Salamander Offshore Wind Farm

Offshore EIA Report

Volume ER.A.4, Annex 12.9: Cumulative Assessment Population Viability Analysis (PVA)

SALAMANDER

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Salamander Offshore Wind Farm Annex ER.A.4, Annex 12.9: Cumulative Assessment Population Viability Analysis (PVA)

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Acronyms and abbreviations

Term	Definition
BDMPS	Biologically Defined Minimum Population Scales
CEA	Cumulative Effects Assessment
CPC	Counterfactual of Final Population Size
CPS	Counterfactual of Annualised Population Growth-rate
CRM	Collision Risk Modelling
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
INTOG	Innovation and Targeted Oil and Gas
MRSea	Marine Renewables Strategic Environmental Assessment
MSP	Mean Seasonal Peak
PVA	Population Viability Analysis

1 Introduction

1 This Annex presents the assessment of cumulative effects on ornithological receptors undertaken for 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 In recent years there have been increasing numbers of potential sites for offshore wind developments around the UK, particularly in the North Sea, such as through the most recent ScotWind and Innovation and Targeted Oil & Gas (INTOG) leasing rounds. With increased offshore wind development comes increased risk to seabirds present in the area, particularly through collision risk and/or distributional effects. To try to fully understand the extent of these potential impacts on seabird populations, the cumulative impact of existing and potential sites must be considered alongside the impact of the Salamander Project alone.

3 Population Viability Analysis (PVA) is a method for modelling the population-level consequences of estimated mortalities from collision risk and distributional responses. PVA uses the estimated demographic rates for a population (typically survival and productivity) in a mathematical model to forecast future levels of a population. The Natural England (NE) PVA tool (Searle *et al.,* 2019) was used to simulate population trends for multiple scenarios which were compared with the baseline scenario (without offshore wind development). Models were run for all scenarios with and without the proposed Berwick Bank Offshore Windfarm, 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).

4 The following species are addressed:

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

5 Kittiwake and gannet predicted mortalities arise from both collision risk and distributional responses while guillemot and razorbill are only assessed for distributional responses. For kittiwake, distributional responses have generally only been assessed in Scottish waters, therefore only displacement mortality from Scottish offshore wind farms has been included in the cumulative assessment.

6 The Natural England (NE) PVA tool (Searle *et al*., 2019; Mobbs *et al*., 2020) 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).

7 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, 2023a), the two metrics considered are:

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

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

8 Impact scenarios defined for input to the NE PVA tool and output plots of CPS and CPC can be found in Appendix III: Impact scenarios for PVA and Appendix V: PVA plots.

2 Methods

9 To determine the cumulative impacts, mortality estimates from the Salamander Project were combined with those of other offshore wind farms. Projects were only included if they were operational, under construction, consented or had their application submitted prior to October 2023. For the breeding season, projects were included based on species-specific foraging ranges from Woodward *et al.* (2019), calculated from the Salamander Project; in the non-breeding season the Biologically Defined Minimum Population Scales (BDMPS) regions from Furness (2015) were used to screen in projects.

10 To assess cumulative collision impacts, seasonal mortality estimates were collated directly. However, for distributional responses, mean seasonal peak (MSP) abundance estimates were collated and used for the estimation of potential mortality due to distributional responses for each of the relevant projects. All estimates were taken from the Berwick Bank Wind Farm Cumulative Effects Assessment (CEA) (SSE Renewables, 2022a), apart from where the application was submitted after their submission, in which case collision mortalities and MSP abundance estimates for distributional responses were taken from individual project Environmental Impact Assessment Reports (EIARs).

11 MSP estimates were used in displacement matrices (see Appendix I: Cumulative MSP abundance estimates and Appendix II: Cumulative displacement matrices) to generate estimates of potential mortality due to distributional responses, following the Matrix Approach (JNCC *et al.,* 2022) and methodology recommended by NatureScot guidance (see Annex ER.A.4.12.5: Displacement Assessment for more explanation). This has been an accepted approach for several applications, such as East Anglia Two Offshore Windfarm and Hornsea Four (English waters) and Green Volt (Scottish waters). This is to ensure the Matrix Approach is consistently applied across all projects considered.

2.1 Assigning impacts to regional populations

12 Breeding season impacts were all attributed to the regional population breeding adults. In the non-breeding season impacts were scaled by contribution of the regional population to the Furness BDMPS population. This results in a proportion of the non-breeding season impacts being assigned to birds that do not make up the regional population.

13 Kittiwake non-breeding season Furness BDMPS 375,815 in spring and 480,815 adults in autumn. The regional population of adults is calculated (as detailed in the regional population note, annex B of the Displacement Assessment Technical Appendix A.3.12.4) at 202,258 birds. As a practical approach we assume the regional population is represented in the smaller spring number and so forms 54% of the BDMPS. Therefore 54% of impacts calculated in the non-breeding season are applied to the regional population.

14 Guillemot has a regional population that is assumed to be present year-round so the number of adults in winter is the same as the regional breeding adult population, 407,959 individuals. In this case all impacts calculated in breeding and non-breeding season are applied to the regional population.

15 Razorbill has a wider non-breeding season range and so the regional population of adults which is calculated at 70,208 birds is part of a non-breeding season BDMPS population of 302,314 individuals. This results in us applying 23% of the impacts from the non-breeding season to the regional population.

16 Gannet non-breeding season BDMPS is taken from the smaller of the two totals, the 'spring' BDMPS of Furness (2015). This is a population of 163,701 adult birds. As Furness calculates that 70% of UK breeding adults are present in the UK North Sea and Channel waters BDMPS in spring we assume that 70% of our regional population of breeding adults is also present, that is 70% of 423,894 birds which is 296,726 breeding adults. This figure is considerably more than the whole BDMPS calculated by Furness, due to the rapid growth of the gannet population seen in the North Atlantic since his figures were compiled prior to 2022. Using the same range of sites that form the regional population considered here it can be shown that the calculated population is now considerably larger than that at the time of the Furness BDMPS report (432,894 breeding adults compared to 368,218 breeding adults). Therefore, impacts are allocated in the non-breeding season at the same ratio to those in the regional population and the whole BDMPS as they would have been in the Furness populations but applied to the larger calculated current regional population.

17 Furness figures show that 154,821 adults of the total population of 368,218 birds were present in the UK North Sea and Channel waters BDMPS which is 42% of the breeding adults as some of the colonies we included in the regional population are not included in the Furness BDMPS total. 94.5% of the UK North Sea and Channel spring population is from sites comprising the regional population and therefore we apply 94.5% of the impacts to the regional population of 423,894 breeding adults.

Table 1 Breeding season regional populations used within PVAs Salamander Project (adult individuals)

Species	Regional population
Kittiwake	202,258
Guillemot	407,959
Razorbill	70,208
Gannet	432,894

2.2 Seasonality

18 There were some discrepancies in the seasons which were used to assign impacts between the Salamander Project and the Berwick Bank Wind Farm CEA. In line with the rest of the Salamander Project's ornithology impact assessment, this cumulative assessment will present all impacts in relation to NatureScot (2020) seasons. As such, for some species corrections had to be applied. NatureScot (2020) seasons are presented in Table 2 with corrections presented in Table 3.

Table 2 Seasons as described in NatureScot (2020)

Species	Breeding season	Non-breeding season
Kittiwake	mid Apr – Aug	Sep – mid Apr
Guillemot	Apr – mid Aug	Mid Aug – Mar
Razorbill	Apr – mid Aug	Mid Aug – Mar
Gannet	mid Mar – Sep	Oct – mid Mar

Table 3 Species-specific seasonal corrections applied to Berwick Bank CEA data to match NatureScot (2020) seasonal definitions (as presented in Table 2)

Species	Breeding season	Non-breeding season
Kittiwake	No correction	Combine autumn and spring migration impacts presented in Berwick Bank EIAR
Guillemot	No correction	No correction
Razorbill	No correction	Combine autumn migration, winter period and spring migration impacts presented in Berwick Bank EIAR
Gannet	No correction	Combine autumn and spring migration impacts presented in Berwick Bank EIAR

2.1 Avoidance rates for collision risk

19 Within this cumulative assessment, estimated mortalities from collision are presented using avoidance rates from Ozsanlav-Harris *et al.* (2023). While some projects have presented estimates using these recent avoidance rates, some presented those estimated using SNCBs (2014) avoidance rates, therefore a correction was applied to allow effective comparison between projects. This correction was calculated from the formula:

$$C_{OH} = C_{SNCB} \times \frac{1 - AR_{OH}}{1 - AR_{SNCB}}$$

20 Where C_{OH} is the number of collisions estimated using Ozsanlav-Harris *et al.* (2023) avoidance rates, C_{SNCB} is the number of collisions estimated using SNCBs (2014) avoidance rates, AR_{SNCB} is the SNCB (2014) avoidance rate for kittiwake or gannet, and AR_{OH} is the Ozsanlav-Harris *et al.* (2023) avoidance rate for kittiwake or gannet. After the avoidance rates were input into the formula, the final correction factor was determined (0.727; see below).

$$C_{OH} = C_{SNCB} \times \frac{1 - 0.992}{1 - 0.989} = C_{SNCB} \times \frac{0.008}{0.011} = C_{SNCB} \times 0.727$$

21 The correction factor was multiplied by the collisions estimated from the SNCB (2014) rates to obtain estimates using Ozsanlav-Harris *et al.* (2023) avoidance rates. The correction factor was the same per species and season as the avoidance rates for both kittiwake and gannet are the same.

2.2 Projects screened into quantitative assessment

22 Table 4 presents all projects with planning or licence applications submitted before October 2023 that were screened in for quantitative cumulative impact assessment. Not all projects will be screened in per species and season, with species-specific collision mortality and MSP abundance estimates for distributional responses presented in Table 5 to Table 10. Projects screened out of assessment are highlighted in blue.

Table 4 Long list of Projects included in quantitative cumulative impact assessment. Projects included in the CEA will be species and season specific.

Development	Distance from Salamander Project (km)	Project status (as of October 2023)
Aberdeen Bay (EOWDC)	56.5	Operational
Beatrice Offshore Windfarm	121.5	Operational
Berwick Bank Offshore Windfarm	121.6	Application submitted
Blyth Demonstration Site	269.8	Operational
Dogger Bank A & B Offshore Windfarm	376.9	Under construction
Dogger Bank C & Sofia Offshore Windfarm	369.4	Pre-construction
Dudgeon Offshore Windfarm	542.0	Operational
Dudgeon Extension Offshore Windfarm	534.8	Application submitted
East Anglia One Offshore Windfarm	678.7	Operational
East Anglia One NORTH Offshore Windfarm	663.2	Consented
East Anglia Two Offshore Windfarm	688.4	Consented
East Anglia Three Offshore Windfarm	640.1	Pre-construction
ForthWind Offshore Wind Demonstration Project	211.3	Consented
Galloper Offshore Windfarm	706.6	Operational

Development	Distance from Salamander Project (km)	Project status (as of October 2023)
Green Volt Offshore Windfarm	24.0	Application submitted
Greater Gabbard Offshore Windfarm	706.6	Operational
Gunfleet Sands Offshore Windfarm	747.5	Operational
Hornsea Project One Offshore Windfarm	473.2	Operational
Hornsea Project Two Offshore Windfarm	466.1	Operational
Hornsea Three Offshore Windfarm	487.4	Consented
Hornsea Four Offshore Windfarm	435.0	Consented
Humber Gateway Offshore Windfarm	479.8	Operational
Hywind Scotland Pilot Park	8.43	Operational
Inch Cape Offshore Windfarm	130.9	Consented
Kentish Flats Offshore Windfarm	776.3	Operational
Kincardine Offshore Windfarm	73.2	Operational
Lincs, Lynn and Inner Dowsing Offshore Windfarm	525.5	Operational
London Array Offshore Windfarm	740.3	Operational
Methil Offshore Wind Demonstration Zone	211.3	Operational
Moray East Offshore Windfarm	101.0	Operational

Development	Distance from Salamander Project (km)	Project status (as of October 2023)
Moray West Offshore Windfarm	114.6	Pre-construction
Neart na Gaoithe Offshore Windfarm	159.8	Under construction
Norfolk Boreas Offshore Windfarm	588.2	Consented
Norfolk Vanguard Offshore Windfarm	602.8	Consented
Pentland Floating Offshore Windfarm	210.9	Variation application submitted
Race Bank Offshore Windfarm	524.2	Operational
Rampion Offshore Windfarm	939.4	Operational
Rampion 2 Offshore Windfarm	935.0	Application submitted
Scroby Sands Offshore Windfarm	623.6	Operational
Seagreen A & B Offshore Windfarm	108.3	Under construction
Sheringham Shoal Project Offshore Windfarm	551.7	Operational
Sheringham Shoal Extension Offshore Windfarm	543.3	Application submitted
Sofia Offshore Windfarm	353.8	Pre-construction
Teeside Offshore Windfarm	327.6	Operational
Thanet Offshore Windfarm	762.1	Operational
Triton Knoll Offshore Windfarm	498.9	Operational

Development	Distance from Salamander Project (km)	Project status (as of October 2023)
West of Orkney Offshore Windfarm	207.3	Application submitted
Westermost Rough Offshore Windfarm	455.8	Operational

2.2.1 Kittiwake

23 For kittiwake, mortality estimates collated and presented in the Berwick Bank CEA (SSE Renewables, 2022a) were preferentially used and supplemented from individual project applications where necessary. Where estimates were taken from the Berwick Bank CEA, collision mortalities and MSP abundance estimates for the non-breeding season had to be corrected to match NatureScot (2020) seasons. To do this, estimates for the autumn and spring migrations periods were added together. There were some projects for which this correction did not have to be applied since impacts were already presented in relation to NatureScot (2020) seasons, these are marked with a " * " in Table 5 and Table 6.

24 The following projects were screened into assessment for kittiwake during the breeding and non-breeding season (Table 5 and Table 6). Kittiwake are generally only assessed for displacement effects in Scottish waters, therefore there are some projects within the BDMPS region for which there were no displacement data available. For both seasons, estimated mortality from collision and distributional responses were combined to run PVAs.

Table 5 Kittiwake collated collision mortality during the breeding and non-breeding seasons (NatureScot, 2020). Projects screened out of assessment shaded in blue, a short-dash indicates the project was screened in but no estimate was available.

