho obrazu o pohybe počas invázie a budúcich potrebách ochrany krahule hôrnej sú potrebné ďalšie odchty krúžkovaných jedincov, či prioritnejšie údaje z GPS a satelitných sledovaní.

Key words: *Surnia ulula*, winter invasions, ringing results, European countries

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Introduction

The northern hawk owl *Surnia ulula* (hereafter hawk owl) is one of the least-studied owls which breeds across the circumpolar boreal forest zone (Duncan & Duncan 1998). The nominate subspecies, *S. u. ulula* is distributed in Eurasia, from Scandinavia through Siberia to Kamchatka and Sakhalin. North American subspecies, *Surnia u. caparoch*, occurring from Alaska to Canada, Newfoundland and extreme N-US, is distinctly darker than nominate *ulula* (Duncan & Duncan 1998). Third subspecies, *S. u. tianschanica* breeds in Tian Shan of Central Asia, NW and NE China and perhaps N Mongolia. It has the dark parts of the plumage more blackish and the white purer than the nominate (Mikkola 2014).

The population status of the hawk owl is poorly known because of low breeding densities in a vast and remote distribution range. Classical methods to obtain information on population sizes and densities are even more difficult in the case of this owl due to the irruptions. Numbers of the breeding pairs were reported to fluctuate up to 100 per cent with cycles of small mammal prey populations (Duncan & Duncan 1998). Anecdotal evidence suggests that populations have declined since the late 1800s and early 1900s (Mikkola 1983) but this

trend cannot be seen in more recent breeding bird counts. In Finland, one to 120 nests were found between 1986–2012 (Saurola 2012) and one to 117 annual nests between 2013–21 (Linnut yearbooks 2013–21). Valkama et al. (2014) estimated the total Finnish breeding population to fluctuate between 500 and 4900. The Norway population is thought to be between 1000 and 10 000 but can in some years fall below 100 (Sonerud 1994) and that of Sweden can in good years go up to ten thousand (Ulstrand & Högstedt 1976) but is more often between 500 and 5000 pairs (Sulkava & Huhtala 1995). The North American population has been estimated to be between 10 000 and 50 000 pairs (Duncan & Harris 1997) and that of northern Russia 10 000 – 100 000 (Sulkava 1997).

This paper concentrates mainly on the nominate subspecies and their invasions in Europe. These irruptions south of its breeding range are interesting events that periodically remind us how little we know about this atypical northern owl, resembling in many ways the Eurasian sparrow hawk *Accipiter nisus*.

Material and Methods

To obtain data on the number of hawk owls observed in 2010–22 the citizen data were partly extracted from the

national bird websites as follows:

<https://birdingbelarus.by> for Belarus
<https://www.birds.cz/avif/> for Czech Republic (hereafter
Czechia)
<https://dofbasen.dk> for Denmark
<https://elurikkus.ee/en> for Estonia
www.tiira.fi for Central Finland (BirdLife Suomenselkä
area, Figure 6). Note that in Figures 3–5 this material
represents the entire Finland.
www.putni.lv for Latvia
www.artobservasjoner.no for Southeastern Norway (Oslo
and Akershus area, Figure 6). *Note that in Figures 3–5
this material represents the entire Norway.*
<http://clanga.com/index.php/home/show//en/> for Poland
www.artportalen.se for South Sweden (Skåne area, Figure 6).
*Note that in Figures 3–5 this material represents the
entire Sweden.*
www.dutchbirdalerts.nl for The Netherlands

Dale (2022) has evaluated the value of citizen data in studying owl irruptions and concluded that in the case of the hawk owl irruptions, citizen and survey data from the same area gave similar results. In addition, citizen data had the advantage that large amounts of information are collected over wide areas. In our data, we have tried to remove the overlapping observations most likely concerning the same bird reported by two or more observers. In countries of Central and Western Europe, the hawk owl is a rare vagrant, e.g. in Germany and the Netherlands. For those countries where the species has to be reported to the respective national rarities committee, the citizen data were compared with the officially accepted records and adjusted for those that remained undocumented. The invasion year includes the records from September to December and records from January to April the following year. Thus, e.g. 2021 includes records from the period 1/9/ 2021 – 30/4/ 2022.

The degree of overlap has been calculated to show if there are significant annual differences in the invasion observation between the countries. The index used is modified from MacNaughton & Wolf's (1973) "Index on Community Similarity":

$$C = \sum (2m) / \sum (a + b)$$

In which a = annual percentage of owl observations in country a, b = annual percentage of owl observations in country b, m = minimum annual percentage in either country a or b. The nearer 1.0 the index is, the higher the

overlap of the invasion years in the countries compared. A low value indicates that there is very little overlap in the invasion years between the two countries.

In this paper, we have included also countries where no hawk owl have been recorded during the study period and we have presented known historical records to get a better picture of the southern limits of the invasions in the past. The annual data from 2011 to 2020 have been plotted on a set of maps (Figures 3–5) and two Tables (1 and 2). Only well-studied southern areas (Figure 6) were selected from Norway, Sweden and Finland to avoid mixing the breeding birds with the invading owls. Therefore in Figures 3–5 these smaller areas represent the entire country.

Invasions in 2010–2022

The following 15 European countries were studied more closely from September 2010 to April 2022: namely Belarus (9), Chechia (4), Denmark (67), Estonia (499), Finland (563), France (1), Germany (17), Latvia (54), Lithuania (18), Norway (197), Poland (43), Slovakia (0), Sweden (270), The Netherlands (1) and Ukraine (4). During the study period recorded owl numbers are stated in the brackets and being 1743 in total.

From Finland to Poland and Czechia the invasions years were very similar, 2013–14, 2017–18 and 2021–22. The overlap between Estonia and Finland in annual observations was the highest in the entire material (similarity index 0.69), closely followed by the overlap in the main invasion years with these two countries and Latvia (0.61). In Sweden three clear irruption years were 2012–13, 2016–17 and 2019–20, two first ones being the same as in Norway and the last was one year before Norway and two years before Finland, Estonia and Latvia. The invasion year overlap for Sweden was high only when it was compared with Norway (0.54). In Denmark, the clear invasions years were 2013–14, 2016–17 and 2019–20 but Danish annual observations had very low overlap with all other countries. In Poland, peak years were not at all as clear as in the other countries but the overlap was clear with Latvia (similarity index 0.58).

From monthly observations in Lithuania, 61% were from November–January (Fig. 1). The December peak was the same as in Latvia (Fig. 2). Belarus' monthly observations had a peak in November and February and no owls had been seen in March and April. In Czechia, the peak irruption months were November and February and no observations in September and April (Fig.1). Very few observations from Slovakia had peaks in November and March, the first peak being similar with Czechia.

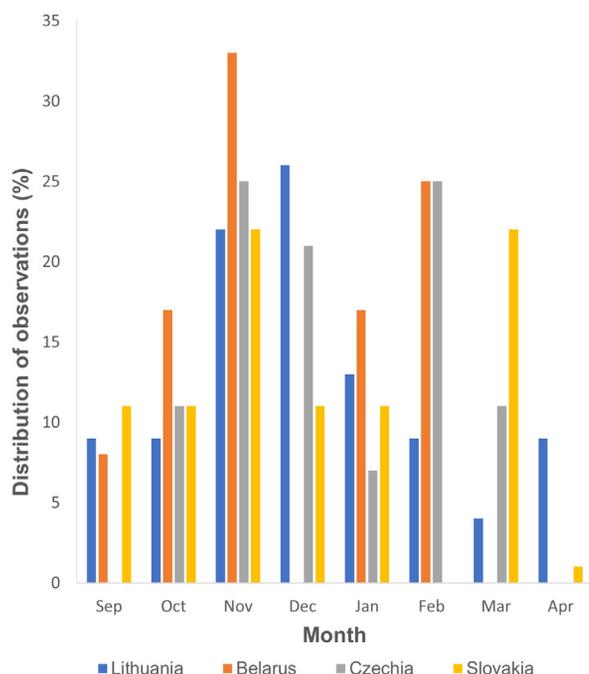


Fig. 1. Percentage distribution of the monthly northern hawk owl *Surnia ulula* observations in Lithuania (N = 23), Belarus (N = 12), Czechia (N = 28) and Slovakia (N = 9).

Obr. 1. Percentuálne zastúpenie mesačných pozorovaní krahule hňmej v Litve (N=23), Bielorusku (N= 12), Česku (N = 28) a Slovensku (N = 9).

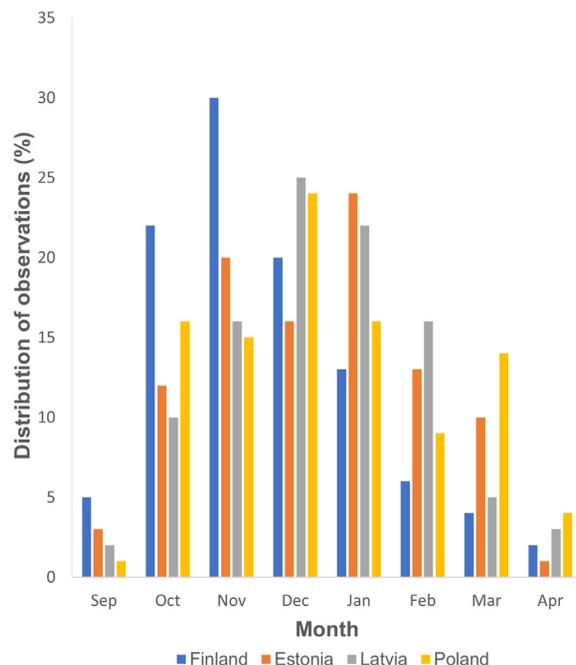


Fig. 2. Percentage distribution of the monthly northern hawk owl *Surnia ulula* observations in Finland (N = 931), Estonia (N = 499), Latvia (N = 87) and Poland (N = 85).

Obr. 2. Percentuálne zastúpenie mesačných pozorovaní krahule hňmej vo Fínsku (N=931), Estónsku (N= 499), Lotyšsku (N = 87) a Polsku (N = 85).

Monthly observations from Denmark included 2871 reported records (not necessarily different birds) from 2000–22 and the distribution is September – 0.9 %; October – 6.5; November – 18.5; December – 19.6; January – 26.8; February – 13.7; March – 6.0, and April – 8.0 %. A clear peak was in January just like in Sweden while in Finland it was in November (Fig. 2).

In Germany, monthly observations of hawk owls took place between September and April but the peak period was early December (Krüger 2013).

In Finland, the winter invasion started in September and had its peak in November while in Estonia 61% of the observations were from November–January (Fig. 2). In Latvia, a large part (47%) of monthly observations were from December–January indicating that the irruption peaked a little later than in Estonia and Finland (Fig. 2).

In Poland, monthly records in Fig. 2 take place fairly equally from October to March and these include also 42 older observations (Ruprecht & Szwagrzak 1988, Tomiałojć 1990, Tomiałojć & Stawarczyk 2003, Stawarczyk et al. 2017). The irruption peaked in December but hawk owls have been recorded in all

months from September to April (Fig. 2).

Monthly observations from the Skåne area in South Sweden include 316 observations from 2000–21 and the distribution is September–5.7%; October–16.1; November – 18.5; December – 19.6; January – 26.8; February – 13.7; March – 6.0, and April – 8.0 %. A clear peak is in January while in Finland it is in November (Fig. 2).

In Finland it has been noted that hawk owls may stop their invasion even for a longer period obviously if finding good food (= small mammal) resources. Although the birds were not individually marked it was obvious that 62 owls out of 131 were seen in the same area at least on two consecutive days in 2021. At least 4 owls stayed in the same area for up to four months: Jalasjärvi 7/11–20/03, Kuortane 31/10–10/03 and 25/10–4/03 and Lapua 30/10–24/03. The best-studied owl in Kuortane was recorded 32 times during 25/10–4/03 in an area of 13 ha (Mikkola et al. 2022).

Förschler et al. (2015) reported a very long stay of one overwintering hawk owl in the Black Forest at least from 23/11/2014–7/04/2015, which is even longer than those noted in Finland.

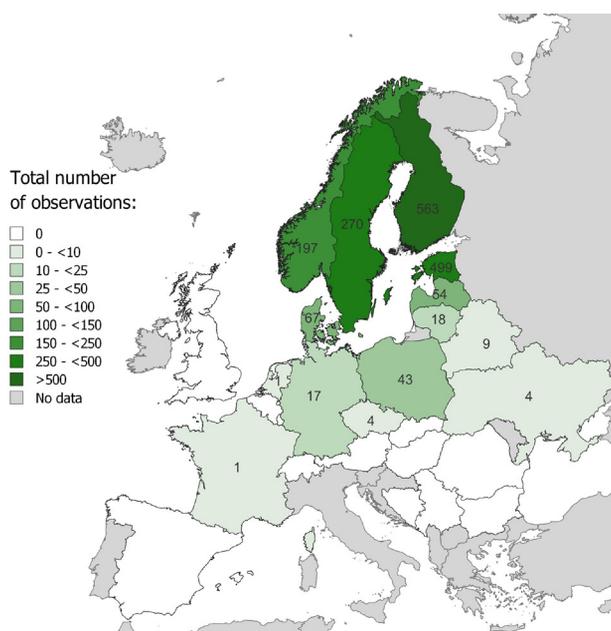


Fig. 3. The northern hawk owl (*Surnia ulula*) total observations during years 2010–2021.

Obr. 3. Celkové pozorovania krahule hôrnej (*Surnia ulula*) v priebehu rokov 2010–2021.

Country details

Austria

Albegger (2022) has recently summarized all 19 hawk owl observations from Austria. The first dates back to before 1807 and the species were last recorded in 1990. Between 2010 and 2022, therefore, there are no records.

Belarus

Belarus has 8 records from our study period. Most of them have been published (Nikiforov & Samusenko 2014; Kovaljonok 2020; Samusenko 2020; Protocol BOFC 2022). One internet record was added from October 2014 (Birding Belarus 2/11/2020). These nine records are included in Figures 3–5 and Table 1. In Belarus, the year 2013 is the best invasion year with 33% of the observations. Interestingly, two more observations were made in November 2022 in Gomel and Vitebsk regions, obviously due to the early arrival of winter in 2022 (Not included in Table 1).

Belgium

There are five old records from Belgium, two out of five are from the 1800s and the others falling between 1923 and 1943 (Vlavico 1989). In this century only one more hawk owl sighting is recorded from Vlaanderen city

from 03/12/2005 (www.naturpunt.be). The year 2005 was listed as an invasion year in Finland and species was seen also in the Netherlands.

Bosnia and Herzegovina

Avibase (2023) lists the hawk owl as any other common species for Bosnia and Herzegovina. However, according to Almir Hukić (pers. comm.), there are no

Tab. 1. The northern hawk owl (*Surnia ulula*) invasions (% of all observations from 2010 to 2022) in twelve European countries in 2010–2022. Data sources are presented in Material and Methods. Bold percentages indicate the main invasion years in a particular country.

| Invasion Year | Norway (197) | Sweden (270) | Finland (563) | Estonia (499) | Latvia (54) | Lithuania (18) | Poland (43) | Denmark (67) | Germany (17) | Belarus (9) | Czechia (4) | Ukraine (4) |
|---------------|--------------|--------------|---------------|---------------|-------------|----------------|-------------|--------------|--------------|-------------|-------------|-------------|
| 2010–11 | 0 | 0 | 3.4 | 1.8 | 7.4 | 0 | 9.3 | 0 | 5.9 | 23.5 | 0 | 0 |
| 2011–12 | 0 | 0 | 8.2 | 5.2 | 0 | 0 | 9.3 | 0 | 0 | 0 | 0 | 0 |
| 2012–13 | 15.7 | 41.5 | 2.8 | 3.8 | 11.1 | 11.1 | 14 | 11.5 | 0 | 0 | 0 | 0 |
| 2013–14 | 1.5 | 1.9 | 19.2 | 18.5 | 11.1 | 16.7 | 14 | 18 | 64.7 | 35.3 | 0 | 0 |
| 2014–15 | 0 | 0.7 | 4.4 | 3 | 9.3 | 11.1 | 9.3 | 0 | 5.9 | 5.9 | 0 | 0 |
| 2015–16 | 2.6 | 3.3 | 1.2 | 1.6 | 5.6 | 0 | 7 | 9.8 | 5.9 | 0 | 0 | 0 |
| 2016–17 | 34.5 | 29.6 | 2.5 | 5 | 3.7 | 5.6 | 0 | 24.6 | 0 | 5.9 | 0 | 0 |
| 2017–18 | 4.1 | 1.9 | 27.4 | 40.3 | 31.5 | 38.9 | 7 | 0 | 0 | 23.5 | 0 | 0 |
| 2018–19 | 1.5 | 1.9 | 4.5 | 2.8 | 1.8 | 11.1 | 0 | 1.6 | 5.9 | 0 | 0 | 0 |
| 2019–20 | 8.1 | 14.4 | 0.7 | 1.6 | 1.8 | 0 | 2.3 | 32.8 | 0 | 0 | 0 | 0 |
| 2020–21 | 30.5 | 3.7 | 2.3 | 6.8 | 1.9 | 0 | 16.3 | 0 | 0 | 0 | 5.9 | 0 |
| 2021–22 | 1.5 | 1.1 | 23.3 | 9.6 | 14.8 | 5.6 | 11.6 | 11.6 | 11.8 | 0 | 0 | 0 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Tab. 1. Invázie (% so všetkých pozorovaní od 2010–2022) krahule hôrnej (*Surnia ulula*) v dvanástich európskych krajinách v rokoch 2010–2022. Zdroje údajov sú uvedené v Materiály a metodike. Zvýraznené hodnoty percent predstavujú hlavné invázne roky v príslušnej krajine.

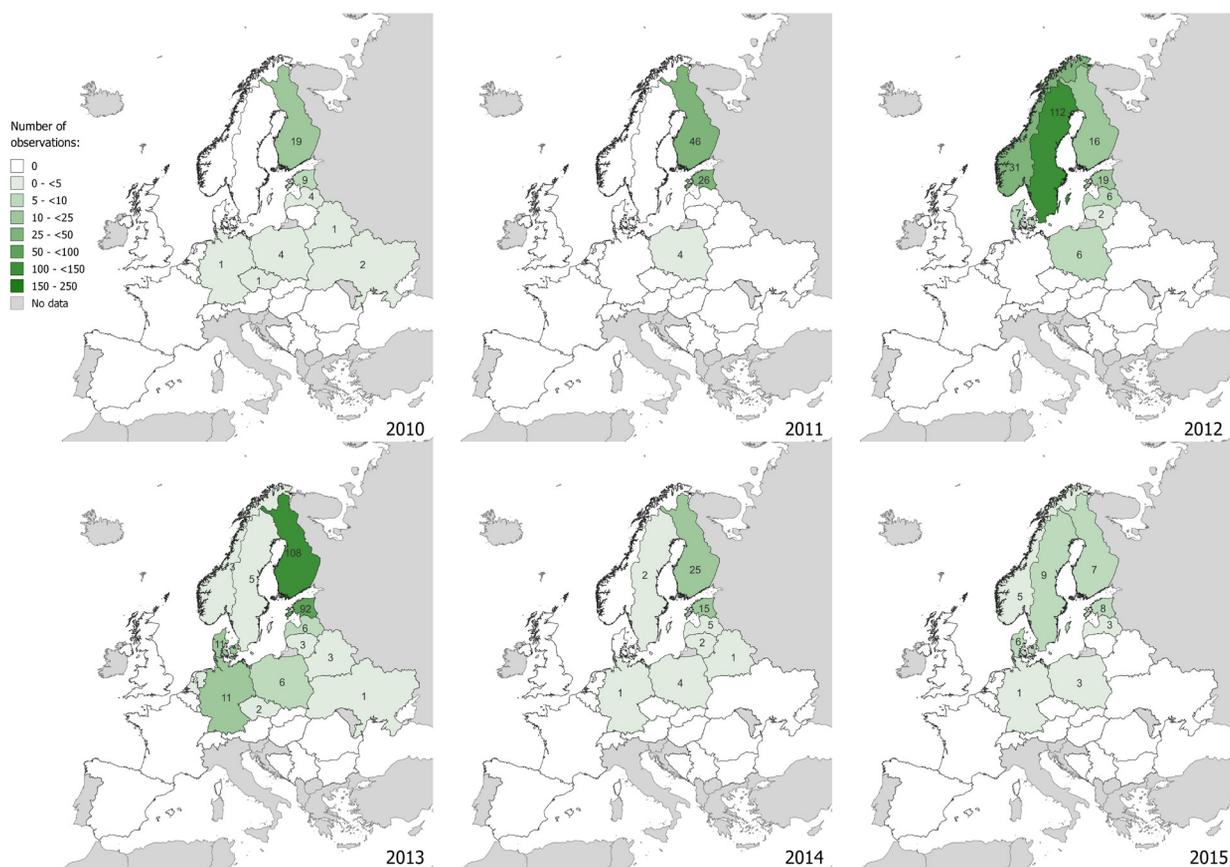


Fig. 4. Annual observations of the northern hawk owl (*Surnia ulula*) observations during years 2010-2015.

Obř. 4. Ročné pozorovania krahule hórnej (*Surnia ulula*) v priebehu rokov 2010-2015.

official records of that species in the country, only some unverified rumours that one hawk owl was ostensibly killed in Bosnia in the close past. The matter was never investigated nor confirmed by the officials.

Bulgaria

Simeonov et al. (1990) list the hawk owl as one possible species to occur in Bulgaria but according to Zlatozar Boev (pers. comm.), this species has officially never been recorded so far in the country.

Czechia

There are 37 official records from Czechia mainly from the records of the Faunistic Committee of the Czech Society for Ornithology supplemented with one observation from Avif, the Faunistic database of the Czech Society for Ornithology (<https://www.birds.cz/avif/>). Between 1851 and 1949 a total of 27 records were made; from 1950 to 1999 seven and from this

century four records, namely 1/10/2010; 1–9/02/2014, 9–23/03/2014 and 31/08/2017. Invasion years 2013–14 and 2017–18 correspond well with these observations (cf. Figures 3–5 and Table 1).

