SEAGREEN PVA METHODS AND OUTPUTS – ADDENDUM REPORT

Prepared for Sue King Consulting Ltd

DMP Statistical Solutions UK Ltd

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DMP STATS

DMP STATS The Coach House, Mount Melville House, St. Andrews, Scotland KY 168 NT, UK +44(0) 1334 477 544 mail@dmpstats.com

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AUTHOR	B. Caneco
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VERSION	ISSUED DATE	REASON FOR ISSUE
1.0	18 December 2018	Issued for Information & review
2.0	15 January 2019	Review comments on Version 1 addressed. Added tables with median predicted population sizes after 25 years, for incremental additional mortalities scenarios
3.0	03 April 2019	Added results from models for Guillemots (Forth Islands, Fowlsheugh & St Abb's Head to Fast Castle SPAs) and Puffin (Forth Islands SPA) populations, with revised demographic parameters and incremental additional mortalities scenarios. Analysis and model outputs for specific scenarios of additional mortalities due to collision and displacement effects in each considered population also included.
3.1	11 April 2019	Minor edits from proofing
3.2	07 May 2019	Amended typo in Table 4 (Guillemot stable age structure). Issued as the final version of Addendum report.

CONTENTS

ABBREVIATIONS AND ACRONYMS

MS	Marine Scotland
RSPB	The Royal Society for the Protection of Birds
SNH	Scottish Natural Heritage
PVA	Population Viability Analysis
SPA	Special Protection Area

DMP STATS The Coach House, Mount Melville House, St. Andrews, Scotland KY 168 NT, UK +44(0) 1334 477 544 mail@dmpstats.com

1 SUMMARY

This addendum report presents the methods and main outputs from a revised PVA study for Phase 1 of the Seagreen wind farm project. Following the requirements defined by Seagreen and Sue King Consulting Ltd, this follow-up analysis was performed for all the species and SPAs considered in the precedent PVA study (Caneco and Donovan, 2018) and involved a review of the demographic parameters used as model inputs and the application of a revised set of impact scenarios. Population model structure and starting population sizes remained unchanged from the previous analysis. For kittiwake and guillemot, additional modelling was conducted for the populations at St Abb's Head to Fast Castle SPA.

2 REVISED PVA DESCRIPTION

The PVAs presented here refer to a follow-up analysis to address remarks by SNH, MSS and the RSPB on previous PVA work carried out for the Seagreen Phase 1 offshore windfarm development project (Caneco and Donovan, 2018).

By specification of Sue King Consulting Ltd, the revised modelling involved: (i) a review and update of demographic parameters used as model inputs, favouring site-specific estimates, and (ii) the adoption of a new set of potential windfarm impact scenarios on the studied populations.

The revised analysis was carried out for each of the previously considered populations, with the addition of the populations of Kittiwake and Guillemot for the St Abb's Head to Fast Castle SPA. Table 1 presents the modelled populations and associated counts obtained from expert advice and literature. These population counts were taken as the number of breeders (i.e. adults) in the starting year of the population models. Numbers shown in Table 1 are identical to those used in Caneco and Donovan (2018), for the populations considered therein.

Table 1: Colonies and SPAs considered in the revised analysis and corresponding population counts in terms of numbers of breeders. Number of breeders subsequently converted to total number of birds and used as the initial population size in the PVA models.

Species	SPA	Initial population size (breeding individuals)	Year of counts	Source
Gannet	**Forth Islands**	150518	2014	SNH (2017)
Puffin	**Forth Islands**	90010	2009-2017	SNH (2017)
Razorbill	**Forth Islands**	7792	2017	SNH (2018)
	Fowlsheugh	9950	2015	
Guillemot	**Forth Islands**	38573	2017	SNH (2018)
	Fowlsheugh	74379	2015	
	St Abbs Head to Fast Castle	48516	2016	
Kittiwake	**Forth Islands**	9326	2017	SNH (2017)
	Fowlsheugh	19310	2015	
	St Abbs Head to Fast Castle	6668	2016	SNH (2017)

Input demographic parameters were reviewed and checked against other relevant PVA studies (e.g. Bureau Waardenburg, 2018; CEH, 2018b; Trinder, 2015), and amended with SPA-specific estimates when available. In cases where local estimates were unavailable, preference was given to broader scale estimates based on combined independent studies collated in Horswill and Robinson (2015). In the absence of local estimates, combined regional and national level estimates are believed to generate parameter values that express more accurately the underlying degree of uncertainty in model simulations. The updated model inputs used in the revised analysis, and respective literature sources with review comments, are shown in Table 2 and Table 3 respectively.

Table 2: Species' features and demographic rates used in the revised PVA models. Parameter values modified in relation to the previous PVA study (Caneco and Donovan, 2018) are highlighted in blue.

Species	Age first breeding[1]	Final age (A)	Eggs/pair[2]	SPA		Survivals						Productivities	
						$S_{1\to2}$	$S_{2\to3}$	$S_{3\to4}$	$S_{4\to5}$	$S_{5\to6}$	S_A	P_{A-1}	P_A
Gannet	5	5	1	**Forth Islands**	**Mean**	0.542	0.779	0.859	0.863		0.916	0	0.698
					SD	0.013	0.007	0.005	0.005		0.003	0	0.071
Puffin	5	6	1	**Forth Islands**	**Mean**	0.892	0.892	0.892	0.76	0.805	0.935	0.648	0. 648
					SD	0.009	0.009	0.009	0.019	0.017	0.007	0.157	0.157
Razorbill	5	5	1	**Forth Islands**	**Mean**	0.794	0.794	0.905	0.905		0.905	0	0.564
					SD	0.134	0.134	0.050	0.050		0.050	0	0.070
				Fowlsheugh	**Mean**	0.794	0.794	0.895	0.895		0.895	0	0.459
					SD	0.134	0.134	0.067	0.067		0.067	0	0.236
Guillemot	6	6	1	**Forth Islands**	**Mean**	0.560	0.792	0.917	0.939	0.939	0.939	0	0.681
					SD	0.013	0.034	0.022	0.015	0.015	0.015	0	0.152
				Fowlsheugh	**Mean**	0.560	0.792	0.917	0.939	0.939	0.939	0	0.681
					SD	0.013	0.034	0.022	0.015	0.015	0.015	0	0.152
				St Abb's Head to Fast Castle	**Mean**	0.560	0.792	0.917	0.939	0.939	0.939	0	0.681
					SD	0.013	0.034	0.022	0.015	0.015	0.015	0	0.152
Kittiwake	4	4	2	**Forth Islands**	**Mean**	0.790	0.790	0.854			0.854	0	0.674
					SD	0.092	0.092	0.051			0.051	0	0.357
				Fowlsheugh	**Mean**	0.790	0.790	0.854			0.854	0	0.808
					SD	0.092	0.092	0.051			0.051	0	0.331
				St Abb's Head to Fast Castle	**Mean**	0.790	0.790	0.854			0.854	0	0.661
					SD	0.092	0.092	0.051			0.051	0	0.337

[1] Age of first breeding taken from Horswill and Robinson (2015)
[2] Maximum number of eggs per pair taken from Snow & Perrins (1998)

Table 3: Comments on values selected for demographic rates used in the revised analysis (presented in Table 2)

Species	SPA	Demographic parameter	Source	Comments
Gannet	**Forth Islands**	P_A	Horswill and Robinson (2015)	SPA-specific estimates not available. Eastern UK figures used instead. Suggested experience-specific productivity not applied
		$S_{1\to2}$, …, S_A	Wanless *et al.* (2006)	Bass Rock survival rates estimates
Puffin	**Forth Islands**	$P_{A\text{-}1}$ & P_A	CEH (2018a)	Mean and SD based on annual breeding success estimates in Isle of May (2007 – 2016)
		$S_{1\to2}$, …, $S_{5\to6}$	Horswill and Robinson (2015)	No recent, good quality, data available on juvenile and immature survival rates in UK colonies. Using estimates from study on Atlantic puffins from Canada (Breton *et al.*, 2006)
		S_A	Harris *et al.* (2005)	Isle of May adult survival estimates
Razorbill	**Forth Islands**	P_A	CEH (2018a)	Mean and SD based on annual breeding success estimates in Isle of May (2007 – 2016)
		$S_{1\to2}$ & $S_{2\to3}$	Horswill and Robinson (2015)	SPA-specific estimates not available. UK national level estimates used. Literature provides a single mean (0.630) and SD (0.209) for the first 2 age-classes. Corresponding annual mean rate computed as exp(log(0.63)/2) = 0.794. Approximate annual SD (0.134) derived from 1000 draws from a beta distribution with mean=0.63 and SD=0.209.
		$S_{3\to4}$, $S_{4\to5}$, S_A	Harris *et al.* (2000)	Isle of May survival estimates
	Fowlsheugh	P_A	Horswill and Robinson (2015)	SPA-specific estimates not available. Northern UK figures used instead.
		$S_{1\to2}$ & $S_{2\to3}$	Horswill and Robinson (2015)	idem to Razorbill in Forth Islands
		$S_{3\to4}$, $S_{4\to5}$, S_A	Horswill and Robinson (2015)	SPA-specific estimates not available. UK national level estimates
Guillemot	**Forth Islands**	P_A	CEH (2018a)	Mean and SD based on annual breeding success estimates in Isle of May (2007 – 2016)
		$S_{1\to2}$, $S_{2\to3}$ & $S_{3\to4}$	Horswill and Robinson (2015)	Isle of May survival estimates from Harris *et al.* (2007)
		$S_{4\to5}$, …, S_A	Horswill and Robinson (2015)	Follows source recommendation for combined survival rates from colonies sharing wintering areas (Reynolds *et al.*, 2011).