Development	Breeding season collision mortality	Non-breeding season collision mortality
Aberdeen Bay (EOWDC)	6.5	3.6
Beatrice	37.8	20.4
Berwick Bank*	309.8	188.4
Blyth Demonstration Site	1.5	2.2
Dogger Bank A & B		312.7
Dogger Bank C & Sofia		224.0
Dudgeon		-
Dudgeon Extension		8.7
East Anglia One		101.8
East Anglia One NORTH		8.7
East Anglia Two		64.0
East Anglia Three		8.7
ForthWind*	0.0	0.0
Galloper		18.2
Greater Gabbard		18.9
Green Volt*	5.4	8.4
Gunfleet Sands		-
Hornsea Project One		10.2
Hornsea Project Two		8.7
Hornsea Three		50.2
Hornsea Four		21.8

Development	Breeding season collision mortality	Non-breeding season collision mortality
Humber Gateway		1.5
Hywind Scotland Pilot Park	12.4	1.5
Inch Cape	29.1	23.3
Kentish Flats & Kentish Flats Extension		2.9
Kincardine	16.0	7.3
Lincs, Lynn and Inner Dowsing		1.5
London Array Offshore Windfarm		1.5
Methil Demonstration	0.0	0.0
Moray East	17.5	5.1
Moray West	56.0	21.8
Neart na Gaoithe	5.8	13.8
Norfolk Boreas		32.0
Norfolk Vanguard		25.5
Pentland*	3.2	0.9
Race Bank		12.4
Rampion 2		27.1
Scroby Sands		-
Seagreen A & B	45.1	78.5
Sheringham Shoal		-
Teeside	23.3	16.0
Thanet		0.7
The Salamander Project*	14.0	0.0
Triton Knoll		48.0
West of Orkney*	10.8	36.4
Westernmost Rough		0.0
Total (with Berwick Bank)	**594.1**	**1437.1**
Total (without Berwick Bank)	**284.3**	**1248.8**

Table 6 **Kittiwake collated mortality due to distributional responses during the breeding and non-breeding seasons (NatureScot, 2020). Projects screened out of assessment shaded in blue, a short-dash indicates project screened in but no estimate available.**

	Breeding season		Non-breeding season	
Development	**Displacement mortality 30% / 1%**	**Displacement mortality 30% / 3%**	**Displacement mortality 30% / 1%**	**Displacement mortality 30% / 3%**
Aberdeen Bay (EOWDC)	2	6	0	0
Beatrice†	4	13	7	20
Berwick Bank*	63	190	75	225
Blyth Demonstration Site	2	5	4	13
Dogger Bank A & B				
Dogger Bank C & Sofia				
Dudgeon				
Dudgeon Extension & Sheringham Shoal Extension				
East Anglia One				
East Anglia One NORTH				
East Anglia Two				
East Anglia Three				
ForthWind*	0	0	0	1
Galloper				
Greater Gabbard				
Green Volt*	1	2	1	2
Gunfleet Sands				
Hornsea Project One				
Hornsea Project Two				
Hornsea Three				
Hornsea Four				
Humber Gateway				
Hywind Scotland Pilot Park	0	1	-	-
Inch Cape	12	35	6	19
Kentish Flats & Kentish Flats Extension				
Kincardine	1	2	-	-
Lincs, Lynn and Inner Dowsing				
London Array Offshore Windfarm				
Methil Demonstration	1	2	-	-

	Breeding season		Non-breeding season	
Development	**Displacement mortality 30% / 1%**	**Displacement mortality 30% / 3%**	**Displacement mortality 30% / 1%**	**Displacement mortality 30% / 3%**
Moray East†	6	18	-	-
Moray West†	21	62	8	23
Neart na Gaoithe	6	19	6	19
Norfolk Boreas				
Norfolk Vanguard				
Pentland*†	2	5	0	1
Race Bank				
Scroby Sands				
Seagreen A & B	10	29	14	41
Sheringham Shoal				
Teeside				
Thanet				
The Salamander Project*	11	33	1	2
Triton Knoll				
West of Orkney*†	3	10	4	11
Westernmost Rough				
Total (with Berwick Bank)	**145**	**432**	**126**	**377**
Total (without Berwick Bank)	**82**	**242**	**51**	**152**

2.2.2 Guillemot

25 Guillemot mortality estimates collated and presented in the Berwick Bank CEA (SSE Renewables, 2022a) were preferentially used and supplemented from individual project applications where necessary.

26 The projects listed in Table 7 were screened into assessment for guillemot during the breeding and non-breeding season and displacement matrices ran on cumulative MSP abundance estimates (with and without Berwick Bank) (Appendix II: Cumulative displacement matrices). As the non-breeding season regional population is the same as is defined for the breeding season, the same projects are screened in for both periods.

Table 7 Guillemot collated mortality due to distributional responses during the breeding and non-breeding seasons (NatureScot, 2020)

Development	Breeding season			Non-breeding season		
	60% / 5%	60% / 3%	50% / 1%	60% / 3%	60% / 1%	50% / 1%
Aberdeen Bay (EOWDC)	16	10	3	4	1	1
Beatrice	408	245	68	50	17	14
Berwick Bank*	2225	1335	371	795	265	221
ForthWind* Demonstration	13	8	2	7	2	2
Green Volt*	133	80	22	290	97	81
Hywind Scotland Pilot Park	7	4	1	38	13	11
Inch Cape	131	79	22	57	19	16
Kincardine	19	11	3	0	0	0
Moray East	295	177	49	10	3	3
Moray West	733	440	122	687	229	191
Seagreen A & B*	742	445	124	158	53	44
The Salamander Project*	108	65	18	212	71	59
Total (with Berwick Bank)	**4830**	**2899**	**805**	**2308**	**770**	**643**
Total (without Berwick Bank)	**2605**	**1564**	**434**	**1514**	**505**	**422**

2.2.3 Razorbill

27 As with guillemot, MSP abundance estimates were preferentially taken from the Berwick Bank Wind Farm CEA (SSE Renewables, 2022a), and supplemented by individual EIARs, where applicable. The seasonal split during the non-breeding period is presented differently in the Berwick Bank CEA to that for the Salamander Project, therefore estimates had to be corrected to match NatureScot (2020) seasons. To do this, estimates for the autumn migration, wintering period and spring migration were added together to get estimates for the full NatureScot (2020) non-breeding period. Where the correction was not applied as NatureScot (2020) seasons were already used, projects are marked with a " * " in Table 8.

28 The projects listed in Table 8 were screened into assessment for razorbill during the breeding and non-breeding season and displacement matrices ran on cumulative MSP abundance (with and without Berwick Bank) (Appendix II: Cumulative displacement matrices). Projects screened out of assessment during the breeding period are highlighted in blue.

Table 8 **Razorbill collated mortality estimates for distributional responses during the breeding and non-breeding seasons (NatureScot, 2020). Projects screened out of assessment shaded in blue**

Development	Breeding season			Non-breeding season		
	60% / 5%	60% / 3%	50% / 1%	60% / 3%	60% / 1%	50% / 1%
Aberdeen Bay (EOWDC)	5	3	1	2	1	0
Beatrice	26	16	4	40	13	11
Berwick Bank*	121	73	20	319	106	89
Blyth Demonstration Site				4	1	1
Dogger Bank A & B				303	101	84
Dogger Bank C & Sofia				186	62	52
Dudgeon				26	9	7
Dudgeon Extension & Sheringham Shoal Extension				108	36	30
East Anglia One				9	3	3
East Anglia One NORTH				6	2	2
East Anglia Two				7	2	2
East Anglia Three				75	25	21
ForthWind	2	1	0	2	1	1
Galloper				10	3	3
Greater Gabbard				8	3	2
Green Volt*	14	8	2	1	0	0
Gunfleet Sands				1	0	0
Hornsea Project One				146	49	41
Hornsea Project Two				119	40	33
Hornsea Three				140	47	39
Hornsea Four				80	27	22
Humber Gateway				1	0	0
Hywind Scotland Pilot Park	1	1	0	13	4	4
Inch Cape	43	26	7	63	21	18
Kentish Flats & Kentish Flats Extension				0	0	0
Kincardine	1	0	0	0	0	0
Lincs, Lynn and Inner Dowsing				2	1	0
London Array Offshore				1	0	0
Methil Demonstration				0	0	0
Moray East	73	44	12	23	8	7

Development	Breeding season			Non-breeding season		
	60% / 5%	60% / 3%	50% / 1%	60% / 3%	60% / 1%	50% / 1%
Moray West	84	51	14	132	44	37
Neart na Gaoithe	10	6	2	108	36	30
Norfolk Boreas				30	10	8
Norfolk Vanguard				182	61	51
Pentland				0	0	0
Rampion				83	28	23
Rampion 2				135	45	38
Scroby Sands				0	0	0
Seagreen A & B	287	172	48	43	14	12
Sheringham Shoal				29	10	8
Teeside				1	0	0
Thanet				1	0	0
The Salamander Project*	10	6	2	9	3	2
Triton Knoll				22	7	6
West of Orkney				2	1	1
Westernmost Rough				7	2	2
Total (with Berwick Bank)	**677**	**407**	**112**	**2479**	**826**	**690**
Total (without Berwick Bank)	**556**	**334**	**92**	**2160**	**720**	**601**

2.2.4 Gannet

29 Collision mortality and MSP abundance estimates for gannet in the breeding season were preferentially taken from the Berwick Bank CEA, where possible (SSE Renewables, 2022a). Where these were not available, they were taken from individual project EIARs. Where estimates were taken from the Berwick Bank CEA, collision mortalities and MSP abundance estimates for the non-breeding season had to be corrected to match NatureScot (2020) seasons. To do this, estimates for the autumn and spring migrations periods were added together. There were some projects for which this correction did not have to be applied since impacts were already presented in relation to NatureScot (2020) seasons, these are marked with a " * " in Table 9.

30 The subsequent projects were screened into assessment for gannet during the breeding and non-breeding season (Table 9 and Table 10). For both seasons, estimated mortality from collision and distributional responses were combined to run PVAs.

Table 9 **Gannet collated collision mortality during the breeding and non-breeding seasons (NatureScot, 2020). Projects screened out of assessment shaded in blue, a short-dash indicates project screened in but no estimate available.**

Development	Breeding season collision mortality	Non-breeding season collision mortality
Aberdeen Bay (EOWDC)	2.9	3.6
Beatrice	26.9	42.9
Berwick Bank*	100.4	10.9
Blyth Demonstration Site		3.6
Dogger Bank A & B	58.9	100.4
Dogger Bank C & Sofia	10.9	15.3
Dudgeon	16.0	42.2
Dudgeon Extension & Sheringham Shoal Extension		4.4
East Anglia One	2.2	99.6
East Anglia One NORTH	8.7	8.7
East Anglia Two	9.5	19.6
East Anglia Three	3.6	26.9
ForthWind*	0.7	0.0
Galloper		32.0
Greater Gabbard		10.2
Green Volt*	13.6	2.3
Gunfleet Sands		0.0
Hornsea Project One	2.2	8.7
Hornsea Project Two	5.1	14.5
Hornsea Three	7.3	7.3
Hornsea Four	13.8	7.3
Humber Gateway		2.2
Hywind Scotland Pilot Park	4.4	1.5
Inch Cape	78.5	6.5
Kentish Flats & Kentish Flats Extension		1.5
Kincardine	2.2	0.0
Lincs, Lynn and Inner Dowsing		2.2
London Array Offshore Windfarm		2.2
Methil Demonstration		0.0
Moray East	58.9	32.0
Moray West	7.3	2.2
Neart na Gaoithe	64.7	10.2

Development	Breeding season collision mortality	Non-breeding season collision mortality
Norfolk Boreas	10.2	12.4
Norfolk Vanguard	5.8	17.5
Pentland*†	2.9	0.0
Race Bank	24.7	11.6
Rampion		48.0
Rampion 2		1.3
Scroby Sands*	-	0.0
Seagreen A & B	115.6	12.4
Sheringham Shoal	10.2	2.9
Teeside	3.6	1.5
Thanet		0.0
The Salamander Project*	4.0	2.0
Triton Knoll	19.6	68.4
West of Orkney*†	47.5	49.2
Westernmost Rough		0.0
Total (with Berwick Bank)	**742.8**	**748.1**
Total (without Berwick Bank)	**642.4**	**737.2**

Table 10 Gannet collated mortality due to distributional responses during the breeding and non-breeding seasons (NatureScot, 2020). Projects screened out of assessment shaded in blue, a short-dash indicates project screened in but no estimate available.

Development	Breeding season		Non-breeding season	
	Displacement mortality 70% / 1%	Displacement mortality 70% / 3%	Displacement mortality 70% / 1%	Displacement mortality 70% / 3%
Aberdeen Bay (EOWDC)	0	1	0	0
Beatrice	1	3	0	0
Berwick Bank*	33	99	12	37
Blyth Demonstration Site			0	0
Dogger Bank A & B	16	47	17	51
Dogger Bank C & Sofia	8	24	9	28
Dudgeon	0	1	0	1
Dudgeon Extension & Sheringham	3	8	5	14
East Anglia One	1	3	26	78
East Anglia One NORTH	1	3	4	11

Development	Breeding season		Non-breeding season	
	Displacement mortality 70% / 1%	Displacement mortality 70% / 3%	Displacement mortality 70% / 1%	Displacement mortality 70% / 3%
East Anglia Two	1	4	8	23
East Anglia Three	3	9	13	38
ForthWind*	0	1	0	1
Galloper			8	25
Greater Gabbard			1	4
Green Volt*	1	3	0	1
Gunfleet Sands			0	0
Hornsea Project One	5	14	7	20
Hornsea Project Two	3	10	9	27
Hornsea Three	9	28	11	32
Hornsea Four	6	17	8	23
Humber Gateway			0	0
Hywind Scotland Pilot Park	0	0	0	0
Inch Cape	17	50	6	19
Kentish Flats & Kentish Flats Extension			0	0
Kincardine	1	3	0	0
Lincs, Lynn and Inner Dowsing			0	0
London Array Offshore Windfarm			0	0
Methil Demonstration			0	0
Moray East	4	12	2	7
Moray West	20	59	4	12
Neart na Gaoithe	14	42	6	17
Norfolk Boreas	9	26	16	47
Norfolk Vanguard	2	6	20	61
Pentland*†	4	11	1	3
Race Bank	1	2	0	1
Rampion			4	12
Rampion 2			1	4
Scroby Sands*	-	-	0	0
Seagreen A & B	21	62	7	21
Sheringham Shoal	0	1	0	1
Teeside	0	0	0	0
Thanet	-	-	0	0

Development	Breeding season		Non-breeding season	
	Displacement mortality 70% / 1%	Displacement mortality 70% / 3%	Displacement mortality 70% / 1%	Displacement mortality 70% / 3%
The Salamander Project*	3	9	3	8
Triton Knoll	1	4	0	1
West of Orkney*†	6	18	8	25
Westernmost Rough			0	0
Total (with Berwick Bank)	**194**	**580**	**216**	**653**
Total (without Berwick Bank)	**161**	**481**	**204**	**616**

2.2.5 Summary

31 Table 11 presents a summary of mortality estimates used in PVA, derived from those presented in Sections 2.2.1 to 2.2.4. The mortality estimates are comprised of mortalities arising from collision and distributional responses (kittiwake and gannet) and distributional responses only (guillemot and razorbill). To arrive at these values, the non-breeding season mortality estimates presented in Sections 2.2.1 to 2.2.4 have been scaled to the contribution of the regional population, following the method presented in Section 2.1.

Table 11 Summary of breeding and non-breeding impacts scaled to contribution of regional population to BDMPS, inputted into PVA models

Species		Annual mortalities							
Displacement Rate		30%		60%			70%		50%
Mortality Rate		1%	3%	1%	3%	5%	1%	3%	1%
Breeding season									
Kittiwake*	Including Berwick Bank	739.1	1026.1	-	-	-	-	-	-
	Excluding Berwick Bank	366.3	568.6	-	-	-	-	-	-
Guillemot	Including Berwick Bank	-	-	-	2899	4830	-	-	805
	Excluding Berwick Bank	-	-	-	1564	2605	-	-	434
Razorbill	Including Berwick Bank	-	-	-	407	677	-	-	112

Species		Annual mortalities							
Displacement Rate		30%		60%			70%		50%
Mortality Rate		1%	3%	1%	3%	5%	1%	3%	1%
Gannet*	Excluding Berwick Bank	-	-	-	334	556	-	-	92
	Including Berwick Bank	-	-	-	-	-	936.8	1322.8	-
	Excluding Berwick Bank	-	-	-	-	-	803.4	1123.4	-
Non-breeding season									
Kittiwake*	Including Berwick Bank	844	979.6	-	-	-	-	-	-
	Excluding Berwick Bank	701.9	756.4	-	-	-	-	-	-
Guillemot	Including Berwick Bank	-	-	770	2308	-	-	-	643

Species		Annual mortalities							
Displacement Rate		30%		60%			70%		50%
Mortality Rate		1%	3%	1%	3%	5%	1%	3%	1%
	Excluding Berwick Bank	-	-	505	1514	-	-	-	422
Razorbill	Including Berwick Bank	-	-	190	570.2	-	-	-	158.7
	Excluding Berwick Bank	-	-	165.6	496.8	-	-	-	138.2
Gannet*	Including Berwick Bank	-	-	-	-	-	911	1324.1	-
	Excluding Berwick Bank	-	-	-	-	-	889.5	1278.8	-

**Including collision mortality*

2.3 PVA assessment methodology

32 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, 2023a). All PVA modelling was undertaken using the PVA Tool version 2.0 (Searle *et al.*, 2019).

