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ESTIMATING GREYLAG GOOSE BREEDING POPULATION SIZE AND PRODUCTIVITY

Status and recommendations for post-breeding population counts and age ratio surveys in breeding range states of Management Unit 1 of the NW/SW European population of Greylag Goose: Denmark, Norway, Sweden, and Finland

EGMP Technical Report No. 23

Prepared by the EGMP Data Centre

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Introduction

The NW/SW European population of Greylag Goose (*Anser anser*) has increased more than seven-fold since the 1980s, resulting in widespread agricultural damage and increased risks to public health and air safety. To help address the growing socio-economic concerns associated with this population, while maintaining the population in a favourable conservation status and providing sustainable hunting opportunities, an International Single Species Management Plan (ISSMP) was adopted in 2018 by the AEWA Meeting of the Parties, which mandated the development of an Adaptive Flyway Management Programme (AFMP) for the NW/SW European population of Greylag Goose (Powolny *et al.* 2018, Nagy *et al.* 2021).

Two breeding management units (MUs) were defined within the population: MU1, which is centred in Scandinavia and is migratory, and MU2, which is centred in the Netherlands and neighbouring countries and is largely sedentary. An information-gap decision model was developed for the period 2020-2022, and an internationally coordinated population management programme for both MUs was planned to start in 2023. However, due to important knowledge gaps, particularly related to summer population counts and productivity estimates, combined with an apparently large bias in the offtake estimates and lack of offtake assessment protocols, the move to dynamic decision-making and coordinated management across the range was not possible. This was acknowledged by the Range States during the 8th Meeting of the European Goose Management International Working Group (EGM IWG8) in June 2023, and it was decided to maintain the current level of offtake at least until EGM IWG9 in June 2024.

In this document, we summarize the results of the post-breeding counts of Greylag Geese carried out in the MU1 breeding Range States (Norway, Finland, Sweden, and Denmark) during the period 2021-2023. We also provide recommendations for future monitoring efforts to ensure the data necessary for managing the NW/SW European population of Greylag Geese at MU level, as agreed by the EGM IWG (see Nagy *et al.* 2021).

1. Greylag Goose post-breeding counts and age ratio surveys

To resolve some of the data quality issues mentioned above, species-specific summer counts of Greylag Goose were carried out in each of the Fenno-Scandinavian Range States to provide an estimated post-breeding population size for MU1.

As breeding phenology and behaviour differs between the four Range States, which is also the case for the landscape and habitats available to the Greylag Geese during their annual cycle, it was decided not to establish a shared monitoring protocol. Instead, each Range State designed population counts to embrace national conditions. National efforts and results are summarized below, and results of national surveys are presented in more detail in appendices 1-4.

Norway

Summer counts in key counties were used along with data from national hunting bag statistics and the Norwegian breeding bird monitoring scheme to produce population models for estimating the post-breeding population size (Yoccoz 2024 (Appendix 1)). Modelled results indicated a post-breeding population in Norway of 145,000 birds (95% credible intervals: 115,000-175,000) in 2022. The population appears to have been growing until 2015, followed by a stabilization in recent years; a pattern that apparently corresponds well with other (localized or indirect) monitoring programs.

Surveys of age ratios have been carried out in two different areas: Vesterålen (2020-2022) and Oslo Fjord (2020-2023). The average estimate of juvenile proportion in 2022 was 27,9 %.

Finland

Until recently, no major efforts had been established to estimate the total breeding population size of Greylag Goose in Finland, where birds from both European populations (NW/SW and C European) are breeding (see Piironen & Laaksonen 2023). In 2021-2023, post-breeding counts were carried out in August to fill this knowledge gap and to serve international management needs, including the provision of data requested by the EGMP. The goal was to estimate the total breeding population sizes of both populations by utilizing information from GPS-tagged individuals to provide information on migration patterns as well as to estimate count bias (see Lindén & Seimola 2024 (Appendix 2)).

A pilot survey was carried out in August 2021, followed by organized counts in 2022 and 2023. In 2023, the number of Greylag Geese belonging to the NW/SW European population was estimated at 21,866 individuals (SD ± 3957). Thirty-eight GPS-tagged individuals were present within the dates and areas covered by the survey.

The proportion of young was estimated based on the data from aged flocks, or flocks where only a subsample was aged, and separate estimates were produced for the NW/SW population and the Central European population. In 2023, the proportion of juveniles in the NW/SW population was estimated at 0.1782 (SE ± 0.0363) (Lindén & Seimola 2024).

Sweden

Autumn goose population counts have been carried out annually in Sweden since 1977, since 1984 including post-breeding counts of Greylag Geese in September (Haas *et al.* 2022 (Appendix 3)). Gaps in coverage are filled by using opportunistic data from birdwatchers reporting to the national online portal Artportalen (www.artportalen.se) (Haas *et al.* 2022). The total number of Greylag Geese reported in September 2022 was 248,115, and the total number for 2023 was 214,382.

Juvenile proportion was surveyed for the first time in September 2022, resulting in a juvenile proportion of 5,0%. In August 2023, the corresponding proportion was 7,5%.

Denmark

In Denmark, Greylag Goose has been counted annually in January and September since the 1980s, and since 2004 it is embedded in the NOVANA (National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environment) monitoring programme. Since 2017, the post-breeding count has only taken place every two years. Every six years, a country-wide count of moulting waterbirds is conducted in July/August, thus also providing a national estimate for the post-breeding population of Greylag Geese.

To provide an estimate of the current post-breeding population size, a total count was carried out in August 2022 by involvement of professional/experienced counters from the NOVANA network, and volunteers recruited through various channels. A dedicated attempt to involve hunters and birdwatchers with limited bird counting experience was made, which resulted in the recruitment of nearly 100 new volunteers. Count results were combined with results from the national reporting portal of BirdLife Denmark (DOFbasen, www.dofbasen.dk), and an estimate of the number of birds present in important SPAs normally covered by aerial surveys was eventually added. The total number of geese reported was ~147,000 (Jensen *et al.* 2023a (Appendix 4)).

The previous estimate, from the NOVANA count in August 2018 (involving land-based counts by the experienced NOVANA counters, aerial surveys, and additional data from DOFbasen), was 111,337 (Holm *et al.* 2021). Following the summer counts in 2022, the Danish NOVANA-programme has moved its biannual post-breeding country-wide count of Greylag Goose from September to August. This will generate regular counts that are comparable to the 2022 count as well as previous total summer counts from July/August. In August 2023, the NOVANA count resulted in a preliminary total of ~163,900 Greylag Geese.

No age survey has been carried out in Denmark, but according to the Danish wing survey, juvenile birds constituted 17% of the annual harvest. The age ratio (number of juveniles pr. adult) obtained from the wing survey has been declining markedly over the last decades, from ~0.7 in 2000/2001 to ~0.2 in 2022/2023, reaching an overall low in 2007/2008 (www.fauna.au.dk, see Figure 1). Note that this does not necessarily reflect the breeding success in Denmark, as birds from other MU1 Range States are included in the Danish harvest. Further to that, as juvenile geese are more vulnerable to hunting compared to adults (Jensen *et al.* 2023b), the age ratio obtained from the wing survey is likely to be biased high.

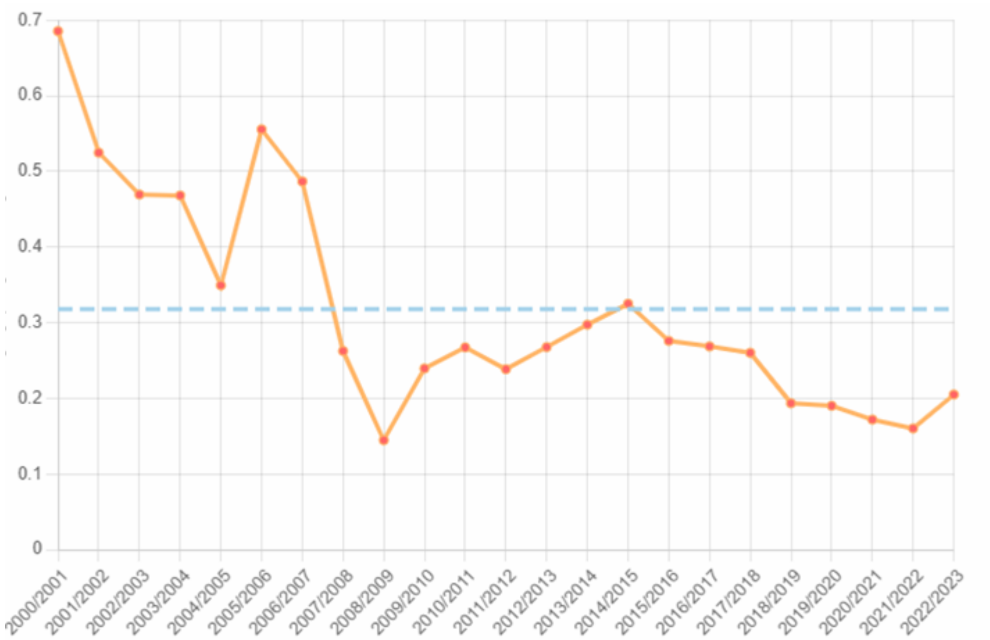

Figure 1. Number of juvenile Greylag Geese pr. adult obtained from the Danish wing survey during the hunting seasons 2000/2001-2022/2023; average value indicated by the blue dashed line. Source: www.fauna.au.dk.

Timing of count – Migration and hunting

In Denmark and Finland, counts carried out in August are expected to avoid periods of migration. In June-July, moulting birds from neighbouring countries are present in Denmark, and from September onwards, migrating birds from (mainly) Norway, Sweden and Finland arrive while Danish breeding birds start moving south (Clausen *et al.* 2023). The Swedish count in September is expected to include most (if not all) Finnish breeding birds, whereas some local breeding birds may have left the country.

When counting in early/mid-August, most of the open hunting season (indicated in brackets for each Range State) is avoided in Denmark (1 Aug to 31 Jan, but only on agricultural fields until 1 Sept), Finland (10 Aug to 31 Dec, with some regional exceptions), and Norway (10 Aug to 23 Dec, with some regional exceptions). The September count in Sweden takes place during the hunting season (11 Aug to 31 Jan).

Total estimated population size of MU1

The first complete results of post-breeding counts in MU1 were available from 2022, resulting in an estimated population of 540,115 individuals (see above and Doc. AEWA/EGMIWG/9.8). Applying the method described by Johnson (2023, see Appendix 5), the corresponding estimated number of breeding pairs in MU1 was 128,463 (112,030 – 143,390) in 2022. In 2018, the number of breeding pairs in MU1 was believed to be about ~84,000 and the target for MU1 is 70,000 breeding pairs (see Nagy *et al.* 2021).

2. Recommendations for future monitoring

As regular post-breeding counts and age ratio surveys are necessary for managing the NW/SW European population of Greylag Geese at MU level, provision of such data must be given priority in the coming years. However, the recommendations given here reflect the trade-off between the ideal data set, existing monitoring programmes and the limitations imposed by availability of resources and funding, assuming that cost-effective solutions are more likely to gain support from Range States.

Post-breeding counts

Acknowledging that the estimated post-breeding totals of Greylag Geese in Denmark and Sweden are based on raw counts (Haas *et al.* 2022, Jensen *et al.* 2023a), whereas estimates from Norway and Finland constitute modelled totals (Lindén & Seimola 2024, Yoccoz 2024), we recommend that:

- **Norway explores further ways to improve the model-based estimates** of the post-breeding population, providing updated estimates on an annual basis or at least biannually, and in the latter case coinciding with population counts in Denmark.

- **Finland continues to organise counts in August and assess detection probability** based on information from GPS-tagged individuals. Even though the results are not currently used directly in the total estimate for the population size of MU1, the survey is very valuable to our general understanding of the migration patterns of the NW/SW European population of Greylag Goose, and the developed models may help to provide an improved overall estimate for the post-breeding population size of MU1.

- **Sweden maintains the annual population count in September**, ideally with a focus on determining which proportions of the Finnish and Swedish breeding populations are found in Sweden during the count. This could be done by use of GPS-tagged individuals, see below. Investigating whether the count could be moved to August (in line with the Danish NOVANA count) is also recommended, as this would maximise the use of the data available from Finland while avoiding periods of hunting and migration and making simultaneous age determination of counted individuals easier.

- **Denmark maintains the biannual population count in August and introduce surveys of productivity**. Both may be carried out simultaneously. The dedicated goose count under the NOVANA scheme provides similar coverage to the special summer count set up in 2022, avoiding the additional work of including inexperienced counters. Since count data are supplemented with data from DOFbasen (www.dofbasen.dk), anyone can submit data, thus we do not see a need to formally include all volunteers wanting to contribute. In fact, the process of recruiting new volunteers is very time-consuming and may mainly serve other purposes than contributing to improving data (e.g. awareness-raising and stakeholder engagement) (Jensen *et al.* 2023a). Furthermore, we recommend investigating whether returning to the annual population counts would be feasible, thus aligning with counts in other range states to provide annual updates of the total post-breeding population size in MU1.

Age ratios

Due to moult and wear of juvenile feathers, distinguishing between age groups in late autumn often proves very difficult, and the juvenile ratio is thus likely to be underestimated. **We recommend carrying out age surveys of Greylag Goose in all MU1 Range States during the summer months and no later than 15 September.** Note that in MU2, where Greylag Goose breeds slightly earlier, it is recommended to carry out age surveys before 1 September (Koffijberg 2022).

Sampling flocks of varying size is important to obtain a representative sample of family flocks and non-breeding flocks. It is important to note that the juvenile ratio is often significantly higher in small flocks than in large flocks (Jensen *et al.* 2023b, Lindén & Seimola, 2024).

Use of GPS-tagged geese

We recommend continuing to investigate migratory movements (including moult migration) and estimating count bias by use of GPS-tagged individuals. This will ensure optimal planning of counts by estimating the share of birds from a given range state present at the time of counting.

In September, it is assumed that most birds from Finland have arrived in Sweden, thus the Finnish count is currently excluded from the total estimate of MU1 population size. It is also assumed that all birds from the Central European population of Greylag Goose have left Sweden. However, it remains unclear whether these assumptions are valid (but see Piironen & Laaksonen 2023), and we recommend investigating this further.

Estimating number of breeding pairs

While an estimated number of breeding pairs exist from Norway (Yoccoz 2024), post-breeding numbers of Greylag Geese have not been transformed into an estimated number of breeding pairs in the other three Range States.

We recommend estimating the national breeding population sizes as well as the estimated total number of pairs in Management Unit 1 based on the methodology described in Appendix 5 (Johnson 2024), which has been reviewed and approved by the Greylag Goose Task Force.

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APPENDIX 1

Population estimates of Greylag Goose for Norway in 2022

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The counts made in different counties (Vestfold_Telemark/Østfold in South, Trøndelag Mid-Norway, Rogaland in SouthWest and Vesterålen in North Norway) all indicate a relatively stable population in the last 3-5 years. Counts from the Breeding Bird Monitoring program (ca 400 1 km2 routes randomly distributed in Norway) show the same stabilization in the last years after an increase in 2010-2018.

The hunting statistics for the whole country show an increase until 2015 and thereafter a decrease.

We used a simple population dynamics model to estimate population size from the hunting statistics:

N_t = Number of birds before hunting season year t (i.e., include young birds produced in year t)

$N_t = N_{t-1}\,(1-\phi)\,\lambda$,

where ϕ is the proportion of birds harvested, and λ the population growth rate (assumed to happen after the hunting season).

Hunting statistics were available for the years 1991 to 2022 (32 years). A Bayesian approach was used to estimate N_0, the initial population size (ie in 1991), the final population size in 2022, and the parameters ϕ and λ. We used models with constant parameters ϕ and λ, as well as time-varying ϕ and λ. In the latter case we assumed normal distribution of the ϕ_t and λ_t, with informative priors for the distributions of the mean and standard deviations of ϕ_t and λ_t. In addition, we used another model using the Breeding Bird Monitoring data, assuming that:

$BB_t = \theta\,N_t$, where BBt is the number of birds counted in the monitoring program, and θ is the proportion counted. Note that one could have an additional correcting factor since Nt is the number of birds after the reproductive season (including young birds) and not the number of breeding pairs, but given the relationship between the two is constant, this would result in similar estimates.

The model based on hunting statistics only, with time-varying parameters, and for the whole country gave the following estimates (x1000 for number of birds, and with 95% credible intervals in []):

N (1991): 76 [66 – 88]

N (2022): 134 [105 – 169]

λ (mean): 1.15 [1.13 – 1.18]

ϕ (mean): 0.12 [0.10 – 0.14]

The model based on hunting statistics and TOV data (only available after 2010), with time-varying parameters, and for the whole country gave the following estimates (x1000 for number of birds, and 95% credible intervals):

N (2010): 101 [91 – 116]

N (2022): 155 [127 – 176]

λ (mean): 1.15 [1.12 – 1.18]

ϕ (mean): 0.10 [0.09 – 0.11]

θ : 0.0027 [0.0024 – 0.0030] (Note that the 400 routes cover a bit more than 1 ‰ of Norway, but that there is a somewhat higher proportion of routes along the coast because of accessibility).

Based on these two models, we can estimate that the number of birds (x1000) pre-hunting is 145 [115 – 175]. Assuming a 30% proportion of young birds based on what is known otherwise and the actual counts in Vesterålen and Vestfold/Østfold, that corresponds to ca 50,000 breeding pairs [40 to 61,000].