Species	SPA	Demographic parameter	Source	Comments
Guillemot	Fowlsheugh	P_A	CEH (2018a)	SPA-specific estimates not available. Isle of May estimates used instead, favoured over broader regional estimates
		$S_{1\to2}$, …, S_A	Horswill and Robinson (2015)	SPA-specific estimates not available. Using the same estimates as those applied to Guillemot in Forth Islands
	St Abb's Head to Fast Castle	P_A	CEH (2018a)	Productivity estimates available in JNCC (2018) for Guillemot in St Abbs. However, very short time-series (2016-2018) provides annual average markedly higher (0.80) than nearby colonies (Isle of May and Farne Islands). Conservative approach taken by using the long time-series based estimates from Isle of May
		$S_{1\to2}$, …, S_A	Horswill and Robinson (2015)	SPA-specific estimates not available. Using the same estimates as those applied to Guillemot in Forth Islands
Kittiwake	Forth Islands	P_A	CEH (2018a)	Mean and SD based on annual breeding success estimates in Isle of May (2007 – 2016)
		$S_{1\to2}$, …, S_A	Horswill and Robinson (2015)	SPA-specific estimates not available. UK national level estimates used instead. Now assuming first two age-classes as juveniles (i.e. $S_{1\to2}$ & $S_{2\to3}$), upon review of age-specific survival estimates (Table 18 *in* Horswill and Robinson, 2015). This option predicts smaller asymptotic growth rates that better conform to Kittiwake population trajectories observed in recent years.
	Fowlsheugh	P_A	JNCC (2018)	Mean and SD based on annual breeding success estimates in Fowlsheugh (1986 – 1990 & 1993 – 2016)
		$S_{1\to2}$, …, S_A	Horswill and Robinson (2015)	Idem to Kittiwake in Forth Islands
	St Abb's Head to Fast Castle	P_A	JNCC (2018)	Mean and SD based on annual breeding success estimates in St Abb's Head to Fast Castle (1987 – 2018)
		$S_{1\to2}$, …, S_A	Horswill and Robinson (2015)	Idem to Kittiwake in Forth Islands

There were no changes in terms of population model structure and simulation methods (detailed in Caneco and Donovan, 2018). The stable age distribution calculated from input parameters assumed for each species is provided in Table 4 and was amended where input parameters changed. As in the previous analysis, the number of breeders (Table 1) was combined with the stable age distribution to obtain the size of each of the remaining age-classes in the starting year. Each model projected the population forward in one-year steps up to 25 years (the lifetime of the windfarm), and each 25-years

Table 4: Stable age structure underlying each population model

Species	SPA	Age-Class					
		1	2	3	4	5	6
Gannet	**Forth Islands**	0.183	0.098	0.076	0.064	0.579	
Puffin	**Forth Islands**	0.149	0.127	0.107	0.091	0.066	0.460
Razorbill	**Forth Islands**	0.144	0.112	0.087	0.077	0.580	
	Fowlsheugh	0.127	0.101	0.080	0.072	0.619	
Guillemot	**Forth Islands**	0.170	0.092	0.070	0.062	0.056	0.550
	Fowlsheugh	0.170	0.092	0.070	0.062	0.056	0.550
	St Abb's Head to Fast Castle	0.170	0.092	0.070	0.062	0.056	0.550
Kittiwake	**Forth Islands**	0.170	0.133	0.105	0.592		
	Fowlsheugh	0.187	0.144	0.111	0.557		
	St Abb's Head to Fast Castle	0.168	0.132	0.104	0.596		

simulation was run 1000 times to obtain indicative population trajectories and estimates of uncertainty associated with those trends.

The revised set of windfarm impacts scenarios, modelled as additional mortalities applied to the baseline/unimpacted populations, was examined under two different approaches:

- incremental additional mortalities, i.e. a range of potential additional adult deaths per annum, with incremental steps and maximum deaths specific to each population;
- specific additional mortalities per annum for certain collision and displacement scenarios.

Table 5 provides the incremental mortality scenarios applied to each modelled population, expressed in terms of additional adult deaths. In line with the previous analysis, additional deaths were also applied to the remaining age-classes in proportion to their presence in the population derived via the stable age distribution. The implicit assumption in apportioning additional mortalities this way is that mortality due to wind farm effects have constant age selectivity (i.e. the per-capita rate of additional mortality is fixed across ages). This assumption is likely to be conservative, especially for Gannets and Kittiwakes, as their younger age-classes are known to be absent from offshore areas where the windfarm turbines are deployed. For example, once juvenile gannets leave their natal area, most migrating to wintering grounds on the west coast of Africa, they may not return until they are five or six years old and ready to breed themselves. This is evidenced by the small proportion of immature birds recorded during sea surveys. Such birds are identifiable through their plumage characteristics and consistently represented less than 5% of gannets seen on the Seagreen sites (Seagreen, 2018).

Table 5: Range of impact scenarios, and respective incremental steps, evaluated under each population model, expressed in terms of additional adult deaths in the starting year. '0' additional deaths denote the baseline/unimpacted population case.

Species	SPA	Range of additional adult deaths	Additional deaths increments
Gannet	**Forth Islands**	0 – 1500	25
Puffin	**Forth Islands**	0 – 100	10
Razorbill	**Forth Islands**	0 – 100	10
	Fowlsheugh	0 – 100	10
Guillemot	**Forth Islands**	0 – 60	10
	Fowlsheugh	0 – 100	10
	St Abb's Head to Fast Castle	0 – 40	10
Kittiwake	**Forth Islands**	0 – 160	20
	Fowlsheugh	0 – 300	20
	St Abb's Head to Fast Castle	0 – 50	10

With regard to kittiwake, birds in the first and second year pre-breeding, may remain at sea most of the year or move into coastal areas but often far from their natal colonies (Coulson 2011). During the breeding season, approximately 95% of kittiwakes observed during at sea surveys were adults and, whilst this proportion was lower during the winter, the birds present at this time are thought to be less likely to come from local colonies. This is because Scottish birds generally disperse by late August covering a vast wintering range extending as far as Greenland and eastern Canada. Kittiwakes which winter in the Firth of Forth are more likely to include adults and juveniles from distant breeding areas (Seagreen, 2018).

Specific additional mortalities for a set of impact scenarios representing bird deaths due to turbine collisions and habitat displacement effects, or their combined effect, were provided for two population groups based on age-class breeding ability: adults (i.e. breeding age-classes) and sub-adults (i.e. immature age-classes). Numbers were provided by Seagreen based on the apportioning of collision and/or displacement mortality calculated for each species at each SPA for purposes of Habitat Regulations Appraisal. Table 6 presents the specific impact scenarios, and associated additional mortalities, considered for each modelled population. The number of adult deaths shown in Table 6 were previously adjusted for sabbatical birds (i.e. the percentage of adults that do not breed in a given year), as per Scoping Opinion advice[1] (MS LOT, 2017). To apply the defined scenarios to the models,

[1] Assuming rates of 10% sabbaticals for gannet and kittiwake, and 7% sabbaticals for puffin, guillemot and razorbill and puffin.

additional deaths in each group were subsequently apportioned to age-classes based on the population's stable age distribution – using the asymptotic proportions standardized over the respective grouped age-classes (i.e. summing up to one). Models for specific additional mortalities therefore assume that collisions and displacement effects have different impacts on different portions of the populations (i.e. the per-capita rate of additional mortality is specific to breeding status).

Absolute numbers of additional deaths only strictly apply to the first year of simulation. They were converted to a per-capita mortality rates (assumed constant over time) so the number of additional deaths in a year will increase proportionately with an increase in the simulated population size and vice-versa.

Table 6: Modelled impact scenarios for specific additional mortalities due to collision and displacement effects (numbers already discounted for sabbaticals)

Species	Spa	Impact	Alpha		Bravo		A+B		A + B + F & T 2018		A + B + F & T 2014		A + B + F & T 2014 + UK N Sea		A + B + F & T 2014 + UK N Sea and Channel	
			Adult	Sub-adult	Adult	Sub-adult	Adult	Sub-adult	Adult	Sub-adult	Adult	Sub-adult	Adult	Sub-adult	Adult	Sub-adult
Gannet	Forth Islands	Collision	176	5	128	3	260	7	423	12	822	25	-	-	904	93
Puffin	Forth Islands	Displacement	18	18	26	26	37	36	127	158	-	-	-	-	-	-
Razorbill	Forth Islands	Displacement	4	3	3	2	7	5	26	25	-	-	-	-	-	-
	Fowlsheugh	Displacement	38	32	30	26	58	49	89	88	-	-	-	-	-	-
Guillemot	Forth Islands	Displacement	11	10	9	7	17	15	46	53	-	-	-	-	-	-
	Fowlsheugh	Displacement	38	32	30	26	58	49	89	88	-	-	-	-	-	-
	St Abb's Head to Fast Castle	Displacement	8	8	7	5	13	11	24	24	-	-	-	-	-	-
Kittiwake	Forth Islands	Collision	6	1	5	1	9	1	20	3	49	4	57	7	-	-
	Fowlsheugh	Collision	28	3	24	2	40	5	51	6	80	9	98	17	-	-
	St Abb's Head to Fast Castle	Collision	3	1	3	0	4	1	8	1	16	3	21	6	-	-
	Forth Islands	Collision + Displacement	8	1	7	1	12	2	-	-	64	5	70	8	-	-
	Fowlsheugh	Collision + Displacement	36	4	31	3	52	6	-	-	98	10	116	19	-	-
	St Abb's Head to Fast Castle	Collision + Displacement	4	1	4	1	6	1	-	-	19	2	25	6	-	-

3 REVISED PVA OUTPUTS

PVA outputs shown here follow the same structure as those presented in Caneco and Donovan (2018). Thus, together with over-arching views of the simulations, the main counterfactual metrics displayed are:

1. The ratio of impacted to unimpacted annual growth rate (i.e. counterfactual of growth rate)
2. the ratio of impacted to unimpacted population size (i.e. counterfactual of population size)
3. centile for unimpacted population size that matches the 50th centile for impacted population size

Counterfactual metrics were derived following a matched runs approach (Green, 2014; Jitlal *et al.*, 2017), whereby stochasticity is applied to the population before wind farm impacts are applied.

