Annual survival in the Swedish Lesser White-fronted Geese

Hans Schekkerman &
Kees Koffijberg

Sovon-report 2019/63

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Sovon Vogelonderzoek Nederland, Nijmegen

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COLOFON

Natuurplaza (gebouw Mercator 3)
Toernooiveld 1
P.O. Box 6521
NL- 6503 GA Nijmegen
The Netherlands

Telefoon: (024) 7410410
Email: info@sovon.nl
Homepage: www.sovon.nl

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1. Introduction

1.1. Introduction and backgrounds

The Lesser White-fronted Goose *Anser erythropus* (hereafter LWfG) is a small, highly migratory, Arctic-nesting goose that occupies a breeding range from Scandinavia eastward to Chukotka in eastern Siberia. During the 19th and 20th centuries, the species underwent a massive population decline across all parts of its range. Hunting pressure along the migration route, especially in the Black Sea and Caspian Sea regions, is thought to have contributed to this decline (Jones *et al.* 2008).

Since the early 1980s, the Swedish breeding population has been reinforced by 'Projekt Fjällgås' of the Svenska Jägareförbundet, by adding young birds to the population on the breeding grounds, either with Barnacle Goose foster parents (until 2000) or by releasing groups of young birds from two breeding stations just before they are able to fly (from 2010 onwards) (e.g. von Essen 1991, Andersson & Holmqvist 2010).

Both in the 1980s-1990s and after 2010, released birds have been individually marked with colour rings, as were a small number of birds captured outside the breeding season. A database with all ringing data and all resightings has been prepared to enable analyses of the fates and demography of birds from this project.

1.2. Aims of the study

The aim of this study is to use the resighting data to estimate annual survival rates of LWfG released in Projekt Fjällgås, taking into consideration (if the data allow this) possible differences in survival between:

- Age-classes;
- Sexes;
- Time periods;
- Birds released as juveniles (around fledging age) or as yearlings (just over 1 year old, so released in their second calendar-year or first summer);
- Birds released by different methods (with foster parents vs. in groups).

Ultimately, the aim is to use these survival estimates and existing data on reproductive output of the population to model its expected (near)future development and assess its viability. In addition, the results can be used to evaluate the release program and eventually adapt the chosen strategies. Hence, the results are highly relevant for the national action plan for the species in Sweden and for the forthcoming revision of the international single species action plan by AEWA.

This report presents the results of the survival analyses. A draft version of this report and the results of the analyses were also presented in a workshop in Ammarnäs, Sweden, May 2019. Results presented here include input given during that meeting.

2. Data and methods

2.1. Setting up a database

The database with sighting information was compiled during 2018, by Christine Kowallik for Projekt Fjällgås. Input data consisted of ringing and resighting data collected by the project coordinator(s) in Sweden and numerous volunteer ring readers in the flyway, mainly submitted through the online portal of geese.org. While preparing the database for the survival analyses, an extensive data check and data cleaning procedure was carried out to check for errors and avoid duplicate entries. Moreover, a uniform database structure was developed by Christine Kowallik, Kees Koffijberg and Niklas Liljebäck, in order to be able to import all different datasets and facilitate various future analyses. For the resighting data, five data sources were combined into one dedicated Access database:

(1) Data collected by Projekt Fjällgås during the first project phase until about 2010 (by that time coordinated by the late Lambart von Essen, Åke Andersson and Bosse Fagerström). Data originate both from people working in the field in Sweden and a network of dedicated ring readers in the flyway, especially The Netherlands;
(2) Data collected for a national review of occurrence of LWfG in the Netherlands in 2005 (Koffijberg *et al.* 2005), by Henk van der Jeugd (Sovon). This data contained more detailed information on sighting dates, but for the rest was mainly identical to the dataset under (1);
(3) Data collected by Projekt Fjällgås after 2010 (second project phase), mainly referring to records in the breeding area (Niklas Liljebäck);
(4) Data from the national ringing centre in Stockholm, referring to birds found dead (usually by submitting data on the metal ring number);
(5) Data submitted to geese.org, the online portal to record ringing and resighting information for individually marked birds. These data refer to the second project phase from 2010 onwards. Data were mainly reported by dedicated volunteer ring readers. At present, this is the most important source of data collection and also provides immediate feedback to observers when observations have been entered online or in the field (when using the BirdRing App).

All ringing data were combined into one database as well, but kept separately from the resighting data. All ringing data in the second project phase from 2010 was already made available in geese.org, in order to give observers immediate feedback when submitting resightings.

Table 1 gives some summary records of the amount of data available in the database now, and used for the survival analyses.

2.2. Input data for analysis

The database used for this analysis was last updated in November 2018 (but can be easily updated at any time). It contains the ringing data of all birds released in the project from 1984 up to and including 2017, and both dead recoveries and live resightings of these birds up to 30 November 2018.

The total number of individual geese marked in this period is 663: 17 wild-born birds caught at a moulting site (13 adults, 4 yearlings), and 646 young birds raised at the breeding stations (table 1). Young geese were released in 2 disjunctive periods: 1984-1999 and 2010-2017.

In the first period (1984-1999), 213 of the 266 young (80%) were released with Barnacle Goose foster parents while 53 (20%) were released in groups without foster parents. All young released with foster parents were (near-) fledglings, while 85% of those released in groups were 1 year old and only 15% were fledglings (5 birds in 1985 and 3 in 1990). Hence in total 221 marked fledglings (83%) and 45 yearlings (17%) were released (table 1). Numbers of released males (136) and females (126) were fairly similar and of only 4 individuals (1.4%) the sex was unknown.

In the second period (2010-2017), Barnacle Goose foster parents were no longer used and all 380 young birds were released in groups without parents in the breeding area in the Arjeplog mountains (Svaipa) in Swedish Lapland (372) or on a moulting site (Hudiksvall, 8 birds, 2013 only). 79% (301) were released as fledglings, 21% (79) as yearlings (table 1). Numbers of known males (126) and females (116) released were again balanced but as many as 138 (36%) remained unsexed.

