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Supplemental Information

**Rapid formation of new migration route
and breeding area by Arctic geese**

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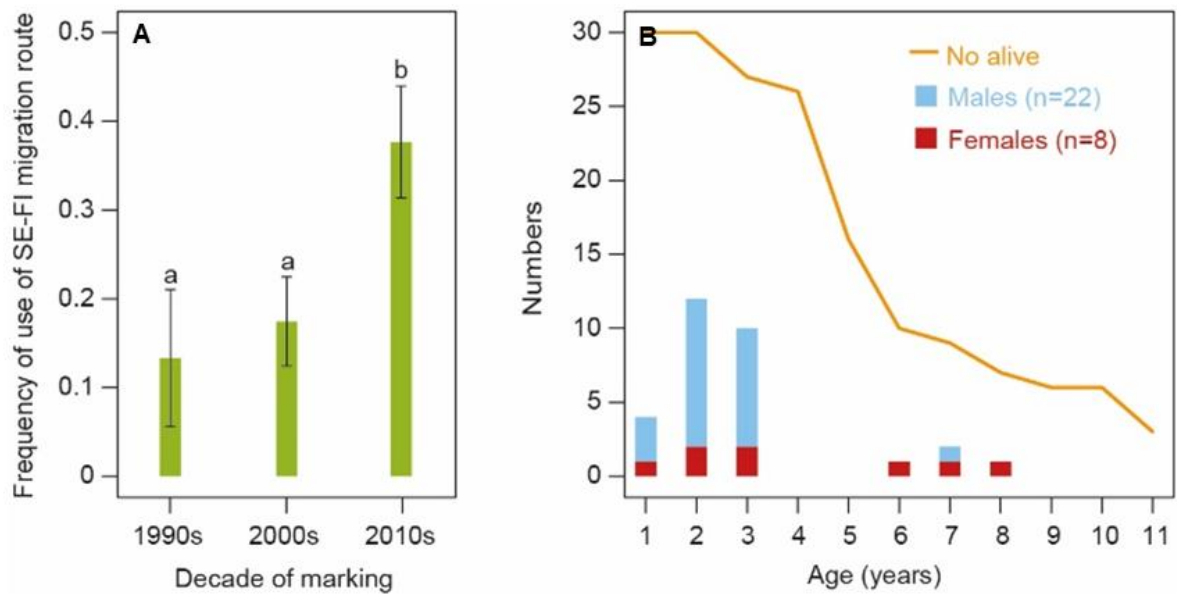


Figure S1. Consistency in occurrence and age composition by neckbanded individuals using the Swedish-Finnish migration route. Related to Figure 1. (A) The frequency of individuals using the Swedish-Finnish migration route in the course of their lifetime during three decades. Individuals were assigned to the decade when they lived most of their lifetime (Anova single factor analysis of variance, $F_{2,74} = 11.288$; with Tukey posthoc pairwise comparisons, $p < 0.05$). Bars show standard deviations. (B) The first observation of use of the Swedish-Finnish migration route in relation to age in 30 individuals with known age (neckbanded in their first year). Males moved more frequently than females, taking into account the sex composition of the entire number of marked first-year birds ($X^2 = 4.31$, $p < 0.05$). Among adult birds (without known age) there was no significant difference between sexes ($X^2 = 0.39$, $p > 0.05$).