33 Prior to PVA modelling, displacement matrices were used to estimate the number of cumulative mortalities due to distributional responses during the breeding and non-breeding season for all species (Appendix I: Cumulative displacement matrices). Displacement matrices following the Matrix Approach as described in JNCC *et al.* (2022), in line with NatureScot guidance. The displacement and mortality rates used in matrices are presented in Table 12 and Table 13 and follow NatureScot guidance and the Applicant Approach (30% displacement and 1% mortality for kittiwake in all seasons; 50% displacement and 1% mortality for auks in all seasons, and 70% displacement and 1% mortality for gannet in all seasons).

Table 12 Displacement and mortality rates used in displacement matrices

Species	Percentage of birds displaced	Breeding season mortality	Non-breeding season mortality
Kittiwake	30%	1% and 3%	1% and 3%
Guillemot	60%	3% and 5%	1% and 3%
	50%	1%	1%
Razorbill	60%	3% and 5%	1% and 3%
	50%	1%	1%
Gannet	70%	1% and 3%	1% and 3%

Table 13 Applicant Approach displacement and mortality rates used in displacement matrices

Species	Percentage of birds displaced	Breeding season mortality	Non-breeding season mortality
Kittiwake	30%	1%	1%
Guillemot	50%	1%	1%
Razorbill	50%	1%	1%
Gannet	70%	1%	1%

2.3.1 Demographic parameters

34 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 14). Default parameters in the tool are derived from Horswill and Robinson (2015).

35 Models included environmental and demographic stochasticity, but not density dependence, 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 14 Summary of demographic rates for PVA species (NE PVA tool default values derived from SMP data)

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

2.3.1 PVA reference populations

36 Reference populations used for each species in the modelling are presented in Table 15. 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 of the Salamander Project 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 III: Impact scenarios for PVA.

Table 15 Seabird regional breeding populations considered under PVA

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

2.3.2 Survival by age class and sabbatical rates

37 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. This assessment has made no allowance for sabbatical birds as the NE PVA tool does not currently allow for sabbatical rates to be included.

38 Sabbatical adults were not excluded from the impacts and impacts were not applied to age classes other than adults.

2.3.3 Model duration

39 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: Results.

40 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).

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

2.3.4 Modelled mortality (impact scenarios)

42 For each species, each baseline simulation was paired with an impact scenario and mean impact on adult survival rate was calculated for input into PVA models (Table 16). Kittiwake and gannet mortalities arise

from the combined estimated impact due to collision risk and distributional response effects, while guillemot and razorbill mortalities arise from effects due to distributional responses only.

43 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.

44 In many ways this approach is similar to that used for non-breeding season apportioning used previously in Scottish projects for example for Berwick Bank (SSE Renewables 2022b). The difference here is that apportioning is done to the regional population and not a single colony.

45 Southwards migration of gannet post-breeding means the non-breeding season population is smaller than that for the breeding season. Therefore, the same approach of apportioning as used in previous offshore wind applications, for example Berwick Bank (SSE Renewables 2022b) was employed. 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 on the assumption that the regional population contribute in the same proportion. More detail on this approach is given in Appendix III: Impact scenarios for PVA.

Table 16 Modelled impact scenarios and mean impact on adult survival rate (applicant approach rates indicated with '*')

Scenario name	Impacts modelled	Mean impact on adult survival rate
Kittiwake[†]		
Scenario 1 *(with Berwick Bank)*	Breeding season: 30%/3% displacement + CRM	0.00992
	Non-breeding season: 30%/3% displacement + CRM	
Scenario 2: Applicant Approach *(with Berwick Bank)*	Breeding season: 30%/1% displacement + CRM*	0.00783
	Non-breeding season: 30%/1% displacement + CRM*	
Scenario 3 *(without Berwick Bank)*	Breeding season: 30%/3% displacement + CRM	0.00634
	Non-breeding season: 30%/3% displacement + CRM	
Scenario 4: Applicant Approach *(without Berwick Bank)*	Breeding season: 30%/1% displacement + CRM*	0.00528
	Non-breeding season: 30%/1% displacement + CRM*	
Guillemot		
Scenario 1 *(with Berwick Bank)*	Breeding season: 60%/5% displacement	0.01750
	Non-breeding season: 60%/3% displacement	
Scenario 2	Breeding season: 60%/3% displacement	0.00899

Scenario name	Impacts modelled	Mean impact on adult survival rate
(with Berwick Bank)	Non-breeding season: 60%/1% displacement	
Scenario 3: Applicant Approach *(with Berwick Bank)*	Breeding season: 50%/1% displacement*	0.00354
	Non-breeding season: 50%/1% displacement*	
Scenario 4 *(without Berwick Bank)*	Breeding season: 60%/5% displacement	0.01010
	Non-breeding season: 60%/3% displacement	
Scenario 5 *(without Berwick Bank)*	Breeding season: 60%/3% displacement	0.00507
	Non-breeding season: 60%/1% displacement	
Scenario 6: Applicant Approach *(without Berwick Bank)*	Breeding season: 50%/1% displacement*	0.00209
	Non-breeding season: 50%/1% displacement*	
Razorbill		
Scenario 1 *(with Berwick Bank)*	Breeding season: 60%/5% displacement	0.01776
	Non-breeding season: 60%/3% displacement	
Scenario 2 *(with Berwick Bank)*	Breeding season: 60%/3% displacement	0.00850
	Non-breeding season: 60%/1% displacement	

Scenario name	Impacts modelled	Mean impact on adult survival rate
Scenario 3: Applicant Approach *(with Berwick Bank)*	Breeding season: 50%/1% displacement*	0.00386
	Non-breeding season: 50%/1% displacement*	
Scenario 4 *(without Berwick Bank)*	Breeding season: 60%/5% displacement	0.01500
	Non-breeding season: 60%/3% displacement	
Scenario 5 *(without Berwick Bank)*	Breeding season: 60%/3% displacement	0.00712
	Non-breeding season: 60%/1% displacement	
Scenario 6: Applicant Approach *(without Berwick Bank)*	Breeding season: 50%/1% displacement*	0.00328
	Non-breeding season: 50%/1% displacement*	
Gannet		
Scenario 1 *(with Berwick Bank)*	Breeding season: 70%/3% displacement + CRM	0.00624
	Non-breeding season: 70%/3% displacement + CRM	
Scenario 2: Applicant Approach *(with Berwick Bank)*	Breeding season: 70%/1% displacement + CRM*	0.00436
	Non-breeding season: 70%/1% displacement + CRM*	
Scenario 3	Breeding season: 70%/3% displacement + CRM	0.00567

Scenario name	Impacts modelled	Mean impact on adult survival rate
(without Berwick Bank)	Non-breeding season: 70%/3% displacement + CRM	
Scenario 4: Applicant Approach *(without Berwick Bank)*	Breeding season: 70%/1% displacement + CRM*	0.00399
	Non-breeding season: 70%/1% displacement + CRM*	

† *displacement estimates from Scottish sites only*

2.3.5 Model outputs (population metrics)

46 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).

47 Testing the sensitivities of these metrics has suggested that CPC 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) determined 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.

48 CPS has been found to be more sensitive to trend than CPC and so should be interpreted with more care. Where impacts of a similar magnitude were tested on populations with differing trends (i.e. increasing, stable, declining), those with declining populations were estimated to experience a more severe effect to the same level of impact. Cook and Robinson (2016) also state the relationship between CPS and the magnitude of the impact is non-linear, especially under severe predicted impacts, therefore interpreting low to moderate impacts may be more straightforward than for those which are more severe.

49 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

50 After 35 years, the baseline regional kittiwake population is estimated to decrease slightly from 202,258 birds to 192,760 birds without additional impacts, while under Scenario 1 (30% / 3% displacement + CRM), the regional population is estimated to decline to 126,128 birds (137,899 birds with the Applicant Approach) (Table 17). Without Berwick Bank, the CPC indicates only a small effect on the regional population, however there is estimated to be a 20% to 24% decrease in the counterfactuals of final population size (CPS) (Scenarios 3 and 4). With Berwick Bank, this increases to 29% to 35%. However, CPS may not be the best metric to assess impacted versus unimpacted population size for populations with an already declining trend, so interpretation should be done with care (see Section 2.3.5). Model outputs for 25 and 50-years are presented in Appendix IV: PVA results (25 and 50 years).

Table 17 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	192,760	-	-
Including Berwick Bank			
Scenario 1 *30% / 3% displacement + CRM*	126,128	0.988 (0.988 – 0.989)	0.654 (0.641 – 0.665)
Scenario 2 *30% / 1% displacement + CRM**	137,899	0.991 (0.990 – 0.991)	0.715 (0.703 – 0.726)
Excluding Berwick Bank			
Scenario 3 *30% / 3% displacement + CRM*	146,752	0.992 (0.992 – 0.993)	0.762 (0.749 – 0.774)
Scenario 4 *30% / 1% displacement + CRM**	153,846	0.994 (0.993 – 0.994)	0.798 (0.785 – 0.810)

51 For guillemot, the baseline regional population is expected to continue to increase with a regional population of 1,209,339 birds estimated in 2065 (compared to a starting regional population of 407,959; Table 18). Cumulatively, the effect of offshore wind farms is expected to result in a smaller increase in the regional population, although the extent of displacement mortality affects the size of increase considerably. For example, Scenario 1 estimates there to be 50% reduction in the counterfactual of final population size, however under the Applicant Approach (50% displacement, 1% mortality, with Berwick Bank; Scenario 3), this decreases to a 13% change in counterfactual of final population size. The confidence intervals around counterfactuals are relatively small. Model outputs for 25 and 50-years are presented Appendix IV: PVA results (25 and 50 years).

Table 18 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	1,209,339	-	-
Including Berwick Bank			
Scenario 1 *60% / 3-5% displacement*	595,234	0.980 (0.980 – 0.981)	0.492 (0.488 – 0.496)

Guillemot scenarios	Median pop. size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
Scenario 2 *60% / 1-3% displacement*	841,287	0.990 (0.990 – 0.990)	0.696 (0.691 – 0.700)
Scenario 3 *50% / 1% displacement**	1,048,917	0.996 (0.996 – 0.996)	0.867 (0.862 – 0.872)
Excluding Berwick Bank			
Scenario 4 *60% / 3-5% displacement*	804,411	0.989 (0.989 – 0.989)	0.665 (0.661 – 0.670)
Scenario 5 *60% / 1-3% displacement*	985,963	0.994 (0.994 – 0.994)	0.816 (0.811 – 0.820)
Scenario 6 *50% / 1% displacement**	1,111,892	0.998 (0.998 – 0.998)	0.919 (0.914 – 0.924)

52 The baseline model for razorbill indicates the regional population is estimated to decline from 70,208 to 20,836 birds by 2065 (Table 19). With the addition of impacts under Scenario 1 and Scenario 3, 9,755 and 17,660 birds are estimated after 35 years respectively. It is likely there will be impact to the regional population, even when Berwick Bank data are excluded. Under the Applicant Approach (50% displacement and 1% mortality rates; Scenarios 3 and 6), the change in the counterfactual of population size is less (15% and 13% decrease for Scenarios 3 and 6 respectively). As this population is already expected to follow a declining population trend, the effect of the cumulative impacts is to increase the decline in population. As explained for kittiwake, CPS may not be the best metric to assess impacted versus unimpacted population size for populations with an already declining trend, so interpretation should be done with care (see Section 2.3.5). Model outputs for 25 and 50-years are presented in Appendix IV: PVA results (25 and 50 years).

Table 19 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	20,836	-	-
Including Berwick Bank			
Scenario 1 *60% / 3-5% displacement*	9,755	0.979 (0.978 – 0.980)	0.468 (0.448 – 0.486)
Scenario 2 *60% / 1-3% displacement*	14,498	0.990 (0.989 – 0.991)	0.697 (0.673 – 0.720)
Scenario 3 *50% / 1% displacement**	17,660	0.995 (0.995 – 0.996)	0.849 (0.822 – 0.876)
Excluding Berwick Bank			
Scenario 4 *60% / 3-5% displacement*	10,977	0.982 (0.981 – 0.983)	0.528 (0.506 – 0.547)
Scenario 5 *60% / 1-3% displacement*	15,371	0.992 (0.991 – 0.992)	0.739 (0.714 – 0.763)
Scenario 6 *50% / 1% displacement**	18,113	0.996 (0.995 – 0.997)	0.871 (0.843 – 0.899)

53 In 2065, the baseline regional population of gannet is estimated to increase from 423,894 birds to 544,009 birds. Under Scenario 1, the population is estimated at 417,106 birds, compared to 451,731 birds under Scenario 2 (Table 20). The counterfactual of final population size indicates there will be a cumulative impact to the gannet regional population, ranging between 16% (Scenario 4) and 23% (Scenario 1). Model outputs for 25 and 50-years are presented in Appendix IV: PVA results (25 and 50 years).

Table 20 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	-	-
Including Berwick Bank			
Scenario 1 *70% / 3% displacement + CRM*	417,106	0.993 (0.992 – 0.993)	0.767 (0.760 – 0.773)
Scenario 2 *70% / 1% displacement + CRM*	451,731	0.995 (0.995 – 0.995)	0.831 (0.824 – 0.838)
Excluding Berwick Bank			
Scenario 3 *70% / 3% displacement + CRM*	427,347	0.993 (0.993 – 0.994)	0.786 (0.779 – 0.792)
Scenario 4 *70% / 1% displacement + CRM*	459,297	0.995 (0.995 – 0.996)	0.844 (0.837 – 0.851)

4 Conclusion

54 Kittiwake populations in the UK have been steadily declining for several years and this is reflected in the PVA results (Table 17). Projecting forward, the 25- and 35-year baseline models predict a slow, continuing decline in the absence of wind farm impacts, with the kittiwake breeding season regional population predicted at 192,911 birds and 188,642 birds in 2055 and 2065, respectively. Population declines in unimpacted scenarios are also predicted for razorbill (Table 19). When cumulative impacts are applied, the median population size after 35 years for razorbill decreases by between 13% and 53% (Scenario 6 and Scenario 1, respectively). The ratio of final population size should be interpreted with care for these species, due to their existing population trends.

55 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 1,772,250 individuals and 423,898 individuals to 595,725 individuals, respectively (Table 18). Counterfactuals of final median population size for both species indicated that there is likely to be a negative cumulative effect when comparing impacted and unimpacted conditions, with the highest percentage difference in final population size after 35 years estimated at 51% (Scenario 1) for guillemot and 36% (Scenario 1) for gannet.

56 Including mortality estimates from Berwick Bank makes a considerable difference to estimates of population size and ratios of counterfactuals for all species. However, the use of different displacement and mortality estimates also leads to relatively large differences in predicted percentage change in ratios of counterfactuals over impacted periods. Post-construction site-specific monitoring of offshore wind farms in the North Sea will be helpful to determine the most realistic collision and displacement mortality rates to be fed into PVA models.

