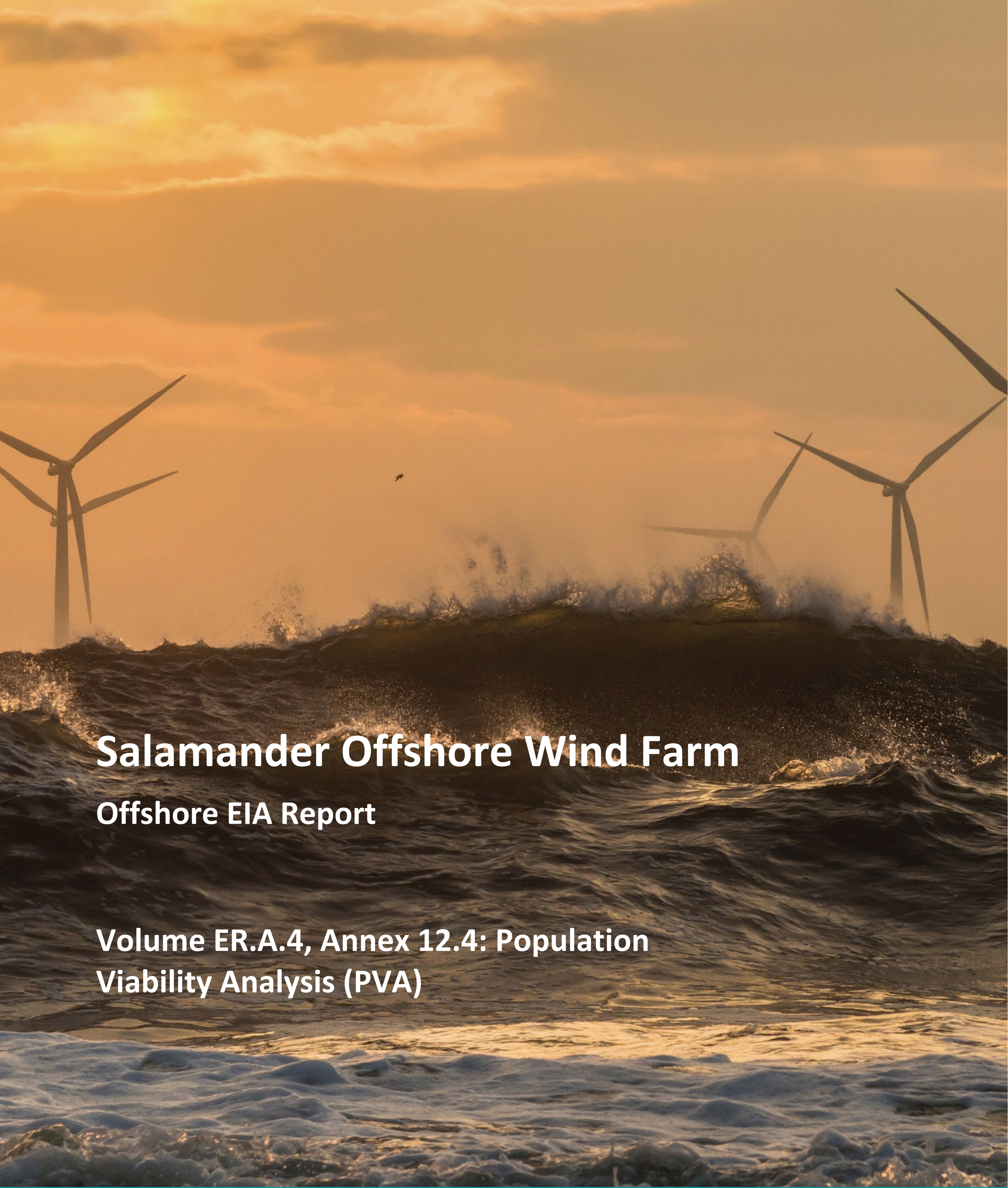

Salamander Offshore Wind Farm

Offshore EIA Report

Volume ER.A.4, Annex 12.4: Population Viability Analysis (PVA)

SALAMANDER

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Salamander Offshore Wind Farm: Annex ER.A.4.12.4: Population Viability Analysis

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Acronyms and abbreviations

Term	Definition
BTO	British Trust for Ornithology
BDMPS	Biologically Defined Minimum Population Scales
CEH	Centre for Ecology and Hydrology
CPC	Counterfactual Growth Rate
CPS	Counterfactual Population Size
CRM	Collision Risk Modelling
sCRM	Stochastic Collision Risk Modelling
MD-LOT	Marine Directorate – Licensing Operations Team
NE	Natural England
PVA	Population Viability Analysis
SNCB	Statutory Nature Conservation Bodies
SMP	Seabird Monitoring Programme

1 Introduction

1 This Technical Appendix presents the potential regional-level population impacts to seabirds arising from the operation of the proposed Salamander Offshore Wind Farm (hereafter 'the Salamander Project'). The Salamander Project is being developed by Salamander Wind Project Company Limited (formerly called Simply Blue Energy (Scotland) Limited), a joint venture between Simply Blue Group, Ørsted and Subsea7.

2 The Salamander Project may give rise to a range of impacts; collision risk and distributional responses (displacement/barrier effects) are quantified for assessment resulting in estimates of mortality for each species of concern, as agreed through consultation, and set out in Annex ER.A.4.12.3: Collision Risk Modelling Report and Annex ER.A.4.12.5: Displacement Assessment.

3 As described in Annex ER.A.4.12.5: Displacement Assessment, modelling of distributional responses has been undertaken using the matrix method presented within the joint Statutory Nature Conservation Bodies (SNCB) guidance (JNCC *et al.,* 2022) and SeabORD, a model developed by the Centre of Ecology and Hydrology (CEH) (Mobbs *et al.,* 2018; Searle *et al.,* 2018). To assess collision risk, stochastic (sCRM) (McGregor *et al.,* 2018) and deterministic (Band, 2012) Collision Risk Models (CRM) were used, more detail can be found in in Annex ER.A.4.12.3: Collision Risk Modelling Report. Following advice from the Marine Directorate – Licensing Operations Team (MD-LOT) and NatureScot (Scoping Opinion from MD-LOT dated 21st June 2023 and NatureScot advice on Salamander Offshore Wind Farm EIA Scoping Report dated 5th May 2023), the matrix method and sCRM outputs were used in the impact assessment.

4 The population-level consequences of estimated mortalities due to collision and distributional responses were considered for seabirds in relation to their regional breeding populations. Population Viability Analysis (PVA) is a method used to model population-level consequences of estimated mortality. PVA uses seabird demographic rates (typically survival and productivity) to forecast future levels of a population with and without mortality (i.e. impacts) applied. Natural England (NE) commissioned CEH to devise a standard PVA tool for use in assessments of offshore wind developments (Searle *et al*., 2019). This is now referred to as the NE PVA tool and is used in the assessment for the Salamander Project.

5 The species assessed for collision risk and distributional responses and therefore assessed in PVA are:

- Black-legged kittiwake (*Rissa tridactyla*), hereafter 'kittiwake';
- Common guillemot (*Uria aalge*), hereafter 'guillemot';
- Razorbill (*Alca torda*);
- Atlantic puffin (*Fratercula arctica*), hereafter 'puffin'; and
- Northern gannet (*Morus bassanus*); hereafter 'gannet'.

6 These species were selected for further assessment due to their known susceptibility to negative impacts of offshore wind developments, and the level of impact from the Salamander project predicted through CRM and assessment of distributional responses.

7 The NE PVA tool was used to simulate population trends for a range of impact scenarios arising from the Salamander Project, predicted to start in 2030 (as this is when the Salamander Project is expected to be operational) and modelled for operational life spans of 25, 35 and 50 years, following advice from NatureScot (advice on Salamander Offshore Wind Farm EIA Scoping Report dated 5th May 2023).

8 The key outputs from the NE PVA tool are the ratios between impacted and unimpacted (baseline) scenarios, termed 'counterfactuals', which allow meaningful interpretation of the predicted effects against

the populations in question. Following NatureScot guidance (NatureScot, 2023), the two metrics considered are:

a. the counterfactual of final population size (CPS); and

b. the counterfactual of annualised population growth-rate (CPC).

9 Impact scenarios inputted into the NE PVA tool and output plots of CPS and CPC can be found in Appendix I: Impact scenarios for PVA and Appendix III: NE PVA tool plots.

2 Methods

2.1 Assessment method

10 The NE PVA tool (Searle *et al*., 2019) uses a stochastic Leslie Matrix Model (Caswell, 2000) to estimate population size, using species-specific age and life-history data (NatureScot, 2023). All PVA modelling was undertaken using the PVA Tool version 2.0 (Searle *et al*., 2019)

2.1.1 Demographic parameters

11 In the PVA models, the productivity and survival rates for each species were obtained from the default parameters contained in the NE PVA tool, with the region type for breeding success data, colony-specific survival rate and sector to use within breeding success region set as 'Global', 'National' and 'Global', respectively (Table 1). Default parameters in the tool are derived from Horswill and Robinson (2015).

12 Models included environmental and demographic stochasticity, but not density dependence, as has been standard practice based on scoping advice for other Scottish developments (e.g. Pentland Floating Offshore Windfarm). Density dependence was not modelled due to a lack of available data. Although correctly scaled and applied density dependence would be expected to improve the performance of the unimpacted population model against 'real world' values, inappropriate density dependence could invalidate the outcome. Therefore, unless specific knowledge of the form and degree of density dependence is known it is preferable to investigate and interpret the significance of modelled impacts using a density independent model. Across a regional population there are quite possibly several different density dependent traits involved, further complicating its inclusion in this type of analysis and supporting the decision not to include it in the population model.

Table 1 Summary of demographic rates for PVA species (NE PVA tool default values derived from SMP data)

Demographic	Kittiwake		Guillemot		Razorbill		Puffin		Gannet	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Adult survival	0.854	0.077	0.940	0.025	0.895	0.067	0.907	0.083	0.919	0.042
Productivity (per pair)	0.60	0.326	0.583	0.189	0.497	0.172	0.574	0.211	0.697	0.086
Age of first breeding	4	-	6	-	5	-	5	-	5	-
Max brood size (per pair)	2	-	1	-	1	-	1	-	1	-
Survival 0 → 1	0.790	0.0001	0.560	0.058	0.063	0.0001	0.709	0.108	0.424	0.045
Survival 1 → 2	0.854	0.077	0.792	0.152	0.063	0.0001	0.709	0.108	0.829	0.026
Survival 2 → 3	0.854	0.077	0.917	0.098	0.895	0.067	0.709	0.108	0.891	0.019
Survival 3 → 4	0.854	0.077	0.938	0.107	0.895	0.067	0.760	0.093	0.895	0.019
Survival 4 → 5	0.854	0.077	0.940	0.025	0.895	0.067	0.805	0.083	0.919	0.042
Survival as adult	0.854	0.077	0.940	0.025	0.895	0.067	0.805	0.083	0.919	0.042

2.1.1 PVA reference populations

13 Reference populations used for each species in the modelling are presented in Table 2. For the breeding season, regional populations were derived using species-specific foraging ranges presented by Woodward *et al.* (2019) where the total number of breeding adults from all colonies within the foraging range for each species were combined to derive the breeding season regional population. Non-breeding season regional populations are based on BDMPS (Furness, 2015). More detailed methodology is presented in Annex ER.A.4. 2.8: Offshore Ornithology Regional Populations Report. It is these estimates that are used within the PVA; more detail can be found in Appendix I: Impact scenarios for PVA.