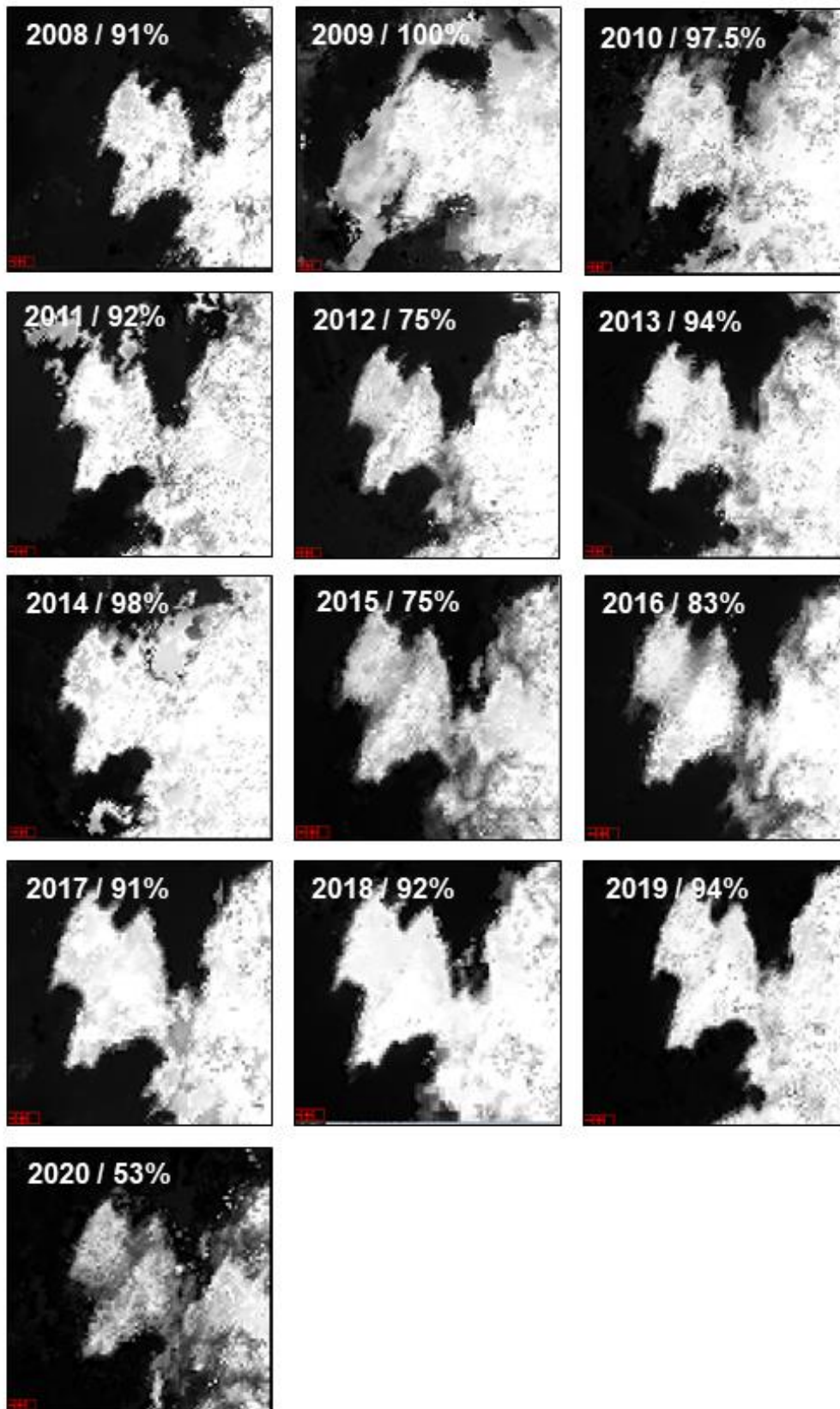


Figure S2. Snow cover in late May on Admiralty Peninsula, western Severny Island, Novaya Zemlya, 2008-2020. Related to Figure 3. Images were derived from the MODIS satellite, with a resolution of 500 m. Legends denote year / % snow cover. Source: MODIS/Terra Surface Reflectance 8-Day L3 Global 500m from <https://earthdata.nasa.gov/>.

