Ornis Norvegica (2022), **45**: 1–9
doi: 10.15845/on.v45i0.3425

Relative magnitude of two Northern Hawk-Owl *Surnia ulula* irruptions to southern Norway: comparison of citizen data and survey data

Svein Dale

Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences, P.O.Box 5003, NO-1432 Ås, Norway. Correspondence: svein.dale@nmbu.no

Abstract. The Northern Hawk-Owl *Surnia ulula* occurs as an irruptive species to southern parts of Fennoscandia. Large numbers of individuals were recorded in the autumns of 2016 and 2020 but assessing the relative magnitude of irruptions is challenging. Systematic surveys allow direct comparisons but are time-consuming and will therefore be limited in time and space. Citizen data may provide large amounts of information for wide areas but may in particular suffer from spatial biases in the observation effort of birdwatchers. I compared the 2016 and 2020 irruptions of Northern Hawk-Owls to southern Norway, and found that citizen data indicated that numbers in 2016 were ca. 2–3 times larger than in 2020. However, the relative magnitude differed geographically, and the 2016 irruption was larger in western and southern counties, whereas the difference was smaller in eastern counties (in particular in Innlandet county). Systematic surveys in eastern regions (Oslo and Akershus) indicated that Northern Hawk-Owl densities were similar in the two irruption years. Overall, Northern Hawk-Owls were recorded at the same rate (approximately one owl per 16 km), and density was estimated to be 0.09–0.18 individuals/km^2 in 2016 and 0.08–0.13 individuals/km^2 in 2020. Thus, citizen data and survey data from the same geographical region concurred. However, due to the geographical variation in relative irruption size and spatial variation in observer density and biases in observation effort, the overall difference between the two years is difficult to assess. The 2016 irruption was likely larger than the 2020 irruption, but the difference was probably smaller than suggested by citizen data.

Keywords: Hawk-Owl autumn density, citizen science, irruption, survey data

INTRODUCTION

The Northern Hawk-Owl *Surnia ulula* (hereafter Hawk-Owl or owl) occurs as an irruptive species to areas south of the regular breeding range (Mikkola 1983, Cramp 1985, Newton 2006). Hawk-Owls are scarce breeders in southern Norway (Sonerud 1994) but have occurred in large numbers in autumn and winter in certain years. Recent large irruptions have occurred in e.g. 1983–84 (Jacobsen 1984), in 2016–17 (Dale 2017), and in 2020–2021 (this study). The number of individuals involved in Hawk-Owl irruptions have rarely been estimated, but 2,000–4,000 individuals were thought to be present in Värmland county in southwest Sweden during the 1983–84 irruption (Svensson et al. 1999), corresponding to ca. 0.1–0.2 owls/km^2. Dale (2017) estimated that a large proportion of the Fennoscandian population moved south in 2016, with around 10,000–20,000 individuals reaching southern Norway, and with densities of around 0.1–0.2 owls/km^2 in boreal forest. However, assessing the relative magnitude of irruptions is challenging because of variable sources of data, and possible biases in different sources of data.

Classical methods to obtain information on population sizes and densities may be difficult to apply in the case of irruptive species. Irruptions occur with long time intervals, and systematic surveys may therefore be logistically limited to a small number of study areas. Generalizing results to assess the total size of an irruption may therefore suffer from biases if there is spatial variation in density, e.g. in relation to habitat type, elevation, latitude, or other environmental factors affecting the species in question.

Recently, there has been a large increase in the use of data gathered by volunteers, amateur birdwatchers and other non-professionals (e.g. Silvertown 2009, Dickinson et al. 2010, 2012). Such citizen science can provide large amounts of data with a wide spatial and temporal distribution and has the potential to contribute to analyses of large-scale ecological phenomena such as the magnitude of bird irruptions. However, citizen data have a large number of possible biases (Dickinson et al. 2010, Tulloch & Szabo 2012, Brown & Williams 2019), including uneven geographical distributions of observers and habitat-biased observation effort. Biases may also be introduced due to variable observer motivations; some birdwatchers report bird observations stemming from general outdoor activities whereas others visit specific areas in search of rare species (Tulloch & Szabo 2012). Thus, citizen data need to be evaluated with caution and possible biases need to be identified.

Here, I compare the magnitude of two recent Hawk-Owl irruptions to southern Norway with two sources of data. First, I use citizen data and compare the number of Hawk-Owls reported to an online biodiversity data base in 2016 versus 2020. Second, I conducted systematic surveys in boreal forest in southeastern Norway both in 2016 (see Dale 2017) and in 2020, and a large proportion of the survey lines were identical in the two years. The study objective was to test whether citizen data and survey data showed similar patterns, or whether possible biases led to different patterns.