Denmark

Rosendahl (1973) wrote that during his time the hawk owls irrupted until Denmark at least 30 times, mentioning especially the years 1941–42, 1950–51 and 1971–72. According to Rosendahl (1973), some invading owls will continue further south until Switzerland and Romania (!). Christensen & Rasmussen (2015) revised all Danish records until 1965. The new status before 1965 is 26 records of 26 birds, the first confirmed record was a male shot on 20/01/1822. All observations are from late September–January, exceptionally April–May, with the majority from October–December. Ehmsen (2004) published a detailed paper on the mass invasion of the hawk owl between 1983–84 and also the

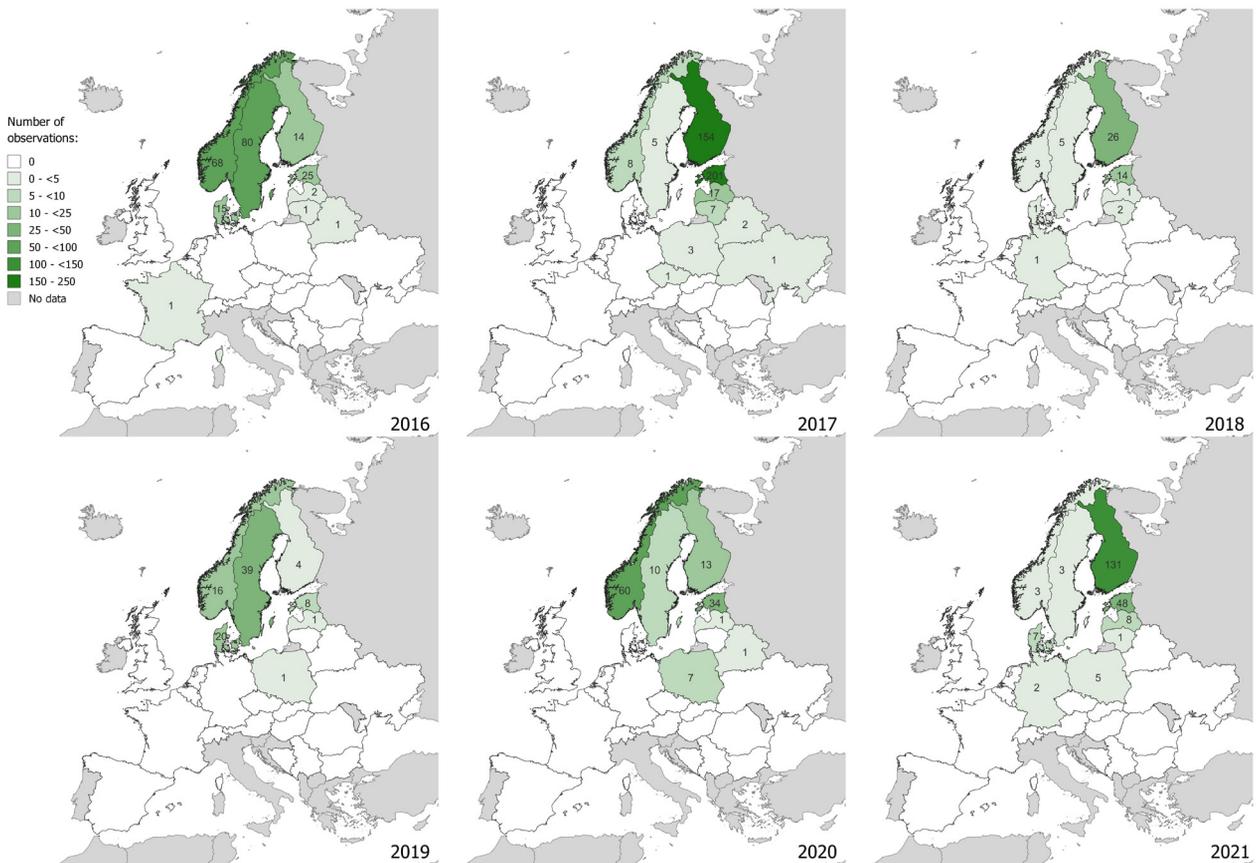


Fig. 5. Annual observations of the northern hawk owl (*Surnia ulula*) observations during years 2016–2021.

Obř. 5. Ročné pozorovania krahule hōrnej (*Surnia ulula*) v priebehu rokov 2016–2021.

smaller invasion 1989–90. It was estimated that between September and May 1983–84, some 350 to 400 hawk owls arrived in Denmark from Norway, Finland and also from northern Russia.

Between 2010 and 2022 a total of 67 owls were recorded in Denmark (<https://dofbasen.dk>) and the clear invasions years are 2013–14, 2016–17 and 2019–20 (Figures 3–5 and Table 1). Interestingly, Danish annual observations have a very low overlap with all other countries (Table 2). Ehmsen (2004) was assuming that Danish owls are originating from Norway, Finland and northern Russia, which is the only country of origin proven with ringing results as shown later.

Estonia

The Estonian Rarities Committee has approved the following hawk owl breeding records: 1893, 1942, 1947, 1974, 2013 and 2014, when three nests were found in the country (Paal 2014). Despite of increase in birdwatching,

no more breeding records have been made after 2014. All hawk owl invasion observations between 2010 and 2022 were collected mainly from <https://elurikkus.ee/en> (Figures 3–5). A total of 499 observations are included in Table 1 and the monthly comparison (Fig. 2). Materials from Estonia and Finland are identical in the main invasions years, i.e. 2013–14, 2017–18 and 2021–22, during which 68.4 – 69.9 % of all irrupting owls were seen in Estonia and Finland (Table 1). The similarity index indicating the overlap between Estonia and Finland in annual observations is the highest in the entire material (0.69, Table 2).

Finland

Finnish web page Tarsiger.com was publishing hawk owl observations from Europe until 2017 but unfortunately not after that. From South Finland, it listed 17 hawk owl observations between 16/10/2003–7/02/2004, 49 next season 19/09/2004–6/02/2005, 171 between 31/08–

Tab. 2. Similarity Index of the northern hawk owl (*Surnia ulula*) annual invasions in twelve European countries 2010–2022. Bold black numbers indicate a significant overlap in the main invasion years (similarity index over 0.50) and grey shaded values very low overlap in the invasion years (similarity index below 0.20) between the countries.

Tab. 2. Index podobnosti ročných invázií krahule hórnej (*Surnia ulula*) v dvanástich európskych krajinách v rokoch 2010-2022. Tučné čierne čísla označujú výrazné prekryvanie v hlavných rokoch invázie (index podobnosti nad 0,50) a sivo podfarbené hodnoty veľmi nízke prekryvanie v rokoch invázie (index podobnosti pod 0,20) medzi krajinami.

| Similarity Index | Norway | Sweden | Finland | Estonia | Latvia | Lithuania | Poland | Denmark | Germany | Belarus Czechia Ukraine |
|--|-------------|-------------|-------------|-------------|-------------|-----------|-------------|---------|---------|-------------------------------|
| Norway | 1 | 0.54 | 0.2 | 0.28 | 0.31 | 0.18 | 0.32 | 0.36 | 0.11 | 0.08 |
| Sweden | 0.54 | 1 | 0.25 | 0.31 | 0.34 | 0.15 | 0.23 | 0.31 | 0.14 | 0.13 |
| Finland | 0.2 | 0.25 | 1 | 0.69 | 0.61 | 0.36 | 0.45 | 0.21 | 0.33 | 0.34 |
| Estonia | 0.28 | 0.31 | 0.69 | 1 | 0.61 | 0.41 | 0.48 | 0.22 | 0.3 | 0.33 |
| Latvia | 0.31 | 0.34 | 0.61 | 0.61 | 1 | 0.44 | 0.58 | 0.39 | 0.32 | 0.32 |
| Lithuania | 0.18 | 0.15 | 0.36 | 0.41 | 0.44 | 1 | 0.31 | 0.27 | 0.2 | 0.25 |
| Poland | 0.32 | 0.23 | 0.45 | 0.48 | 0.58 | 0.31 | 1 | 0.25 | 0.32 | 0.24 |
| Denmark | 0.36 | 0.31 | 0.21 | 0.22 | 0.39 | 0.27 | 0.25 | 1 | 0.2 | 0.09 |
| Germany | 0.11 | 0.14 | 0.33 | 0.3 | 0.34 | 0.2 | 0.32 | 0.2 | 1 | 0.18 |
| Belarus Czechia Ukraine | 0.08 | 0.13 | 0.34 | 0.33 | 0.32 | 0.25 | 0.24 | 0.09 | 0.18 | 1 |

31/12/2005 and 18 owls 30/09–4/11/2007. From South and Central Finland 600 observations 1/09–10/11/2013.

France

From France, we have found five observations, three very old ones 1/01/1803, 1/07/1834 and 1/01/1842 (INPN 2022). Two recent observations are from Habère-Poche, Haute-Savoie 15/11/2008 (www.ornithomedia.com) and 1/04/2017 Côte d’Azur (INPN 2022). The last one fits very well as the continuation of large invasions noted in 2016–17 in Norway and Sweden, a year before those in Finland, Estonia and Latvia (Table 1).

Germany

There is a very detailed study of invading hawk owls from Germany starting from April 1790 until the winter of 2013–14 and covering 171 records of 179 owls (Krüger 2013). From the period afterwards, there are five records from the winter half-years until 2021–22 that have been accepted by the Deutsche Avifaunistische Kommission (DAK in litt.www.dda-web.de), including one well-documented record from southern Germany (Förschler et al. 2015 and Püschel & Stark 2017). Table 1 shows the German data for our study period indicating that 2013–14 was the most important invasion year in the country (64.7 % of 17

observations). Hawk owls have been recorded in all parts of Germany, but mainly in the northern federal states of Mecklenburg-Vorpommern and Niedersachsen (52) and least in southern Germany, such as in Baden-Württemberg and Rheinland-Pfalz (Table 5 in Krüger 2013). The overlap in the main invasion years between German and the rest of the countries is very low, especially with Norway and Sweden (Table 2).

Hungary

Hawk owl is a rare invader in Hungary, where only two records have been approved thus far: March 1937 and October 1976 (Szép et al. 2021).

Latvia

Latvia has 54 observations for our study period (Table 1). Hawk owl has also bred in North Latvia in 1860 (Löwis 1893) and some single summer birds have been recorded between April and August in 1991, 1997 and 2003 (Baumanis & Celmiņš 1995). Invading hawk owls have been seen every winter since 2005 – only 2011–12 remain zero in the database (<http://www.putni.lv/surulu.htm>). The major irruptions have taken place in 2013–14, 2017–18 and 2021–2 (Table 1). The similarity index presenting the overlap is the highest with Finland, Estonia and Poland (Table 2).

Lithuania

Since 1915 Lithuania has 32 records. Before our study period owls were seen: 1915–1, 1976–1, 1978–1, 1986–1, 1991–1, 2005–1, 2006–2, 2007–1 and 2009–2. On June 20, 1978, one hawk owl was heard in the northern most part of the country but the nest was not found. A total of 21 observations took place between 2010 and 2022 and clear irruption years were 2013–14 and 2017–18. The last one 2021–22 was not as large as in Finland and Latvia (Table 1). Like in Belarus, autumn 2022 brought already three more observations from Lithuania (not in Table 1). The invasion year overlap between Finland, Estonia and Latvia is high (Table 2).

Luxemburg

Avibase (2023) lists hawk owl as rare and accidental in the country but we have no further information.

Norway

Dale & Sonerud (2022) published data on hawk owl irruptions in Norway, and Svein Dale gave us detailed numbers of Oslo and Akershus, southeastern Norway (Figure 6). During our study period 2010–22, a total of 197 owls were recorded and the clear irruptions years were 2012–13, 2016–17 and 2020–21 (Table 1). The overlap in the annual observations (= similarity index) is high only with Sweden (0.54) as in all other countries the main invasion years are a year later than in Norway and Sweden (Table 2). Dale (2017) estimated that the majority of the Fennoscandian hawk owl population invaded the south in 2016 and that some 10 000 to 20 000 owls were reaching South Norway. Later in this paper, we show that it is highly unlikely that the origin of all these owls would have been Fennoscandia.

Poland

In the 19th century and up to the 1920s hawk owl was a fairly regular visitor with some influxes, especially in Masuria and Pomerania. In the second half of the 20th century, there was only one record in 1970. The modern series of sightings began in 2002 and 43 records exist from 2010–22 (Figures 3–5 and Table 1). Peak years are not at all as clear as in the other countries but the similarity is clear with Latvia (0.58; Table 2).

Romania

In the study period from 2010 to 2022, there are no records of the hawk owls in Romania (Cristi Domsa, pers. comm.). According to BirdLife, Romania there is only one old record from 1904 when a dead bird was collected

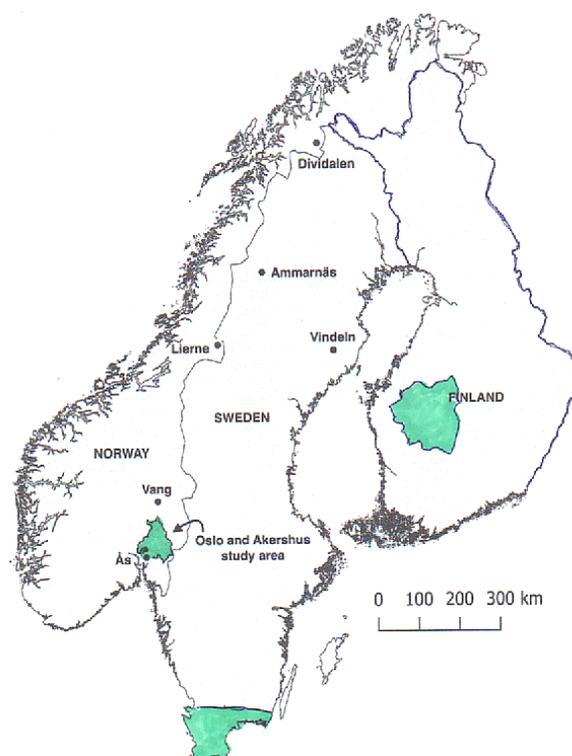


Fig. 6. Norway, Sweden and Finland study areas are shown in green. See the text for the details. Based on the map from Dale & Sonerud (2022).

Obr. 6. Študované územie v Nórsku, Švédsku a Fínsku zvýraznené zelenou farbou. Viac informácií v texte. Na základe mapy Dale & Sonerud (2022).

from Timișoara by a forester and that bird is now mounted in the Bariat Museum collection.

Russia

In Russia, irrupting hawk owls are known to cover great distances and travel in highly variable directions (Dement'ev & Gladkov 1966). Russian hawk owls have been wandering occasionally to western Alaska (Duncan & Duncan 1998), so there the paler *Surnia u. ulula* could meet the darker *S. u. caparoch*. Any outcome of such meetings has not been reported this far.

Serbia

Avibase (2023) lists hawk owl in Serbia as rare/accidental but according to Nenad Spremo, there are no officially accepted records.

Slovakia

Only 14 records exist from Slovakia even from the

historical times when Slovakia was part of Czechoslovakia (1918 – 92) or part of the Austrian-Hungarian Monarchy (all data before 1918). Mostly observations are from the 19th century, five records from the 20th century but none from the 21st century nor our study period 2010 – 22.

Spain

Avibase (2023) lists hawk owls in Spain as rare and accidental. This is almost misleading as the only observation this far is from one ship-assisted North American subspecies *Surnia ulula caparoch*. This owl, the first-year male, was found on board a ship and photographed on 24/10/1924 in Las Palmas, Gran Canaria. From there the “hitchhiker” continued in that same boat until Rotterdam where it died on 7/11/1924 and is now mounted in Leiden’s Biodiversity Center as nr 5, register number 5409 (Gutiérrez et al. 2013).

Sweden

Sweden has excellent citizen data on hawk owl invasions in www.artportalen.se from where observations were collected for South Sweden (Skåne area including Halland, Kronoberg, Småland and Västergötland) (cf. Fig. 6). Our study period 2010 – 22 had 270 records (Figures 3–5 and Table 1). There are three clear irruption years, 2012–13, 2016–17 and 2019 – 20, two first ones are the same as in Norway and the last is one year before Norway and even two years before Finland, Estonia and Latvia. The overlap in the invasion years is high only when compared with Norway (Table 2).

Switzerland

Danish Rosendahl (1973) wrote that the first invading hawk owls continue until Switzerland but this far species is recorded in that country only three times in 1864, 1903 and 1917 (Vogelwarte.ch). However, lately, German authors (Püschel & Stark 2017) added more old observations to Switzerland for the winters 1859/60, 1900/01 and 1915/16. For our study period, no records are known.

The Netherlands

Dutch observations were too few to put in our Tables but the first hawk owl from Amerongen, Utrecht was seen on 5/10/1920 (van den Berg & Bosman 1999), the second from Brunssum, Limburg on 2/04/1995 and the third from Hooghalen, Drenthe on 30 – 31/10/2005 (van der Vliet et al. 2006, Wiegant et al. 2007). A fourth bird from Zwolle Overijssel got a lot of publicity as it was seen in the area from 12/11/2013 – 10/02/2014 (Haas et al. 2014, 2015, see also www.dutchavifauna.nl). The last two

observations fit well with known invasions in Finland, Estonia and Latvia. As stated before later in 2005 hawk owl was seen also in Belgium.

The United Kingdom

From British islands, there are much fewer observations than one would have expected. This could indicate that hawk owl is very reluctant to cross any large water bodies or open sea (also Hopper 2005) if not able to hitchhike a boat as the American subspecies has done a few times (Guiguet 1978). The British Rarities Committee has approved one hawk owl from Shetland where the same bird was seen between 12/09–21/09/1983. Also, Sweden had that autumn a very large irruption estimated to contain 2000–4000 owls (Svensson et al. 1999). Another hawk owl was seen and photographed on 16/12/2017 in North Yorks (www.birdguides.com) but now it is known that this owl escaped six days earlier from the Harrogate Bird of Prey Centre, category E. There are some very old observations like 29/12/1860 Shetland, Scotland and 21/11/1898 Aberdeenshire, Scotland, both of them being shot birds.

American subspecies *S. u. caparoch* is famous for its long boat trips, one of the oldest observations is from Cornwall 30/03/1830. The owl was found exhausted on board a collier a few miles from Looe, sea area Plymouth, en route to Waterford, Ireland. Now that owl is at the National Museum of Dublin, Ireland (Acc. No. NMINH 1959.13.1 (The British Rarities Committee).

Ukraine

Hawk owl invasion records for Ukraine include four records (Figures 3–5 and Table 1) all from clear invasion years 2010–11, 2013–14 and 2017–18. Two observations from NE Ukraine, 23/10 and 16/11/2010, have been published (Knysh & Malyshok 2010).

Ringling Results

Unfortunately, ringling results are still limited to knowing the invasion details but hawk owl can move even over two thousand km within or outside its normal breeding range (Solonen 2017). The most exciting recoveries in Finland are those from owls ringling in Kuivaniemi, Liminka and Kittilä (Valkama et al. 2014, Valkama 2015). One young from the Kuivaniemi nest was found in 1981 from the Ob-River in Siberia 2795 km east of the ringling site. Another young from Liminka was captured in October near Norilsk mining city 2659 km east of the nest. The third young one ringling in Kittilä was shot 152 days later 26/10/2015

in Omsk, Russia 2720 km east. This means an average movement of 18 km per day which is the remarkable speed of any migration for such a distance.

Interestingly thus far at least eight hawk owls have been found in Norway after they have been ringed in Finland (Recoveries Atlas 2021). Five hawk owl young were ringed in Nousiainen in 1986, and one of them was found dead 115 days later in Vologda, Russia after flying 1005 km east from the nest and another young was flying 599 km to the opposite direction (west) when it was found injured in South Norway 200 days later from ringing (Valkama et al. 2014).

Some Finnish hawk owls have been flying to Sweden after the ringing, for instance near Lompolo, Ylläs 31/05/2011 ringed one-year-old was controlled in Jockfall Överkalix, Sweden as a breeding bird 14/05/2016 being thus six years old. Sweden has the ringed hawk owl age record in Europe when in Överkalix 2/06/2011 ringed one-year-old bird was found partly eaten on 22/04/2020 in Saittarova, Tärendö 105 km north of the ringing site (Ove Stefansson, e-mail 25/10/2022).

Swedish hawk owls have been wandering after the ringing at least four times to Norway and five times to Finland and eleven have moved far to Russia, like the young one ringed in Småland which was shot down in October 1974 at the White Sea, i.e. some 1500 km north from the ringing place (Fransson et al. 2001). Seven out of 11 recoveries from Russia are concerning the first-year birds, two of which were flying to Murmansk, Russia (some 1300 km north from the ringing sites), one to Jaroslav (1500 km east) and one to Perm near Ural mountains (1834 km east).

Although Finnish and Swedish hawk owls have often (12 at least) been recovered in Norway, the owls ringed in that country have been found in Sweden only one time this far. In April 1984 a male ringed in Norway was found dead in Kalix, Sweden 1986. It had moved 826 km north from the ringing site. Norway has also far distance recoveries from Russia, for instance, Hedmark in May 1985 ringed owl was found in June 1986 NE side of the Moscow area (Sonerud 1994).

Russian ringing results are not well known but at least one on Veliki island at Kandalaksha, the White Sea 26/06/1983 ringed one-year-old owl was found dead after the large invasion on 6/07/1984 in Reersø, Denmark (Ehmsen 2004).

These limited ring recoveries are proving that movements from west to east and from north to south and vice versa are taking place over the Palaearctic boreal

forest zone. The EURING databank (2023) mapped most of the above-mentioned ring recoveries, which can be seen at <https://migrationatlas.org/node/1580>.

Origin of the Invasions

In the Nordic countries, it has been often debated what is the origin of the irrupting owls in the region. In Norway, authors (Hagen 1956, Dale 2017) seem to be convinced that even mass invasions originate within Fennoscandia, but northern Russian origin is supported in Finland (Mikkola 1983, Sulkava&Huhtala 1995, Mikkola et al. 2022), Sweden (Edberg 1955, Svensson et al. 1999) and especially in Denmark (Ehmsen 2004) where they have the first recovery of a Russian ringed hawk owl.

It must have been the Swedish Edberg (1955) who was the first to spell out that the large hawk owl invasions, like that in 1950–51 noted in all Nordic countries, must have originated from Russia (still the Soviet Union at that time). Unfortunately, the better-known Norwegian owl authority Hagen (1956) override the less famous Edberg by claiming that the invasion originated purely from the Fennoscandia.

Before any ringing results, Mikkola (1983) agreed with Edberg and suggested that also 1957 sizeable hawk owl irruption originated from Russia because in Finland only three nests were found while in northern Russia 1957 was an excellent vole year and hawk owls nested in large numbers (Bianki & Koshkina 1960). This autumn and winter influx was noted also in Germany (Berndt 1959).

All our recent observations make it even more obvious that no large influx of the hawk owls could originate only from our Nordic breeding populations. The top examples of that are the years 2013, 2017 and 2021. In 2013 only one nest was reported in Finland (Honkala et al. 2014) and during the autumn a large number of hawk owls invaded Finland, more than in any previous decades (Södersved 2013) and the same sizeable influx continued to Estonia (Paal 2014). The same story in 2017 when only five nests were reported in Finland (Björklund et al. 2018), but even alone in a limited study area in Westcentral Finland (= Suomenselkä) 154 irrupted owls were observed (Table 1). In 2021 three hawk owl nests were found (Honkala et al. 2022) but the autumn and winter invasion was again massive, and our study area number of observations was 131. Therefore, we feel safe to conclude that the origin of the irrupting hawk owls must be mainly from outside Finland, and where else it could be than in the east.

Conclusions

Like two other northern owls, i.e. great grey owl (*Strix nebulosa*) and snowy owl (*Bubo scandiacus*), hawk owl leads a nomadic life, dispersing extensively within its breeding range in response to regional food availability and therefore to climatic conditions (Mikkola 1983, Solonen 2017). It seems that the main part of the hawk population occurs annually in those northern boreal forests, where the voles are most available, preferably so numerous that the next year breeding will be facilitated (Sulkava & Huhtala 1995).

