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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: Krahuľa 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 hôrnych 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 inváziií 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 krahuľa hôrna v Dánsku.

Na získanie lepšieho obrazu o pohybe počas invázie a budúcich potrebách ochrany krahule hôrnej sú potrebné ďalšie odchyty 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.

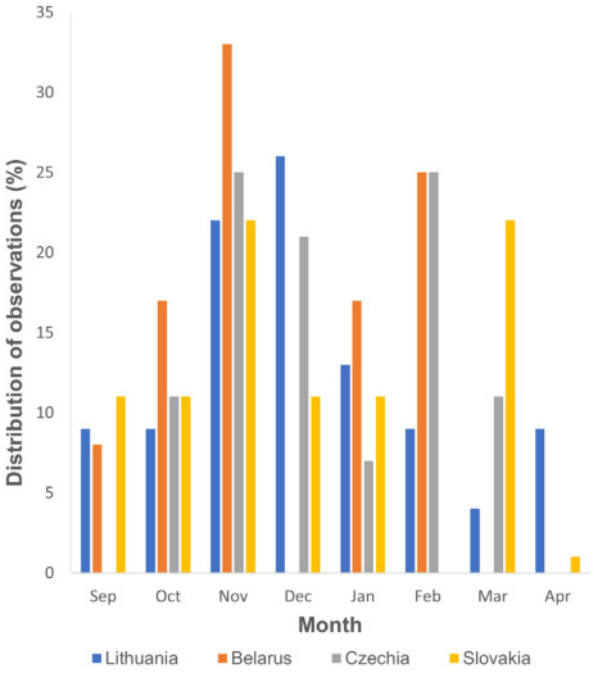

Fig. 1. Percentage distribution of the monthly northern hawk owl *Surnia ulula* observations in Lithuania (N = 23), Belarus (N = 12), Czechia (N = 28) and Slovakia (N = 9).
Obr. 1. Percentuálne zastúpenie mesačných pozorovaní krahule hôrnej v Litve (N=23), Bielorusku (N= 12), Česku (N = 28) a Slovensku (N = 9).

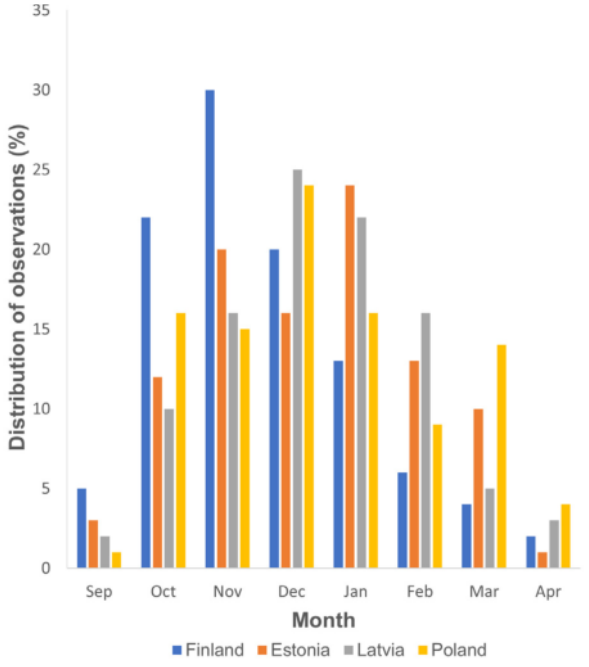

Fig. 2. Percentage distribution of the monthly northern hawk owl Surnia ulula observations in Finland (N = 931), Estonia (N = 499), Latvia (N = 87) and Poland (N = 85).
Obr. 2. Percentuálne zastúpenie mesačných pozorovaní krahule hôrnej vo Fínsku (N=931), Estónsku (N= 499), Lotyšsku (N = 87) a Polsko (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 – 11.7; December – 14.9; January – 26.3; February – 16.1; March – 8.2, and April – 1.0 %. 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.