METHODS

Citizen data

To obtain data on the number of Hawk-Owls observed in 2016 and 2020, all Hawk-Owl reports were extracted from the website of the National Biodiversity Information Centre (www.artsobservasjoner.no). This website is an online portal for reporting species observations from the whole of Norway, and is used widely by birdwatchers to report bird observations. The website was launched in 2008. In 2021, the data base contained about 20 million bird observations. In 2016, ca. 1.34 million bird observations were submitted whereas in 2020 the number was ca. 1.58 million. Most observations are reported by members of BirdLife Norway (www.birdlife.no) and other amateur birdwatchers. Observations reported to the website of the local branch of the BirdLife Norway in Oslo and Akershus (www.nofoa.no) have to a large degree been exchanged with the national online portal, but a small number of owl observations from Oslo and Akershus that were only available through www.nofoa.no were not included in the present study because the objective was to illustrate irruption patterns from the major source of citizen data.

For each irruption, I retrieved the number of Hawk-Owl observations submitted to the website (hereafter reports) for each month during August–December in 2016 and 2020. Irruptions continued into the early parts of the following years, but with lower number of reports. Thus, autumn and early winter were considered to reflect the magnitude of the irruptions in sufficient detail. Hawk-Owl reports were summarized at three different scales. First, I used reports from all counties in southern Norway (Innlandet, Viken, Oslo, Vestfold and Telemark, Agder, Rogaland, Vestland, Møre and Romsdal, and Trøndelag counties) to illustrate the total magnitude of the irruptions. Second, I restricted analyses to southeastern Norway (Innlandet, Viken, Oslo, and Vestfold and Telemark counties) to illustrate the magnitude of the irruptions to the region where most of the Hawk-Owls arrive (Dale 2017). For these two spatial scales I analysed both monthly and total numbers. Third, I summarized total numbers for each irruption for individual regions (mostly former counties) in southeastern Norway (Oppland, Hedmark, Oslo and Akershus, Østfold, Buskerud, Vestfold, Telemark, Aust-Agder, Vest-Agder, Rogaland, Hordaland, Sogn and Fjordane, Møre and Romsdal, Sør-Trøndelag, Nord-Trøndelag) to illustrate regional variation in the irruptions. Oppland and Hedmark are now merged to Innlandet county, Østfold, Akershus and Buskerud are now Viken county, Vestfold and Telemark are now Vestfold and Telemark county, Aust-Agder and Vest-Agder are now Agder county, Hordaland and Sogn and Fjordane are now Vestland county, and Sør-Trøndelag and Nord-Trøndelag are now Trøndelag county. Former counties were used because they correspond to local branches of BirdLife Norway, which has implications for interpreting number of owl reports (see below).

For the Oslo and Akershus region, which was the geographical region where systematic surveys were conducted (see below), the number of owl reports was processed in more detail. First, I excluded Hawk-Owls only observed by the author to make the citizen data for this relatively small area independent from the survey data. Second, I used the number of different observation sites instead of the number of observation reports because some members of the local branch of BirdLife Norway with special permission to handle data in the online portal had screened data from 2016 and merged most reports from the same site, but not for 2020. I used the map plotting function on www.artsobservasjoner.no to count the number of different sites manually (> 2 km distance between plots, following Dale 2017). Similarly, for all the other former counties in southeastern Norway, I counted the number of Hawk-Owl reports that spanned several days because in most cases such reports were due to merging of multiple reports from the same site by members of BirdLife Norway with special permission to handle data in the online portal. Citizen data were retrieved from www.artsobservasjoner.no on 1 September 2021.

Field surveys

Field surveys were conducted in the Oslo and Akershus regions of southeastern Norway (59.71–60.46°N, 10.59–11.91°E; ca. 5000 km^2). Oslo and Akershus have mostly boreal forests in hills above 200 m a.s.l. The boreal forests are dominated by Norway Spruce *Picea abies* and Scots Pine *Pinus sylvestris* and are heavily influenced by modern forestry with a large proportion of clear-cuts. The lowlands (below ca. 200 m a.s.l.) have a large proportion of agricultural land, but farmland is often mixed with forest patches and forest corridors. Southern parts of the lowlands are within the nemoral zone, otherwise the study area is within the boreal zone with cold winters and regular snow cover.

Hawk-Owl field surveys were conducted in boreal forests within Oslo and Akershus during the autumns

Table 1. Number of observations of Northern Hawk-Owls *Surnia ulula* from southern and southeastern Norway reported to the website of the National Biodiversity Information Centre (www.artsobservasjoner.no) during two irruptions (2016 and 2020). P-values refer to one-sample χ^2-tests comparing number of reports in 2016 and 2020 versus expected values assuming similar numbers in each year.