(Note that this gives an estimate of 108 [92 to 125] for the year 2006, with the estimated value given then within the credible interval)

We also ran simple population models with different values of initial population sizes N0, ϕ and λ, to assess what were the values giving patterns similar to those observed in actual counts done in different counties. I used initial values in 1991 between 50 and 120,000, and λ between 1.03 and 1.16. The numbers harvested were used directly in the model. Restricting the simulations to those given a final population size between 50,000 and 180,000, most of the dynamics showed a decline after 2010 which do no correspond to the actual counts in August. The values obtained using the Bayesian approach (N_1991 = 76, λ = 1.15) correspond as expected to an increase until 2015 and stabilization thereafter, but other scenarios are plausible and reflected in the relatively wide credible intervals of parameter estimates.

We also run similar models for the northern part of Norway only (counties Trøndelag, Nordland, Troms and Finnmark). It gave the following estimates:

N (1991): 49 [43 – 56]

N (2022): 74 [59 – 91]

λ (mean): 1.13 [1.11 – 1.15]

ϕ (mean): 0.10 [0.09 – 0.12]

That is, about half of the population is in the counties Trøndelag to Finnmark.

```
### Code used to estimate the population size

# First some simulations of possible trajectories suing different initial values and lamnbdas

Ninit <- seq(50000, 120000, by=2000)

lambda <- seq(1.03,1.16, by=0.0025)

n.Ninit <- length(Ninit)

n.lamb <- length(lambda)


N_gg <- array(0, dim=c(n.Ninit, n.lamb, 32))


for (i.init in 1:n.Ninit){

 for (i.lamb in 1:n.lamb){

  N_gg[i.init, i.lamb, 1] <- Ninit[i.init]

  for (i.year in 2:32) {

   N_gg[i.init, i.lamb, i.year] <-(N_gg[i.init, i.lamb, i.year-1]-gghunt$total[i.year-1])*lambda[i.lamb]

  }

 }

}


as.matrix(N_gg[,,32]>50000)+as.matrix(N_gg[,,32]<180000)

index.gg <- which(as.matrix(N_gg[,,32]>50000)+as.matrix(N_gg[,,32]<180000)==2, arr.ind = T)

nrow(index.gg)
```

```
par(mfrow=c(8,6))
for (i in 1:nrow(index.gg)) {
  plot(1992:2023, N_gg[index.gg[i,1], index.gg[i,2],]/1000, type="l",
       las=1, xlab="Year", ylab="N geese (x1000)", cex.lab=0.8)
  title(main=paste(Ninit[index.gg[i,1]]/1000,"and lambda", lambda[index.gg[i,2]]), cex.main=.9)
}

# restricting to North Norway: Trøndelag and north
gghunt$north <- gghunt$Tr+gghunt$Nordland+gghunt$TF
plot(1992:2023, gghunt$north)

Ninit <- seq(10000, 80000, by=2500)
lambda <- seq(1.03,1.16, by=0.0025)
n.Ninit <- length(Ninit)
n.lamb <- length(lambda)

N_gg_n <- array(0, dim=c(n.Ninit, n.lamb, 32))

for (i.init in 1:n.Ninit){
  for (i.lamb in 1:n.lamb){
    N_gg_n[i.init, i.lamb, 1] <- Ninit[i.init]
    for (i.year in 2:32) {
      N_gg_n[i.init, i.lamb, i.year] <-(N_gg_n[i.init, i.lamb, i.year-1]-gghunt$north[i.year-
1])*lambda[i.lamb]
    }
  }
}

as.matrix(N_gg_n[,,32]>20000)+as.matrix(N_gg_n[,,32]<80000)
```

```
index.gg_n <- which(as.matrix(N_gg_n[,,32]>20000)+as.matrix(N_gg_n[,,32]<80000)==2, arr.ind = T)

nrow(index.gg_n)


par(mfrow=c(6,6))

for (i in 1:nrow(index.gg_n)) {

 plot(1992:2023, N_gg_n[index.gg_n[i,1], index.gg_n[i,2],]/1000, type="l",

    las=1, xlab="Year", ylab="N geese (x1000)")

 title(main=paste(Ninit[index.gg_n[i,1]]/1000,"and lambda", lambda[index.gg_n[i,2]]))

}


###############  Fitting a very simple dynamical model to estimate pop size based on hunting statistics and strong priors

### using stan

library(rstan)


gg_data <- list(T=32, harvested = as.numeric(gghunt$total))

gg_data
$T
[1] 32

$harvested
 [1] 11190  6540  9960 10030 10840  8810  8610  8710  8300  81
40 11170 10360 11200 11140 11290 10820 12140
[18] 13640 13490 15640 14160 14640 16690 17070 20280 15830 166
70 16340 15320 13180 12840 12260


fit1 <- stan(

 file = "pop_harv.stan",  # Stan program

 data = gg_data,    # named list of data

 chains = 4,          # number of Markov chains

 warmup = 1000,         # number of warmup iterations per chain

 iter = 4000,          # total number of iterations per chain

)

summary(fit1)
```

```
print(fit1, pars=c("N_0", "lambda", "phi", "N[32]"), probs=c(0.05, .1,.5,.9, 0.95))


fit2 <- stan(
  file = "pop_harv2.stan",  # Stan program
  data = gg_data,    # named list of data
  chains = 4,             # number of Markov chains
  warmup = 1000,          # number of warmup iterations per chain
  iter = 4000,            # total number of iterations per chain
)
summary(fit2)
print(fit2, pars=c("N_0", "mu_lambda", "phi", "N[32]"), probs=c(0.05, .1,.5,.9, 0.95))


fit3 <- stan(
  file = "pop_harv3.stan",  # Stan program
  data = gg_data,    # named list of data
  chains = 4,             # number of Markov chains
  warmup = 1000,          # number of warmup iterations per chain
  iter = 6000,            # total number of iterations per chain
)
print(fit3, pars=c("N_0", "mu_lambda", "mu_phi", "N[32]"), probs=c(0.05, .1,.5,.9, 0.95))


fit3b <- stan(
  file = "pop_harv3b.stan",  # Stan program
  data = gg_data,    # named list of data
  chains = 4,             # number of Markov chains
  warmup = 1000,          # number of warmup iterations per chain
  iter = 10000,            # total number of iterations per chain
)
print(fit3b, pars=c("N_0", "mu_lambda", "mu_phi", "N[32]"), probs=c(0.05, .1,.5,.9, 0.95))
print(fit3b, pars=c("N[16]"), probs=c(0.05, .1,.5,.9, 0.95))
```

```
# north norway only
gg_data_n <- list(T=32, harvested = as.numeric(gghunt$north))

fit1_n <- stan(
  file = "pop_harv_n.stan",  # Stan program
  data = gg_data_n,    # named list of data
  chains = 4,             # number of Markov chains
  warmup = 1000,          # number of warmup iterations per chain
  iter = 3000,            # total number of iterations per chain
)

print(fit1_n, pars=c("N_0", "lambda", "phi", "N[32]"), probs=c(0.05, .1,.5,.9, 0.95))

fit2_n <- stan(
  file = "pop_harv2_n.stan",  # Stan program
  data = gg_data_n,    # named list of data
  chains = 4,             # number of Markov chains
  warmup = 1000,          # number of warmup iterations per chain
  iter = 3000,            # total number of iterations per chain
)

print(fit2_n, pars=c("N_0", "mu_lambda", "phi", "N[32]"), probs=c(0.05, .1,.5,.9, 0.95))

fit3_n <- stan(
  file = "pop_harv3_n.stan",  # Stan program
  data = gg_data_n,    # named list of data
  chains = 4,             # number of Markov chains
  warmup = 1000,          # number of warmup iterations per chain
  iter = 7000,            # total number of iterations per chain
)
```

```
print(fit3_n, pars=c("N_0", "mu_lambda","sigm_lambda", "mu_phi", "sigm_phi", "N[32]"),
probs=c(0.05, .1,.5,.9, 0.95))


### adding TOV data

# First without the missing TOV data

gg_tov <- read.csv("Ngeese_tov.txt")[,-1]


gg_data_4 <- list(T=13, harvested = as.numeric(gghunt$total[20:32]), N_tov = as.numeric(gg_tov$N))


fit4 <- stan(

  file = "pop_harv4.stan",  # Stan program

  data = gg_data_4,    # named list of data

  chains = 4,             # number of Markov chains

  warmup = 1000,          # number of warmup iterations per chain

  iter = 2000,            # total number of iterations per chain

)

print(fit4, pars=c("N_0", "mu_lambda","sigm_lambda", "mu_phi", "sigm_phi", "N[13]", "p_tov"),
probs=c(0.05, .1,.5,.9, 0.95))

print(fit4, pars=c("mu_lambda","sigm_lambda", "mu_phi", "sigm_phi", "p_tov"), probs=c(0.05,
.1,.5,.9, 0.95), digits=4)


# adding all years

gg_data_4b <- list(T=32, T_tov=13, harvested = as.numeric(gghunt$total), N_tov =
as.numeric(gg_tov$N))


fit4b <- stan(

  file = "pop_harv4b.stan",  # Stan program

  data = gg_data_4b,    # named list of data

  chains = 4,             # number of Markov chains

  warmup = 1000,          # number of warmup iterations per chain

  iter = 7000,            # total number of iterations per chain

)
```

```
print(fit4b, pars=c("N_0", "mu_lambda","sigm_lambda", "mu_phi", "sigm_phi", "N[32]", "p_tov"), probs=c(0.05, .1,.5,.9, 0.95))
```

```
print(fit4b, pars=c("mu_lambda","sigm_lambda", "mu_phi", "sigm_phi", "p_tov"), probs=c(0.05, .1,.5,.9, 0.95), digits=4)
```

APPENDIX 2

Results from greylag goose August survey in Finland 2022–2023

Compiled: 22.2.2024

Andreas Lindén & Tuomas Seimola, Natural Resources Institute Finland

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1. The survey

No major efforts have earlier been made in Finland to estimate the total breeding population size of greylag geese (GG). To fill this knowledge gap and to serve international management needs, The Natural Resources Institute Finland (Luke) has in collaboration with University of Turku (Antti Piironen) started an effort, with the goal to estimate the total population size of based on a new GG survey in August, utilizing the information from birds with GPS-loggers. We also sample the age structure of the flocks. During 2021 we made a pilot study of the August survey, covering approximately the Southern coast of Finland.

The August survey was done during two consecutive days in beginning of August before the field hunting season start (10. August). In both 2022 and 2023 this was on 5.–6. (7.) August. The ca 70 survey areas are predefined polygons covering the best known and likely gathering sites of GG along the Finnish Baltic Sea coastal areas from Northern Ostrobothnia to the Eastern Gulf of Finland (Fig. 1). Surveys were conducted early in the morning (sunrise to around 9–10 a.m.) before the GG move to roost at the sea or estuaries, where counting is difficult. Some roosts easy to count are included. Most of the roost sites included were counted between 11 a.m. and 18 p.m. The surveyors are instructed to cover all major fields and possible coastal bays in the given polygon.

Figure 1. The network of ca 70 sampling sites (polygons) in 2023. During the survey, in total 35 of 38 active GPS-tagged birds were located inside these areas, i.e., the sites are estimated to cover 92 % of the birds (95% CI = 79–98 %). The country is divided into five regions (not shown here).

The number of individuals in all flocks was counted and their accurate positions were reported. The accurate time of the observations was also recorded. If a GPS-tagged bird (with a neck collar) is seen, it is noted and reported. Whenever possible (flock close enough), the geese were aged into two classes (young = 1 cy, or ad = +1 cy). In large flocks, where it was difficult to age all individuals, a subsample of the flock was aged, when possible. Our current recommendation is to sample 200 individuals, but the sample may be smaller as well.

To assess the detection probability, we checked for each GPS-tagged bird (around 40–50 individuals), whether they i) occurred in any of the areas (polygons) at the time of the survey, and ii) whether they were present in a flock that was counted, i.e., “in the right place at the right time”. At the time of the survey, the GPS loggers were set to fix the location with an interval of ten minutes. Possible visual observation of GPS-tagged birds has no large role here, but naturally helps in the interpretation of data.

2. Estimates of the population size

While the actual sampling areas are non-random, prioritizing the best habitats and known good localities, e.g., based citizen data collected by bird watchers, we presume that the GPS-tagged birds are randomly distributed among the sampling sites and other possible non-sampled areas (see example in Fig. 2). Based on this assumption, we may estimate the proportion of GPS-tagged bird flocks observed in the survey and extrapolate the result to estimate total population size. The survey aims to cover as large part of the population as possible, so that it simultaneously provides a reasonable minimum estimate of the post-breeding population size and covers a large share of the tagged birds, making estimation of the population size more robust.

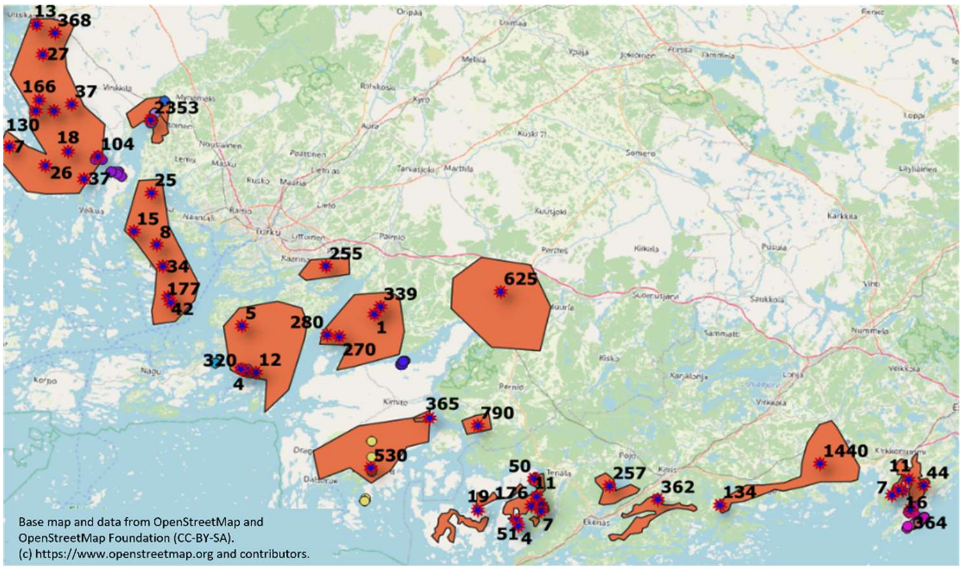


Figure 2. An example of surveyed areas (polygons), in Southwest Finland in 2022. Stars are sites with observations of GG, with flock sizes indicated as numbers.

In 2023 there were 38 GPS-tagged GG individuals within the area during the survey, and 20 of these were determined to be present in observed flocks, and hence, regarded as observed. Here, the same detection probability (P_D; average estimate: 20 / 38 = 53%), based on data from the whole country, was presumed to apply to the whole survey. We may amend this assumption at a later point.

The country was divided into five regions, and for each of the regions, the population size was estimated based on the total number of observed birds (T_{REGION}) and the common detection probability (P_D). The region-specific estimated population sizes are: $N_{REGION} = T_{REGION} / P_D$. The regional share of the population sizes was assigned to the two flyways according to the probability of membership of the western flyway (P_W), separately for each of the five regions. The probability of Central flyway membership for the given reason is then $1 - P_W$. Both the data and principle for determining flyway membership was from Piironen & Laaksonen 2023 – *Proc. R. Soc. B*, https://doi.org/10.1098/rspb.2023.1528).

The inference was done using a simple simulation with 10 M random draws, based on that the uncertainty of the binomial distribution parameter p is Beta(α, β) -distributed with parameters: α = 1 + "the number of successes", and β = 1 + "the number of failures", in the Bayesian context. The common detection probability (P_D), was hence presumed to a random number from the distribution Beta(α = 1+ 20, β = 1 + 18), which for each draw can be applied to get an estimate of population size for each region (currently presuming equal P_W). Further, the region-specific flyway memberships were drawn from Beta-distributions with the same logic (see also Piironen & Laaksonen 2023). Applying all these randomly drawn probabilities to the observed region-specific counts, and summing the estimates together for each flyway separately, provides the simulated distribution of flyway specific estimates (Fig. 3, Table 2).

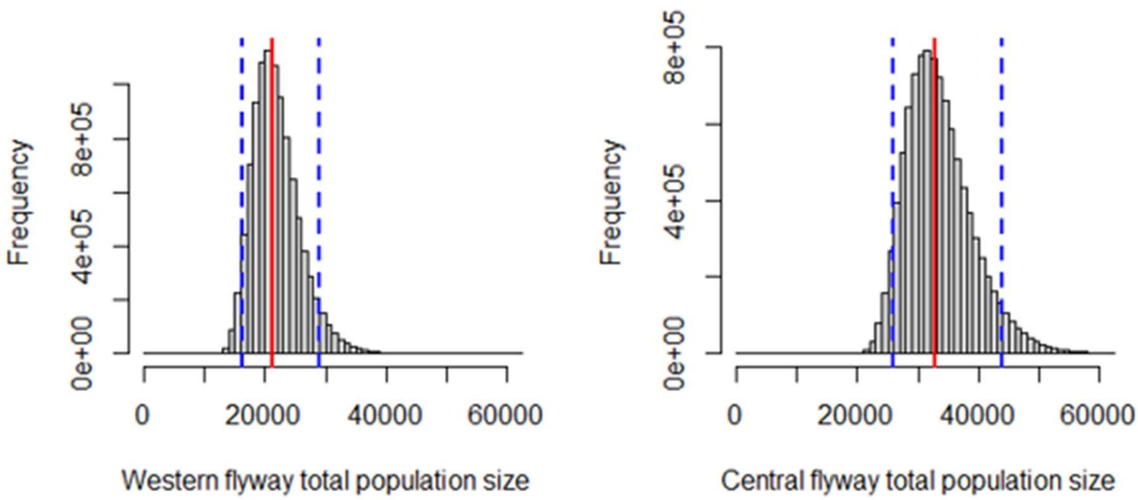


Figure 3. Histograms of the simulated values, describing the estimated distribution of Western- and Central flyway total population sizes in year 2023.