In-depth interpretation and implications of the results presented here are not part of the scope of this report.

3.1 Gannet – Forth Islands SPA

3.1.1 Incremental mortality scenarios

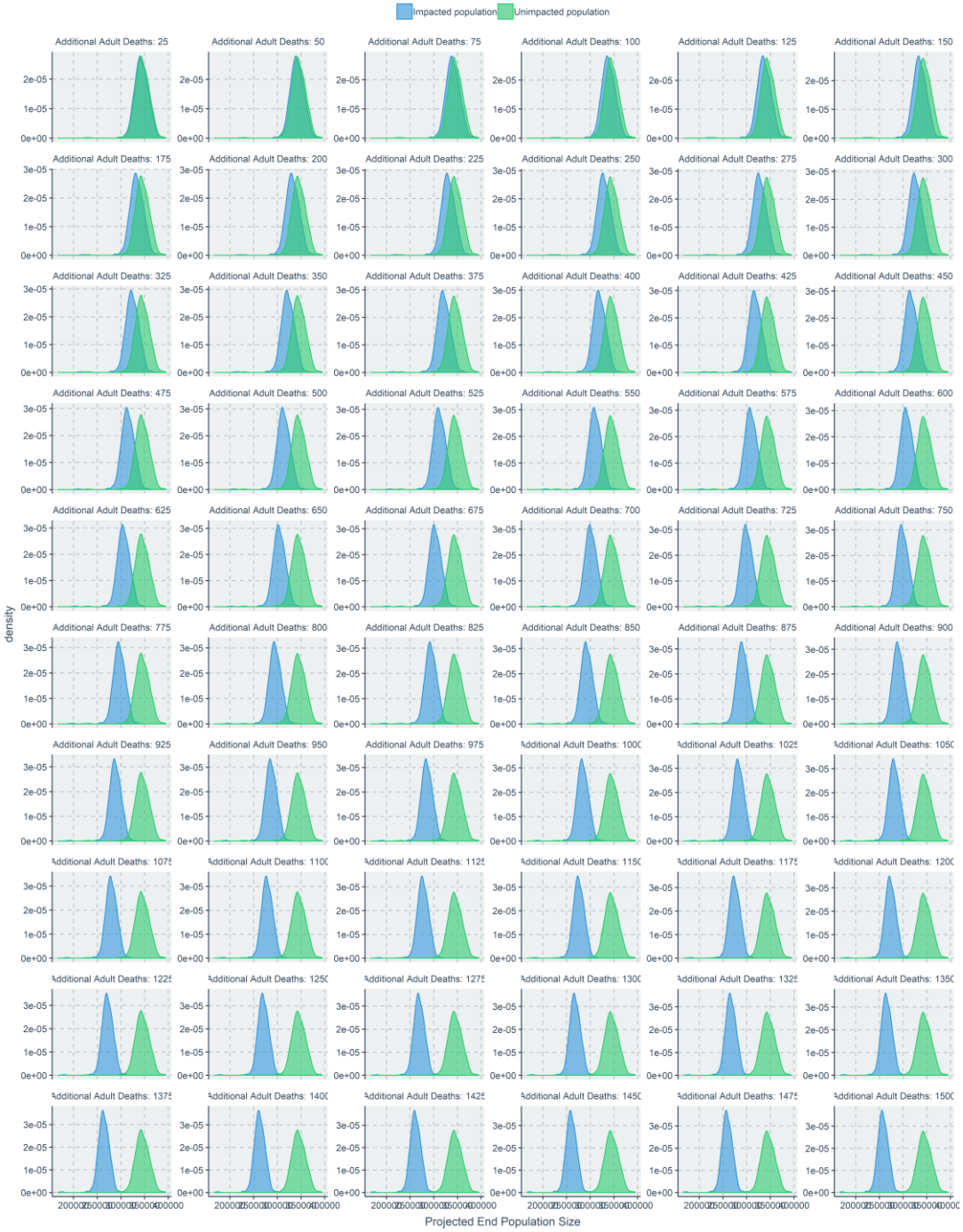

Figure 1: Gannet at Forth Islands SPA – Density distributions of simulated population sizes after a 25-year post-construction period. Each plot represents a different impact scenario in terms of additional adult mortalities, together with the distribution of predicted unimpacted population sizes after 25 years.

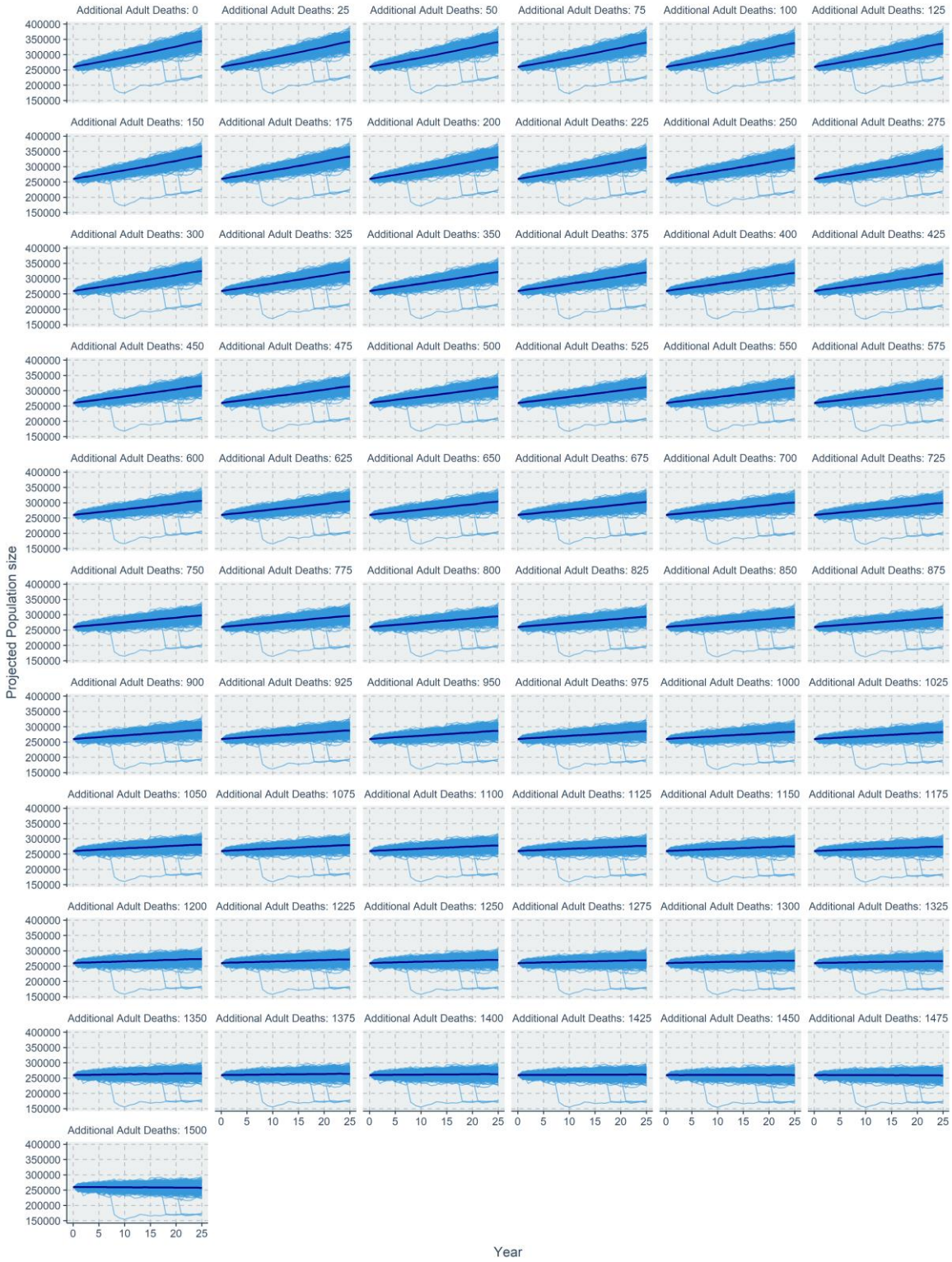

Figure 2: Gannet at Forth Islands SPA – Projections of population sizes over a 25-year time-frame. Each plot represents a different impact scenario in terms of additional adult mortalities (starting at 0 i.e. unimpacted). Individual blue lines are different realisations of the population trajectory, when population parameters are sampled from their distributions. The dark blue line is the median at each time point.