Interestingly, all handbooks, like Mikkola 1983, Scherzinger & Mebs 2020, etc., see hawk owl irrupting more or less regularly only until North Germany. This paper shows that hawk owls reach at least France, Austria, Switzerland, Czechia, Slovakia, Ukraine, Hungary and Romania but not Spain, Slovenia, Bosnia & Herzegovina, Montenegro, Italia, Albania, Serbia, Moldavia and Bulgaria. Old observations from the southern countries, like the United Kingdom, France, Switzerland, Slovakia, Hungary and Romania, could indicate that the invasions before our study period were larger or that owls moved further south for some other reason, like the colder climate.

Still limited but so far most interesting ringing recoveries are demonstrating clearly, that even the young ones from the same nest can invade after breeding in opposite directions, like from Finland to South Norway vs. Northern Russia or Siberia. These movements are comparable with those of the snowy and great grey owls. So, it is maybe artificial to talk about hawk owl populations in Norway, Finland or Sweden as we have done above.

Improving our knowledge of hawk owl invasions would require further ringing results and preferably GPS tagging of several birds for satellite tracking as has been done already with the great grey and snowy owls in Norway (Roar Solheim, pers.comm.). Only then we could see how hawk owls are using their vast distribution area and how well they cope with climate warming. Mysterud (2016) has already shown that drastic changes in the arctic vole and lemming populations due to wet winter and icy snow conditions affect seriously the life of many boreal owls.

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Diet composition of White-tailed Eagles inhabiting two adjacent inland lakes in Northern Greece

Zloženie potravy orliakov morských obývajúcich dve priľahlé vnútrozemské jazerá v severnom Grécku

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Abstract: In territorial raptors, breeding performance and foraging behaviour are affected by territory characteristics as the abundance and availability of different prey species varies between habitats. In this study, we examined the diet of two White-tailed Eagle pairs, occupying neighbouring territories in two adjacent inland lakes in Northern Greece. We assess the diet composition of the species in the southernmost part of its European range and evaluate any intraspecific differences in the diet that may reflect resource and/or niche partitioning between territories. We found that birds and specifically waterbirds comprise the largest and quantitatively most important part of the White-tailed Eagle's diet, with fish being the second most important prey group that was only found in the nest remains from one territory. There was high diet overlap between the two territories and when considering only avian prey our results suggest that the species predate on heavier (and the most common) waterbird species. A main factor that could be driving differences in the abundance and availability of different prey species between territories could be lake physiography, as our results point to a segregation and a subsequent resource partitioning between territories, with each pair utilizing an adjacent lake and its associated habitats. Competition and territoriality therefore seem to be important intraspecific interactions that along with prey availability could promote changes in territory size and ultimately affect individual fitness.

Abstrakt: U teritoriálnych dravcov sú hniezdna produktivita a lovné správanie ovplyvnené charakteristikami teritória ako je početnosť a dostupnosť jednotlivých druhov koristi. Tieto charakteristiky sa však medzi habitatmy odlišujú. V tejto štúdiu sme skúmali potravu dvoch párov orliaka morského, ktoré osídlili susedné teritória dvoch priľahlých vnútrozemských jazier v severnom Grécku. Hodnotíme zloženie potravy v najjužnejšej časti jeho európskeho areálu a vyhodnocujeme všetky vnútro druhové rozdiely v potrave, ktoré môžu odrážať rozdelenie zdrojov a/alebo ník medzi teritóriami. Zistili sme, že vtáky, konkrétne vodné vtáky tvoria najväčšiu a kvantitatívne najdôležitejšiu časť potravy orliaka morského, pričom ryby sú druhou najdôležitejšou skupinou koristi, ktorá sa našla len v potravných zvyškoch v hniezde z jedného územia. Medzi oboma teritóriami došlo k vysokému prekrytiu zloženia potravy a hodnotiac iba vtáciu korisť, naše výsledky naznačujú, že druh loví ťažšie (a najbežnejšie) druhy vodného vtáctva. Hlavným faktorom, vedúcim k rozdielom v početnosti a dostupnosti jednotlivých druhov koristi medzi územia, tak môže byť fyzická geografia jazera, keďže naše výsledky poukazujú na segregáciu a následné rozdelenie zdrojov medzi teritóriami pričom každý pár využíva priľahlé jazero a jeho pridružené biotopy. Konkurencia a teritorialita sa preto zdajú byť dôležitými vnútro druhovými interakciami, ktoré sa spolu s dostupnosťou koristi podporujú zmeny veľkosti teritória a v konečnom dôsledku ovplyvňujú individuálnu kondíciu.

Key words: *Haliaeetus albicilla*, intraspecific competition, foraging ecology, niche partitioning, prey remains

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Introduction

Apex predators play an important role in ecosystems, directly affecting prey densities through the entire food web (Ripple et al. 2014). Understanding the spatial and temporal variation in diet and foraging strategies of top predators, such as raptors, is a critical issue in ecology and conservation (Newton 2010). Prey abundance is an important factor shaping reproductive performance, and because of their position in the food chain raptors are often used as indicators of ecosystem health (Sergio et al. 2008, Newton 2010).

The White-tailed Eagle (*Haliaeetus albicilla*, hereafter WTE) is an apex predator closely associated with the aquatic environment. The species is an opportunistic generalist in terms of food, with fish, waterbirds, medium sized mammals and, locally, reptiles making up the main diet components (Cramp & Simmons 1980). However, the relative importance of these components in the diet may vary locally (Ekblad et al. 2016, Nadjafzadeh et al. 2016). In Greece, one of the southernmost limits of the species' distribution, the WTE was widespread and locally common during the 19th and 20th centuries. However, the last decades the species suffered a steep decline and even reached the verge of extinction in the country with an estimated population of 1–4 pairs in the 1990s (Handrinos & Akriotis 1997). Today, following the general recovery of the species in Europe and the Balkans, and possibly as a result of the relatively more effective protection of wetlands, the population shows an increasing trend and has recovered to about 13 pairs, with a presence in all the large wetlands of Northern Greece, even in artificial lakes (Vavylis et al. 2021; Westrip & BirdLife International 2022). Due to the small size of the population, however, the species is still classified as Endangered (EN) in the Mediterranean and as Critically Endangered (CR) in Greece according to IUCN (Legakis & Maragou 2009; Westrip & BirdLife International 2022).

In territorial bird species, such as most raptors, breeding performance and foraging behaviour are intertwined and are affected by territory characteristics as the abundance and availability of different prey species varies between habitats (Steenhof & Newton 2007). Indeed, food availability is considered as the main limiting factor affecting annual reproduction in raptors (Newton 2010), however, it can also be influenced by weather, habitat quality, predation and finally competition (Hakkarainen & Korpimäki 1996, Steenhof et al. 1997, Newton 1998, Krüger 2004). Raptors have few predators and are thus more likely to be influenced by competition but evaluating its relative importance in shaping diet patterns and territoriality is a challenging

task (Martínez-Hestekamp et al. 2018). According to theoretical expectations, larger predators should compete more strongly than smaller ones (Schoener 1983), diet overlap should be lower during prey shortage and diet similarity should be especially reduced in neighbouring pairs (Korpimäki 1987). This overlap may be reduced through resource partitioning (both in terms of species and biomass) and/or spatial segregation of feeding areas (Pianka 1974, Steenhof & Kochert 1985, Cecere et al. 2018).

In the present study, we examined the diet of two White-tailed Eagle pairs, occupying neighbouring territories in two adjacent inland lakes in Northern Greece. Specifically, the aims of this study were (a) to report the diet composition of the species in the southernmost part of its European range and (b) to evaluate any intraspecific differences in the diet that may reflect resource and/or niche partitioning between territories.

Methods

Study site

Our study took place in the Koroneia and Volvi National Park located in Northern Greece (Fig. 1). The National Park is covered mainly by agricultural areas, followed by forests and semi-natural areas as well as wetlands and two main water bodies. The two lakes, Koroneia and Volvi, are sites of international importance as part of the Ramsar Convention and the Habitats Directive and are designated as Special Protected Areas for birds (Natura 2000 sites GR1220001 and GR1220009). Lake Koroneia is a shallow, highly eutrophic lake with a surface area of approximately 35 km² and a maximum depth of less than 3 m. Through the course of the years, the lake's surface area and water quantity and quality has declined dramatically (Mitraki et al. 2004, Gantidis et al. 2007), ultimately leading to die-offs of fish and bird populations and periodic droughts resulting even in the complete disappearance of surface water. In 2005 a restoration plan was implemented and since 2014 the lake has an almost stable depth thus favouring the re-establishment of fish populations (Ntonou et al. 2017). On the other hand, Lake Volvi is the second largest lake of Greece with a surface area of 68 km² and is a deep, eutrophic lake of tectonic origin. The lake is impacted by run-off from agricultural activities and animal husbandry, however it is regarded as less impacted by anthropogenic pressures than Lake Koroneia (Zacharias et al. 2002, Gantidis et al. 2007). Each lake holds a White-tailed Eagle territory (estimated by direct observation at 103.8 and 58.3 km² for Koroneia and Volvi respectively, distance between nests ~20km) and preliminary population monitoring and territory mapping show some level of

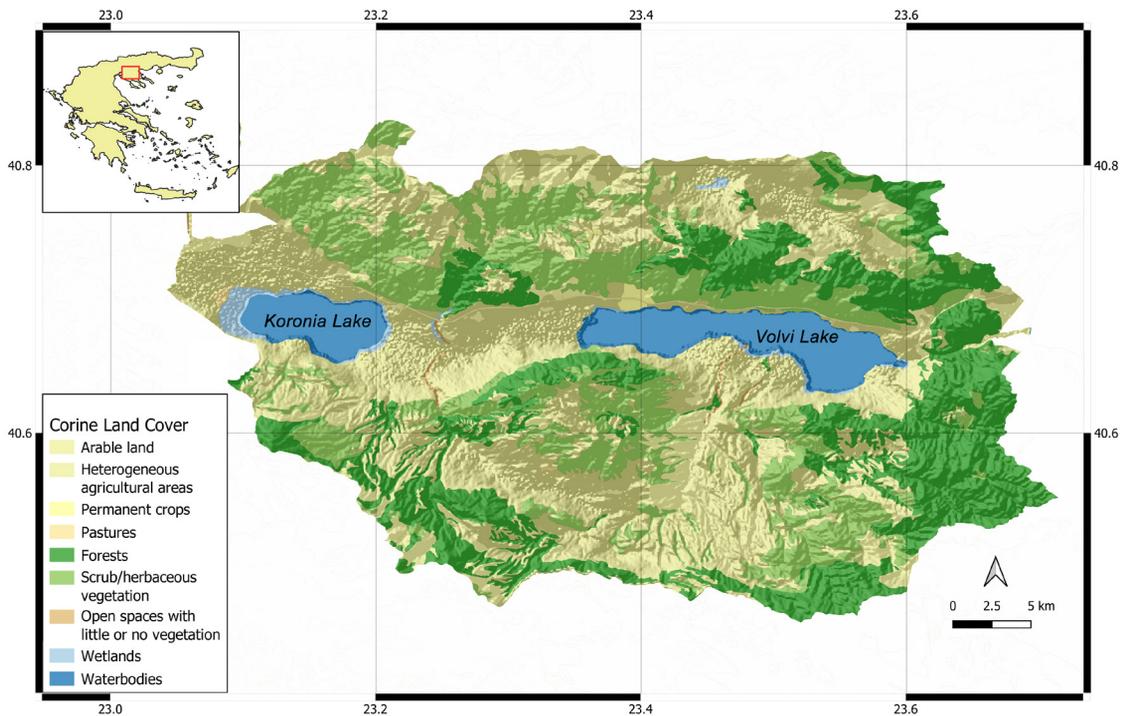


Fig 1. Map of the study area - Koroneia and Volvi National Park along with main land cover classes according to Corine classification. The two lakes correspond to the two territories.

Obr. 1. Mapa skúmanej oblasti - Koroneia a Volvi národný park spolu s hlavnými triedami krajinej pokrývky podľa klasifikácie Corine. Dve jazerá zodpovedajú dvom teritóriám.

segregation, with birds using the lake and the surrounding area for perching/hunting and roosting, whereas they have also been seen hunting in the mountainous areas around the lakes (Sidiropoulos et al. 2022).

Diet data

White-tailed Eagle nesting territories were visited, and prey remains were collected two to four times per season in April-October between 2013 and 2021. In total we gathered prey remains from 18 samples from the Koroneia territory and seven samples from the Volvi territory. In Koroneia, the samples consisted of 4-37 prey items, whereas the number of prey items per sample in Volvi was 4-20. Collection event frequency and number of prey items for each territory and year can be found in Table 1. All prey material from the nest was collected in each visit to avoid finding remains from the same prey in subsequent visits. All collections were stored individually and analysed separately. The contents of each pellet were determined when possible, however since most pellets were fragmented, we did not calculate the number of individuals per pellet (in such cases, a single individual of a prey species was assumed). Remains were identified to

the lowest identifiable taxonomic level (most of the times we reached species-level identification using the hairs of mammals, the feathers, humeri, tarsometatarsi, legs and bills of birds, species-specific bones of fish and scales and scutes of reptiles). Remains were identified using personal reference collections and/or field identification guides (Arnold et al. 1978, Brown et al. 1987, Teerink 1991). The number of items of each species was determined as the minimum number of individuals (MNI) at each collection i.e., if more than one part of the same species were found they were considered to originate from one individual, unless they differed in size and anatomical position thus indicating that they come from different individuals (Marti et al. 2007). Each territory final sample consisted of the sum of the MNIs of each collection.

Diet composition

Prey remains from each territory were combined to calculate the proportion of each prey group in the diet by dividing the number of individuals of a specific taxon by the total number of prey individuals. We also calculated the relative importance in biomass (%) defined as the number of individuals multiplied by the average body

Tab 1. Number of collection events and prey items for each White-tailed eagle territory and year in Northern Greece.

Tab 1. Počet zberov a položiek koristi pre každé teritórium a rok orliaka morského v severnom Grécku.

| Year | Koroneia territory | | Volvi territory | |
|------|--------------------|--------------|-----------------|--------------|
| | n collections | n prey items | n collections | n prey items |
| 2013 | 1 | 4 | - | - |
| 2014 | 2 | 18 | - | - |
| 2016 | 2 | 9 | - | - |
| 2017 | 2 | 29 | - | - |
| 2018 | 2 | 37 | - | - |
| 2019 | 2 | 14 | - | - |
| 2020 | 2 | 25 | 4 | 20 |
| 2021 | 4 | 20 | 2 | 8 |
| 2022 | 1 | 11 | 1 | 4 |

mass of each prey species reported in the literature (Cramp & Simmons 1980 for birds, Bobori et al. 2010 for fish and Jackson 1980 for reptiles). Body mass values for species not included in the previous references were retrieved from Encyclopaedia of Life (EOL; available from (Encyclopaedia of Life, 2022)). Dietary niche breadth was calculated using the standardised Levin’s (Bsta) and diversity of trophic spectrum was estimated using the Shannon (H’) index (Krebs 1999). The Levin’s index ranges from 0 (lowest niche breadth) to 1 (highest niche breadth). For the Shannon index higher values indicate higher diet diversity. Diet overlap between habitats was assessed by means of Pianka’s (O) index (Pianka 1973) that ranges between 0 (total separation) and 1 (total overlap). Since there was an uneven sampling effort between territories that could bias our comparison of diet composition between them, we employed a rarefied sample analysis to mitigate the problem. We drew a random subset of seven collections from Koroneia and recalculated the diet breadth, diet diversity and diet overlap indices. We followed this procedure five times to evaluate differences between territories. Differences in diet composition between territories were tested using a Welch t-test, whereas to visualise and aid the interpretation of these differences between territories, we summarized the composition data using non-metric multidimensional scaling (NMDS), for all years and both sites using Euclidean distance. The ordination analysis relied on Bray–Curtis dissimilarity and it was performed in the “vegan” R package (Oksanen et al. 2013). All statistical analyses were performed in R 4.2 (R Core Team 2022), plots were prepared using the R package “ggplot2” (Wickham & Chang 2015) and maps were designed with QGIS (v. 3.22).

Results

A total of 199 prey items belonging to at least 30 prey taxa were identified from 25 collection events from two nests. Overall, birds were the most common prey consisting 70.9% of the diet, followed by fish (15.1%) and to a smaller extent by reptiles and mammals consisting 10.6% and 3.5% of the diet (Table 2). Mammals such as sheep and wild boar were apparently consumed mainly as carrion, reflecting at least occasional scavenging of the species. Altogether, 17 bird species were identified in the diet, most of them waterbirds (they use wetlands as their main habitat). The most common prey species were the Coot (*Fulica atra*) and the Great Crested Grebe (*Podiceps cristatus*) making up more than 40% of consumed birds. Other important bird species were the Black-headed Gull (*Chroicocephalus ridibundus*), Shelduck (*Tadorna tadorna*) and Moorhen (*Gallinula chloropus*). Regarding fish remains, the Carp (*Cyprinus carpio*) and the Perch (*Perca fluviatilis*) were the most common species found in the remains. The reptile component consisted mainly of chelonians (tortoises and turtles). When examining each territory separately, in Volvi, diet was found to consist exclusively of birds whereas the other categories were only identified in the Koroneia territory. That is further reflected by both niche-breadth (B) and prey diversity (H’) indices that were found to be 1 and 0 for the Volvi territory whereas B = 2.1 and H = 0.43 for Koroneia. However, considering only avian prey, the distribution of the body mass of consumed birds did not significantly differ between territories (Fig. 2; Kolmogorov-Smirnov test D = 0.16, p-value = 0.28),

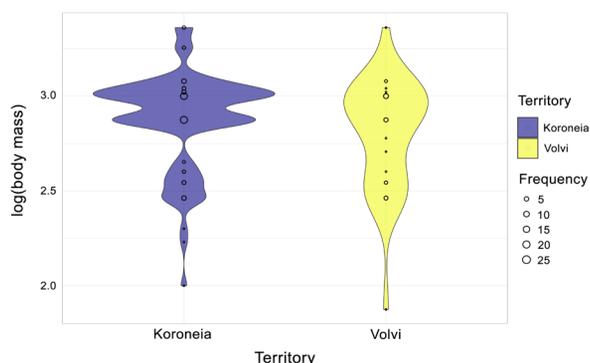


Fig. 2. Distribution of biomass (log body mass) of avian prey consumed in Koroneia and Volvi territories. Circles are proportional to the number of prey observations.

Obr. 2. Distribúcia biomasy (log hmotnosti) vtáčej koristi skonsumovanej v teritóriách Koroneia a Volvi. Kruhy sú úmerné počtu pozorovaní koristi.

Tab 2. Diet composition of White-tailed eagle territories in Northern Greece. Main prey taxa are presented as numbers of prey individuals, proportion in the diet (number of individuals of a specific taxon/total prey items) and proportion of each prey taxon in the diet in terms of biomass.

Tab 2. Zloženie potravy orliaka morského v teritóriách severného Grécka. Hlavné taxóny koristi sú uvedené v počtoch jedincov koristi, proporcií v potrave (počet jedincov konkrétneho taxónu/celkové položky koristi) a podiel každého taxónu koristi v potrave z hľadiska biomasy.

| | Koroneia territory | | | Volvi territory | | | Overall | | |
|--|--------------------|-------------|-------------|-----------------|------------|-------------|------------|-------------|-------------|
| | n | % | biomass (%) | n | % | biomass (%) | n | % | biomass (%) |
| Birds | 109 | 65.3 | 69.6 | 32 | 100 | 100 | 141 | 70.9 | 74.7 |
| Shelduck (<i>Tadorna tadorna</i>) | 8 | 4.8 | 7.9 | 2 | 6.3 | 9.8 | 10 | 5 | 8.2 |
| Mallard (<i>Anas platyrhynchos</i>) | 4 | 2.4 | 3.6 | 1 | 3.1 | 4.5 | 5 | 2.5 | 3.8 |
| Great Crested Grebe (<i>Podiceps cristatus</i>) | 22 | 13.2 | 18.1 | 9 | 28.1 | 36.8 | 31 | 15.6 | 21.3 |
| Great Cormorant (<i>Phalacrocorax carbo</i>) | 3 | 1.8 | 5.7 | 1 | 3.1 | 9.4 | 4 | 2 | 6.3 |
| Glossy Ibis (<i>Plegadis falcinellus</i>) | 0 | 0 | 0 | 1 | 3.1 | 2.5 | 1 | 0.5 | 0.4 |
| Grey Heron (<i>Ardea cinerea</i>) | 3 | 1.8 | 4.5 | 0 | 0 | 0 | 3 | 1.5 | 3.7 |
| Little Egret (<i>Egretta garzetta</i>) | 2 | 1.2 | 0.7 | 0 | 0 | 0 | 2 | 1 | 0.6 |
| Moorhen (<i>Gallinula chloropus</i>) | 5 | 3 | 1.4 | 3 | 9.4 | 4.3 | 8 | 4 | 1.9 |
| Coot (<i>Fulica atra</i>) | 25 | 15 | 15.5 | 6 | 18.8 | 18.4 | 31 | 15.6 | 16 |
| Unidentified Rallidae | 1 | 0.6 | 0.5 | 0 | 0 | 0 | 1 | 0.5 | 0.4 |
| <i>Tringa</i> sp. | 1 | 0.6 | 0.1 | 0 | 0 | 0 | 1 | 0.5 | 0.1 |
| Unidentified Charadriiformes | 1 | 0.6 | 0.1 | 0 | 0 | 0 | 1 | 0.5 | 0.1 |
| Black-headed Gull (<i>Chroicocephalus ridibundus</i>) | 7 | 4.2 | 1.7 | 5 | 15.6 | 5.9 | 12 | 6 | 2.4 |
| Yellow-legged Gull (<i>Larus michahellis</i>) | 6 | 3.6 | 5.2 | 1 | 3.1 | 4.3 | 7 | 3.5 | 5 |
| Domestic Pigeon (<i>Columba livia domestica</i>) | 3 | 1.8 | 1 | 1 | 3.1 | 1.6 | 4 | 2 | 1.1 |
| Collared Dove (<i>Streptopelia decaocto</i>) | 1 | 0.6 | 0.2 | 0 | 0 | 0 | 1 | 0.5 | 0.1 |
| Syrian Woodpecker (<i>Dendrocopos syriacus</i>) | 0 | 0 | 0 | 1 | 3.1 | 0.3 | 1 | 0.5 | 0.1 |
| Hooded Crow (<i>Corvus cornix</i>) | 0 | 0 | 0 | 1 | 3.1 | 2.1 | 1 | 0.5 | 0.4 |
| Unidentified Passeriformes | 1 | 0.6 | 0 | 0 | 0 | 0 | 1 | 0.5 | 0 |
| Unidentified Birds | 13 | 7.8 | 3.2 | 0 | 0 | 0 | 13 | 6.5 | 2.7 |
| Fish | 30 | 18 | 13.4 | 0 | 0 | 0 | 30 | 15.1 | 11.1 |
| Carp (<i>Cyprinus carpio</i>) | 21 | 12.6 | 11.1 | 0 | 0 | 0 | 21 | 10.6 | 9.2 |
| Unidentified Cyprinidae | 2 | 1.2 | 0.7 | 0 | 0 | 0 | 2 | 1 | 0.5 |
| Pike (<i>Esox lucius</i>) | 1 | 0.6 | 0.4 | 0 | 0 | 0 | 1 | 0.5 | 0.3 |
| Perch (<i>Perca fluviatilis</i>) | 5 | 3 | 0.9 | 0 | 0 | 0 | 5 | 2.5 | 0.7 |
| Unidentified Fish | 1 | 0.6 | 0.3 | 0 | 0 | 0 | 1 | 0.5 | 0.3 |
| Reptiles | 21 | 12.6 | 12 | 0 | 0 | 0 | 21 | 10.6 | 10 |
| Balkan Pond Turtle (<i>Mauremys rivulata</i>) | 5 | 3 | 1.8 | 0 | 0 | 0 | 5 | 2.5 | 1.5 |
| Hermann's Tortoise (<i>Eurotestudo hermanni</i>) | 8 | 4.8 | 5.9 | 0 | 0 | 0 | 8 | 4 | 4.9 |
| Greek Tortoise (<i>Testudo graeca</i>) | 5 | 3 | 2.9 | 0 | 0 | 0 | 5 | 2.5 | 2.4 |
| Unidentified Testudinidae | 2 | 1.2 | 1.3 | 0 | 0 | 0 | 2 | 1 | 1.1 |
| European Green Lizard (<i>Lacerta viridis</i>) | 1 | 0.6 | 0 | 0 | 0 | 0 | 1 | 0.5 | <0.1 |
| Mammals | 7 | 4.2 | 5.1 | 0 | 0 | 0 | 7 | 3.5 | 4.3 |
| Northern White-breasted Hedgehog (<i>Erinaceus roumanicus</i>) | 2 | 1.2 | 1 | 0 | 0 | 0 | 2 | 1 | 0.8 |
| Wild boar (<i>Sus scrofa</i>) | 3 | 1.8 | 2.5 | 0 | 0 | 0 | 3 | 1.5 | 2.1 |
| Sheep (<i>Ovis aries</i>) | 2 | 1.2 | 1.6 | 0 | 0 | 0 | 2 | 1 | 1.4 |
| Shannon index (H') | | 0.43 | | | 0 | | | 0.38 | |
| Diet breadth (B) | | 2.1 | | | 1 | | | 1.86 | |
| Diet overlap (O) | | | | | | | | 0.95 | |