In period 2, a total of 18 birds (3 wild adults caught on the moulting site, 11 fledglings and 4 yearlings released the breeding area) were released with a satellite transmitter attached.

Information on survival is contained in both resightings of live birds and recoveries of dead individuals obtained after their release. The majority of the available data consists of live resightings, with dead recoveries augmenting information for 13 individuals from the first period (4.9% of the number marked) and 11 (3.0%) from the second period.

Table 1. *Numbers of LWfG released with colour rings, by year, age ate release and release method (fy foster young, gb in a group in the breeding area, nm in a group at a moulting site, wi wild-caught birds).*

age	fledgling			yearling			adult	total
method	fy	gb	gm	gb	nm	wi	wi	
1984	26			7				33
1985	16	5						21
1986	13							13
1987	16							16
1988	8			4				12
1989	13			2				15
1990	8	3		1				12
1991	9							9
1994	17			13				30
1995	20							20
1996	19							19
1997	20			5				25
1998	17			7				24
1999	11			6				17
subtotal	213	8	0	45	0	0	0	266
2010		2		3		4	11	20
2011		7		3				10
2012		24		4				28
2013		31	4	10	4			49
2014		37		17				54
2015		55		10			2	67
2016		75		12				87
2017		66		16				82
subtotal	0	297	4	75	4	4	13	397
total	213	305	4	120	4	4	13	663

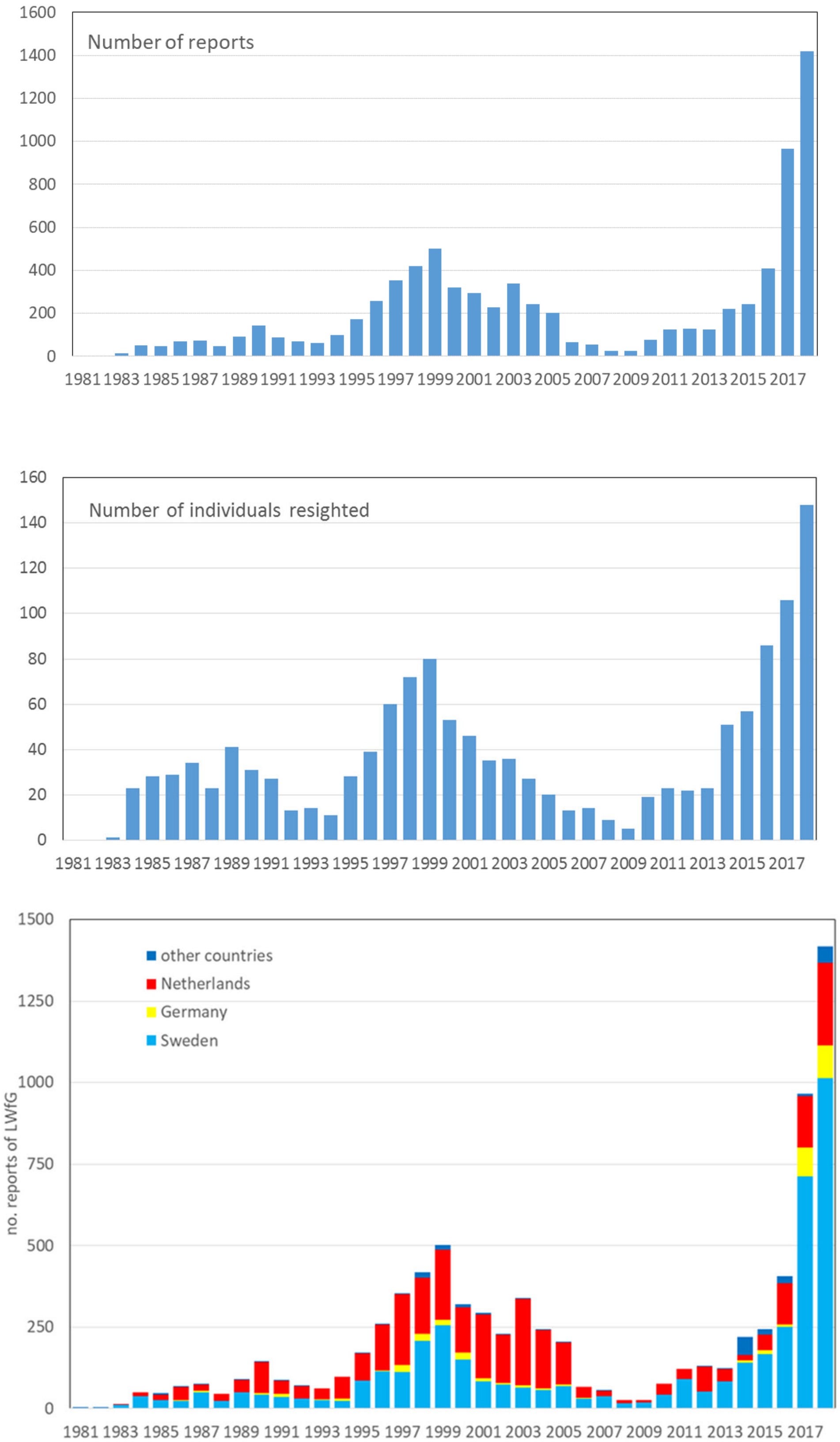

Figure 1. *Summary of records of resighting data. From top to bottom number of reports per year (including multiple resightings of the same individuals, until 1 December 2018), number of individuals reported per year (multiple sightings same individual counted once) and number of reports per country (continued next page).*