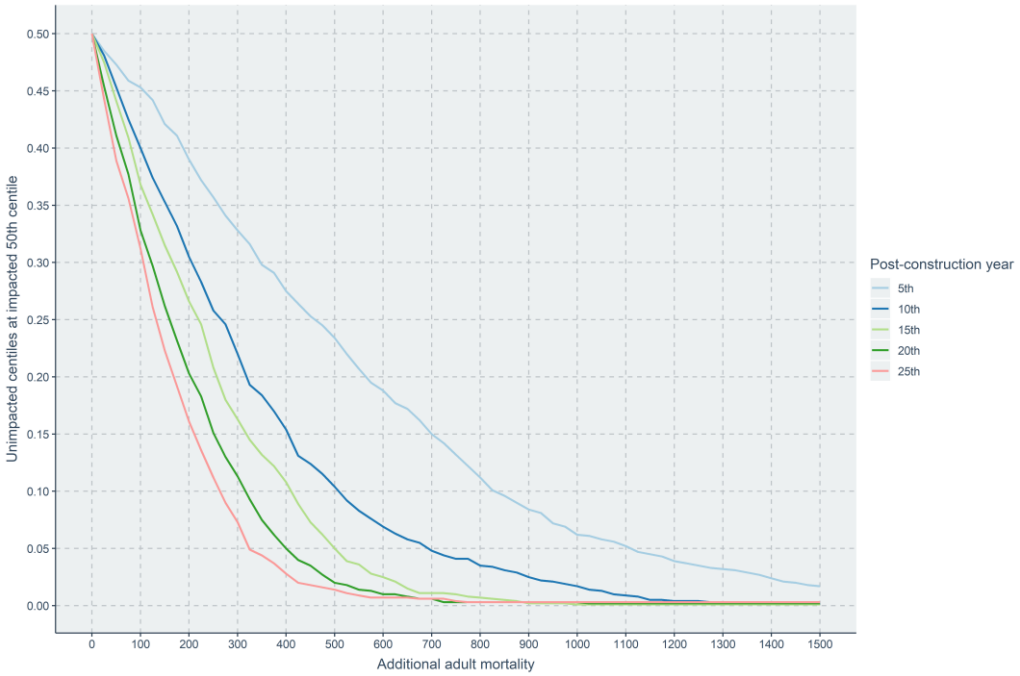

Figure 3: Gannet at Forth Islands SPA – The median of the impacted population size as a centile of the unimpacted population size, under a range of impact scenarios (incremental additional adult deaths – x-axis). For example, 0.3 means the median (50th percentile) of the impacted projections sits at the 30th percentile of the unimpacted projections. Individual lines represent years post-construction (5-25 years).

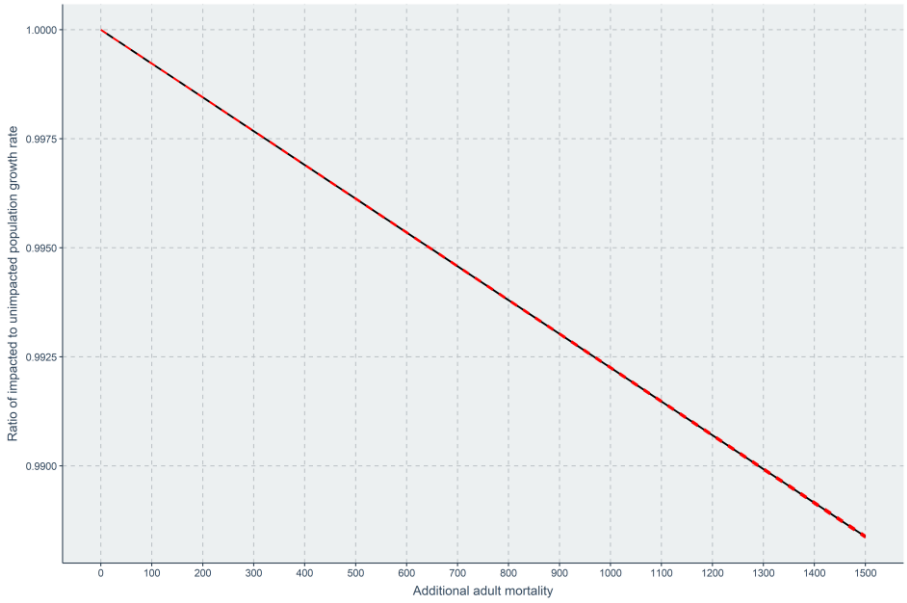

Figure 4: Gannet at Forth Islands SPA – Ratio of impacted to unimpacted growth rates under a range of impact scenarios (incremental additional adult deaths – x-axis) i.e. 0.9 means a 10% decrease in the growth rate under the impact scenario. Figures are based on paired simulations for the impacted and unimpacted populations i.e. based on the same sampled population parameters. The black line represents the 50th percentile (median), red lines give the central 95% of simulated values (2.5% and 97.5% reference points).

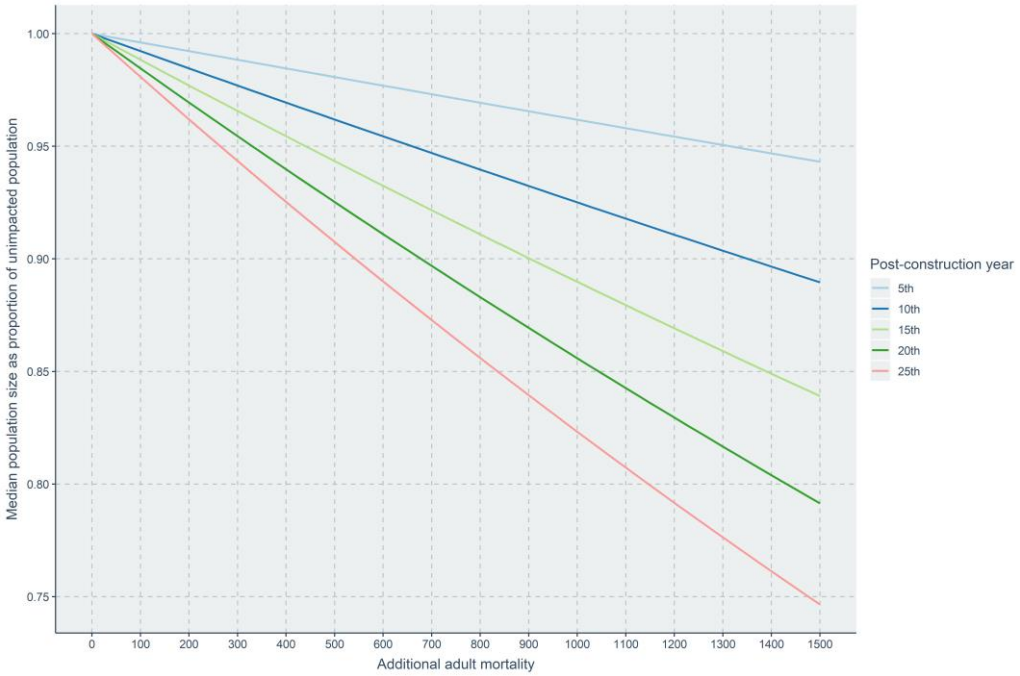

Figure 5: Gannet at Forth Islands SPA – The median of the ratio of impacted to unimpacted population sizes from the simulations, for a range of impact scenarios i.e. 0.5 means the impacted population size is one-half the unimpacted population size. Impact scenarios, in terms of incremental additional adult deaths, are given on the x-axis. Individual lines represent post-construction time points (projected 5 – 25 years).

