Summer count of Greylag Geese in Denmark 2022

Scientific briefing from DCE – Danish Centre for Environment and Energy

AARHUS UNIVERSITY
DCE - DANISH CENTRE FOR ENVIRONMENT AND ENERGY

Data sheet

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1 Background

The NW/SW European population of Greylag Geese has increased more than seven-fold since the 1980s, resulting in substantial increases in conflicts with agriculture and in risk of bird strikes. The species is an important quarry species in most European countries. As a result, an International Single Species Management Plan (ISSMP) was developed in 2018 under the auspices of the European Goose Management Platform (EGMP) and the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA), with the overall aim of maintaining the population in a favourable conservation status, while at the same time addressing the growing socio-economic concerns associated with this population and to provide for sustainable hunting opportunities (Powolny, T. et al. 2017).

The plan defines the overall strategic framework for the population, including what measures will be required to achieve this goal. A key action is the establishment of an internationally coordinated adaptive harvest management programme encompassing monitoring, assessment and decision-making protocols (Nagy et al. 2021). It is important to note that the NW/SW European Greylag Goose population is divided into two management units (MU1 and MU2) (Fig. 1). MU1 breeds in Norway, Sweden, Denmark and Finland, and winters in the Netherlands, Belgium, Denmark, Sweden, France, Spain and Portugal, whereas MU2 consists of resident birds in Germany, the Netherlands, Belgium and France. Each unit has its own population target, and each MU must thus be managed independently. Further east the Central European population is found, which breed in Eastern Europe from the Gulf of Finland to Croatia and migrate to wintering sites in mainly Tunisia and Algeria (Madsen et al. 1999).

A prerequisite for the decision-making tool to set optimal and sustainable hunting quotas for each MU, is knowing the population size for each MU. Because the two MUs mix during winter, the size of these MUs can only be defined during summer time, when the geese in MU1 and MU2 are spatially separated, i.e. after the breeding period and before the autumn migration begins. At present, such a population inventory does not exist for MU1.

The overarching goal of this project was therefore to estimate the summer population size of the Greylag Goose in Denmark.

In Denmark Greylag Geese counts are covered by the NOVANA (the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environment) monitoring program, and have since the 1980s been counted during January and September, but not during summer, except every six year where a country-wide count of moulting waterbirds are conducted. The target species for this count is moulting Mute Swans and diving ducks, but because all waterbirds are counted, a national total can also be estimated for Greylag Geese. For the latest count in mid July-late August 2018, 111,337 Greylag Geese was reported (Holm et al. 2021). In the NOVANA programme "August censuses" are carried every 2 years between these complete censuses, but these counts are dedicated to counting Special Protection Areas designated for Eurasian Spoonbill and some species of waders, hence is a partial count focused on designated species whose occurrence peaks in August and is therefore not sufficient to form the basis of a total national population count, as Greylag Geese are found almost everywhere in Denmark. Thus, for the August census every 2 years to function as a method for estimating a national summer population of Greylag Geese, the count will have to be assisted by additional counts outside these protected areas.

In this project we will develop a model to identify the most important areas to cover in addition to the protected areas. Furthermore, if the model performs well, it can be used to estimate the number of Greylag Geese in areas that are not counted. Greylag Geese are also counted during the September counts, but this count was not thought of as a solution, mainly because post breeding movements and autumn migration are in full progress. Thus, the assumptions have been that the MU's would be mixed in September, and the work to disentangle the MU's would be too expensive compared to setting up an August count.

The NOVANA counts are mainly carried out by a large network of volunteers, who count at predefined sites, the same observers count regularly. Thus, newly identified areas outside the fixed NOVANA sites will have to be covered by either paid staff or new recruited volunteers. In this project we strived at recruiting new volunteers to participate in the count of Greylag Goose, particularly hunters, and evaluate citizen science as a population monitoring method. Finally, based on the experiences and results in this project, we will suggest a cost-efficient way to do the summer monitoring of Greylag Geese, for future use in the NOVANA monitoring programme.

Further information about the project as well as publications and public outreach related to the project can be found at the project website: https://projects.au.dk/da/can/projekter/graagaastaelling.