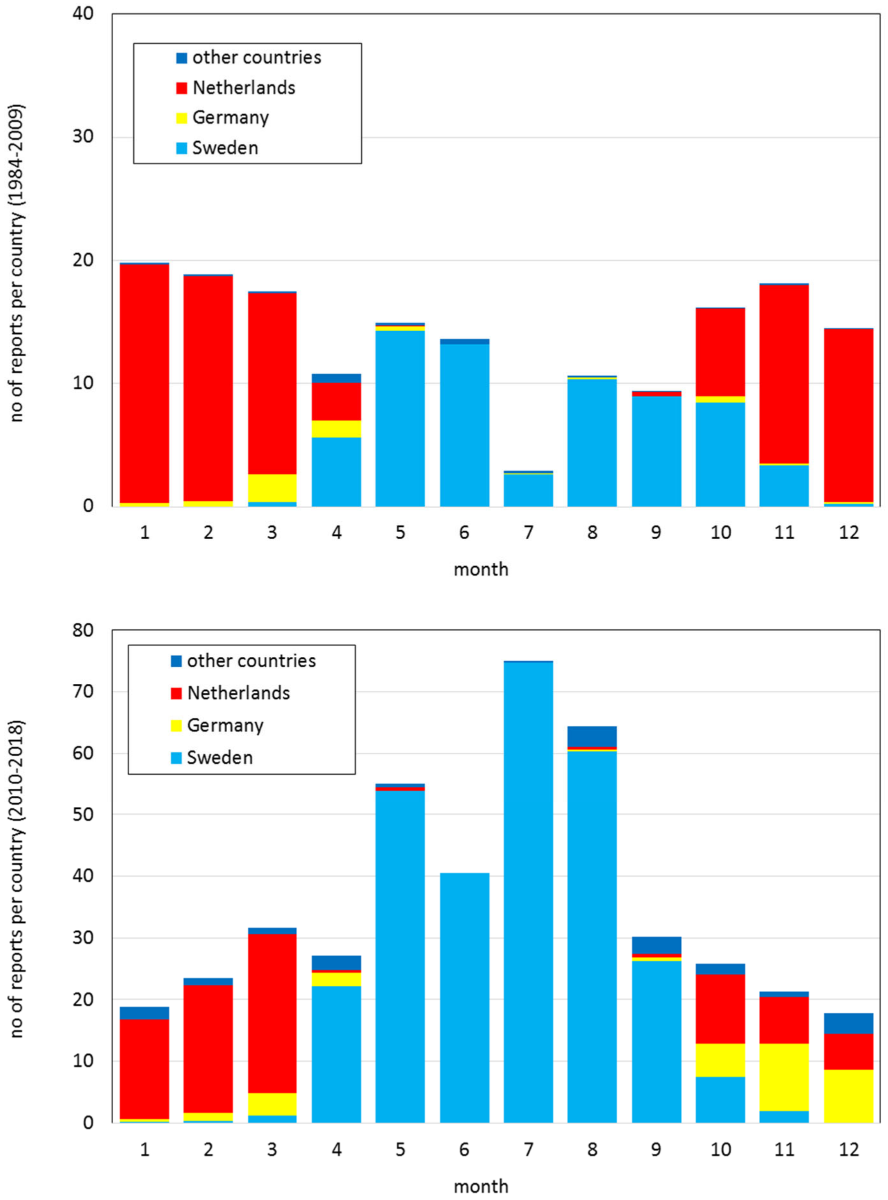

Figure 1 (continued). *Summary of records of resighting data. Shown is the number of reports (including multiple resightings of the same individuals) per month, per country, for 1984-2009 (first project period, top) and 2010-2018 (second project period, bottom).*

2.3. Considerations prior to survival analysis

The two disjunctive release periods with no young birds (with marks) released in the 10 years between 1999 and 2010, and the difference in release method with Barnacle Goose foster parents used only before 2000, suggested to break up the survival analysis into two separate parts.

The first analysis (period 1) includes birds released as young in 1984-1999. Although individuals from this group continued to be reported until 2013, extending the analysis for this entire period, many years after the last new releases, may introduce bias. On the one hand the mean age of the marked sample will start to rise from the last release year onwards, and senescence effects may become evident after some time. On the other hand the sample may become progressively dominated by birds of high intrinsic quality by selective survival.

In both cases the sample is no longer representative of the population as a whole. Also, in the end the sample of birds still alive became too small to derive survival estimates with any precision. Therefore the analysis for period 1 was extended no further than 2003. Beyond this 4th year after the last release, the annual number of individuals reported alive sank below 30.

The analysis for period 2 was restricted to the years 2012-2017, as only few birds were released in 2010 (5 birds) and 2011 (10 birds), rendering any survival estimates for those years highly imprecise. Also, none of the birds released as yearlings in these years were sexed.

Age effects on survival can be assessed for both periods. We use a fairly simple age structure with separate estimates for survival in the 1st year of life (from fledging to about 1 year old), 2nd year (1 to 2 years old), and all older ages taken together ('adult'). This age structure can be simplified further by equalising parameter values for 2nd-year and adult survival, resulting in a '1st-year *vs*. older' contrast.

Note however that 1st-year survival is estimated only for birds released as fledglings and hence always pertains to the release year, while 2nd-year survival can be estimated for both birds released as yearlings (in their release year) and for birds released as fledglings (in their second year after release). This means that for 2nd-year survival it is possible to distinguish separate effects of age and 'release year', but for 1st-year survival these are fully confounded. Hence, estimates of 1st-year survival should primarily be compared to 2nd-year survival of the group released as yearlings.

In period 1, effects of release method (foster parents vs. group) and age at release are confounded as only fledglings were released with Barnacle Goose foster parents while nearly all of those released in groups were yearlings. The just 8 fledglings released in groups (in just 2 years) are too few to separately estimate their survival and compare it to that of birds released as yearlings. To avoid that the estimates for fledglings released with foster parents become confounded with some young released without, these 8 birds were omitted from the analysis. So in period 1, 'release method' fully coincides with 'age at release'.

In period 2, no young were released with foster parents, and both fledglings and yearlings were released in groups. So in this period we can assess the effect of release age on 2nd-year and adult survival (though not on 1st-year survival, see above), but no effect of release method.