Table 7: Gannet at Forth Islands SPA – Annual growth rates of simulated populations under a range of impact scenarios, for projections over 25 years. Reference points are the 2.5th, 50th (median) and 97.5th percentiles of the distribution of simulated growth rates. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median growth rates	2.5 percentile of simulated growth rates	97.5 percentile of simulated growth rates
0	0	1.011	1.007	1.015
25	43	1.011	1.007	1.015
50	86	1.011	1.007	1.015
75	129	1.011	1.007	1.015
100	173	1.011	1.007	1.015
125	216	1.010	1.006	1.014
150	259	1.010	1.006	1.014
175	302	1.010	1.006	1.014
200	345	1.010	1.006	1.014
225	388	1.010	1.006	1.014
250	432	1.009	1.005	1.014
275	475	1.009	1.005	1.013
300	518	1.009	1.005	1.013
325	561	1.009	1.005	1.013
350	604	1.009	1.005	1.013
375	647	1.008	1.004	1.013
400	691	1.008	1.004	1.012
425	734	1.008	1.004	1.012
450	777	1.008	1.004	1.012
475	820	1.008	1.004	1.012
500	863	1.007	1.003	1.012
525	906	1.007	1.003	1.011
550	950	1.007	1.003	1.011
575	993	1.007	1.003	1.011
600	1036	1.007	1.003	1.011
625	1079	1.006	1.003	1.011
650	1122	1.006	1.002	1.010
675	1165	1.006	1.002	1.010
700	1209	1.006	1.002	1.010
725	1252	1.006	1.002	1.010
750	1295	1.005	1.002	1.010
775	1338	1.005	1.001	1.009
800	1381	1.005	1.001	1.009
825	1424	1.005	1.001	1.009
850	1468	1.005	1.001	1.009
875	1511	1.005	1.001	1.009
900	1554	1.004	1.000	1.008
925	1597	1.004	1.000	1.008
950	1640	1.004	1.000	1.008
975	1683	1.004	1.000	1.008
1000	1726	1.004	1.000	1.008
1025	1770	1.003	0.999	1.007
1050	1813	1.003	0.999	1.007
1075	1856	1.003	0.999	1.007
1100	1899	1.003	0.999	1.007
1125	1942	1.003	0.999	1.007
1150	1985	1.002	0.998	1.006
1175	2029	1.002	0.998	1.006
1200	2072	1.002	0.998	1.006
1225	2115	1.002	0.998	1.006
1250	2158	1.002	0.998	1.006
1275	2201	1.001	0.997	1.005
1300	2244	1.001	0.997	1.005
1325	2288	1.001	0.997	1.005
1350	2331	1.001	0.997	1.005
1375	2374	1.001	0.997	1.005
1400	2417	1.000	0.996	1.004
1425	2460	1.000	0.996	1.004
1450	2503	1.000	0.996	1.004
1475	2547	1.000	0.996	1.004
1500	2590	1.000	0.996	1.004

Table 8: Gannet at Forth Islands SPA – Median of predicted population sizes after a 25-year post-construction period for a range of impact scenarios. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median end-point population size at 25 years
0	0	344434
25	43	342768
50	86	341111
75	129	339461
100	173	337818
125	216	336183
150	259	334556
175	302	332937
200	345	331325
225	388	329720
250	432	328123
275	475	326533
300	518	324951
325	561	323376
350	604	321808
375	647	320248
400	691	318696
425	734	317151
450	777	315614
475	820	314083
500	863	312560
525	906	311044
550	950	309535
575	993	308034
600	1036	306539
625	1079	305051
650	1122	303570
675	1165	302095
700	1209	300627
725	1252	299166
750	1295	297711
775	1338	296263
800	1381	294822
825	1424	293388
850	1468	291961
875	1511	290540
900	1554	289125
925	1597	287718
950	1640	286317
975	1683	284922
1000	1726	283535
1025	1770	282155
1050	1813	280781
1075	1856	279415
1100	1899	278055
1125	1942	276701
1150	1985	275354
1175	2029	274013
1200	2072	272679
1225	2115	271351
1250	2158	270028
1275	2201	268710
1300	2244	267399
1325	2288	266094
1350	2331	264795
1375	2374	263502
1400	2417	262216
1425	2460	260935
1450	2503	259660
1475	2547	258391
1500	2590	257129

3.1.2 Specific mortality scenarios

Table 9: Gannet at Forth Islands SPA - Relevant PVA metrics from models with impact scenarios for specific additional mortalities due to collisions and/or displacement effects

Impact	Scenario	Adults	Sub-Adults	Median Growth rate	Median end size at 25 years (individuals)	Median counterfactual of growth rates	Median counterfactual of population size at 25 years	Centile of unimpactacted matching the 50th centile of impacted
Baseline	**Unimpacted**	0	0	1.012	346574	1.000	1.000	0.500
Collision	**Alpha**	176	5	1.011	338472	0.999	0.977	0.296
Collision	**Bravo**	128	3	1.011	340676	0.999	0.983	0.341
Collision	**A+B**	260	7	1.010	334690	0.999	0.966	0.215
Collision	**A+B+F & T 2018**	423	12	1.009	327439	0.998	0.945	0.111
Collision	**A+B+F & T 2014**	822	25	1.007	310308	0.996	0.895	0.009
Collision	**A+B+F & T 2014 + NSea & Channel**	904	93	1.006	305165	0.995	0.881	0.005

3.2 Puffin – Forth Islands SPA

3.2.1 Incremental mortality scenarios

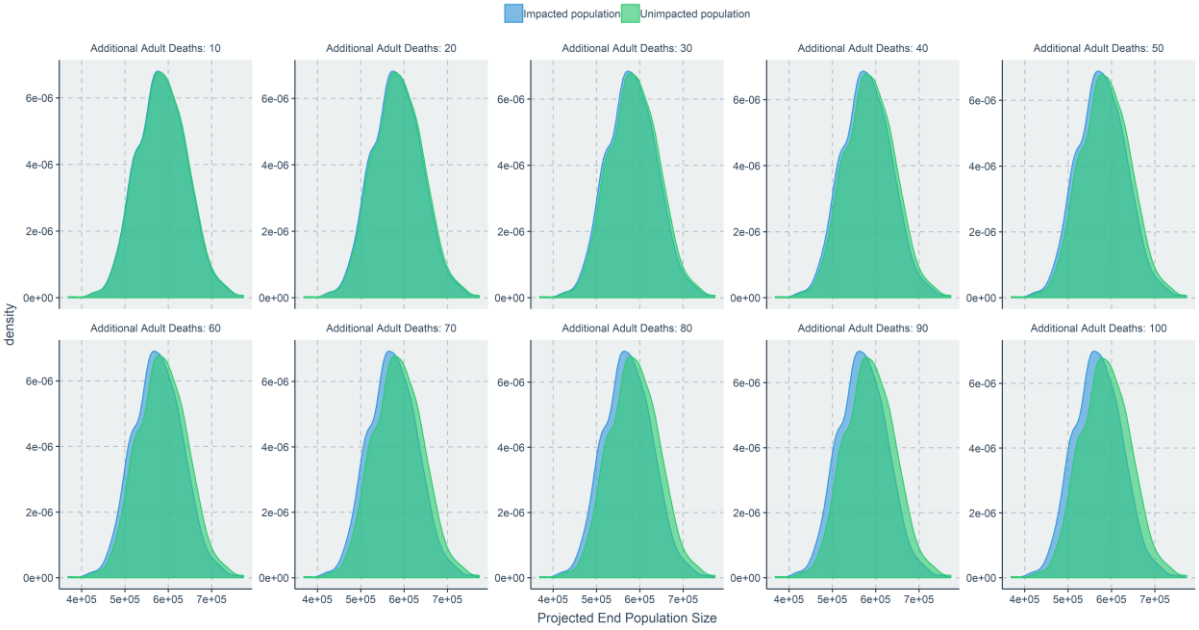

Figure 6: Puffin at Forth Islands SPA – Density distributions of simulated population sizes after a 25-year post-construction period. Each plot represents a different impact scenario in terms of additional adult mortalities, together with the distribution of predicted unimpacted population sizes after 25 years.