Table 2 Seabird regional breeding populations considered under PVA

Species	Regional population (breeding individuals)
Kittiwake	202,258
Guillemot	407,959
Razorbill	70,208
Puffin	287,593
Gannet	423,894

2.1.2 Survival by age class and sabbatical rates

14 Within the PVA tool, survival rate can be set as age-dependent or the same across all age groups. For the baseline scenario, the default survival values from the age dependent function provided in the NE PVA tool were used.

15 Note that assessment for the Salamander Project has made no allowance for sabbatical birds. For guillemot and razorbill, estimated occurrences of sabbatical birds are low (~8% per year), although this figure may have changed since data were collected in the early 1990s. However, even if appropriate rates were to exist, the NE PVA tool does not currently allow for sabbatical rates to be included, although a 'discount' to impacts equivalent to the sabbatical rate could be applied before models are run. In this case no 'discount' has been applied to the collision or displacement mortality estimates in respect of sabbatical birds for any species including auks and kittiwake.

2.1.3 Model duration

16 To understand population declines, and to place predicted mortalities from the Salamander Project into context, 50-year baseline models were run for each species. Seabird colony data for the UK and Ireland (from the SMP) spanning 1985 to 2022 were provided by the BTO (data received 25th May 2023) and used to derive breeding and non-breeding season regional populations (for more detail see Annex ER.A.4.12.8: Offshore Ornithology Regional Populations Report. Baseline models were run from the most recent year of data collection within the SMP dataset (2022) to 2080. The baseline populations at the end of this modelled period, in the absence of any wind farm development, are reported alongside results from impacted scenarios in Section 3.

17 The PVAs used to model the population consequences of predicted impacts were also run from 2022 and impacts were assumed to commence in 2030, based on the Salamander Project programme and an assumed commissioning date of December 2029. Impacts were modelled to last for 25, 35 and 50 years as requested by MD-LOT and NatureScot (Scoping Opinion dated 21st June 2023 and NatureScot advice on Scoping Report dated 5th May 2023).

18 For each species, each simulation was run 5,000 times to obtain a population trajectory and associated uncertainty due to environmental and demographic stochasticity.

2.1.4 Modelled mortality (impact scenarios)

19 For each species, each baseline simulation was paired with an impact scenario (Table 3). Kittiwake and gannet mortalities arise from the combined estimated impact due to collision risk and distributional

response effects, while guillemot, razorbill and puffin mortalities arise from effects due to distributional responses only.

20 In most cases it is likely the breeding season population will form a small proportion of birds subject to impact in the non-breeding population when birds mix more freely within a wider population. The result being that impacts to the regional population are diluted. To account for this, the ratio of birds from the breeding season population compared to non-breeding season population was multiplied by the estimated mortality in the non-breeding season to give the mortality estimate for the regional population in the non-breeding season. This, plus the breeding season mortality was used to derive the mean annual impact on adult survival rate.

21 Southwards migration of gannet post-breeding means the non-breeding season population is smaller than that for the breeding season. Therefore, non-breeding season mortality estimates were scaled to reflect the proportion of UK birds' contributing to the total North Sea and English Channel non-breeding season population. More detail on this approach is given in Appendix I: Impact scenarios for PVA.

Table 3 Modelled impact scenarios and mean impact on adult survival rate

Species	Scenario name	Impacts modelled	Mean impact on adult survival rate
Kittiwake	**Scenario 1**	Breeding season: 30%/3% displacement + CRM Non-breeding season: 30%/3% displacement + CRM	0.00029
	Scenario 2	Breeding season: 30%/1% displacement + CRM Non-breeding season: 30%/1% displacement + CRM	0.00017
Guillemot	**Scenario 1**	Breeding season: 60%/5% displacement Non-breeding season: 60%/3% displacement	0.00078
	Scenario 2	Breeding season: 60%/3% displacement Non-breeding season: 60%/1% displacement	0.00033
Razorbill	**Scenario 1**	Breeding season: 60%/5% displacement Non-breeding season: 60%/3% displacement	0.00019
	Scenario 2	Breeding season: 60%/3% displacement Non-breeding season: 60%/1% displacement	0.00010
Puffin	**Scenario 1**	Breeding season: 60%/5% displacement Non-breeding season: n/a	0.00003

Species	Scenario name	Impacts modelled	Mean impact on adult survival rate
	Scenario 2	Breeding season: 60%/3% displacement	0.00002
		Non-breeding season: n/a	
Gannet	**Scenario 1**	Breeding season: 70%/3% displacement + CRM	0.00006
		Non-breeding season: 70%/3% displacement + CRM	
	Scenario 2	Breeding season: 70%/1% displacement + CRM	0.00004
		Non-breeding season: 70%/1% displacement + CRM	

2.1.5 Model outputs (population metrics)

22 The key outputs from the PVA tool are the CPS and CPC (Searle *et al.*, 2019, NatureScot, 2023). These are the ratios of the impacted to unimpacted (baseline) scenarios and allow meaningful interpretation of the predicted effects against the populations in question (Cook and Robinson, 2016).

23 Testing the sensitivities of these metrics has suggested that counterfactual of growth rate is useful to illustrate impacts regardless of population status or trend (Green, 2014; Cook and Robinson, 2016; Jital *et al.*, 2017). Cook and Robinson (2016) also found CPS can be used to robustly assess the population level effects of impacts for stable or increasing populations and may also offer a useful context for the counterfactual of growth rate. CPS has been found to be more sensitive to trend than CPC and so should be interpreted with more care.

24 All impacts are assigned to adult birds. This is likely to be the most precautionary approach since any impacts to adult birds will have a larger effect on the overall population.

3 Results

25 After 35 years, the baseline regional kittiwake population is estimated to decrease from 202,258 birds to 192,638 birds without additional impacts while under Scenario 1 (30% /3% displacement + CRM), the population is estimated to decline to 190,425 birds (Table 4). In comparison, under Scenario 2 (30% /1% displacement + CRM), a decline in the regional population to 191,208 birds is estimated. This results in median counterfactual estimates with confidence intervals reaching or overlapping with 1. Model outputs for 25 and 50-years are presented in Table 14 and Table 15 in the appendix.

Table 4 Kittiwake PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 35 years

Kittiwake scenarios	Median pop. size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	192,638	-	-
Scenario 1 (30% / 3% displacement +CRM)	190,425	1.000 (0.999 – 1.000)	0.988 (0.973 – 1.000)
Scenario 2 (30% / 1% displacement +CRM)	191,208	1.000 (0.999 – 1.000)	0.993 (0.977 – 1.007)

26 For guillemot, the baseline regional population is expected to continue to increase with a regional population of 1,210,611 birds estimated in 2065 after 35 years of operation (compared to a starting regional population of 407,959; Table 5). Despite estimated impacts from the Salamander Project, the regional population of guillemot is still estimated to increase with 1,173,661 birds and 1,194,145 birds estimated under Scenario 1 (60% displacement/ 3-5% mortality) and Scenario 2 (60% displacement/ 1-3% mortality) respectively. The counterfactual metrics fall just below 1 indicating a small impact of the displacement predicted from modelling. Model outputs for 25 and 50-years are presented in Table 16 and Table 17.

Table 5 Guillemot PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 35 years

Guillemot scenarios	Median pop. size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	1,210,611	-	-
Scenario 1 (60% / 3-5% displacement)	1,173,661	0.999 (0.999 – 0.999)	0.969 (0.964 – 0.974)

Guillemot scenarios	Median pop. size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Scenario 2 (60% / 1-3% displacement)	1,194,145	1.000 (0.999 – 1.000)	0.987 (0.981 – 0.992)

27 Similar to kittiwake, the razorbill regional population is estimated to decline from 70,208 birds to an estimated 20,896 birds predicted by the baseline model after 35 years (Table 6). With the addition of impacts under Scenario 1 (60 displacement / 3-5% mortality) and Scenario 2 (60% displacement / 1-3% mortality), 20,725 and 20,827 birds are estimated after 35 years respectively. However, counterfactual metrics are at or close to 1 and have confidence intervals overlapping with 1 indicating a very small impact of the Salamander Project on the regional population. Model outputs for 25 and 50-years are presented in Table 18 and Table 19.

Table 6 Razorbill PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 35 years

Razorbill scenarios	Median pop. size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	20,896	-	-
Scenario 1 (60% / 3-5% displacement)	20,725	1.000 (0.999 – 1.001)	0.992 (0.961 – 1.024)
Scenario 2 (60% / 1-3% displacement)	20,827	1.000 (0.999 – 1.001)	0.996 (0.965 – 1.027)

28 Projecting forward, after 35 years the baseline regional puffin population with no impacts from the Salamander Project is estimated to decrease from 287,593 birds to 90,975 birds (Table 7). With the addition of impacts from the Salamander Project, the regional population is estimated to decline to 90,718 birds (Scenario 1; 60% / 3-5% displacement) and 90,829 birds (Scenario 2; 60% / 1-3% displacement). Counterfactual metrics are at or close to 1 and have confidence intervals overlapping with 1 indicating a very small impact of the development on the regional population Model outputs for 25 and 50-years are presented in Table 20 and Table 21.

Table 7 Puffin PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 35 years

Puffin scenarios	Median pop. size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	90,975	-	-
Scenario 1(60% / 3-5% displacement)	90,718	1.000 (1.000 – 1.000)	0.999 (0.984 – 1.014)
Scenario 2 (60% / 1-3% displacement)	90,829	1.000 (1.000 – 1.000)	0.999 (0.984 – 1.015)

29 In 2065, the baseline regional population of gannet is estimated to increase from 423,894 birds to 544,009 birds while under Scenario 1 conditions (70% displacement / 3% mortality + CRM), the population is estimated at 541,247 birds (Table 8). With the addition of Scenario 2 impacts (70% displacement / 1% mortality + CRM), the PVA model estimated the gannet regional population to increase to 541,848 birds. Counterfactual metrics are at or close to 1 and have confidence intervals overlapping with 1 indicating a very small impact of the development on the regional population. Model outputs for 25 and 50-years are presented in Table 22 and Table 23.

Table 8 Gannet PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 35 years

Gannet scenarios	Median pop. size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	544,009	-	-
Scenario 1 (70% / 3% displacement +CRM)	542,147	1.000 (1.000 – 1.000)	0.998 (0.990 – 1.000)
Scenario 2 (70% / 1% displacement +CRM)	542,920	1.000 (1.000 – 1.000)	0.998 (0.991 – 1.010)

4 Conclusions

30 The regional kittiwake population has been steadily declining for several years and this is reflected in the PVA results (Table 4). Projecting forward, the 25- and 35-year baseline model predicts a slow, continuing decline in the absence of wind farm impacts, with the kittiwake breeding season regional population predicted at 193,180 birds and 192,638 birds in 2055 and 2065 respectively. By 2080, 50-years from the start of the operational phase of the Salamander Project, the median kittiwake population size is estimated to decrease slightly by a further 1% under Scenario 1 and Scenario 2.