	Southern Norway[1]				Southeastern Norway[2]			
Month	**2016**	**2020**	**Ratio**	**p**	**2016**	**2020**	**Ratio**	**p**
August	53	33	1.61	0.031	24	19	1.26	0.45
September	443	112	3.96	< 0.001	178	79	2.25	< 0.001
October	728	171	4.26	< 0.001	351	132	2.66	< 0.001
November	449	184	2.44	< 0.001	262	153	1.71	< 0.001
December	376	110	3.42	< 0.001	213	76	2.80	< 0.001
Total	1874	581	3.23	< 0.001	874	443	1.97	< 0.001

[1] Innlandet, Viken, Oslo, Vestfold and Telemark, Agder, Rogaland, Vestland, Møre and Romsdal, and Trøndelag counties

[2] Innlandet, Viken, Oslo, and Vestfold and Telemark counties

of 2016 (245.7 km; Dale 2017) and 2020 (312.7 km), and a total distance of 178.0 km was identical in the two years (Appendix 1). Surveys were conducted by stopping and scanning at every clear-cut along the survey lines. As argued by Dale (2017), this method was chosen because Hawk-Owls hunt from elevated perches giving a wide view such as from remaining trees on forest clear-cuts (Sonerud 1992, 1997) when the ground is not snow-covered (Sonerud 1986, Nybo & Sonerud 1990), and because clear-cuts were the most common open habitat in the study area. Scans were only made with hand-held binoculars (10 x magnification), and a spotting scope was only used to confirm species identity of distant individuals. The perpendicular distance from the survey line to the Hawk-Owl was measured from maps at www.norgeskart.no or www.norgeibilder.no, depending on which website had map details or aerial photographs permitting the most exact plotting of the owl. Surveys were usually done from sunrise to late afternoon or sunset.

Surveys were conducted by driving with a car, bicycling, hiking on foot, or skiing, mainly on forestry roads (narrow gravel roads with little traffic; car, bicycle, ski) or paths (foot). There were no differences in observation rate in relation to mode of locomotion [car: 0.053 owls/km (15 owls, 283.7 km), bicycle: 0.079 owls/km (17 owls, 214.9 km), foot: 0.041 owls/km (1 owl, 24.4 km), ski: 0.056 owls/km (2 owls, 35.4 km); expected values if encounter rates were equal: car: 17.8 owls, bicycle: 13.5 owls, foot and ski: 3.7 owls; $\chi^2 = 1.48$, df = 2, p = 0.48].

In 2016, surveys were conducted on five days during 25 September–29 October (median date = 21 October; Dale 2017). In 2020, surveys were conducted on 14 days during 2 September–21 December (median date = 23 November; Appendix 1). All surveys except two (5 and 10 December 2020) were conducted during snow-free conditions. One of the exceptions was used to provide a comparison with an identical survey stretch from 2016. Snowfalls may cause redistribution of individuals in response to more difficult hunting conditions on clear-cuts (Sonerud 1986, Nybo & Sonerud 1990). Some individuals may turn to hunt more inside forest and thereby reducing detectability (Sonerud 1986, Nybo & Sonerud 1990). However, the two survey days with snow on the ground in 2020 did not have a lower observation rate (mean 0.039 owls/km) than the 12 survey days with snow-free conditions (mean 0.065 owls/km; U-test of observation rates of individual surveys: U = 10, p = 0.70), and these data were therefore combined in subsequent analyses.

Analyses

For the citizen data, one-sample χ^2-tests were used to compare number of reports in 2016 and 2020 versus expected values assuming similar numbers in each year. For the survey data, comparisons of the magnitude of the two irruptions were first made using observation rates (number of owls recorded/km surveyed). Although the Hawk-Owl observation rate during specific surveys increased as a function of time of the day (Appendix 2), surveys in 2016 and 2020 did not differ much in which parts of the day they took place (2016: mean time of day = 11:46 hours; 2020: mean time of day = 12:02 hours). Thus, comparisons of 2016 and 2020 were not corrected for time of day. Wilcoxon signed-ranks test was used for pairwise comparison of number of owls observed along five survey lines that were identical in the two years. These surveys were conducted on five different days in five different areas each year.

Next, density estimates were compared between 2016 and 2020. Following Dale (2017), I estimated

Table 2. Number of observations of Northern Hawk-Owls *Surnia ulula* during August–December from individual regions (mostly former counties) in southern Norway reported to the website of the National Biodiversity Information Centre (www.artsobservasjoner.no) during two irruptions (2016 and 2020). The table includes total number of reports, and how many of the reports spanned multiple dates (i.e. merged reports, in brackets). For Oslo and Akershus, the number of sites is also given (excluding owls only observed by the author). P-values refer to one-sample χ^2-tests comparing number of reports in 2016 and 2020 versus expected values assuming similar numbers in each year.