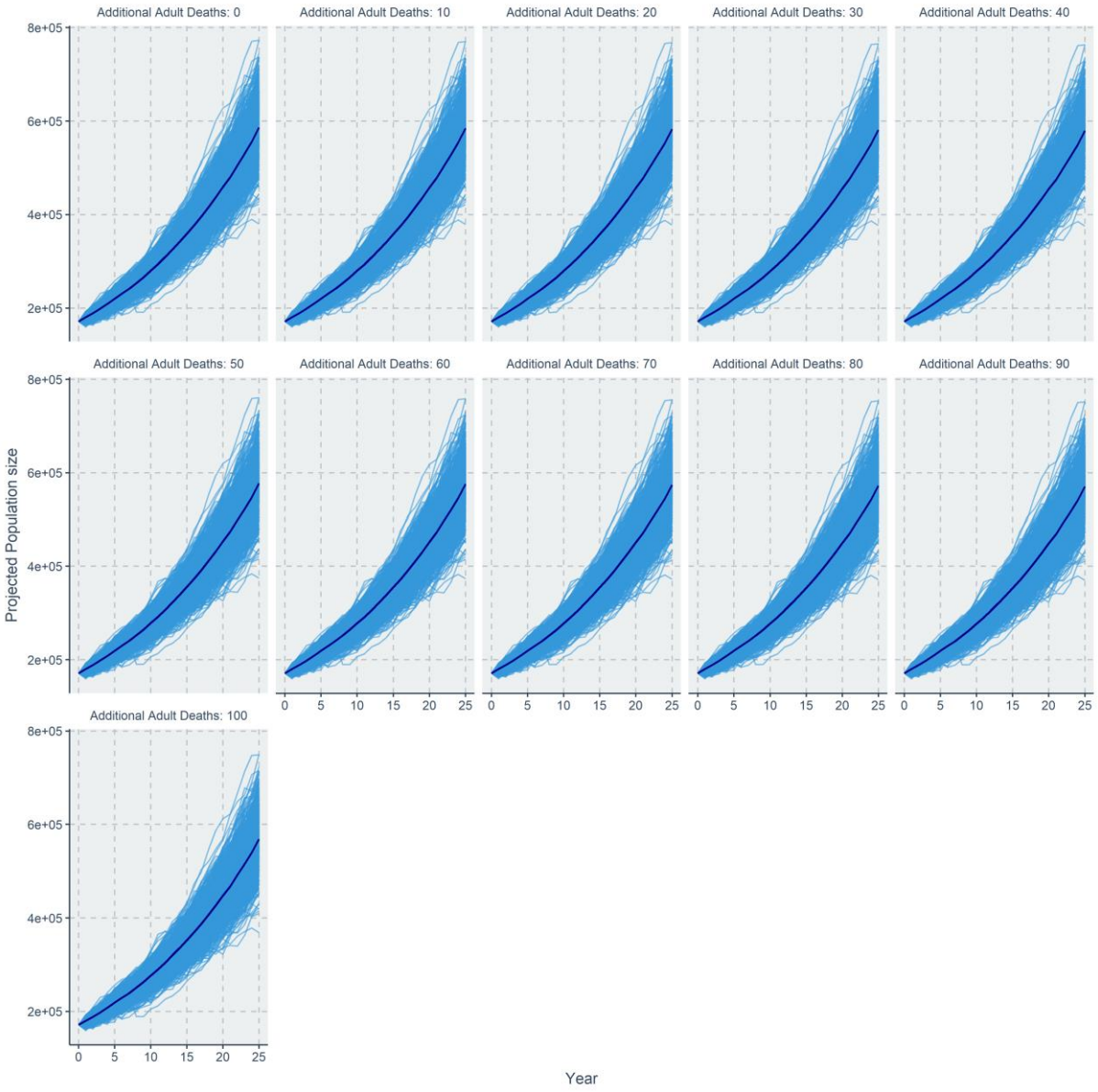

Figure 7: Puffin at Forth Islands SPA – Projections of population sizes over a 25-year time-frame. Each plot represents a different impact scenario in terms of additional adult mortalities (starting at 0 i.e. unimpacted). Individual blue lines are different realisations of the population trajectory, when population parameters are sampled from their distributions. The dark blue line is the median at each time point.

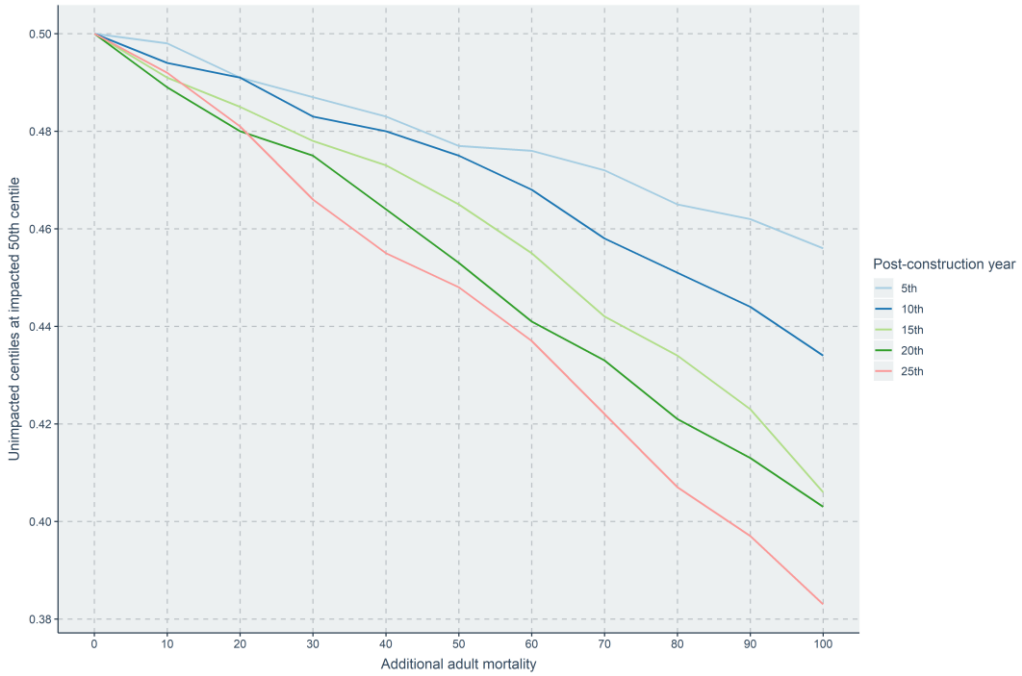

Figure 8: Puffin at Forth Islands SPA – The median of the impacted population size as a centile of the unimpacted population size, under a range of impact scenarios (incremental additional adult deaths – x-axis). For example, 0.3 means the median (50th percentile) of the impacted projections sits at the 30th percentile of the unimpacted projections. Individual lines represent years post-construction (5-25 years).

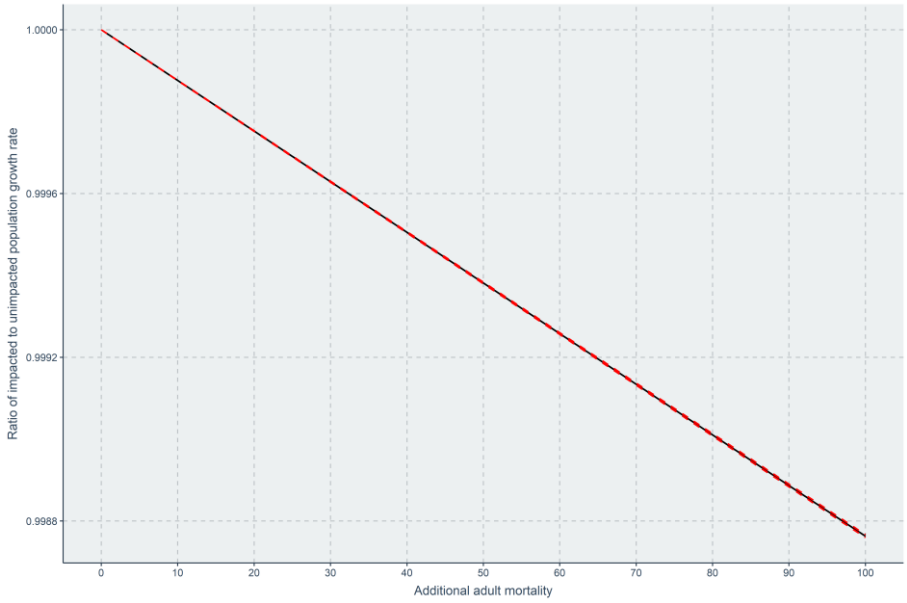

Figure 9: Puffin at Forth Islands SPA – Ratio of impacted to unimpacted growth rates under a range of impact scenarios (incremental additional adult deaths – x-axis) i.e. 0.9 means a 10% decrease in the growth rate under the impact scenario. Figures are based on paired simulations for the impacted and unimpacted populations i.e. based on the same sampled population parameters. The black line represents the 50th percentile (median), red lines give the central 95% of simulated values (2.5% and 97.5% reference points).

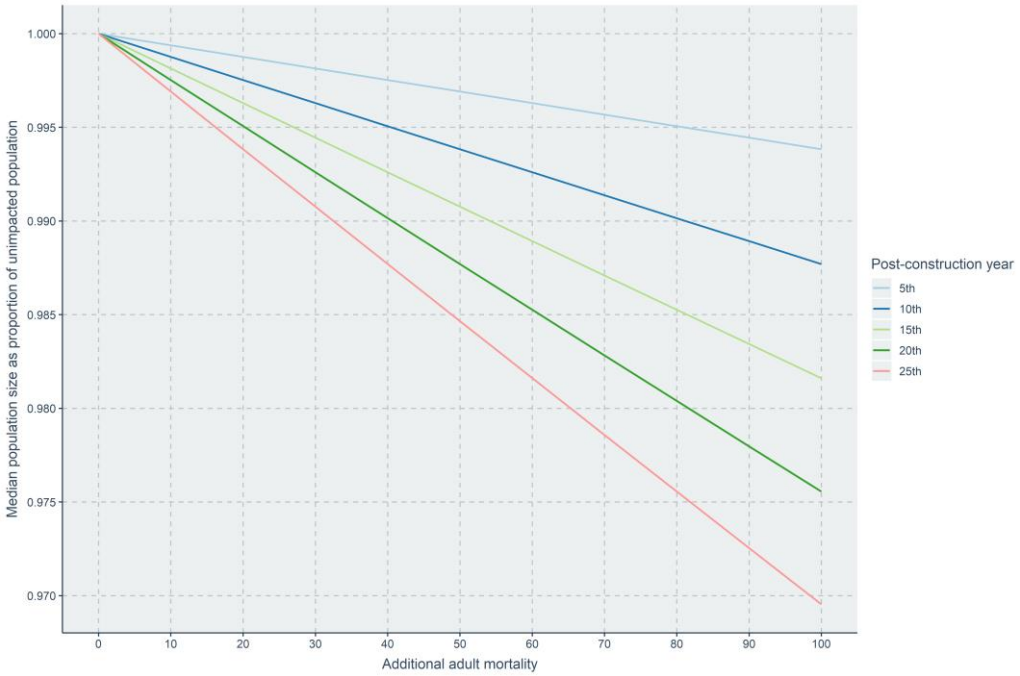

Figure 10: Puffin at Forth Islands SPA – The median of the ratio of impacted to unimpacted population sizes from the simulations, for a range of impact scenarios i.e. 0.5 means the impacted population size is one-half the unimpacted population size. Impact scenarios, in terms of incremental additional adult deaths, are given on the x-axis. Individual lines represent post-construction time points (projected 5 – 25 years).