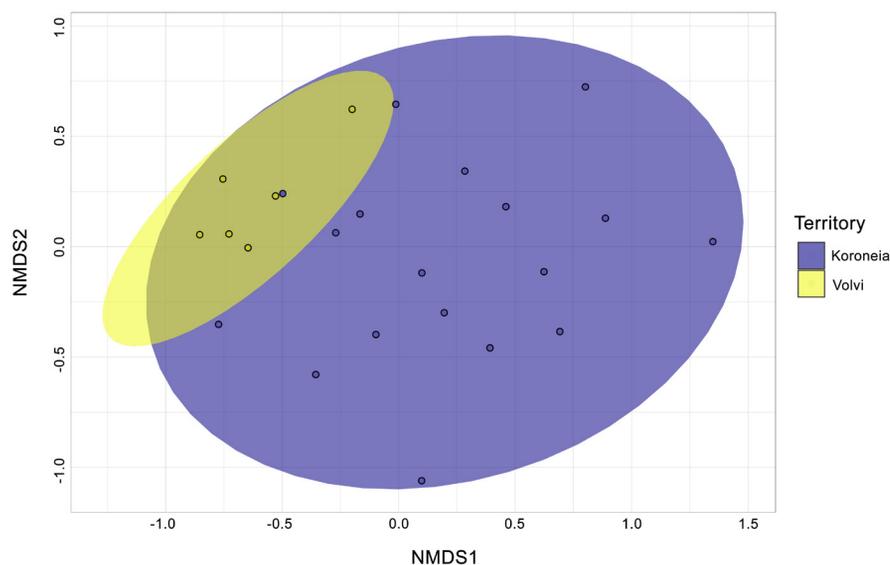


Fig. 3. NMDS ordination of diet composition in pre remains of White-tailed Eagles nests for Koroneia (purple) and Volvi (yellow) territories. Points indicate sampling events, and ellipses represent standard deviation for territory centroids.

Obr. 3. NMDS ordinácia zloženia potravy orliaka morského v teritóriách Koroneia (fialová) and Volvi (žltá). Body označujú jednotlivé zbery vzoriek a elipsy štandardnú odchýlku centroidov teritórií.

suggesting that the species preys on the heavier (and the most common) waterbird species in both territories. The NMDS plot based on species level indicated a degree of overlap in consumption of prey families between territories (Fig. 3; stress = 0.18, k = 2), showing that Volvi territory diet composition comprises only a fraction of the more diverse Koroneia territory diet. That result further reflects the high diet overlap index of the two territories (Pianka's $O = 0.95$). When analysing the five rarefied subsamples from Koroneia, results were found to be consistent with the full data analysis, thus showing a reduced bias rising from uneven sampling. Levin's niche breadth index ranged from 1.89 to 2.26 (mean $B = 2.15$), whereas Shannon diversity index ranged from 0.38 to 0.43 (mean $H' = 0.41$). The diet overlap index of the two territories was found to be >0.9 in all random subsamples and ranged from 0.9 to 0.97 (mean $O = 0.93$).

Discussion

We found that birds and specifically waterbirds comprise the largest and quantitatively most important part of the WTE diet, with the Great Crested Grebe and Eurasian coot being the most important food source in both lake habitats. Fish were the second most important prey group, found only in nest remains from the Koroneia territory. Our results on diet composition are in line with other studies on the species' diet that report those two groups as the main prey, however at different proportions depending on the cover of water versus land in surrounding habitat

(Helander 1983, Ekblad et al. 2016). The fact that the diet consists mostly of birds is typical for WTE populations living in coastal habitats, often in northern latitudes, with similar results reported from Scandinavia (Sulkava et al. 1997, Ekblad et al. 2016) and Scotland (Watson et al. 1992, Whitfield et al. 2013). On the other hand, WTEs breeding in inland areas seem to prefer fish prey, for example in Lapland in Northern Finland (Sulkava et al. 1997, Ekblad et al. 2020), Lithuania (Dementavičius et al. 2020) and Germany (Nadjafzadeh et al. 2013), whereas fish were also found to represent a high contribution to the diet in Greenland (Wille & Kampp 1983). However, higher bird consumption has also been reported for inland populations, such as in our case, and our results are more similar to the species' diet in Hungary and Romania (Horváth 2003, Sandor et al. 2015), where birds prey mainly on Eurasian coot and wildfowl. It has been found that also in Lake Baikal nearly 80% of WTE prey consisted of waterfowl (Mlíkovský 2009). An important aspect of raptor feeding ecology is foraging strategy and prey choice. The most frequent bird species identified in the prey remains are species commonly found in great numbers in the area suggesting that the species relies on locally abundant resources (Handrinos et al. 2015). Specifically, for the WTE, it has been suggested that when prey was abundant, eagles preferred large over small fish and slow over agile waterfowl species (Nadjafzadeh et al. 2016) which is further reflected in our results regarding biomass contribution and species

consumption frequency (Fig. 2). Particularly notable is the importance of reptiles in the diet, since these seldom appear in the diet of the WTE (Cramp & Simmons 1980). However, in Northern Greece tortoises are an important part of the diet of some large raptors, in particular the Golden Eagle (*Aquila chrysaetos*), the Egyptian Vulture (*Neophron percnopterus*) and even the Cinereous Vulture (*Aegypius monachus*) (Skartsi et al 2015, Dobrev et al. 2015, Sidiropoulos et al 2022). A significant fact may be that all the shells of the tortoises were broken, while those of the turtles were found whole. This may indicate that the former may have been scavenged after been killed by traffic or by kleptoparasitism from Golden Eagles, while the latter were actually captured by the WTE.

In this study, we used the number of prey items as units. A potential shortcoming of such an approach is that large prey remains tend to be better preserved than small remains such as those of waterbird fledglings, so small-sized prey could be under-represented (Mersmann et al. 1992, Redpath et al. 2001, Marti et al. 2007). Furthermore, fish remains can be underrepresented in prey remains as they are soft, thus biasing the estimates of the proportion of fish in the diet (Mersmann et al. 1992, Sulkava et al. 1997). Additionally, mammalian scavengers such as wild boars (*Sus scrofa*) or foxes (*Vulpes vulpes*) might have removed fallen items from under the nests (Ekblad et al. 2016). However, as the data are assumed to be similarly affected over both territories it allows us to examine their differences regarding prey composition. Furthermore, we had a relatively small sample (a total of 25 sampling events with two to four events per year for nine years), and especially for Volvi territory with only seven collection events, that could at some level prevent us from drawing concrete conclusions. The small number of prey items collected in Volvi also precludes us from identifying rare prey. Despite the abovementioned potential biases in the data, our results still can provide some evidence on the variation in diet composition between territories as a result of differences in the availability of prey in the feeding habitats of each territory.

A main factor that could be driving differences in the abundance and availability of different prey species between territories could be lake physiography. Volvi is a deep lake compared to the very shallow Koroneia, the latter being a more suitable fishing ground. The WTE uses a “sit-and-wait” hunting mode to capture profitable prey (Nadjafzadeh et al. 2016) and rarely captures flying birds whereas only fish that occur close to the surface are preyed upon (Helander 1983, Ekblad et al. 2016). This strategy is therefore reflected in the diet composition of

the two territories, so the consumption of fish in Volvi would be expected to be rare as the lake’s depth would pose a hunting limitation. Furthermore, fish in deep lakes could perform diel movements as a response to the daily light cycle thus ascending to shallower depths after dusk and descending deeper after dawn (Mehner 2012). Such behaviour would be incompatible with the hunting activity of a diurnal raptor such as the WTE. In any case, diet composition data point to a segregation and a subsequent resource partitioning between territories, with each pair utilizing an adjacent lake and its associated habitats. Competition and territoriality therefore seem to be important intraspecific interactions that along with prey availability could promote changes in territory size and ultimately affect individual fitness (Schoener 1968, Adams 2001, Martínez-Hesterkamp et al. 2018). In our case these processes could shape territory stability; Volvi territory has been occupied more erratically in the past 10 years whilst showing very low productivity (Sidiropoulos et al. 2022). However future monitoring efforts need to continue in order to shed light to such hypothesis.

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Greater spotted eagles (*Clanga clanga*) pale morph “fulvescens” breeding during five consecutive years

Orly hrubozobé (*Clanga clanga*) forma “fulvescens” hniezdenie počas piatich po sebe nasledujúcich rokov

Valery C. DOMBROVSKI

Abstract: The paper describes the observation in Belarus of an adult greater spotted eagle breeding female pale morph “fulvescens”, which retained the same light colour of plumage for five successive years. The data on the presence of pale morph adult birds in the collections of some zoo museums is also analysed.

Abstrakt: Príspevok opisuje pozorovanie dospelaj samice orla hrubozobého bledej formy “fulvescens” počas hniezdenia v Bielorusku, ktorá si zachovala rovnaké svetlé sfarbenie peria počas piatich po sebe nasledujúcich rokov. Analyzované sú tiež údaje o výskyte dospelých jedincov bledej formy v zbierkach niektorých zoologických múzeí.

Key words: Belarus, raptors, pale morph, reproduction

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Introduction

The pale morph of the greater spotted eagle, *Clanga clanga* “fulvescens”, is a colour variation characterised by replacing the dark brown tones of the covering plumage with light ochre, yellowish, or rufous tones. Flight and tail feathers remain brown or greyish-brown, typical of the species. All studies below agree that this “fulvescens” plumage occurs in young birds. However, there is no consensus on whether light colouration persists in adulthood. Several authors argue that this colour appears, although rarely, in adult plumage (Shtegman 1937, Dementiev et al. 1951, Cramp & Simmons 1980, Ferguson-Lees & Christie 2001, Forsman 1999, 2016). However, in some publications, the description of “fulvescens” plumage is given only for young or immature birds (Alström et al. 1992, Beaman & Madge 1998, Svensson et al. 2009).

This paper describes the first observation in Belarus of an adult breeding female of the greater spotted eagle pale morph “fulvescens”, which retained the same light colour of plumage for five successive years.

Results

During 2018–2022, in the Gomel region of Belarus, a nest of the spotted eagle was monitored using a camera trap. Each year, the pair bred successfully. The female had an unusually light ochre-golden colour of individual parts of the plumage, while the male and chicks were a more typical dark greater spotted eagle (Fig. 1).

The colouration of the female corresponded to the description of the final adult plumage of the pale morph “fulvescens” in Dementiev et al. (1951). Since the occurrence of pale morph adult individuals is very rare, I present below a complete description of this individual.

The general bright golden ochre plumage tone encompassed the head, neck, chest, belly, flanks and underwing coverts (Fig. 2a). Most of the light plumage had faintly noticeable thin brown stems and tiny brown rounded apical specks, and on the “trousers”, there were thicker blurry brownish-red streaks (Fig. 2b). The upperwing coverts and rump were light brown with ochre edges (Fig. 2c). The scapulars and upper back were darker brown with narrow buffy edges. The lower back, uppertail



Fig. 1. Greater spotted eagle female pale morph “fulvescens” at the nest in 2018–2020 (A–C), as well as her male and chick (D).
Obř. 1. Variácie operenia samice orla hrubozobého formy “fulvescens” (A–D).

and undertail were pale cream, almost white, contrasting with the neighbouring darker parts of the plumage (Fig. 2d). The flight and tail feathers were brownish-grey and had traces of dark cross-striation. No noticeable differences in the colour of the female plumage were found between years (Fig. 3).

While working in the archives of the zoological museums of the Zoological Institute of the Russian Academy of Science and Moscow State University (Dombrovski & Demongin 2006), we examined eleven individuals of the greater spotted eagle of the pale morph “fulvescens”. Of these, at least three individuals were over three years old, thus presumably adults, with plumage colouration similar to our breeding female from Belarus (Fig. 4a, b). Two of them were caught during the nesting period: on July 21, 1891, in the Pskov region of Russia and on August 24, 1900, in the Samara region of Russia. Four were young birds in the classical plumage of the first year (Fig. 4c, d). The differences between the analysed

age plumages were as follows: all light parts of plumage in young birds were monochromatic, without streaks or dots, their wing coverts had less dark brown tones, and the light borders on the feathers were broader and more contrasting.

Discussion

Although many authors recognise the existence of “fulvescens” plumage in adult birds, ornithologists still widely believe that it occurs only in juveniles and immatures. It is likely, on this basis, in Siberia, the authors considered that all breeding pale birds were “on different stages of post-juvenile moulting” (Karyakin et al. 2014). The extreme rarity of observations of adults in “fulvescens” plumage compared to young birds suggests that, in most cases, light juvenile plumage is indeed usually replaced by dark one during moulting. Dick Forsman’s opinion expressed on his website in April 2017 is especially revealing: “Fulvescens keeps the



Fig. 2. Greater spotted eagle colour of various (A–D) parts of “fulvescens” female plumage.

Obr. 2. Variácie farby peria (A–D) “fulvescens” formy samice orla hrubozobého.

diagnostic light plumage only for two years, after which it gradually moults into a darker and browner plumage resembling an ordinary greater spotted eagle.” (<http://www.dickforsman.com/bird-identification/>). In his later book (Forsman 2016), he also says that “older fulvescens

birds are browner and irregularly streaked, and far less striking in appearance compared to the juveniles”.

In this regard, each record of adult birds of the pale morph “fulvescens” acquires a specific scientific interest. Our results show that during five consecutive years,



Fig. 3. The female of greater spotted eagle morph “fulvescens” at the nest in 2021 (A) and 2022 (B).

Obr. 3. Samica orla hrubozobého forma fulvescens” na hniezde v roku 2021 (A) a 2022 (B).



Fig. 4. An adult (A, B) and a juvenile (C, D) spotted eagles “fulvescens” from the Zoological Museum of the Zoological Institute of the Russian Academy of Sciences.

Obr. 4. Dospelý (A, B) a mladý (C, D) orol hrubozobý “fulvescens” zo Zoologického múzea Zoologického ústavu Ruskej akadémie vied.

the adult female retains a fairly light tone of plumage (at least the head and underbody), which contrasts with the flight feathers. Thin brown stems and small brown rounded apical spots on most of the light plumage were faintly visible and did not hide the overall plumage bright golden-buff tone. From a distance, such a bird may appear indistinguishable from typical young “fulvescens” birds. Interestingly, there are remnants of stripes on our female’s flight and tail feathers. It is believed that such stripes should not be present in “fulvescens” plumage. Dementiev et al. (1951) also indicated that in the Buzuluk district of the Kuibyshev region (Russia), “two golden chicks were found in the same golden form as their parents”. Thus, our well-documented data confirm that adult birds may partially retain the light colouration of the “fulvescens” plumage, similar to that of young birds.

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A first detailed description of building a new nest and new data on the courtship behaviour of golden eagle

Prvý podrobný opis stavby nového hniezda a nové údaje o imponovaní orla skalného

Ivaylo ANGELOV

Abstract: The nest building and courtship behaviours of the golden eagle are poorly represented in the scientific literature. The paper reports on the first detailed description of building a new nest by a pair of golden eagles. Reciprocal pendulum flight by the pair as part of a pre-breeding courtship display is described for the first time. The “mock attack” between the members of the pair is confirmed to serve the courtship function.

Abstrakt: Poznatky o stavbe hniezda a imponovanie orla skalného sú vo vedeckej literatúre málo zastúpené. Príspevok informuje o prvom podrobnom opise stavby nového hniezda párom orlov skalných. Prvýkrát je opísaný vzájomný kyvadlový let páru ako súčasť predhniezdneho dvorenia. Potvrďuje sa, že “predstieraný útok” medzi členmi páru plní funkciu dvorenia.

Key words: nest building, display, reciprocal pendulum flight, mock attack

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Introduction

The nest-building behaviour in birds is still considered understudied (Breen et al. 2016). Among diurnal birds of prey for a long time, it used to be little studied and poorly represented in the scientific literature (Meyburg 1967, Newton 1979), but in recent decades a few detailed studies were published (Gargett 1990, Fernandez 1992, Margalida & Bertran 2000, Xirouchakis & Mylonas 2007, Martínez et al. 2022).

The golden eagle (*Aquila chrysaetos* Linnaeus, 1758) has a Holarctic distribution and occupies the role of apex predator in different ecosystems (Watson 2010). Even though it is the fifth most studied raptor species (Buechley et al. 2019), only a few publications reported on aspects of its nest-building behavior (Camenzind 1968, Fernandez & Leoz 1986, Aoyama et al. 1988, Ellis et al. 2009, McIntyre & Paulson 2015), while Ellis & Schmitt (2017) provided a general description.

For building nests, golden eagles use branches and sticks and line them with grass, moss and lichen (Watson 2010). This behaviour can occur at any time of the year, but it is most frequent from autumn through late winter (Watson 1997) with most buildings in weeks just prior to laying (Gordon 1955) and usually done between 10 a.m. and 1:30 p.m. (Dixon 1937). In the Central Balkans, the breeding season starts in the second half of January, when birds perform aerial displays, reconstruction of the nest and mating (Grubač 1988, Michev et al. 1989). Nest building of already existing nests varies greatly between pairs, with some almost doubling the size of nests before egg-laying, while others are barely changed (Camenzind 1968). Before egg-laying and throughout the nestling period, the pairs add “greenery” to the nest (Meyburg 1969, Bergo 1987, Watson & Rae 2019), consisting of fresh tree branches with green leaves. Usually, the eagles remove these branches when the leaves begin to wilt and replace

them with fresh ones (Watson & Rae 2019). In Japan, one pair of golden eagles studied by continuous video monitoring added 109 items of nesting material during 95 days before egg-laying, with both birds contributing roughly equally (Aoyama et al. 1988). During a 46-year-long survey, Kochert & Steenhof (2012) reported 14% of pairs never built a new nest and stated that it remains unclear why some pairs build and use newly constructed nests and others do not. Regarding the building of a completely new nest by golden eagles, to my knowledge, only Fernandez & Leoz (1986) provide some brief, but very general information for the construction of a newly built tree nest.

The nest-building of birds has been associated with courtship and pair formation (Soler 1998). However, the courtship behaviour of even well-studied raptors has been under-reported (Ellis, 1992). Watson (1997) stated 25 years ago that the courtship in golden eagle is poorly documented in the literature and it remains so until today. Golden eagles usually make very conspicuous and long dives to their nests and make undulating displays (sequences of dives followed by ascents) that serve mostly territorial signalling and defence functions (Harmata 1982, Collopy & Edwards 1989). Variation of the undulating display is the rarely seen “pendulum flight”, also described as the “figure of eight” (Crane & Nellist 1999), but the eagles frequently perform flights that are intermediate between the two (Bergo 1987). They are often associated with the presence of intruder within the nesting territory (Bergo 1987). Usually, males initiate undulating flights but they may be followed by the female (Negro & Galvan 2018). The aerial manoeuvres may give individuals the opportunity to gauge skills (Watson 1997) and reveal individual qualities (Wiacek 2004). In terms of proportion of the total flight time of the male and female, these displays account for respectively 0.4% and 0.1% (Collopy & Edwards 1989). However, at the beginning of the breeding season, undulating flights may take a huge amount of the daily flight time, e.g., one single territorial male in Ethiopia, displayed 51% of the time during 115 minutes of observation (Clouet et al. 1999). The undulation displays may serve also a “nuptial” function, such as pair bonding (Brown & Amadon 1968, Bahat 1989 in Watson 2010, Crane & Nellist 1999). However, recent observations by Reid et al. (2019) could neither confirm nor reject this. “Mock attacks” within the pair are rarely observed (Grubač 1988, Ivanovskii 2010, Crane & Nellist 1999) and Bergo (1987) recorded only nine such cases (seven of them between newly establishing pairs) and suggested that they serve courtship function during pair formation.

The paper presents first quantified details on the building of a completely new nest and provides additional details on the poorly understood courtship behaviour of the golden eagle.

Material and methods

Studied area

The observations covered the period of nest-building before the onset of egg-laying. The work was conducted for 16 days during 31.01 – 4.03.1999 in “Sinite Kamani” Nature Park, Eastern Balkan range, Sliven province, Bulgaria (approximate coordinates N42.71° E26.36°). The area is a low mountain, with many scattered cliffs along the south-facing slopes of the mountain, and an oak-dominated forest with few openings. Dominant tree species were sessile oak (*Quercus petraea*), hungarian oak (*Quercus frainetto*), turkey oak (*Quercus cerris*) and montpellier maple (*Acer monspessulanum*). Observations were made with a binocular (10x50) and telescope (20 – 60 x 60) by one to three people, from a viewpoint located in a very small opening in the forest, next to a bigger meadow trespassed by a rarely used tourist path. It was distanced at 400 m from a cliff nest of a pair of adult golden eagles, and situated 130 m lower in elevation. The pair of eagles never showed any signs of distress due to the presence of observers. The cliff in the area of the nest was about 25 m high and the nesting niche was not known to have been used anytime in the past, so it was built by the birds for the first time. For the whole time, a total of 31 h 16 min were spent in observations, 45.7% in the morning and 54.3% in the afternoon. Detailed notes on the behaviour were recorded by minute using the method “ad libitum” (Altmann 1974). All cases of nest building were recorded, with the type of material brought to the nest and the location from where it was collected. Unusual behaviours were described in detail. When the birds perched, it was possible to distinguish them, with the smaller male being significantly darker on the breast than the female. Special attention was devoted to behaviours concerning nest building, courtship, territorial displays and interspecific relationships with other raptors. The observed behaviour of the birds is described according to Bergo (1987), Watson (2010) and Ellis & Schmitt (2017).