Region	**2016**	**2020**	**Ratio**	**p**
Oppland	127 (0)	102 (0)	1.25	0.10
Hedmark	55 (2)	51 (0)	1.08	0.70
Oslo and Akershus	58 (17)	154 (0)	0.38	< 0.001
Sites	48	47	1.02	0.92
Østfold	39 (4)	10 (1)	3.90	< 0.001
Buskerud	159 (33)	61 (6)	2.61	< 0.001
Vestfold	226 (12)	14 (3)	16.14	< 0.001
Telemark	210 (87)	51 (13)	4.12	< 0.001
Aust-Agder	72 (0)	7 (0)	10.29	< 0.001
Vest-Agder	235 (1)	16 (0)	39.17	< 0.001
Rogaland	184 (36)	12 (3)	15.33	< 0.001
Hordaland	273 (3)	18 (8)	15.17	< 0.001
Sogn and Fjordane	29 (7)	8 (1)	3.63	< 0.001
Møre and Romsdal	45 (0)	19 (0)	2.37	0.001
Sør-Trøndelag	80 (0)	35 (0)	2.29	< 0.001
Nord-Trøndelag	75 (0)	22 (1)	3.41	< 0.001

a minimum density based on the number of owls observed within a survey band that covered most of the owls recorded, and a maximum density based on the number of owls recorded in a more narrow band close to the survey line. Dale (2017) used survey bands with a width on either side of the survey line of 250 m for the minimum density and 50 m for the maximum density. However, based on the observed distribution of perpendicular distances between the survey line and Hawk-Owl locations in the larger data set in the present study, I decided that using slightly wider bands would be more suitable; 300 m on either side of the survey line for the minimum density and 100 m for the maximum density. Compared to the density estimate presented by Dale (2017), the density estimates in the present study are more conservative, i.e. slightly lower.

RESULTS

Citizen data

According to the online portal of the National Biodiversity Information Centre (www.artsobservasjoner.no), there were more than three times as many Hawk-Owl observation reports in southern Norway in 2016 as in 2020 (Table 1). When restricting the sample to reports from southeastern Norway, there were more than twice as many reports in 2016 as in 2020 (Table 1). However, when separating the reports from different regions of southeastern Norway, there was a pattern that the most southern regions (Telemark, Vestfold, Østfold) had more reports in 2016 than in 2020, whereas this was not the case for more northern regions (Oslo and Akershus, Hedmark, Oppland; Table 2). For Oslo and Akershus, the area overlapping with the study area for systematic surveys, the difference in number of reports was likely strongly affected by the difference in number of merged reports (Table 2) because there was no difference in number of sites between 2016 and 2020 (Table 2). It is also worth noting that in Oppland and Hedmark almost no merging of reports had taken place, whereas in e.g. Buskerud and Telemark the number of Hawk-Owl reports from 2016 was higher than in 2020 despite a larger number of merged reports (Table 2). The number of merged reports varied considerable between regions (former counties) in 2016 whereas reports had yet rarely been merged for 2020 even though data were retrieved from www.artsobservasjoner.no in September 2021 (Table 2).

Observation rates during surveys

During systematic surveys in 2016, 16 Hawk-Owls were recorded over a total survey distance of 245.7 km (0.065 owls/km). In 2020 the corresponding number was 19 owls recorded in 312.7 km (0.061 owls/km).

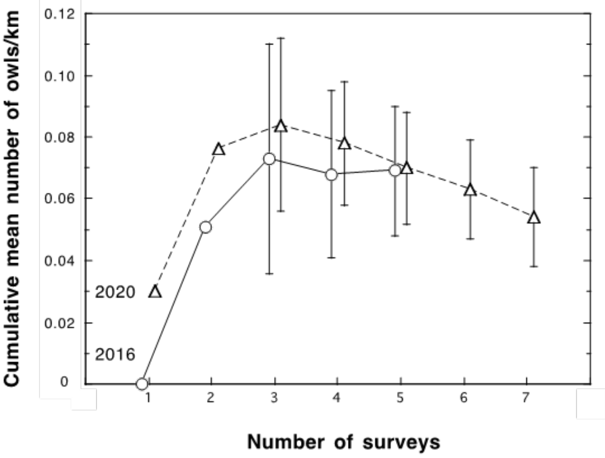


Figure 1. Cumulative mean observation rates (individuals/km survey distance) of Northern Hawk-Owls *Surnia ulula* as a function of number of surveys during 2016 (circles) and 2020 (triangles) in Oslo and Akershus, southeastern Norway. Error bars show SE of mean observation rates from third survey. In 2016, surveys were made on five different days, in 2020 surveys were from 14 different days, but merged to seven survey bouts of 1–4 days where the length of each bout was at least 30 km.

Cumulative observation rates over time indicated that both years converged towards a similar estimate (Figure 1). Overall observation rate for the two irruption years was one owl for every 16 km.

Survey lines of a total of 178.0 km were identical in the two years and were conducted on five different days in five different areas in both years. The number of owls recorded was 11 in 2016 and 12 in 2020 (0–3 owls/survey in 2016, 0–6 owls/survey in 2020; Wilcoxon signed-ranks test: $z = -0.18$, $n = 5$ sites, $p = 0.85$).