31 Population declines in unimpacted scenarios are also predicted for razorbill and puffin breeding season regional populations (Table 6, Table 7). When impacts are applied, the median population size of razorbill decreases by an additional 1% and 0% under Scenario 1 and Scenario 2 respectively compared to 0% for puffin, under both scenarios. Although counterfactuals for kittiwake, razorbill and puffin indicate possible declines in median population size compared to unimpacted conditions, any impacts are expected to be very low.

32 Under baseline conditions the breeding season regional population of guillemot and gannet are predicted to increase after 50 years, rising from 407,959 individuals to 1,776,101 individuals and 423,898 individuals to 595,725 individuals, respectively (Table 17, Table 23). Despite this, median population size is not expected to differ when impacts are applied from that predicted for gannet in either scenario, while for guillemot both scenarios estimate a reduction of the final median population size of 3% and 1% respectively when comparing impacted and unimpacted conditions. For all species considered, change in median growth rate is estimated to be negligible between baseline and impacted scenarios, with all ratio metric (both CPC and CPS) confidence intervals overlapping with one, except for guillemot.

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Appendix I: Impact scenarios for PVA

33 This appendix presents the supporting calculations used to determine the impact scenarios (i.e. mortality estimates due to collision and distribution responses) to model against kittiwake, guillemot, razorbill, puffin and gannet breeding season regional populations. As PVA is being conducted at a regional scale, before the mean impact on survival rate could be derived the total estimated mortality had to be manually calculated.

34 Where the breeding season regional populations are based on foraging range (Woodward *et al.,* 2019) and non-breeding season regional populations are based on BDMPS (Furness, 2015), that is for kittiwake, gannet and razorbill, the breeding season population forms only part of those birds subject to impact in the non-breeding season population. Therefore, the number of mortalities estimated to occur during the non-breeding season will include impacts to birds that are not part of the breeding season regional populations for the Salamander Project. To account for this, the estimated mortality in the non-breeding season was multiplied by the ratio of birds from the regional breeding population compared to the BDMPS non-breeding population. The proportion of non-breeding season mortality which applied to the regional population was added to the breeding season mortality estimate, to obtain the mean annual impact on adult survival rate, which was inputted into the NE PVA tool.

35 In the case of gannet, the non-breeding population within the BDMPS is smaller than the total regional breeding population, despite the BDMPS non-breeding season population being made up of UK and non-UK birds. This is because some UK birds leave UK waters completely during the non-breeding season which is expected to include birds from the regional population colonies. To account for this, mortality estimates from collision and distributional responses in the non-breeding season were scaled in proportion to the UK birds' contribution to the estimated North Sea and English Channel non-breeding season population (as presented in Furness, 2015 but using updated colony sizes; approx. 94.5%).

36 For each focal species two scenarios were run for the breeding and non-breeding season. Multiple scenarios were required as multiple mortality estimates were produced during assessment of distributional responses. For example, for kittiwake, distributional responses were assessed using rates of 30% displacement with 3% mortality as well as 30% displacement with 1% mortality (Table 3 and Annex ER.A.4.12.5: Displacement Assessment). For all species, Scenario 1 uses mortality estimates derived from the highest mortality rates e.g. 3% mortality rate in Scenario 1 compared to 1% mortality rate in Scenario 2 for kittiwake.

Table 9 Parameters used to determine mean impact on kittiwake adult survival rate (% of adult population affected) for each PVA scenario

	Breeding	Non-breeding
Scenario 1 (30%/3% displacement (breeding and non-breeding) + CRM)		
Displacement mortality	33	2
CRM mortality	23	3
Regional population	202,258	627,816
Mortality for PVA	56	1.61
Mean impact on adult survival rate	0.00029	
Scenario 2 (30%/1% displacement (breeding and non-breeding) + CRM)		
Displacement mortality	11	1
CRM mortality	23	3
Regional population	202,258	627,816
Mortality for PVA	34	1.29
Mean impact on adult survival rate	0.000173	

Table 10 Parameters used to determine mean impact on guillemot adult survival rate for each PVA scenario

	Breeding	Non-breeding
Scenario 1 (60%/5% (breeding) 60%/3% (non-breeding) displacement + CRM)		
Displacement mortality	108	212
Regional population	407,959	407,959
Mortality for PVA	108	212
Mean impact on adult survival rate	0.00078	
Scenario 2 (60%/3% (breeding) 60%/1% (non-breeding) displacement + CRM)		
Displacement mortality	65	71
Regional population	407,959	407,959
Mortality for PVA	65	71
Mean impact on adult survival rate	0.0003	

Table 11 Parameters used to determine mean impact on razorbill adult survival rate for each PVA scenario

	Breeding	Non-breeding
Scenario 1 (60%/5% (breeding) 60%/3% (non-breeding) displacement + CRM)		
Displacement mortality	10	9
Regional population	70,208	218,622
Mortality for PVA	10	2.89
Mean impact on adult survival rate	0.0002	
Scenario 2 (60%/3% (breeding) 60%/1% (non-breeding) displacement + CRM)		
Displacement mortality	6	3
Regional population	70,208	218,622
Mortality for PVA	6	0.96
Mean impact on adult survival rate	0.0001	

Table 12 Parameters used to determine mean impact on puffin adult survival rate for each PVA scenario

	Breeding	Non-breeding
Scenario 1 (60%/5% displacement)		
Displacement mortality	11	n/a
Regional population	287,593	n/a
Mortality for PVA	11	n/a
Mean impact on adult survival rate	0.00003	
Scenario 2 (60%/3% displacement)		
Displacement mortality	6	n/a
Regional population	287,593	n/a
Mortality for PVA	7	n/a
Mean impact on adult survival rate	0.00002	

Table 13 Parameters used to determine mean impact on gannet adult survival rate for each PVA scenario

	Breeding	Non-breeding
Scenario 1 (70%/3% displacement (breeding and non-breeding) + CRM)		
Displacement mortality	9	8
CRM mortality	5	4
Regional population	423,894	248,385
Mortality for PVA	14	11.34
Mean impact on adult survival rate	0.00006	
Scenario 2 (70%/1% displacement (breeding and non-breeding) + CRM)		
Displacement mortality	3	3
CRM mortality	5	4
Regional population	423,894	248,385
Mortality for PVA	8	6.62
Mean impact on adult survival rate	0.00004	

Appendix II: PVA results

37 This appendix presents the median population size after 25 years and 50 years alongside the counterfactuals with 95% confidence intervals for each species. The baseline scenario is the predicted population size when no additional impacts have been applied. The resulting population size and counterfactual values are also reported for each species under each impact scenario, again after 25 and 50 years of impact.

Table 14 Kittiwake PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 25 years

Kittiwake scenarios	Median pop. Size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	193,180	-	-
Scenario 1 (30% / 3% displacement +CRM)	191,342	1.000 (0.999 – 1.000)	0.991 (0.977 – 1.004)
Scenario 2 (30% / 1% displacement +CRM)	191,956	1.000 (0.999 – 1.000)	0.995 (0.982 – 1.007)

Table 15 Kittiwake PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 50 years

Kittiwake scenarios	Median pop. Size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	189,059	-	-
Scenario 1 (30% / 3% displacement +CRM)	185,435	1.000 (0.999 – 1.000)	0.983 (0.966 – 1.000)
Scenario 2 (30% / 1% displacement +CRM)	186,816	1.000 (0.999 – 1.000)	0.990 (0.972 – 1.007)

Table 16 Guillemot PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 25 years

Guillemot scenarios	Median pop. Size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	943,195	-	-
Scenario 1 (60% / 3-5% displacement)	921,949	0.999 (0.999 – 0.999)	0.978 (0.973 – 0.982)
Scenario 2 (60% / 1-3% displacement)	934,077	1.000 (0.999 – 1.000)	0.990 (0.986 – 0.995)

Table 17 Guillemot PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 50 years

Guillemot scenarios	Median pop. Size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	1,776,101	-	-
Scenario 1 (60% / 3-5% displacement)	1,697,292	0.999 (0.999 – 0.999)	0.956 (0.951 – 0.962)
Scenario 2 (60% / 1-3% displacement)	1,742,216	1.000 (1.000 – 1.000)	0.981 (0.976 – 0.987)

Table 18 Razorbill PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 25 years

Razorbill scenarios	Median pop. Size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	28,027	-	-
Scenario 1 (60% / 3-5% displacement)	27,835	1.000 (0.999 – 1.001)	0.994 (0.969 – 1.020)
Scenario 2 (60% / 1-3% displacement)	27,946	1.000 (0.999 – 1.001)	0.997 (0.972 – 1.022)

Table 19 Razorbill PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 50 years

Razorbill scenarios	Median pop. Size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	13,587	-	-
Scenario 1 (60% / 3-5% displacement)	13,405	1.000 (0.999 – 1.001)	0.988 (0.948 – 1.032)
Scenario 2 (60% / 1-3% displacement)	13,504	1.000 (0.999 – 1.001)	0.994 (0.953 – 1.036)

Table 20 Puffin PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 25 years

Puffin scenarios	Median pop. Size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	119,966	-	-
Scenario 1(60% / 3-5% displacement)	119,758	1.000 (1.000 – 1.000)	0.999 (0.987 – 1.011)
Scenario 2 (60% / 1-3% displacement)	119,925	1.000 (1.000 – 1.000)	0.999 (0.987 – 1.012)

Table 21 Puffin PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 50 years

Puffin scenarios	Median pop. Size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	60,517	-	-
Scenario 1(60% / 3-5% displacement)	60,373	1.000 (1.000 – 1.000)	0.998 (0.978 – 1.018)
Scenario 2 (60% / 1-3% displacement)	60,346	1.000 (1.000 – 1.000)	0.999 (0.978 – 1.020)

Table 22 Gannet PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 25 years

Gannet scenarios	Median pop. Size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	515,320	-	-
Scenario 1 (70% / 3% displacement +CRM)	514,754	1.000 (1.000 – 1.000)	0.998 (0.992 – 1.000)
Scenario 2 (70% / 1% displacement +CRM)	514,801	1.000 (1.000 – 1.000)	0.999 (0.992 – 1.010)

Table 23 Gannet PVA: Median population size and counterfactuals (5,000 simulations) with upper and lower 95% confidence intervals after 50 years

Gannet scenarios	Median pop. Size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Baseline	595,725	-	-
Scenario 1 (70% / 3% displacement +CRM)	593,130	1.000 (1.000 – 1.000)	0.997 (0.988 – 1.010)
Scenario 2 (70% / 1% displacement +CRM)	593,789	1.000 (1.000 – 1.000)	0.998 (0.989 – 1.010)

Appendix III: NE PVA tool plots

38 This appendix presents the projected population size under each scenario between 2022 and 2080 for each species in addition to the counterfactual of population growth rate (CPC) and counterfactual of population size (CPS). Outputs from the NE PVA tool are plotted with the baseline and impact scenario medial values as solid lines and the confidence intervals as colour-matched dotted lines. In plots at this scale these lines may be difficult to distinguish as proportionally impacts are very small.