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Appendix I: Cumulative MSP abundance estimates

57 The following tables present collated MSP abundance estimates for projects screened into quantitative cumulative assessment, per species and season. Projects screened out of assessment are shaded in blue. More information on data sources and conversion between Furness (2015) and NatureScot (2020) seasons is provided in Sections 2.2 and 2.2 of the main report.

Table 21 Kittiwake collated MSP abundance estimates during the breeding and non-breeding seasons (NatureScot, 2020). Projects screened out of assessment shaded in blue, a short-dash indicates project screened in but no estimate available.

Development	Breeding season MSP abundance	Non-breeding season MSP abundance
Aberdeen Bay (EOWDC)	663	37
Beatrice†	1430	2224
Berwick Bank*	21141	24956
Blyth Demonstration Site	591	1480
Dogger Bank A & B		
Dogger Bank C & Sofia		
Dudgeon		
Dudgeon Extension		
East Anglia One		
East Anglia One NORTH		
East Anglia Two		
East Anglia Three		
ForthWind*	44	60
Galloper		
Greater Gabbard		
Green Volt*	183	232
Gunfleet Sands		
Hornsea Project One		
Hornsea Project Two		
Hornsea Three		
Hornsea Four		
Humber Gateway		
Hywind Scotland Pilot Park	112	-
Inch Cape	3866	2138
Kentish Flats		
Kincardine	229	-
Lincs, Lynn and Inner Dowsing		

Development	Breeding season MSP abundance	Non-breeding season MSP abundance
London Array Offshore Windfarm		
Methil Demonstration	184	-
Moray East†	1963	-
Moray West†	6902	2544
Neart na Gaoithe	2164	2155
Norfolk Boreas		
Norfolk Vanguard		
Pentland*†	546	159
Race Bank		
Scroby Sands		
Seagreen A & B	3235	4572
Sheringham Shoal		
Teeside		
Thanet		
The Salamander Project*	3718	220
Triton Knoll		
West of Orkney*†	1113	1217
Westernmost Rough		
Total (with Berwick Bank)	**48084**	**41994**
Total (without Berwick Bank)	**26943**	**17038**

Table 22 Guillemot collated MSP abundance estimates for distributional responses during the breeding and non-breeding seasons (NatureScot, 2020)

Development	Breeding season MSP abundance	Non-breeding season MSP abundance
Aberdeen Bay (EOWDC)	547	225
Beatrice	13610	2755
Berwick Bank	74154	44171
ForthWind Demonstration Project	417	401
Green Volt	4429	16105
Hywind Scotland Pilot Park	249	2136
Inch Cape	4371	3177
Kincardine	632	0
Moray East	9820	547
Moray West	24426	38174
Seagreen A & B	24724	8800

Development	Breeding season MSP abundance	Non-breeding season MSP abundance
The Salamander Project	3616	11779
Total (with Berwick Bank)	**160995**	**128270**
Total (without Berwick Bank)	**86841**	**84099**

Table 23 Razorbill collated MSP abundance estimates during the breeding and non-breeding seasons (NatureScot, 2020). Projects screened out of assessment shaded in blue

Development	Breeding season MSP abundance	Non-breeding season MSP abundance
Aberdeen Bay (EOWDC)	161	97
Beatrice	873	2221
Berwick Bank	4040	17728
Blyth Demonstration Site		243
Dogger Bank A & B		16812
Dogger Bank C & Sofia		10325
Dudgeon		1437
Dudgeon Extension		6025
East Anglia One		517
East Anglia One NORTH		346
East Anglia Two		410
East Anglia Three		4145
ForthWind	73	123
Galloper		543
Greater Gabbard		471
Green Volt	457	58
Gunfleet Sands		30
Hornsea Project One		8133
Hornsea Project Two		6609
Hornsea Three		7774
Hornsea Four		4435
Humber Gateway		53
Hywind Scotland Pilot Park	30	729
Inch Cape	1436	3521
Kentish Flats		0
Kincardine	22	0
Lincs, Lynn and Inner Dowsing		90

Development	Breeding season MSP abundance	Non-breeding season MSP abundance
London Array Offshore Windfarm		55
Methil Demonstration		0
Moray East	2423	1301
Moray West	2808	7313
Neart na Gaoithe	331	6000
Norfolk Boreas		1673
Norfolk Vanguard		10129
Pentland		16
Rampion		4637
Rampion 2		7522
Scroby Sands		0
Seagreen A & B	9574	2375
Sheringham Shoal		1584
Teeside		83
Thanet		35
The Salamander Project	334	484
Triton Knoll		1226
West of Orkney		364
Westernmost Rough		132
Total (with Berwick Bank)	**22562**	**137804**
Total (without Berwick Bank)	**18522**	**120076**

Table 24 Gannet collated MSP abundance estimates during the breeding and non-breeding seasons (NatureScot, 2020). Projects screened out of assessment shaded in blue

Development	Breeding season MSP abundance	Breeding season MSP abundance
Aberdeen Bay (EOWDC)	35	5
Beatrice	151	0
Berwick Bank*	4735	1769
Blyth Demonstration Site		0
Dogger Bank A & B	2250	2442
Dogger Bank C & Sofia	1155	1351
Dudgeon	53	36
Dudgeon Extension	401	685
East Anglia One	161	3714
East Anglia One NORTH	149	512

Development	Breeding season MSP abundance	Breeding season MSP abundance
East Anglia Two	192	1083
East Anglia Three	412	1793
ForthWind*	64	70
Galloper		1183
Greater Gabbard		174
Green Volt*	130	65
Gunfleet Sands		21
Hornsea Project One	671	944
Hornsea Project Two	457	1264
Hornsea Three	1333	1511
Hornsea Four	791	1089
Humber Gateway		0
Hywind Scotland Pilot Park	10	4
Inch Cape	2398	915
Kentish Flats		13
Kincardine	120	0
Lincs, Lynn and Inner Dowsing		0
London Array Offshore Windfarm		0
Methil Demonstration		0
Moray East	564	319
Moray West	2827	583
Neart na Gaoithe	1987	833
Norfolk Boreas	1229	2249
Norfolk Vanguard	271	2890
Pentland*†	547	159
Race Bank	92	61
Rampion		590
Rampion 2		225
Scroby Sands*	-	0
Seagreen A & B	2956	996
Sheringham Shoal	47	33
Teeside	1	0
Thanet		0
The Salamander Project*	442	369
Triton Knoll	211	39
West of Orkney*†	852	1171

Development	Breeding season MSP abundance	Breeding season MSP abundance
Westernmost Rough		0
Total (with Berwick Bank)	**27694**	**31160**
Total (without Berwick Bank)	**22959**	**29391**

Appendix II: Cumulative displacement matrices

58 Displacement matrices were run on cumulative MSP abundance estimates for projects screened into assessment, per species and season (see Section 2.2), following the Matrix Approach as described in JNCC et al. (2022). Mortality and displacement rates used in matrices are presented in Table 12 and Table 13. Displacement matrices are presented in Table 25 to Table 40. Mortality estimates from displacement matrices were used in PVA models.

Table 25 **Kittiwake breeding season cumulative displacement mortalities *including* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green where applicable. Where NatureScot and Applicant Approach rates are the same, values are coloured orange**

Kittiwake (mid Apr-Aug)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	48	96	144	192	240	481	721	962	1,443	2,404	3,847	4,808
	20%	0	96	192	289	385	481	962	1,443	1,923	2,885	4,808	7,693	9,617
	30%	0	144	289	433	577	721	1,443	2,164	2,885	4,328	7,213	11,540	14,425
	40%	0	192	385	577	769	962	1,923	2,885	3,847	5,770	9,617	15,387	19,234
	50%	0	240	481	721	962	1,202	2,404	3,606	4,808	7,213	12,021	19,234	24,042
	60%	0	289	577	866	1,154	1,443	2,885	4,328	5,770	8,655	14,425	23,080	28,850
	70%	0	337	673	1,010	1,346	1,683	3,366	5,049	6,732	10,098	16,829	26,927	33,659
	80%	0	385	769	1,154	1,539	1,923	3,847	5,770	7,693	11,540	19,234	30,774	38,467
	90%	0	433	866	1,298	1,731	2,164	4,328	6,491	8,655	12,983	21,638	34,620	43,276
	100%	0	481	962	1,443	1,923	2,404	4,808	7,213	9,617	14,425	24,042	38,467	48,084

Table 26 **Kittiwake breeding season cumulative displacement mortalities *excluding* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green where applicable. Where NatureScot and Applicant Approach rates are the same, values are coloured orange**

Kittiwake (mid Apr-Aug)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	27	54	81	108	135	269	404	539	808	1,347	2,155	2,694
	20%	0	54	108	162	216	269	539	808	1,078	1,617	2,694	4,311	5,389
	30%	0	81	162	242	323	404	808	1,212	1,617	2,425	4,041	6,466	8,083
	40%	0	108	216	323	431	539	1,078	1,617	2,155	3,233	5,389	8,622	10,777
	50%	0	135	269	404	539	674	1,347	2,021	2,694	4,041	6,736	10,777	13,472
	60%	0	162	323	485	647	808	1,617	2,425	3,233	4,850	8,083	12,933	16,166
	70%	0	189	377	566	754	943	1,886	2,829	3,772	5,658	9,430	15,088	18,860
	80%	0	216	431	647	862	1,078	2,155	3,233	4,311	6,466	10,777	17,244	21,554
	90%	0	242	485	727	970	1,212	2,425	3,637	4,850	7,275	12,124	19,399	24,249
	100%	0	269	539	808	1,078	1,347	2,694	4,041	5,389	8,083	13,472	21,554	26,943

Table 27 **Kittiwake non-breeding season cumulative displacement mortalities *including* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green where applicable. Where NatureScot and Applicant Approach rates are the same, values are coloured orange**

Kittiwake (Sep – mid Apr)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	42	84	126	168	210	420	630	840	1,260	2,100	3,360	4,199
	20%	0	84	168	252	336	420	840	1,260	1,680	2,520	4,199	6,719	8,399
	30%	0	126	252	378	504	630	1,260	1,890	2,520	3,779	6,299	10,079	12,598
	40%	0	168	336	504	672	840	1,680	2,520	3,360	5,039	8,399	13,438	16,798
	50%	0	210	420	630	840	1,050	2,100	3,150	4,199	6,299	10,498	16,798	20,997
	60%	0	252	504	756	1,008	1,260	2,520	3,779	5,039	7,559	12,598	20,157	25,196
	70%	0	294	588	882	1,176	1,470	2,940	4,409	5,879	8,819	14,698	23,517	29,396
	80%	0	336	672	1,008	1,344	1,680	3,360	5,039	6,719	10,079	16,798	26,876	33,595
	90%	0	378	756	1,134	1,512	1,890	3,779	5,669	7,559	11,338	18,897	30,236	37,795
	100%	0	420	840	1,260	1,680	2,100	4,199	6,299	8,399	12,598	20,997	33,595	41,994

Table 28 **Kittiwake non-breeding season cumulative displacement mortalities *excluding* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green where applicable. Where NatureScot and Applicant Approach rates are the same, values are coloured orange**

Kittiwake (Sep – mid Apr)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	17	34	51	68	85	170	256	341	511	852	1,363	1,704
	20%	0	34	68	102	136	170	341	511	682	1,022	1,704	2,726	3,408
	30%	0	51	102	153	204	256	511	767	1,022	1,533	2,556	4,089	5,111
	40%	0	68	136	204	273	341	682	1,022	1,363	2,045	3,408	5,452	6,815
	50%	0	85	170	256	341	426	852	1,278	1,704	2,556	4,260	6,815	8,519
	60%	0	102	204	307	409	511	1,022	1,533	2,045	3,067	5,111	8,178	10,223
	70%	0	119	239	358	477	596	1,193	1,789	2,385	3,578	5,963	9,541	11,927
	80%	0	136	273	409	545	682	1,363	2,045	2,726	4,089	6,815	10,904	13,630
	90%	0	153	307	460	613	767	1,533	2,300	3,067	4,600	7,667	12,267	15,334
	100%	0	170	341	511	682	852	1,704	2,556	3,408	5,111	8,519	13,630	17,038

Table 29 **Guillemot breeding season cumulative displacement mortalities *including* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green**

Guillemot (Apr- mid Aug)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	161	322	483	644	805	1,610	2,415	3,220	4,830	8,050	12,880	16,100
	20%	0	322	644	966	1,288	1,610	3,220	4,830	6,440	9,660	16,100	25,759	32,199
	30%	0	483	966	1,449	1,932	2,415	4,830	7,245	9,660	14,490	24,149	38,639	48,299
	40%	0	644	1,288	1,932	2,576	3,220	6,440	9,660	12,880	19,319	32,199	51,518	64,398
	50%	0	805	1,610	2,415	3,220	4,025	8,050	12,075	16,100	24,149	40,249	64,398	80,498
	60%	0	966	1,932	2,898	3,864	4,830	9,660	14,490	19,319	28,979	48,299	77,278	96,597
	70%	0	1,127	2,254	3,381	4,508	5,635	11,270	16,904	22,539	33,809	56,348	90,157	112,697
	80%	0	1,288	2,576	3,864	5,152	6,440	12,880	19,319	25,759	38,639	64,398	103,037	128,796
	90%	0	1,449	2,898	4,347	5,796	7,245	14,490	21,734	28,979	43,469	72,448	115,916	144,896
	100%	0	1,610	3,220	4,830	6,440	8,050	16,100	24,149	32,199	48,298	80,498	128,796	160,995

Table 30 **Guillemot breeding season cumulative displacement mortalities *excluding* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green**

Guillemot (Apr- mid Aug)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	87	174	261	347	434	868	1,303	1,737	2,605	4,342	6,947	8,684
	20%	0	174	347	521	695	868	1,737	2,605	3,474	5,210	8,684	13,895	17,368
	30%	0	261	521	782	1,042	1,303	2,605	3,908	5,210	7,816	13,026	20,842	26,052
	40%	0	347	695	1,042	1,389	1,737	3,474	5,210	6,947	10,421	17,368	27,789	34,736
	50%	0	434	868	1,303	1,737	2,171	4,342	6,513	8,684	13,026	21,710	34,736	43,420
	60%	0	521	1,042	1,563	2,084	2,605	5,210	7,816	10,421	15,631	26,052	41,684	52,105
	70%	0	608	1,216	1,824	2,432	3,039	6,079	9,118	12,158	18,237	30,394	48,631	60,789
	80%	0	695	1,389	2,084	2,779	3,474	6,947	10,421	13,895	20,842	34,736	55,578	69,473
	90%	0	782	1,563	2,345	3,126	3,908	7,816	11,724	15,631	23,447	39,078	62,526	78,157
	100%	0	868	1,737	2,605	3,474	4,342	8,684	13,026	17,368	26,052	43,420	69,473	86,841

Table 31 **Guillemot non-breeding season cumulative displacement mortalities *including* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green**