Density estimates

The perpendicular distance between the survey line and owls detected in 2016 and 2020 ranged from 5 m to 870 m ($n = 35$; Figure 2), and was on average 208 m (median 110 m). Most owls (28 out of 35, 80%) were detected at distances < 300 m. The numbers within the three shortest 100 m intervals did not differ between 2016 and 2020 (Fisher exact test: $p = 0.49$; Figure 2). There were 3 individuals in 2016 and 4 individuals in 2020 that were > 300 m from the survey line. Thus, the spatial distribution of Hawk-Owls along the survey lines was similar in the two years, and data on distance from survey lines can therefore be used to compare densities (see below). Within 300 m from the survey lines, the number of owls observed declined with distance from the survey line for each 50 m interval (combining 2016 and 2020: $r_S = -0.90$, $n = 6$, $p = 0.045$; Figure 2).

The minimum density was based on the number owls recorded within 300 m from the survey line, whereas the maximun density was based on the number of owls recorded within 100 m from the survey line (Figure 2). The area covered within 300 m was 147 km^2 in 2016 and 188 km^2 in 2020. Corresponding figures within 100 m were 49 km^2 and 63 km^2 in 2016 and 2020, respectively. Thus, the estimated densities were 0.09–0.18 owls/km^2 in 2016 and 0.08–0.13 owls/km^2 in 2020. The combined density estimate for the two irruption years was 0.08–0.15 owls/km^2.

DISCUSSION

Citizen data

Citizen data for southern or southeastern Norway clearly showed a larger number of Hawk-Owl reports from 2016 than from 2020. Depending on scale, 2016 had 2–3 times more reports than 2020. The 2016 irruption appeared to have a wider range, affecting western and extreme southern parts of Norway much more than in 2020 (Agder, Rogaland, Vestland, Møre and Romsdal, and Trøndelag counties had 1000 reports in 2016 versus 138 in 2020; Table 1). However, both irruptions covered most parts of southeastern Norway, but reporting rate was still twice as high in 2016 as in 2020. This was based on absolute number of reports as provided by basic search functions in the online portal for reporting bird observations. The total number of bird observations reported was 18% higher in 2020 than in 2016 (see Methods). Thus, the difference between the two years would be even higher if numbers had been corrected for total reporting volume.

However, the analysis of smaller regions in southeastern Norway (mostly former counties) showed a pattern where the 2016 irruption appeared to be much larger than the 2020 irruption in the south (especially Telemark, Vestfold, Østfold) whereas this was not the case for more northern counties (Oslo and Akershus, Hedmark, Oppland). Thus, the 2020 irruption affected in particular northeastern areas of southern Norway. However, none of the three analyses of different spatial scales have been corrected for multiple reports of the same bird at the same site. Members of the Local Reports and Rarities Committee (LRSK) in local branches of BirdLife Norway have access to the online portal to merge reports of the same bird observed multiple times. Table 2 indicated that merging had occurred to different degrees in different former counties (local branches of BirdLife Norway correspond to former counties), which represents a challenge for the interpretation of relative irruption magnitude when using basic data search tools in www.artsobservasjoner.no. The online portal has an option to search for all reports disregarding merged reports, but comparisons based on this are likely biased due to possible geographical variation in how many Hawk-