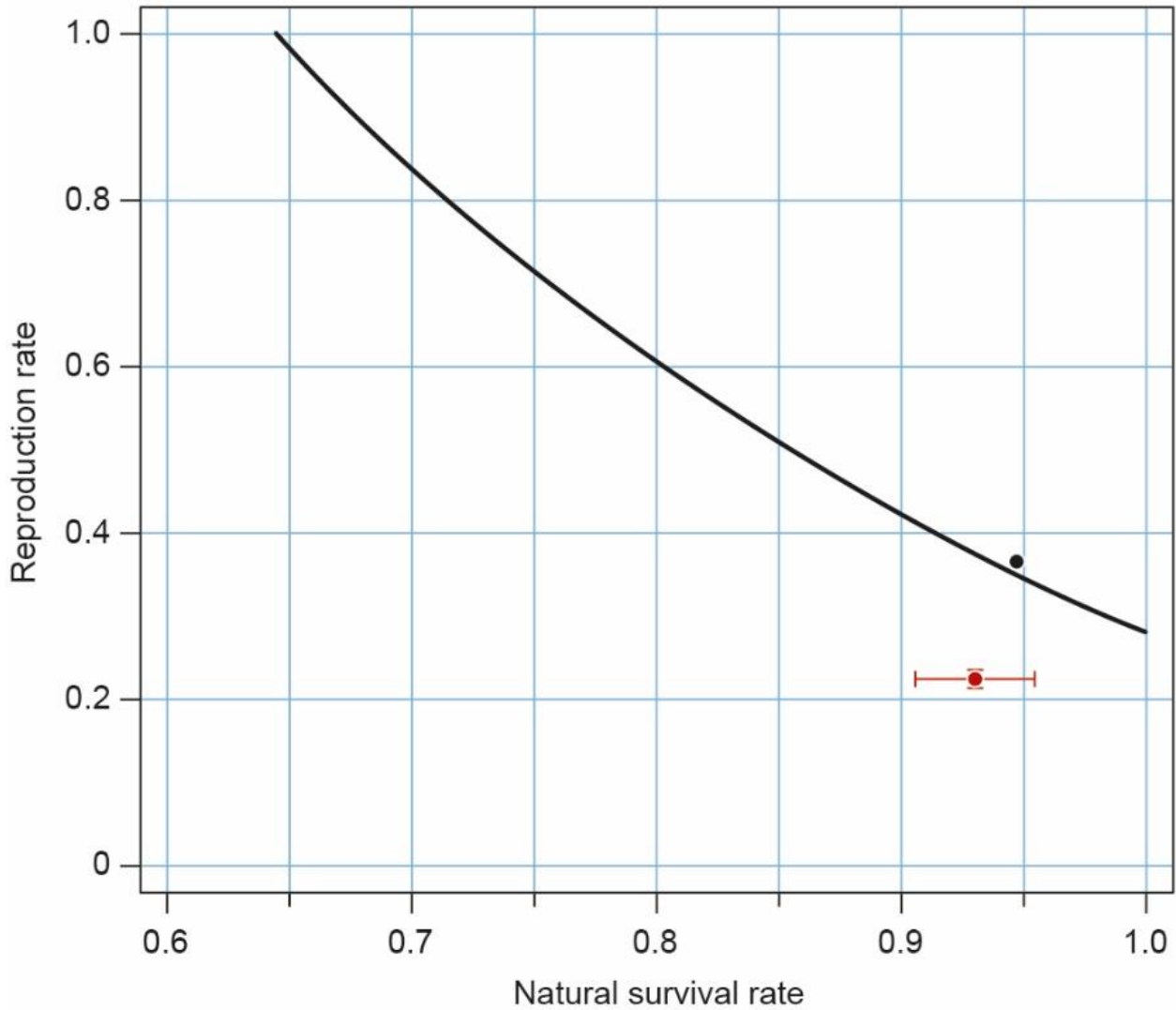


Figure S3. Combinations of natural survival and reproduction rates needed to duplicate the observed growth rate of 1.244 of pink-footed geese in Sweden. Related to the STAR Methods. Combinations of survival and reproduction rates are constraint to be 1 or below and conditioned on a mean harvest rate of 0.022, as estimated for the Novaya Zemlya population aged >1 years. Black dot marks the maximum value and red dot the mean value (\pm sd) of natural survival and reproduction rate from an integrated population model.