Guillemot (mid Aug – Mar)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	128	257	385	513	641	1,283	1,924	2,565	3,848	6,414	10,262	12,827
	20%	0	257	513	770	1,026	1,283	2,565	3,848	5,131	7,696	12,827	20,523	25,654
	30%	0	385	770	1,154	1,539	1,924	3,848	5,772	7,696	11,544	19,241	30,785	38,481
	40%	0	513	1,026	1,539	2,052	2,565	5,131	7,696	10,262	15,392	25,654	41,046	51,308
	50%	0	641	1,283	1,924	2,565	3,207	6,414	9,620	12,827	19,240	32,068	51,308	64,135
	60%	0	770	1,539	2,309	3,078	3,848	7,696	11,544	15,392	23,089	38,481	61,570	76,962
	70%	0	898	1,796	2,694	3,592	4,489	8,979	13,468	17,958	26,937	44,895	71,831	89,789
	80%	0	1,026	2,052	3,078	4,105	5,131	10,262	15,392	20,523	30,785	51,308	82,093	102,616
	90%	0	1,154	2,309	3,463	4,618	5,772	11,544	17,316	23,089	34,633	57,722	92,354	115,443
	100%	0	1,283	2,565	3,848	5,131	6,414	12,827	19,240	25,654	38,481	64,135	102,616	128,270

Table 32 **Guillemot non-breeding season cumulative displacement mortalities *excluding* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green**

Guillemot (mid Aug – Mar)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	84	168	252	336	420	841	1,261	1,682	2,523	4,205	6,728	8,410
	20%	0	168	336	505	673	841	1,682	2,523	3,364	5,046	8,410	13,456	16,820
	30%	0	252	505	757	1,009	1,261	2,523	3,784	5,046	7,569	12,615	20,184	25,230
	40%	0	336	673	1,009	1,346	1,682	3,364	5,046	6,728	10,092	16,820	26,912	33,640
	50%	0	420	841	1,261	1,682	2,102	4,205	6,307	8,410	12,615	21,025	33,640	42,050
	60%	0	505	1,009	1,514	2,018	2,523	5,046	7,569	10,092	15,138	25,230	40,368	50,459
	70%	0	589	1,177	1,766	2,355	2,943	5,887	8,830	11,774	17,661	29,435	47,095	58,869
	80%	0	673	1,346	2,018	2,691	3,364	6,728	10,092	13,456	20,184	33,640	53,823	67,279
	90%	0	757	1,514	2,271	3,028	3,784	7,569	11,353	15,138	22,707	37,845	60,551	75,689
	100%	0	841	1,682	2,523	3,364	4,205	8,410	12,615	16,820	25,230	42,050	67,279	84,099

Table 33 **Razorbill breeding season cumulative displacement mortalities *including* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green**

Razorbill (Apr- mid Aug)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	23	45	68	90	113	226	338	451	677	1,128	1,805	2,256
	20%	0	45	90	135	180	226	451	677	902	1,354	2,256	3,610	4,512
	30%	0	68	135	203	271	338	677	1,015	1,354	2,031	3,384	5,415	6,769
	40%	0	90	180	271	361	451	902	1,354	1,805	2,707	4,512	7,220	9,025
	50%	0	113	226	338	451	564	1,128	1,692	2,256	3,384	5,640	9,025	11,281
	60%	0	135	271	406	541	677	1,354	2,031	2,707	4,061	6,769	10,830	13,537
	70%	0	158	316	474	632	790	1,579	2,369	3,159	4,738	7,897	12,635	15,793
	80%	0	180	361	541	722	902	1,805	2,707	3,610	5,415	9,025	14,440	18,050
	90%	0	203	406	609	812	1,015	2,031	3,046	4,061	6,092	10,153	16,245	20,306
	100%	0	226	451	677	902	1,128	2,256	3,384	4,512	6,769	11,281	18,050	22,562

Table 34 **Razorbill breeding season cumulative displacement mortalities *excluding* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green**

Razorbill (Apr- mid Aug)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	19	37	56	74	93	185	278	370	556	926	1,482	1,852
	20%	0	37	74	111	148	185	370	556	741	1,111	1,852	2,964	3,704
	30%	0	56	111	167	222	278	556	833	1,111	1,667	2,778	4,445	5,557
	40%	0	74	148	222	296	370	741	1,111	1,482	2,223	3,704	5,927	7,409
	50%	0	93	185	278	370	463	926	1,389	1,852	2,778	4,630	7,409	9,261
	60%	0	111	222	333	445	556	1,111	1,667	2,223	3,334	5,557	8,891	11,113
	70%	0	130	259	389	519	648	1,297	1,945	2,593	3,890	6,483	10,372	12,965
	80%	0	148	296	445	593	741	1,482	2,223	2,964	4,445	7,409	11,854	14,818
	90%	0	167	333	500	667	833	1,667	2,500	3,334	5,001	8,335	13,336	16,670
	100%	0	185	370	556	741	926	1,852	2,778	3,704	5,557	9,261	14,818	18,522

Table 35 **Razorbill non-breeding season cumulative displacement mortalities *including* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green**

Razorbill (mid Aug - Mar)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	138	276	413	551	689	1,378	2,067	2,756	4,134	6,890	11,024	13,780
	20%	0	276	551	827	1,102	1,378	2,756	4,134	5,512	8,268	13,780	22,049	27,561
	30%	0	413	827	1,240	1,654	2,067	4,134	6,201	8,268	12,402	20,671	33,073	41,341
	40%	0	551	1,102	1,654	2,205	2,756	5,512	8,268	11,024	16,536	27,561	44,097	55,122
	50%	0	689	1,378	2,067	2,756	3,445	6,890	10,335	13,780	20,671	34,451	55,122	68,902
	60%	0	827	1,654	2,480	3,307	4,134	8,268	12,402	16,536	24,805	41,341	66,146	82,682
	70%	0	965	1,929	2,894	3,859	4,823	9,646	14,469	19,293	28,939	48,231	77,170	96,463
	80%	0	1,102	2,205	3,307	4,410	5,512	11,024	16,536	22,049	33,073	55,122	88,195	110,243
	90%	0	1,240	2,480	3,721	4,961	6,201	12,402	18,604	24,805	37,207	62,012	99,219	124,024
	100%	0	1,378	2,756	4,134	5,512	6,890	13,780	20,671	27,561	41,341	68,902	110,243	137,804

Table 36 **Razorbill non-breeding season cumulative displacement mortalities *excluding* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green**

Razorbill (mid Aug - Mar)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	120	240	360	480	600	1,201	1,801	2,402	3,602	6,004	9,606	12,008
	20%	0	240	480	720	961	1,201	2,402	3,602	4,803	7,205	12,008	19,212	24,015
	30%	0	360	720	1,081	1,441	1,801	3,602	5,403	7,205	10,807	18,011	28,818	36,023
	40%	0	480	961	1,441	1,921	2,402	4,803	7,205	9,606	14,409	24,015	38,424	48,030
	50%	0	600	1,201	1,801	2,402	3,002	6,004	9,006	12,008	18,011	30,019	48,030	60,038
	60%	0	720	1,441	2,161	2,882	3,602	7,205	10,807	14,409	21,614	36,023	57,636	72,046
	70%	0	841	1,681	2,522	3,362	4,203	8,405	12,608	16,811	25,216	42,027	67,243	84,053
	80%	0	961	1,921	2,882	3,842	4,803	9,606	14,409	19,212	28,818	48,030	76,849	96,061
	90%	0	1,081	2,161	3,242	4,323	5,403	10,807	16,210	21,614	32,421	54,034	86,455	108,068
	100%	0	1,201	2,402	3,602	4,803	6,004	12,008	18,011	24,015	36,023	60,038	96,061	120,076

Table 37 **Gannet breeding season cumulative displacement mortalities *including* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green where applicable. Where NatureScot and Applicant Approach rates are the same, values are coloured orange**

Gannet (mid Mar - Sep)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	28	55	83	111	138	277	415	554	831	1,385	2,216	2,769
	20%	0	55	111	166	222	277	554	831	1,108	1,662	2,769	4,431	5,539
	30%	0	83	166	249	332	415	831	1,246	1,662	2,492	4,154	6,647	8,308
	40%	0	111	222	332	443	554	1,108	1,662	2,216	3,323	5,539	8,862	11,078
	50%	0	138	277	415	554	692	1,385	2,077	2,769	4,154	6,924	11,078	13,847
	60%	0	166	332	498	665	831	1,662	2,492	3,323	4,985	8,308	13,293	16,616
	70%	0	194	388	582	775	969	1,939	2,908	3,877	5,816	9,693	15,509	19,386
	80%	0	222	443	665	886	1,108	2,216	3,323	4,431	6,647	11,078	17,724	22,155
	90%	0	249	498	748	997	1,246	2,492	3,739	4,985	7,477	12,462	19,940	24,925
	100%	0	277	554	831	1,108	1,385	2,769	4,154	5,539	8,308	13,847	22,155	27,694

Table 38 **Gannet breeding season cumulative displacement mortalities *excluding* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green where applicable. Where NatureScot and Applicant Approach rates are the same, values are coloured orange**

Gannet (mid Mar - Sep)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	23	46	69	92	115	230	344	459	689	1,148	1,837	2,296
	20%	0	46	92	138	184	230	459	689	918	1,378	2,296	3,673	4,592
	30%	0	69	138	207	276	344	689	1,033	1,378	2,066	3,444	5,510	6,888
	40%	0	92	184	276	367	459	918	1,378	1,837	2,755	4,592	7,347	9,184
	50%	0	115	230	344	459	574	1,148	1,722	2,296	3,444	5,740	9,184	11,480
	60%	0	138	276	413	551	689	1,378	2,066	2,755	4,133	6,888	11,020	13,775
	70%	0	161	321	482	643	804	1,607	2,411	3,214	4,821	8,036	12,857	16,071
	80%	0	184	367	551	735	918	1,837	2,755	3,673	5,510	9,184	14,694	18,367
	90%	0	207	413	620	827	1,033	2,066	3,099	4,133	6,199	10,332	16,530	20,663
	100%	0	230	459	689	918	1,148	2,296	3,444	4,592	6,888	11,480	18,367	22,959

Table 39 **Gannet non-breeding season cumulative displacement mortalities *including* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green where applicable. Where NatureScot and Applicant Approach rates are the same, values are coloured orange**

Gannet (Oct – mid Mar)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	31	62	93	125	156	312	467	623	935	1,558	2,493	3,116
	20%	0	62	125	187	249	312	623	935	1,246	1,870	3,116	4,986	6,232
	30%	0	93	187	280	374	467	935	1,402	1,870	2,804	4,674	7,478	9,348
	40%	0	125	249	374	499	623	1,246	1,870	2,493	3,739	6,232	9,971	12,464
	50%	0	156	312	467	623	779	1,558	2,337	3,116	4,674	7,790	12,464	15,580
	60%	0	187	374	561	748	935	1,870	2,804	3,739	5,609	9,348	14,957	18,696
	70%	0	218	436	654	872	1,091	2,181	3,272	4,362	6,544	10,906	17,450	21,812
	80%	0	249	499	748	997	1,246	2,493	3,739	4,986	7,478	12,464	19,942	24,928
	90%	0	280	561	841	1,122	1,402	2,804	4,207	5,609	8,413	14,022	22,435	28,044
	100%	0	312	623	935	1,246	1,558	3,116	4,674	6,232	9,348	15,580	24,928	31,160

Table 40 **Gannet non-breeding season cumulative displacement mortalities *excluding* Berwick Bank (to the nearest whole bird). Blue coloured cells indicate displacement/mortality rates as recommended by NatureScot, Applicant Approach rates coloured green where applicable. Where NatureScot and Applicant Approach rates are the same, values are coloured orange**

Gannet (Oct – mid Mar)		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	30	60	90	120	150	299	449	599	898	1,497	2,394	2,993
	20%	0	60	120	180	239	299	599	898	1,197	1,796	2,993	4,789	5,986
	30%	0	90	180	269	359	449	898	1,347	1,796	2,694	4,490	7,183	8,979
	40%	0	120	239	359	479	599	1,197	1,796	2,394	3,592	5,986	9,578	11,972
	50%	0	150	299	449	599	748	1,497	2,245	2,993	4,490	7,483	11,972	14,966
	60%	0	180	359	539	718	898	1,796	2,694	3,592	5,388	8,979	14,367	17,959
	70%	0	210	419	629	838	1,048	2,095	3,143	4,190	6,286	10,476	16,761	20,952
	80%	0	239	479	718	958	1,197	2,394	3,592	4,789	7,183	11,972	19,156	23,945
	90%	0	269	539	808	1,078	1,347	2,694	4,041	5,388	8,081	13,469	21,550	26,938
	100%	0	299	599	898	1,197	1,497	2,993	4,490	5,986	8,979	14,966	23,945	29,931

Appendix III: Impact scenarios for PVA

59 Here the supporting calculations used to determine the impact scenarios (i.e. mortality estimates due to collision and distributional responses) to model against kittiwake, guillemot, razorbill, and gannet breeding season regional populations are presented. 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.

60 For kittiwake, gannet and razorbill, 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), 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. This does not apply to guillemot, as the breeding and non-breeding regional population is the same.

61 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. 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; approx. 90%).

62 For each focal species 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 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. Cumulative impacts were also collated with and without Berwick Bank; those including Berwick Bank impacts are clearly labelled.

Table 41 Parameters used to determine mean impact on kittiwake adult survival rate (% of adult population affected) for each PVA scenario. Kittiwake displacement mortalities are only collated for Scottish sites

	Breeding	Non-breeding
Scenario 1 (30%/3% displacement (breeding and non-breeding) + CRM) ***Including Berwick Bank***		
Displacement + CRM mortality	1026.1	979.6
Regional population	202258	627816
Mortality for PVA	1026.1	979.6
Mean impact on adult survival rate	0.00992	
Scenario 2 (30%/1% displacement (breeding and non-breeding) + CRM) ***Including Berwick Bank***		
Displacement + CRM mortality	739	844
Regional population	202258	627816
Mortality for PVA	739	844
Mean impact on adult survival rate	0.00783	
Scenario 3 (30%/3% displacement (breeding and non-breeding) + CRM) ***Excluding Berwick Bank***		
Displacement + CRM mortality	526.3	756.4
Regional population	202258	627816
Mortality for PVA	526.3	756.4
Mean impact on adult survival rate	0.00634	
Scenario 4 (30%/1% displacement (breeding and non-breeding) + CRM) ***Excluding Berwick Bank***		
Displacement + CRM mortality	366.3	701.9
Regional population	202258	627816
Mortality for PVA	366.3	701.9
Mean impact on adult survival rate	0.00528	

Table 42 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) ***Including Berwick Bank***		
Displacement mortality	4830	2309
Regional population	407959	407959
Mean impact on adult survival rate	0.01750	
Scenario 2 (60%/3% (breeding) 60%/1% (non-breeding) displacement) ***Including Berwick Bank***		
Displacement mortality	2898	770
Regional population	407959	407959
Mean impact on adult survival rate	0.00899	
Scenario 3 (50%/1% (breeding and non-breeding) ***Including Berwick Bank***		
Displacement mortality	805	641
Regional population	407959	407959
Mean impact on adult survival rate	0.00354	
Scenario 4 (60%/5% (breeding) 60%/3% (non-breeding) displacement) ***Excluding Berwick Bank***		
Displacement mortality	2605	1514
Regional population	407959	407959
Mean impact on adult survival rate	0.01010	
Scenario 5 (60%/3% (breeding) 60%/1% (non-breeding) displacement) ***Excluding Berwick Bank***		
Displacement mortality	1563	505
Regional population	407959	407959
Mean impact on adult survival rate	0.00507	
Scenario 6 (50%/1% (breeding and non-breeding)		

	Breeding	Non-breeding
Excluding Berwick Bank		
Displacement mortality	434	420
Regional population	407959	407959
Mean impact on adult survival rate	0.00209	