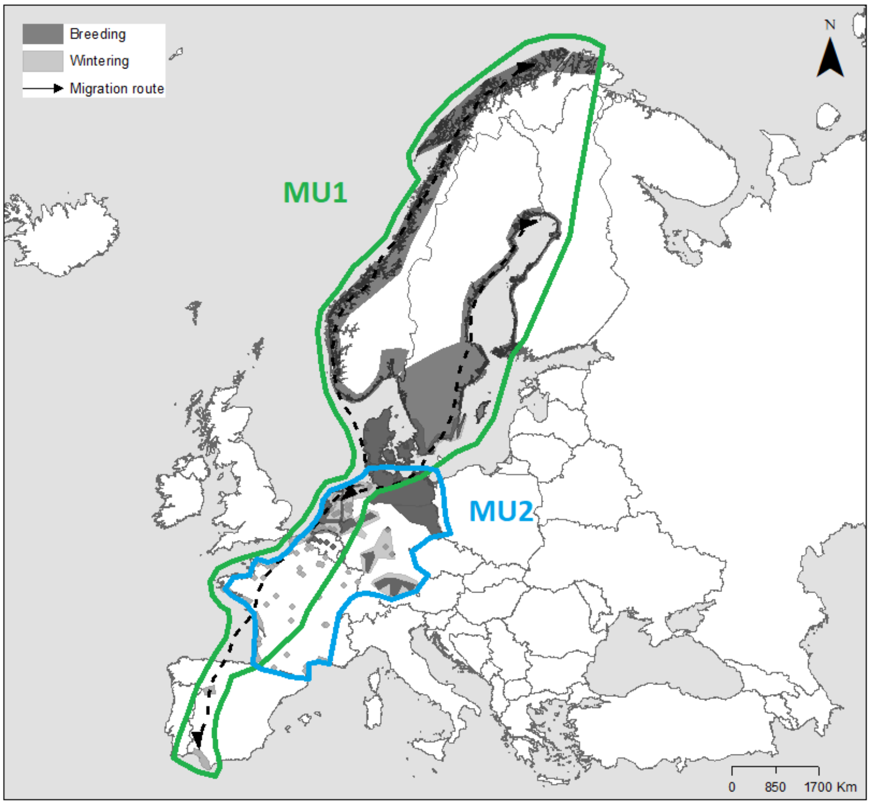

Figure 1. Agreed management units of the NW/SW European population of Greylag Goose (Nagy et al. 2021).

2 Evaluation of citizen science as a population monitoring method

2.1 Recruitment of new volunteers

Abundance of Greylag Geese and other waterbirds in Denmark are traditionally estimated from counts of waterbirds under NOVANA, based on data collected in selected areas by a group of skilled and dedicated ornithologists. Most of the participants are non-paid volunteers, considered as citizen scientists despite their high level of expertise. In this project, we attempted to broaden this group of citizen scientists, with a specific focus on the involvement of hunters. This was done following the assumption that all goose management stakeholders with a general interest in nature would also be willing to participate in obtaining an estimate of the national population of Greylag Geese. A better coverage of the species' national range, ultimately leading to a better population estimate, will improve the basis for taking the pending management decisions at the upcoming meeting of the International Working Group (IWG) of the EGMP.

In order to recruit as many new participants in the project as possible, we aimed our information and invitations at groups already considered stakeholders in goose management issues and expected to have a general interest in birds and nature. Our focus was on hunters, but we made sure to mention that everyone was welcome to sign up as goose counters. Each participant was expected to spend up to a few hours counting geese, and we assisted all participants in choosing one or more sites, preferably in their neighbourhood, from a set of pre-selected sites spread evenly across Denmark. We also made sure to explain that the task (counting all geese at a chosen site) was relatively uncomplicated and did not require any specific skills or experiences, besides the ability to recognize a Greylag Goose and preferably a pair of binoculars. We used a broad range of media to get in contact with volunteers: dedicated articles at websites and in members' magazines, news on social media, information via local and national newspapers, an oral presentation and a poster at a national conference and personal networks (Fig. 2; see the full list on the project website). Furthermore, two staff members (one at Aarhus University and one at the Danish Hunters' Association) were available for direct inquiries and registration during the entire process. Altogether, we succeeded in recruiting 96 people in this type of bird monitoring, adding up to 195 participants in total (99 participated from the NOVANA network).

Figure 2. Poster presented at a Danish wildlife management conference and used afterwards at the project website. The aim was to inform people about the survey and to recruit volunteers.

During the recruitment process, members of the project group helped selecting sites for each participant and also gave advice on methodology, explained the background etc. A number of short texts were produced to help the process and an online portal was established to gather all relevant information (https://projects.au.dk/da/can/projekter/graagaastaelling).

Each participant received a direct, personal link to the portal fugledata.dk where all data were entered on a site-by-site basis, and the data entry process was aimed at being as simple as possible. Participants were suggested to enter the data immediately after the counts.

2.2 Focusing on the involvement of hunters

After the count had taken place, all newly recruited participants were asked to complete a simple questionnaire, requesting information on how successful each element in the process had been and whether they would have interest in being involved in similar projects in the future. 72 individuals (75%) filled in the questionnaire. When requested to describe their recreational background, 93% of respondents identified themselves as either hunters (46 individuals; 64%) or birdwatchers (21 individuals; 29%).

The primary motivation for participating was investigated by providing three predefined statements (either to contribute to research and data collection, to ensure sustainable hunting of Greylag Goose, or due to a general interest in Danish birds) and one open statement. 42 (58%) replied that they wished to contribute to research and data collection, 22 (31%) that they were interested in ensuring sustainable hunting, and 7 (10%) argued that they had a general interest in Danish birds. 1 (1%) wrote in the open statement that the person had a combined interest in contributing data and ornithology.

Several respondents mentioned that they would have preferred to be allowed to indicate more than one option, thus responses to this part of the questionnaire might not be fully indicative of the motivation for participating. However, since only one respondent chose the option to write an open statement, we assume that the three options provided by us generally cover the participants' motivation for joining the goose count.

We compared the main motivation among the two identified groups, hunters and birdwatchers (based on what they replied as their recreational background), which revealed large differences in the motivation for participating (Fig. 3). While the main motivation for both groups appeared to be collection of data, hunters' seem to have a particular emphasis on gathering data to ensure the sustainability of Greylag Goose hunting, whereas birdwatchers tend to participate to increase general knowledge on Danish bird species.