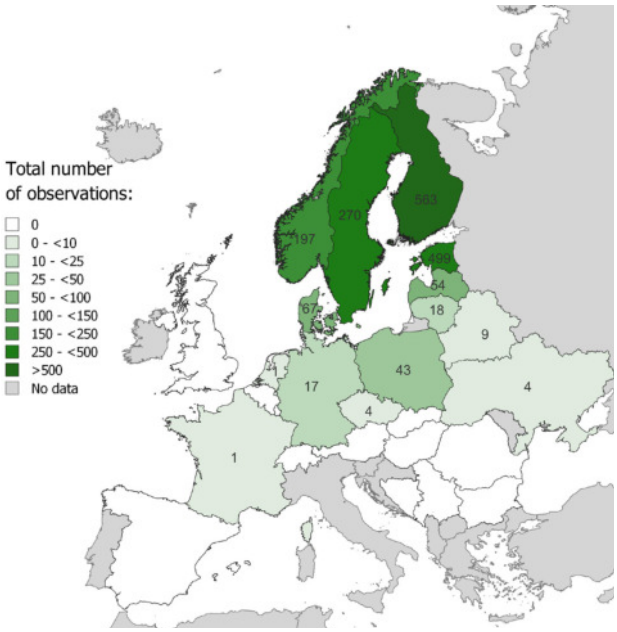

Fig. 3. The northern hawk owl (*Surnia ulula*) total observations during years 2010–2021.
Obr. 3. Celkové pozorovania krahule hôrnej (*Surnia ulula*) v priebehu rokov 2010-2021.

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

Country (obs) / 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**
2011 – 12	0	0	8.2	5.2	0	0	9.3	0	0	0
2012 – 13	**15.7**	**41.5**	2.8	3.8	**11.1**	11.1	**14**	**11.5**	0	0
2013 – 14	1.5	1.9	**19.2**	**18.5**	**11.1**	**16.7**	**14**	**18**	**64.7**	**35.3**
2014 – 15	0	0.7	4.4	3	9.3	11.1	9.3	0	5.9	5.9
2015 – 16	2.6	3.3	1.2	1.6	5.6	0	7	9.8	5.9	0
2016 – 17	**34.5**	**29.6**	2.5	5	3.7	5.6	0	**24.6**	0	5.9
2017 – 18	4.1	1.9	**27.4**	**40.3**	**31.5**	**38.9**	7	0	0	**23.5**
2018 – 19	1.5	1.9	4.5	2.8	1.8	11.1	0	1.6	5.9	0
2019 – 20	8.1	**14.4**	0.7	1.6	1.8	0	2.3	**32.8**	0	0
2020 – 21	**30.5**	3.7	2.3	6.8	1.9	0	**16.3**	0	0	5.9
2021 – 22	1.5	1.1	**23.3**	**9.6**	**14.8**	5.6	**11.6**	**11.6**	**11.8**	0
Total	100	100	100	100	100	100	100	100	100	100