Table 1. Estimated parameters (mean and SD) or percentiles of the posterior distributions of the Western and Central flyway total population sizes in year 2023. The mean and median point estimates are bolded.

Flyway	Mean	SD	p 2½	p 5	p 10	p 50	p 90	p 95	p 97½
Western	**21866**	3957	15688	16429	17349	**21337**	27035	29097	31089
Central	**33566**	5683	24816	25838	27120	**32772**	40993	43995	46897

In the future, we plan to further develop this into a full Bayesian model fitted with MCMC, allowing many more properties of the model. Examples of such properties are region-specific detection probabilities informed by multiple years of data, flock-based detection rates, population growth between years, and integrating with the model on the proportion of young (see next section).

3. Estimates of the proportion of young

The proportion of young was estimated based on the data on aged flocks, or flocks where a subsample was aged. Currently, the estimation procedure is done separately for each year and produces separate estimates for the Western flyway and the Central flyway. The subsample of data included in this analysis, consist of all the flocks where either all individuals or a sample of individuals have been aged, disregarding the other flocks. Hence, we currently presume that the aged/sampled flocks are a random sample of all flocks, regardless of, e.g., flock size. The uncertainty of the estimation procedure is estimated using a bootstrap approach, as described later in the text.

To derive a point estimate of the annual flyway-specific age-ratio, we first estimate the number of young (Y_E; 1 cy birds) in each flock, for the flocks where not all individuals were aged. This was done for each flock separately, by summing the number of identified young (Y_{ID}) with the number of unaged individuals (U) times the proportion of identified young ($P_{young} = Y_{ID} / (Y_{ID} + A_{ID})$; where A_{ID} is the number of identified +1 cy birds). All these notations referred to so far are flock-specific numbers. Hence, as described above, the estimated number of young in a flock is:

$Y_E = Y_{ID} + U \times P_{young}$,

or $Y_E = Y_{ID}$, in flocks where all individuals are aged.

Secondly, the counted or estimated number of young (Y_E) and the total number of counted individuals ($T = Y_{ID} + A_{ID} + U$) for all focal flocks were summed by region; each with their own sums $\Sigma(Y_E)$ and $\Sigma(T)$.

Thirdly, for each region, the estimated annual flyway-specific total number of young and number of individuals was estimated, by multiplying the region-specific sums with the region-specific estimated proportions of birds belonging to the Western flyway (P_W) and the Central flyway ($1 - P_W$), respectively.

Finally, the estimated annual proportion of young for each flyway was obtained by dividing the sum of the flyway-specific numbers of young, with the flyway-specific sum of individuals. In other words, the final point estimates are:

Proportion of 1 cy birds for the Western flyway: $\Sigma\ (P_W\, \Sigma(Y_E))\ /\ \Sigma\ (P_W\, \Sigma(T))$

Proportion of 1 cy birds for the Central flyway: $\Sigma\ ((1 - P_W)\ \Sigma(Y_E))\ /\ \Sigma\ ((1 - P_W)\ \Sigma(T))$

The statistical uncertainty of the estimates was assessed using a bootstrap approach, with the number of resampling events B = 100 000, mimicking the estimation procedure above. Also here, the procedure is (so far) done separately for each year. The aged flocks, or flocks where a subsample was aged, were sampled with replacement, separately for each of five regions, according to the logic of non-parametric bootstrap.

If only a part of the flock was aged, then for each bootstrap trial and each flock, the number of young among the unaged ones (U) was drawn randomly from a binomial distribution, where P_{young} was the estimated proportion of young in the subsample (defined above), much according to the logic of a parametric bootstrap:

$Y_E = Y_{ID} + k$

$k \sim \text{Binomial}(n = U, p = P_{young})$.

Further, for each region and each bootstrap trial, the proportion of birds belonging to the Western flyway (P_{Wboot}) vs. Central flyway ($1 - P_{Wboot}$) was drawn from a Beta distribution, according to the logic and parameters presented in Piironen & Laaksonen (2023), reflecting the uncertainty of flyway membership, in the same way as for the population size estimates. All other steps in the bootstrap were done identically with the estimation procedure of the proportion of young. Uncertainty was assessed as standard errors (SD of the bootstrapped values, and a CI % confidence interval derived with the percentile method. The results are shown in Table 2 below.

Table 2. The estimated proportion of young (Prop. 1 cy), for the Western and Central flyways in 2022 and 2023. Parameter uncertainty is based on a bootstrap approach (B = 100 000) and is presented as standard errors (SE) and a 95 % confidence interval (CI_{low}, CI_{high}).

Flyway	Year	Prop. 1cy	SE	CI_{low}	CI_{high}
West	2022	0.1084	0.0136	0.0833	0.1367
West	2023	0.1782	0.0363	0.1182	0.2578
Central	2022	0.1092	0.0290	0.0702	0.1817
Central	2023	0.1182	0.0242	0.0835	0.1716

A clear feature of these data is that the proportion of young in a flock strongly depends on flock size (Fig. 4). The current approach – described and applied above – accounts for this relationship, however, presuming that the flocks where the birds (or a sample of the flock) are aged, is a representative sample of all flocks with respect to the distribution of flock sizes, e.g., randomly selected with respect to flock size. This assumption is not necessarily true and may be relaxed by amending the method.

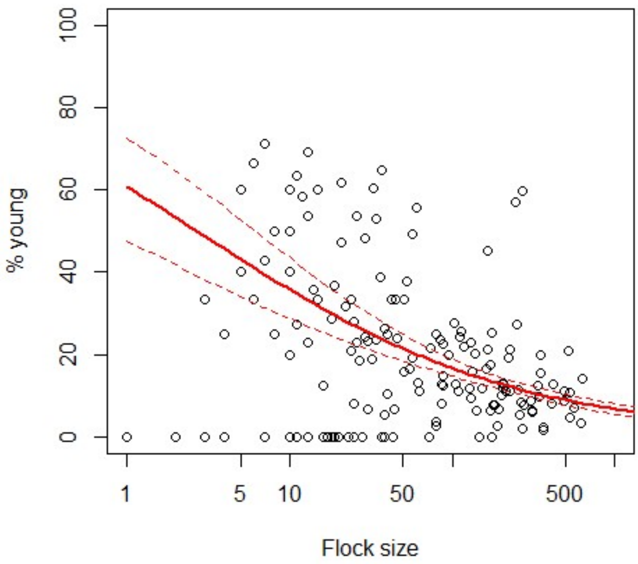


Figure 4. The proportion of young strongly decreases with increasing flock size. Logistic regression (logit link, family = quasibinomial) of the probability of young, explained by the natural logarithm of flock size. The intercept is 0.440 ± 0.273 (SE) and the slope is –0.445 ± 0.050 (SE).

APPENDIX 3

Inventering av höstrastande och övervintrande gäss i Sverige – årsrapport för 2022

Fredrik Haas, Hakon Kampe-Persson och Leif Nilsson
Lunds universitet

Haas, F. Kampe-Persson, H. & Nilsson, L. 2022. Inventering av höstrastande och övervintrande gäss i Sverige – årsrapport för 2022. Biologiska institutionen, Lunds universitet.

Foto: Leif Nilsson

Innehåll

Inledning

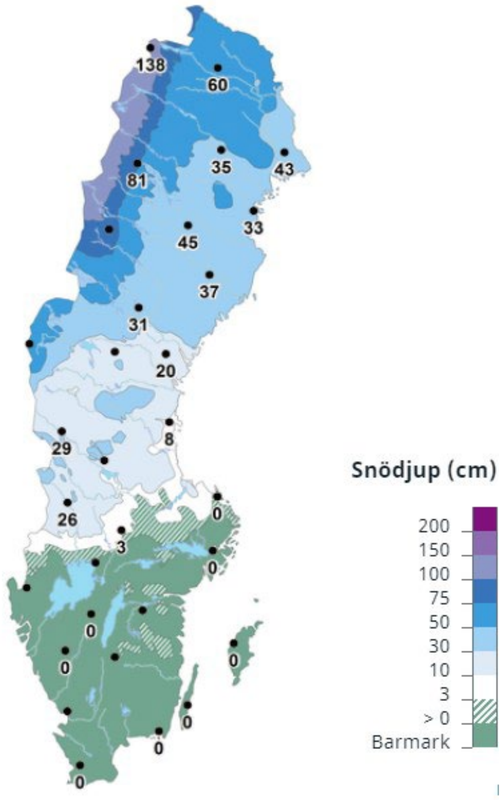
Gåsinventeringarna har under många år till stor del finansierats av Svenska Jägareförbundet, men inventeringarna år 2022 har gjorts på uppdrag av Naturvårdsverket som även är finansiär. I samband med att Naturvårdsverket övertog huvudmannaskapet beslöts att den novemberinventering som tidigare ingått i de nationella inventeringarna skulle utgå. Skälet till detta handlar främst om resurser. Helt kort, resultaten från inventeringarna i november bedömdes kosta mer än de gav. Under 2022 har vuxna gäss av samtliga förekommande arter räknats i januari, september och oktober. Ambitionen har varit att inventeringarna ska vara heltäckande, dvs att samtliga gäss som förekommer i Sverige under perioden för inventeringarna ska räknas. Så blir naturligtvis inte fallet i verkligheten, hur stor del av de verkliga förekomsterna som täcks varierar mellan art och säsong. Förutom inventeringarna av vuxna fåglar har inventeringar i syfte att skatta andelen ungfåglar gjorts för tajgasädgås, grågås och vitkindad gås. Sådana studier har i Sverige tidigare gjorts på tajgasädgås (sedan 2017), men inte på de två sistnämnda arterna. För dessa två arter var 2022 ett försöksår där metodik och omfattning måste utvärderas, något som inte görs i denna rapport.
Resultaten från de olika räkningarna är självfallet intressanta ur ett nationellt perspektiv, men de används även i olika internationella sammanhang. Delar av resultaten levereras till Wetlands International (https://www.wetlands.org/), som bland mycket annat koordinerar inventeringar av våtmarksfåglar och gäss världen över. Dessutom levereras data till European Goose Management Platform (EGMP, https://egmp.aewa.info/). Som namnet antyder samlar de in data från en stor mängd europeiska länder för att på så sätt kunna ge rekommendationer till medlemslemsländerna om exempelvis jaktkvoter som garanterar att gåspopulationerna inte hotas, s.k. adaptiv förvaltning.

Material och metodik

De nationella inventeringarna av gäss i Sverige som presenteras i denna rapport startades i oktober 1977, januari 1978 och i september 1984 . Septemberinventeringarna riktades de första åren uteslutande mot grågås, men sedan 1990-talets början räknas alla gåsarter som påträffas.
I denna rapport presenteras resultaten från de inventeringar som genomfördes i mitten av januari, september och oktober 2022. De rekommenderade inventeringsdagarna var 15–16 januari, 17–18 september och 15–16 oktober. I praktiken innebär det att inventeringarna fokuserats runt dessa datum, men de har i vissa fall genomförts veckan före eller efter respektive datum.

De nationella skattningarna av antalet gäss baseras på data från tre källor:
1) Riktade gåsinventeringar som rapporteras direkt till Lunds universitet eller till Artportalen.
2) Gåsobservationer som gjorts under januari- och septemberinventeringarna av sjöfågel och gäss
3) Övriga gåsobservationer som rapporterats till Artportalen.

Riktade gåsinventeringar
Dessa inventeringar har genomförts under samtliga tre månader men med ett viktigt undantag, inga sådana gåsräkningar gjordes i södra och sydvästra Skåne under januari. Detta påverkar antalet registrerade gäss kraftigt i negativ riktning för alla arter. Under höstinventeringarna räknas gässen antingen när de på kvällen/morgonen flyger till/från sina födosöksområden, på lokaler där de tillbringar dagens vila eller medan de födosöker. Områden som under hösten specialinventerats med avseende på gäss är: Skåne, Tåkern, Östen, Kvismaren med omnejd, Hjälstaviken samt ytterligare ett antal lokaler i södra och mellersta Sverige. Dessutom har flera lokaler som ingår i septemberinventeringarna av sjöfågel (och gäss) även inventerats med avseende på gäss vid oktoberräkningen. För att få en nationell skattning av antalet rastande tundrasädgäss genomfördes undra andra halvan av oktober en rundtur till samtliga områden som tidigare hyst flockar av denna underart i oktober. Under inventeringarna av gäss i januari, som endast genomförs i Skåne (dock ej i de södra och sydvästra delarna detta år), är det födosökande fåglar som står i fokus.



Figur 1. Snödjupet den 15 januari 2022.
Karta hämtad från SMHI.

Januari- och septemberinventeringar av sjöfågel och gäss
I januari och september inventeras årligen sjöfåglar och gäss i ett större antal fördefinierade områden. Områdena kan utgöras av ett kustavsnitt eller en sjö/del av sjö. För en detaljerad metodbeskrivning, se https://www.fageltaxering.lu.se/. Under 2022 inventerades 1084 områden i januari och 219 i september, men självfallet påträffades det inte gäss i samtliga.

Gåsobservationer i Artportalen
Observationer av samtliga gåsarter och perioder har laddats ner från Artportalen och sedan överförts till GIS-skikt. När det varit geografiskt och tidsmässigt överlapp mellan dessa observationer och de observationer som gjorts under punkt 1 eller 2 har data från Artportalen prioriterats bort. När flera rapporter av samma art rapporterats från en lokal har observationerna närmast de rekommenderade datumen prioriterats, men hänsyn har även tagits till hur representativ en given observation bedömts vara för lokalen.

Vid redovisningarna av antalet observerade gäss för Sverige i sin helhet är de numerärer som presenteras för hösten 2020 samt januari 2021 och 2022 baserade på icke kompletta inventeringar. Under ingen av nämnda perioder genomfördes riktade gåsinventeringar i södra och sydvästra Skåne, något som kraftigt påverkar resultaten.

Såväl gässens vinterutbredning som antal påverkas i mångt och mycket av rådande snötäcke. I Figur 1 visas snösituationen i mitten av januari 2022.

Ungfågelräkning av gäss
I syfte att beräkna andelen ungfåglar hos tajga-, grå-, och vitkindad gås räknades antalet ungfåglar och vuxna fåglar i ett antal flockar av nämnda tre arter. Dessa räkningar gjordes i september för grågås och vitkindad gås och i oktober för tajgasädgås. Motsvarande räkningar har för tajgasädgås genomförts sedan 2017, men 2022 års räkningar av ungfåglar av de två andra arterna ska betraktas som pilotinventeringar. Inventeringen av tajgasädgås omfattade Västergötland, Östergötland, Närke, Södermanland och Småland, men det var bara i Närke och Småland som kontrollerbara flockar hittades. Grågåsstudierna genomfördes i södra och mellersta Sverige samt i Västerbotten medan ungfåglar av vitkindade gäss räknades i Blekinge, Skåne och Västerbotten.
För samtliga arter gällde att inventeringarna först och främst riktades mot flockar där samtliga individer kunde observeras, även om det i praktiken ofta är svårt att avgöra vad som utgör en oberoende flock. I varje flock räknades antalet vuxna respektive unga fåglar. I presentationen av resultaten tas ingen hänsyn till de enskilda flockarna, i stället presenteras totalantalet observerade fåglar inom ett landskap och andelen ungfåglar av desamma. Skattningen för hela landet har gjorts

på två olika sätt, dels genom att ta kvoten mellan totalantalet observerade ungfåglar i hela landet och totalantalet observerade fåglar (dvs summan av antalet vuxna och unga fåglar) och dels genom att ta medelvärdet av de ungfågelandelar som beräknats landskapsvis.

