



Annex 11.3C: Collision Risk Modelling of Greenland white- fronted goose

MachairWind Offshore Ornithology

ScottishPower Renewables (SPR)

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1.0 Introduction

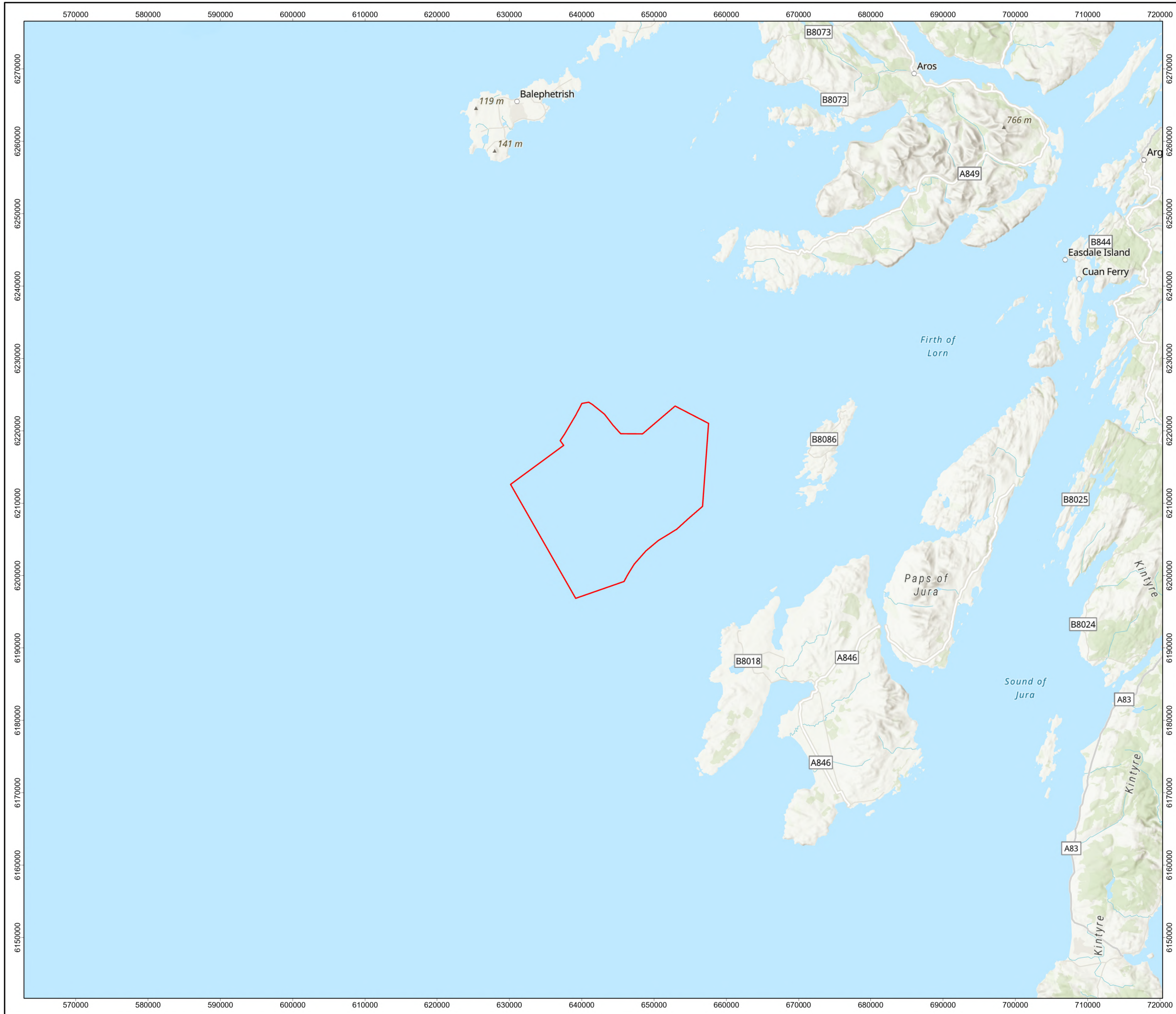
1.1 Project Summary

1. Machairwind Limited ('the Applicant') is proposing the development of the MachairWind Windfarm ('the Project'), an offshore windfarm, located off the west coast of Scotland approximately 15 kilometres (km) to the northwest of Islay and approximately 12.4 km west of Colonsay at the closest points (**Figure 1**).
2. The Offshore Project will comprise up to 144 wind turbine generators (WTGs) with fixed-bottom foundations. The area within which the WTGs and associated infrastructure will be located is the Windfarm Development Area (WDA). The WDA covers an area of 448 km².