Table 10: Puffin at Forth Islands SPA – Annual growth rates of simulated populations under a range of impact scenarios, for projections over 25 years. Reference points are the 2.5th, 50th (median) and 97.5th percentiles of the distribution of simulated growth rates. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median growth rates	2.5 percentile of simulated growth rates	97.5 percentile of simulated growth rates
0	0	1.051	1.039	1.060
10	19	1.050	1.039	1.059
20	38	1.050	1.039	1.059
30	57	1.050	1.039	1.059
40	76	1.050	1.039	1.059
50	95	1.050	1.039	1.059
60	114	1.050	1.039	1.059
70	133	1.050	1.039	1.059
80	152	1.049	1.038	1.059
90	171	1.049	1.038	1.058
100	190	1.049	1.038	1.058

Table 11: Puffin at Forth Islands SPA – Median of predicted population sizes after a 25-year post-construction period for a range of impact scenarios. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median end-point population size at 25 years
0	0	586649
10	19	584835
20	38	583026
30	57	581222
40	76	579424
50	95	577631
60	114	575843
70	133	574061
80	152	572284
90	171	570512
100	190	568748

3.2.2 Specific mortality scenarios

Table 12: Puffin at Forth Islands SPA - Relevant PVA metrics from models with impact scenarios for specific additional mortalities due to collisions and/or displacement effects

Impact	Scenario	Adults	Sub-Adults	Median Growth rate	Median end size at 25 years (individuals)	Median counterfactual of growth rates	Median counterfactual of population size at 25 years	Centile of unimpactacted matching the 50th centile of impacted
Baseline	**Unimpacted**	0	0	1.050	583418	1.000	1.000	0.500
Displacement	**Alpha**	18	18	1.050	580077	1.000	0.994	0.469
Displacement	**Bravo**	26	26	1.050	578598	1.000	0.992	0.460
Displacement	**A+B**	37	36	1.050	576632	1.000	0.988	0.443
Displacement	**A+B+F & T 2018**	127	158	1.049	558328	0.998	0.957	0.336

3.3 Razorbill – Forth Islands SPA

3.3.1 Incremental mortality scenarios

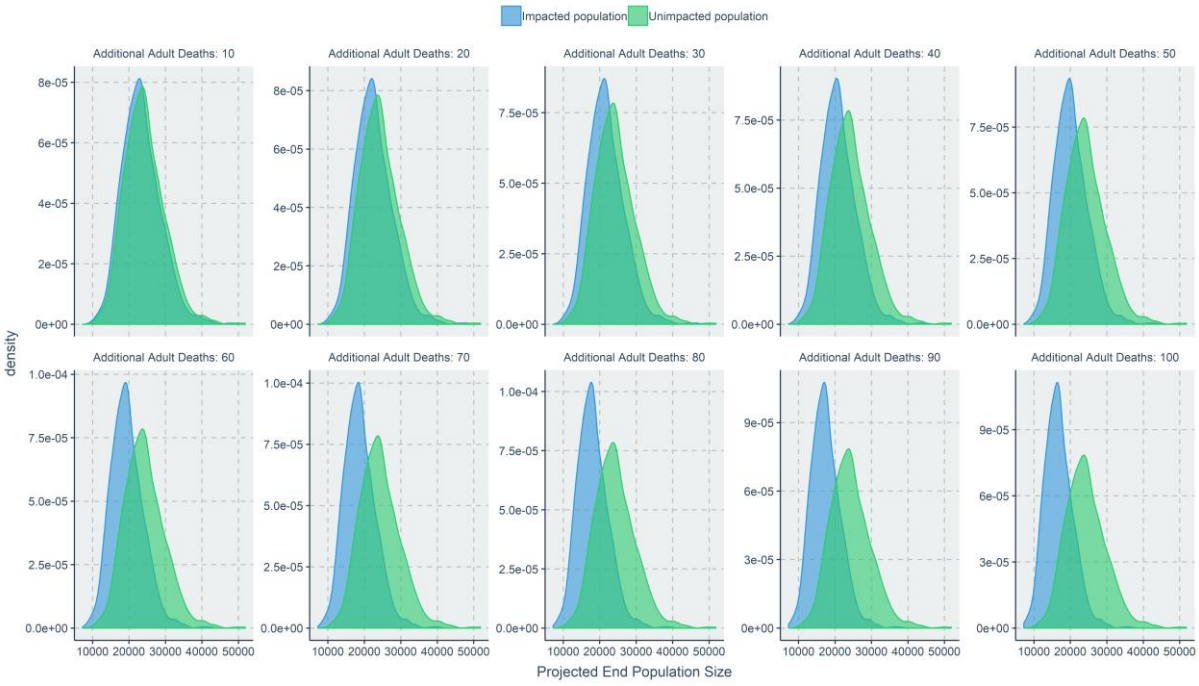

Figure 11: Razorbill at Forth Islands SPA – Density distributions of simulated population sizes after a 25-year post-construction period. Each plot represents a different impact scenario in terms of additional adult mortalities, together with the distribution of predicted unimpacted population sizes after 25 years.

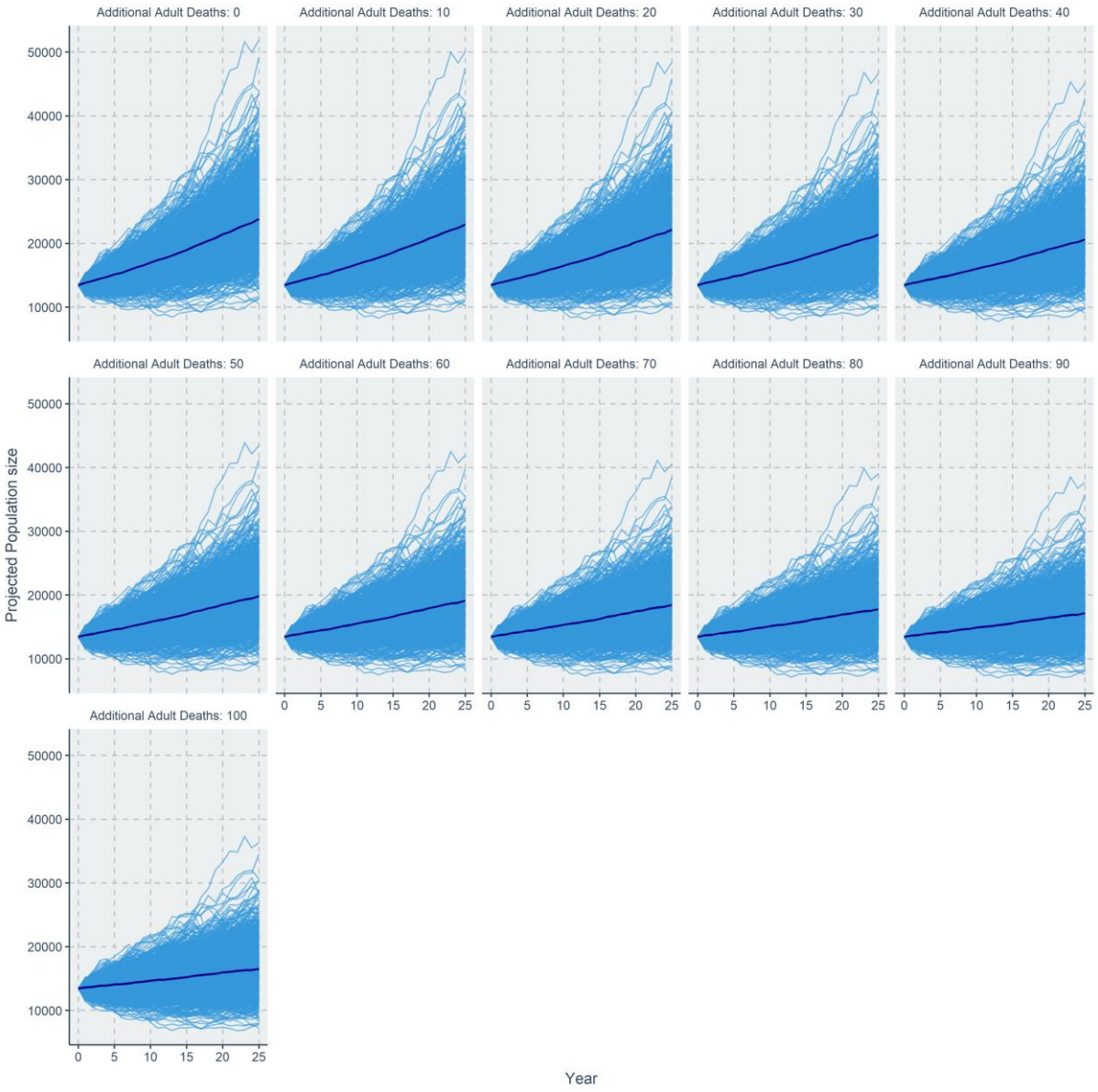

Figure 12: Razorbill at Forth Islands SPA – Projections of population sizes over a 25-year time-frame. Each plot represents a different impact scenario in terms of additional adult mortalities (starting at 0 i.e. unimpacted). Individual blue lines are different realisations of the population trajectory, when population parameters are sampled from their distributions. The dark blue line is the median at each time point.