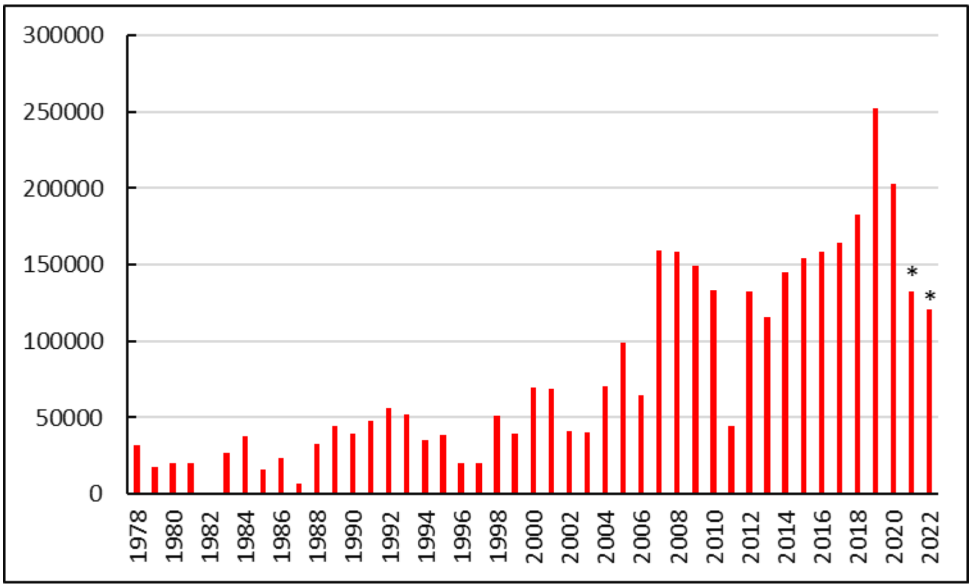
Resultat och diskussion

Under inventeringarna 2022 räknades totalt 120 329 gäss i januari , 327 000 i september och 504 022 i oktober (Tabell 1). Septembersiffran präglas helt av rastande grågäss. Den stora ökningen av rastande gäss som sker mellan september och oktober kommer sig främst av att det är först i oktober som de i Ryssland häckande vitkindade gässen anländer till Sverige. Såväl antalet övervintrande gäss (Figur 2) som höstrastande (Figur 3) har ökat kraftigt. Fram till millennieskiftet noterades det sällan mer än 50 000 gäss i januari, under senare år ligger antalet stadigt över 150 000. Med heltäckande januariinventeringar under 2021 och 2022 hade antalet gäss varit väl över 150 000 även under de två åren. Vid oktoberinventeringarnas start och närmast efterföljande år låg antalet gäss på runt 50 000. Under se senaste åtta åren, med något undantag, har antalet överstigit 500 000. På 40–45 år har således antalet höstrastande gäss tiofaldigats. Det är främst ökade förekomster av grågås och vitkindad gås som drivit upp totalsummorna under höst och vinter.
I januari var gåsförekomsten främst koncentrerad till Skåne och södra Sveriges kustnära områden (Figur 4) . Nordgränsen för de övervintrande gässens utbredning följer relativt väl sydgränsen för snötäcket under inventeringsperioden (Figur 1). Under höstmånaderna var de rastande gässen spridda i hela Sveriges slättbygder med de största mängderna i områden med stora arealer åkermark.

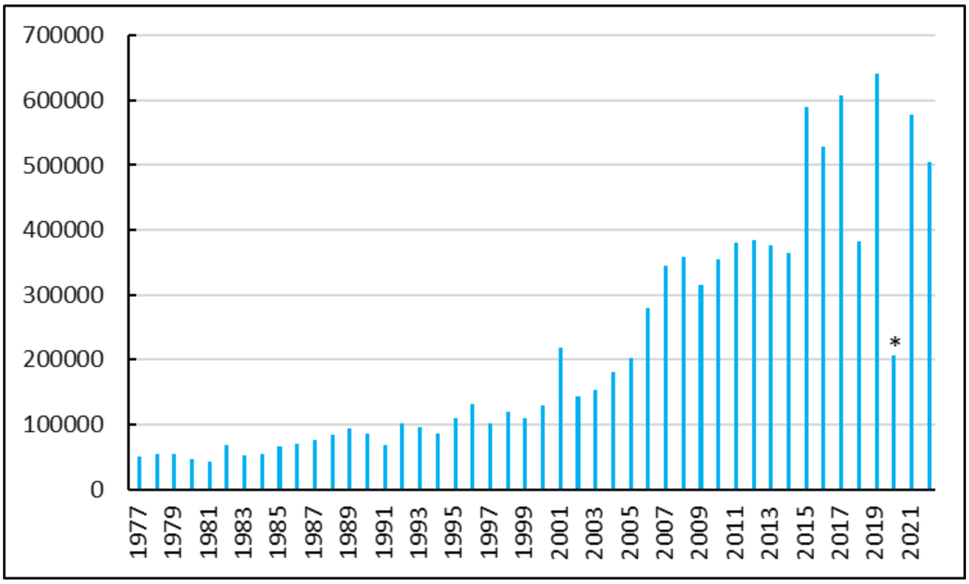
Tabell 1. Antalet gäss av de arter som räknats vid inventeringarna i Sverige 2022.

Art	**Januari***	**September**	**Oktober**
Grågås *Anser anser*	28 255	248 115	126 857
Fjällgås *Anser erythropus*		89	15
Sädgås *Anser fabalis*			
Tajgasädgås *Anser f fabalis*	15 784	642	1047
Tundrasädgås *Anser f rossicus*		43	4266
Tajga/tundrasädgås *Anser f fabalis/rossicus*	10 668	22 249	51 033
Spetsbergsgås *Anser brachyrhynchus*	166	1334	3597
Bläsgås *Anser albifrons*	970	39	4261
Kanadagås *Branta canadensis*	32 269	25 258	23 754
Vitkindad gås *Branta leucopsis*	32 216	29 219	288 600
Prutgås *Branta bernicla*	1	12	590
Rödhalsad gås *Branta ruficollis*			2
Summa	**120 329**	**327 000**	**504 022**

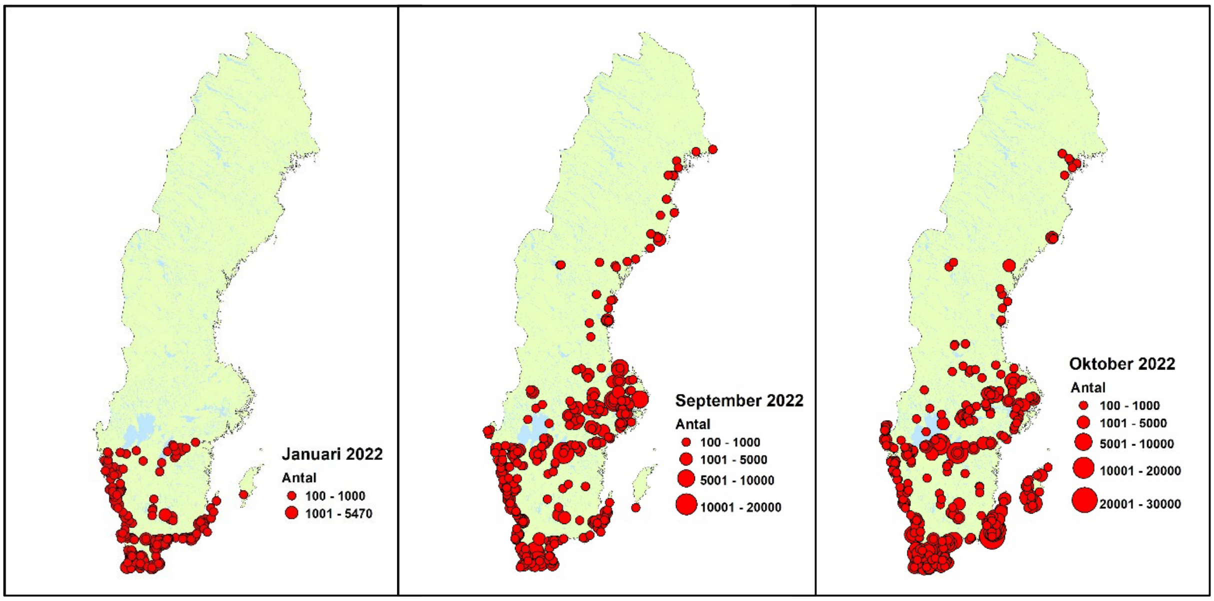
** Indikerar att totalsumman är baserad på ofullständiga inventeringar.*



Figur 2. Totalantalet inräknade gäss vid gåsinventeringarna i Sverige i januari 1978 – 2022.
* indikerar att totalantalet baseras på ofullständiga inventeringar.



Figur 3. Totalantalet inräknade gäss vid gåsinventeringarna i Sverige i oktober 1977 – 2022.
* indikerar att totalantalet baseras på ofullständiga inventeringar.

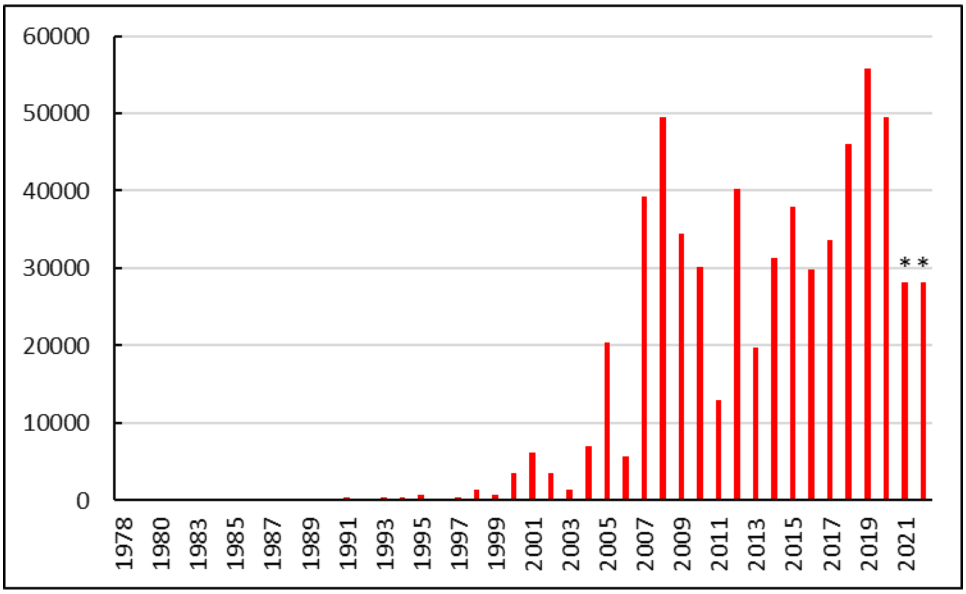


Figur 4. Gässens utbredning under januari, september och oktober 2022.

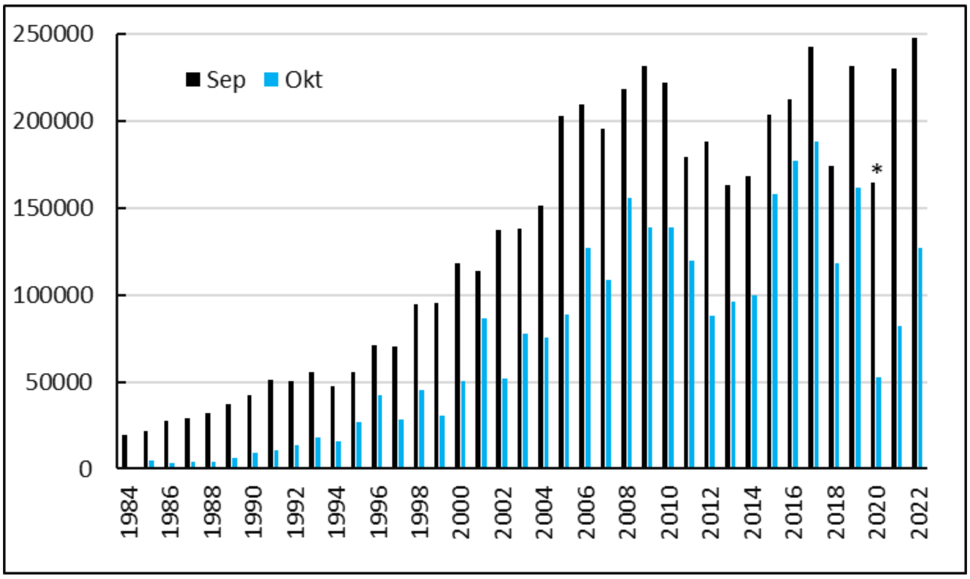
Grågås *Anser anser*

Såväl antalet övervintrande som höstrastande grågäss har ökat kraftigt. Vid de första tio årens inventeringar i januari sågs totalt 314 individer, vilket kan jämföras med de senare åren då det regelbundet noterats mer än 40 000 övervintrande gäss årligen (Figur 5). I januari 2022 registrerades 28 255 grågäss (Tabell 1), en siffra som är alltför låg då inga systematiska inventeringar genomfördes i södra Skåne, där merparten av de övervintrande grågässen i Sverige återfinns. Under hösten var den geografiska täckningen bättre och de 248 115 individer (Tabell 5) som observerades i september 2022 är den högsta noteringen hittills (Figur 6). Samtliga inventeringsmånader visar på samma övergripande mönster med ökande förekomster fram till ca 2010, därefter verkar en viss inbromsning i expansionen ha skett. Från Svensk Fågeltaxerings (http://fageltaxering.se/) standardrutter, som ger en geografiskt representativ bild av nationella trender hos fåglar under häckningstid, kan man skönja en likartad utveckling. Det ökade antalet grågäss som observeras under gåsinventeringarna är en kombination av att rastnings- och övervintringsområdena förskjutits norrut och att populationen i sin helhet blivit större.

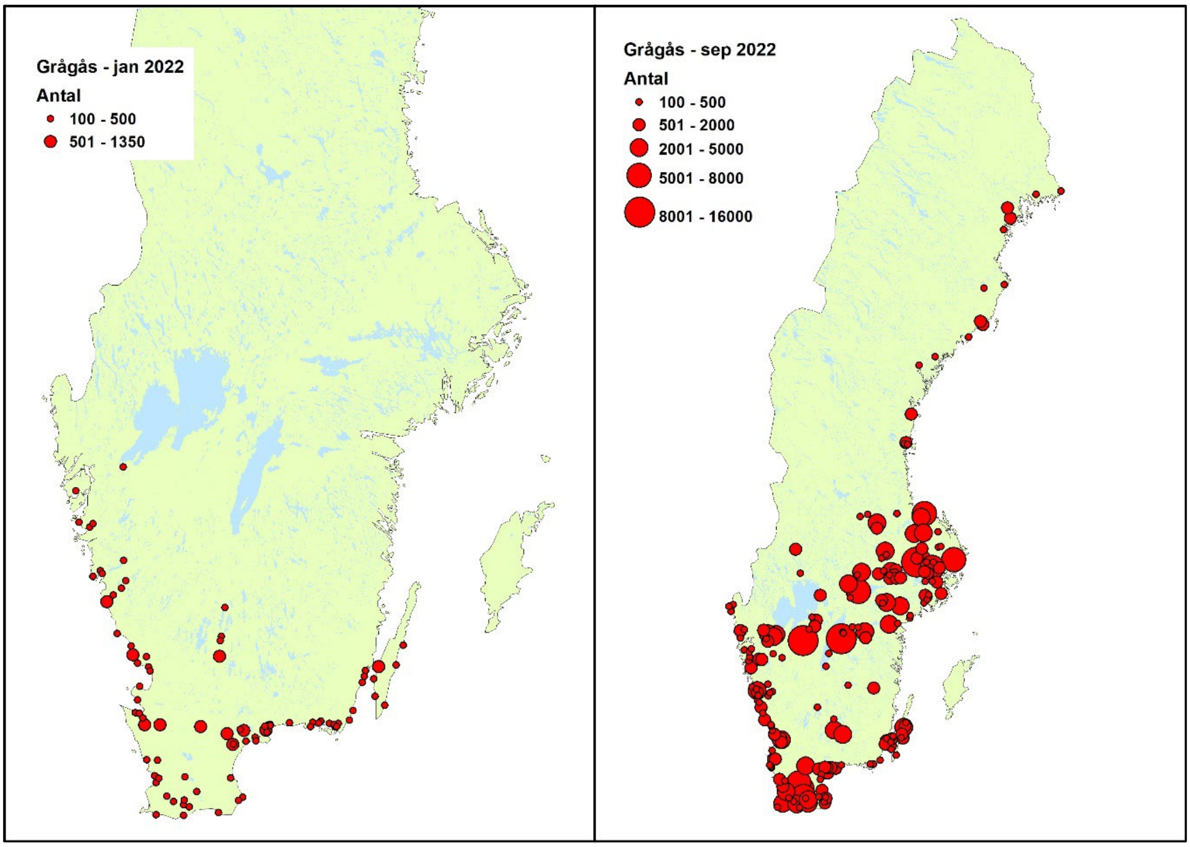
De övervintrande grågässen återfanns främst i Skåne och i kustnära områden i södra Sverige (Figur 7). I september förekom gässen främst i Mellansverige och i Skåne, men relativt stora flockar påträffades längs hela Norrlandskusten. Det fåtaliga uppträdandet under hösten i stora delar av Götalands inland är förmodligen en kombination av att grågässen uppträder relativt sparsamt där och att endast en del av den verkliga förekomsten rapporteras till Artportalen. Frånvaron av höstrastande gäss längs stora delar av Smålandskusten och Gotland kan säkerligen till stor del förklaras av det senare. Dessa utbredningsluckor, som helt säkert delvis beror på ointresse hos fågelskådare att rapportera grågäss, pekar på vikten av att utöka nätverket av frivilliga som är beredda att lägga lite tid på att genomföra riktade gåsinventeringar.



Figur 5. Antalet grågäss *Anser anser* vid januariinventeringarna i Sverige 1978 – 2022.
* indikerar att totalantalet baseras på ofullständiga inventeringar.



Figur 6. Antalet grågäss *Anser anser* vid höstinventeringarna i Sverige 1984 – 2022.
* indikerar att totalantalet baseras på ofullständiga inventeringar.