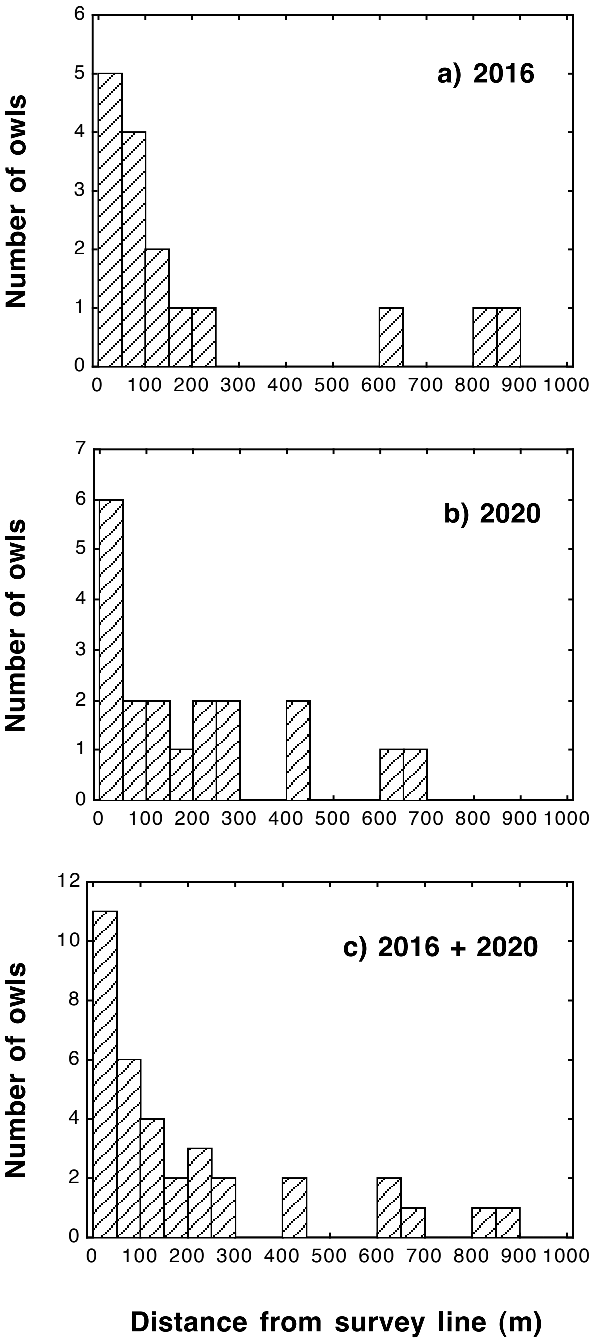


Figure 2. Perpendicular distance from survey line to Northern Hawk-Owls *Surnia ulula* detected during surveys in 2016 and 2020 in Oslo and Akershus, southeastern Norway. a) Data from 2016 (n = 16), b) data from 2020 (n = 19), and c) data from 2016 and 2020 combined (n = 35).

Owls were observed repeatedly. Easily accessible owls close to humans are more likely to be reported repeatedly than owls in remote areas, and multiple reports of the same birds is often due to birdwatchers receiving „alarms" of rare birds through social media, websites or SMS notifications, and thereafter going out to see these birds themselves.

At the local scale of Oslo and Akershus, members of BirdLife Norway had previously merged many reports from 2016, but none yet for 2020, and thus the citizen data thereby gave the impression that 2020 was the largest irruption year. However, a more detailed analysis was made of the number of different sites with reports of Hawk-Owls. The online portal has no direct function for obtaining number of sites, so this had to be done manually. This analysis indicated no difference in number of owls reported in Oslo and Akershus in the two years. The numbers were obtained even when my own observations were excluded, so they are technically independent of the results of the field surveys. The need to do manual merging of multiple reports of the same individuals to obtain the number of different sites with observations limits the usefulness of www.artsobservasjoner.no. For larger data sets, the manual effort needed easily becomes prohibitive, and adding such functions to the system is strongly encouraged.

Survey data

The survey data from Oslo and Akershus showed similar densities during the two irruptions. However, the surveys in 2020 took place about one month later than in 2016 (2016: median date = 21 October; 2020: median date = 23 November). The temporal pattern of the irruptions with a peak in October (see Table 1) would then suggest that the irruption in 2020 was larger than the one in 2016 (i.e., if some owls had disappeared in November, obtaining the same number of observations in November 2020 as in October 2016 would require the 2020 irruption to have been bigger). But the apparent peak in October could be confounded by observation effort by birdwatchers which likely was higher in October than in November. There are more bird reports in the online portal from October than from November (nationally: 1.65 million versus 0.99 million; Oslo and Akershus: 116,000 versus 79,000). Thus, I find it likely that surveys are comparable through October and November, and that the results of the field surveys reflected a similar density in Oslo and Akershus in the two years.

Combining data from both the 2016 and the 2020 irruptions suggested that densities were 0.08–0.15 owls/km^2, similar to a previous estimate (Svensson et al. 1999). The surveys in Oslo and Akershus were distributed across an area of ca. 5,000 km^2, and the boreal forests in these areas are fairly representative for larger areas of southeastern Norway where a large proportion of the irruptive owls were distributed (Dale 2017). Thus, densities recorded during the systematic surveys in Oslo and Akershus may be representative for larger areas of prime Hawk-Owl habitat in boreal forest in southeastern Norway, and judged from the citizen data this may extend at least to Innlandet county.

On the other hand, field surveys were only conducted in areas dominated by boreal forest. Some

Hawk-Owls were reported in farmland areas in the lowlands, and some of the difference between 2016 and 2020 regarding the citizen data might be explained by a larger number of owls in farmland habitat in 2016 than in 2020. In fact, Dale (2017) reported that 26% of the owls recorded in Oslo and Akershus were in other habitats than boreal forest. A preliminary analysis of all data (including citizen data) from 2020 suggests that 6 out of 47 Hawk-Owls (13%) in Oslo and Akershus were observed in farmland areas.

Main data biases

Analyses of the citizen data were not straightforward, in particular due to the variable effort that local branches of BirdLife Norway have put into merging multiple observations of the same bird at the same site over one or more days. This can make comparisons of number of reports misleading. The problem could be solved by generating overviews of the number of different sites with Hawk-Owl observations, but the online portal has no automatic function for doing this, so number of sites must be counted manually from map plots.