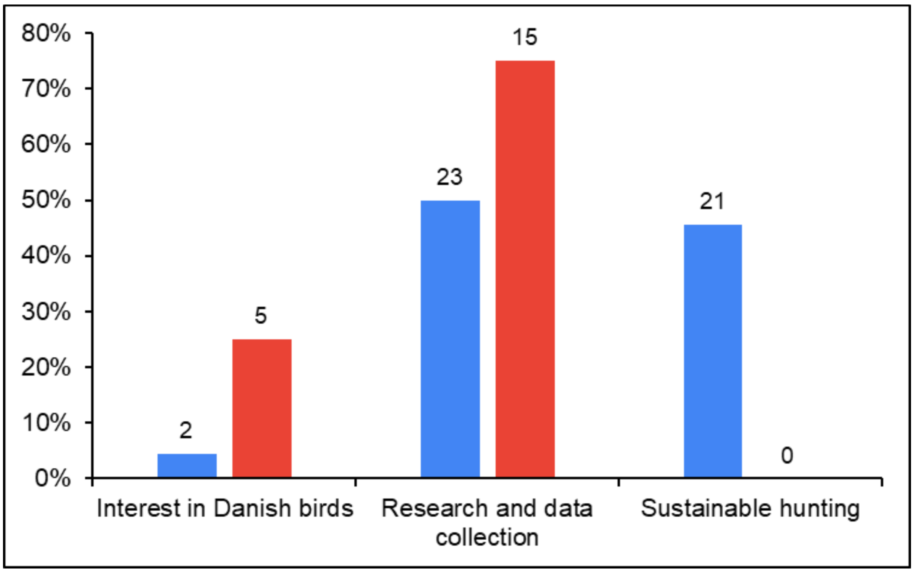

Figure 3. Primary motivation (% of respondents) for the two main groups involved in the Greylag Goose summer count, hunters (blue) and birdwatchers (red). Data labels indicate the number of replies in each category.

We asked how satisfied the participants had been with the main parts of the process, including the quality and level of information, from recruiting to data entering. This was included in the questionnaire to evaluate our interaction with the participants and learn how to improve our efforts in potential similar future projects. The communication effort (including both e-mails and phone calls), the written guidance documents (project description, manual etc.) and the data entering process all had a mean score of roughly 4.5 on a scale from 1 to 5, where 5 was the best possible (Fig. 4). The selection of sites scored lower (c. 3.8), which is probably due to the fact that some participants were allocated sites without geese. Also, some respondents indicated that they would have preferred to choose freely from a map of all included sites instead of the more hand-held procedure chosen by us. In general, birdwatchers were slightly more satisfied with the process, which may be a result of them having more experience in such projects. Almost two thirds of the hunters (63%) had no experience in counting birds, whereas almost half (48%) of the birdwatchers had participated in similar counts more than 10 times.

The majority, 69 (96%) replied that they were interested in participating in similar surveys in the future, while the remaining 3 (4%) replied that they would perhaps participate.

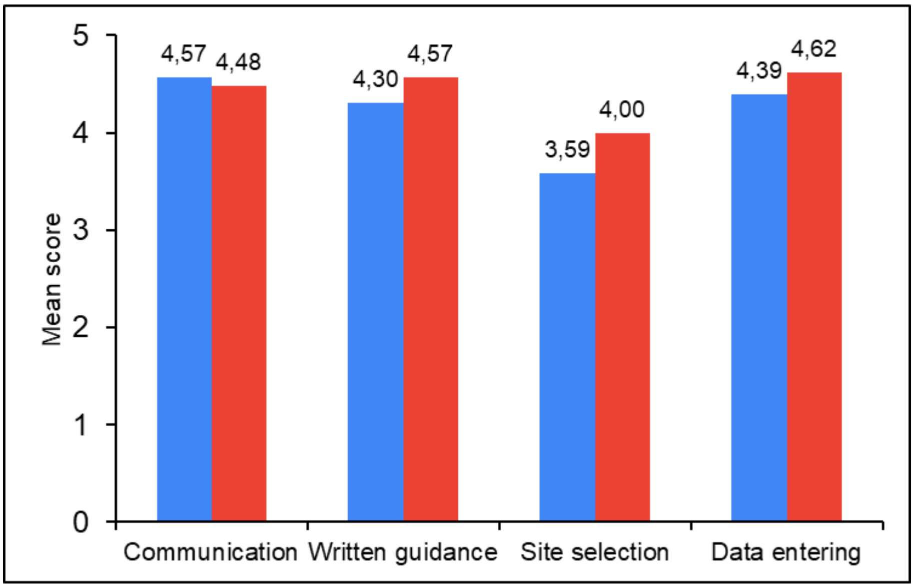

Figure 4. Level of satisfaction by hunters (blue) and birdwatchers (red) with the various parts of the process, as indicated by 72 respondents to our post-count questionnaire. Data labels indicate the mean score of each communication process.

2.3 Recruitment recommendations

The involvement of new participants in centrally organised bird counts implies using a significant amount of time to provide assistance and produce information and recruitment material. The inclusion of new volunteers to many wildlife projects is vital, but also brings additional and unavoidable administrative costs. It is important to keep this in mind when planning new activities, even though a thorough assessment of costs and benefits might not be possible in advance.