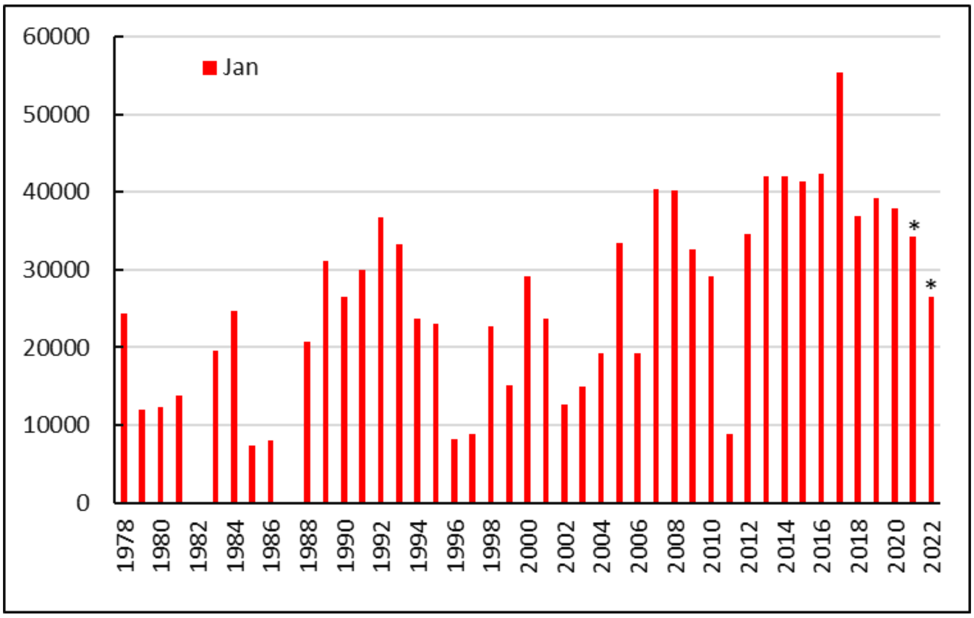


Figur 7. Grågåsens *Anser anser* utbredning i januari (södra Sverige) och september (hela Sverige) 2022.

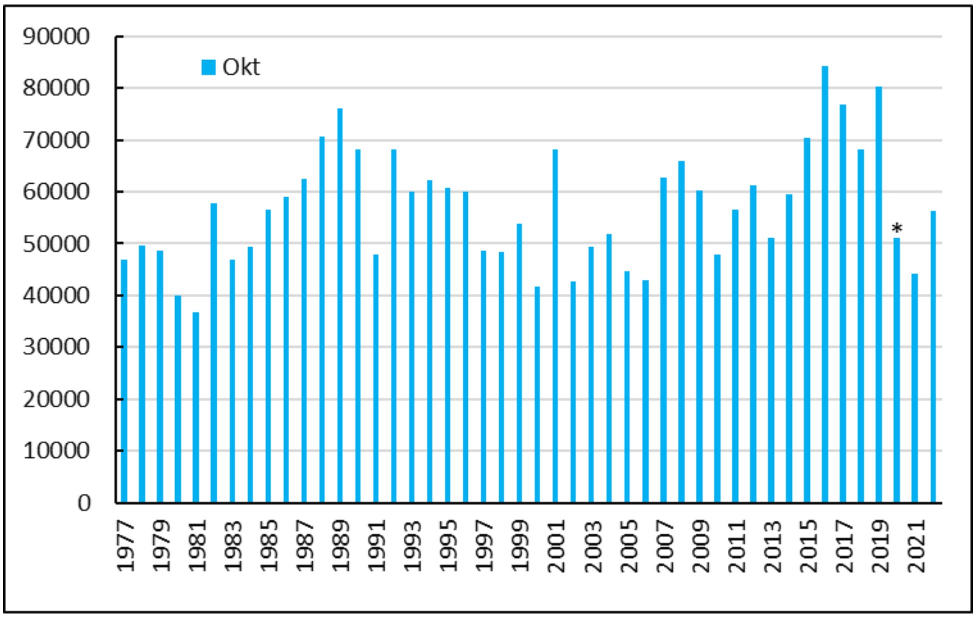
Sädgås *Anser fabalis*

I januari 2022 registrerades 26 452 och i oktober 56 346 (tabell 1) sädgäss. Under såväl rastning som övervintring förekommer två underarter av sädgås i Sverige, tajgasädgås *Anser f. fabalis* och tundrasädgås *Anser f. rossicus*. Den förstnämnda uppträder i Sverige i betydligt större antal än den senare. Man kan på goda grunder anta att den absoluta majoriteten av de sädgäss som redovisas som tajga/tundrasädgås i Tabell 1 är tajgasädgäss. Från den icke-kompletta inventeringen i januari rapporterades inga tundrasädgäss, medan det i oktober rapporterades 4266 individer. Av dessa uppehöll sig 4000 på den traditionella lokalen vid Boterstena vid sjön Östen (Vg). Oktobersiffran är ganska låg, möjligtvis beroende på att höstflyttningen var sen och att en del av de gäss som normalt räknas i Sverige under denna tid därför inte hade anlänt. En indikation på detta är att man vid Östen räknade 15 300 sädgäss i oktober, medan man i november noterade ca 25 000 i samma område. I januari är det ganska stor mellanårsvariation (Figur 8), något som till stor del kan förklaras av vintrarnas hårdhet. Under kalla vintrar med ett snötäckt landskap lämnar gässen landet för sydligare breddgrader. Antalet övervintrande sädgäss har ökat. Under de senaste tio åren har antalet övervintrande gäss legat på ca 40 000, undantaget januari 2017 då 55 000 individer registrerades. Det ökande antalet övervintrande sädgäss kan tillskrivas förändrande flyttningsvanor. Tidigare valde en större andel av gässen att flytta vidare till främst Tyskland och Nederländerna. Sett till hela inventeringsperioden 1977–2022 är det svårt att se någon uppenbar långtidstrend i antalet höstrastande gäss (Figur 9), dock finns under perioden tydliga toppar och dalar.

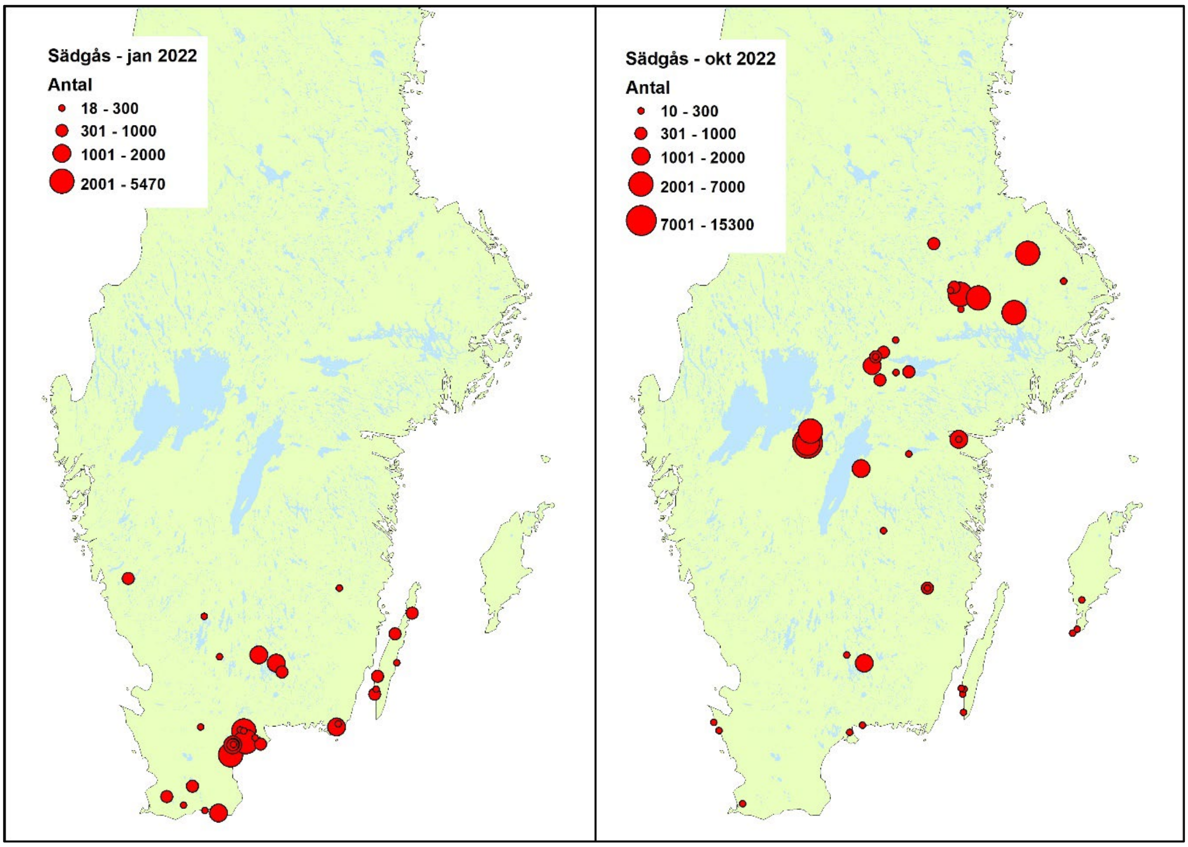
Utbredningen i januari (Figur 10) ska tas med en nypa salt. De observationer som visas är korrekta, det är de som inte visas som bidrar till en felaktig bild. Avsaknaden av riktade inventeringar i södra Skåne gör att förekomsterna i den delen av Sverige helt bygger på data från Artportalen. Baserat på data från Artportalen förekom det ca 3000 sädgäss i södra Skåne efter det att data rensats på gäss som kan ha varit dubbelrapporterade (5000 individer innan rensningen). Under de riktade gåsinventeringarna inom samma område under åren 2018–2020 observerades 10 000 till 17 500 sädgäss. I oktober rastade i det närmaste samtliga sädgäss i Mellansverige med den enskilt största förekomsten vid Östen (15 300 sädgäss varav 4000 var tundrasädgäss). Detta utbredningsmönster är relativt sentida, när inventeringarna startade 1977 fanns det stora flockar av rastande sädgäss i Skåne, medan det saknades större höstflockar vid exempelvis Östen, som då var en vårlokal för arten, men som nu är den viktigaste rastlokalen på hösten för sädgäss. Däremot finns numera endast spridda sädgäss i Skåne vid oktoberräkningen. Rastningsplatserna har således förskjutits norrut under hösten.



Figur 8. Antalet sädgäss *Anser fabalis* vid januariinventeringarna i Sverige 1978 – 2022.
* indikerar att totalantalet baseras på ofullständiga inventeringar.



Figur 9. Antalet sädgäss *Anser fabalis* vid oktoberinventeringen i Sverige 1977 – 2022.
* indikerar att totalantalet baseras på ofullständiga inventeringar.

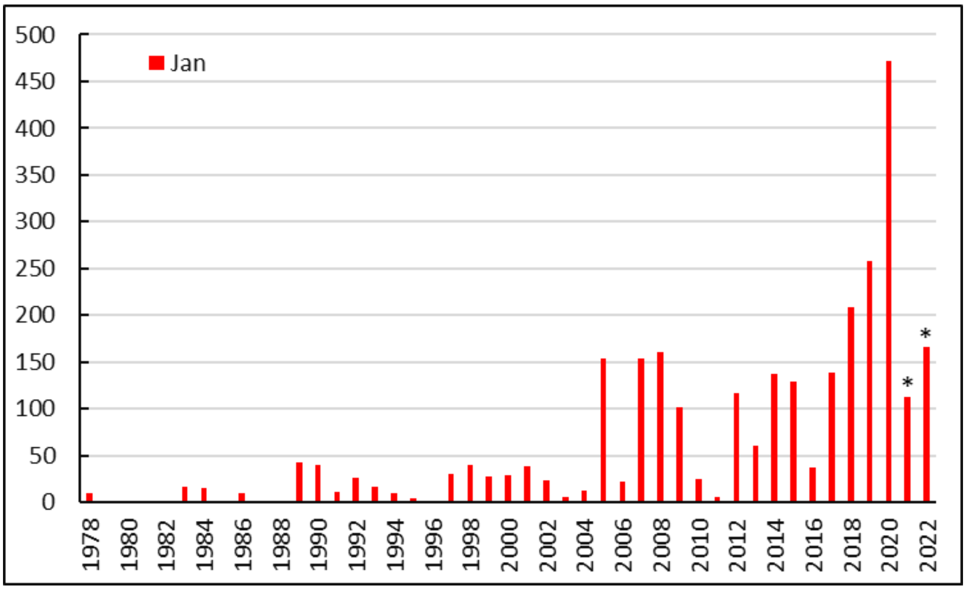


Figur 10. Sädgåsens *Anser fabalis* utbredning i södra Sverige i januari och oktober 2022.

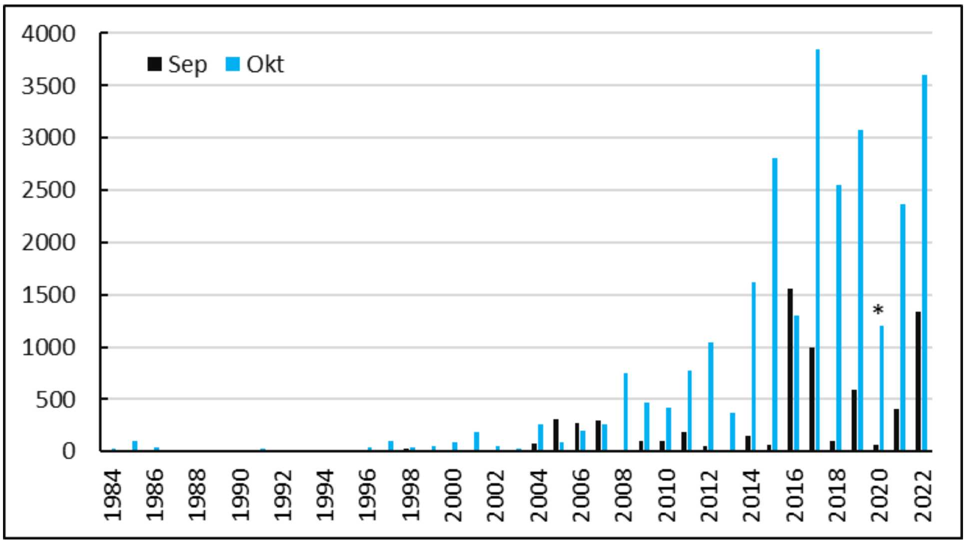
Spetsbergsgås *Anser brachyrhynchus*

Från att vid gåsinventeringarnas start varit en ganska sällsynt art ses den numera i ganska goda antal. Vid inventeringarna 2022 registrerades 166 gäss i januari, 1334 i september och 3595 i oktober (Tabell 1). Noteringen i oktober är den näst högsta hittills. Vid den senaste heltäckande januariinventeringen år 2020 räknades 472 spetsbergsgäss vilket var den högsta siffran fram till dess. För samtliga inventeringsmånader kan man se ett ökat antal från 2000-talet fram till idag (Figur 11 och 12).
Som framgår av Figur 12 har antalet inräknade spetsbergsgäss i Sverige under höstarna ökat mycket markant under de senaste 15 åren. Den kraftigaste ökningen har skett i Närke med Tysslingen som den viktigaste lokalen. Samtidigt konstaterade ornitologerna i Finland att upp till 4000 – 5000 spetsbergsgäss börjat rasta i Liminkaområdet i trakten av Oulu, som är ett känt rastområde särskilt om vårarna för sädgås. Tidigare hade regelbundet mindre antal av spetsbergsgäss setts under vårflyttningen både på den finska och svenska sidan av Bottenviken, men aldrig stora flockar.

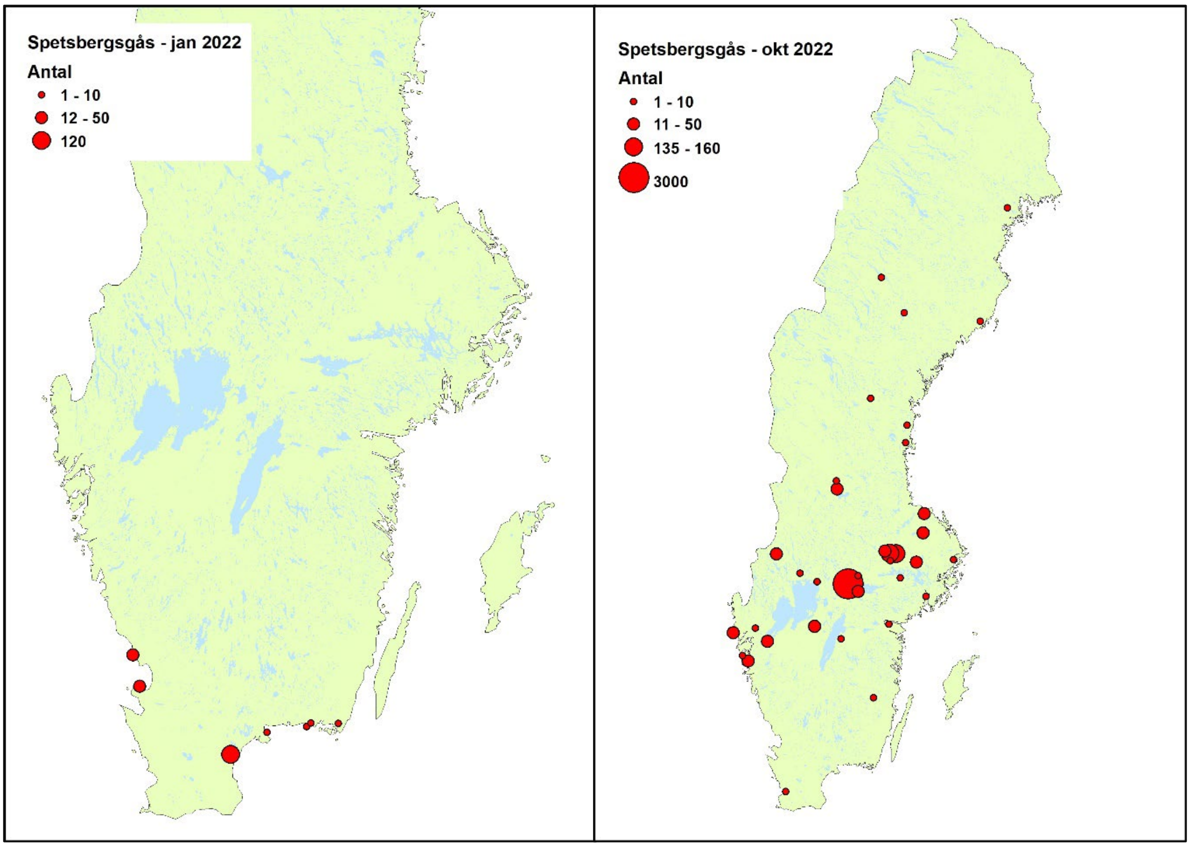
För att närmare studera fenomenet fångades spetsbergsgäss både i vinterområdena och i Finland och märktes med halsringar och satellitsändare. Resultaten från dessa märkningar visade att gässen flyttade till Novaja Zemlja där flera av dem av allt att döma häckade. Spetsbergsgässen hade alltså etablerat en helt ny flyttningsväg och ett nytt häckningsområde. Hela historien har dokumenterats i en uppsats av Madsen m.fl. (2023) i Current Biology 33:1–9.