Hence, an effect of release method (foster parents vs. group release) can be assessed only by comparing the survival of birds released as fledglings with foster parents in period 1 with that of young released as fledglings in groups in period 2. However, it should be borne in mind that any differences observed may be confounded by other factors that have changed between the two time periods.

In period 2, eight birds were released at the moulting site instead of the breeding site (in 2013 only). This number is too small to assess an effect on survival of release site with any statistical power.

Sex differences in survival can be assessed for both periods. In period 1, inclusion of two sex groups in the MARK models (see below) suffices (omitting the 4 unsexed birds); in period 2 three groups are required (M, F, Unknown) or a significant part of the data would be discarded.

Combining information from live resightings and dead recoveries in one analysis ('Burnham model' in program MARK) can increase the precision of the survival estimates and allows separate estimation of 'true survival' and 'fidelity to the study area', which are confounded if live resightings are used only (which yields 'apparent survival'). On the other hand this adds to the model complexity already imposed by the wish to take into account effects of sex, absolute age, release age, and release method. Given that dead recoveries are only available for 3-5% of the marked individuals, we expected that benefits of a combined analysis may not weigh up to this greater complexity, and restricted the analysis to live resightings for now.

Prior to the analyses, it had to be decided how to fit the boundary between years into the annual cycle of the geese. Usually, this boundary is linked with the period in which goslings hatch (in June or July), but in our case this would mean that also the moulting period, in which many birds are reported, would be split over two years. Therefore we chose to split the year on the 1st of May. By that time, all birds have finished wintering and their main part of spring migration and start to prepare for breeding at pre-breeding sites like Ammarnäs and Båtsjaur.

2.4. Survival analyses in MARK

Survival analyses were performed using the Cormack-Jolly-Seber (CJS) model option in program MARK v. 9.0 (White & Burnham 1999). Separate analyses were conducted for data from periods 1 and 2. In the initial analyses, effects of sex, age at release, absolute age, and time (year) were considered, with interactions. Because in period 2 there was basically just one release method and in period 1 the difference between birds released with foster parents vs. in a group was fully confounded with age at release, the effect of release method could not be considered. Effects of sex and age at release were assessed by assigning 4 groups for period 1 (males and females released either as fledgling or yearling) and 6 for period 2 (males, females and unknowns released as fledgling or yearling).

For each time period, an initial model was constructed including sex, age at release, current age (1st-year, 2nd-year, older) and time (years, categorical) and their interactions, for both apparent survival (*phi*) and resighting probability (*p*). This model was then simplified by sequentially dropping interactions and main effects, and by considering a linear time effect instead of independent estimates for each year. Selection of the most parsimonious model(s) was based on (Quasi) Akaike's Information Criterium (QAICc, Anderson & Burnham 2002), using an overdispersion parameter estimated by the *median c-hat* method for the fullest model in which most of the parameters proved estimable. We first identified a parsimonious parametrisation for the resighting probability *p* and only then simplified the model structure for survival *phi*. Finally we re-checked whether the most parsimonious model thus found could yet be improved by a slightly different parameterisation for *p*.

Some explanation of terms in Results

Different models assessed are denoted as {‘model name’}, e.g.: {phi(Sx+R2+Ag3+T) p(Sx+Ag2+T) 9/10}.

The phi() part of the model name describes the structure of the survival part of the model, the p() part that for resighting probability, and 9/10 is extra information denoting that 9 of 10 parameters of the model could be estimated by Mark. The following abbreviations are used for covariates:
Sx = sex (2 classes in period 1, 3 in period 2).
R2 = age at release (fledgling/yearling).
Ag3, Ag2 = ‘real’ age; Ag3=3 classes, Ag2=2 classes (2^{nd}-year and older taken together).
t, T = time effects (year); t = each year independent, T = linear (on logit scale) trend over time.

[Sx.Ag2] = interaction of sex and age effects: age effect may differ for males and females;
Sx*Ag2 = both main effects of Sx and Ag2 and their interaction; Sx+Ag2 = main effects only.

An overview of model selection is given in the Model Results Table. Primary column to look at is ‘Delta (Q)AICc’, giving for each model the difference in (Q)AICc from that of the top-ranking model. Differences >2 units are considered to indicate that one model is ‘better’ than another. The ‘(Q)AiCc weights’ are a different way to express this: they indicate the ‘relative plausibility’ of models.

3. Results

3.1. Period 1 (releases 1984-1999)

Resighting probability

The best model structure for *p* was p(Sx+Ag2+T), i.e. with differences between the sexes (female resighting probability on average 11% higher than that of males) and between age classes (1st-year on average 9% higher than older birds), and a linear increase over time (from 36-61% in 1985 to 85-94% in 2003). There are no interactions in this model: differences between sexes and age classes are independent of each other and also do not change with time (on the scale of the logit link function used by the estimation procedure). See figure 2.

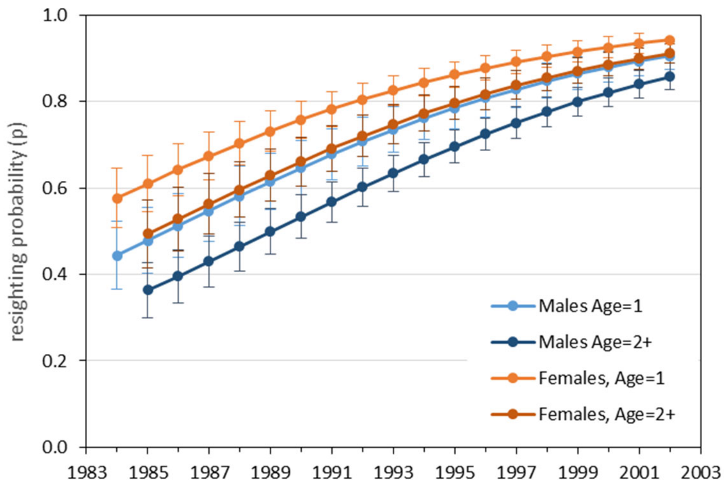

***Figure 2**. Most parsimonious description of resighting probabilities (p) in period 1, with independent effects of age class, sex, and a linear time trend. Bars denote standard errors.*

Survival

The top-ranking model for survival *phi* in period 1 had structure phi(Sx+R2+Ag3+T+[Sx.R2]), i.e. differences between sexes (small in most cases), between the 3 age-classes, and between birds released as fledglings and yearlings (the latter effect differing between sexes), and a moderate overall increase in time. However, this model was not much better supported than a few similar models, including ones without age differences (phi(Sx+R2+ T+[Sx.R2]), dAICc=0.11) and without any sex differences (phi(R2+Ag3+T), dAICc=0.58). As the difference between males and females in the actual survival estimates was very small also in the top model, except for birds released as yearlings in their 2nd (release) year (the Sx.R2 interaction), the former is used here as the model to illustrate effects (figure 3).