Results

Nest building

From the 16 field days with observations, golden eagles were recorded in 11, from which in 10 days both members of the pair. The nest was constructed for a minimum

period of 25 days and nest-building activity was observed in six of them, peaking roughly a month before egg-laying (7 March) – at the end of January and beginning of February. Peak activity was around midday and more than 95% of cases of nest-building occurred between 10 a.m. and 1:30 p.m. In 85% of the cases of nest building, the weather was sunny with temperatures above 4°C. The birds were within sight during 50.2% (15 h 42 m) of the total time, for a daily average of 85 min (8 – 198 min). In total, 65 instances of carrying nesting material into the nest were recorded (2 – 31 per day) with either tree branches (92%), or dry grass (8%). Of the 36 cases, when the sex of the bird was identified, the male brought material in 17 cases, and the female in 19. Branches were collected from the ground (mostly fallen ones) and trees by breaking them off, respectively in 77 and 23% of cases (n = 59), when the place of gathering was identified. The plant material was collected mostly at 200–300 meters from the nest (range 50–600 m). The eagles carried the plant material mostly in the feet, but in 11% of cases in their beak, mostly smaller branches, once a big branch about 70 cm long, and once dry grass. Branches varied in length (10 – 120 cm), but most often, they were about 40–50 cm long. In the 16 days before egg-laying, the studied pair added branches of common ivy (*Hedera helix*). Nine days before egg-laying and on the last day when nest building was observed, the eagles brought on four occasions only dry grass to the nest, used for the lining of the cup, while no branches were added.

While collecting branches from trees, the eagles most often landed within the crowns of larger trees and broke off a single branch with their beak. While flapping during landing and taking off, the birds frequently hit many mostly smaller branches. Occasionally, after perching inside the crown, while searching for a suitable branch, the eagles moved horizontally up to 2 – 3 m along the perch or flapped from one bigger branch to another. In more than 90% of cases, the eagles flew in a mostly straight line from the place of gathering of the material to the nest by using a diving or steep descent flight before landing. On four occasions in flight, an eagle unintentionally dropped the branch and in two cases dove after it either as a play or in an attempt to try to catch it in midair, but without success.

Courtship: reciprocal “pendulum flight”, mock attack and diving flight to enter the nest

On 7 February (a month before egg laying), a two-year-old bird passing through the nesting area was chased away by the male after three deep stoops very close to it

and followed with escorting flight (Bildstein & Collopy 1985), while it was retreating. Very soon, the female appeared from the opposite direction. The pair met and circled together, and then both of them initiated undulating displays. At a moment when the birds were a few hundred meters apart, they simultaneously initiated “pendulum flight” (diagram in Bergo 1987), stooping towards each other, passing with great speed just a few meters one from another, then after ascending and reaching the highest position, turned and dove back, passing very close for the second time.

On 27 February, the male and female circled together and once demonstrated a mock attack, with the male attacking from above, diving for several meters, the female turning half over and presenting talons, after which the birds perched on cliffs in front of the nest immediately followed by copulation. For the whole survey period, six copulations were recorded from 5 to 28 February, with three of them on the 27 and 28, i.e. eight and nine days before the onset of incubation. All copulations were on cliffs, distanced 10 to 600 m from the nest, with three of them at about 200 m.

When the eagles were approaching from a higher position to land in the nest, they used downward closed-wing-stoop or delta-wing-stoop (Ellis & Schmitt 2017) always in cases, when it was energetically justifiable. This was most evident on a day (5 February), when they collected nesting material in 13 cases from an area at higher elevation than the nest and in 12 cases landed in the nest after a steep diving flight. On the 20 of February, the eagles brought material in eight cases, with three of them from a lower position than the nest and then they did not use stooping flight but stooped on the remaining occasions when they were coming from a higher position. Unusual cases included: 31 January – the male carried dry grass in its bill towards the nest, stopped and hovered for 2 sec. at about 20 meters before the nest, then dived in, but lost the grass and tried to catch it unsuccessfully. On the 5 of February – before landing with a branch, the male did a pirouette at 8–10 m above the nest, then landed; 20 of February – one came with a branch from more than 700 m, made two consecutive steep dives towards the nest, but did not land and went back towards the direction where it came from.

Discussion

The paper reports the first description of the building of a completely new nest by the golden eagle. Large raptors rarely build a completely new nest in the year in which they breed (Newton 1979), but the pair that was observed

managed to fledge one chick. The building of a new nest in the golden eagle, is a very rare event to observe, since nests may last for many decades and in exceptional cases after repeated reuse, persist for centuries (Ellis et al. 2009, Jenny et al. 2023). The nest that was built, had below-average size and a large part of it was in a quite narrow, cave-like niche, and only the nest rim was visible from the low observation point. For the 65 recorded cases of carrying nesting material by the birds, the total number may be at least twice higher. The observation showed that the majority of the time, the birds were building the nest in sunny warmer weather, which probably reflects the need for good flying conditions and minimization of the used energy. Similarly, sparrowhawks (*Accipiter nisus*) also did most of the nest building in spurts during warmer days (Newton 1986), while imperial eagles (*Aquila heliaca*) start nest building much earlier than normal in a year with a mild winter (Danko 2007).

The observed pair always collected nesting material within a kilometre radius, but occasionally golden eagles can carry it from 1.5 km (Grubač 1988). Especially in the winter, common ivy and fresh pine (*Pinus* sp.) branches are commonly used for the green lining of the nest in Bulgaria and other parts of Southern Europe, before any deciduous trees turn into leaf (Fernandez & Leoz 1986, Abuladze & Shergalin 2002, I. Angelov, pers. obs.). Such green material can be collected from up to three kilometres if it does not grow in the vicinity (Fernandez & Leoz 1986, Watson & Rae 2019) as it has an important function for signalling towards conspecifics (Canal et al. 2016) and repels ectoparasites (Wimberger 1984, Ontiveros et al. 2008). Previous studies in Bulgaria, involving nest inspection later in spring found scots pine (*Pinus sylvestris*), oaks (*Quercus* sp.), lilac (*Syringa vulgaris*), oriental hornbeam (*Carpinus orientalis*) and rarely oriental beech (*Fagus orientalis*) (Milchev & Georgieva 1992, Kouzmanov et al. 1996).

In nearly a quarter of the cases when branches were brought, they were torn off from trees, by the birds using their beaks. This behaviour probably reflects the need for incorporating stronger branches into the nest structure, since the dead branches on the ground are not as durable as the live ones (Newton 1986). Similarly, for a newly built nest on a tree, Fernandez & Leoz (1986) observed how the eagles tore and removed with their bills unwanted branches around the supporting foundation of the nest. While walking on the ground on the slopes, the birds looked clumsy, frequently balancing with wings. The observation of a mock attack by the male, followed by copulation, supports the hypothesis first expressed

by Bergo (1987), that the mock attacks between the members of the pair serve a courtship function (Grubač 1988, Crane & Nellist 1999). The same has been reported for the verreaux's eagle (*Aquila verreauxii*), especially for newly formed pairs, but it is "very occasionally seen" and the female "seldom does a half-roll" (diagram in Gargett 1990). Similarly, the reciprocal pendulum flight demonstrated by the pair was observed only once during the study and to my knowledge has never previously been described for the species. It followed the successful chasing away of an intruder by the male and most likely also serves a courtship function.

The observed instances of a pirouette and hovering just before entering the nest probably also serve courtship function, as may be the attempts to catch dropped nesting material in mid-air. In the two cases, when the eagles dropped the material before landing in the nest, the possibility for play behaviour could not be dismissed, since the attempts did not seem agile enough and the bird may have caught it if tried harder. For the black eagle, nesting material was sometimes dropped in the air when the bird tried to transfer it from the bill to the legs, or from one leg to the other, but the eagles never tried to retrieve it in mid-air, or from the ground (Gargett 1990). In the cases when the golden eagles were dropping material, such attempts for transfer of the material in flight were not noticed, but easily this may have been the reason. While doing such transfers, the eagles do a "cycling motion of the empty foot, or both feet" (Gargett 1990), which combined with the loosening grip of the carrying leg, may occasionally lead to the dropping of the material.

To the best of my knowledge, the paper is the only one, describing the building of a new nest of golden eagles, with details on the behaviour of the birds that enrich the understanding of the little-studied pre-laying period of the species. I am not aware of other publications describing the reciprocal pendulum flight of the golden eagle, thus it may be the first description of this behaviour. The observation of a mock attack by the male over the female of the pair, followed by copulation, confirms the hypothesis that it serves a courtship function (Bergo 1987).

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Ranging behaviour of an adult female greater spotted eagle (*Clanga clanga*) wintering in Sudan for 10 years, as revealed by satellite telemetry

Správanie dospelej samice orla hrubozobého (*Clanga clanga*) zimujúcej v Sudáne počas 10 rokov, ako ho odhalila satelitná telemetria

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Abstract: Using global position system (GPS) technology, we tracked an adult female greater spotted eagle (*Clanga clanga*) on its wintering grounds in the Sudan-South Sudan borderland during 2005–2015. There were 10 909 GPS locations for this bird in the non-breeding range. Throughout the study, the eagle showed fidelity to its wintering grounds. The non-breeding season coincided with the dry season. The median arrival date was 11 October (n = 10). The median departure date (n = 10) was 4 March, and was less variable than the arrival date. The 95% kernel density estimate (KDE) for all years was 33 838 km², and the 50% KDE encompassed 6 585 km². The wintering range was split between two areas, west and east, with the eagle typically arriving in the western area, where it stayed for some time. It then moved about 330 km to the eastern area, where it would remain for a few weeks before departing for Europe in the spring. In both the western and eastern subareas, the annual home ranges overlapped to a variable extent (14–99%). The high degree of fidelity to the wintering grounds shown by this bird was mirrored by the behaviours of two other adult greater spotted eagles that we tracked (using >1 tracking devices) for 15 years that wintered in South Sudan and Turkey. The number of greater spotted eagles that winter in Africa is a matter of speculation, although virtually all individuals are likely to pass through a narrow corridor near Suez, Egypt. Collectively, these tracking data and the findings of other studies suggest that greater spotted eagles from the western parts of the European breeding range often move to Africa. Further, the Sudd wetlands in South Sudan are important for greater spotted eagles and other rare bird species during the non-breeding season.

Abstrakt: Pomocou technológie globálneho polohového systému (GPS) sme sledovali dospelú samicu orla hrubozobého (*Clanga clanga*) na jej zimovisku na sudánsko-juhosudánskom pohraničí v rokoch 2005-2015. V nehniedznom areáli tohto vtáka bolo zaznamenaných 10909 GPS lokalizácií. Počas celej štúdie orol vykazoval vernosť svojmu zimovisku. Nehniedzne obdobie sa zhodovalo s obdobím sucha. Mediánový dátum priletu bol 11. október (n = 10). Mediánový dátum odletu (n = 10) bol 4. marec a bol menej variabilný ako dátum priletu. Kernelový odhad hustoty (KDE) pre všetky roky predstavoval 95 %, čo je 33838 km² a 50 % KDE zahŕňalo 6585 km². Zimovisko bolo rozdelené medzi dve oblasti, západnú a východnú, pričom orol zvyčajne prilietal do západnej oblasti, kde sa istý čas zdržiaval. Potom sa presunul asi 330 km do východnej oblasti, kde zostal niekoľko týždňov pred jarným odletom do Európy. V západnej aj východnej podoblasti sa ročné domovské okrsky prekrývali v rôznej miere (14 - 99 %). Vysoký stupeň vernosti zimoviskám, ktorý preukázal tento vták, sa odzrkadlil v správaní ďalších dvoch dospelých orlov hrubozobých, ktoré sme sledovali (pomocou >1 sledovacích zariadení) 15 rokov a ktoré zimovali v Južnom Sudáne a Turecku. O počte orlov hrubozobých, ktoré zimujú v Afrike, možno len špekulovať, hoci prakticky všetky jedince pravdepodobne prelietajú úzkym koridorom v blízkosti Suez v Egypte. Súhrnne tieto údaje o sledovaní a zistenia iných štúdií naznačujú, že orly hrubozobé zo západnej časti európskeho hniezdného areálu sa často presúvajú do Afriky. Okrem toho sú mokrade Sudd v Južnom Sudáne dôležité pre orly hrubozobé a iné vzácne druhy vtákov v mimohniedznom období.

Key words: Non-breeding season, site fidelity, ranging behaviour, Sudd wetlands, Sudan

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Introduction

Migration is a common phenomenon among birds, especially those that experience significant seasonal changes in temperature or rainfall or breed at higher latitudes. Migrations are typically driven by changes in food supply, both annually and evolutionarily (Bildstein 2006; Newton 2008). Historically, ecological data collection has focused on the breeding grounds as birds are often tied to nest sites, making their capture easier. Moreover, breeding success can often be determined at these locations. In addition, temperate countries—in which many long-distance migratory birds breed—often have more human and financial resources for bird research compared to countries at lower latitudes, where many of those same bird species overwinter. As a result, far more is known about the ecology of migratory birds in their breeding areas than during migration or in their wintering areas.

The greater spotted eagle (*Clanga clanga*) is a medium- to large-sized migratory species (Ferguson-Lees and Christie 2001; Meyburg and Meyburg 2005; Meyburg et al. 2005; Maciorowski et al. 2015) that breeds in wet forests in Eurasia and is a medium- to long-distance migrant. The global conservation status of the greater spotted eagle is vulnerable (Meyburg et al. 2016; BirdLife International 2022). It has a large breeding distribution, which extends from eastern Poland to the Pacific Ocean in southeast Siberia and Manchuria. However, human activities have caused severe fragmentation within this range (Väli et al. 2019; 2021; Karyakin 2008).

Greater spotted eagles prefer wet habitats in all seasons (Meyburg et al. 1995, Maciorowski et al. 2014, 2015, 2019), including wetlands in the non-breeding season and wet forests or forests adjacent to wetlands during the breeding season. However, during the non-breeding season, they are sometimes found in drier habitats (Brown et al. 1982, Meyburg et al. 1995) and at sites of anthropogenic waste disposal (Lobley 2007, Meadows 2011, Strick et al. 2011, McGrady et al. 2021).

Satellite telemetry has developed significantly in recent decades (Meyburg and Fuller 2007; Cagnacci et al. 2010), and its use has led to a significant advancement in our knowledge of the areas used by many bird species during the non-breeding season, especially birds of prey (Panuccio et al. 2021). The non-breeding (boreal winter, hereafter referred to as “wintering” or “non-breeding”) range of the greater spotted eagle covers a vast area in the subtropics and tropics of Eurasia and Africa (Väli et al. 2021). On wintering grounds, this species can be observed at many locales, which can be distant from one another and hold a few or dozens of individuals (Naoroji and Schmitt 2007; Jeyarajasingam 2012; Prakash 1988; Mallalieu 2007).

Greater spotted eagles spend more than one-third of the year on their wintering grounds. However, their ecology and habitat use within these areas have not been well studied, and very few telemetry studies of wintering birds have been conducted (Meyburg et al. 1995; Pérez-García et al. 2014; McGrady et al. 2021; Väli et al. 2021). In the last 30 years, the development of satellite-based

animal tracking has made it possible to follow bird species over large distances, through remote areas, and over several years (Meyburg and Fuller 2007). Tracking birds during migration and in their wintering grounds contributes to a better understanding of their year-round ecology, including the factors affecting their survival and reproduction. We fitted our first satellite-received transmitter (Platform Transmitter Terminal, PTT) to a nestling greater spotted eagle in North-East Poland in 1992. Over the years, we have deployed additional tags on adults and nestlings, including nine adults between 1995 and 2003. Location data from PTTs are typically less precise than tracking devices using Global Positioning System (GPS) technology.

Material and methods

On 14 July 2005, we captured an adult female greater spotted eagle nesting in the Biebrza River Valley in NE Poland (ca 53.3° N; 22.6° E). We collected a blood sample to determine its sex. Analysis of the sample confirmed that the bird was a greater spotted eagle, and not a *Clanga clanga* x *C. pomarina* hybrid. The eagle was fitted with a 45 g solar-powered GPS-PTT tag (Microwave Telemetry, Inc., USA; ID 57116) as a backpack (Meyburg and Fuller 2007). The transmitter accounted for 2.3% of the eagle's body mass. The bird was ringed (BN 3843 in the Polish ringing scheme; individual identification ring: 1 D) and released (Fig 1). It subsequently reared a chick in that year.



Fig. 1. Female greater spotted eagle with the longest record of fidelity to its wintering area (Göksu River Delta in Turkey (1999 – 2014) with its second transmitter (see page 46). (Photo by Kordian Bartoszek, 24.04.2013).

Obr. 1. Samica orla hrubozobého s najdlhším záznamom fidelity k svojmu zimovisku (delta rieky Göksu, Turecko (1999 - 2014) s druhým vysielateľom (pozri stranu 46). (Foto: Kordian Bartoszek 24.4.2013).

The transmitter uploaded the GPS locations via the Argos satellite system, and provided Argos-Doppler location estimates (http://www.argos-system.org/manual/3-location/34_location_classes.htm). The transmitter was programmed to collect GPS locations every hour during daylight hours. The GPS data collection rates and transmission could be affected by low solar charging, resulting in data collection gaps. GPS data gaps were rare in the early years of the study; however, they became more frequent with time. Moreover, the volume of collected data also declined with transmitter age. Therefore, the data collected during the winter 2014–2015 were excluded from between-year range comparisons due to the small sample size. We tracked this eagle until the PTT device failed on 12 January 2016.

We cleaned the GPS and Argos location datasets to remove outliers and implausible location estimates. The arrival times at and departure from the wintering grounds were objectively determined by applying piecewise regression to a plot of GPS-determined latitudes against the respective date (Limiñana et al. 2007). Arrivals and departures were recorded as the dates and times where the regression “broke,” indicating a change in the bird's flight behaviour between migration and wintering. Subsequently, we directly examined the Argos location data to improve the precision of arrival and departure estimates when there were gaps in the GPS data.

The non-breeding season spans from approximately late September to early April. Therefore, the locations were categorised by the year in which the non-breeding season began. For instance, the locations collected in January 2006 were considered part of the 2005 data because the bird arrived at the non-breeding grounds in the autumn of 2005. Additionally, because the bird generally split its time between two sub-areas within its non-breeding range (west and east), we conducted analyses to understand the characteristics of those sub-areas and elucidate any differences between them. Specifically, we visually inspected the locations in ArcMap (ESRI 2019) and categorised them into either sub-area or as instances of travelling between them (although the bird typically spent only one day or less travelling between sub-areas; see Figs. 2 and 3).

We estimated separately the non-breeding home ranges and core ranges of the bird for each sub-area using 95% and 50% utilisation distributions (UD) from the kernel density estimator (KDE; Worton 1989). We estimated the ranges using all non-breeding data combined for each year and each sub-area by year. We used the data of at least 30 locations in the dataset (year, sub-area, or

sub-area by year) to estimate the home range and the reference bandwidth (i.e. kernel smoothing parameter) to estimate the overall non-breeding home range. For all other home ranges, we first estimated home ranges using the reference bandwidth and then calculated the average bandwidths in each category. We calculated the yearly non-breeding home ranges, including both sub-areas (east and west), the overall home ranges by sub-area for all years combined, and home ranges for each sub-area by year. Then, we re-estimated the home ranges using the average reference bandwidth. We tested for differences in size between the east and west sub-areas by year using a paired t-test.

To estimate the degree of winter site fidelity exhibited by the bird among years in the east and west sub-areas, we calculated the overlap between yearly home ranges (95% KDE) at each sub-area using Bhattacharyya's affinity (BA; Fieberg and Kochanny 2005). A value of 0 indicated no overlap in the total UD, whereas a value of 1 indicated complete overlap. Considering that the values at each site were not normally distributed, we tested for a difference in the overlap between the east and west sub-areas using a Wilcoxon rank sum test.

We calculated the distance travelled between successive hourly locations (hourly step length) to describe the bird's movements. We log-transformed hourly step lengths and used a generalised linear model with a step length response to test for the effects of year, sub-area, and the interaction between them. We excluded step lengths from periods when the bird was categorised as travelling between the west and east sub-areas owing to low sample sizes in most years. Based on Akaike's information criterion corrected for a small sample size (AICc; Burnham and Anderson 2002), the only supported model included interactions between years and sub-areas.

To investigate whether the bird's movements were related to the onset of drier conditions during winter, we examined the monthly averages of enhanced vegetation indices (Africa Soil Information Service: <http://www.africasoils.net/data/datasets?page=1>) within annual KDEs. However, no obvious relationship could be discerned as our data were from a single individual. Therefore, we did not pursue further habitat analyses.

All analyses were performed using R statistical software (version 3.4.4; R Core Team, 2019). We estimated the bird's home ranges using the "adehabitat" package (Calenge 2006) and calculated step lengths using the "adehabitatLT" package in R (Calenge 2006). All statistical tests were performed using base R functions.

Results

In all years (N = 10 winter seasons), the eagle wintered within a narrow latitudinal range (9.2°–10.7° N) in two sub-areas (west and east) centred at approximately 9.9° N; 27.8° E in the Sudan-South Sudan border region. The western sub-area was situated along the Bahr al Arab (the Kiir River) in Scharq Darfur, one of the five states in the Darfur region. The Bahr al Arab flows through southwest Sudan, marks a portion of the international border between Sudan and South Sudan, and becomes part of the Nile River system. The eastern sub-area was located along the Bahr al Gazal, which flows into the White Nile. Wintering coincided with the dry season (November to March), with the driest months being December–February (average rainfall = 0 mm). Precipitation increased significantly within the sites used by this bird from the

Tab. 1. Movement of an adult female greater spotted eagle between two sub-areas of its winter range in the Sudan-South Sudan borderlands, 2005–2015.

| Year | Arrival at wintering ground in west | | Departure from west sub-area | | Arrival at west sub-area again | | Departure from west sub-area again | | Arrival at east sub-area | | Departure from east sub-area again | | Migration | |
|-----------|-------------------------------------|-------|------------------------------|-------|--------------------------------|-----|------------------------------------|-----|--------------------------|-----|------------------------------------|-----|-----------|------------|
| | Year | Day | Year | Day | Year | Day | Year | Day | Year | Day | Year | Day | Year | Day |
| 2005–2006 | 22-Oct | 27.12 | 28.12 | 30.12 | 6.1 | 4.3 | NA | 4.3 | NA | 4.3 | NA | 4.3 | 3 March | ± 2.4 days |
| 2006–2007 | 13-Oct | 18.1 | 20.1 | 3.3 | NA | NA | NA | NA | NA | NA | NA | NA | 4 March | |
| 2007–2008 | 03-Oct | 14.1 | 15.1 | 5.3 | NA | NA | NA | NA | NA | NA | NA | NA | | |
| 2008–2009 | 07-Oct | 4.1 | 5.1 | 28.2 | NA | NA | NA | NA | NA | NA | NA | NA | | |
| 2009–2010 | 14-Oct | 8.12 | 12.12 | 28.12 | 30.12 | 3.1 | 7.3 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | | |
| 2010–2011 | 10-Oct | 27.12 | 29.12 | 2.3 | NA | NA | NA | NA | NA | NA | NA | NA | | |
| 2011–2012 | 08-Oct | 19.12 | 24.12 | 28.2 | NA | NA | NA | NA | NA | NA | NA | NA | | |
| 2012–2013 | 21-Oct | 6.1 | 9.1 | 4.3 | NA | NA | NA | NA | NA | NA | NA | NA | | |
| 2013–2014 | 23-Sep | 10.1 | 13.1 | 3.3 | NA | NA | NA | NA | NA | NA | NA | NA | | |
| 2014–2015 | 15-Oct | - | - | 6.3 | NA | NA | NA | NA | NA | NA | NA | NA | | |
| Mean | 10 Oct | | | | | | | | | | | | 3 March | ± 2.4 days |
| Median | 11 Oct | | | | | | | | | | | | 4 March | |

Tab. 1. Pohyb dospelej samice orla hrubozobého medzi dvoma podoblastami jeho zimoviska na sudánsko-juhosudánskom pohraničí v rokoch 2005–2015.