Expanding the circle of citizen scientists involved in bird counts may bring several benefits in the longer term, and offering a high level of service and guidance during the first count (as has been the case here) is likely to give participants a positive experience (as has also been the case here), which again might increase the chances that they will participate in future surveys and become regular contributors to the bird counts. Involving hunters might bring further gains in terms of mutual understanding between stakeholder groups and secure a greater buy-in on management processes and the need for data.

This project has also illustrated the importance of maintaining a group of dedicated and experienced volunteers in any citizen science project; in this case the experienced bird observers involved in the NOVANA counts. They were able to work independently, almost without any advice or instructions, leaving more time for guiding new participants.

3 Identifying important locations to include in the monitoring of Greylag Geese

We developed a Species Distribution Model (SDM), to identify important Greylag Goose areas in Denmark. SDMs are empirical models quantifying the relationship between field observations and environmental predictor variables, using a selection of environmental variables hypothesised to affect the distribution and/or number of species or individuals (Guisan and Thuiller 2005, Guisan et al. 2013, Guisan and Zimmermann 2000). SDMs have been shown to be a good method for predicting population size for abundant and widely distributed species, like the Greylag Goose (Waldock et al. 2022). However based on the current information and range of variables we were not able to produce a satisfied statistical model accurately estimating the number of Greylag Geese in Denmark. Thus, the model presented in this document is developed using a presence/absence data set, which still makes it possible to estimate where we expect the highest probability of observing Greylag Geese, and thereby identify the most important areas to cover during a total count.

The model was developed on the method described in Jensen et al. (2017) following four steps:

3.1 Step 1. Defining the response variable:

The response variable "goose occurrence" was developed using data from Fugledata.dk. The observations from Fugledata.dk consisted of both 1) the traditional NOVANA observations, entered by the usual network of volunteers, who count at their fixed sites, as well as 2) observations from newly recruited volunteers, consisting of hunters, farmers and bird observers (see chapter 1 for details). The data from Fugledata.dk was supplemented by data from DOFbasen, following the procedure described in Holm et al. (2017). Moreover, observers, who submit data to DOFbasen, traditionally only report birds seen, and will therefore rarely report the observation of 0 Greylag Geese. To expand the dataset, we assumed that in areas where swans, ducks or other goose species were reported, but not Greylag Geese, this would mean that no Greylag Geese were observed. This was the case for 30 unique locations, in addition to the 546 locations with 0 observations from Fugledata.dk. The total number of locations visited sums to 910.

Selection of possible counting sites: Denmark consists of around 200,000 wetlands, and it is therefore not feasible to count Greylag Geese in all of them. To narrow it down, we opted to include wetlands larger than 2000 m2 in the selection of sites that the observers could choose from, as we assumed that wetlands below this size would not contain a significant number of Greylag Geese. The result was 64,094 wetlands included as possible counting sites. We did not include coastlines or fjords in the model development, even though these were counted during the project. The range and development of environmental variables for coastlines and fjords were expected to differ from those developed for inland wetlands, e.g. we expected depth and protection from wind to have an effect on the occurrence of geese along the coast. Thus, these areas would require their own model including a different range of environmental variables, which was beyond the time frame of this project. Many of the important coastlines and fjords possible to cover from land, are however covered by the network of NOVANA observers. Thus, we expect most of these areas to be covered already, with the exception of the areas, which are difficult to cover from land, e.g. the South Funen archipelago, which will have to be counted by plane.

Selection of dates: In Denmark, the Greylag Goose usually breeds in lakes, bogs and marshes with reedbeds or shrubs, near meadows or grasslands where they can forage on green vegetation. They breed early in the year, and goslings are observed from early April. The adult birds moult their flight feathers at the end of the breeding season (until mid-June). During this period, when they are not able to fly, successful breeders are very cautious and hide around marshes and small lakes. Whereas the non-breeders often gather in larger flocks in "safe" areas, like Saltholm. After the breeding season, the geese gather in increasingly larger flocks, and during August Greylag Geese from more northern breeding populations start arriving in Denmark and move further south. It is therefore important to do the count before the migration starts and the management units mix. The ideal time would be July, but due to summer holidays, we did not find it feasible to get enough people out counting, and instead the first weekend of August including 2 days on either side (i.e. 4-9 August) was chosen and advertised as the count period. Except for the Wadden Sea region, where the count had to be conducted in conjunction with dedicated wader counts during mid-month spring-tides around 15-17 August. Hence we extracted data from Fugledata.dk for the period 1-17 August and from DOFbasen for the period 1-14 August. 79% was counted during the count weekend +/-2 days (4-9 August) and 3% was counted in the Wadden Sea region slightly later, thus we expect a minimum of double counting.

Selection of the time of day: Based on results from a pilot study in 2021, we decided that the counts should take place at wetlands between 11-18, as the geese often forage scattered in the agricultural landscape during the morning and then return to the roost sites during the day. Thus, we assumed that the number of geese foraging outside the wetlands was at a minimum between 11-18. This behaviour was confirmed during the project period using data from GPS-tagged Greylag Geese (Fig. 5) (AU CAN - GPS-sporing af Grågæs).