Figur 11. Antalet spetsbergsgäss *Anser brachyrhynchus* vid januariinventeringarna i Sverige 1978 – 2022. * indikerar att totalantalet baseras på ofullständiga inventeringar.



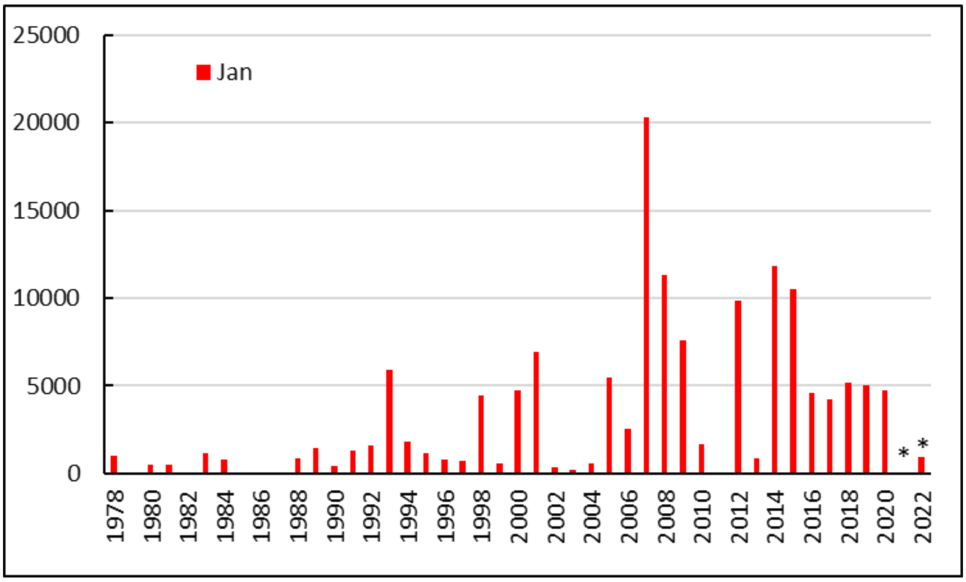
Figur 12. Antalet spetsbergsgäss *Anser brachyrhynchus* vid höstinventeringarna i Sverige 1984 – 2022. * indikerar att totalantalet baseras på ofullständiga inventeringar.



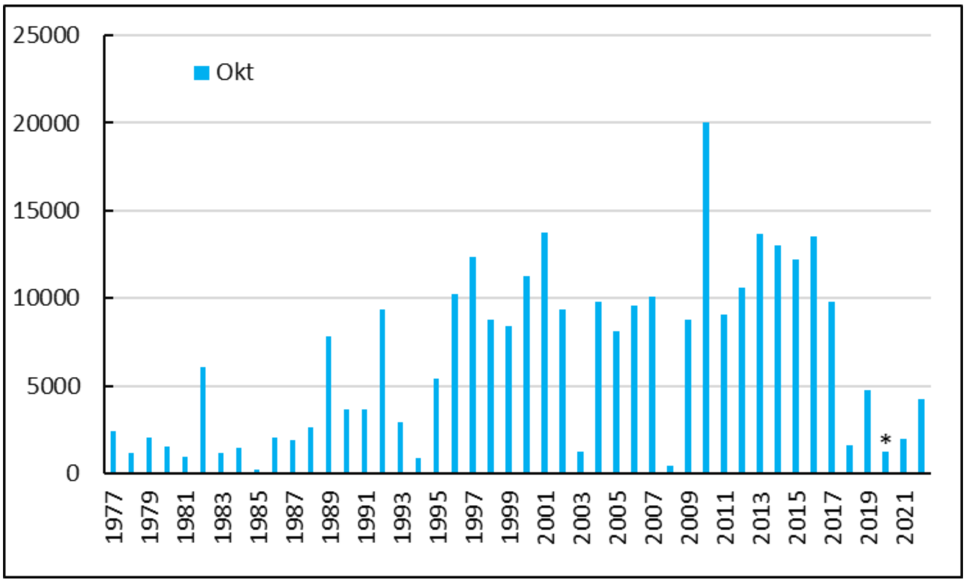
Figur 13. Spetsbergsgåsens *Anser brachyrhynchus* utbredning i januari (södra Sverige) och oktober (hela Sverige) 2022.

Bläsgås *Anser albifrons*

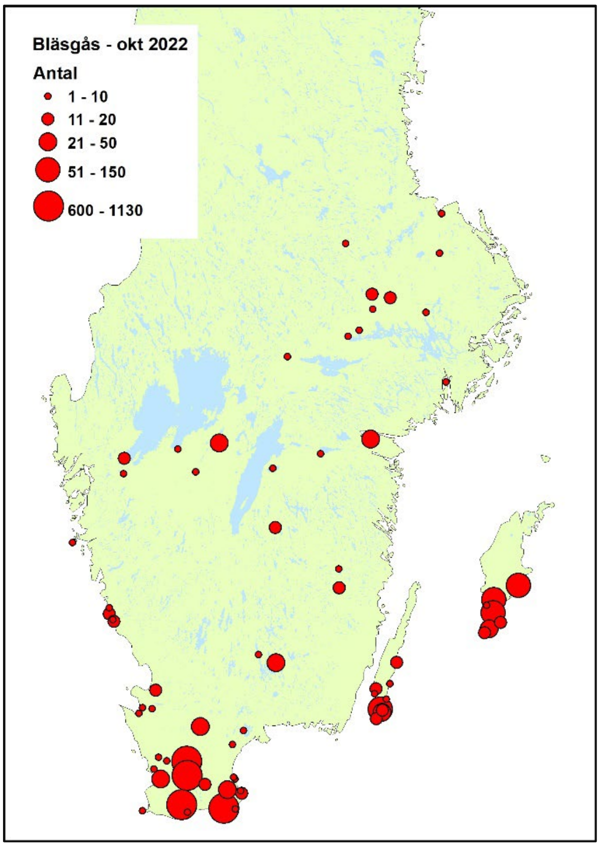
De största mängderna övervintrande bläsgäss brukar återfinnas i södra Skåne, dvs i det område som inte inventerades tillfredsställande i januari 2022. Det som kort kan konstateras är att antalet övervintrande bläsgäss ökade fram till perioden 2005–2015 (Figur 14). Efter denna period, då det regelbundet observerades fler än 10 000 gäss, verkar en minskning skett. Under senare år har ett typiskt antal legat på runt 5000. Utvecklingen i oktober (Figur 15) påminner om den i januari. Här kan man se ett ökande antal fram till mitten av 1990-talet, som sen åtföljs av en relativt stabil period fram till 2017. Därefter har betydligt färre bläsgäss registrerats. AI oktober påträffades bläsgäss i stora delar av södra Sverige med de största antalen i Skåne och på Gotland och Öland (Figur 16). Anledningen till minskningen i januari är oklar, men i oktober skulle den kunna bero på att bläsgässen senarelagt höstflyttningen och att inventeringarna i oktober därmed ligger innan rastningstoppen.



Figur 14. Antalet bläsgäss *Anser albifrons* vid januariinventeringarna i Sverige 1978 – 2022.
* indikerar att totalantalet baseras på ofullständiga inventeringar.



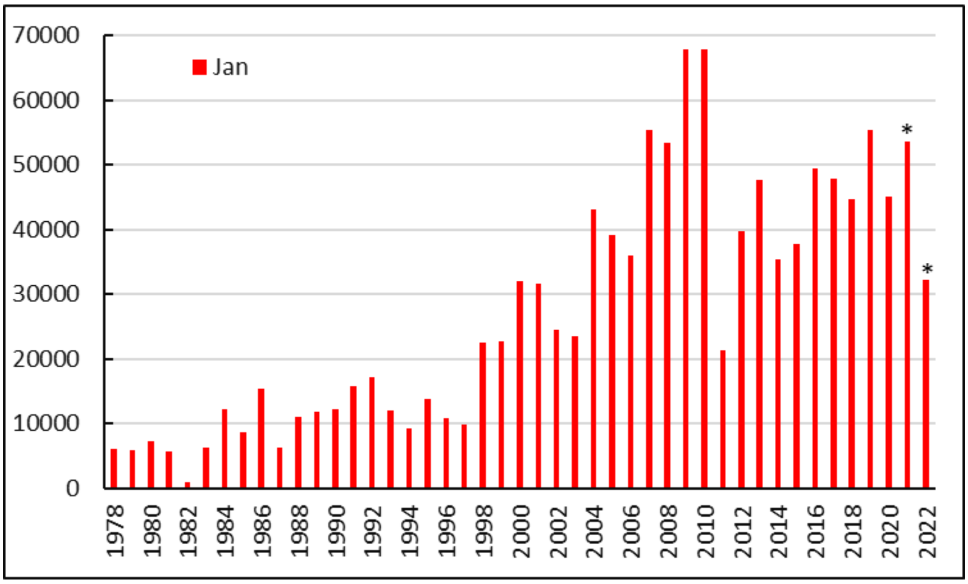
Figur 15. Antalet bläsgäss *Anser albifrons* vid oktoberinventeringarna i Sverige 1977 – 2022. * indikerar att totalantalet baseras på ofullständiga inventeringar.



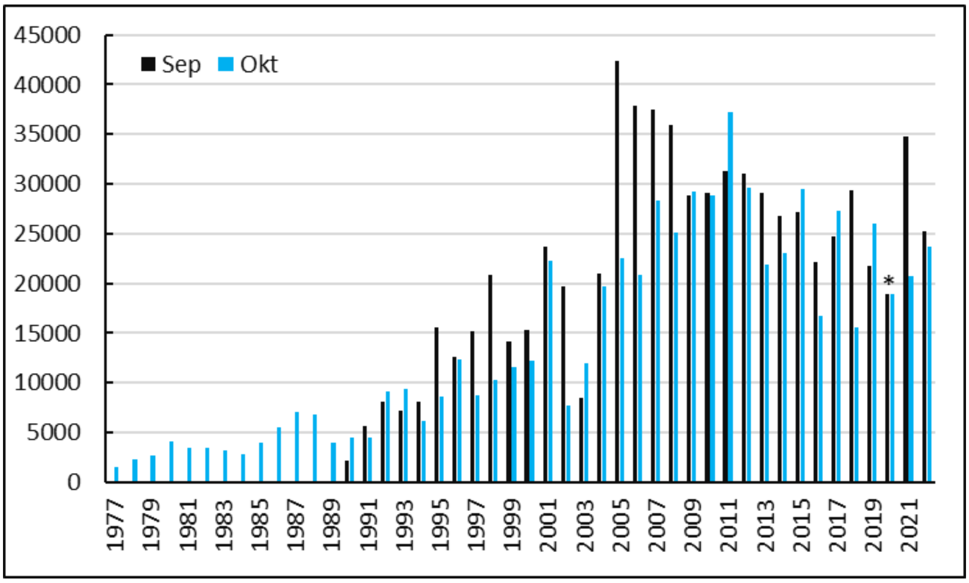
Figur 16. Bläsgåsens *Anser albifrons* utbredning i södra Sverige i oktober 2022.

Kanadagås *Branta canadensis*

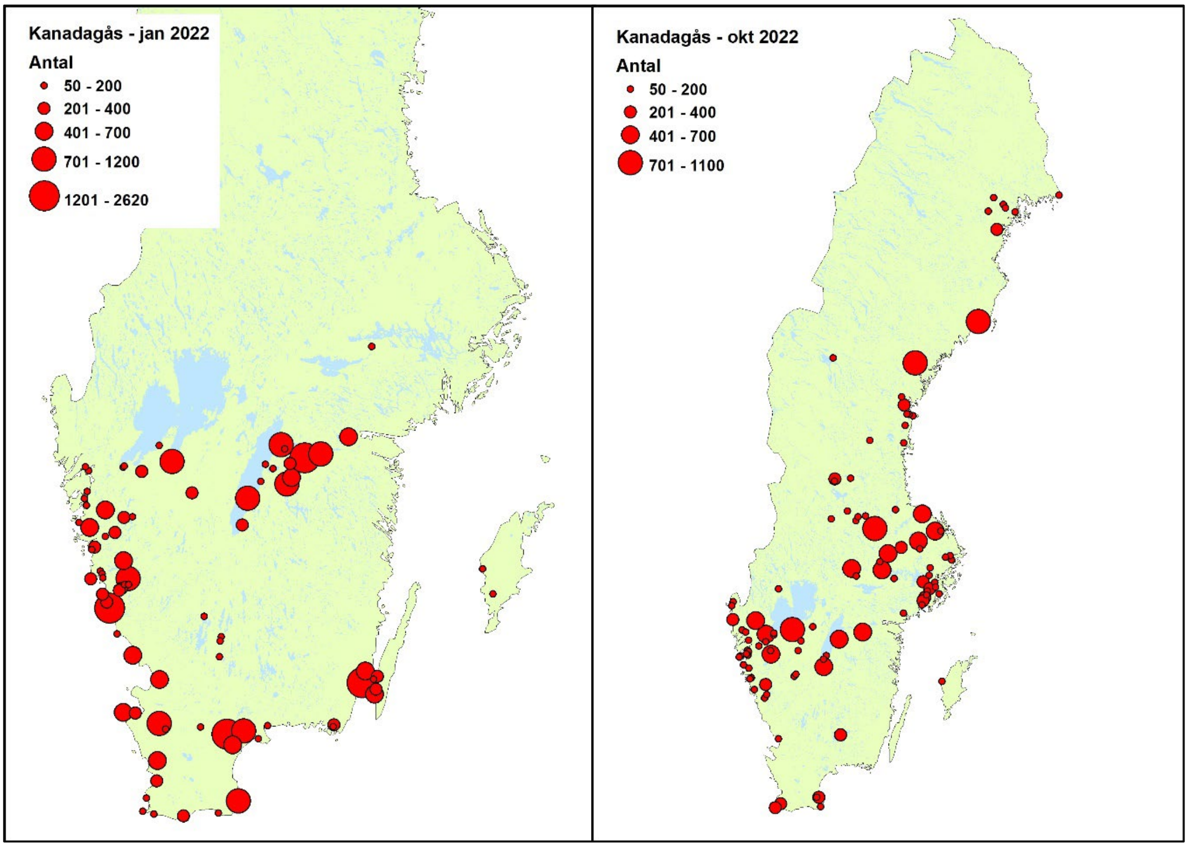
Att få till något som ens liknar heltäckande inventeringar av kanadagås under höstmånaderna är i det närmaste ogörligt då de under den årstiden förekommer spritt över stora delar av landet. I januari räknades 32 296 gäss medan det under september och oktober registrerades 25 258 respektive 23 754 individer (Tabell 1). Antalet övervintrande gäss (Figur 17) ökade fram till slutet av 2000-talet, för att därefter minska till en nivå som varit relativt stabil. Utvecklingen i oktober (Figur 18) har varit likartad. Baserat på bl.a. inventeringarna av kanadagås i oktober visade Liljebäck m.fl. (Wildlife Biology 2021: wlb.00733) att antalet rastande kanadagäss ökade signifikant fram till 2010 för att därefter minska och att denna minskning åtminstone delvis var kopplad till jakt.
Till skillnad från övriga gåsarter återfanns en hel del övervintrande kanadagäss i Mellansverige och då främst i Östergötland (Figur 19). Därutöver påträffades de främst i kustnära områden i södra Sverige. I oktober noterades de flesta kanadagässen i Mellansverige, men enstaka större förekomster registrerades även längs norrlandskusten.



Figur 17. Antalet kanadagäss *Branta canadensis* vid januariinventeringarna i Sverige 1978 – 2022. * indikerar att totalantalet baseras på ofullständiga inventeringar.



Figur 18. Antalet kanadagäss *Branta canadensis* i Sverige i september 1990 – 2022 och i oktober 1977 – 2022. * indikerar att totalantalet baseras på ofullständiga inventeringar.



Figur 19. Kanadagåsens *Branta canadensis* utbredning i januari (södra Sverige) och oktober (hela Sverige) 2022.