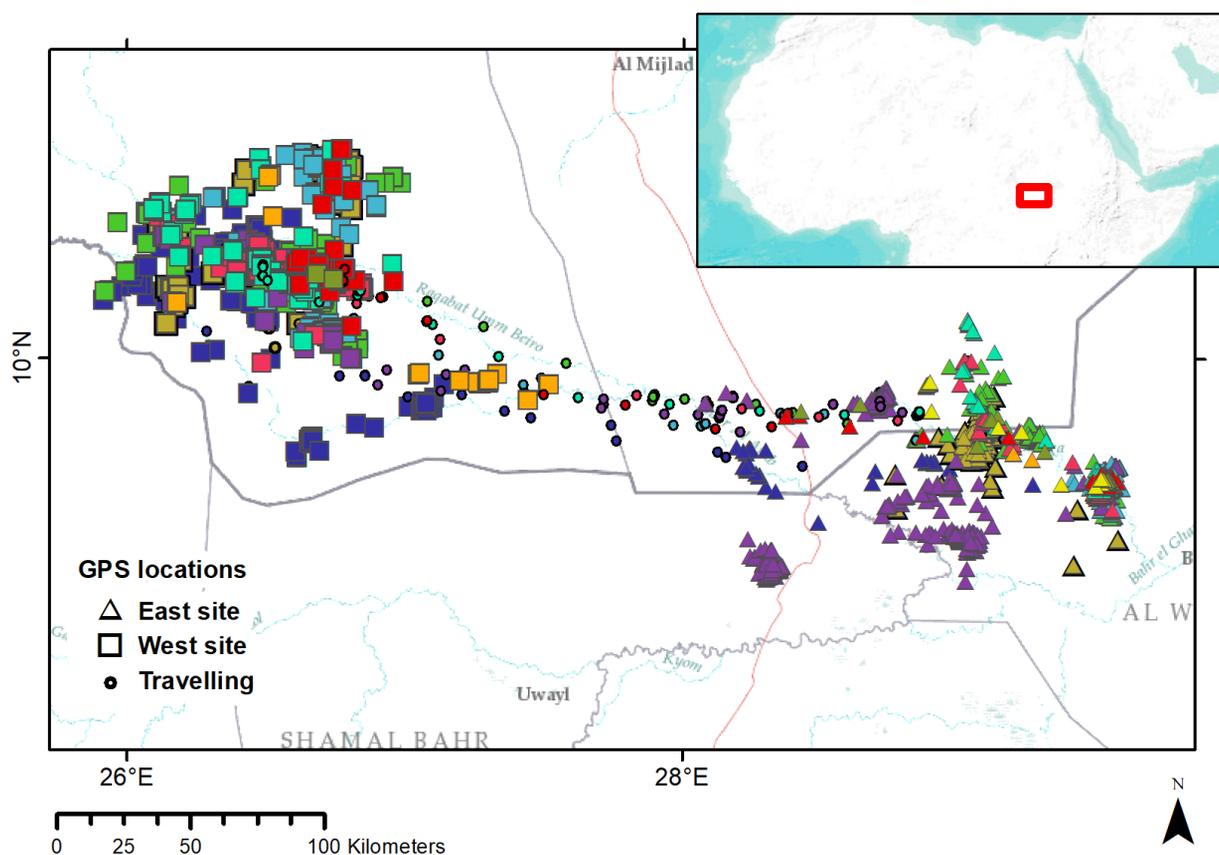


Fig. 2. Global Positioning System (GPS) locations of a tracked adult female greater spotted eagle on its non-breeding grounds in Sudan-South Sudan during 2005–2016. Squares are locations in the western sub-area; triangles are locations in the eastern sub-area; circles are locations of the bird as it moves between the sub-areas. Colours represent different years.

Obr. 2. Lokalizácie globálneho polohového systému (GPS) sledovanej dospeljej samice orla hrubozobého v mimohniezdnom území v Sudáne a Južnom Sudáne v rokoch 2005 - 2016. Štvorce reprezentujú miesta v západnej podoblasti; trojuholníky sú miesta vo východnej podoblasti; kruhy sú miesta, kde sa vták pohybuje medzi podoblastami. Farby predstavujú rôzne roky.

northwest to the southeast. The arrival dates were in September and October and were more variable than the spring departure dates, which occurred during 10 days in February–March (Table 1, Fig. 2). The median autumn arrival and spring departure dates were 11 October and 4 March, respectively. The eagle showed fidelity to its general wintering area (Fig. 2), where it was tracked each year.

The eagle arrived at the western end of its winter range every year during autumn migration. Throughout the winter, it moved between the two sub-areas (Tables 1 and 2, Fig. 2). In seven of the nine years, the bird arrived and settled in the western sub-area in Scharq Darfur (Sudan). It then moved approximately 330 km (from late December to early January) to an eastern sub-area in South Sudan, where it settled until the spring migration. In the winter of 2005, it moved from the west to the east and back to the

west, from where it migrated north. In 2009, it moved from the west to the east, back to the west, and then again to the east before migrating (Tables 1 and 2, Figs. 2 and 3). The eagle typically travelled between the western and eastern sub-areas in a single day, but sometimes the journey lasted as much as four days (Table 1, Fig 3).

From 2005 to 2016, we recorded 10 909 GPS locations for the greater spotted eagle in its non-breeding range (Table 2, Fig. 2). Using data from all years and sub-areas, the non-breeding 95% and 50% KDE home range estimates were 33 838 km² and 6 585 km², respectively. The estimates and averages for the years and sub-areas are listed in Table 2 and plotted in Fig. 4; maps are shown in Figs. 1 and 4. Both the 95% and 50% home ranges in the western sub-area were significantly larger than those in the eastern sub-area (paired t-tests: 95% KDE: $t = -3.10$, $df = 8$, $p = 0.01$; 50% KDE: $t = -2.28$, $df = 8$, $p = 0.05$).

| Year | Site | n locations | Home ranges (km ²) | | n step-lengths | Average step-length ± SE (km) |
|--------------------------|------------|-------------|--------------------------------|-------------|----------------|-------------------------------|
| | | | 95% KDE | 50% KDE | | |
| 2005 | Overall | 1471 | 32544 | 4467 | 1296 | 1.80 ± 0.00 |
| | West | 1369 | 3776 | 493 | 1203 | 1.40 ± 0.00 |
| | East | 82 | 2944 | 443 | 75 | 3.81 ± 0.10 |
| | Travelling | 20 | - | - | 18 | 2.05 ± 0.09 |
| 2006 | Overall | 1412 | 29742 | 6452 | 1220 | 1.25 ± 0.00 |
| | West | 926 | 2355 | 238 | 795 | 0.78 ± 0.00 |
| | East | 480 | 1087 | 221 | 420 | 2.11 ± 0.01 |
| | Travelling | 6 | - | - | 5 | 4.18 ± 1.19 |
| 2007 | Overall | 1421 | 37247 | 8068 | 1243 | 1.32 ± 0.00 |
| | West | 783 | 3466 | 336 | 669 | 1.22 ± 0.01 |
| | East | 618 | 2213 | 342 | 556 | 1.07 ± 0.00 |
| | Travelling | 20 | - | - | 18 | 13.01 ± 0.72 |
| 2008 | Overall | 1511 | 32833 | 7187 | 1320 | 1.50 ± 0.00 |
| | West | 814 | 3146 | 485 | 707 | 1.13 ± 0.01 |
| | East | 671 | 823 | 186 | 588 | 1.42 ± 0.00 |
| | Travelling | 26 | - | - | 25 | 13.95 ± 0.58 |
| 2009 | Overall | 1481 | 46580 | 11419 | 1289 | 1.78 ± 0.00 |
| | West | 468 | 2986 | 520 | 397 | 1.17 ± 0.01 |
| | East | 941 | 4027 | 594 | 832 | 1.82 ± 0.01 |
| | Travelling | 72 | - | - | 60 | 5.40 ± 0.17 |
| 2010 | Overall | 1236 | 35085 | 7920 | 1069 | 1.07 ± 0.00 |
| | West | 567 | 1822 | 285 | 482 | 1.08 ± 0.01 |
| | East | 637 | 1691 | 292 | 557 | 0.56 ± 0.00 |
| | Travelling | 32 | - | - | 30 | 10.56 ± 0.49 |
| 2011 | Overall | 1124 | 34606 | 6620 | 960 | 1.24 ± 0.00 |
| | West | 353 | 3102 | 478 | 279 | 1.48 ± 0.01 |
| | East | 726 | 1391 | 179 | 639 | 0.80 ± 0.00 |
| | Travelling | 45 | - | - | 42 | 6.44 ± 0.28 |
| 2012 | Overall | 651 | 31890 | 4199 | 543 | 0.50 ± 0.00 |
| | West | 120 | 3563 | 559 | 90 | 0.93 ± 0.04 |
| | East | 531 | 736 | 159 | 453 | 0.42 ± 0.00 |
| | Travelling | 0 | - | - | 0 | - |
| 2013 | Overall | 546 | 30659 | 4541 | 448 | 1.66 ± 0.01 |
| | West | 99 | 2089 | 336 | 70 | 2.81 ± 0.09 |
| | East | 428 | 753 | 155 | 363 | 1.17 ± 0.01 |
| | Travelling | 19 | - | - | 15 | 8.14 ± 0.82 |
| 2014 | Overall | 47 | 27193 | 4980 | 30 | 3.22 ± 0.25 |
| | West | 2 | - | - | 1 | 6.50 ± NA |
| | East | 45 | 2910 | 306 | 29 | 3.10 ± 0.26 |
| | Travelling | 0 | - | - | 0 | - |
| 2015 | Overall | 9 | - | - | 7 | 11.36 ± 1.44 |
| Average among years ± SE | Overall | | 33838 ± 5308 | 6585 ± 2227 | | 1.41 ± 0.00 |
| | West | | 2923 ± 684 | 415 ± 115 | | 1.19 ± 0.00 |
| | East | | 1857 ± 1130 | 288 ± 142 | | 1.25 ± 0.00 |
| | Travelling | | - | - | | 9.50 ± 0.06 |

Tab 2. Kernel density estimator (KDE) home range sizes (95% and 50%), and average step-lengths (distance between successive hourly locations) of an adult female greater spotted eagle during the non-breeding season (boreal winter) 2005 – 2015 in the Sudan-South Sudan borderlands. Analyses are for all winter locations, locations in the western sub-area, locations in the eastern sub-area and locations as the eagle travelled between the sub-areas. A bandwidth of 26.43 km was used to estimate the overall home range, 6.27 km to estimate the home range of the western sub-area and 5.74 to estimate the home range of the eastern sub-area. A minimum of 30 locations was required to estimate a home range.

Tab. 2. Veľkosti domovského okrsku (95% a 50%) metódou odhadu jadrovej hustoty (KDE) a priemerné dĺžky krokov (vzdialenosti medzi po sebe nasledujúcimi hodinovými lokalitami) dospelej samice orla hrubozobého počas nehniedznej sezóny (boreálna zima) v rokoch 2005 - 2015 na sudánsko-juhosedánskom pohraničí. Analýzy sa týkajú všetkých zimných lokalít, lokalít v západnej podoblasti, lokalít vo východnej podoblasti a lokalít, keď orol putoval medzi podoblastami. Na odhad celkového domovského okrsku sa použila honnota vyhladzovacieho parametra 26,43 km, na odhad domovského okrsku západnej podoblasti 6,27 km a na odhad domovského okrsku východnej podoblasti 5,74 km. Na odhad domovského okrsku bolo potrebných minimálne 30 lokalít.

Tab. 3. Degree of overlap (Bhattacharyya's affinity; 1 = total overlap, 0 = no overlap) of western and eastern wintering sub-areas used by an adult female greater spotted eagle in the Sudd Wetlands of Sudan/South Sudan, 2005–2013.

Tab. 3. Stupeň prekrytia (Bhattacharyyaho afinita; 1 = úplné prekrytie, 0 = žiadne prekrytie) západných a východných podoblastí zimovania využívaných dospelou samicou orla hrubozobého v Suddských mokradiach v Sudáne/Južnom Sudáne v rokoch 2005–2013.

| West | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|------|------|------|------|------|------|------|------|------|------|
| 2005 | NA |
| 2006 | 0.84 | NA |
| 2007 | 0.31 | 0.33 | NA |
| 2008 | 0.62 | 0.81 | 0.61 | NA | NA | NA | NA | NA | NA |
| 2009 | 0.76 | 0.76 | 0.71 | 0.84 | NA | NA | NA | NA | NA |
| 2010 | 0.72 | 0.81 | 0.53 | 0.83 | 0.84 | NA | NA | NA | NA |
| 2011 | 0.65 | 0.73 | 0.75 | 0.81 | 0.9 | 0.82 | NA | NA | NA |
| 2012 | 0.28 | 0.22 | 0.53 | 0.32 | 0.37 | 0.32 | 0.46 | NA | NA |
| 2013 | 0.17 | 0.35 | 0.82 | 0.58 | 0.49 | 0.53 | 0.62 | 0.55 | NA |
| East | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
| 2005 | NA |
| 2006 | 0.22 | NA |
| 2007 | 0.2 | 0.56 | NA |
| 2008 | 0.23 | 0.03 | 0.16 | NA | NA | NA | NA | NA | NA |
| 2009 | 0.2 | 0.13 | 0.1 | 0.15 | NA | NA | NA | NA | NA |
| 2010 | 0.25 | 0.48 | 0.53 | 0.79 | 0.14 | NA | NA | NA | NA |
| 2011 | 0.22 | 0.15 | 0.3 | 0.96 | 0.15 | 0.86 | NA | NA | NA |
| 2012 | 0.23 | 0.07 | 0.22 | 0.99 | 0.15 | 0.79 | 0.96 | NA | NA |
| 2013 | 0.24 | 0.06 | 0.2 | 0.99 | 0.16 | 0.78 | 0.96 | 0.99 | NA |
| 2014 | 0.24 | 0.39 | 0.49 | 0.81 | 0.24 | 0.87 | 0.88 | 0.84 | 0.84 |

The BA measurements of overlap of the annual UDAs at the east sub-areas averaged 0.45 ± 0.05 (range: 0.03–0.99), and those at the west sub-areas averaged 0.60 ± 0.04 (range: 0.17–0.90; Table 3). The annual home ranges in the western sub-area exhibited a significantly greater overlap than those in the eastern sub-area (Wilcoxon rank sum test: $W = 573$, $p = 0.02$).

Hourly step lengths ranged from 0 to 51 km (mean = 17.6 km across all years, see Fig. 6). The averages for all data from all years, and the averages by year and by sub-area, are listed in Table 2. The step lengths from the west site were shorter than those from the east site, with variation observed over the years (Table 4).

Discussion

In this study, a breeding adult female greater spotted eagle was tracked during ten consecutive boreal winters. Although these data are from a single individual, they are unique as no other greater spotted eagle has been followed during so many consecutive winters using a GPS tag. Nor, as far as we know, has any other eagle species, apart from the lesser spotted eagle (Meyburg 2021), been tracked for such a long duration. The data presented in this study provide novel insights regarding the wintering ecology of the greater spotted eagle, providing a theoretical basis for further investigations with larger sample sizes.

Among the “spotted eagles” (i.e., both greater and lesser) that migrate from Europe to Africa via Suez, the proportion which is greater spotted eagle is unknown. However, this proportion is probably larger than that suggested by observations reported from Lebanon, Israel, and Egypt (Meyburg et al. 2020). This is because most

Tab. 4. Results from the most supported model for step length by a female greater spotted eagle during the non-breeding season (boreal winter) during 2005–2014.

Tab. 4. Výsledky najviac podporovaného modelu pre dĺžku kroku samice orla hrubozobého v mimohniezdnom období (boreálna zima) v rokoch 2005–2014.

| Predictor variable | Estimate ± SE | 95% Confidence Interval |
|--------------------|---------------|-------------------------|
| Sub-area: West | -0.7 ± 0.06 | (-0.83, -0.57) |
| Year: 2006 | -0.18 ± 0.11 | (-0.4, 0.04) |
| 2007 | -0.52 ± 0.11 | (-0.74, -0.3) |
| 2008 | 0.02 ± 0.11 | (-0.2, 0.23) |
| 2009 | -0.05 ± 0.12 | (-0.28, 0.18) |
| 2010 | -0.88 ± 0.12 | (-1.11, -0.64) |
| 2011 | -0.5 ± 0.13 | (-0.74, -0.25) |
| 2012 | -0.92 ± 0.15 | (-1.21, -0.62) |
| 2013 | 0.42 ± 0.16 | (0.1, 0.73) |
| 2014 | 0.69 ± 0.51 | (-0.31, 1.69) |

Too few data existed to include 2015. The categorical predictor variable Sub-area: West was in reference to East, and the years were in reference to 2005.

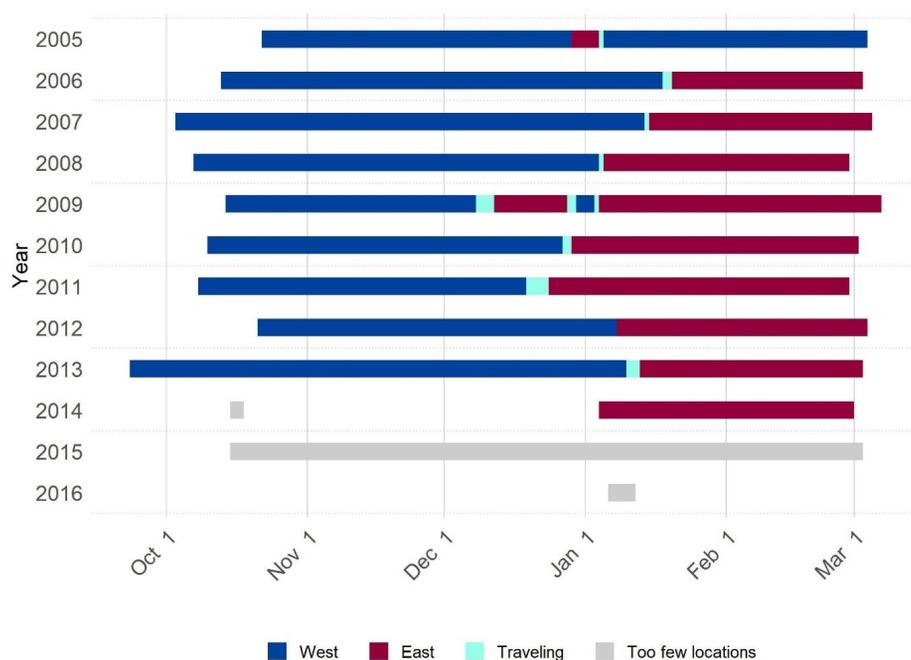


Fig. 3. Temporal use by an adult female greater spotted eagle of western and eastern sub-areas within its wintering grounds in the Sudan-South Sudan borderlands during 2005–2014. **Obr. 3.** Časové využívanie západných a východných podoblastí dospelou samicou orla hrubozobého na jeho zimovisku v sudánsko - juhosudánskom pohraničí v rokoch 2005 - 2014.

greater spotted eagles that use this route along the eastern Mediterranean coast may go unrecorded by observers, as they are mistaken for the much more common lesser spotted eagle (Bijlsma 1983). Over 11 days in September–October 2019 only, 8 751 raptors were counted in Lebanon, 80 identified as *C. clanga* and 2 682 as *C. pomarina*. In 42 other cases, it was not possible to determine the species, as these eagles are often difficult to distinguish (Meyburg et al. 2020). Approximately 5% of the spotted eagles that migrated over the Suez in autumn were determined by us to be *C. clanga* (B.-U. Meyburg, unpublished data). Of the seven adult greater spotted eagles we had tracked from Poland, five wintered in Africa, and only two in Greece and Turkey (Meyburg et al. 1998). Dombrovski et al. (2018) tracked eight individuals, four of which wintered in the Nile Valley.

Habitat

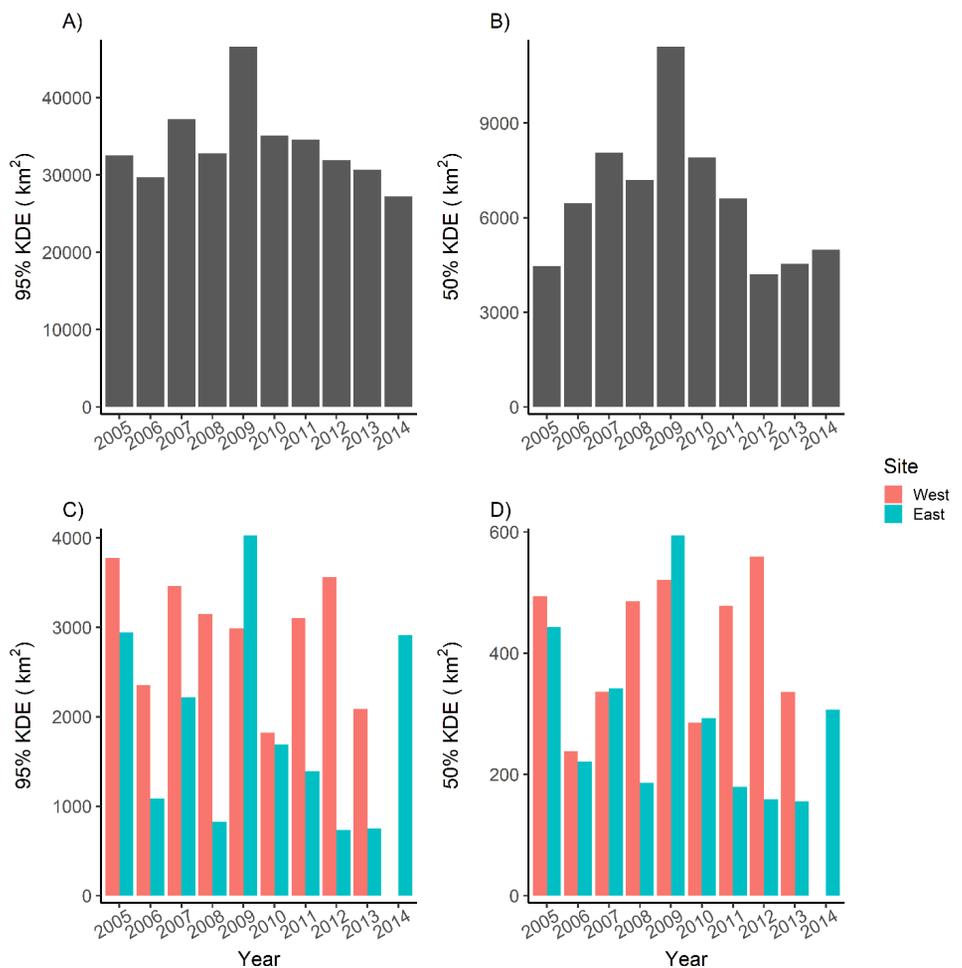
Greater spotted eagles winter in Europe, Africa, and southern Asia. However, little is known about the relative importance of these areas to wintering birds. In Europe, greater spotted eagles winter in Spain, France, Italy, and the Balkan Peninsula (Maciorowski et al. 2019; Pérez-García et al. 2014; Meyburg et al. 2020). Further east, this species winters mostly in Turkey (Kirwan et al. 2008), the Middle East and the Arabian Peninsula (Lobley 2007; McGrady et al. 2021), the north of the Indian subcontinent (Naorji

and Schmitt 2007), and Southeast Asia and southern China (Mallalieu 2007; Jeyarajasingam 2012) and exceptionally in Japan and Taiwan (Meyburg et al. 2020).