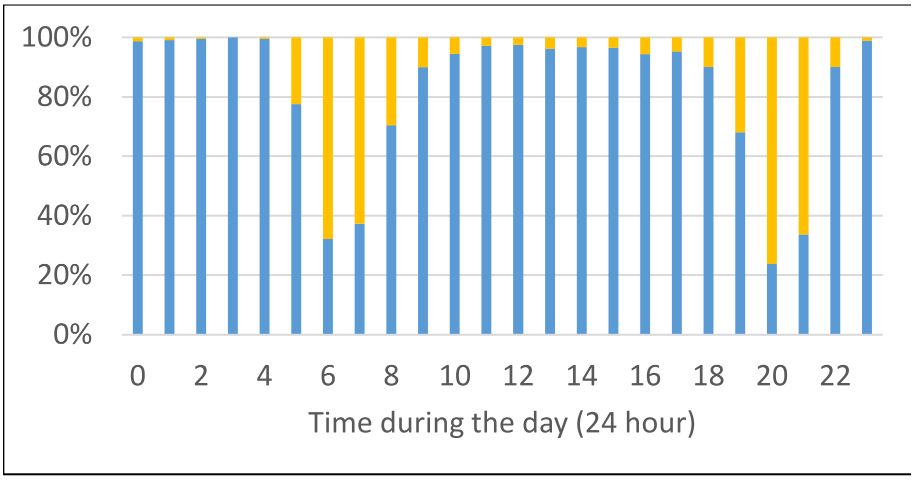

Figure 5. Percentage of Greylag Geese foraging (yellow) and roosting (blue) during 24 hours in week 31 (1-7 August 2022) at Agersø, Denmark. Figure by Signe Wiemann Cieslak

3.2 Step 2. Selecting environmental predictor variables

In this study we investigated the following twelve environmental variables, hypothesised to explain wetland selection by geese; 1) presence of breeding pairs during Atlas III 2014-2017 Danmarks Fugle - Grågås, 2) size of the wetland, 3) type of wetland (lake or marsh) based on paragraph 3 registration[1], 4) area of agricultural land, 5) area of grassland, 6) area of forest, 7) area of urbanisation, 8) area of open land, e.g. moorland, 9) area of sea, 10) distance to coast, 11) area of other wetlands and 12) areas not classified, in a buffer of respectively 1 and 2 km around the wetland. The models using data from a 1 and 2 km buffer around the wetlands respectively, were very similar and only results from the model using a 1 km buffer is presented. Furthermore, as the buffer area around the wetland will increase with the size of the wetland, we expect some correlation between the size of the wetland and the buffer area. To correct for this we also ran the model using the percentage of each variable type within the buffer. However, the models using the size of area vs the percentage of the area provided similar results and only results from the model using the size area is presented. Environmental variable 2-12 was obtained from Levin (2019). The environmental variables are standardised to allow comparison between datasets. Presence of collinearity between explanatory variables was tested using Pearson's correlation coefficient. Values of $r > 0.7$ was used as a threshold to diagnose collinearity (Dormann et al. 2013).

3.3 Step 3. Building the models

The presence of geese represents any use of a given wetland during the study period (observation value 1), versus no observed use of a wetland (0). To predict the occurrence of Greylag Geese we fitted a generalised linear model (GLM) with a binomial distribution. To produce parsimonious models for goose occurrence, we included only six environmental variables showing the strongest individual correlation to goose abundance, while not being strongly correlated with each other.

3.4 Step 4 - Evaluating the models

We used a repeated (10 times) split sample approach for evaluating the goose occurrence model. The model was fitted using 70% of the data and evaluated using the area under the curve (AUC) of a receiver-operating characteristics (ROC) plot calculated on the excluded 30% (Fielding and Bell 1997). A rough guide for classifying the accuracy of the models is: AUC 0.90–1 = excellent; 0.80–0.90 = good; 0.70–0.80 = fair; 0.60–0.70 = poor; and 0.50–0.60 = fail (Swets, 1988). This approach provides a good evaluation of the model performance beyond the calibration dataset and is used regularly in SDMs to predict beyond the calibrated geographic area (Petitpierre et al. 2012).

3.5 Results

The six environmental variables which correlated the most with goose occurrence, while not being strongly correlated with each other, were area of wetland ($r= 0.286$, $n= 640$, $p< 0.01$), area of agricultural land ($r= 0.121$, $n= 640$, $p< 0.05$,), area of grassland ($r= 0.313$, $n= 640$, $p< 0.01$), area of sea ($r= 0.157$, $n= 640$, $p< 0.01$) as well as presence of breeding pairs ($p< 0.01$) and type of wetland (lake or marsh) ($p< 0.01$) (Appendix A1).

The response curves for the predictors were consistent with hypothesised predictions; thus we found the highest probability of greylag goose occurrence in areas with large wetlands, more agricultural land, more grassland, large area of sea and in areas with a presence of breeding pairs (Fig.

[1] Naturbeskyttelsesloven LBK nr 240 af 13/03/2019

6; Appendix A2). Probability of occurrence was higher in lakes compared to marshes that may have dried out during the summer period. The model using these variables achieved an AUC of 0.74, thus a fair model.

3.6 Monitoring recommendations

84 wetlands had a probability of 75% or more of containing Greylag Geese; these 84 wetlands are listed in Appendix A3 and in red/dark red colours on Fig. 6. With the exception of one wetland, all 84 wetlands were located in a square where breeding pairs had been observed during Atlas III 2014-2017. 10 wetlands out of the 84, were marshes, and the rest were lakes. Furthermore, in the 1 km buffer around the 84 wetlands there was a minimum of 519,022 m^2 or ~50-hectare grassland. Besides these rules of thumb, it is difficult to make firm conclusions of where to count Greylag Geese in Denmark, other than saying that in general, the highest probability of finding Greylag Geese is on large lakes, surrounded by large areas of grass, agriculture and sea, in regions of the country where there is a breeding population of geese. A factor, which we were not able to control for, was whether the field was harvested or ploughed, something which can vary greatly in August depending on the weather conditions, which we in fact experienced during the count. We expect a higher probability of observing geese in areas with non-ploughed but harvested fields, as geese mainly feed on spilt grain between stubble and not directly on the crops.