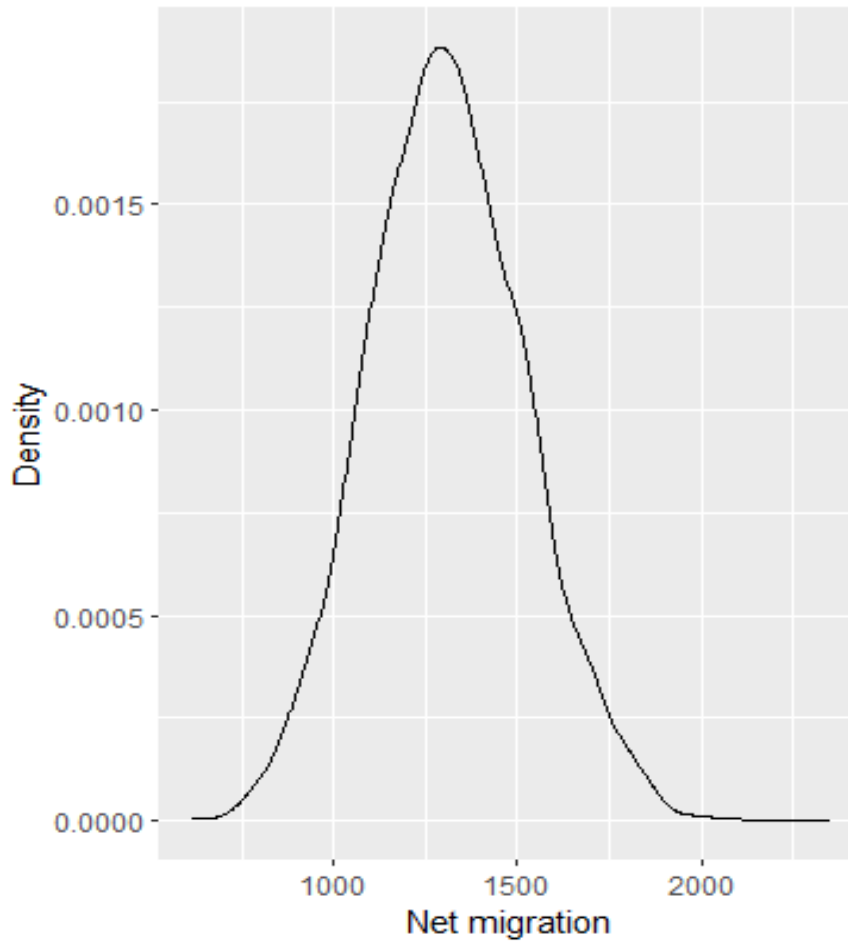


Figure S4. Density plot of cumulative net migration in Sweden from 2001-2019, based on the replicates of each year's number of migrants summed across years for each replicate. Related to the STAR Methods.

Code	Age/sex	Spring			Autumn		
		2018	2019	2020	2018	2019	2020
A0*	ad F	FI					
A1**	ad F	FI-SV	BE-NL-DK-FI-SV	BE-DK-SE-FI-SV	SV-NO-DK-BE	SV-NO-DK-BE	SV-DK-NL-BE
A2	ad F	FI-SV	DK-NO-DK-NO-SV		SV-NO-DK		
A3***	ad F	FI-NZ	NL-DK-SE-FI-NZ	DK-SE-DK-SE-FI-NZ	NZ-SE-NL	NZ-RU-SE-DK	NZ-SE
A4	ad F	FI-SV	DK-NO-SE-SV	DK-SE-NO-SV	SV-NO-DK	SV-NO-DK	SV-NO-DK
A5***	ad M	FI-NZ	BE-DK-SE-FI-NZ	DK-SE-DK-SE-FI-NZ	NZ-SE-NL-BE	NZ-RU-SE-DK	NZ-SE
A6**	ad M	FI-SV					
A7**	2cy M	FI-SV	DK-NO-SV	DK-NO-SV	SV-DK	SV-NO-DK	SV-DK
A8	ad M	FI-NZ	GE-DK-SE-FI-NZ		NZ-LT-PL-GE	NZ-RU-SE	
A9	2cy M	FI-SV	DK-NO-SV	DK-NO-SV	SV-NO-DK	SV-NO-DK	
4A	ad F		FI-NZ			NZ-SE-DK-SE-DK	
4B	ad F		FI-SV				
4C	ad F		FI-SV			SV-DK-NL-DK	
4F	ad F		FI-NZ	SE-FI-NZ		NZ-SE	NZ-RU-SE-DK
4G	ad F		FI-NZ	DK-SE-FI-NZ		NZ-RU-SE-DK	NZ-FI-SE
4H*	ad F		FI				
4J	ad F		FI-NZ	DK-SE-FI-NZ		NZ-SE-DK	NZ-RU-FI-SE-DK
4K	ad F		FI-SV	NL-DK-NO-SV		SV-NO-DK-NL	SV-NO-DK-NL
4M	ad F		FI-NZ	DK-SE-FI-NZ		NZ-SE-DK	NZ-RU-FI-SE-DK
4N	ad F		FI-NZ	DK-SE-FI-NZ		NZ-SE-DK	NZ-RU-SE-DK
4P	ad F		FI-NZ	DK-SE-FI-NZ		NZ-SE-DK	NZ-FI-SE