In birds released as fledglings, we see a 1st-year survival of 60-76% which is fairly high. Survival of these birds in the following year is even higher (80-90%) but then seems to drop a bit again as they become adults (70-82%). However, note that this latter effect is not strongly supported by the data as models with 3 and with 2 age classes differed only by 1.08 AICc units.

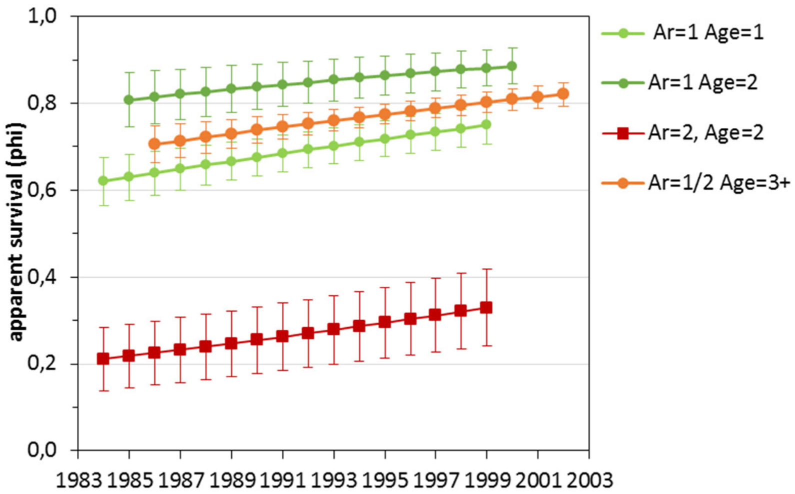

***Figure 3**. Estimates of survival probabilities (phi) in period 1 according to model {phi(R2+Ag3+T) p(Sx+Ag2+T)} with independent effects of 3 age classes, sex, and a linear time trend (Ar= release age, 1 fledgling, 2 yearling). This model performed only slightly less well than the top model which differed in estimating 2nd-year survival of birds released as yearlings higher in females (0.4-0.6) than in males (0.1-0.2). Bars denote standard errors.*

Remarkably, survival in the 2nd year of life was very much lower in birds released as yearlings (i.e. in their release year) than in birds released as fledglings (in the year after their release year). It was also much lower than survival in the first (release) year of birds released as fledglings. Remember that age at release and release method were confounded in this period, and that virtually all fledglings were released with foster parents but yearlings as a group without foster parents. A plausible interpretation of this result is therefore that the presence of the foster parents raised the survival of the fledglings in their first year after release by a significant amount, relative to that of birds released without foster parents (as yearlings). It is not so hard to think of reasons why this might be so (foster parents will contribute vigilance against predators, knowledge of migration route and staging sites, etc.). For the alternative interpretation that the difference is an effect of the age at which birds were released, mechanistic scenarios are less straightforward, and moreover this interpretation is made less plausible by the results from period 2 (see below).

3.2. Period 2 (2010-2018)

Resighting probability

The best model structure for *p* was p(Ag2+T), i.e. resighting probability differed between age classes (1st -year on average 21% higher than older birds), and increased linearly over time (from 22-31% in 2012 to 95-99% in 2017). This is similar to the structure in period 1 but without a sex difference. Notice that the estimated linear increase in *p* is quite steep, and that in recent years apparently almost all marked birds that were alive were observed in the field. This does correspond to an overall increase in effort to identify ringed birds (see figure 1). However, the evidence for both the age and the time effects on *p* is not very strong; a model with a time effect only scored just 0.2 AIC units lower, and a model with both omitted (hence with constant *p*) 0.8 units lower than p(Ag2+T).

Survival

Top-ranking model for survival was phi(R2+Ag2), with independent effects of age (2 classes) and of age at release, but no sex difference and no effect of time. The second-best model (scoring 1.9 AIC units higher) was phi(R2+Ag3), differing only in having three age classes instead of two. These results were not different when p was assumed constant in time instead of increasing (a formulation for *p* that did not receive much less support, as mentioned above). As there was thus no significant change in survival over time, the estimates from the top-ranking model can be summarised by their means:

Group/age	Estimate	SE	95% lcl	-	ucl
Ar=1, Age=1	0.287	0.052	0.197	-	0.399
Ar=2, Age=2	0.256	0.107	0.103	-	0.508
Ar=1 Age=2+, Ar=2 Age=3+	0.611	0.095	0.418	-	0.774

and those of the second best model as (also depicted in figure 3):

Group/age	Estimate	SE	95% lcl	-	ucl
Ar=1, Age=1	0.286	0.052	0.196	-	0.397
Ar=1, Age=2	0.664	0.153	0.339	-	0.883
Ar=2, Age=2	0.265	0.113	0.104	-	0.530
Ar=all, Age=3+	0.572	0.129	0.322	-	0.789