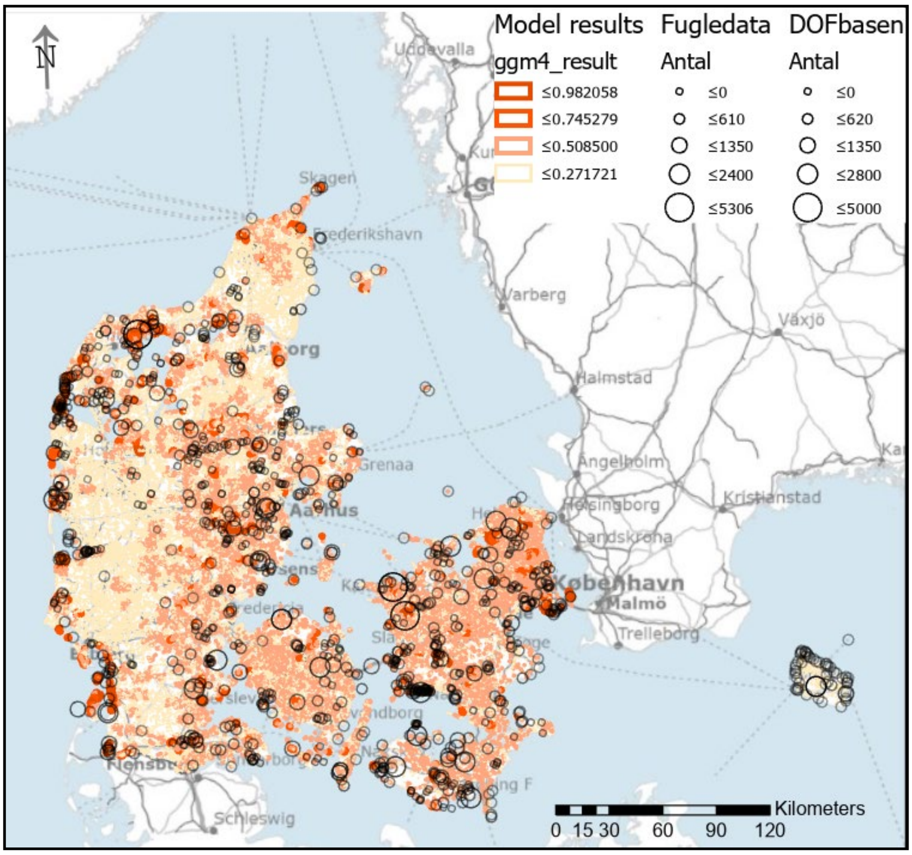

Figure 6. Field observations (open circles) and predicted probability of occurrence (red-sand colours) of Greylag Geese during early August in Denmark. The predictions were computed using a GLM model and values of wetland area, presence of breeding pairs, area of agricultural land, area of grassland, area of sea and type of wetland (lake or marsh).

4 Estimating a national summer population of Greylag Geese

Based on the current information and range of predictor variables we were not able to produce a satisfied statistical model accurately estimating the number of Greylag Geese in Denmark, and particularly in those areas not covered by the counting network. The models where either overdispersed (GLM model with a quasi-poisson distribution) or would not converge (zero-inflated model with a negative binomial distribution). The reason is presumably our very skewed dataset, where more than 50% of the counts are 0 observations, and very few counts of more than 1000. Thus for 2022, we will have to rely on count data, and further investigations are needed if areas not counted shall be estimated through a model framework.

Based on the count data, a total of ~141,000 Greylag Geese were counted during early August. A total of 23,032 were counted by the newly recruited volunteers, 106,606 were reported by the NOVANA network and additional 11,479 were extracted from DOFbasen. We expect this number to be a minimum estimate, as not all sites have been counted, e.g. the majority of the South Funen Archipelago, which will have to be counted by plane. In July 2018 almost 6,300 birds was counted by plane in the South Funen Archipelago, so if the same number of birds appeared there in 2022, the national total will add up to ~147,000.

The latest total count of Greylag Geese in Denmark during summer was in 2018, where a total of 111,337 were counted (Grågås i Holm et al. 2021). As mentioned earlier this count was dedicated to moulting Mute Swans and offshore diving ducks, hence with less focus on Greylag Geese.

5 Cost-efficient way to do the summer monitoring, for future use in the NOVANA programme

In Denmark, Greylag Geese are counted during summertime under the current NOVANA monitoring program, every:

- 6 years during the "August total count" (Fældefugletælling, next planned in 2025)
- 2 years during the "September total count" (September, next planned in 2023)

It is important to note, however, that the current NOVANA program is subject to financial negotiations and revisions.

5.1 What does it take to upgrade these counts to total counts of Greylag Geese?

5.1.1 August total count every 6 years

If it is agreed by the EGM IWG that a population count of each MU shall take place every 6 years, the August total count is by far the most cost-effective, as this already takes place as a total count. The results from this study can then be used to improve the count, making sure that the more important areas are covered. This however assumes that the years of the August counts can be agreed with the other range states.