Each year, the tracked eagle wintered in an area west of the Sudd wetlands, one of the largest wetlands on the planet and a Ramsar site (<https://rsis.ramsar.org/ris/1622>). The eastern sub-area is located in the Bahr al Ghazal drainage basin (a region in the Sudd and the largest of the Nile’s sub-basins: 520 000 km²). The Bahr al Ghazal feeds into the White Nile (Bahr al Dschabal). The wetlands are fed seasonally by variable volumes of water flowing from Lake Victoria but are also subject to seasonal rains (Zwarts et al. 2009, Williams 2019). The western sub-area is situated along the Bahr al Arab.

In seven of the nine winters for which we have data, the eagle arrived in the western sub-area, Bahr al Arab, which marks part of the international border between Sudan and South Sudan. In all but one year, it spent the latter part of the winter in the eastern sub-area, from where it also departed in the spring. Unlike the western sub-area, the eastern sub-area has permanently flowing rivers. In the western sub-area, the rivers usually dry up as the dry season (winter) progresses. Thus, desiccation in the western sub-area may have caused the eagle to spend most of the second half of its wintering period in the eastern sub-area, which is a part of the Sudd wetlands. The distribution of plant species in the Sudd depends on

Fig. 4. Sizes of annual non-breeding home ranges (95% and 50% kernel density estimator, KDE) of an adult female greater spotted eagle by year (A and B) and by sub-area (east and west) by year (C and D), during 2005–2014.
Obr. 4. Veľkosti ročných mimohniezdných domovských okrskov (95% a 50% odhad jadrovej hustoty, KDE) dospeljej samice orla hrubozobého podľa rokov (A a B) a podľa podoblastí (východná a západná) podľa rokov (C a D), počas rokov 2005 - 2014.



the water’s permanence and depth. Plant diversity and the existence of water result in high numbers and diversity of wild animals (Zwarts et al. 2009). Between November and April, seasonal grasslands are an “extremely favourable habitat for birds” (Howell et al. 1988), including raptors and their potential prey species.

The extensive wintering home range of the tracked eagle

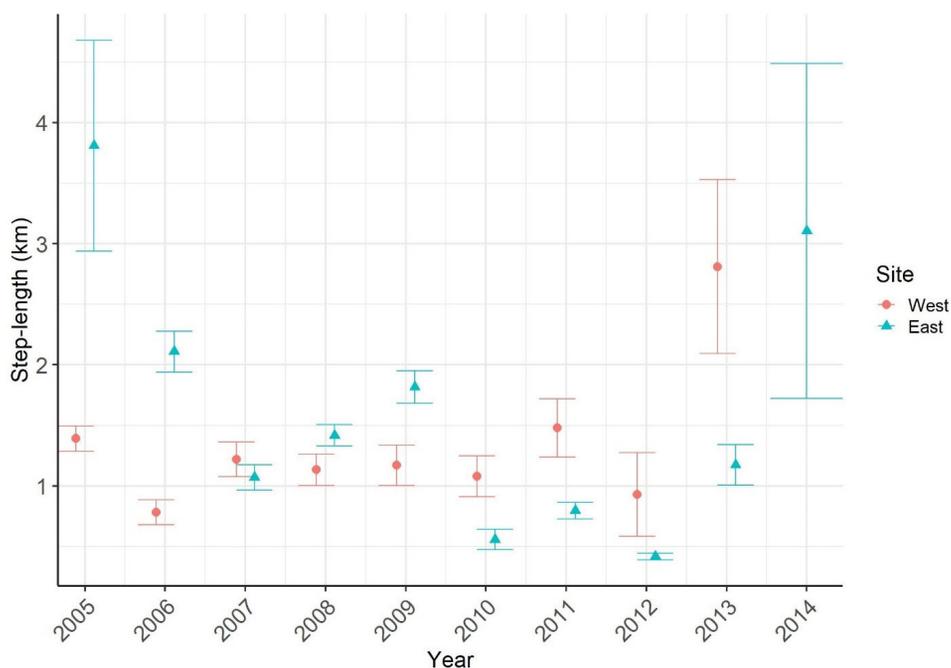
The winter home range of this eagle was larger than that of most other greater spotted eagles that have been tracked (see below). This was mainly due to the distance between the west and east sub-areas; in any given year, each sub-area typically covered <10% of the total winter range (Table 2, Fig. 4). In both sub-areas, the home range size fluctuated between years. The western sub-region in the Sharq Darfur region of Sudan receives less rainfall than the eastern sub-region in South Sudan (M.E.

Elshamy, personal communication). This may explain why the eagle shifted its activity to the east sub-region during the second (drier) half of the wintering season. As with other species (Ferguson-Lees and Christie 2001, Newton 2008), it is likely that the availability of suitable habitat and food affects the winter home range size of the greater spotted eagle. Some areas within the winter home range of the tracked bird may have been inaccessible due to dense vegetation or may have held only low densities of potential prey (Howell et al. 1988; Zwarts et al. 2009), which may have contributed to the large home range size. Moreover, the degree of overlap between years was moderately high, suggesting some degree of concentration in the availability of food resources across years.

We speculate that the tracked eagle moved between sub-areas because of seasonal changes in water availability. This view is bolstered by the eagle’s relatively consistent timing of movement from west to east, mostly in January.

Fig. 6. Average hourly step-lengths of an adult female greater spotted eagle on its wintering grounds in Sudan-South Sudan by year and by sub-area.

Obr. 6. Priemerné hodinové dĺžky krokov dospelaj samice orla hrubozobého na jeho zimovisku v Sudáne a Južnom Sudáne podľa rokov a podoblastí.



However, data from other tracked greater spotted eagles suggest that winter-ranging behaviour varies between individuals, even when they winter relatively close to one another. For instance, a male greater spotted eagle that we tracked consecutively using two tags (PTT IDs: 23895 and 60550) spent the winters from 2000 to 2015 in and near the Abyei region (approx. 9.545° N; 28.558° E), which is situated between the two sub-areas used by our tracked female. In contrast to the female, the range of the male bird was not bipartite, and the home range was commensurately smaller. However, the tracking results of the two eagles are not directly comparable for the following reasons: the male was tracked using less precise Doppler tracking technology, and the tracking was not continuous for the entire period of 2000–2015 (B.-U. Meyburg and Maciorowski, unpublished data).

The size of the Sudd is highly variable throughout the year. During the wet season (April–October), it may extend to over 130 000 km², comprising 13% of the total area of South Sudan. Flood levels and areas of inundation (i.e., the extent of the wetlands) depend mostly on discharge from equatorial lakes and Lake Victoria, which peak in late summer and early autumn. At this time, the Sudd is at its largest. As winter progresses, the western areas dry out. This can affect food availability and may have forced the tracked eagle to move eastwards and closer to the main river (i.e., the White Nile, Bahr al Jabel), where the landscape was still flooded (M.E.

Elshamy, personal communication). However, in specific years, the eagle moved more than once between the sub-areas, suggesting a scenario more complicated than seasonal drying from the west. Furthermore, the ca 330 km move between the western and eastern sub-areas was accomplished in a brief period, which could suggest that the food availability or habitat conditions along the transit route were not ideal, although the male mentioned above also wintered in the area between the two sub-areas.

Previous telemetry studies

Despite its rarity, the greater spotted eagle was among the earliest raptor species tracked via satellite telemetry (Meyburg et al. 1995; Meyburg and Meyburg 2005). Despite this long history of tracking, we are aware of only a few publications that use telemetry data to provide information on the home ranges and movements of this species in wintering areas. In October 1993, a greater spotted eagle of unknown gender was caught in western Saudi Arabia and fitted with a transmitter. It then moved south into Yemen, where it remained from 28 November 1993 to 2 February 1994, approximately 104 km east of Sana. Its home range covers approximately 50 km² (Meyburg et al. 1995). Meanwhile, an Estonian-reared, male greater spotted eagle tracked during the first four years of its life exploited a small area (12.7 km², 95% KDE) in Spain during winter and showed high inter-annual fidelity to the wintering area (Pérez-García et al.

2014). Another study reported that the ranges of a non-adult greater spotted eagle in southwestern Yemen during three consecutive winters overlapped considerably. In that case, the range size estimates averaged 47.5 ± 5.3 km² for the 50% KDE, and $1\,658 \pm 357$ km² for the 95% isopleth KDE (McGrady et al. 2021). Dombrovski et al. (2018) tracked eight *C. clanga*, four of which wintered in the Nile Valley. Moreover, Maciorowski et al. (2019) collected data from nine eagles (one adult and eight juveniles) during one entire wintering period in southern Europe and reported home ranges of 6.7–1 522 km² (mean 89.7 km²). Five juveniles were tracked by Mischenko et al. (2022) for 14 months, of which one eagle wintered on the southern border of Sudan with South Sudan on the White Nile. However, no information was provided regarding their home range size.

Fidelity to the wintering area

The bird tracked in this study joins the ranks of other adult eagles that show longstanding fidelity to their wintering site. Since 1995, we have tagged adult greater spotted eagles and hybrids (*C. clanga* × *pomarina*) in North-East Poland using Argos-Doppler tracking transmitters (PTTs). The female reported herein was the first to be fitted with a GPS device. All six *Clanga clanga* tagged since 1995—for which we could identify the wintering grounds in at least two years—showed inter-annual fidelity to their respective wintering grounds (B.-U. Meyburg, unpublished data).

To our knowledge, the 15 consecutive winter use of the same area on the Göksu River Delta in Turkey (1999 – 2014; 36.296°N; 33.979°E) by an adult female is the longest record of greater spotted eagle fidelity to its wintering area. That bird was tracked (using two different devices, IDs: 08138 and 003), and visually observed, photographed and filmed on the wintering grounds (B.-U. Meyburg and Maciorowski, unpublished data). Moreover, a male greater spotted eagle that we had tracked using two tags consecutively (IDs: 23895 and 60550) spent an equally long time during 2000–2015 on its wintering grounds in and near the Abyei region (9.545° N; 28.558° E) in the Sudan/ South Sudan border area (B.-U. Meyburg and Maciorowski, unpublished data).

As with many species, the wintering ecology of the greater spotted eagle has not been studied in detail. This knowledge gap undermines conservation efforts, as does a similar lack of detailed information regarding its migration across its wide range. Thus, addressing these gaps is essential, and requires further studies, including data from more individuals.

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Owls' responses to forest conservation in the Alps

Odozvy sov na ochranu lesov v Alpách

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Abstract: As inhabitants of cavities, some owl species benefit from natural processes, different tree compositions and higher volumes of dead wood. We assumed that protected areas would have a positive impact on the owl community. We compared the abundance of calling owls on 22 lines in managed versus protected forests. Here, we recorded the acoustic communication of owls. The composition of the owl community did not differ between areas. However, we found the impact of forest landscape integrity index and altitude on the diversity of owls. Forests in protected areas probably need time to develop natural and heterogeneous habitat structures. The conservation priority should be to increase the integrity of the forests. Our results also confirmed that managed forests can have a high diversity of owls.

Abstrakt: Ako obyvatelia dutín, niektoré druhy sov ťažia z prírodných procesov, odlišného stromového zloženia a vyššieho objemu mŕtveho dreva v chránených oblastiach. Predpokladali sme, že chránené územia budú mať pozitívny vplyv na spoločenstvo sov. Porovnávali sme početnosť volajúcich sov na 22 líniiach v hospodárskych a chránených lesoch. Tu sme zaznamenávali akustickú komunikáciu sov. Zloženie spoločenstva sov sa medzi oblastami nelíšilo. Zistili sme však vplyv indexu integrity lesnej krajiny a nadmorskej výšky na diverzitu sov. Lesy v chránených územiach pravdepodobne potrebujú čas na rozvoj prirodzených a heterogénnych štruktúr biotopov. Prioritou ochrany by malo byť zvýšenie integrity lesa. Naše výsledky tiež potvrdili, že obhospodarované lesy môžu mať vysokú diverzitu sov.

Key words: forest management, landscape integrity, owl community, protected areas, biological conservation, ecology, bioacoustics

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Introduction

Forest management is an essential factor affecting forest ecosystems (Buckley & Mills 2015, Hinsley et al. 2015, Hermy 2015). Throughout history, forests in central Europe have been managed in many ways. Coppices and large clearings have been replaced by high-forest management. Current management mainly includes clear-felling on small areas and a shelterwood system in even-aged forests (Kirby & Watkins 2015, Savill 2015). Undoubtedly, forest management affects habitat suitability for many birds (Paillet et al. 2010, Fuller 2012). Species that require large old trees, mixed coniferous and deciduous habitats and more open structures with well-developed

ground flora are particularly affected (Enoksson et al. 1995, Angelstam 2004, Jansson et al. 2004). In contrast, the protection of forest areas is one of the primary tools for biodiversity conservation (Morales-Hidalgo et al. 2015, Law et al. 2021). Despite the importance of protected areas for preserving biodiversity, some groups of organisms and forest species can benefit from managed forests (Schall et al. 2018). Clear-cuts and restocked areas can support a wide variety of species absent from more mature forests (Hinsley et al. 2015). Forest owl species are typically dependent on tree cavities for roosting and nesting. The forests in the Alps are inhabited by four owl species – the tawny owl (*Strix aluco*), the Ural owl (*Strix*

uralensis), the Tengmalm's owl (*Aegolius funereus*) and the pygmy owl (*Glaucidium passerinum*). Two species – the eagle owl (*Bubo bubo*) and the long-eared owl (*Asio otus*) need a semi-open environment.

The tawny owl is a medium-sized owl that inhabits almost all European forest types (Galeotti 2001). It is a dominant species, especially in deciduous woodlands, forests and open parklands. In contrast, the pygmy owl, the Tengmalm's owl and the Ural owl are originally boreal species that prefer mixed and coniferous forests (Mikkola 1983). The Ural owl also occupies old beech forests in Central Europe (Voous 1960, Danko et al. 2002). The long-eared owl's typical habitat is the semi-open landscape, where it uses forest edges and groups of trees as breeding habitats (Mikkola 1983). It uses available nests of other birds, so it is not dependent on tree cavities and holes. In Annex I of the Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild bird species, eight are owls. Four occur in our study area (Tengmalm's, pygmy, Ural and eagle owl).

Despite the well-known ecology and habitat requirements of forest owls living in Europe, very little is known about the impact of protected areas on owl populations. Also, the responses of the owl communities to

the environment in mountain areas are poorly researched. We hypothesized that: (i) the number of calling owls will be lower in managed compared to protected areas and (ii) the number of species and diversity of owls will be higher in areas with more suitable forest management and environmental parameters (i.e., in protected areas). The result of the study can help to understand whether protected areas in mountains can provide better conditions for owl species.

Material and methods

Study areas

The study sites were located at 630 – 1260 m a.s.l. in the Alps, Austria. The forests consisted of deciduous and coniferous trees, predominantly Norway spruce (*Picea abies*) and European beech (*Fagus sylvatica*). The managed forests were selected from areas controlled by the Austrian national forestry company Bundesforste (N 47.792390°, E 15.003097° and N 47.788820°, E 14.873991° and N 47.271191°, E 12.790635°). Coniferous trees dominate in this area. Information on average values of environmental parameters within 300 m buffer around recorders is provided in Table 1 and in the Supplementary Table S1. The protected areas were located in the Duerrenstein Wilderness Area (N 47.762007°, E

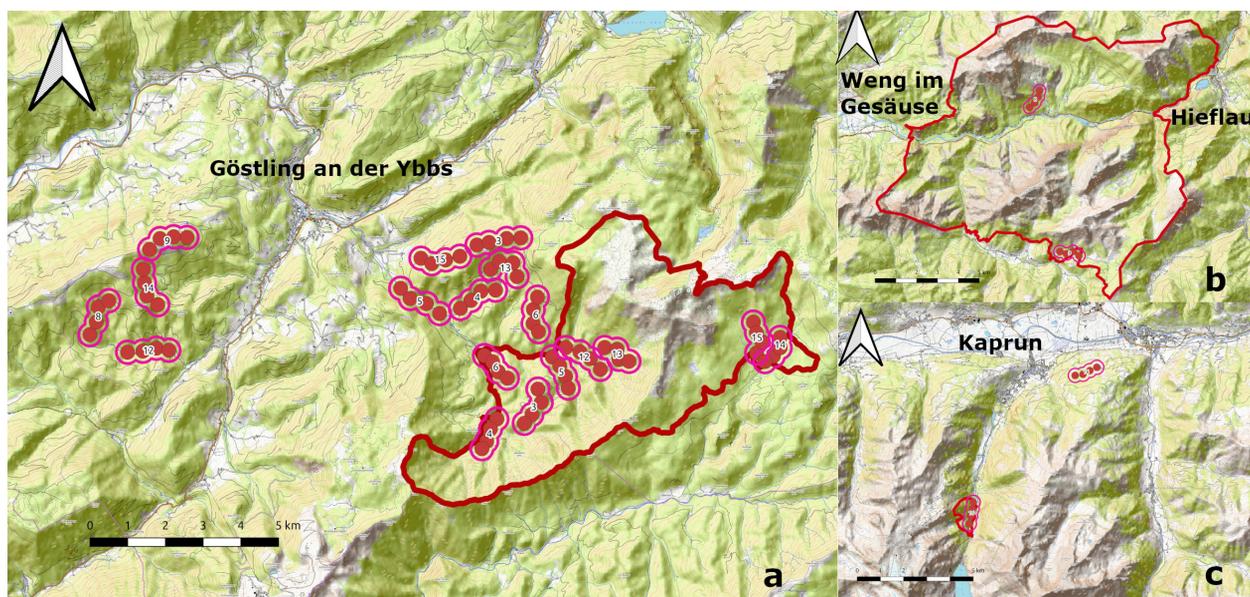


Fig. 1. The map of the Duerrenstein Wilderness Area (a), the NP Gesäuse (b), the Nature reserve Kesselfall and Kaprun (c). The points represent recorders, the line around the points - 300 m buffer area, the bold red line - represents the border of the protected area. The numbers identify individual transects – pairs (inside and outside protected areas).

Obr. 1. Mapa oblasti divočiny Durrenstein (a), NP Gesäuse (b), prírodnej rezervácie Kesselfall a Kaprun (c). Body predstavujú nahrávače, línia okolo bodov – 300 m bufer, hrubá červená čiara - hranica chráneného územia. Čísla identifikujú jednotlivé transekty - dvojice (vnútri a mimo chránených oblastí).

Tab. 1. Average values of environmental parameters in protected and managed areas.

Tab. 1. Priemerné hodnoty environmentálnych faktorov v chránených a obhospodarovaných oblastiach.

| | Protected area | Managed area |
|----------------------------------|----------------|--------------|
| Coniferous forest (%) | 36.8 | 56.5 |
| Deciduous forest (%) | 51.7 | 34.6 |
| Tree cover density | 71.4 | 75.5 |
| Forest landscape integrity index | 6.1 | 5 |

15.021724°, Fig. 1), the Nature Reserve Kesselfall (N 47.213183°, E 12.722890°) and the Gesaeuse National Park (N 47.586255°, E 14.640948°). In the Duerrenstein Wilderness Area, during the ongoing research, the primary habitat was mixed forests with dominant beech and spruce trees. This area represents the largest unmanaged area in Austria. It was established in 1997–2001, and new parts are still added to this area. Only a small part is secured by forest management to improve a more natural tree composition. In the Nature Reserve Kesselfall, deciduous forests with a predominance of beech prevailed. In contrast, spruces and beeches dominated in Gesaeuse NP. Forests have been unmanaged on most of the territory since 2002 when the national park was established.

Field methods

Owl calls were recorded using Audiomoth recorders (Hill et al. 2019) – programmable devices for ecological research. Recording started at sunset and lasted until sunrise. The recorders were installed at sites in the Duerrenstein Wilderness Area and managed forests surrounding this area in 2021 (May, June and October) and in Gesaeuse NP, Kesselfall National Reserve and managed forests in Kaprun in 2022 (April and May). We prepared pairs of lines that were placed in managed and protected forests. These pairs had a similar altitude and location (at the bottom of a valley, on a slope – horizontal or vertical, on a ridge) because different owl species prefer other parts of the mountains. Our pairwise approach minimized the risk of data bias. On each 1 km line, four devices were placed 330 meters apart. The number of territorial males was identified for each line. Six recorders were damaged and did not record sound during field research. In these cases, the number of territorial males per line was calculated from three points. The rest of the 82 recorders recorded an average of 15.6 nights (min. 4 – max. 29 nights). The recordings were downsampled in frequency – from 0 to 8 kHz – to reduce the size. We used Audiomoth recorders installed on young trees about 2 meters above the ground

in a plastic bag. The gain was set to medium.

Calls of each species were processed individually. A total of 2295 recordings of tawny owls, 237 of Tengmalm’s owls, 48 of pygmy owls, 241 of long-eared owls and 4 of Ural owls were identified. We manually checked all nights for owl calls. Tawny owl calls were compared using spectrograms. In particular, the frequency and shape of the third note were proper parameters for male identification. The number of individuals by other species (the pygmy and Tengmalm’s owl) was identified by different sound frequencies and simultaneous recording of several males using all recorders on the line. We could therefore distinguish whether the same male was recorded on several recorders or if it was a different male. Some unusual calls or mysterious recordings were discussed with other experienced bird call experts. The number of territories was based on the number of individual territorial males. Contact calls were not considered. We also recorded the contact calls of the eagle and Tengmalm’s owls during the survey. These calls were not associated with any territories. They could belong to birds without a territory or young birds.