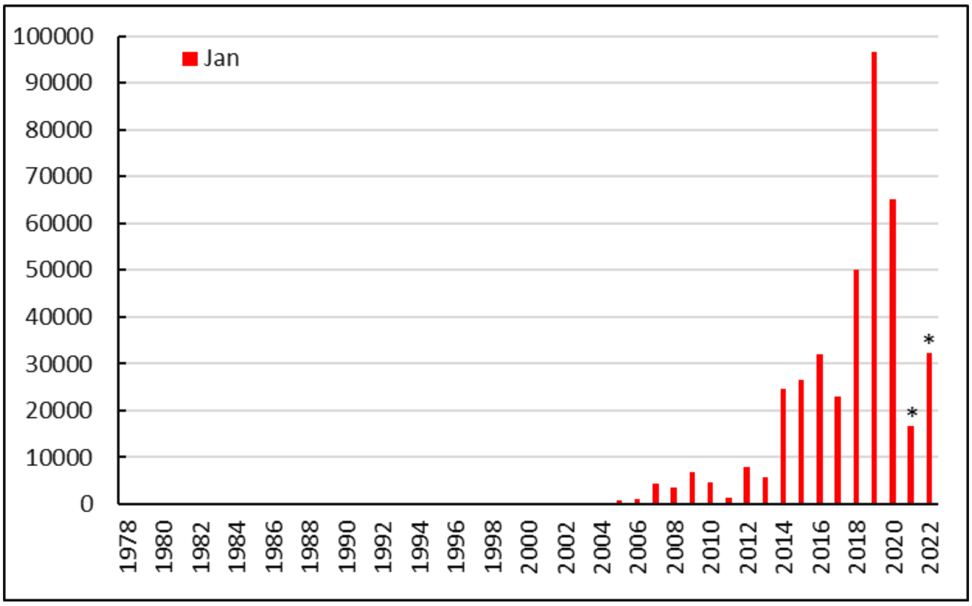
Vitkindad gås *Branta leucopsis*

Förekomsten av vitkindad gås är den som genomgått den mest dramatiska förändringen under inventeringarnas gång. Antalet övervintrande gäss var som mest några hundra fram till 2005, efter dess har det skett en kraftig ökning (Figur 20). År 2019 noterades 97 000 individer, vilket är den högsta noteringen hittills. Antalet för januari 2022 summerades till drygt 32 000 fåglar, men då utan att några egentliga gåsinventeringar genomförts i södra Skåne. En tjuvtitt på vad som rapporterades från detta område i januari 2023, då riktade inventeringar genomfördes, ger följande: ca 90 000 registrerades i området i fråga, dvs nära nog tre gånger så många som totalsumman för hela Sverige 2022.

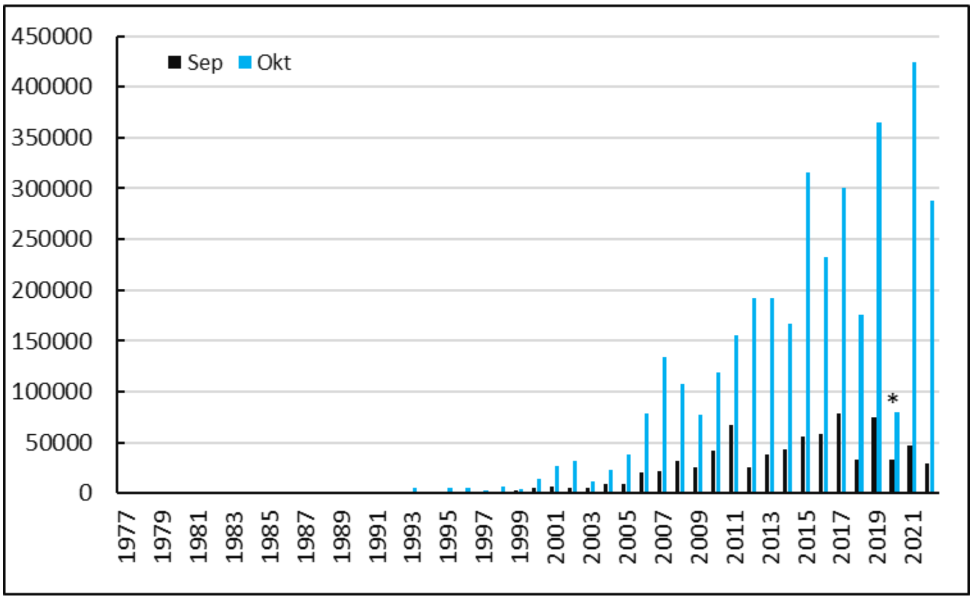
Ökningen av antalet övervintrande gäss kan tillskrivas två faktorer, ökande populationsstorlek och en förskjutning av övervintringsområdet norrut. År 1981 skattades den population som häckar i Ryssland och övervintrar i Västeuropa till under 100 000, knappt 40 år senare (2018) skattades den till 1,4 miljoner – den årliga ökningen under denna period har varit ca 9% (Barnacle goose Russia/Germany & Netherlands population - AEWA status report 1980-2018). I början av 1980-talet övervintrade mer än 90 % av denna population i Nederländerna, år 2018 var andelen nere i 58 %. Under samma period har andelen som övervintrar i Tyskland, Danmark och Sverige ökat. Föga förvånande har även antalet höstrastande vitkindade gäss ökat kraftigt i Sverige (Figur 21). Septembersiffrorna påverkas väsentligt av höstflyttningens förlopp. Vissa år har relativt många gäss anlänt från tundran, andra år har färre hunnit komma vid tiden för inventeringen. Liksom i januari observerades det i oktober låga antal fram till början av 2000-talet, efter det har det skett en kraftig ökning. Under de tre senaste åren med kompletta inventeringar i oktober har det registrerats

290 000 till 425 000 rastande individer. Givet en total populationsstorlek på 1,4 miljoner så innebär det att 20–30 % av totalpopulationen rastade samtidigt i oktober i Sverige under de åren.

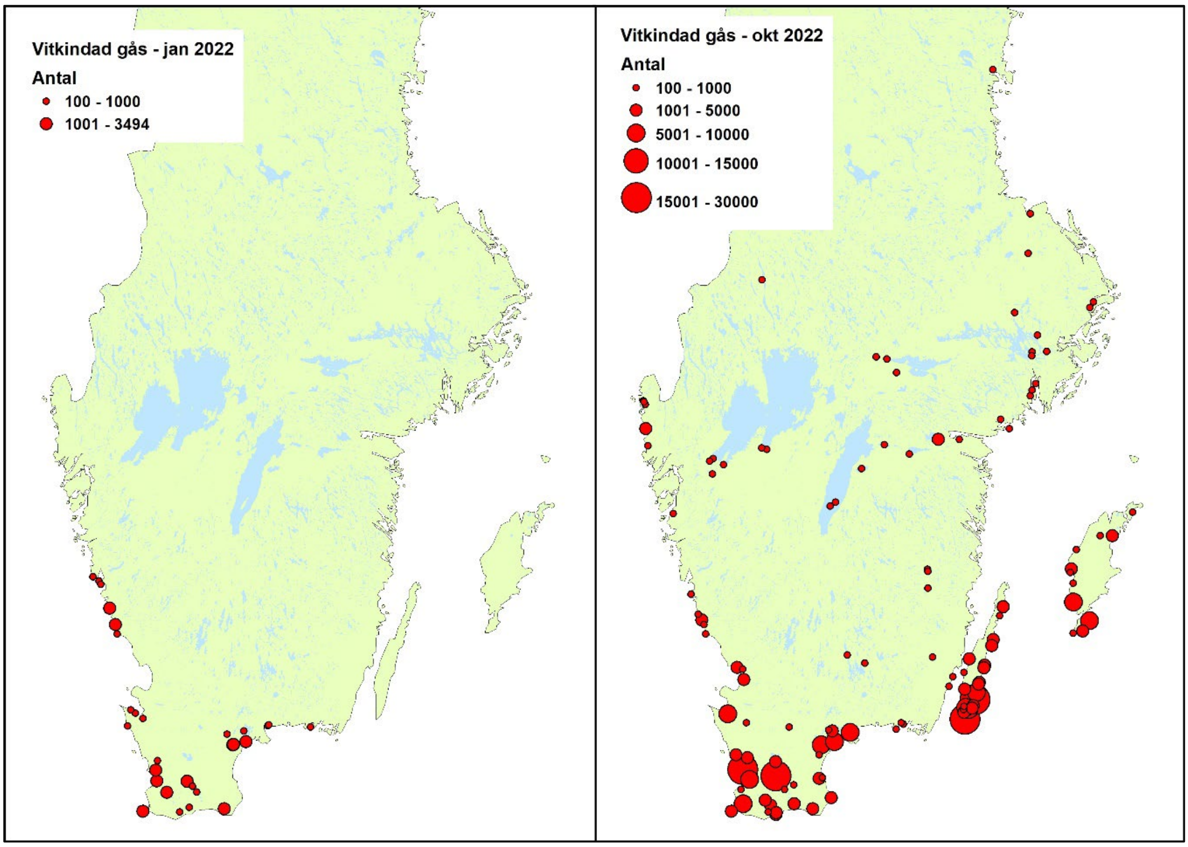
I januari 2022 begränsades förekomsten till södra Sveriges kustområden och till Skåne (Figur 22). I oktober uppträdde flockar av rastande vitkindade gäss ganska spritt i södra Sverige, men de riktigt stora koncentrationerna återfanns på Öland och i Skåne. Av de totalt 288 600 individer som registrerades sågs 118 030 gäss i det förstnämnda landskapet och 100 195 i det sistnämnda.



Figur 20. Antalet vitkindade gäss *Branta leucopsis* vid januariinventeringarna i Sverige 1978 – 2022. * indikerar att totalantalet baseras på ofullständiga inventeringar.



Figur 21. Antalet vitkindade gäss *Branta leucopsis* i Sverige i september 1990 – 2022 och i oktober 1977 – 2022. * indikerar att totalantalet baseras på ofullständiga inventeringar.



Figur 22. Den vitkindade gåsens *Branta leucopsis* utbredning i södra Sverige i januari och oktober 2022.

Ungfågelinventeringar

Under hösten 2022 inventerades ungfåglar av tajgasädgås, grågås och vitkindad gås. Syftet var att beräkna förhållandet mellan gamla och unga fåglar för att få ett mått på respektive arts häckningsframgång. Resultaten från dessa inventeringar presenteras i Tabell 2. Tajgasädgässen räknades främst i Närke och där utgjorde ungfåglarna 11,9 % av de kontrollerade fåglarna, resultatet från motsvarande inventering i Småland var snarlikt. Ungfågelräkningar av grågäss utfördes i sju landskap. Under dessa inventeringar åldersbestämdes 10 162 gäss (gamla+unga) i 45 flockar. Andelen ungfåglar varierade avsevärt mellan landskapen. I Skåne, Blekinge och Uppland låg andelen ungfåglar på 2,5–4,4 %, i övriga landskap mellan 10,7 och 15,1 %. Andelen ungfåglar totalt hamnade på 5,0 % medan medelvärdet för landskapsandelarna var 8,5 %. Vitkindad gås studerades i tre landskap: i de två sydliga noterades 40,4 respektive 51,0 % ungfåglar vilket kan jämföras med 8,3 % ungfåglar i Västerbotten.

En fråga som måste ställas är om de stora skillnaderna i andelen ungfåglar mellan olika landskap hos grågås och vitkindad gås speglar verkligheten, dvs regionala skillnader i häckningsframgång, eller om stickproven inte varit representativa? På detta finns inget säkert svar, men för dessa två arter krävs inför kommande säsonger att inventeringsmetodik, tidpunkt för inventeringarna och geografiskt urval tänks igenom. Andelen ungfåglar av de arter som inventerats under 2022 ska rapporteras till EGMP (https://egmp.aewa.info/). Här förväntas det att respektive rapporterande land ska komma in med årsvisa skattningar av andelen ungfåglar för i landet i stort, dvs ett värde per art och land. Hur Sverige ska lyckas med det för grågås och vitkindad gås, som båda i stort sett häckar i hela landet, är en nöt att knäcka.

Tabell 2. Andel (%) ungfåglar per landskap av totalantalet kontrollerade fåglar (Ind, vuxna + unga) inom landskapet samt det antal flockar som gässen kontrollerats i. "Andel ungfåglar" baseras på totalsummorna för antalet ungfåglar respektive kontrollerade gäss, "Medel" är medelvärdet av landskapsandelarna.

	Taigasädgås			Grågås			Vitkindad gås		
Landskap	**Andel**	**Ind**	**Flock**	**Andel**	**Ind**	**Flock**	**Andel**	**Ind**	**Flock**
Skåne				2,5	6507	15	40,4	166	2
Blekinge				4,3	793	4	51,0	110	2
Småland	11,5	312	1						
Södermanland				15,1	377	2			
Närke	11,9	2538	5	10,7	336	2			
Uppland				4,4	384	2			
Hälsingland				11,1	741	4			
Västerbotten				11,7	1024	16	8,3	193	2
Totalt		**2850**	**6**		**10162**	**45**		**469**	**6**
Andel ungfåglar	**11,9**			**5,0**			**29,7**		
Medel	**11,7**			**8,5**			**33,2**		

Tack

Först av allt, stort tack till alla inventerare som år efter år hjälper till med att inventera gäss. Utan de insatserna skulle denna rapport inte ha kunnat skrivas.
Inventeringarna av sjöfåglar och gäss finansieras av Naturvårdsverket, tema landskap. De riktade gåsinventeringarna av gäss i september och oktober finansierades även de av Naturvårdsverket.

APPENDIX 4

Summer count of Greylag Geese in Denmark 2022

Scientific briefing from DCE – Danish Centre for Environment and Energy

Date: 3. Januar 2023 | **1**

AARHUS UNIVERSITY

DCE - DANISH CENTRE FOR ENVIRONMENT AND ENERGY

Data sheet

Scientific briefing from DCE – Danish Centre for Environment and Energy

Category: Scientific briefing

Title: Summer counts of Greylag Geese in Denmark 2022

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Front page photo: Greylag Geese. By J.P. Kjeldsen

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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.

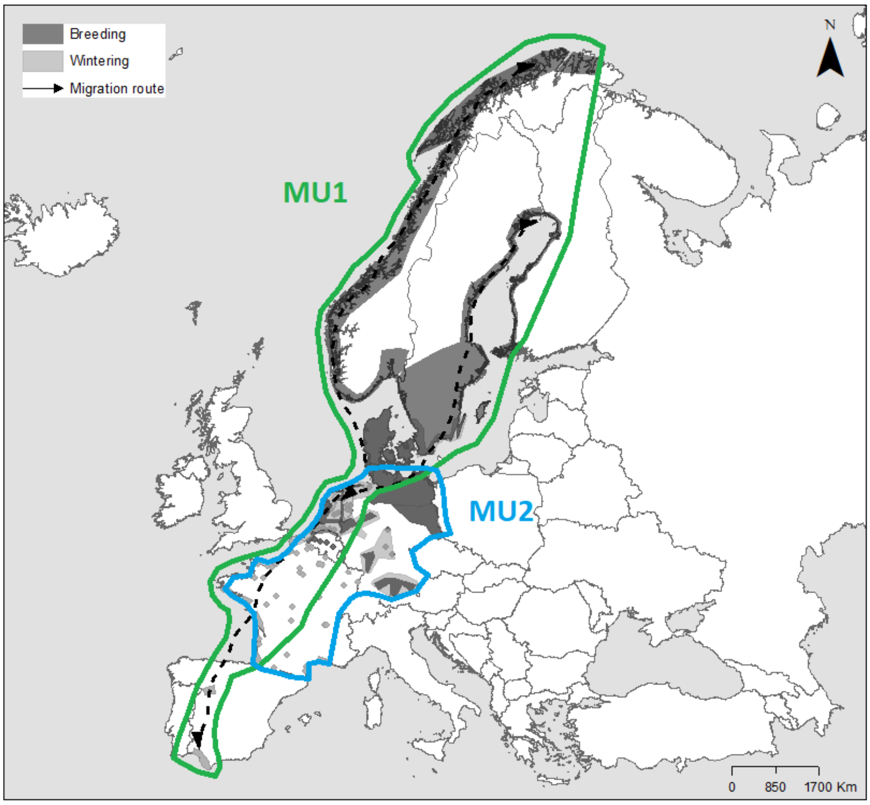
In Denmark Greylag Geese counts are covered by the NOVANA (the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environment) monitoring program, and have since the 1980s been counted during January and September, but not during summer, except every six year where a country-wide 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.

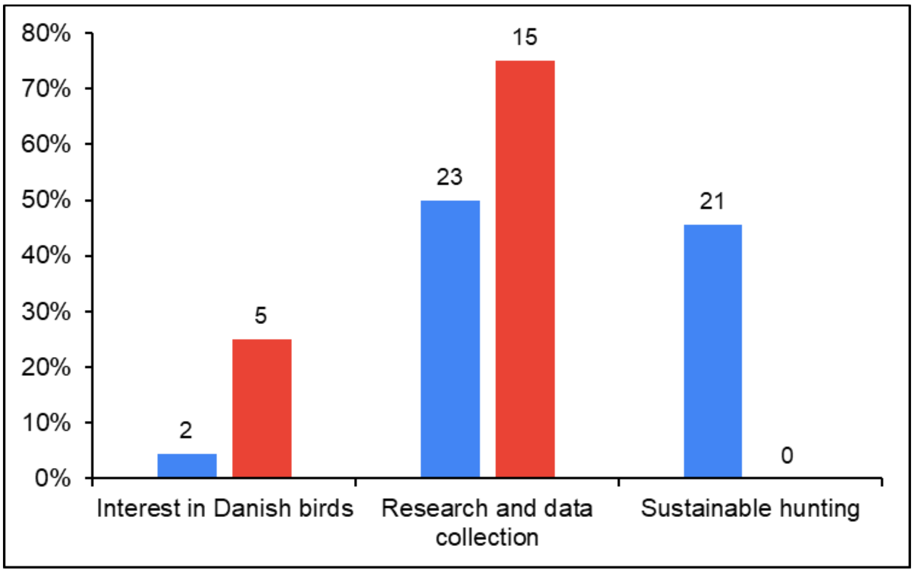


Figure 3. Primary motivation (% of respondents) for the two main groups involved in the Greylag Goose summer count, hunters (blue) and birdwatchers (red). Data labels indicate the number of replies in each category.