Table S1. Summary of spring and autumn migration routes (countries with total stopover duration of >1d) by pink-footed geese tagged in Oulu, western Finland in the springs of 2018 and 2019, respectively. Related to Figure 2. Spring was taken as January-May, autumn as September-December. In bold individuals are indicated that migrated to Novaya Zemlya. Country and area codes: BE (Belgium), DK (Denmark), FI (Finland), GE (Germany), LT (Lithuania), NL (Netherlands), NO (Norway), NZ (Novaya Zemlya, Russia), PL (Poland), RU (Russia, mainland), SE (Sweden), SV (Svalbard, Norway).

Notes: *no GPS-signals received after leaving Finland (but 4H was still observed in following seasons); **A1 was paired to A6, and A7 (their 2nd-calendar year young) traveled with them in spring 2018. ***A3 was paired with A5 but split up temporarily in winter 2018/2019; Note also that A7 was shot in DK on 20-9-2020, 4A and 4C were shot in DK on 21-12-2019, A2 died in SV on 02-06-2019, and 4B last sent GPS data in SV on 14-05-2019 and was not observed afterwards.

Year	Productivity	Productivity	Days above 0 °C	Days above 0 °C
	Svalbard population % juveniles	Novaya Zemlya population % juveniles	Svalbard No. days in May	Novaya Zemlya No. days in May
1981	0.08	NA	4	0
1982	0.218	NA	4	0
1983	0.167	NA	7	0
1984	0.197	NA	10	0
1985	0.132	NA	4	0
1986	0.128	NA	5	0
1987	0.236	NA	9	0
1988	0.17	NA	9	0
1989	0.082	NA	7	0
1990	0.124	NA	1	0
1991	0.222	NA	9	2
1992	0.063	NA	4	6
1993	0.186	NA	7	2
1994	0.129	NA	7	1
1995	0.263	NA	6	7
1996	0.178	NA	1	3
1997	0.145	NA	4	0
1998	0.119	NA	0	0
1999	0.115	NA	13	0
2000	0.056	NA	6	2
2001	0.117	NA	2	0
2002	0.112	NA	8	1
2003	0.142	NA	8	2
2004	0.124	NA	11	1
2005	0.076	NA	8	4
2006	0.182	NA	18	2
2007	0.131	NA	7	0
2008	0.133	NA	5	0
2009	0.109	NA	15	0
2010	0.221	NA	20	1
2011	0.188	NA	10	6
2012	0.106	NA	5	5
2013	0.125	NA	8	3
2014	0.122	NA	9	1
2015	0.157	NA	9	9
2016	0.209	NA	23	7
2017	0.083	NA	4	0
2018	0.167	NA	27	0
2019	0.090	0.052	9	1
2020	0.184	0.266	18	7

Table S2. Productivity (% of juveniles of juveniles in autumn flocks) of Novaya Zemlya and Svalbard breeding pink-footed geese and number of days in May with average daily mean temperature above 0 °C on Svalbard (average of the two stations Svalbard Airport and Ny-Ålesund) and at two points on Severny Island, Novaya Zemlya (75.1 N 55.8 E and 74.1 N 55.4 E). Related to Figure 3.