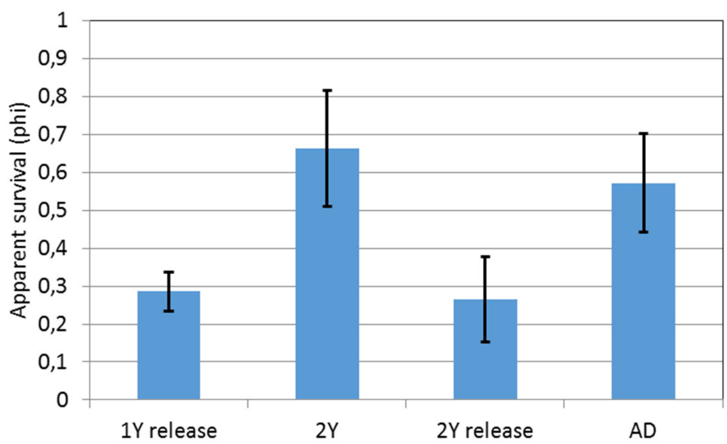

Figure 3. *Estimates of survival probabilities (phi) in period 2 according to model phi(R2+Ag3) (thus second model in table mentioned on top of this page). 1Y release Ar =1, Age =1, 2Y Ar=1, Age =2, 2Y release Ar=2, Age=2, AD Ar=all, Age=3+. Bars denote standard errors.*

Here we see a similar pattern as in period 1 with respect to the relatively low survival in the 2nd (release) year of birds released as yearlings. However, now the birds released as fledglings have an equally low survival in their release year (1st year). This supports the interpretation of the result in period 1, that the large difference in survival during the release year between birds released as fledglings and as yearlings in period 1 reflects the positive effect of young birds being guided by (foster) parents. In period 2, when both the fledglings and the yearlings were released without parental care from adults, the survival in the release year was low in both groups. This indicates that releasing captive reared young LWfG without parent birds is associated with a substantial 'cost' in terms of their survival in the year after their release, compared to that of wild-reared young (assuming that these survive at a rate similar to that of young with Barnacle foster parents).

In the birds released as fledglings we further see a similar pattern as in period 1: increase in survival from 1st to 2nd year, and then a slight drop again to somewhat lower level as birds become adults.

When comparing survival rates between the two large time periods, the most striking difference is the lower survival of adult geese in period 2:

Age group	Period 1	Period 2
1st-year	62-75%	29%
2nd-year, released as fledgling	81-89%	66%
2nd-year, released as yearling	21-33%	27%
Adult (>2nd year)	71-82%	57-61%

The survival rates in recent years may have been affected by predation from White-tailed Eagles and foxes, which has occurred in the breeding area in some of the recent years. On the basis of the current data however it cannot be excluded that the captive-bred birds still have a lower survival after several years of free life, although this does perhaps not seem very plausible.

To check this, we also explored an analysis with the data from the adult birds that were wild-caught in 2010 included in the dataset. Probably because this group consisted of only 4 males and 6 females (so very small sample size), the results were not very clear as the survival of these birds was estimated poorly.

4. Conclusions and recommendations

4.1. Summary of key findings and references

This report presents the first effort to estimate annual survival rates in the LWfG from the Swedish breeding population. It is among the first studies at all to quantify annual survival probabilities in this highly threatened species. An extensive dataset with live resightings was used as input in a mark-recapture survival analyses in MARK. At present, resighting probabilities of the marked birds are very high, i.e. >95%, thus reflecting nearly the entire ringed population. This is made possible by a large number of volunteer ring readers and dedicated effort of the project to facilitate ring reading at key staging sites (see Figure 1). Figure 4 summarises the survival rates described in chapter 3. The main conclusions that can be drawn from the analyses are:

- During the first project phase (period 1, releases until 1999) there was an overall increase in annual survival probabilities in all age-classes in the course of the project, i.e. between 1984-2003. Survival was lowest in birds that had been released as yearlings, without any parental care, followed by first-year survival in birds that had been released as juveniles with Barnacle Goose as forster parents. Remarkably, survival was slightly higher in the 2nd year after release for birds released as juveniles than in adult birds (3 years and older, birds released as juveniles and yearlings combined);
- During the second project phase (period 2, after 2010) there was no trend in survival rates over time (but note that this period spans just five years). Birds released as yearlings had rather similar (low) survival probabilities as those in the first project phase. However, first-year survival in birds released as juveniles was lower (and now comparable with birds released as yearlings) than in the first project phase, likely because juveniles were now released without parental care. Again, survival in the 2nd year after release for birds released as juvenile was somewhat higher than adult survival. Adult survival in the second period was lower than in the first period, but also subject to some variation (note standard error). Again note that the period for which this could be calculated is rather short, as only data from 2012-2017 were taken into account.

The lower survival of yearlings may rise the question if it is a good strategy to wait for releases of 2nd year birds, but observations on the breeding grounds do suggest that those birds may enhance the survival probabilities of the birds released as juvenile, as the 2nd year birds take over some of the tasks that are usually taken care of by adults, in terms of guidance and vigilance. It is not clear yet why fewer birds released as 2nd year (yearling) in both period 1 and period 2 survive, compared to the other groups. A difference with birds released as juvenile is, that 2nd year birds are in full wing moult when released, and usually start to fly later than the birds released as juveniles. This may increase e.g. predation risk. However, direct observations to confirm this are lacking.

For LWfG in general, little information on annual survival is available. Lampila (2001) used count data from two areas used by the birds breeding in Northern Norway to assess apparent mortality and survival rates. In this analysis, first-year survival was estimated at 24%, thus slightly lower than calculated for the second project phase in Sweden, but much lower than in the juveniles released with foster parents in Sweden in the 1980s and 1990s. Survival of 2nd year birds was estimated at 48%, which is again much lower than measured in the Swedish population (at least for birds released as juveniles). Adult survival probabilities were estimated to be 84%, which comes close to the estimates for the Swedish population around 2000 (the analysis from Lampila referred to data collected in 1985-1999, thus coinciding with period 1 of the Swedish project). Note that due to different methods these estimates are not fully comparable, but still some of the differences found are substantial. From the other flyways of LWfG there are no data available (or published) on capture-recapture analysis.