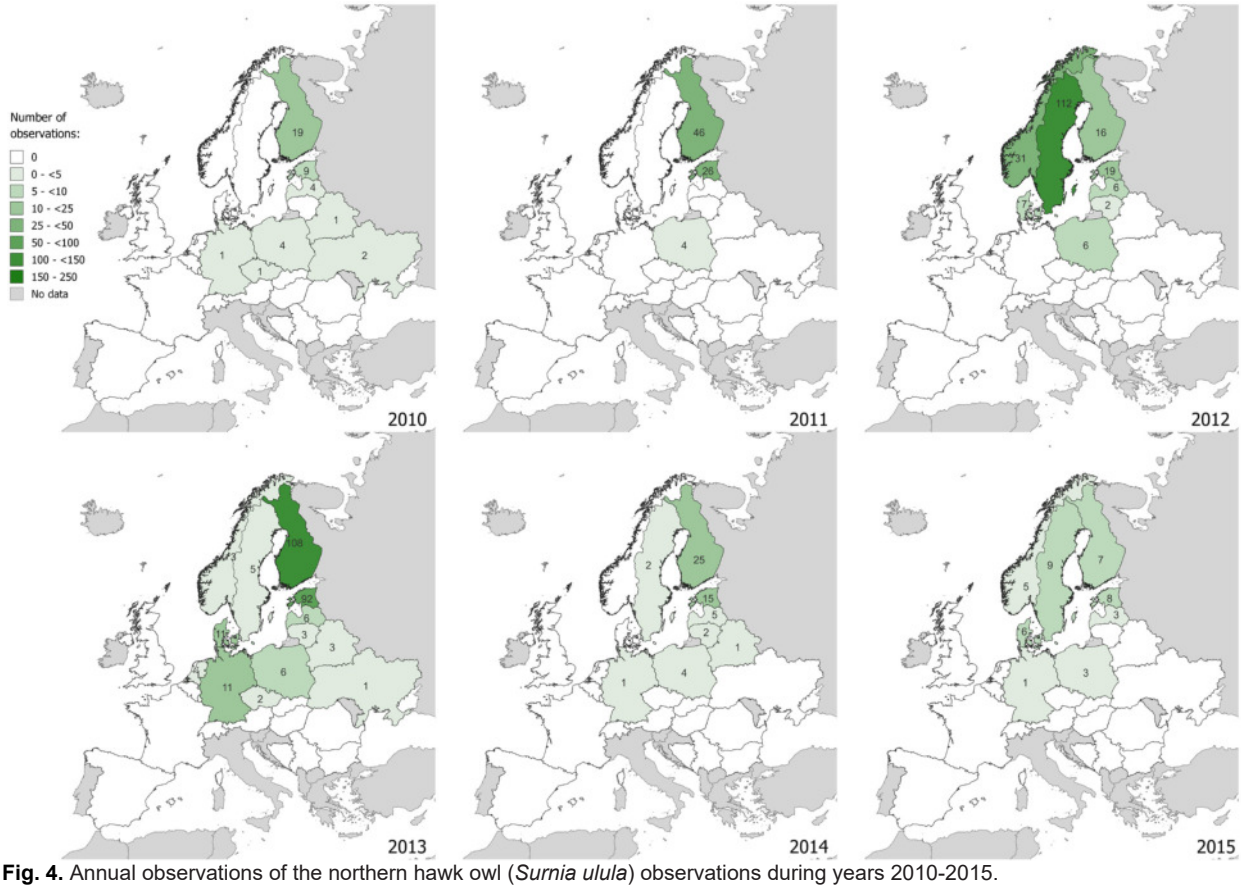

Fig. 4. Annual observations of the northern hawk owl (*Surnia ulula*) observations during years 2010-2015.
Obr. 4. Ročné pozorovania krahule hôrnej (*Surnia ulula*) v priebehu rokov 2010-2015.