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.

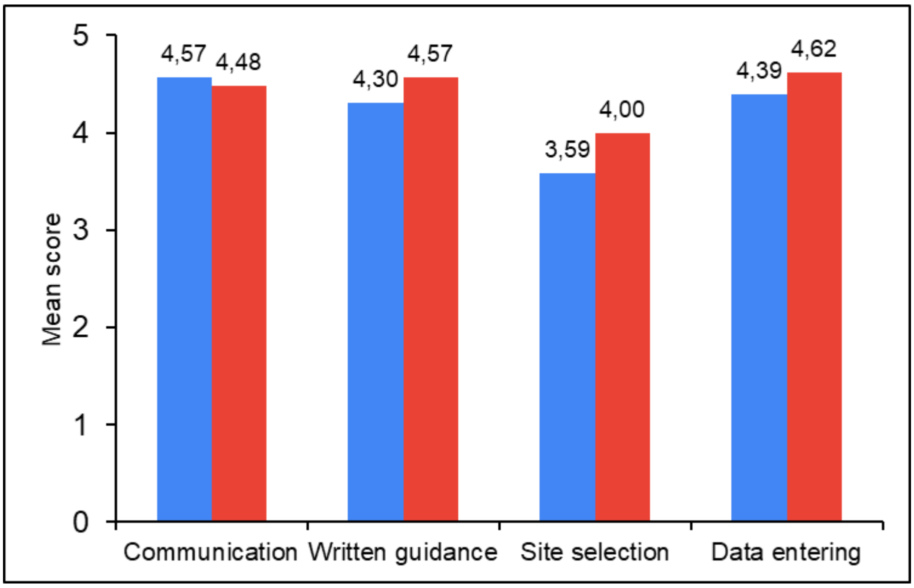


Figure 4. Level of satisfaction by hunters (blue) and birdwatchers (red) with the various parts of the process, as indicated by 72 respondents to our post-count questionnaire. Data labels indicate the mean score of each communication process.

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).

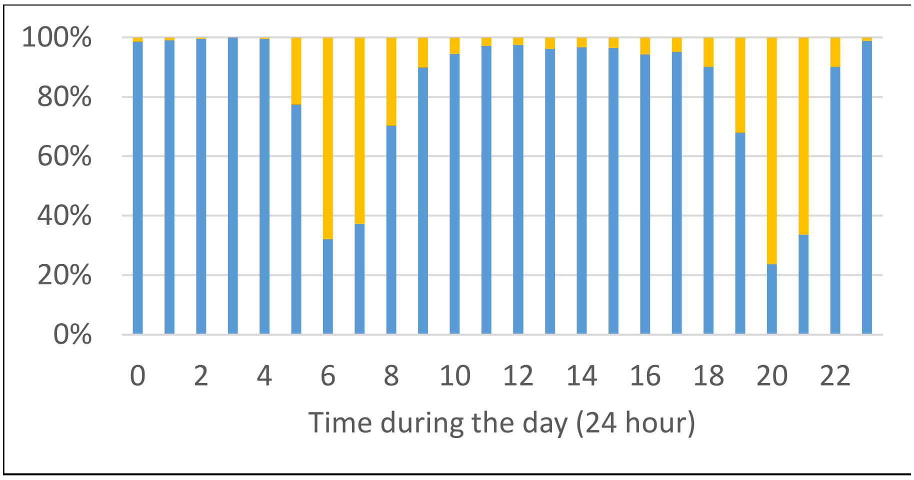


Figure 5. Percentage of Greylag Geese foraging (yellow) and roosting (blue) during 24 hours in week 31 (1-7 August 2022) at Agersø, Denmark. Figure by Signe Wiemann Cieslak

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 m² 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.

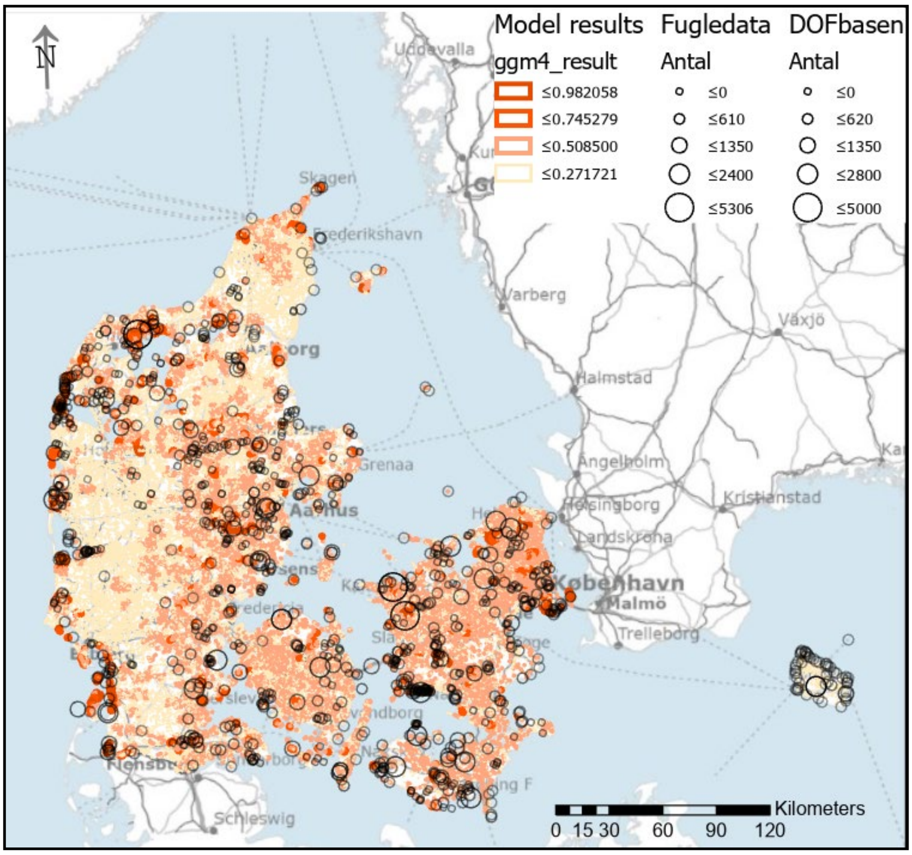


Figure 6. Field observations (open circles) and predicted probability of occurrence (red-sand colours) of Greylag Geese during early August in Denmark. The predictions were computed using a GLM model and values of wetland area, presence of breeding pairs, area of agricultural land, area of grassland,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

t.

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

APPENDIX 5

Aarhus University

Estimating the Approximate Number of Breeding Pairs of Greylag Geese from "Summer" Censuses

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20 January 2024

In this document, we provide a description of how the number of breeding pairs in the spring might be calculated from post-breeding censuses for the two management units of the NW/SW European Population of Greylag Geese. We stress that the method only gives a rough approximation for the number of breeding pairs because data are insufficient to do otherwise. In particular, the age structure of the population in the censuses is unknown, and there are no empirical estimates of breeding propensity nor summer survival of breeding birds. Nonetheless, we can use the general structure and initial parameterization of a post-breeding matrix model for Greylag Geese to perform the calculations (AEWA EGMIWG Inf.8.14 GG Modelling Progress Report .pdf. We note that the original matrix model has three age classes, but we recently realized that 4-age classes are required to correctly account for breeding only at age 3+ years. In what follows, we explicitly account for uncertainty about model parameters to the extent possible. *However, we cannot stress strongly enough that there are insufficient empirical data to verify our estimates of the number of breeding pairs and, thus, we urge caution in their use.*

We here provide the steps for performing the calculations and describe the assumptions adopted. The R code and data are provided as appendices.

1. Determine the finite rates of population growth (λ) from the censuses in each management unit for an appropriate multi-year period using a log-linear model. We used 2017 – 2022 in what follows. Generate thousands of replicates of λ for each unit based on the slope and se(slope) of the log-linear models.
2. Generate the same number of replicates of annual survival in the absence of offtake using the method of Johnson et al. (2012). To estimate survival in the presence of offtake, we assume that the rate of offtake of adults and juveniles is 0.1 (Johnson and Koffijberg 2021) and that annual survival of young is 90% of that of older birds. Initially, we assume these survival rates are applicable to both management units. These assumptions can easily be modified if desired.
3. Use the replicate estimates of annual survival to construct replicate population matrices for each management unit, in which the recruitment rate is the only unknown. Then for each management unit, estimate the replicate recruitment rates by finding the root of a function equating the dominant eigen value of the replicate matrices with the empirical estimates of population growth rate.
4. Once the replicate estimates of recruitment are available for each management unit, construct replicate, fully parameterized population matrices. From these matrices, calculate replicates of the stable age distributions in the fall.

5. Obtain the the fall census values for each management unit, draw replicates assuming a Poisson distribution, and multiply these by the replicates of the third element of the stable age distributions to generate replicates of the number of birds aged ≥3 years in fall. We used estimates of 2022, but only for the countries for which they were available.
6. For Management Unit 2 (sedentary), divide the replicates of adults in fall by 2 times the square root of annual survival of adults. Thus, we assume six months of mortality (both from natural causes and offtake) from spring to fall. For Management Unit 1 (migratory), we assume that no offtake occurs during the breeding season, so we divide the number of adults in fall by 2 times the square root of the natural survival rate. In both cases, dividing by 2 assumes that the breeding propensity of birds aged ≥3 years is 1 (while that of birds aged 2 years is zero). We now have replicates of the number of breeding pairs for each management unit.
7. Generate the means and confidence intervals of these estimates.

We here provide some preliminary results. Annual survival rates for both management units (mean and 95% confidence intervals) are:

- Survival of birds aged ≥2 years: 0.795 (0.709 – 0.849)
- Survival of birds aged <2 years: 0.716 (0.638 – 0.764)

For Management Unit 1 (migratory):

- Population growth rate 2017 – 2022: 1.032 (0.957 – 1.111)
- Recruitment rate: 0.562 (0.430 – 0.780), equating to a fall proportion of young of 0.358 (0.300 – 0.438)
- Stable age distribution:
$$\begin{bmatrix} 0.248 & (0.216 - 0.293) \\ 0.172 & (0.156 - 0.192) \\ 0.132 & (0.125 - 0.140) \\ 0.447 & (0.375 - 0.503) \end{bmatrix}$$
- For a fall population of 389,115 (Sweden + Denmark) in 2022, the estimated number of breeding pairs is 119,984 (109,963 – 129,196). In 2018, the number of breeding pairs (all countries) in Management Unit 1 was believed to be about 84,000 (S. Nagy, pers. commun.).

For Management Unit 2 (sedentary):

- Population growth rate 2017 – 2022: 1.050 (1.024 – 1.077)
- Recruitment rate: 0.636 (0.470 – 1.050), equating to a fall proportion of young of 0.384 (0.320 – 0.0.512)
- Stable age distribution:
$$\begin{bmatrix} 0.262 & (0.227 - 0.333) \\ 0.178 & (0.162 - 0.207) \\ 0.559 & (0.460 - 0.611) \end{bmatrix}$$
- For a fall population of 629,302 (Netherlands + Nordrhein-Westfalen,Germany) in 2022, the estimated number of breeding pairs is 196,918 (171,770 – 209,963). In

2018, the number of breeding pairs (all countries) in Management Unit 2 was believed to be about 139,401 (S. Nagy, pers. commun.).

Appendix I: R code for estimating the number of breeding pairs of Greylag Geese in Management Units 1 and 2.

```
rm(list=ls())

library(popbio)     # library for matrix model analyses

z = 10000 # no. of replicates
seed = 1234
CI.fun = function(x) {
  mu = mean(x)
  CI = quantile(x,probs=c(0.025,0.975))
  return(c(mu,CI))
}

# post-breeding population growth rates ######################
counts = read.csv('GGSummercounts.csv',header=TRUE)

m1 = with(counts,lm(log(SE_sept[13:18])~year[13:18])) # 2017-22 SWEDEN only
set.seed(seed)
lambda1 = exp(rnorm(z,mean=m1$coef[2],sd=sqrt(diag(vcov(m1)))[2]))
CI.fun(lambda1)

m2 = with(counts,lm(log(NL[13:18])~year[13:18]))
set.seed(seed)
lambda2 = exp(rnorm(z,mean=m2$coef[2],sd=sqrt(diag(vcov(m2)))[2]))
CI.fun(lambda2)

# estimates of survival ########################################
# method of moments for gamma distribution
MOM.gamma = function(mean,var) {
 gamma.s = var/mean
 gamma.a = mean/gamma.s
 return(c(gamma.a,gamma.s))
 }

s.fcn = function(mass,p,alpha) {
  set.seed(seed)
  p^(1/(exp(3.22+0.24*log(mass)+rnorm(z,0,sqrt(0.087)))-alpha))
}

# ... replicates of body mass
mean.var = function(mu1,sd1,mu2,sd2) mean(sd1^2,sd2^2) + ((mu1-mu2)/2)^2
```

```
alpha = 3
massm.mean = 3.509 # male mass (Dunning 2008)
massm.sd = 0.321
massf.mean = 3.108 # female mass (Dunning 2008)
massf.sd = 0.274
mass.mean = (massm.mean+massf.mean)/2
mass.var = mean.var(massm.mean,massm.sd,massf.mean,massf.sd)
gamma.parm = MOM.gamma(mass.mean,mass.var)
set.seed(seed)
mass = rgamma(z,shape=gamma.parm[1],scale=gamma.parm[2]) # generate mass replicates

# ... replicates of proportion alive at max longevity (Johnson et al. 2012)
set.seed(seed)
p = rbeta(z,3.34,101.24)

# ... replicates of survival
phia = s.fcn(mass,p,alpha)*0.9 # adult survival (*0.9 assumes h = 0.1)
phiy = phia*0.9          # young survival
CI.fun(phia)
CI.fun(phiy)

#... MU1

# estimate recruitment rate ######################################
r1 = NULL
for (i in 1:z) {
  fcn = function(x) {
    lambda1[i]-
as.numeric(eigen(matrix(c(0,0,phia[i]*x,phiy[i],0,0,0,phia[i],phia[i]),nrow=3,ncol=3,byrow=T)
)$values[1])}
  r1[i] = round(uniroot(fcn,c(0,5),extendInt='yes')$root,2)
}
CI.fun(r1)
CI.fun(r1/(1+r1))

# generate SADs ################################################
SAD1 = matrix(nrow=3,ncol=z)
lam1 = NULL
for (i in 1:z) {
  A = matrix(c(0,0,phia[i]*r1[i],phiy[i],0,0,0,phia[i],phia[i]),ncol=3,byrow=TRUE)
  lam1[i]=as.numeric(eigen(A)$values[1])
  SAD1[,i] = eigen.analysis(A)$stable.stage
}
apply(SAD1,1,CI.fun)

# generate breeding-pair estimates ##############################
set.seed(seed)
```

```
N1 = rpois(z,counts$SE_sept[18]+counts$DK_Sep[18])
CI.fun(N1)
Afall1 = SAD1[3,] * N1
bp1 = Afall1/(2*sqrt(phia/0.9)) # no summer offtake
CI.fun(bp1)

#... MU2

# estimate recruitment rate ####################################
r2 = NULL
for (i in 1:z) {
  fcn = function(x) {
    lambda2[i]-
as.numeric(eigen(matrix(c(0,0,phia[i]*x,phiy[i],0,0,0,phia[i],phia[i]),nrow=3,ncol=3,byrow=T)
)$values[1])}
  r2[i] = round(uniroot(fcn,c(0,5),extendInt='yes')$root,2)
}
CI.fun(r2)
CI.fun(r2/(1+r2))

# generate SADs ###########################################
SAD2 = matrix(nrow=3,ncol=z)
lam2 = NULL
for (i in 1:z) {
  A = matrix(c(0,0,phia[i]*r2[i],phiy[i],0,0,0,phia[i],phia[i]),ncol=3,byrow=TRUE)
  lam2[i]=as.numeric(eigen(A)$values[1])
  SAD2[,i] = eigen.analysis(A)$stable.stage
}
apply(SAD2,1,CI.fun)

# generate breeding-pair estimates ##############################
set.seed(seed)
N2 = rpois(z,mean(counts$NL[18])+mean(counts$DE_NW[18]))
CI.fun(N2)
Afall2 = SAD2[3,] * N2
bp2 = Afall2/(2*sqrt(phia))
CI.fun(bp2)
```

Appendix II: csv file used for estimates of fall population size of Greylag Geese.

year	SE_sept	DK_Sep	NL	DE_NW	DE_Ni	BE
2005	199833	89159	100000	NA	NA	NA
2006	210709	101942	NA	NA	NA	NA
2007	196455	106314	NA	NA	NA	NA
2008	225131	138354	NA	NA	NA	NA
2009	228806	154545	234844	NA	NA	NA
2010	224750	171877	NA	NA	NA	3828
2011	177587	117146	NA	30957	NA	3800
2012	188667	141268	439000	21726	NA	3374
2013	163248	124236	369754	25797	NA	4373
2014	166305	114094	432692	27501	NA	4842
2015	202114	120042	431902	24422	NA	4048
2016	212889	141494	428232	29409	NA	5789
2017	239606	130401	469322	31665	NA	5144
2018	169888	NA	495216	30293	40490	4943
2019	231535	140269	458659	33314	53374	NA
2020	NA	NA	513661	32744	63273	NA
2021	230125	161513	565457	29712	49842	6000
2022	248115	141000	596890	32412	NA	9000