1.2 Purpose of this report

3. This report presents estimated collision risks due to the Project, to the British and Irish Greenland white-fronted goose population as a whole and also to the sub-population which winters on Islay.





Windfarm Development Area (WDA)

N

0 5 10 20 Kilometres



1	21/04/2026	MMM	MMM	NG/SO	NG/SO
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2.0 Methods

2.1 Overview

4. The migratory collision risk model (mCRM¹) was used to estimate collision risks to the total British and Irish Greenland white-fronted goose population, and also to the sub-population which over-winters on Islay.
5. The mCRM, an update of SOSS-MAT produced by Wright et al., (2012), differs from the seabird CRM in the method for estimating the size of the population at-risk of collisions. In the seabird CRM this is derived from the density of birds recorded during baseline surveys. In the mCRM the population at risk is calculated as the migratory population multiplied by the proportion of migration flightpaths (species-specific and pre-populated in the mCRM) which cross the WDA.
6. Collision assessment was applied to the total British and Irish population and also to the large sub-population that winters on Islay. It is uncertain what proportion of this population may cross the WDA, therefore two approaches were applied. The first used the same proportion calculated for the whole population (i.e. using the built-in methods in the mCRM), while the second took a highly precautionary approach and made the assumption that all of the Islay population could cross the WDA in both spring and autumn. These two approaches are therefore considered likely to bracket the most likely real proportion of this population which could be at risk.

2.2 Avian migration collision risk model (mCRM)

2.2.1 Bird input parameters

7. The biometrics and avoidance rates used in mCRM are presented in **Table 1**. These are the values pre-populated in the mCRM tool.

Table 1: Greenland white-fronted goose biometrics and avoidance rates (AR) used in the mCRM to generate collision estimates (\pm standard deviation).

Species	Greenland white-fronted goose
mCRM AR	0.999 \pm 0.0001
Body length mean (metres)	0.72 \pm 0.06
Wingspan mean (metres)	1.48 \pm 0.06
Flight speed mean (m/s)	18.75 \pm 7.19
Flight type: Flapping or Gliding	Flapping
% of flights upwind	50
% of flights at collision risk height	100

8. Additional input parameters specific to the mCRM are summarised in **Table 2**. The biogeographic and Islay populations are provided in Fox et al., (2024).

¹ <https://hidefdevo.shinyapps.io/mCRM/>



Table 2: Additional bird input parameters used in the mCRM.

Parameter	Value	Unit
Biogeographic population (i.e. Britain and Ireland)	14,997	Individuals
Islay population	4,926	Individuals
Pre-breeding migration	Mar - Apr	Month
Post-breeding migration	Sep - Nov	Month

2.2.2 Windfarm input parameters

9. Two alternative wind turbine options were modelled, representing the Most Likely Scenario (MLS) and the Worst Case Scenario (WCS). The number of turbines and their specifications are provided in **Table 3**.

Table 3: Turbine specifications used in the mCRM.

Input Parameter	Most Likely Scenario	Worst Case Scenario
Number of turbines	97	144
No. of rotor blades	3	3
Maximum chord (m)	7.5	6.5
Rotor radius (m)	138	118
Rated RPM	7.43	8.05
Mean blade pitch (°)	3.5	3.5
Latitude (°)	56.03	56.03
Mean Wind Farm Width (km)	29	29

10. The predicted monthly time that turbines will be operational (and therefore when collisions are possible) are presented in **Table 4**.

Table 4: Offshore windfarm proportion of time operational by month.

Month	Monthly operations (%)	Monthly downtime (%)
January	97.0	3
February	96.1	3
March	95.2	3
April	92.4	3
May	90.9	3
June	90.3	3
July	91.3	3
August	92.1	3
September	94.9	3
October	96.5	3
November	97.2	3
December	96.6	3



11. In addition, a custom shapefile was used to apply the WDA boundary being proposed for the Project (**Figure 1**).

2.2.3 Assumptions

12. Following the advice in Woodward et al., (2023), it was assumed that 100% of birds pass through the WDA at collision risk height (**Table 1**). This is unlikely to be realistic but is a precautionary assumption to make in the absence of robust goose flight height data from the location of the WDA.
13. It should also be noted that Woodward et al., (2023) recommend an avoidance rate for all goose species of 99.98%, rather than the value of 99.90% in the mCRM. The latter (as used in this assessment) generates collision risks five times higher than the former.
14. Spring migration may occur during March and April (Fox et al., 2024) and autumn migration between September and October, but since the migration CRM operates on the basis that each bird only makes a single crossing of the WDA, the selection of which month this occurs in has no effect on the results. Therefore, it was assumed that all birds passed through the WDA in March and November, as these have a greater proportion of time with the turbines operational than in April and October, and so was a precautionary assumption.