Furthermore, habitat selection of both owls and birdwatchers may influence the citizen data. Maps of all bird observation reports submitted to the national online portal clearly show that birdwatchers have an observation effort biased towards areas close to roads and settlements, and hence also a bias towards lowland and farmland areas. These spatial biases are probably linked to where birdwatchers live and what kind of habitats they prefer to visit (Tulloch & Szabo 2012). Large areas of boreal forest are rarely visited, which is problematic in the context of irruptions of an owl strongly linked to boreal forest. Dale (2017) estimated that only 0.5–1.4% of the Hawk-Owls in boreal forest in Innlandet county were detected in 2016. Detection rates may be much higher in lowlands where Hawk-Owls come in closer contact with areas frequented by birdwatchers. For example, Dale (2017) estimated that 20–39% of all Hawk-Owls in Vestfold (a lowland area with much farmland and many birdwatchers) were detected in 2016. Thus, reporting rates in citizen data bases such as www.artsobservasjoner.no must be weighted for observation effort, but there is no easy way to do this. In addition, yearly differences in the (small) proportion of the owls in farmland may have a large effect on the number of Hawk-Owl reports in the citizen data set. In combination, this makes it difficult to extrapolate from number of Hawk-Owl reports to actual number of owls present in the two irruptions.

Citizen data potentially have other biases such as differences in the ability of different observers to detect and identify birds, whereas systematic surveys done by the same person do not have this problem. However, if citizen data involve large data sets collected by a large number of different persons, it is likely that any differences in observer competence are levelled out across different years or different regions. In the case of the Hawk-Owl, both detection and identification are fairly straightforward, and observations were made by a large number of observers, so there is no reason to believe that differences in observer skills were a problem.

The main bias of the systematic surveys was that they were only conducted in boreal forest in a small region. Information on owl densities in other forest regions and in farmland areas were lacking. However, in many years owls in farmland likely represent a small part of the irruptions (Dale 2017, Dale & Sonerud unpublished data), so systematic surveys in boreal forest should be a priority, especially in northeastern parts of southern Norway which is the main region utilized by Hawk-Owls during irruptions as well as during breeding (Sonerud 1994, Dale 2017).

Conclusions

Both citizen data and survey data can have biases that may affect evaluations of relative numbers of Hawk-Owls. Thus, all sources of data need to be evaluated with caution, and possible biases need to be assessed. In the case of large-scale phenomena such as owl irruptions, citizen data have the advantages that large amounts of information are collected over wide areas but may be highly sensitive to biases in the spatial distribution of observers and habitat-specific observation effort of the observers. Systematic surveys, on the other hand, have the advantage of a high degree of comparability across years but may suffer from lower spatial representativeness. In the case of the Hawk-Owl irruptions, citizen and survey data from the same areas gave similar results. However, combining citizen data across different regions probably exaggerated the relative magnitude of the 2016 irruption because in 2020 the majority of owls were likely in areas with low observation effort, in particular in their main habitat of boreal forest where few birdwatchers spend time.

Acknowledgements. I thank Geir A. Sonerud and two anonymous reviewers for comments on the manuscript.

REFERENCES

Brown, E.D. & Williams, B.K. 2019. The potential for citizen science to produce reliable and useful information in ecology. Conservation Biology 33: 561–569.

Cramp, S. (ed.) 1985. The Birds of the Western Palearctic. Vol. IV. Terns to Woodpeckers. Oxford University Press, Oxford.

Dale, S. 2017. Density, numbers and probable origin of Northern Hawk-Owls *Surnia ulula* in southern Norway during the 2016 irruption. Ornis Norvegica 40: 1–13.

Dickinson, J.L., Zuckerberg, B. & Bonter, D.N. 2010. Citizen science as an ecological research tool: challenges and benefits. Annual Review of Ecology and Systematics 41: 149–172.

Dickinson, J.L., Shirk, J., Bonter, D.N., Bonney, R., Crain, R.L., Martin, J., Phillips, T. & Purcell, K. 2012. The current state of citizen science as a tool for ecological research and public engagement. Frontiers in Ecology and the Environment 10: 291–297.

Haftorn, S. 1971. Norges fugler. Universitetsforlaget, Oslo.

Jacobsen, O.W. 1984. Invasjonsforløp av haukugler *Surnia ulula* i Hordaland høsten og vinteren 1983/84. Vår Fuglefauna 7: 135–139.

Mikkola, H. 1983. Owls of Europe. T & AD Poyser, Calton, UK.

Newton, I. 2006. Advances in the study of irruptive migration. Ardea 94: 433–460.

Nybo, J.O. & Sonerud, G.A. 1990. Seasonal changes in diet of Hawk-Owls *Surnia ulula*: importance of snow cover. Ornis Fennica 67: 45–51.

Silvertown, J. 2009. A new dawn for citizen science. Trends in Ecology and Evolution 24: 467–471.

Sonerud, G.A. 1986. Effect of snow cover on seasonal changes in diet, habitat, and regional distribution of raptors that prey on small mammals in boreal zones of Fennoscandia. Holarctic Ecology 9: 33–47.

Sonerud, G.A. 1992. Search tactics of a pause-travel predator: adaptive adjustments of perching time and move distances by Hawk-Owls (*Surnia ulula*). Behavioral Ecology and Sociobiology 30: 207–217.

Sonerud, G.A. 1994. Haukugle *Surnia ulula*. In: Gjershaug, J.O., Thingstad, P.G., Eldøy, S. & Byrkjeland, S. (eds.): Norsk fugleatlas. Norsk Ornitologisk Forening, Klæbu.