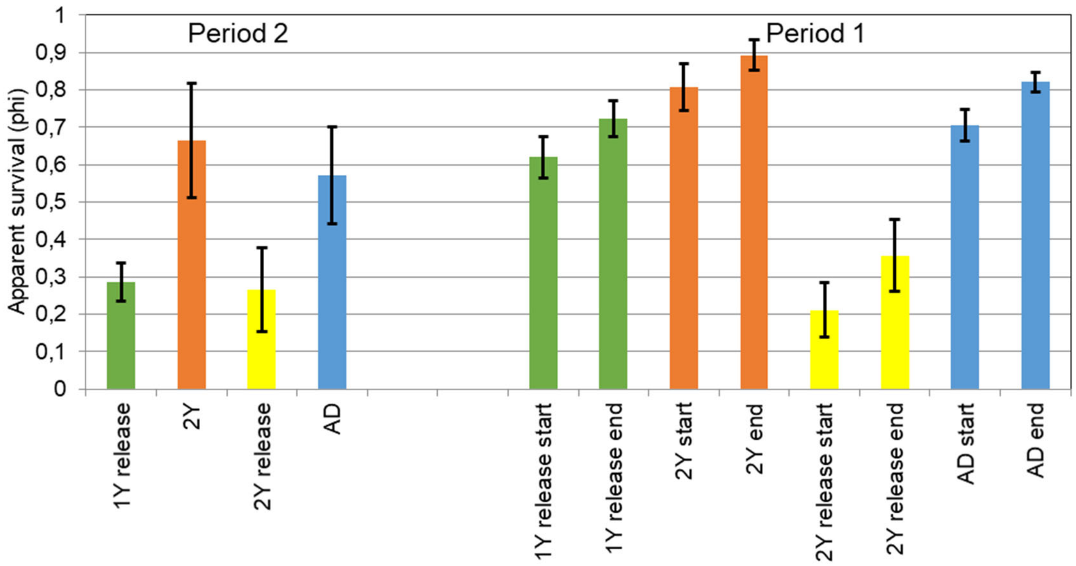

Figure 4. *Comparison of annual survival rates (bars denote standard error) for the second project phase (left part) and the first project phase (right part, values given for beginning and end of the time series, reflecting the overall increase in survival in time, see Figure 3). Colours group the same age-class: juveniles released in their first-year (green), 2nd year of birds released as juveniles (orange), birds released as yearlings (yellow) and adults, i.e. birds of 3 years and older (blue). Bars denote standard errors. Survival rates were calculated from 1 May to 1 May.*

In many other goose species, adult survival rates often exceed 80% (first-year survival usually being lower), but of course depends on whether any additive mortality occurs due to hunting. The latter is less likely in the Swedish LWfG population (although also these birds are known to be shot accidentally, e.g. in autumn 2018 in The Netherlands and presumably also in Germany), but appears in most other goose species in Europe. This makes it difficult to draw direct comparisons. Particularly the survival rates of released birds (both juveniles and yearlings) and adults in the second project phase seem to be low in this context. It should be examined further if the survival estimates are associated with the situation on the Swedish breeding grounds (e.g. predation by White-tailed Eagle) or other factors, either during the breeding season, or other parts of the year. The problems with aspects like predation in release areas are not new and have also been recorded in other reinforcement programs (e.g. Aleutian Cackling Goose, Mini *et al.* 2011).

Few data are available on survival of released birds in other *Anatidae* species. Released Mallards in France had a survival of 18% (±7%) in their first year (Champagnon *et al.* 2008) whereas in Marbled Teal in Spain, ducklings trapped in summer and released as fledglings later on had survival rates of 54-85% (Green *et al.* 2005). In a restoration program for Hawaiian Geese, Black *et al.* (1997) mention survival rates ranging from 0% to 87%, with considerable variation among release sites. This also suggests that in future calculations on LWfG, it may be of added value to include release site (at present two sites in the same region) as a co-variable in the analysis. This becomes even more important, if releases are planned outside the core breeding area in the Arjeplog mountains.

4.2. Recommendations

With the establishment of a dedicated database with all relevant capture and resighting information (also linked to the geese.org portal), it is important to continue ringing and ring-reading activities, in order to keep track on the fate of the Swedish LWfG population. Moreover, experiences in 2018-2019 have shown that it has become difficult to assess numbers in the flyway by just adding count data or summing up observations, as birds tend to disperse in winter and not all birds pass the known key sites, and some stay there only very shortly (so turnover confounds total numbers counted). Therefore, we would recommend the following strategy for future years:

Fieldwork and data collection:

- Continue to use individually marked birds in the release groups and document the exact release site of all released birds (or at least distinguish the main sites), especially when also new regions in which releases are planned become established;
- Maintain/continue and expand ring-reading activities in order to retain the high resighting probability, enabling statistically robust annual survival estimates. Intensive ring-reading is especially important at key-sites which are visited by a large part of the population, such as Ammarnäs/Båtsjaur (pre-breeding sites), Hjälstaviken (autumn), Oudeland van Strijen (winter), Petten (winter), Røden Fed/Denmark (spring, no activities yet), Svartåmynningen/Roxen (spring), Sundsvall (spring) and potential other sites especially visited by released birds (e.g. Lippe in Germany);
- Continue to collect data on annual productivity and preferably also pair constellations (potential (new) breeding pairs);
- Collect data on numbers of ringed and unringed birds, which can add to estimates of population size. This should preferably be done at key sites, where a large part of the population gathers;
- Use satellite/gps-tagging to discover new stopover and wintering sites (as for an increasing number of birds, these are currently unknown).