GIS layers were used to analyze the influence of selected parameters (forest landscape integrity index, tree cover density and altitude). They were analyzed in a 300-meter buffer area around the recorders. We selected this distance based on field experience that small owl species (Tengmalm’s and pygmy owl) can be identified at a distance of 300 m. The forest landscape integrity index (flii hereinafter) integrates data on observed and inferred forest pressures and lost forest connectivity to generate the first globally consistent, continuous index of forest integrity as determined by the degree of anthropogenic modification (Grantham et al. 2020). This index summarizes geospatial information on forest loss based on satellite data, roads (also forest roads), agriculture, inferred human pressure modelled based on proximity to the observed pressures, and change in forest connectivity. Tree cover density (TCD hereinafter) was created in the frame of the tender “EEA/IDM/R0/18/009 – High-Resolution land cover characteristics for the 2018 reference year” as part of the EEA Copernicus Land Monitoring Service (CLMS, <https://land.copernicus.eu>). The TCD raster product provides information on proportional crown coverage per pixel at a spatial resolution of 10 m and ranging from 0% (all areas not covered by trees) to 100%, with tree cover density defined as the „vertical projection of tree crowns to a horizontal earth’s surface“ (European Environment Agency). Altitude was identified

from a topographic map and using GPS on site. The boundaries of the protected areas were obtained from the Duerrenstein Wilderness Area, the Gesaeuse NP and the Salzburg Provincial Government.

Analyses

The composition of the owl communities (the number of territorial males of different owl species recorded in managed and protected areas) was compared using Fisher's Exact Test. Student's t-test was used for analyzing the number of territorial males of individual species. In the case of the long-eared owl, we did not analyze the data with a Student's t-test because the sample was too small. A Generalized linear model (GLM) in R software (version 4.2.1) was used to understand the effect of the environment on the number of tawny owl territorial males. Only uncorrelated parameters – the type of the area (protected or managed), tree cover density, flii and altitude were selected for this analysis. In the case of the tawny owl, the Poisson distribution was used. Other owl species were not analyzed due to small sample sizes. A Shannon diversity index was also calculated for each line and analyzed in the GLM with the same environmental parameters as for individual species (see above). The index was calculated from all recorded owl species (including long-eared and Ural owl). In this case, the Gaussian distribution was used. All calculations for each line were performed in QGIS in Lambert Azimuthal Equal Area projection (EPSG:3035). We used Moran's I and Monte-Carlo simulation (1000x) to test spatial autocorrelation in "spdep" R package (Bivand and Wong 2018). The number of territorial males – for the tawny owl (Moran's I = -0.077, p = 0.822), the

Tengmalm's owl (Moran's I = 0.052, p = 0.416), the pygmy owl (Moran's I = -0.127, p = 0.634), the long-eared owl (Moran's I = 0.156, p = 0.13) and Shannon diversity index (Moran's I = 0.198, p = 0.132) were not significantly autocorrelated.

Results

Number of individuals

A total of 45 owl territorial males were recorded in protected areas and 49 territorial males in managed areas (Fig. 2). The results did not confirm the different composition of the owl community between protected and managed areas (Fisher's Exact Test, p = 0.2056). The total abundance of territorial males of the tawny owl (t = -0.48795, df = 20, p = 0.6309), the Tengmalm's owl (t = 1.3182, df = 20, p = 0.2023) and the pygmy owl (t = -0.56796, df = 20, p = 0.5764) were not significantly different between protected and managed areas. Only five males (4 in the managed areas and 1 in the protected area) of the long-eared owl were recorded. The distribution of observations also confirmed the similarity between the abundances in the two areas (Fig. 3a-e).

The pygmy and Tengmalm's owls were recorded only on slopes and ridges. All territorial males of both species were registered at a higher altitude – above 800 m a.s.l. No preference was found for the tawny owl. It occupied all types of forests and terrain forms. This study revealed that even coniferous forests are regularly occupied by this species. It was also recorded on the mountain ridge more than 1200 m a.s.l. During the research, only one Ural owl male was recorded. It needs a large territory, so their density is lower than other smaller species. The average diversity of owls did not significantly differ between managed (Shannon index = 0.620) and protected areas (0.378).

Impact of forest modification

The selected environmental parameters did not significantly affect the tawny owl numbers (Table 2). Owl diversity was positively influenced by the increase in the forest landscape integrity index and altitude (Table 3). A total of 10 transects belonged to the category of medium forest integrity (>6.0 and <9.6) and 12 transects to low forest integrity. The highest value was recorded in the primeval forest (flii = 8.75) in the Rothwald area (part of the Duerrenstein Wilderness Area). However, the diversity of owls reached the maximum value in managed forests with low integrity (flii = 4.92) and higher altitudes (1010 m a.s.l.). Tree cover density and area protection did not have a significant effect.

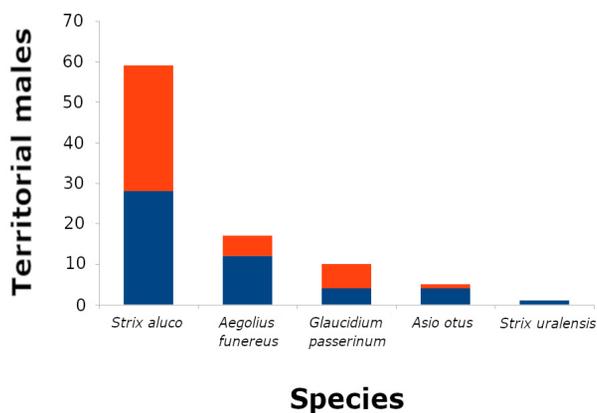


Fig. 2. The number of territorial males in two types of areas. Blue colour – managed forests, orange colour – protected forests.
Obr. 2. Počet teritoriálnych samcov v dvoch typoch oblastí. Modrá farba – hospodárske lesy, oranžová farba – chránené lesy.

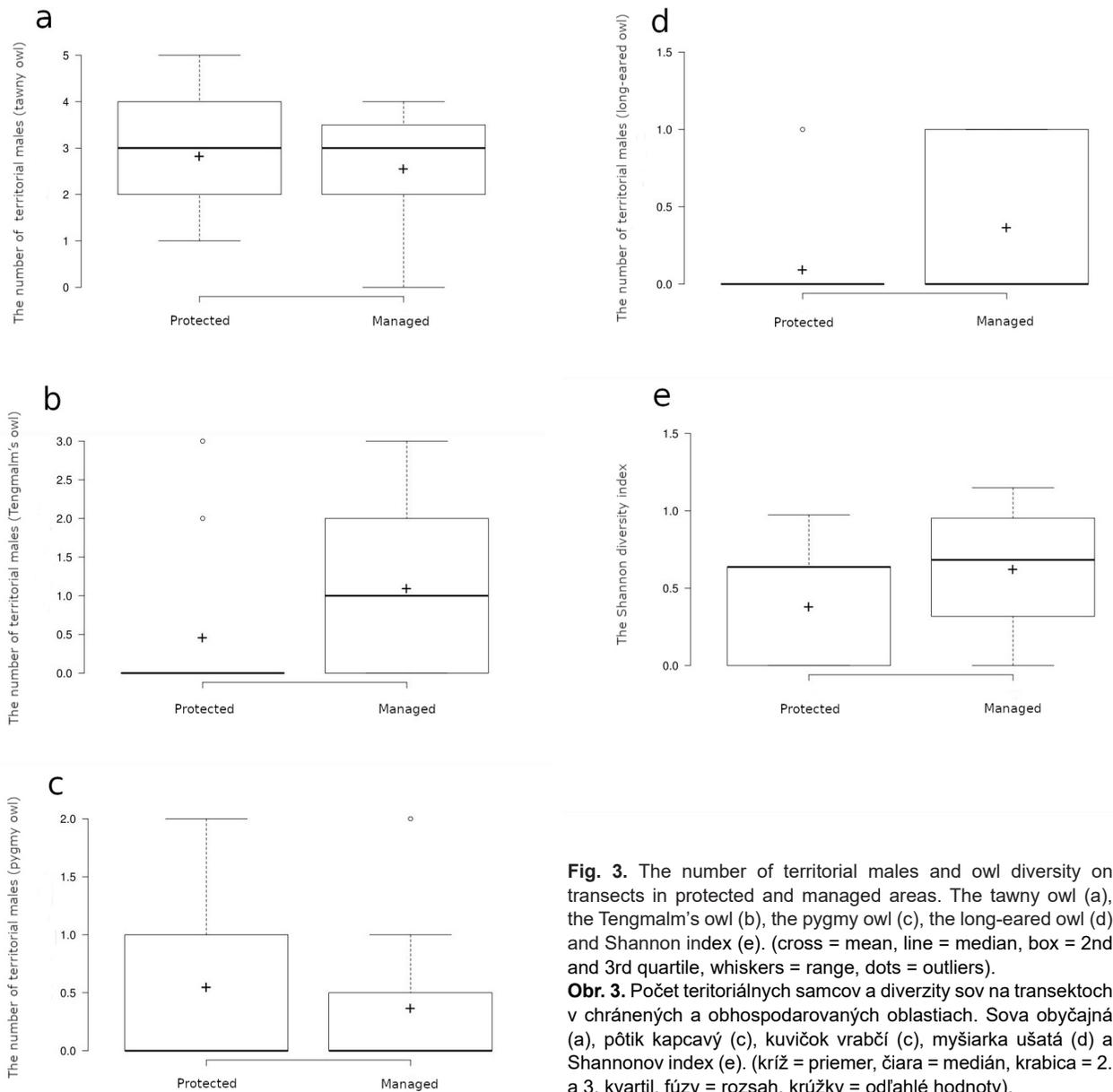


Fig. 3. The number of territorial males and owl diversity on transects in protected and managed areas. The tawny owl (a), the Tengmalm's owl (b), the pygmy owl (c), the long-eared owl (d) and Shannon index (e). (cross = mean, line = median, box = 2nd and 3rd quartile, whiskers = range, dots = outliers).

Obr. 3. Počet teritoriálnych samcov a diverzity sov na transektoch v chránených a obhospodarovaných oblastiach. Sova obyčajná (a), pôtik kapcavý (b), kvičok vrabčí (c), myšiarka ušatá (d) a Shannonov index (e). (kríž = priemer, čiara = medián, krabica = 2. a 3. kvartil, fúzy = rozsah, krúžky = odľahlé hodnoty).

Discussion

Protected areas and human pressure
 Managed forests in Europe are different from natural forests (Savill 2015). Coniferous trees are usually preferred by foresters in managed forests and in higher density. Their presence represents an important parameter for the pygmy and Tengmalm's owl (Pačenovský & Šotnár 2010, Brambila et al. 2015, Mestecăeanu & Mestecăeanu 2020, Ševčík et al. 2021). The forest management can produce smaller or larger clearings that

may provide preferred habitats (Rumbutis et al. 2017) or impact fledglings production (Hakkarainen et al. 1997). Our research did not confirm significant differences in the number of territorial males between protected and managed areas (prediction i).

Human pressure on the forest ecosystems in our study was evaluated using the forest landscape integrity index (flii). We found that the combination of higher altitude and rising flii positively influenced the diversity of owls. The transects with low flii were also present in protected

Tab. 2. GLM – Impact of environmental parameters on the number of territorial males (tawny owl)**Tab. 2.** GLM – Vplyv environmentálnych parametrov na počet teritoriálnych samcov (sova obyčajná)

| Coefficient | Estimate | Std. Error | z-value | p-value |
|----------------------------------|----------|------------|---------|---------|
| Intercept | 1.193 | 1.33 | 0.897 | 0.37 |
| Protected forest | 0.082 | 0.285 | 0.288 | 0.773 |
| Tree cover density | -0.014 | 0.017 | -0.822 | 0.411 |
| Forest Landscape Integrity Index | 0.001 | 0.072 | 0.015 | 0.988 |
| Altitude | 0.001 | 0.001 | 1.083 | 0.279 |

Tab. 3. GLM – Impact of environmental parameters on the owl diversity (Shannon index)**Tab. 3.** GLM – Vplyv environmentálnych parametrov na diverzitu sov (Shannonov index)

| Coefficient | Estimate | Std. Error | t-value | p-value |
|----------------------------------|----------|------------|---------|---------------|
| Intercept | -1.114 | 0.65 | -1.713 | 0.1048 |
| Tree cover density | 0.001 | 0.009 | 0.165 | 0.8708 |
| Forest landscape integrity index | 0.095 | 0.036 | 2.607 | 0.0184 |
| Altitude | 0.001 | 0 | 3.115 | 0.0063 |
| Protected forest | -0.293 | 0.145 | -2.019 | 0.0596 |

bold represent significant value / túčné písmo reprezentuje štatisticky preukazné hodnoty

areas, two in the Duerrenstein Wilderness Area close to the borders of the protected area and three in the Gesaeuse NP and the Nature Reserve Kesselfall. A large part of the forests in this area were managed until the creation of protected areas. Despite its wilderness status, a dense network of forest roads is still preserved. This most probably caused the relatively lower score of the forest landscape integrity index. Therefore, forest integrity still remains an issue in protected areas.

Habitat suitability for species associated with open forest structures in protected areas may decrease in the first three decades after the end of management (Braunisch et al. 2019). There is also more evidence that bird communities of common forest species do not differ significantly between protected and managed areas (Virkkala et al. 1994, Müller et al. 2007, Ameztegui et al. 2018, Lešo et al. 2019). However, protected areas can offer better conditions for species inhabiting tree holes and cavities (Müller et al. 2007, Brunet et al. 2010, Felton et al. 2016, Lešo et al. 2019). It is also evident that a generalist species, such as the tawny owl, can be similarly abundant in managed and protected areas. The quality of forest habitats is also affected by the duration without management. Almost 80 years since establishing the protected area may not be enough to increase the quality of the forest habitat (Löhmus et al. 2005). The Duerrenstein Wilderness Area is still growing, so forest management in new areas is stopped or adapted to the wilderness goal.

We can conclude that forest stands at higher altitudes with a higher forest integrity index support a higher

diversity of owls. This is consistent with the hypothesis that diversity of owls is higher in areas with more suitable forest management and environmental parameters (prediction *ii*). The most diverse sites were on slopes and ridges, possibly because these parts are usually the least managed anyway.

Natural factors influencing owl distribution

In addition to forest management, climate change also negatively affects the availability of coniferous trees and other habitat types, which may reduce the distribution of the Tengmalm's and pygmy owls (Brambilla et al. 2015). Altitude is one of the parameters that affect the distribution of forest owls in the mountains. The tawny owl is a species that was recorded in the study area at different altitudes and geomorphological forms. Similar results were also found in an Italian study, where the tawny owl occupied all habitats below the tree line (Marchesi et al. 2006). These findings contrast another study where its distribution was restricted to low altitudes, probably due to competition from the Ural owl (Vrezec & Tome 2004). In our study areas, we recorded only one territory of the Ural owl, so the smaller tawny owl did not have a direct competitor in the forest habitat. The Tengmalm's owl spatially prefers peaks and ridges in Slovakia (Šotnár et al. 2020). We can partially confirm these findings, even though we also recorded territorial males on the slopes. Most of pygmy owl males were also recorded there.

Protected areas should preserve natural habitats that provide suitable conditions for endangered species. However, managed forests can also provide an appropriate

environment for several owl species. Our study identified forest integrity as an essential parameter influencing owl diversity. The integrity of the forest can be increased by reducing the density of forest roads and minimizing the loss of tree cover in the area. Further research should focus on beneficial forestry methods and how to increase the ecological integrity of forest habitats.

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Bill deformities in Egyptian vulture (*Neophron percnopterus percnopterus*): a noteworthy record from Rajasthan, India

Deformácie zobáka u zdochlinára bieleho (*Neophron percnopterus percnopterus*): pozoruhodný nález z Rádžastánu v Indii

Hira PUNJABI & Arockianathan SAMSON

Abstract: Beak deformities may be permanent or temporary and are caused by various factors. Despite its vast geographical area in India, there has been little research on beak deformities in wild birds, and few cases have been reported. In the present study, we described, as far as we know, the first known report of a beak deformity in the Egyptian vulture (*Neophron percnopterus percnopterus*) worldwide. On 6 January 2014, the first author (HP) recorded the Egyptian vulture with a heavily deformed bill on the garbage dump in Jorbeed, Bikaner, Rajasthan, India. The causes of the bill abnormality in this individual are unknown, but our record increases the knowledge of the presence of development deformities in Egyptian vultures. We highlight the importance of photographs as a valuable tool for documenting bird beak deformities. In conclusion, we encourage other researchers to report the records of beak deformities, which is necessary for a better understanding of this phenomenon and its insights into the ecological and physiological implications of this condition considerably affecting bird survival.

Abstrakt: Deformácie zobáka môžu byť trvalé alebo dočasné a sú spôsobené rôznymi faktormi. Napriek rozsiahlej geografickej oblasti sa deformácie zobáka u voľne žijúcich vtákov v Indii skúmali len málo a bolo zaznamenaných len niekoľko prípadov. V tejto štúdii sme opísali, pravdepodobne, prvú známu deformáciu zobáka u zdochlinára bieleho (*Neophron percnopterus percnopterus*) na svete. Dňa 6. januára 2014 prvý autor (HP) zaznamenal supu egyptského so silne deformovaným zobákom na skládke odpadu v Jorbeed, Bikaner, Rajasthan, India. Príčiny abnormality zobáka u tohto jedinca nie sú známe, ale náš záznam rozširuje poznatky o výskyte vývojových deformácií u zdochlinárov bielych. Zdôrazňujeme význam fotografií ako cenného nástroja na dokumentovanie deformácií zobáka vtákov. Na záver vyzývame ďalších výskumníkov, aby hlásili záznamy o deformáciách zobáka, za účelom lepšieho pochopenia tohto fenoménu a poznania jeho ekologických a fyziologických dôsledkov výrazne ovplyvňujúceho prežívanie vtákov.

Key words: birds of prey, foraging, disease, case report, avian keratin disorder

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Introduction

Beak deformities are rarely reported in wild birds, which may be because they are infrequent (Pomeroy 1962; Craves 1994). Beak deformities may be permanent or temporary and are caused by various factors (Pomeroy 1962). The main causes are genetic mutations, injuries, diseases, nutritional deficiencies, contact with chemical pollutants, problems during incubation, and inadequate wear of the rhinotheca (Pomeroy 1962; Craves 1994). Following these epizootic episodes, considerable research efforts have been invested to identify the possible causes of these deformities, known as Avian Keratin Disorder

(AKD hereinafter), characterized by debilitating beak overgrowth and other abnormalities of keratinized tissues (Handel et al. 2010; Van Hemert & Handel 2010; Handel & Van Hemert 2015). Recently, evidence indicated that the deformities observed in black-capped chickadees (*Poecile atricapillus*) in Alaska showed significant relationship between poecivirus infection and AKD and provided evidence that poecivirus is indeed an avian virus, infecting and actively replicating in beak tissues (Zylberberg et al. 2018). However, whether this virus is involved in the epizootic episodes recorded in other World regions is still unclear, and poecivirus continues

to warrant further investigation as a candidate agent of AKD. Despite its extensive geographical area in India, there has been little research on the occurrence of beak deformities in wild birds, and few cases have been reported (Devendra & Asish 2018; Siva et al. 2021; Anurag & Yadav 2022; Chouhan et al. 2022; Aurobindo & Shreya 2023). The present study described the first known report of a beak deformity in the Egyptian vulture (*Neophron percnopterus percnopterus*) worldwide.

Observation

On 6 January 2014, the first author (HP) recorded the Egyptian vulture with a heavily deformed bill on the garbage dump in Jorbeer, Bikaner, Rajasthan, India (N 27.96649, E 73.38150). The individual had a grossly elongated maxilla and mandible (Fig.1). In addition to being elongated, the maxilla was quite curved downward, and the colouration of the beak was greyish-black. The Egyptian vulture was moving on the ground, consuming some carcasses and was distant from other individuals. We never found this individual at the dump during the subsequent visits.

Discussion

Around the World, very few beak abnormalities have been reported in raptors. It was, for instance, observed in bald eagles (*Haliaeetus leucocephalus*) (Gilberstonet al.1991; Bowermanet al.1994; Collen et al.2010), peregrine falcons (*Falco peregrines*) (Collen et al. 2010), American kestrels (*Falco sparverius*) (Ferniet al.2003; Collen et al.2010), ospreys (*Pandion haliaetus*) and red-tailed hawks (*Buteo jamaicensis*) (Eltzroth 1996; Tinajero & Rodríguez-Estrella 2011).

Egyptian vultures feed mainly on carrion but are opportunistic and also prey on small mammals, cacoons, birds, and reptiles (Naroji 2006; Samson & Ramakrishnan 2016). The scavenging, capturing, and consuming of these kinds of carrion and prey require specific skills and abilities. Handling food by birds with bill deformities may cause a functional limitation (Van Hemert & Hallen 2010). Bill deformities may also avert birds against a defence adjacent to ectoparasites (Clayton et al. 2005; Rodríguez-Estrella 2011), which may decrease their health condition. Functional limitations and decreasing



Fig. 1. Bill deformity in Egyptian vulture (*Neophron percnopterus percnopterus*) recorded in Jorbeed, Bikaner, Rajasthan, India.
Obr. 1. Deformácia zobáka zdochlinára bieleho (*Neophron percnopterus percnopterus*) zaznamenaná v Jorbeed, Bikaner, Rajasthan, India.

health conditions can affect fitness and survival, which may be the reason that bill abnormalities are typically rare (<1%) in wild bird populations (Pomeroy 1962; Tweit et al. 1983; Nogales et al. 1990; Rockwell et al. 2003), and most reports are of single individuals (Craves 1994). Thus, we believe that the abnormality observed in our case has not significantly affected the scavenging abilities of the given individual. Our observation contrasts with other ones on different species where the bill abnormality may lead to the death of the bird (van Hemet 2007; Marti et al. 2008).

Egyptian vultures are widely distributed across the Old World, with their breeding range from southern Europe to northern Africa and eastern to western and south Asia. They are rare vagrants in Sri Lanka (Ali & Ripley 1978). In India, two recognized subspecies are present: *Neophron percnopterus percnopterus*, widely distributed worldwide, and *Neophron percnopterus ginginianus*, primarily distributed in India and Nepal. Both the subspecies distributions overlap in northern India and Pakistan (Naoroji 2006; Angelov et al. 2013; Mishra et al. 2018) and may interbreed (Mishra et al. 2018). Naoroji (2006) stated that *Neophron percnopterus percnopterus* and *Neophron percnopterus ginginianus* are locally migratory. Based on the bill colouration (Grayish-black), the individual with bill deformity was *Neophron percnopterus percnopterus*, a migratory species in India. The causes of the bill abnormality in this individual are unknown, but our record increases the knowledge of the presence of development deformities in Egyptian vultures.

We highlight the importance of photographs as a valuable tool for documenting bird beak deformities. In conclusion, we encourage other researchers to report the records of beak deformities, which is necessary for a better understanding of this phenomenon and its insights into the ecological and physiological implications of this condition considerably affecting bird survival.

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