If the count has to take place more often, there are two opportunities, either the biannual August censuses of Spoonbill and waders should be expanded to include Greylag Geese (with more designated sites to cover), or the September total count, which both takes place every 2 years (see below).

5.1.2 August census every 2 years

The August census is a partial count carried out in protected areas for Spoonbill and waders, and in its current setup it is not sufficient to form the basis of a national population total count, as Greylag Geese are found everywhere in Denmark. Thus, in order for the August census to function as a method for estimating the national summer population of Greylag Geese, the count will have to be improved by additional counts outside the protected areas. The additional counts can be added by either involving volunteers through citizen science, by hiring a number of professional observers, or a mix (which all NOVANA counts are). Furthermore, the August census will have to be supported by an aerial count of the South Funen Archipelago, where land-based observations are not feasible. Thus, upgrading the August census with extra land-based observations from either volunteers or professionals will be comparable to the work done during this project, where the majority of the project staff time was used on recruiting and assisting volunteers. In addition to this, funding will be needed for an aerial count of the South Funen Archipelago.

5.1.3 September total count every 2 years

The September count in Denmark is part of an internationally coordinated count, which likewise takes place in Sweden, Germany, the Netherlands and Belgium. However, the September count was not thought of as a feasible solution, because the MU's would presumably be mixed, and it would be too difficult (and thus expensive) to disentangle the two units. Given the relatively high expenses to recruit volunteers and coordinate an August total count, we have included it here as a possibility and identified the main issues and how they may be dealt with.

Challenge 1) In September the MU's would be mixed, however as long as birds from MU1 have not crossed the borders of MU2, this may be a minor issue. And even if some birds do cross the borders, several on-going tagging (and neckband) projects may assist in tracking movements and eventually help to quantify the number of "cross MU movements" (eg. AU CAN - Tracking of Greylag Geese). Additionally, the timing of autumn migration is likely dynamic and has changed in the past decades. In the 1980s, 1990s and early 2000s, Norwegian birds were arriving in the Netherlands well before the September count (some already in August). Nowadays they arrive later, but either way the current distribution cannot be projected on data from the past (Kees Koffijberg pers. comment). It should be noted, that to insure the national favourable reference population values, the national population size must be known in addition to the MU level population size.

Challenge 2) The September count is taking place within the first part of the open hunting season, whereas the August count would be just at the beginning of the open season. However, this issue is similar for other species, eg. Pink-footed Goose, and it can be corrected for if we know the size of the harvest that has taken place prior to the count. In Denmark we may obtain this information from the wing survey.

Challenge 3) In the Adaptive Flyway Management Programme (AFMP), the parameter used for assessments of Favourable Reference Value (FRV) is breeding pairs, and from a September count, this may be more challenging to assess as compared to a count in summer. The summer counts, however, also need conversion from individuals to breeding pairs anyway.

When all of this is said the greatest advantage of a September count is that it already exists and takes place every 2 years, thus the expenses of adjusting the September count to provide a post-harvest national population size, may be less than adjusting the August census, which also takes place every 2 years.

5.2 Conclusions

The population size of the Greylag Goose in Denmark during summer will be used together with estimates from the rest of the Nordic countries to give an overall population size estimate of MU1. This is a prerequisite for the NW/SW European population of Greylag Geese to be managed at MU level. Thus, the count in Denmark and the most cost-effective way forward must be seen in the light of what is possible and done in the rest of the range states of MU1, and to some degree comparable to what is done in MU2. In table 1 such an overview is presented.

From the pros and cons in this table, the following important points should be noted:

1) Sweden has chosen to use the September count as a proxy for the Greylag Goose population in Sweden.

2) Due to a migratory divide, two populations of Greylag Goose occur in Finland: the NW/SW European population, mainly breeding in the Gulf of Bothnia, and the Central European population, mainly breeding in the Gulf of Finland. As Greylag Goose surveys in Finland have focused on areas in the Gulf of Finland, the results are not relevant for managing the NW/SW European population. However, it is assumed that most Finnish Greylag Geese belonging to the NW/SW European population are staging in Sweden in September, thus we expect these birds to be included in the September survey in Sweden (also belonging to MU1).

3) There is an agreement that the Breeding Bird index is not sufficient to be used between total population counts, therefore the total population counts will have to be done more regularly than every 6 years to be used in an adaptive harvest management framework.

4) Lessons from Denmark in particular, show that setting up an additional monitoring program using volunteers is very time demanding, compared to using an existing network of observers (e.g. the NOVANA network), which most likely can be expanded and maintained with less time-use.

In light of these challenges, it is advised to thoroughly investigate if and how the September counts can be used to estimate the population size at a national level. One important factor here is quantifying the abundance of Norwegian and Swedish birds present in Denmark at the time of the count. The many tagging projects ongoing in several range states such as Sweden, Denmark and the Netherlands, might be used to overcome some of the obstacles in using the September count.

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Tabel 1. Overview pros, cons as well as solutions for July/August vs September counts of Greylag Goose in each range state.