Table 43 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) ***Including Berwick Bank***		
Displacement mortality	677	570.2
Regional population	70208	218622
Mortality for PVA	677	570.2
Mean impact on adult survival rate	0.01776	
Scenario 2 (60%/3% (breeding) 60%/1% (non-breeding) displacement) ***Including Berwick Bank***		
Displacement mortality	407	190
Regional population	70208	218622
Mortality for PVA	407	190
Mean impact on adult survival rate	0.00850	
Scenario 3 (50%/1% (breeding and non-breeding) ***Including Berwick Bank***		
Displacement mortality	112	158.7
Regional population	70208	218622
Mortality for PVA	112	158.7
Mean impact on adult survival rate	0.00386	
Scenario 4 (60%/5% (breeding) 60%/3% (non-breeding) displacement) ***Excluding Berwick Bank***		
Displacement mortality	556	496.8

	Breeding	Non-breeding
Regional population	70208	218622
Mortality for PVA	556	496.8
Mean impact on adult survival rate	0.01500	
Scenario 5 (60%/3% (breeding) 60%/1% (non-breeding) displacement) ***Excluding Berwick Bank***		
Displacement mortality	334	165.6
Regional population	70208	218622
Mortality for PVA	334	165.6
Mean impact on adult survival rate	0.00712	
Scenario 6 (50%/1% (breeding and non-breeding) ***Excluding Berwick Bank***		
Displacement mortality	92	138.2
Regional population	70208	218622
Mortality for PVA	92	138.2
Mean impact on adult survival rate	0.00328	

Table 44 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) ***Including Berwick Bank***		
Displacement + CRM mortality	1322.8	1324.1
Regional population	423894	248385
Mortality for PVA	1322.8	1324.1
Mean impact on adult survival rate	0.00624	
Scenario 2 (70%/1% displacement (breeding and non-breeding) + CRM) ***Including Berwick Bank***		
Displacement + CRM mortality	936.8	911
Regional population	423894	248385

	Breeding	Non-breeding
Mortality for PVA	936.8	911
Mean impact on adult survival rate	0.00436	
Scenario 3 (70%/3% displacement (breeding and non-breeding) + CRM) ***Excluding Berwick Bank***		
Displacement + CRM mortality	1123.4	1278.8
Regional population	423894	248385
Mortality for PVA	1123.4	1278.8
Mean impact on adult survival rate	0.00567	
Scenario 4 (70%/1% displacement (breeding and non-breeding) + CRM) ***Excluding Berwick Bank***		
Displacement + CRM mortality	803.4	889.5
Regional population	423894	248385
Mortality for PVA	803.4	889.5
Mean impact on adult survival rate	0.00399	

Appendix IV:PVA results (25 and 50 years)

63 Table 45 to Table 52 present 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 45 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	192,911	-	-
Including Berwick Bank			
Scenario 1 *30% / 3% displacement + CRM*	142,022	0.988 (0.988 – 0.989)	0.736 (0.724 – 0.746)
Scenario 2 *30% / 1% displacement + CRM**	151,530	0.991 (0.990 – 0.991)	0.785 (0.773 – 0.796)
Excluding Berwick Bank			
Scenario 3 *30% / 3% displacement + CRM*	158,908	0.993 (0.992 – 0.993)	0.822 (0.810 – 0.833)
Scenario 4 *30% / 1% displacement + CRM**	164,056	0.994 (0.993 – 0.994)	0.850 (0.837 – 0.861)

Table 46 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	188,642	-	-
Including Berwick Bank			
Scenario 1	103,332	0.988	0.548

Kittiwake scenarios	Median pop. size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
30% / 3% displacement + CRM		(0.988 – 0.989)	(0.535 – 0.558)
Scenario 2 *30% / 1% displacement + CRM**	117,324	0.991 (0.990 – 0.991)	0.622 (0.608 – 0.634)
Excluding Berwick Bank			
Scenario 3 *30% / 3% displacement + CRM*	128,537	0.993 (0.992 – 0.993)	0.681 (0.667 – 0.694)
Scenario 4 *30% / 1% displacement + CRM**	137,107	0.994 (0.993 – 0.994)	0.726 (0.711 – 0.740)

Table 47 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	941,356	-	-
Including Berwick Bank			
Scenario 1 *60% / 3-5% displacement*	565,265	0.981 (0.980 – 0.981)	0.600 (0.595 – 0.604)
Scenario 2 *60% / 1-3% displacement*	725,746	0.990 (0.990 – 0.990)	0.770 (0.766 – 0.774)
Scenario 3 *50% / 1% displacement**	850,538	0.996 (0.996 – 0.996)	0.902 (0.898 – 0.907)
Excluding Berwick Bank			
Scenario 4 *60% / 3-5% displacement*	702,748	0.989 (0.989 – 0.989)	0.745 (0.741 – 0.750)
Scenario 5 *60% / 1-3% displacement*	813,611	0.994 (0.994 – 0.995)	0.863 (0.859 – 0.868)
Scenario 6 *50% / 1% displacement**	887,529	0.998 (0.997 – 0.998)	0.941 (0.936 – 0.946)

Table 48 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	1,772,250	-	-
Including Berwick Bank			
Scenario 1 *60% / 3-5% displacement*	647,888	0.980 (0.980 – 0.981)	0.366 (0.362 – 0.369)
Scenario 2 *60% / 1-3% displacement*	1,058,338	0.990 (0.990 – 0.990)	0.598 (0.594 – 0.602)
Scenario 3 *50% / 1% displacement**	1,447,294	0.996 (0.996 – 0.996)	0.817 (0.812 – 0.822)
Excluding Berwick Bank			
Scenario 4 *60% / 3-5% displacement*	993,183	0.989 (0.989 – 0.989)	0.561 (0.557 – 0.565)
Scenario 5 *60% / 1-3% displacement*	1,327,340	0.994 (0.994 – 0.994)	0.749 (0.744 – 0.753)
Scenario 6 *50% / 1% displacement**	1,572,709	0.998 (0.998 – 0.998)	0.888 (0.882 – 0.893)

Table 49 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	27,955	-	-
Including Berwick Bank			
Scenario 1 *60% / 3-5% displacement*	16,194	0.979 (0.978 – 0.980)	0.579 (0.560 – 0.595)
Scenario 2 *60% / 1-3% displacement*	21,537	0.990 (0.989 – 0.991)	0.771 (0.749 – 0.791)
Scenario 3 *50% / 1% displacement**	24,829	0.995	0.889

Razorbill scenarios	Median pop. size at end of modelled period (adult individuals)	Median counterfactuals	
		CPC	CPS
		(0.995 – 0.996)	(0.867 – 0.911)
Excluding Berwick Bank			
Scenario 4 *60% / 3-5% displacement*	17,596	0.982 (0.981 – 0.983)	0.631 (0.611 – 0.648)
Scenario 5 *60% / 1-3% displacement*	22,478	0.992 (0.991 – 0.993)	0.804 (0.782 – 0.825)
Scenario 6 *50% / 1% displacement**	25,345	0.996 (0.995 – 0.997)	0.905 (0.882 – 0.929)

Table 50 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	13,556	-	-
Including Berwick Bank			
Scenario 1 *60% / 3-5% displacement*	4,614	0.979 (0.978 – 0.980)	0.341 (0.320 – 0.359)
Scenario 2 *60% / 1-3% displacement*	8,121	0.990 (0.989 – 0.991)	0.600 (0.570 – 0.628)
Scenario 3 *50% / 1% displacement**	10,734	0.995 (0.995 – 0.996)	0.794 (0.758 – 0.828)
Excluding Berwick Bank			
Scenario 4 *60% / 3-5% displacement*	5,468	0.982 (0.981 – 0.983)	0.404 (0.382 – 0.425)
Scenario 5 *60% / 1-3% displacement*	8,819	0.992 (0.991 – 0.993)	0.652 (0.620 – 0.682)
Scenario 6 *50% / 1% displacement**	11,121	0.996 (0.995 – 0.997)	0.822 (0.786 – 0.857)

Table 51 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	-	-
Including Berwick Bank			
Scenario 1 *70% / 3% displacement + CRM*	425,967	0.993 (0.992 – 0.993)	0.826 (0.820 – 0.832)
Scenario 2 *70% / 1% displacement + CRM**	451,060	0.995 (0.995 – 0.995)	0.875 (0.869 – 0.881)
Excluding Berwick Bank			
Scenario 3 *70% / 3% displacement + CRM*	433,357	0.993 (0.993 – 0.994)	0.841 (0.835 – 0.847)
Scenario 4 *70% / 1% displacement + CRM**	456,138	0.995 (0.995 – 0.996)	0.885 (0.879 – 0.891)

Table 52 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	-	-
Including Berwick Bank			
Scenario 1 *70% / 3% displacement + CRM*	408,824	0.993 (0.992 – 0.993)	0.686 (0.679 – 0.693)
Scenario 2 *70% / 1% displacement + CRM**	458,311	0.995 (0.995 – 0.995)	0.769 (0.762 – 0.776)
Excluding Berwick Bank			
Scenario 3 *70% / 3% displacement + CRM*	422,804	0.993 (0.993 – 0.993)	0.711 (0.704 – 0.717)
Scenario 4 *70% / 1% displacement + CRM**	468,100	0.995 (0.995 – 0.995)	0.786 (0.779 – 0.793)

Appendix V: PVA Plots

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 total population size of kittiwake regional population under four scenarios between 2022 and 2080. Confidence interval presented as dotted line**

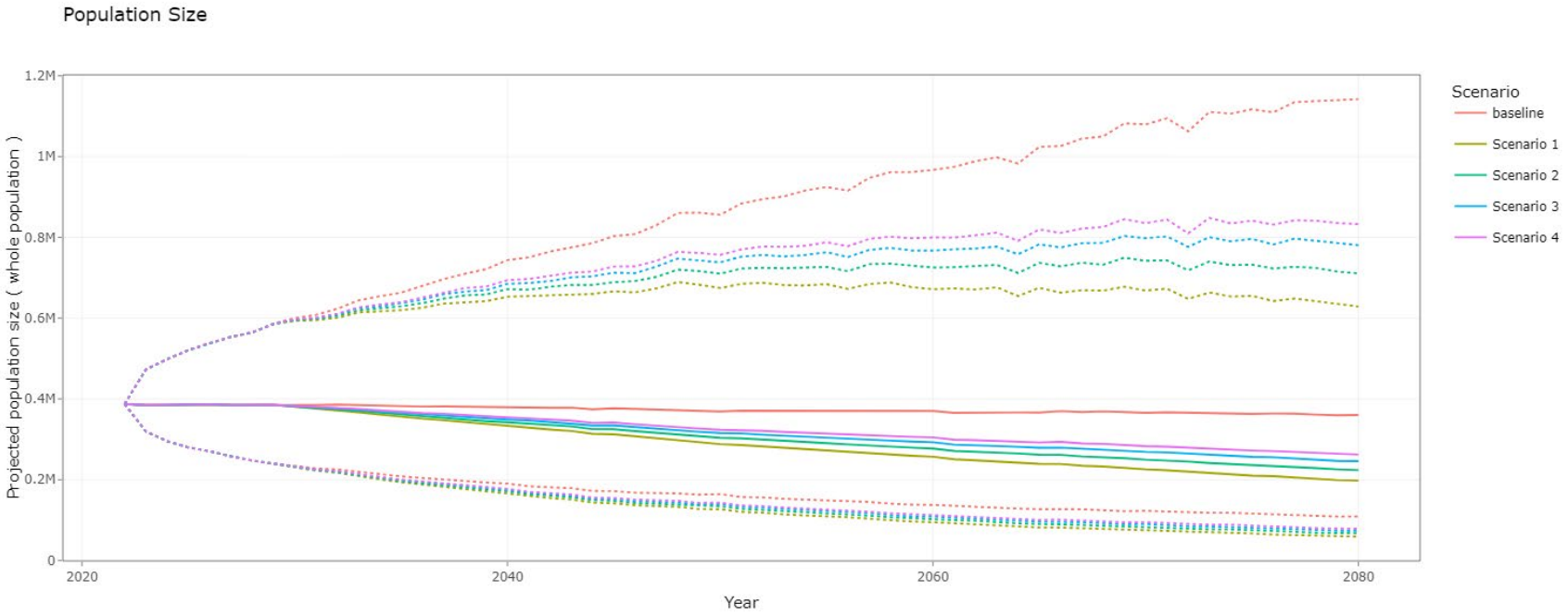

Figure 2 Counterfactual of population growth rate (CPC) for kittiwake regional population over a 50-year period. Confidence intervals presented as dotted lines

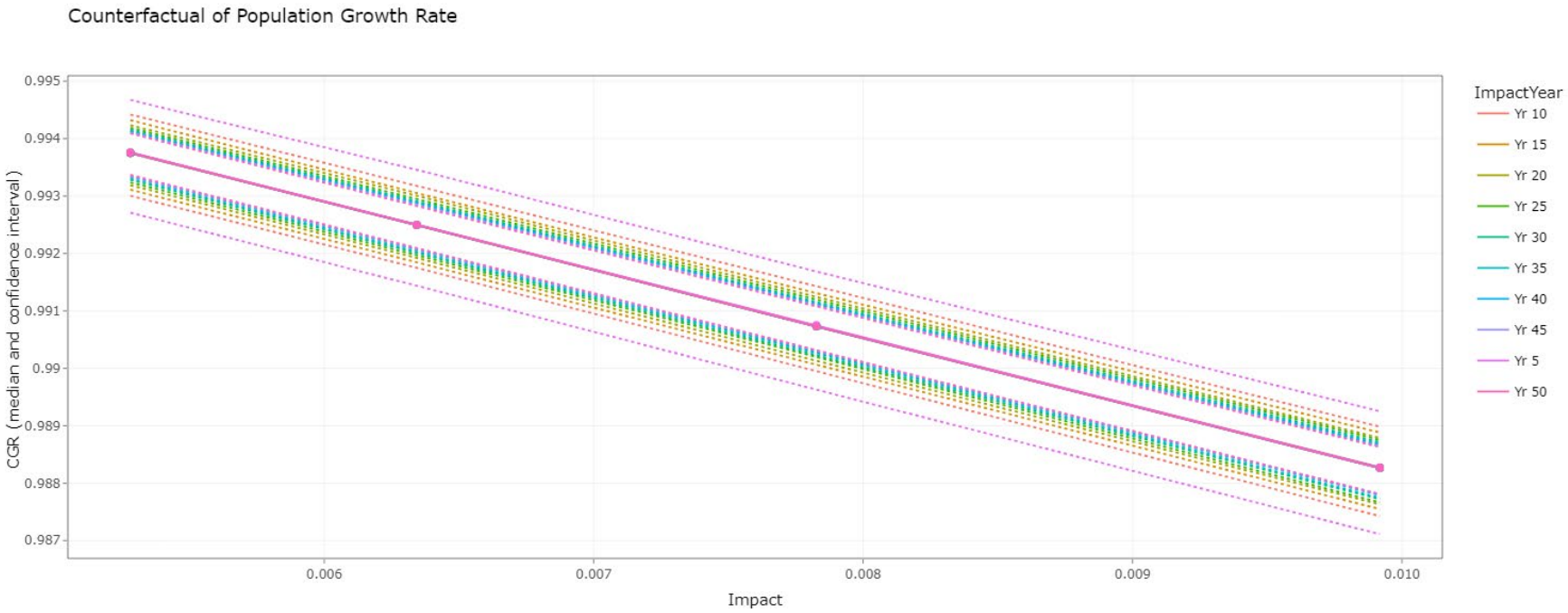

Figure 3 Counterfactual of population size (CPS) for kittiwake regional population over a 50-year period. Confidence intervals presented as dotted lines