Analyses:

- Maintain the dedicated database structure, expand this with information of pair-status and reproductive output of marked individuals, in order to be enable future analyses for various purposes, including a proper evaluation of the species conservation actions;

- Establish a routine to include data on survival, productivity and census data into one integrated population analysis (Integrated Population Model, IPM), in order to monitor changes in population size and demography. Fortunately, as these data are available for LWfG, it would be a promising step to have annual (modelled, expected) population figures derived, and compare those with actual census data. As mentioned above, the current situation is that census data and observations are not sufficient anymore to get a precise estimate of the population size as part of the staging and wintering sites are unknown;
- The survival analysis presented in this report is a first step in establishing such a modelling routine, and can be further refined with addition of new data. The current survival rates calculated for the second project phase still cover a rather short period (5 years), and as seen in the first project phase, survival may increase in time. Therefore we recommend to repeat the survival analysis in near future, when more years can be included.

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6. Appendix (volgende pagina)

Excerpts from the MARK results table for each period showing details of the 15 top ranking models, four best models with a 'full' structure for phi (used to find the best structure for p), and the 'full' model with complete time and group effects.

Period 1

nr	model (phi)	model (p)	AICc	delta AICc	AICc weights	Likeli-hood	N. par	Devi-ance
1	Sx+R2+Ag3+T+[Sx.R2]	Sx+Ag2+T	1152.06	0.00	0.15	1.00	11	626.45
2	Sx+R2+T+[Sx.R2]	Sx+Ag2+T	1152.17	0.11	0.14	0.95	9	630.68
3	R2+Ag3+T	Sx+Ag2+T	1152.64	0.58	0.11	0.75	9	631.15
4	Sx+R2+Ag2+T+[Sx.R2]	Sx+Ag2+T	1152.66	0.60	0.11	0.74	10	629.11
5	R2+Ag2+T	Sx+Ag2+T	1153.07	1.00	0.09	0.61	8	633.63
6	Sx+R2+T+[Sx.R2]	T	1153.68	1.61	0.07	0.45	7	636.29
7	Sx+R2+T	Sx+Ag2+T	1154.61	2.54	0.04	0.28	8	635.17
8	Sx+R2+Ag3+T+[Sx.R2]	Ag2+T	1154.61	2.55	0.04	0.28	10	631.06
9	Sx+R2+Ag3+T	Sx+Ag2+T	1154.63	2.57	0.04	0.28	10	631.08
10	Sx+R2+Ag2+T+[Sx.R2]	T	1154.83	2.77	0.04	0.25	8	635.39
11	Sx+R2+Ag3+T+[Sx.R2]	T	1155.34	3.28	0.03	0.19	9	633.85
12	Sx+R2+Ag3+[Sx.R2]	Sx+Ag2+T	1155.41	3.34	0.03	0.19	10	631.86
13	Sx+R2+Ag3+T+[Sx.R2] +[Sx.Ag3]	Sx+Ag2+T	1155.71	3.65	0.02	0.16	13	625.95
14	Sx+R2+Ag3+T+[Sx.R2] +[Sx.Ag3]+[R2.Ag3]	Sx+Ag2+T	1156.10	4.04	0.02	0.13	14	624.25
15	Sx+R2+T	T	1156.16	4.10	0.02	0.13	6	640.81
23	max	Sx+Ag2+T	1169.24	17.18	0.00	0.00	22	620.49
24	max	Sx+T	1170.93	18.87	0.00	0.00	21	624.32
25	max Sx+Ag3+T	Sx+T	1171.38	19.32	0.00	0.00	23	620.49
26	max	Sx+R2+Ag3+T	1173.45	21.39	0.00	0.00	24	620.42
42	max	max	2388.49	1236.43	0.00	0.00	36	1809.18

Period 2

nr	modelphi	modelp	QAICc	Delta QAICc	AICc Weights	Likeli-hood	N. Par	Devi-ance
1	R2+Ag2	Ag2+T	201.56	0.00	0.208	1.00	6	44.916
2	R2+Ag2	T	201.78	0.22	0.186	0.90	5	47.213
3	R2+Ag2	.	202.35	0.79	0.140	0.67	4	49.84
4	R2+Ag2	Ag2	203.19	1.63	0.092	0.44	5	48.621
5	R2+Ag3	Ag2+T	203.46	1.90	0.081	0.39	7	44.724
6	R2+Ag2+T	.	203.91	2.35	0.064	0.31	5	49.336
7	R2+Ag3+[R2.Ag3]	Ag2+T	204.36	2.80	0.051	0.25	8	43.531
8	R2+Ag3	Ag2	205.22	3.66	0.033	0.16	6	48.574
9	R2+Ag3+T	.	205.79	4.23	0.025	0.12	6	49.150
10	Ag3	Ag2+T	205.95	4.39	0.023	0.11	6	49.302
11	R2+Ag3+[R2.Ag3]	Ag2	206.33	4.77	0.019	0.09	7	47.597
12	R2+Ag3+T+[R2.Ag3]	.	206.87	5.31	0.015	0.07	7	48.140
13	Sx+R2+Ag3 DM 9/9}	Ag2+T	206.95	5.38	0.014	0.07	9	43.991
14	Sx+R2+Ag3+[R2.Ag3]	Ag2+T	207.68	6.12	0.010	0.05	10	42.606
15	R2	Ag2+T	207.79	6.23	0.009	0.04	5	53.223
32	max	Ag2+T	244.64	43.08	0.000	0.00	30	34.058
33	max	T	246.45	44.89	0.000	0.00	29	38.281
34	max	Ag3+T	246.94	45.38	0.000	0.00	31	33.923
35	max	Ag2	248.47	46.91	0.000	0.00	29	40.300
49	max	max	298.75	97.19	0.000	0.00	54	24.839

max = Sx+R2+Ag3+T+[R2.Ag3]+[Ag3.T]+[Sx.R2]+[Sx.Ag3]+[Sx.T]+[Sx.R2.Ag3]+[R2.Ag3.T]+[Sx.Ag3.T]+[Sx.R2.Ag3.T]

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projekt fjällgås

Sovon Dutch Centre for Field Ornithology

Postbus 6521
6503 GA Nijmegen
Toernooiveld 1
6525 ED Nijmegen
T (024) 7 410 410

E info@sovon.nl
I www.sovon.nl

Sovon

Schekkerman H. & Koffijberg K.

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