Figure 1 Projected population size of kittiwake regional population under three scenarios between 2022 and 2080. Confidence interval presented as dotted line

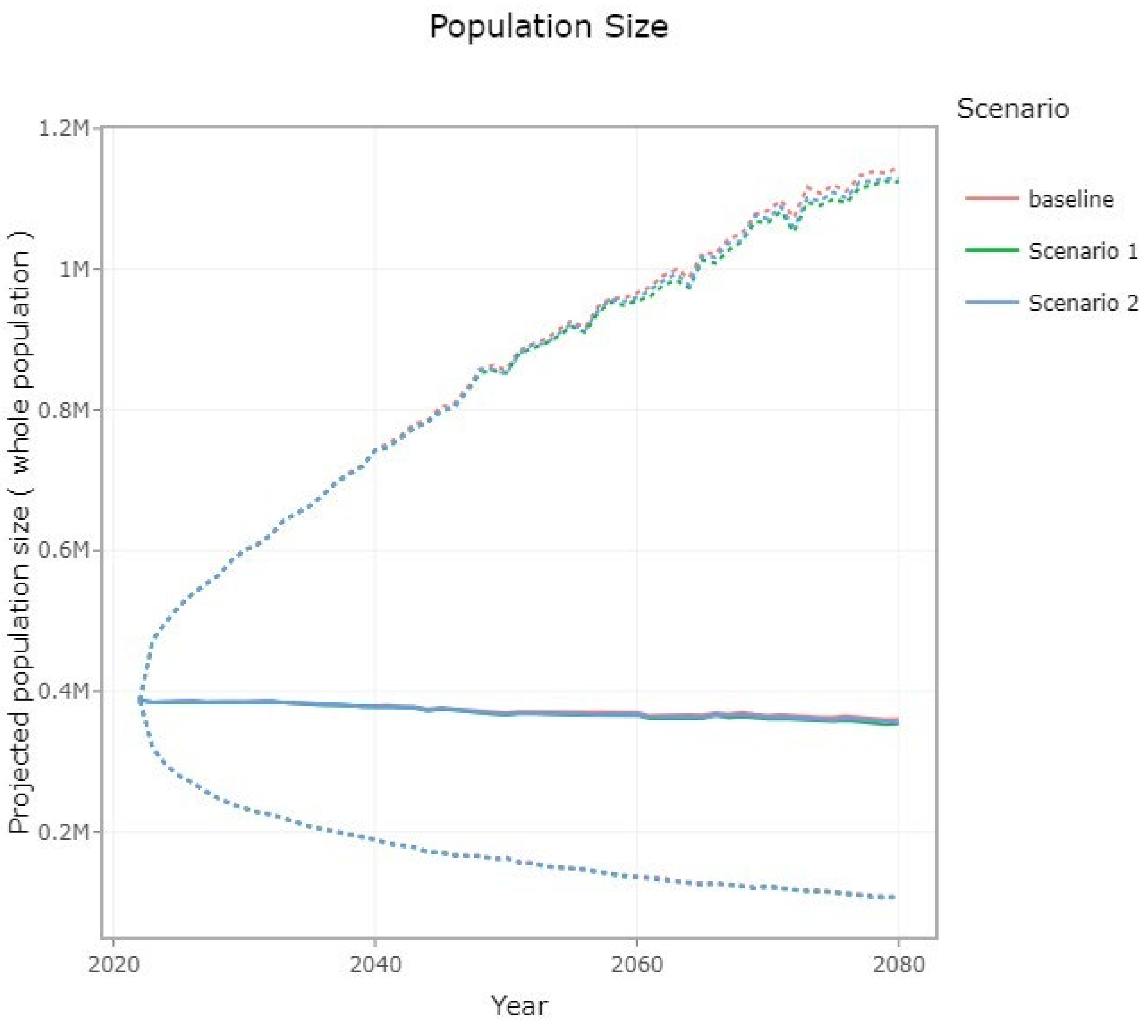

Figure 2 Counterfactual of population growth rate (CPC) for kittiwake regional population over a 50-year period. Confidence interval presented as dotted line

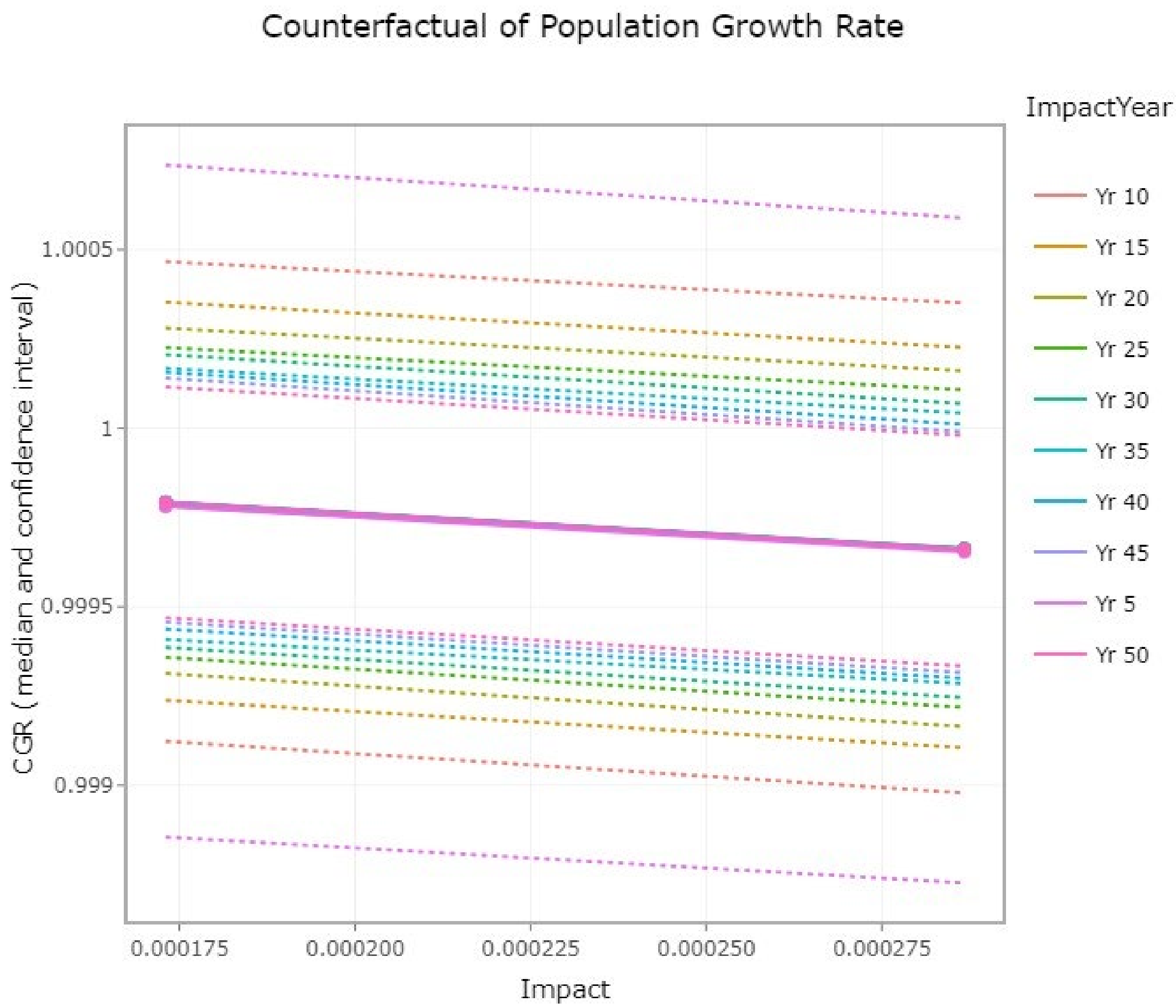

Figure 3 Counterfactual of population size (CPS) for kittiwake regional population over a 50-year period. Confidence interval presented as dotted line

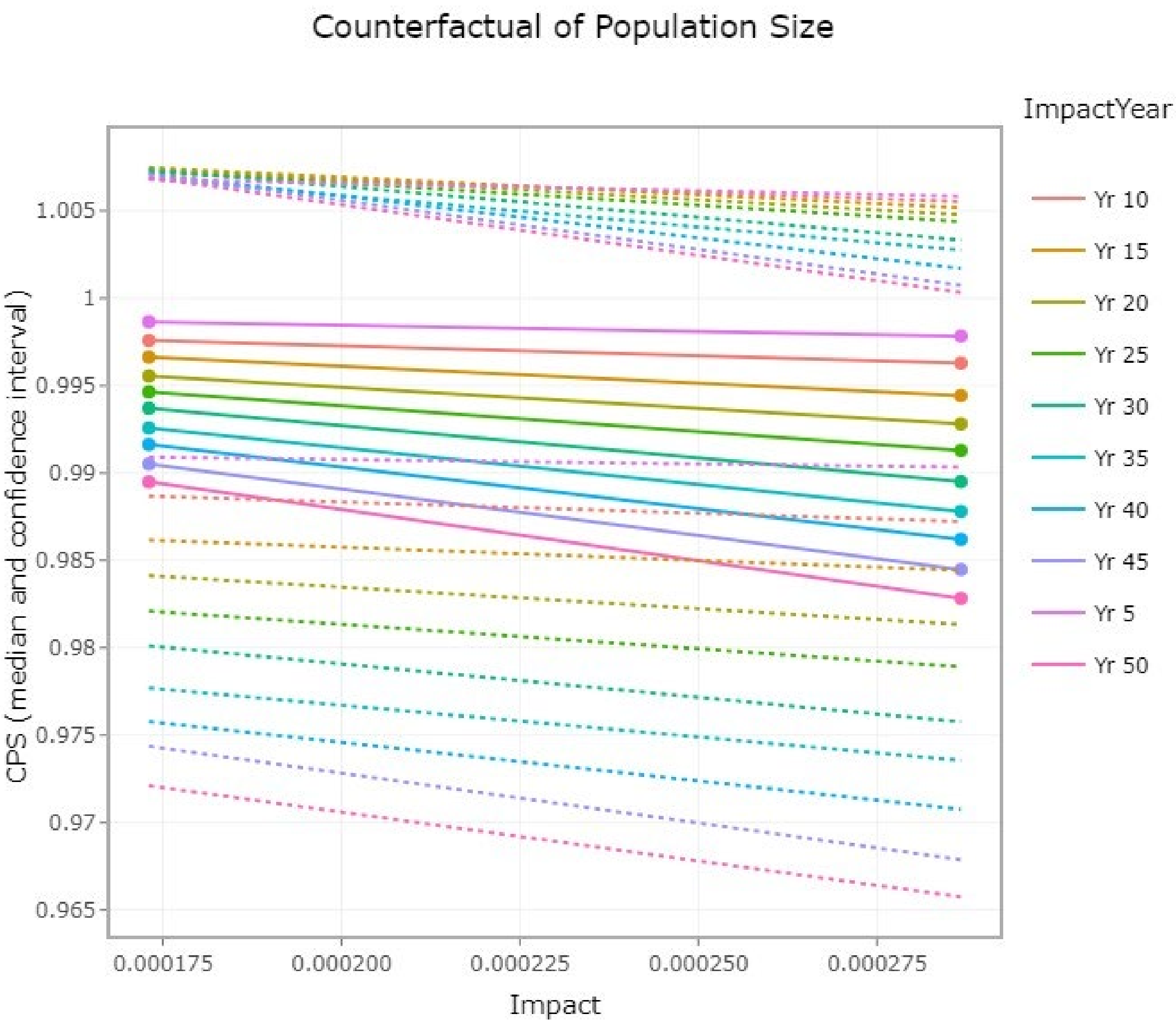

Figure 4 Projected population size of guillemot regional population under three scenarios between 2022 and 2080. Confidence interval presented as dotted line