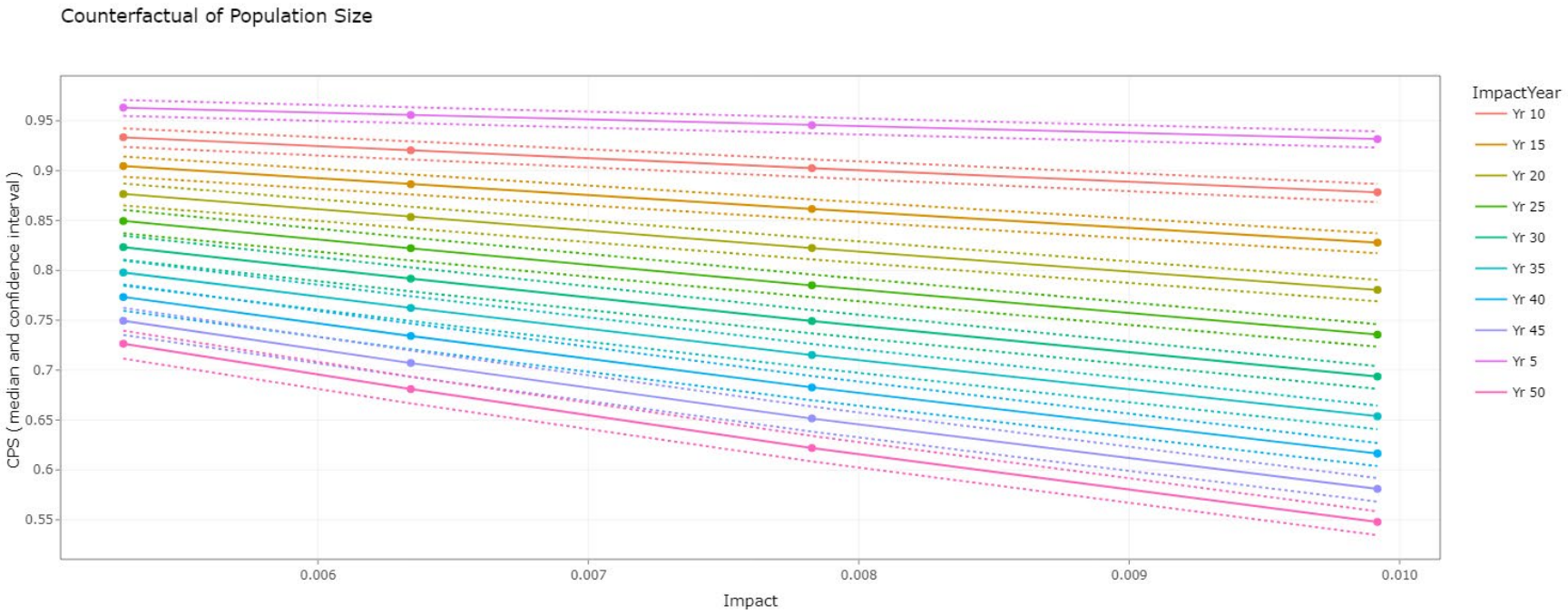

Figure 4 **Projected total population size of guillemot regional population under four scenarios between 2022 and 2080. Confidence intervals presented as dotted lines**

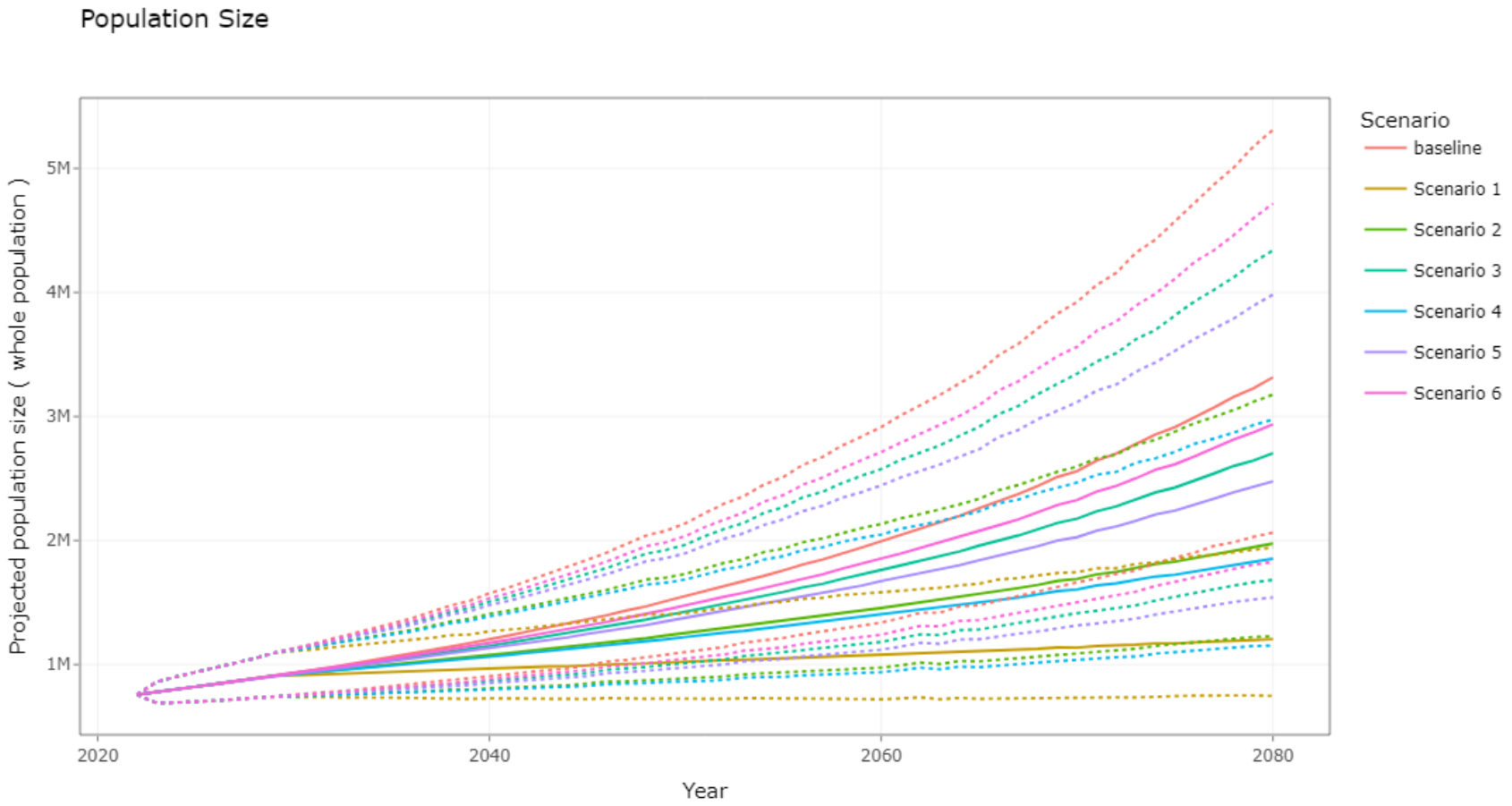

Figure 5 **Counterfactual of population growth rate (CPC) for guillemot regional population over a 50-year period. Confidence intervals presented as dotted lines**

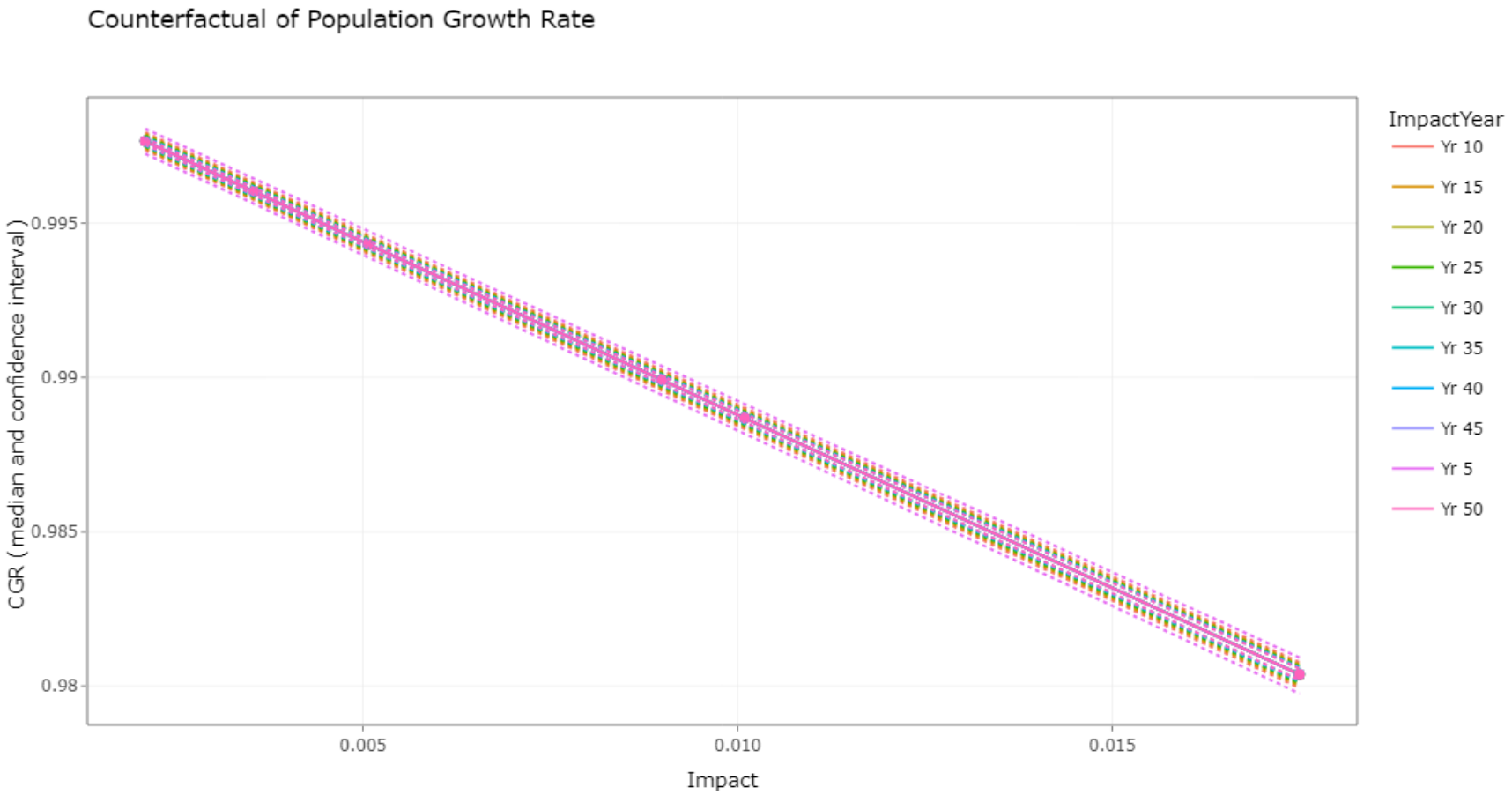

Figure 6 **Counterfactual of population size (CPS) for guillemot regional population over a 50-year period. Confidence intervals presented as dotted lines**

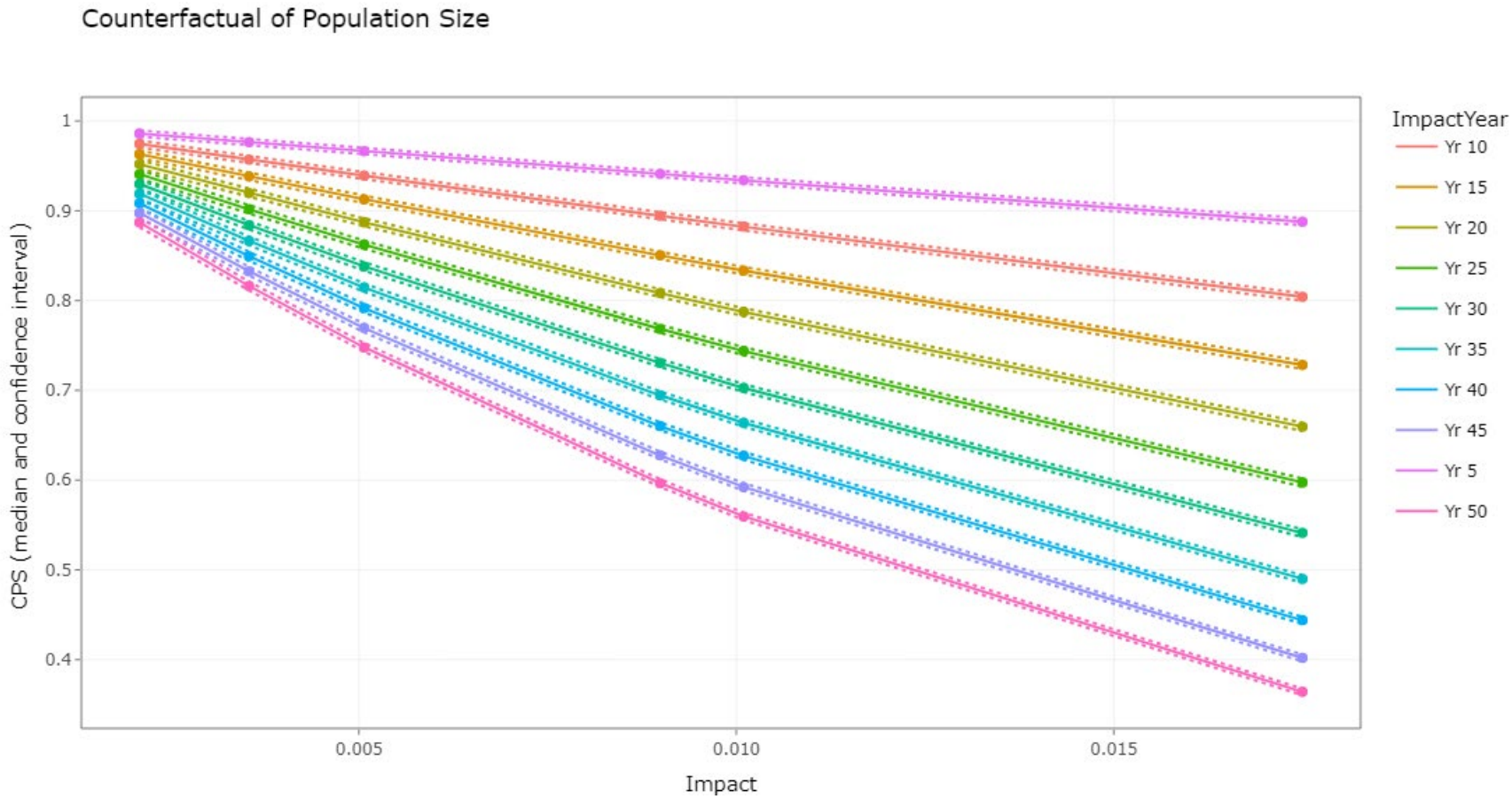

Figure 7 **Projected total population size of razorbill regional population under four scenarios between 2022 and 2080. Confidence intervals presented as dotted lines**