Year	Sweden Autumn peak numbers	Finland Spring peak numbers	Nn est	sd	# Migration	sd	% Migration	sd
2000	87	215	NA	NA	NA	NA	NA	NA
2001	184	250	95.0	2.8	89.0	2.8	48.4	1.5
2002	52	300	199.9	5.5	-147.9	5.5	-284.5	10.6
2003	26	400	57.3	1.5	-31.3	1.5	-120.3	5.9
2004	263	500	29.0	0.8	234.0	0.8	89.0	0.3
2005	88	500	298.9	7.6	-210.9	7.6	-239.7	8.6
2006	197	650	98.5	2.4	98.5	2.4	20.0	1.2
2007	267	1100	232.4	6.2	34.6	6.2	13.0	2.3
2008	753	885	295.5	7.7	457.5	7.7	60.8	1.0
2009	474	850	813.5	21.1	-339.5	21.1	-71.6	4.5
2010	416	800	543.2	15.0	-127.2	15.0	-30.6	3.6
2011	775	1440	505.4	12.7	269.6	12.7	34.8	1.6
2012	1043	1946	882.2	18.1	160.8	18.1	15.4	1.7
2013	373	1170	1141.2	25.9	-768.2	25.9	-206.0	6.9
2014	1618	2304	410.3	9.8	1207.7	9.8	74.6	0.6
2015	2846	1708	1710.3	42.3	1135.7	42.3	39.9	1.5
2016	1304	2900	3241.8	67.7	-1937.8	67.7	-148.6	5.2
2017	3852	4335	1514.6	45.5	2337.4	45.5	60.7	1.2
2018	2546	4220	3836.8	134.9	-1290.8	134.9	-50.7	5.3
2019	3069	5400	2920.2	137.1	148.8	137.2	4.8	4.5
2020	4147	5970	NA	NA	NA	NA	NA	NA

Table S3. Annual peak autumn pink-footed goose counts in Sweden, peak spring counts in Finland, estimated autumn population size by an IPM (Nn est), estimated immi- and emigration in numbers (# migration) and proportion of the estimated population size (% migration), as well as standard deviations (sd). Related to Figure 1 and the STAR Methods.

Year	Natural survival rate	sd	Reproduction rate	sd	Harvest rate	sd
2000	0.925	0.027	0.191	0.008	0.008	0.003
2001	0.930	0.025	0.169	0.009	0.000	0.000
2002	0.932	0.024	0.203	0.007	0.015	0.004
2003	0.934	0.024	0.203	0.007	0.006	0.002
2004	0.937	0.023	0.222	0.007	0.006	0.002
2005	0.937	0.022	0.203	0.007	0.006	0.002
2006	0.938	0.022	0.276	0.015	0.011	0.003
2007	0.933	0.024	0.197	0.007	0.008	0.002
2008	0.934	0.023	0.185	0.008	0.021	0.004
2009	0.931	0.024	0.252	0.010	0.014	0.003
2010	0.944	0.020	0.293	0.018	0.004	0.001
2011	0.949	0.019	0.216	0.007	0.011	0.002
2012	0.942	0.020	0.185	0.008	0.017	0.003
2013	0.939	0.021	0.203	0.007	0.022	0.004
2014	0.941	0.021	0.209	0.007	0.060	0.006
2015	0.948	0.019	0.209	0.007	0.005	0.002
2016	0.939	0.022	0.321	0.024	0.050	0.005
2017	0.911	0.030	0.180	0.009	0.063	0.007
2018	0.895	0.034	0.362	0.035	0.046	0.006
2019	0.879	0.040	0.209	0.007	0.063	0.008

Table S4. Mean values of year-specific simulated natural survival rates from a year-specific beta distribution (θ_t), simulated reproduction rates from a year-specific gamma distribution (r_t) and estimated annual harvest rates of Novaya Zemlya pink-footed geese in Denmark (h_t^r), as well as standard deviations (sd). Related to the STAR Methods.