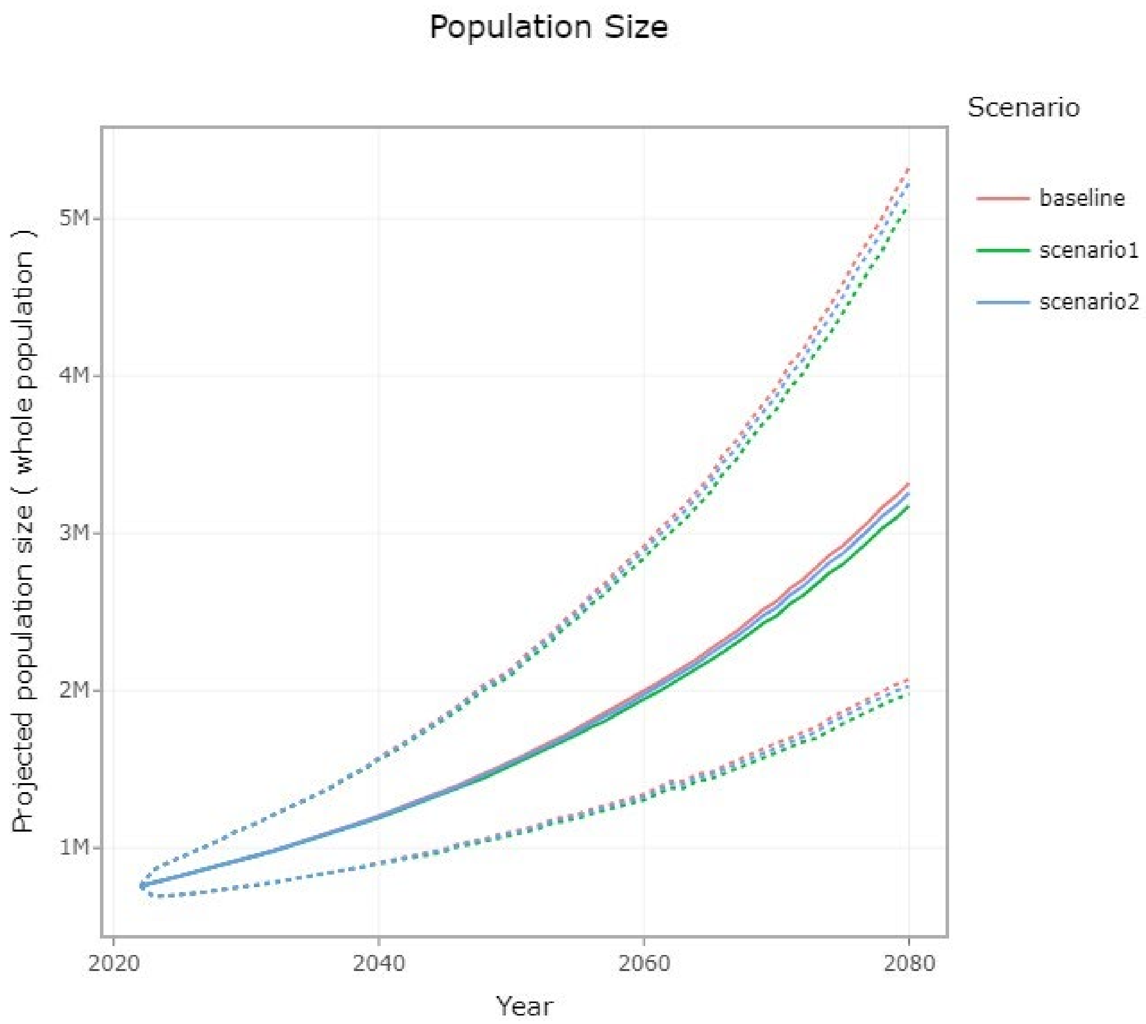

Figure 5 Counterfactual of population growth rate (CPC) for guillemot regional population over a 50-year period. Confidence interval presented as dotted line

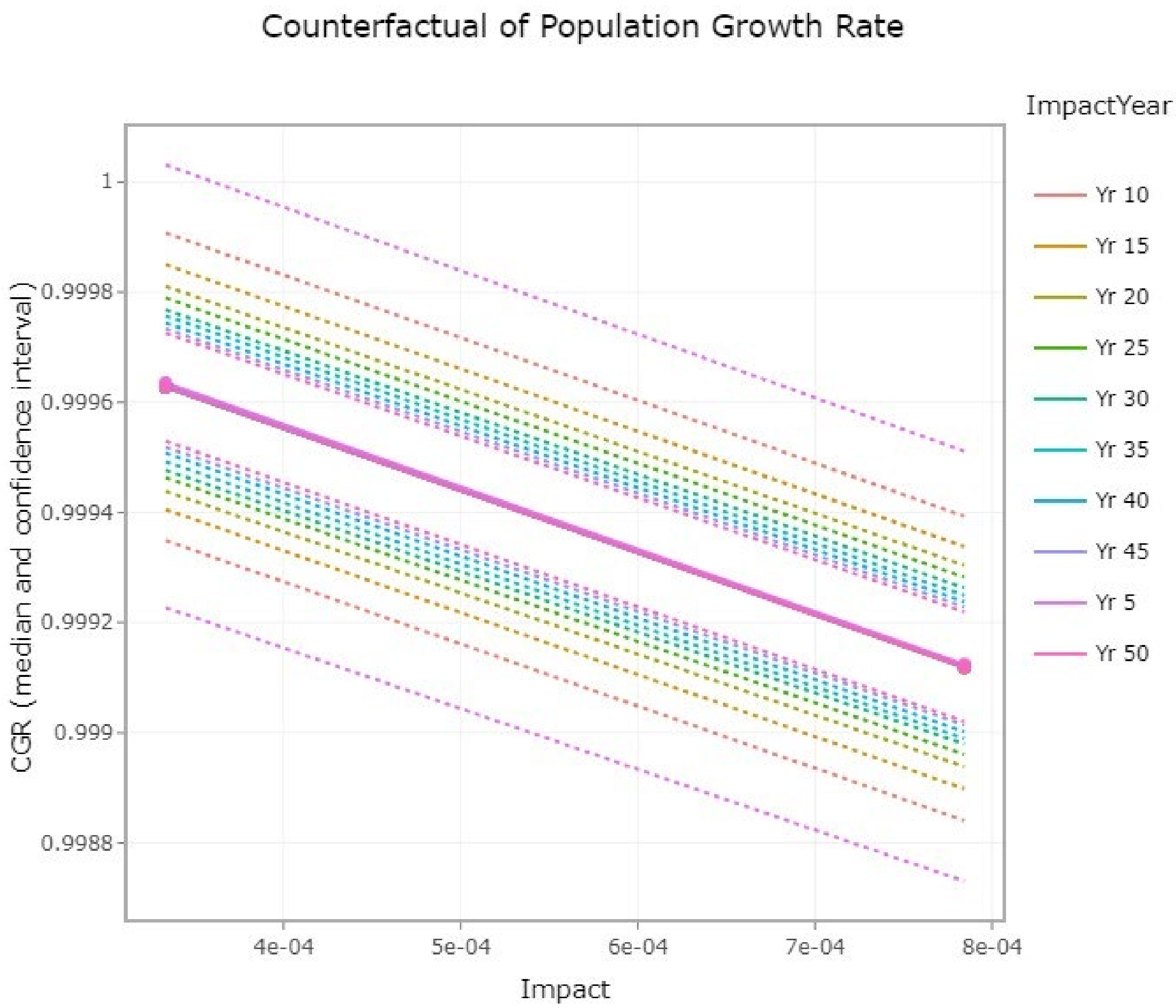

Figure 6 Counterfactual of population size (CPS) for guillemot regional population over a 50-year period. Confidence interval presented as dotted line