3.0 Results

15. The predicted seasonal and annual collision risks for the total Britain and Ireland and Islay populations for each design scenario and flightpath proportions are provided in **Table 5**.

Table 5: Predicted seasonal and annual collisions obtained using mCRM for the total British and Irish population and the Islay sub-population of Greenland white-fronted goose.

Population assessed	N	Proportion of flightpaths crossing the Project footprint	Design scenario	Collision risk (mean +/- standard deviation)		
				Pre-breeding total	Post-breeding total	Annual total
British and Irish	14,997	0.073	MLS	0.04 +/- 0.03	0.04 +/- 0.03	0.08 +/- 0.04
			WCS	0.05 +/- 0.03	0.06 +/- 0.04	0.11 +/- 0.05
Islay	4,926	0.073	MLS	0.01 +/- 0.01	0.01 +/- 0.01	0.03 +/- 0.01
		0.073	WCS	0.02 +/- 0.01	0.02 +/- 0.01	0.04 +/- 0.02
		1.0	MLS	0.18 +/- 0.12	0.19 +/- 0.12	0.37 +/- 0.17
		1.0	WCS	0.25 +/- 0.16	0.25 +/- 0.16	0.50 +/- 0.22

16. The annual collision risk estimated for the British and Irish population was between 0.08 and 0.11 birds per year (for the most likely and worst case scenarios respectively). For the Islay sub-population the predicted annual collision risk was between 0.03 (MLS and 7.3% flightpaths at risk) and 0.5 (WCS and 100% of flightpaths at risk).
17. The mean adult annual survival rate for white-fronted goose on Islay is 0.828 (Griffin et al., 2020). At this rate the background mortality of the British and Irish population is 2,579. The addition of a precautionary maximum of 0.11 to this would increase the mortality rate by 0.004%, while using the MLS mortality of 0.08, this increase would be 0.003%.
18. The mean adult annual survival rate for white-fronted goose on Islay is 0.828 (Griffin et al., 2020). At this rate the background mortality of the Islay population is 847. The addition of a precautionary maximum of 0.50 to this would increase the mortality rate by 0.059%, while using the MLS mortality of 0.37, this increase would be 0.04%.



4.0 Discussion

19. It is apparent that, despite the application of high levels of precaution, with a worst-case assumption that all of the Islay population flies through the WDA at rotor height twice a year, the Project is highly unlikely to represent a detectable risk to either the Islay or British and Irish Greenland white-fronted goose populations. This is due to a combination of (a) generally low risks of collision on migration, since birds are only at risk up to twice per year and (b) high goose avoidance rates.
20. The predicted increases in mortality rate were very low in all cases, with only the combination of worst case windfarm design and the highly precautionary assumptions that all of the Islay population will cross the WDA at rotor height giving an increase in mortality in excess of 0.02%.
21. However, this value (0.059%) was obtained using the lower avoidance rate of 99.9% pre-populated in the mCRM. Application of the goose avoidance rate value recommended by Woodward et al., (2023) of 99.98% would result in a maximum increase in mortality of 0.012%, well below the 0.02% threshold at which NatureScot consider further consideration may be required (e.g. through the use of population viability analysis).
22. It is clear therefore, that even under highly precautionary assumptions, the levels of estimated mortality will be undetectable against natural background variations and will therefore have no detectable effect on the Greenland white-fronted goose population.
23. Nonetheless, to ensure a fully precautionary assessment, the Natural England (NE) Population Viability analysis (PVA) tool was used to investigate the potential effect on the Islay population of the predicted impact levels. Although the NE PVA was developed for modelling seabird populations it is equally suitable for other bird species. Demographic parameters were obtained from the most recent published Greenland white-fronted goose PVA (Trinder, 2015). The results, provided in **Appendix A**, confirm that even with the worst case precautionary mortalities the effect on the Islay population will be undetectable, with a maximum counterfactual of population size (CPS) after 35 years of 0.9979 (**Table A2**).
24. Thus, no further assessment is considered necessary.