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

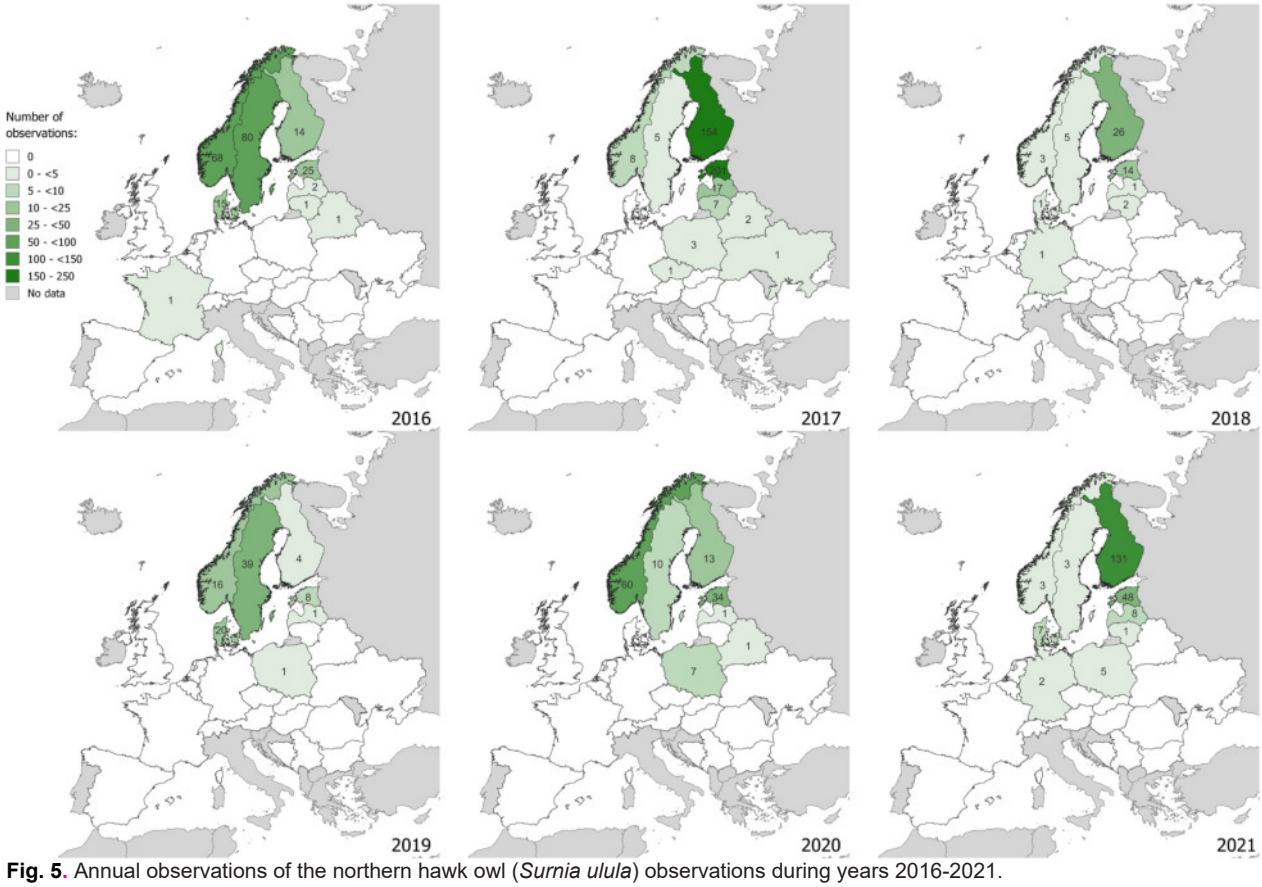

Fig. 5. Annual observations of the northern hawk owl (*Surnia ulula*) observations during years 2016-2021.
Obr. 5. Ročné pozorovania krahule hôrnej (*Surnia ulula*) v priebehu rokov 2016-2021.

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 hôrnej (*Surnia ulula*) v dvanástich európskych krajinách v rokoch 2010-2022. Tučné čierne čísla označujú výrazné prekrývanie v hlavných rokoch invázie (index podobnosti nad 0,50) a sivo podfarbené hodnoty veľmi nízke prekrývanie 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 Habére-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 unlike 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 from Timişoara by a forester and that bird is now mounted in the Bariat Museum collection.

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 zvýraznene zelenou farbou. Viac informácii v texte. Na základe mapy Dale & Sonerud (2022).

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 exists 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 Västergotland) (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, Drehnte 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).

Ringing Results

Unfortunately, ringing 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 ringed 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 ringing site. Another young from Liminka was captured in October near Norilsk mining city 2659 km east of the nest. The third young one ringed 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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