Range state	July/August count	Solutions	September count	Solutions
Norway	Pilot study, not often eg. every 6 years.		Large numbers have left south, remaining birds not covered in census so far	
Sweden	Not counted		Total count	
Finland	Not counted, most have already left.		Not counted, most have already left	
Denmark	Counted every 6 years, partial every 2 years.		Total count	
Germany	Partly counted (2 out of 16 Länder).		Total count	
Netherlands	Total count		Total count	
Belgium	Total count		Total count	
Pros	Before hunting season. Possible to assess productivity. National population size. Easier conversion to breeding pairs.		Organised in most range states. Long term data.	
Cons	Not organised in all range states. Hardly feasible in some Nordic countries (notably Sweden).	Extensive funding is needed in several range states. Continued work on recruiting volunteers and producing models. Find alternative ways to estimate the population size in between count years. The Breeding Bird Index is judged too uncertain to be used in years between counts.	Mid hunting season. No assessment of productivity possible. Migration has started. Cannot differentiate between migratory and resident birds in MU1. Difficult to convert to breeding pairs.	Wing survey can assist in the hunting issue (available in DK). Productivity will have to be done in summer.

			Coverage in most countries is not complete so additional work is needed to achieve total estimates.	GPS projects can help to differentiate between the two units, but it is a dynamic situation.

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Appendix A1 - Correlation values

Table A1. Correlation values between explanatory variables and the dependent variable for Greylag Goose occurrence. * p< 0.10, **p<0.05, ***p< 0.01. Area of other wetlands was removed due to significant correlation with Grass area (r=0.934, n=640, p<0.01). Presence of breeding pairs and type of wetland was tested with a Wilcoxon rank sum test.

Explanatory variable	Goose abundance
Wetland area	0.286***
Grass area	0.313***
Agricultural area	0.121**
Forest area	0.028
Urban area	-0.010
Open area	0.050
Sea area	0.157***
Distance to coast	-0.069
Area of other wetlands	0.256***
Areas not classified	-0.014
Presence of breeding pairs	***
Type of wetland (lake or marsh)	***

Appendix A2 - Correlation matrix of top 6 variables

Correlation matrix for the top six explanatory variables; FGdata_Antal: Number of Greylag Goose, Area_s: Standardized wetlands area, Agri_s: Standardized area of agricultural land, Grass_s: Standardized area of grassland, Sea_s: Standardized area of sea, Breeding_pairs: Presence of breeding pairs during Atlas III 2014-2017 Danmarks Fugle – Grågås, Water type: Type of wetlands (lake/marsh).

Appendix A3 - List of wetlands with a probability of observing Greylag Geese of 75% or more

Water body centre coordinate (ETRS 1989 UTM Zone 32N)

Probability	X	Y
1.00	506341.4	6321098
0.99	577301.4	6301405
0.99	454261.3	6289894
0.99	453497.7	6189434
0.99	638863.7	6178480
0.99	495851	6317766
0.98	735408.3	6173203
0.97	539529.1	6325498
0.96	491828	6316851
0.95	470005.7	6118026
0.95	451986.3	6281379
0.95	535046.2	6174020
0.95	721874.3	6165438
0.93	471961.7	6116560
0.93	735288.3	6172417
0.92	738025.2	6171960
0.92	452713.4	6192660
0.91	471952.7	6116572
0.91	453728.7	6191208
0.91	450318.7	6277958
0.91	504499.5	6320264
0.90	453720.7	6191259
0.89	453798.7	6191630
0.88	721144.7	6167189
0.88	735358.3	6172993

0.88	507079.6	6321430
0.87	735751.3	6171158
0.86	453278.4	6193268
0.86	735614.2	6174972
0.85	453720.7	6191259
0.85	457116.3	6305028
0.85	636071.7	6159999
0.84	506067.4	6320975
0.84	453966.1	6193274
0.83	452672.3	6192659
0.83	453739.7	6190933
0.83	507535.9	6321632
0.83	467424.7	6112972
0.83	485418.2	6267892
0.83	453716.7	6191451
0.83	576987.3	6305646
0.82	499682.9	6319608
0.82	449476.1	6153195
0.82	454141.7	6193143
0.82	450740.7	6193092
0.81	675260.6	6123601
0.81	467424.7	6112972
0.81	721751.4	6165635
0.81	560675.9	6193130
0.80	450544.7	6194055
0.80	451518.7	6194109
0.80	688579.4	6205340
0.80	452652.3	6192661
0.79	453739.7	6190933
0.79	499093.9	6319351
0.79	446783.9	6172826

0.79	452962.7	6192739
0.79	480107.7	6115559
0.79	619653.5	6345274
0.79	453741.7	6191102
0.78	551921.7	6375382
0.78	556041.9	6191554
0.78	535046.2	6174020
0.78	450294.7	6192181
0.78	454141.7	6193143
0.77	453739.7	6190933
0.77	453583.3	6286047
0.77	478415.5	6085087
0.77	479844	6109404
0.77	664663.7	6078178
0.77	452964.7	6192745
0.76	445375.8	6225761
0.76	496639	6318125
0.76	471403.7	6117525
0.76	721232.3	6208723
0.76	535046.2	6174020
0.76	621052.5	6345525
0.76	483878.3	6259841
0.76	451060.7	6190200
0.75	721529.6	6165996
0.75	479758.7	6111983
0.75	479346.7	6120600
0.75	446643.9	6172206
0.75	535046.2	6174020
0.75	621249.5	6345490
0.75	621242.5	6345492