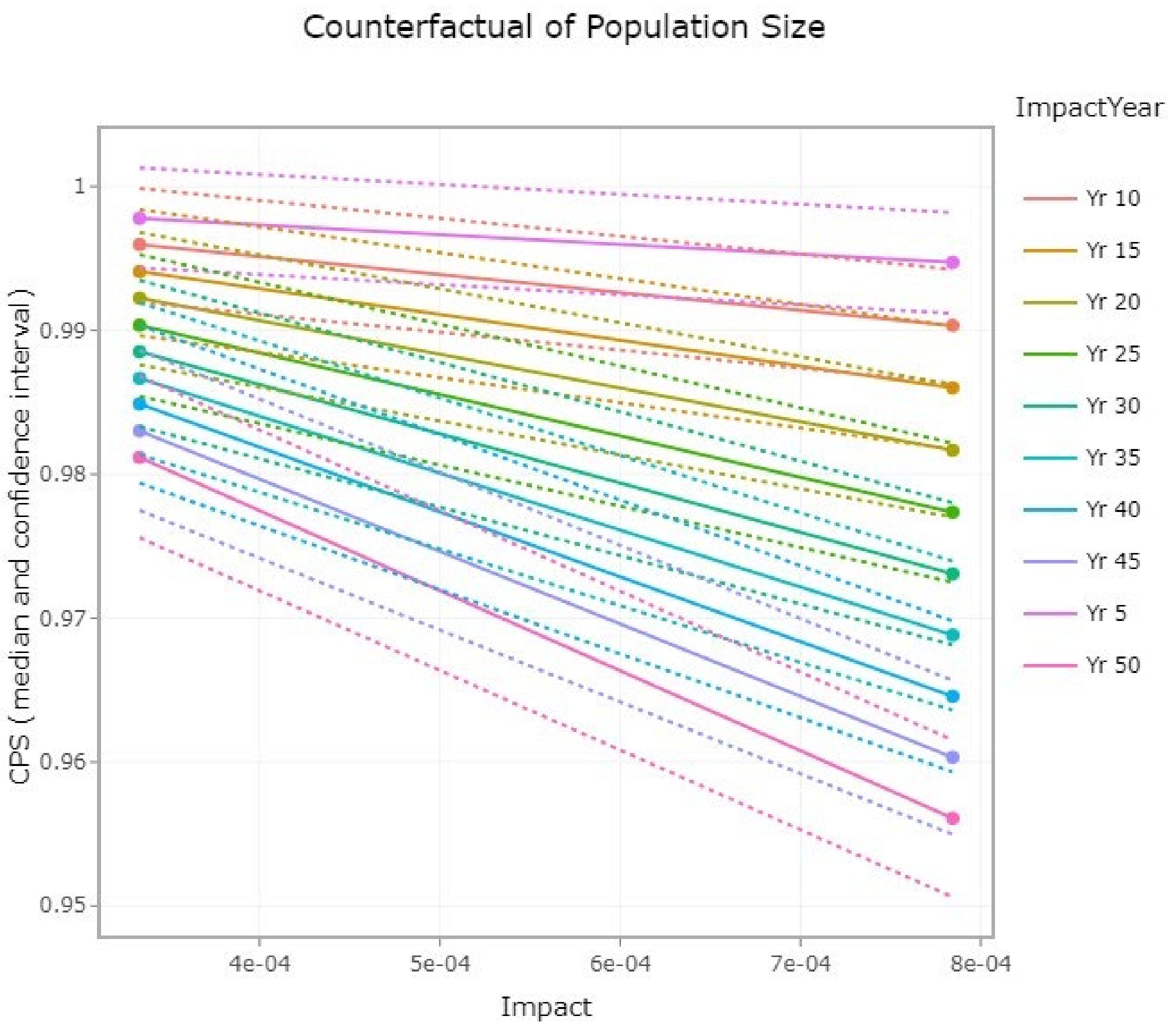

Figure 7 Projected population size of razorbill regional population under three scenarios between 2022 and 2080. Confidence interval presented as dotted line

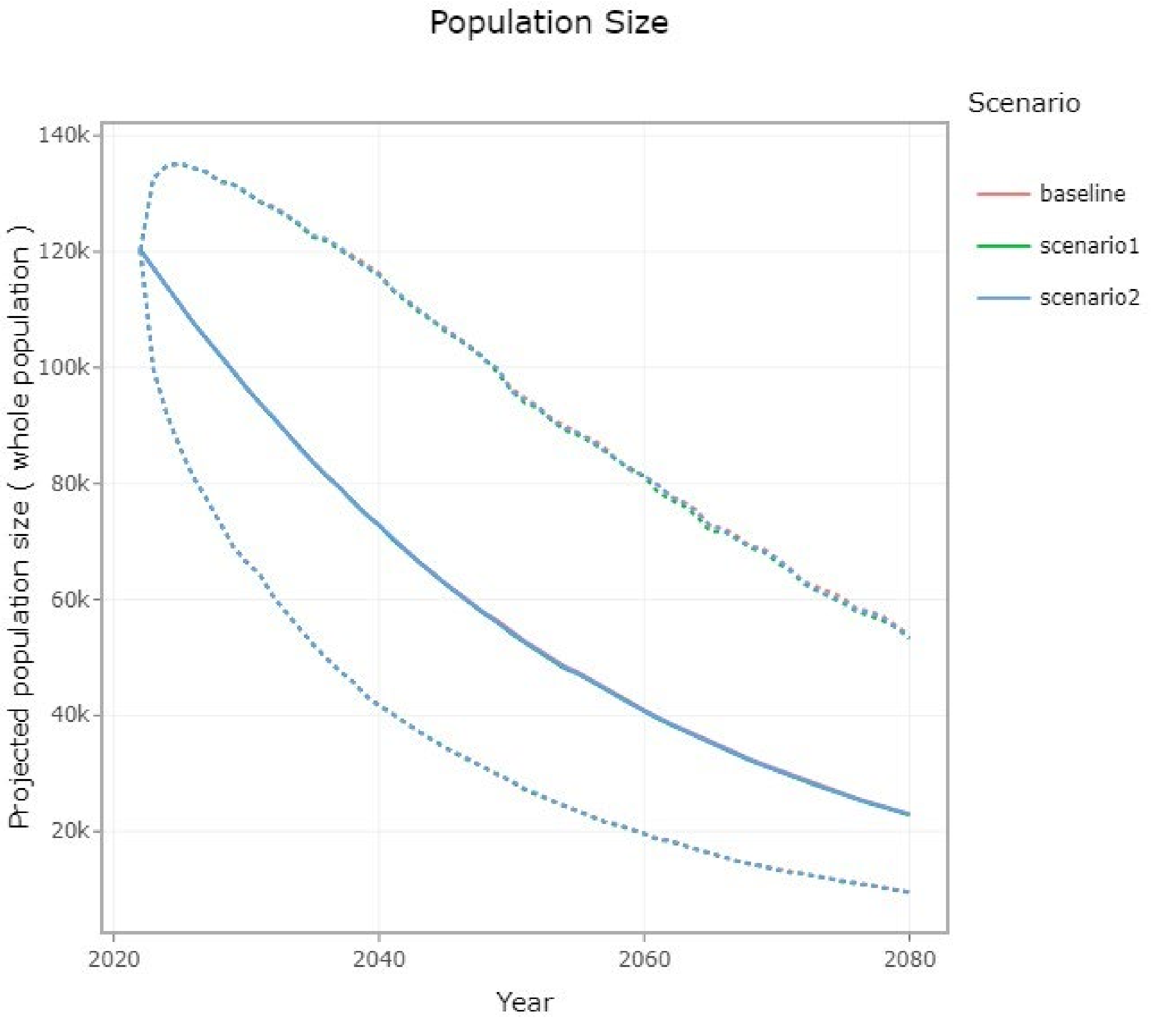

Figure 8 Counterfactual of population growth rate (CPC) for razorbill regional population over a 50-year period. Confidence interval presented as dotted line

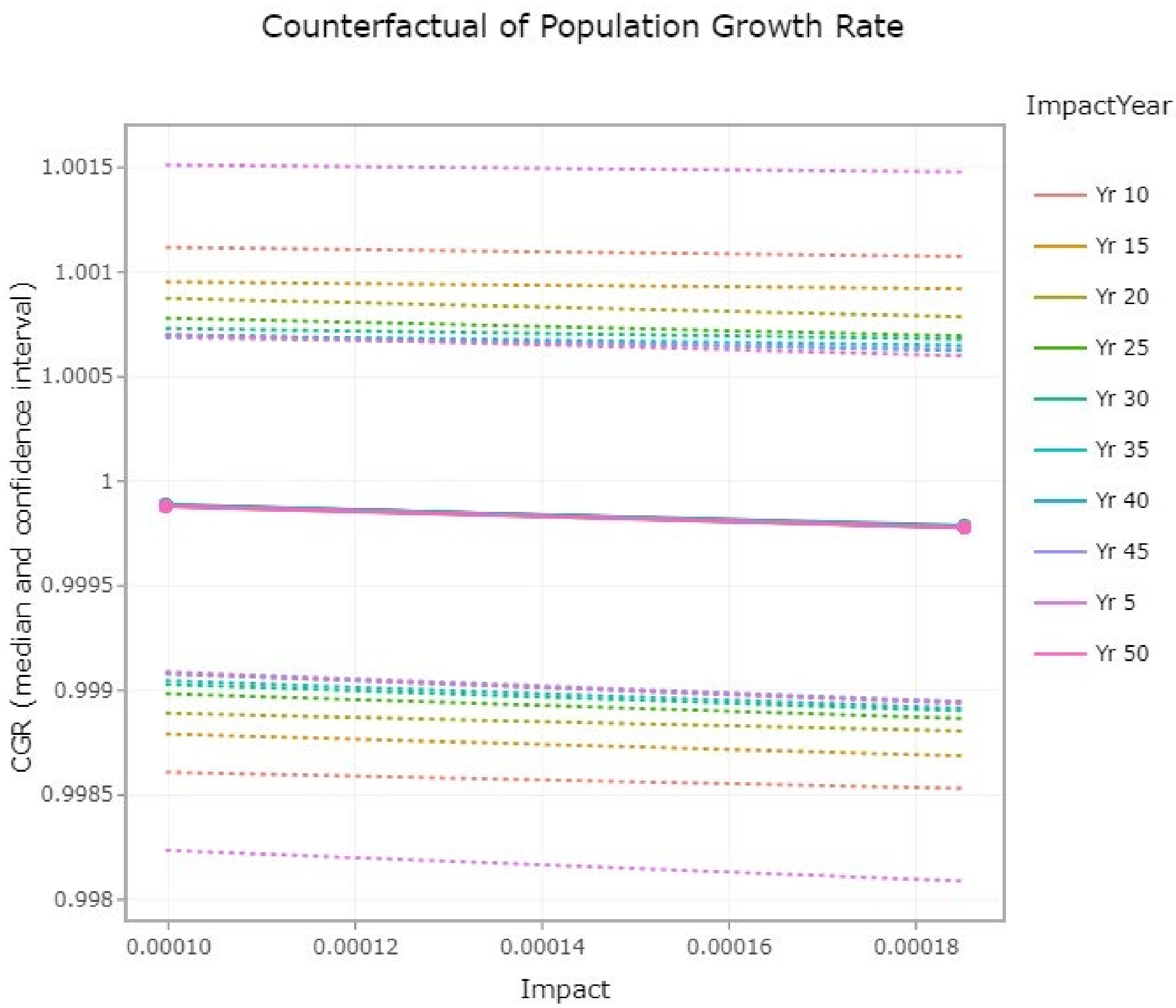

Figure 9 Counterfactual of population size (CPS) for razorbill regional population over a 50-year period. Confidence interval presented as dotted line