5.0 References

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Appendix A



Table A1. Inputs: Greenland white-fronted goose, Islay population

Baseline parameters	Settings	Impact parameters	Values
Reference name	GWFG	Number of scenarios of impact	4
Type	Simulation	Are impacts applied separately to each subpopulation	FALSE
Case studies	None	Are impacts specified separately for immatures	FALSE
Model to use for environmental stochasticity	Beta/Gamma	Are standard errors of impacts available	FALSE
Choose model for density dependence	No density	Should random seeds be matched for impact scenarios	TRUE
Include demographic stochasticity in model	TRUE	Impacts are specified as	Relative
Number of simulations	5000	Years in which impacts are assumed to begin	2035
Random seed	1971	Years in which impacts are assumed to end	2070
Years for burn in	5	Scenario A name	MLS 7pct flights
Species	Greenland white-	Scenario A Impact on productivity rate per pair mean	0
Age at first breeding	3	Scenario A Impact on adult survival rate	6.090134e-06
Is there an upper constraint on productivity in the model	TRUE	Scenario A Impact on immature survival rate mean	0
Maximum brood size per pair chicks will be constrained to be no greater than	5	Scenario B name	WCS 7pct flights
Number of subpopulations	1	Scenario B Impact on productivity rate per pair mean	0
Units for initial population size	all.individuals	Scenario B Impact on adult survival rate	8.120179e-06
Are baseline demographic rates specified separately for immatures	TRUE	Scenario B Impact on immature survival rate mean	0
Initial population size	4926	Scenario C name	MLS 100pct
Year	2021	Scenario C Impact on productivity rate per pair mean	0
Productivity rate per pair mean	0.37	Scenario C Impact on adult survival rate per pair mean	7.511165e-05
Productivity rate per pair standard deviation	0.05	Scenario C Impact on immature survival rate mean	0
Adult survival rate Mean	0.876	Scenario D name	WCS 100pct
Adult survival rate standard deviation	0.074	Scenario D Impact on productivity rate per pair mean	0
Immatures survival rates 0 to 1 mean	0.876	Scenario D Impact on adult survival rate	0.0001015022
Immatures survival rates 0 to 1 standard deviation	0.074	Scenario D Impact on immature survival rate mean	0
Immatures survival rates 1 to 2 mean	0.876		
Immatures survival rates 1 to 2 standard deviation	0.074		
Immatures survival rates 2 to 3 mean	0.876		
Immatures survival rates 2 to 3 standard deviation	0.074		
Units for output	whole.population		



Table A2. Outputs: Greenland white-fronted goose, Islay population

Scenario	Impact	Increase in mortality rate	Years since impact	C-PGR					C-PS					50% Quantiles	
				Med.	Mean	SD	LCI	UCI	Med.	Mean	SD	LCI	UCI	Q-UNIMP-50%	Q-IMP-50%
MLS 7pct flights	0.0	0.0000061	25	1.0000	1.0000	0.0019	0.9961	1.0037	1.0010	1.0019	0.0613	0.8843	1.1297	49.76	50.56
WCS 7pct flights	0.0	0.0000081	25	1.0000	1.0000	0.0019	0.9962	1.0040	1.0000	1.0019	0.0614	0.8874	1.1302	50.36	49.62
MLS 100pct flights	0.4	0.0000751	25	0.9999	0.9999	0.0020	0.9960	1.0037	0.9986	1.0001	0.0617	0.8814	1.1271	49.86	50.36
WCS 100pct flights	0.5	0.0001015	25	0.9999	0.9999	0.0020	0.9959	1.0038	0.9956	0.9983	0.0624	0.8821	1.1317	50.08	49.88
MLS 7pct flights	0.0	0.0000061	35	1.0000	1.0000	0.0017	0.9967	1.0033	1.0000	1.0026	0.0697	0.8744	1.1484	49.92	50.14
WCS 7pct flights	0.0	0.0000081	35	1.0000	1.0000	0.0017	0.9967	1.0033	1.0000	1.0018	0.0697	0.8726	1.1450	49.92	50.18
MLS 100pct flights	0.4	0.0000751	35	0.9999	0.9999	0.0017	0.9966	1.0033	0.9977	1.0006	0.0701	0.8696	1.1460	49.42	50.68
WCS 100pct flights	0.5	0.0001015	35	0.9999	0.9999	0.0017	0.9966	1.0033	0.9937	0.9979	0.0703	0.8712	1.1449	49.34	50.76
MLS 7pct flights	0.0	0.0000061	50	1.0000	1.0000	0.0014	0.9971	1.0028	1.0004	1.0045	0.0817	0.8553	1.1739	50.56	49.50
WCS 7pct flights	0.0	0.0000081	50	1.0000	1.0000	0.0014	0.9971	1.0028	1.0010	1.0028	0.0817	0.8509	1.1758	50.38	49.74
MLS 100pct flights	0.4	0.0000751	50	1.0000	1.0000	0.0014	0.9971	1.0029	0.9975	1.0020	0.0817	0.8461	1.1759	50.02	50.00
WCS 100pct flights	0.5	0.0001015	50	0.9999	0.9999	0.0014	0.9971	1.0028	0.9962	0.9981	0.0822	0.8448	1.1687	49.84	50.12