Sonerud, G.A. 1997. Hawk-Owls in Fennoscandia: population fluctuations, effects of modern forestry, and recommendations on improving foraging habitats. Journal of Raptor Research 31: 167–174.

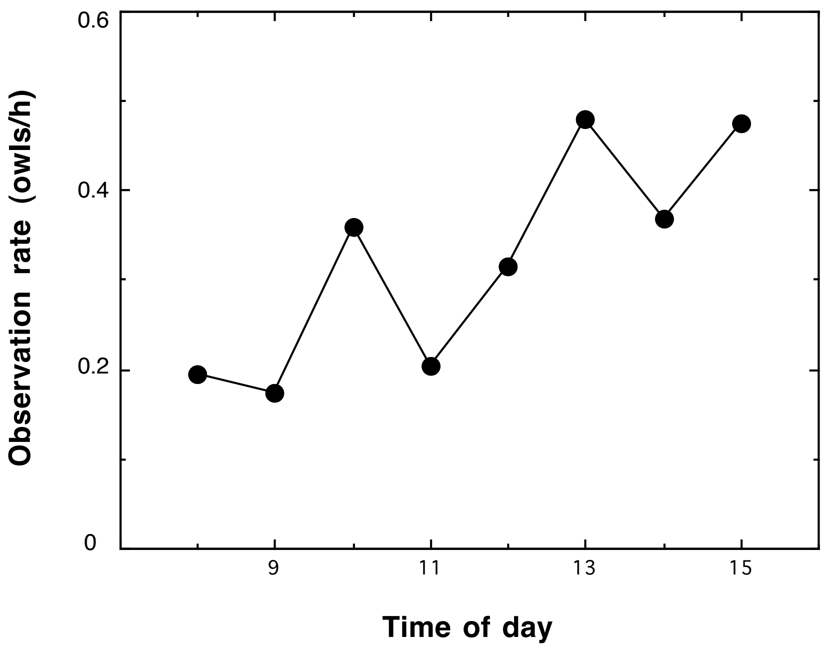
Svensson, S., Svensson, M. & Tjernberg, M. 1999. Svensk Fågelatlas. Sveriges Ornitologiska Förening, Stockholm.

Tulloch, A.I.T. & Szabo, J.K. 2012. A behavioural ecology approach to understand volunteer surveying for citizen science datasets. Emu – Austral Ornithology 112: 313–325.

Received 06.09.2021. Accepted 22.11.2021

Appendix 1. Overview of Northern Hawk-Owl *Surnia ulula* surveys conducted in 2016 (based on Dale 2017) and in 2020 (this study) in Oslo and Akershus, southeastern Norway.

Year/survey area	Municipality	Date	Km surveyed	No. of owls observed	Km overlapping with 2016
2016					
Sagstusjøen–Viksjøen	Nes, Aurskog-Høland	25.09	47.5	0	
Kampåa–Grønnsjøen	Nes, Eidsvoll	05.10	39.7	4	
Sjonken–Stråtjernet–Øyangen	Nannestad, Hurdal	21.10	41.9	5	
Mangen-Mjermen	Aurskog-Høland	25.10	75.7	4	
Nordmarka (center)	Oslo	29.10	40.9	3	
2020					
Jeppedalen–Skrukkelia	Hurdal	02.09	14.0	1	
Vestmarka (south, center)	Asker, Bærum	13.09	10.4	0	
Kampåa	Nes	16.10	5.4	0	
Vestmarka (southwest)	Asker	18.10	3.8	0	
Krokskogen	Bærum	08.11	12.0	1	
Vestmarka (northwest)	Bærum	14.11	4.5	0	
Nordmarka (center)	Oslo	20.11	40.9	6	40.9
Nordmarka (east)	Oslo, Nittedal	26.11	36.5	4	
Kjekstadmarka	Asker	28.11	4.1	0	
Mangen–Mjermen	Aurskog-Høland	01.12	68.3	4	62.5
Vestmarka (northeast)	Bærum	05.12	12.7	0	
Sjonken–Stråtjernet–Nordåsen	Nannestad	10.12	39.2	2	33.5
Sagstusjøen–Bjørknessjøen	Nes	16.12	37.0	1	19.2
Kampåa–Nordre Holsjøen	Nes, Eidsvoll	21.12	23.9	0	21.9



Appendix 2. Observation rate (number of individuals/hour survey effort) of Northern Hawk-Owls *Surnia ulula* in relation to time of day (hourly intervals) during the autumns of 2016 and 2020 in Oslo and Akershus, southeastern Norway. The data point for the period 0800–0900 hours also included lesser amounts of data for the period 0640–0800 hours, and the period 1500–1600 hours also included lesser amounts of data for the period 1600–1700 hours. Observation rate of owls increased with time of day ($r_s = 0.83$, n = 8, p = 0.028).