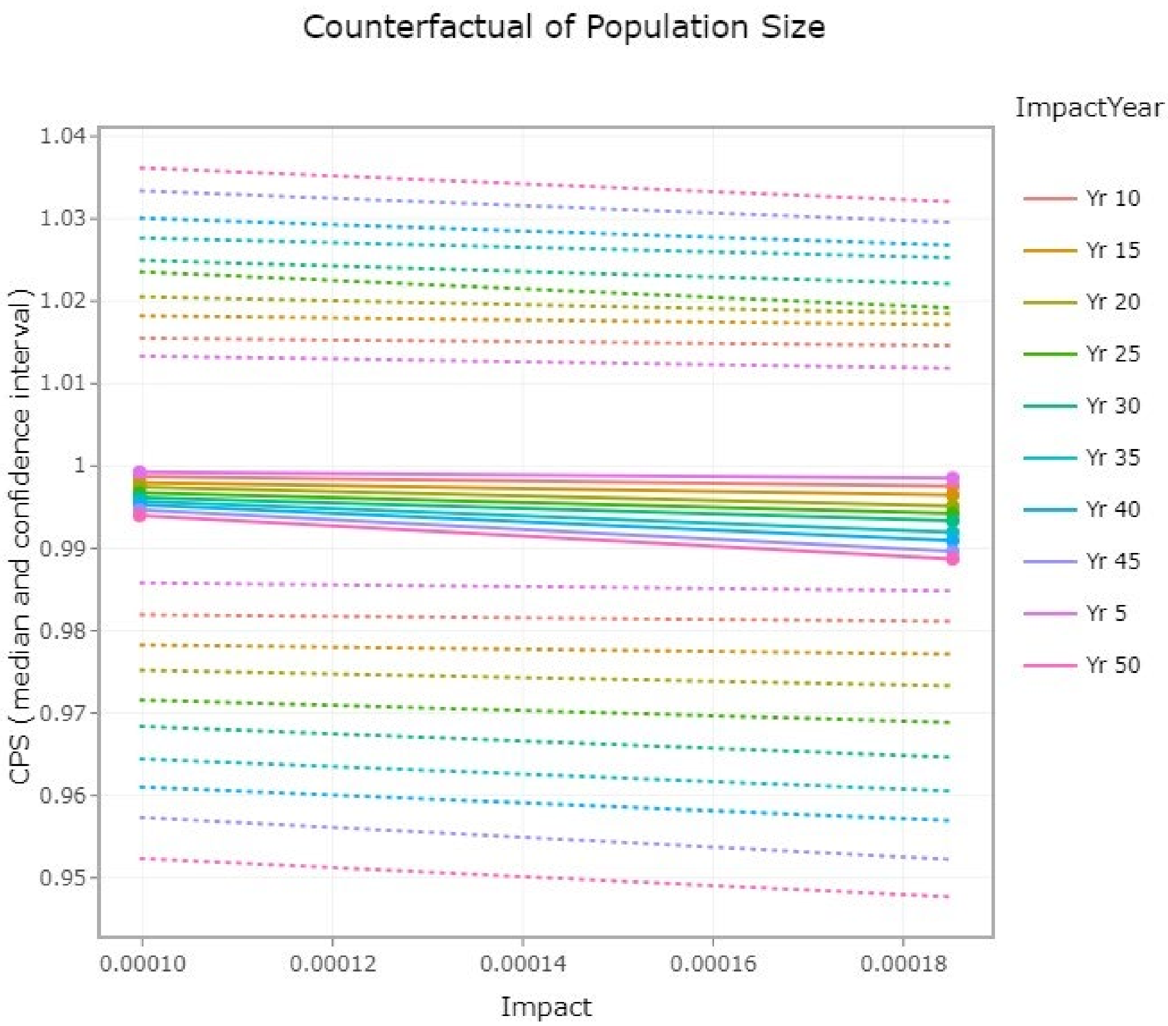

Figure 10 Projected population size of puffin regional population under three scenarios between 2022 and 2080. Confidence interval presented as dotted line

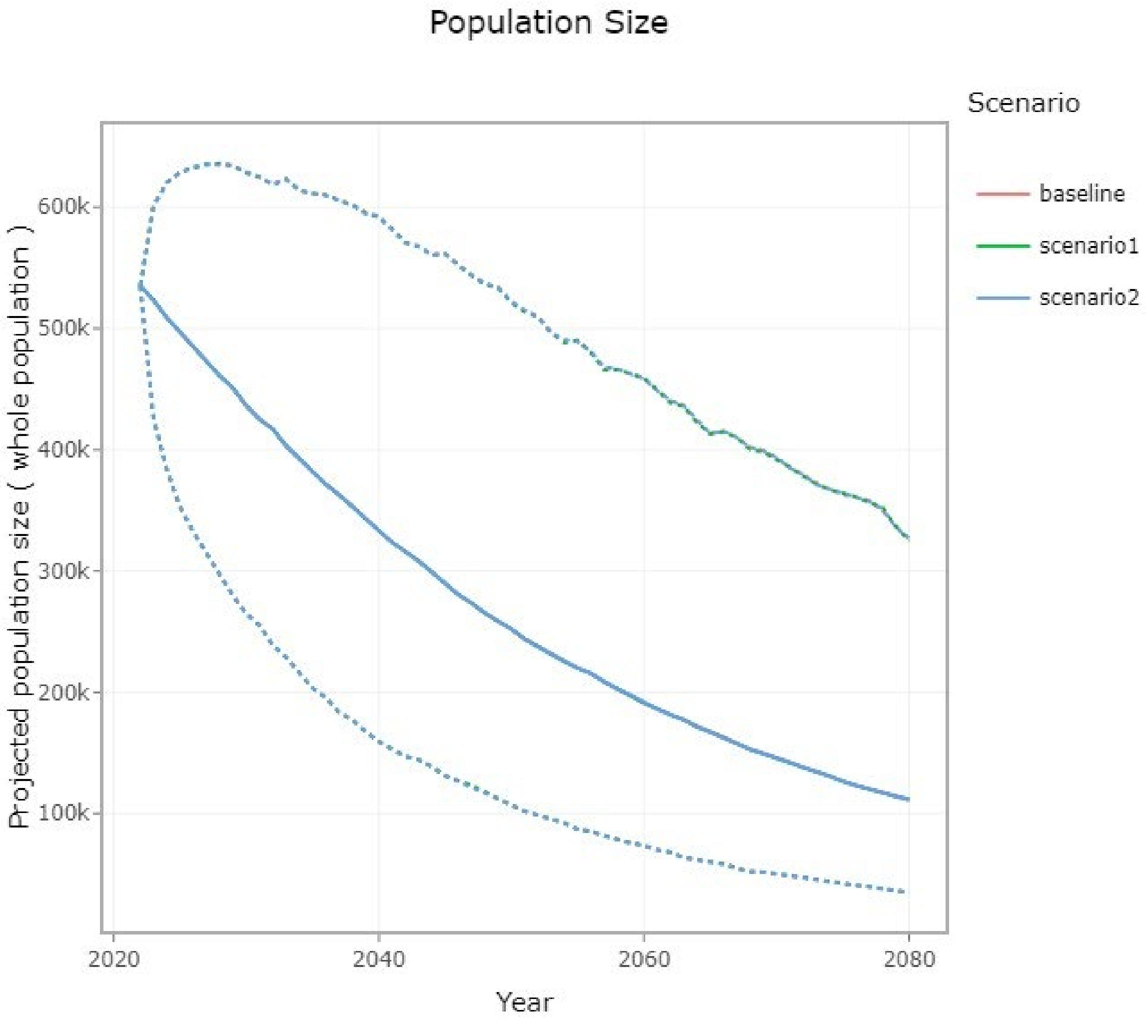

Figure 11 Counterfactual of population growth rate (CPC) for puffin regional population over a 50-year period. Confidence interval presented as dotted line

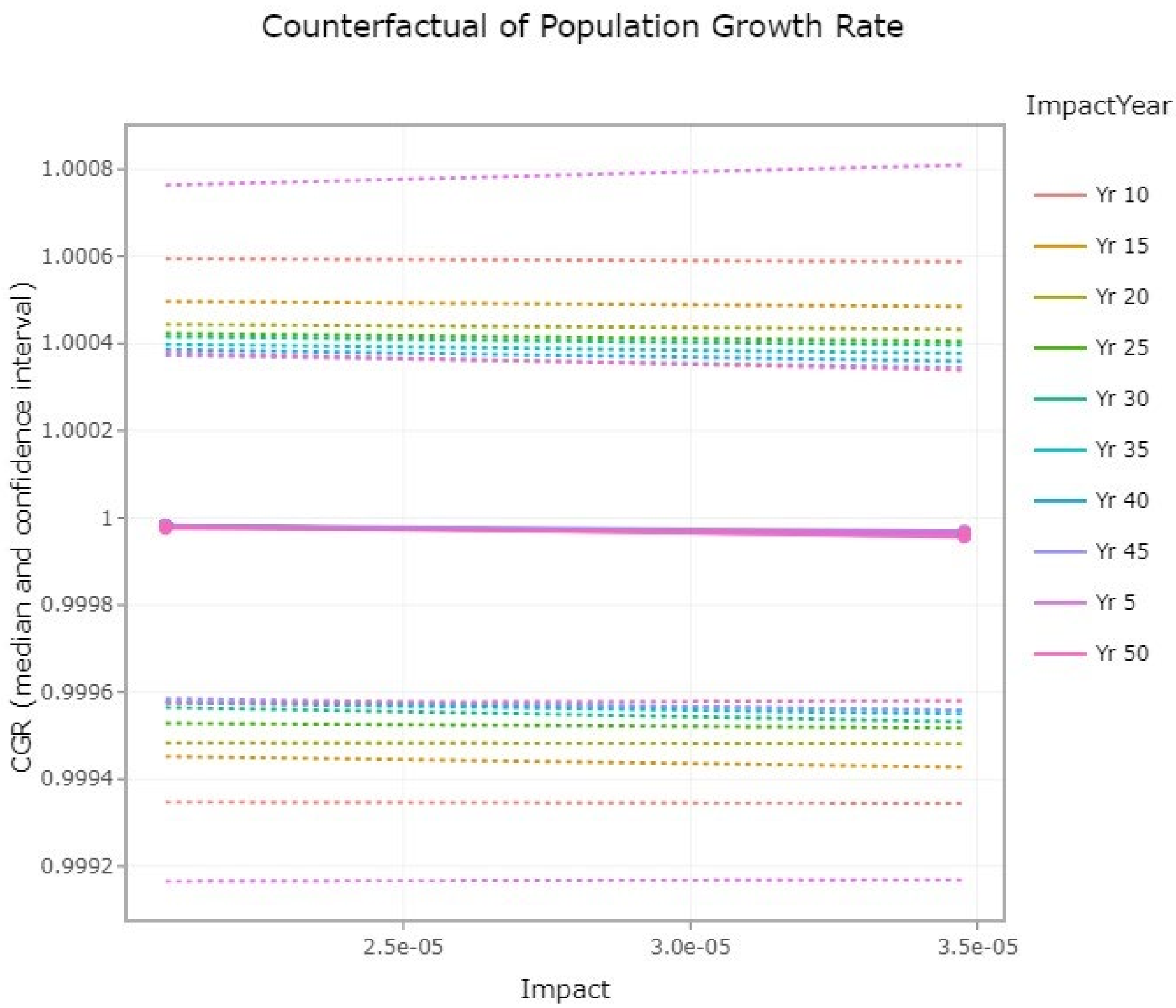

Figure 12 Counterfactual of population size (CPS) for puffin regional population over a 50-year period. Confidence interval presented as dotted line