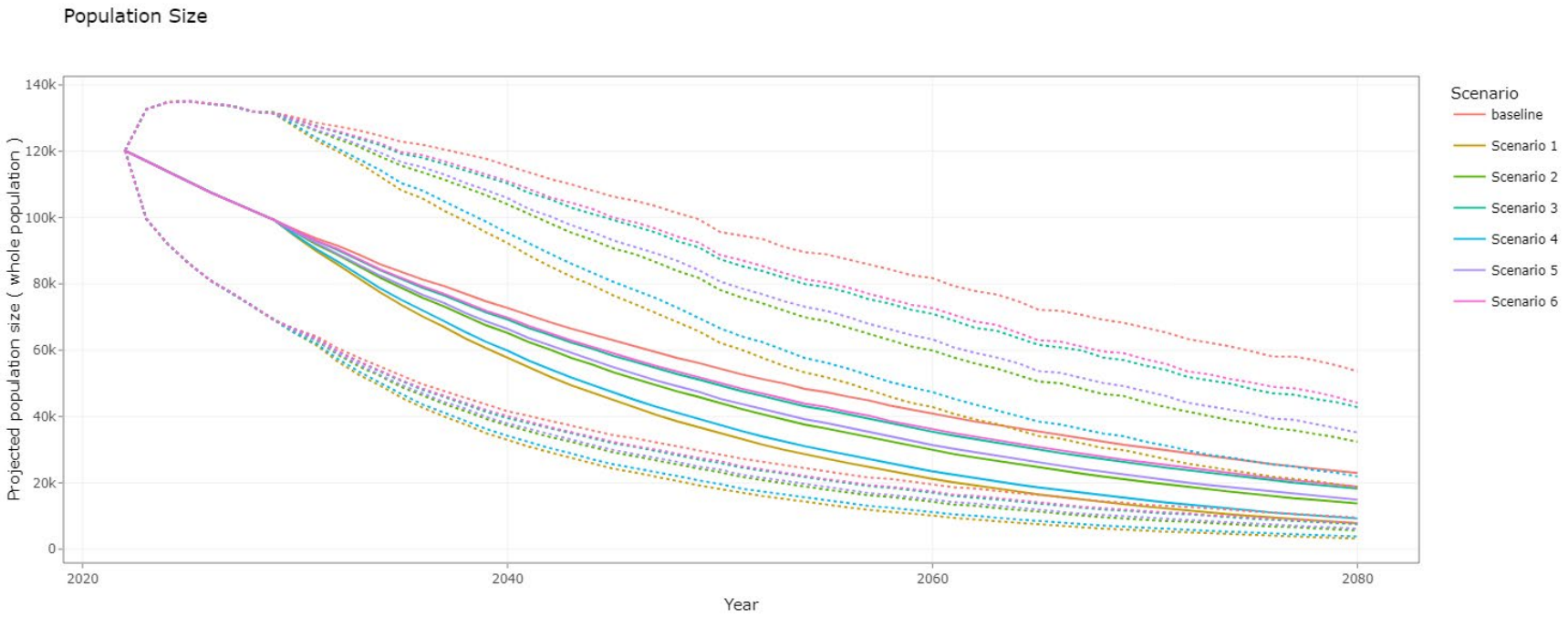

Figure 8 Counterfactual of population growth rate (CPC) for razorbill regional population over a 50-year period. Confidence intervals presented as dotted lines

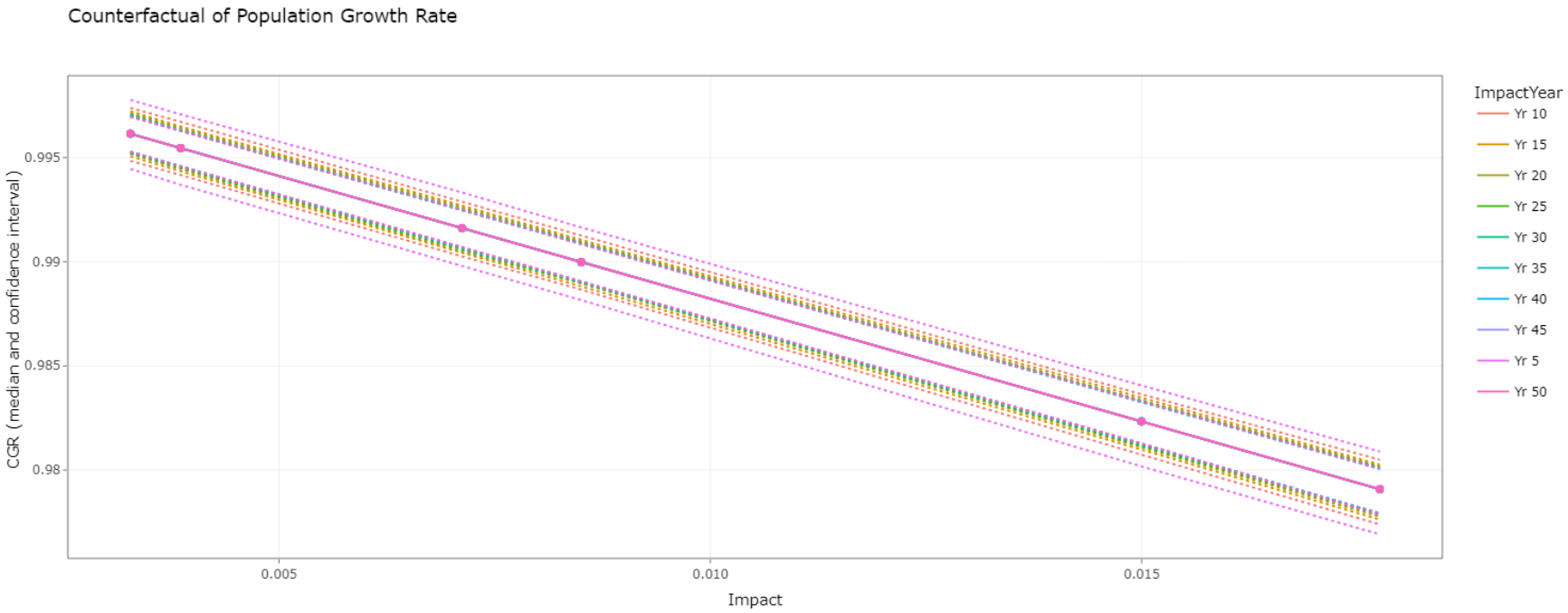

Figure 9 **Counterfactual of population size (CPS) for razorbill regional population over a 50-year period. Confidence intervals presented as dotted lines**

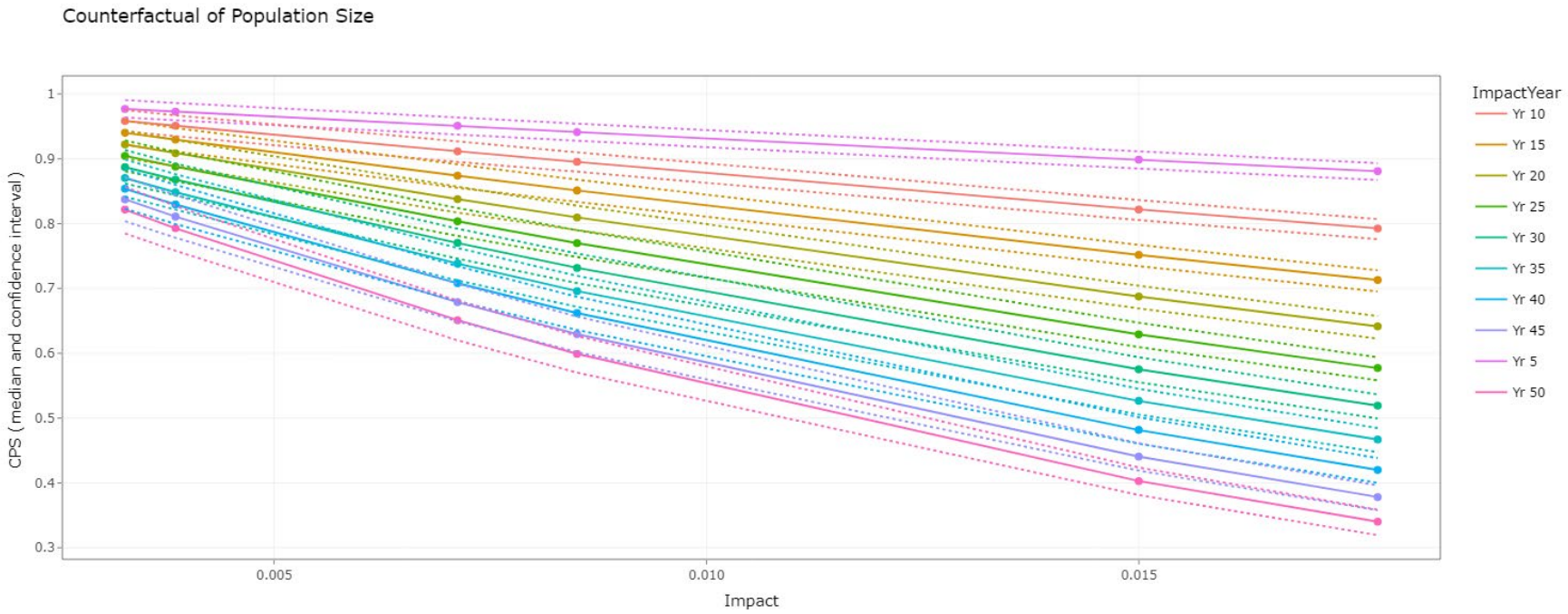

Figure 10 Projected total population size of gannet regional population under four scenarios between 2022 and 2080. Confidence intervals presented as dotted lines

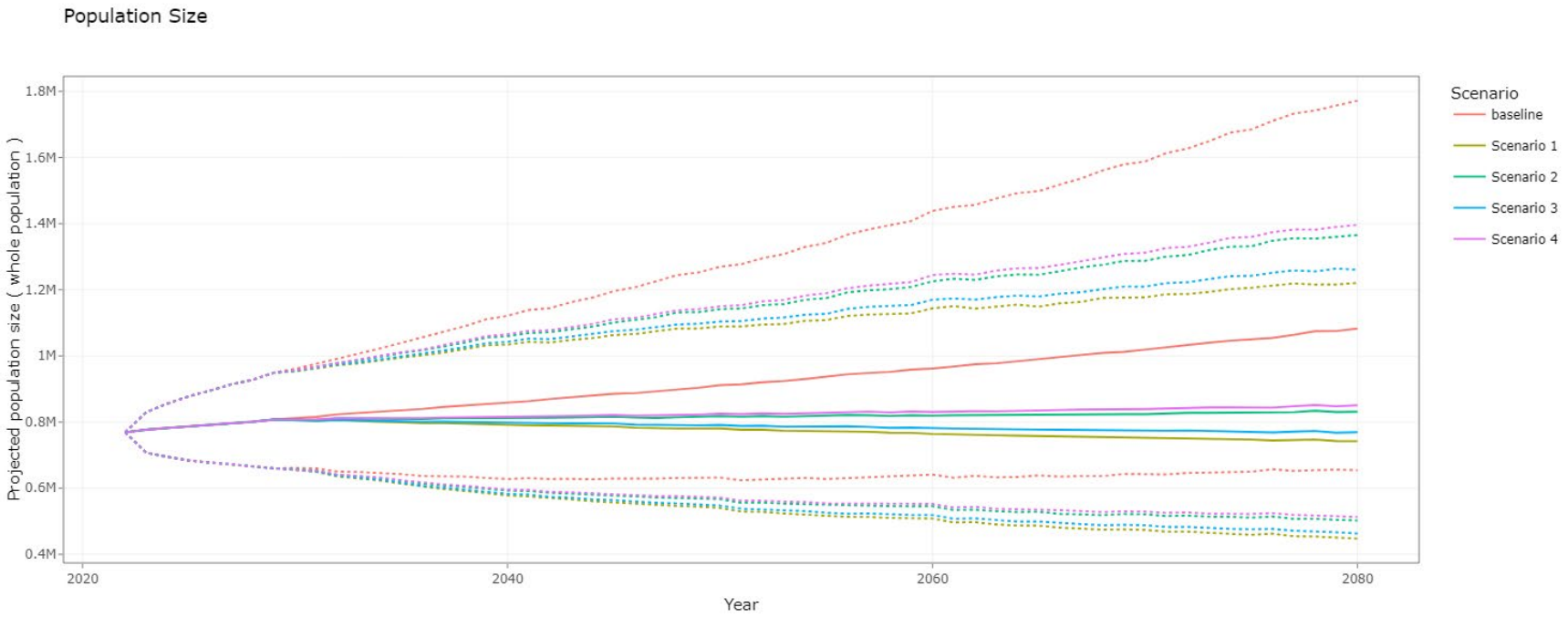

Figure 11 Counterfactual of population growth rate (CPC) for gannet regional population over a 50-year period. Confidence intervals presented as dotted lines

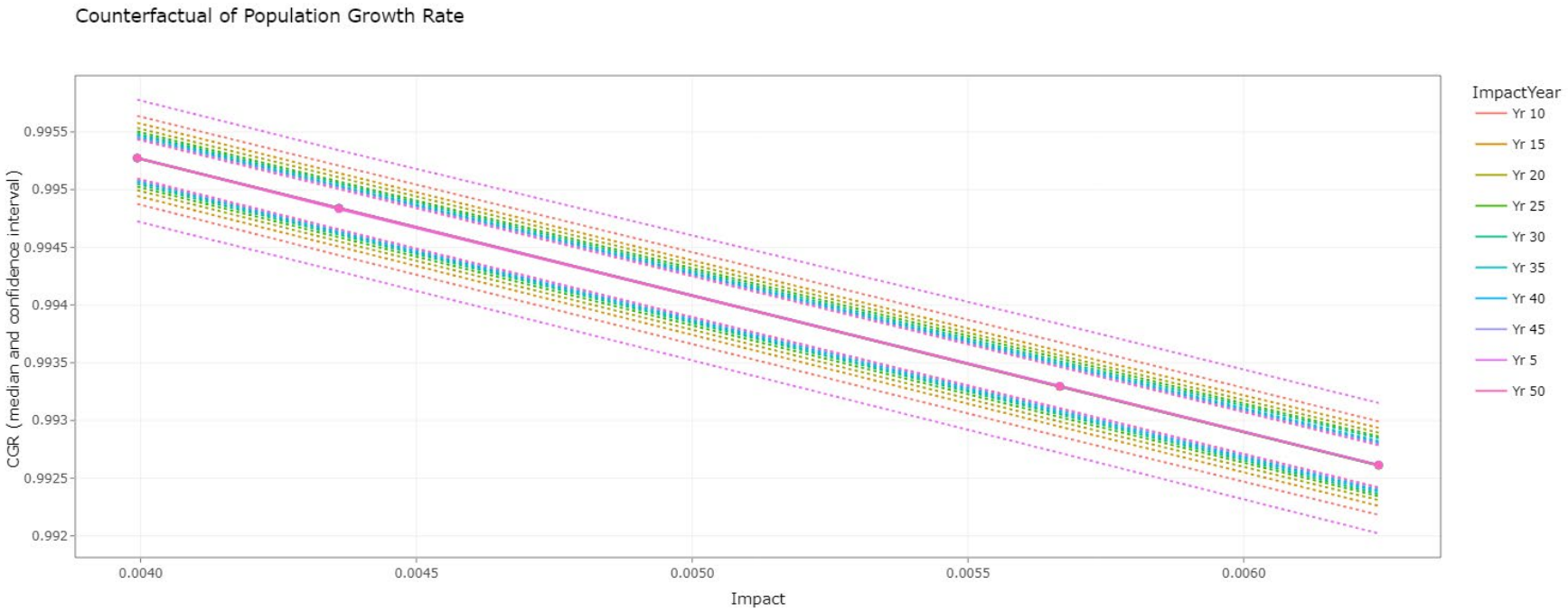

Figure 12 Counterfactual of population size (CPS) for gannet regional population over a 50-year period. Confidence intervals presented as dotted lines