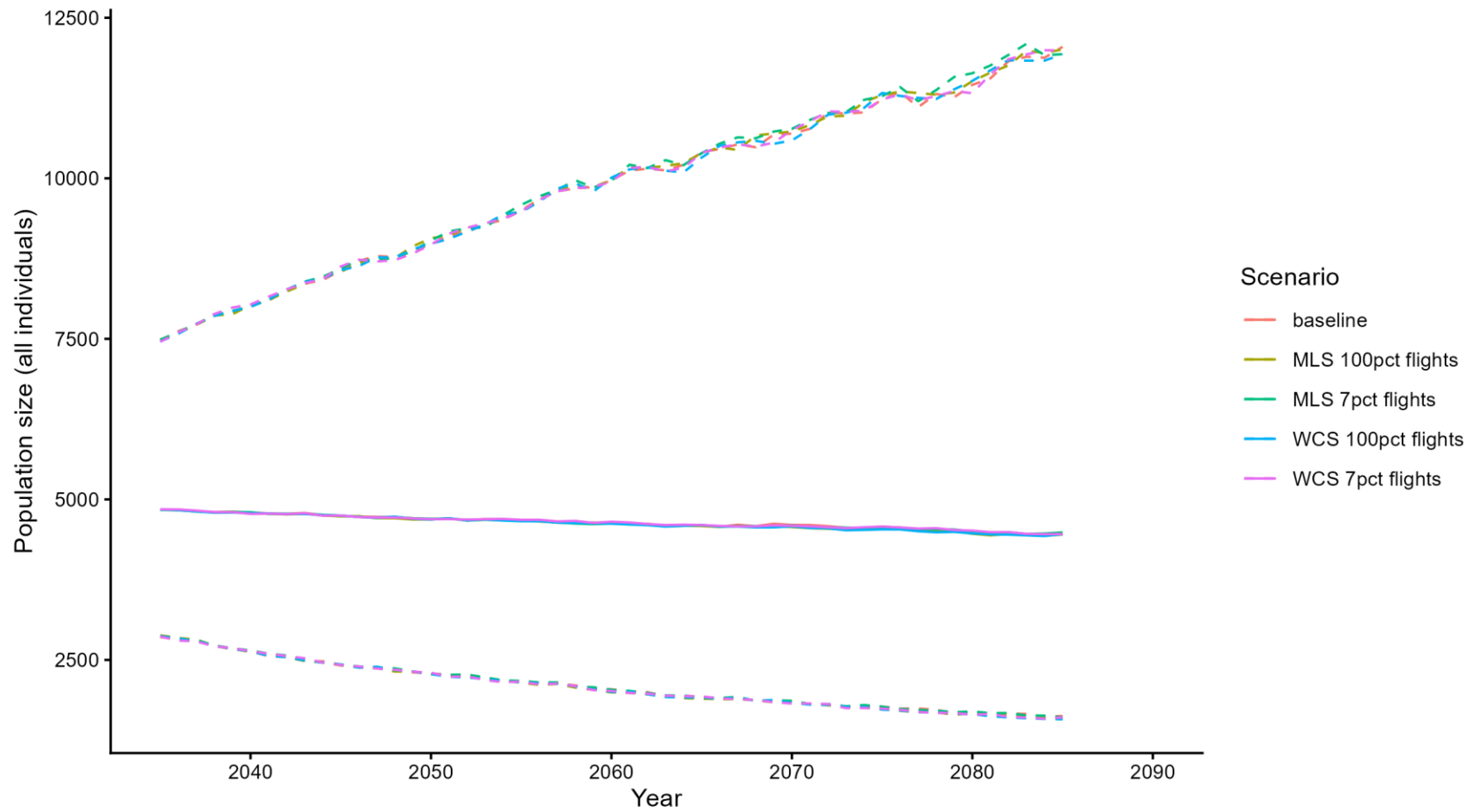


Figure A1. Greenland white-fronted goose, Islay population