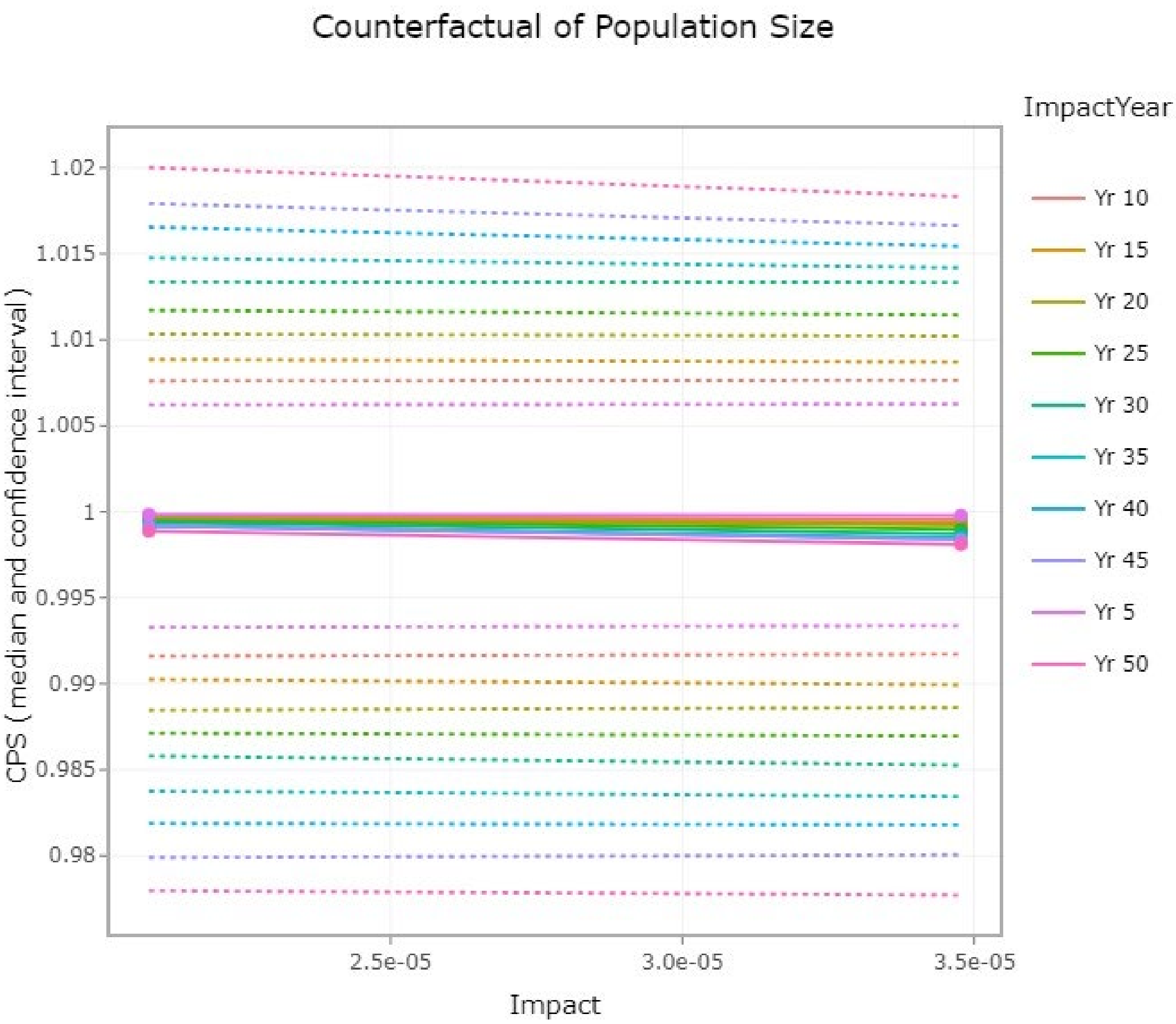

Figure 13 Projected population size of gannet regional population under three scenarios between 2022 and 2080. Confidence interval presented as dotted line

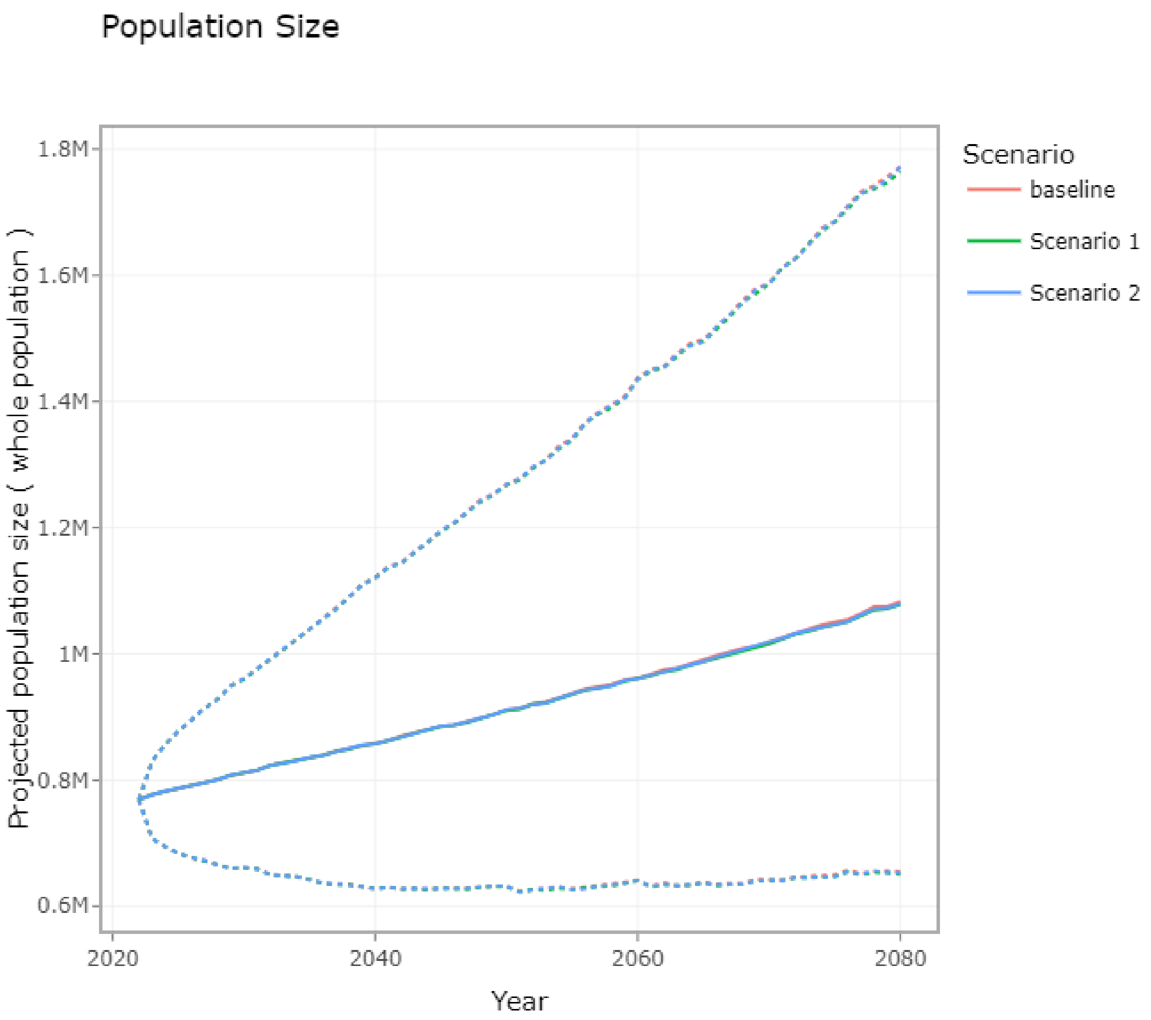

Figure 14 Counterfactual of population growth rate (CPC) for gannet regional population over a 50-year period. Confidence interval presented as dotted line

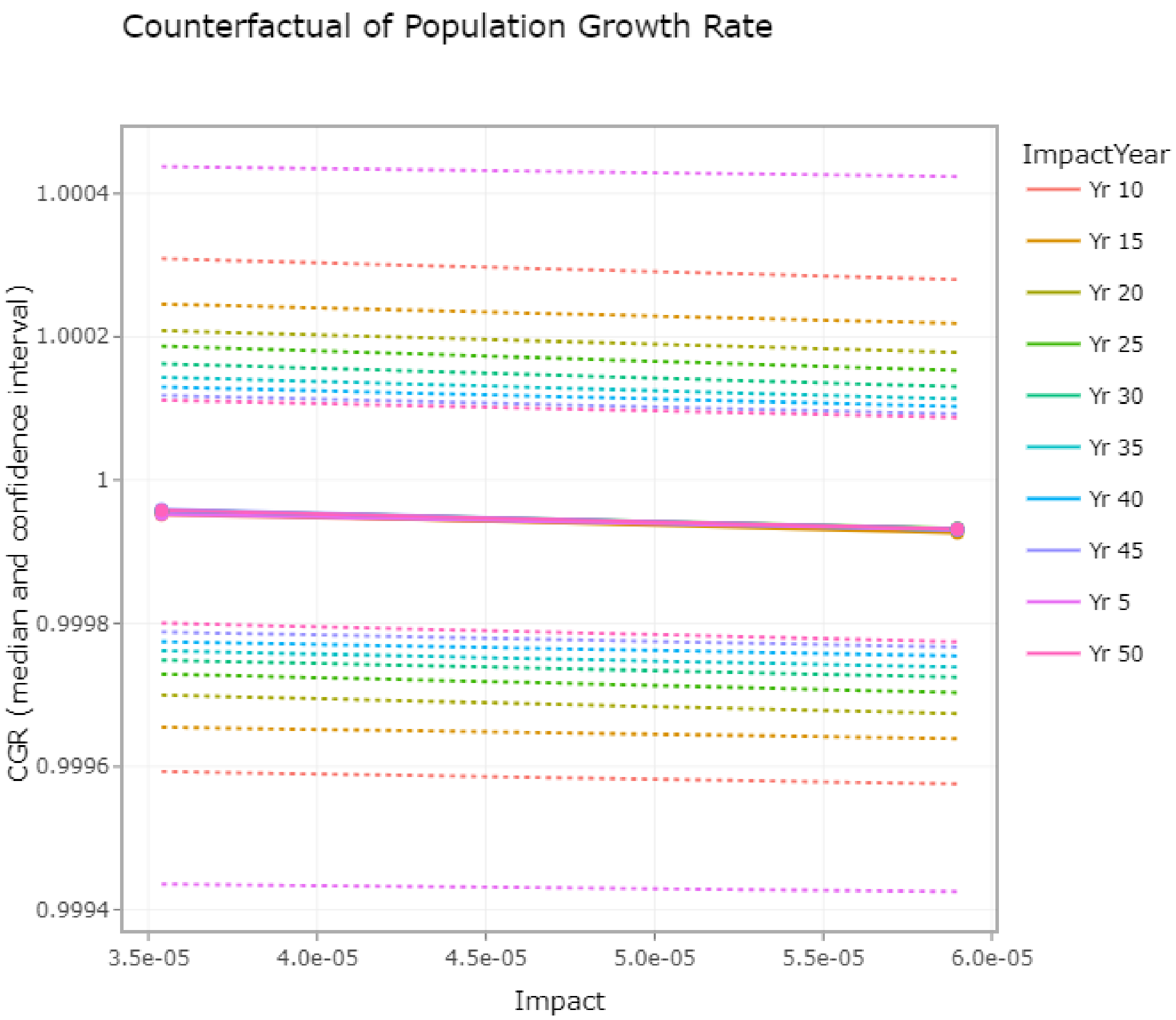

Figure 15 Counterfactual of population size (CPS) for gannet regional population over a 50-year period. Confidence interval presented as dotted line