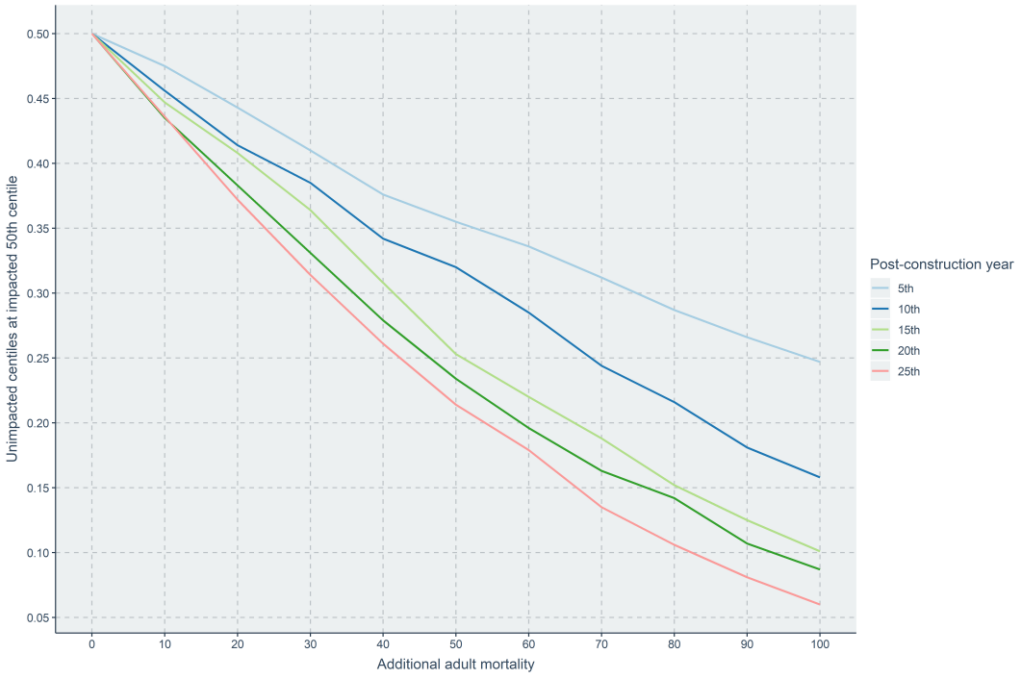

Figure 13: Razorbill at Forth Islands SPA – The median of the impacted population size as a centile of the unimpacted population size, under a range of impact scenarios (incremental additional adult deaths – x-axis). For example, 0.3 means the median (50th percentile) of the impacted projections sits at the 30th percentile of the unimpacted projections. Individual lines represent years post-construction (0-25 years).

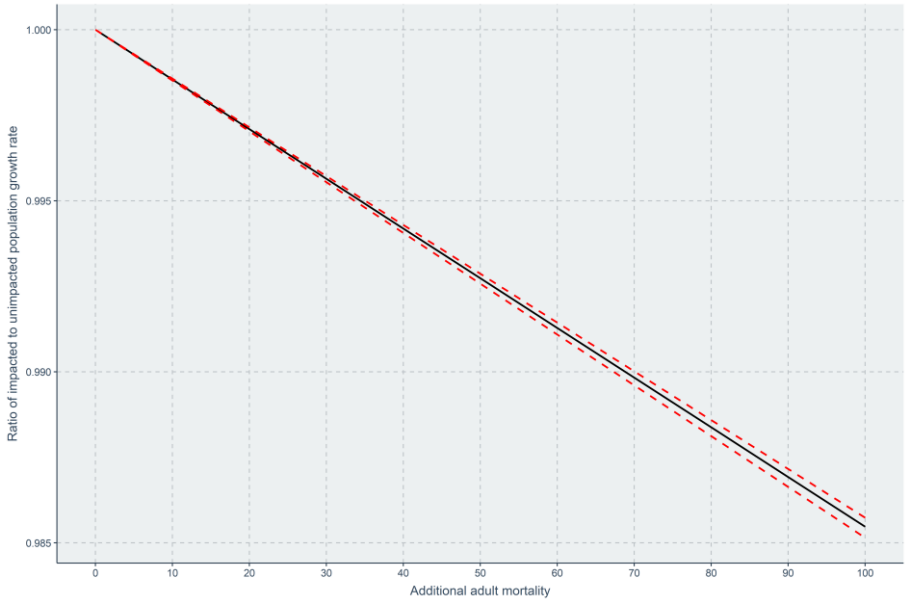

Figure 14: Razorbill at Forth Islands SPA – Ratio of impacted to unimpacted growth rates under a range of impact scenarios (incremental additional adult deaths – x-axis) i.e. 0.9 means a 10% decrease in the growth rate under the impact scenario. Figures are based on paired simulations for the impacted and unimpacted populations i.e. based on the same sampled population parameters. The black line represents the 50th percentile (median), red lines give the central 95% of simulated values (2.5% and 97.5% reference points).

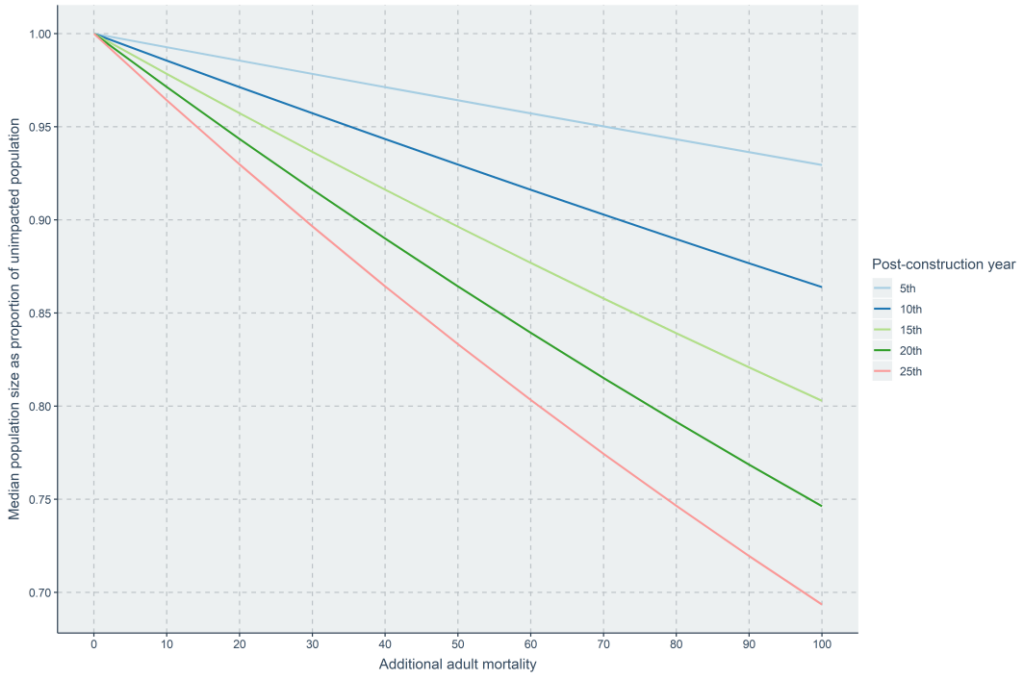

Figure 15: Razorbill at Forth Islands SPA – The median of the ratio of impacted to unimpacted population sizes from the simulations, for a range of impact scenarios i.e. 0.5 means the impacted population size is one-half the unimpacted population size. Impact scenarios, in terms of incremental additional adult deaths, are given on the x-axis. Individual lines represent post-construction time points (projected 5 – 25 years).

Table 13: Razorbill at Forth Islands SPA – Annual growth rates of simulated populations under a range of impact scenarios, for projections over 25 years. Reference points are the 2.5th, 50th (median) and 97.5th percentiles of the distribution of simulated growth rates. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median growth rates	2.5 percentile of simulated growth rates	97.5 percentile of simulated growth rates
0	0	1.023	1.002	1.042
10	17	1.022	1.001	1.041
20	34	1.020	0.999	1.039
30	52	1.019	0.998	1.038
40	69	1.017	0.996	1.036
50	86	1.016	0.995	1.035
60	103	1.014	0.994	1.033
70	121	1.013	0.992	1.032
80	138	1.011	0.991	1.030
90	155	1.010	0.989	1.029
100	172	1.008	0.988	1.027

Table 14: Razorbill at Forth Islands SPA – Median of predicted population sizes after a 25-year post-construction period for a range of impact scenarios. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median end-point population size at 25 years
0	0	23824
10	17	22974
20	34	22153
30	52	21360
40	69	20595
50	86	19856
60	103	19141
70	121	18453
80	138	17788
90	155	17146
100	172	16527

3.3.2 Specific mortality scenarios

Table 15: Razorbill at Forth Islands SPA - Relevant PVA metrics from models with impact scenarios for specific additional mortalities due to collisions and/or displacement effects

Impact	Scenario	Adults	Sub-Adults	Median Growth rate	Median end size at 25 years (individuals)	Median counterfactual of growth rates	Median counterfactual of population size at 25 years	Centile of unimpactacted matching the 50th centile of impacted
Baseline	**Unimpacted**	0	0	1.024	24260	1.000	1.000	0.500
Displacement	**Alpha**	4	3	1.024	23905	0.999	0.985	0.473
Displacement	**Bravo**	3	2	1.024	24004	1.000	0.989	0.483
Displacement	**A+B**	7	5	1.023	23653	0.999	0.975	0.459
Displacement	**A+B+F & T 2018**	26	25	1.020	21842	0.996	0.900	0.323

3.4 Razorbill – Fowlsheugh SPA

3.4.1 Incremental mortality scenarios

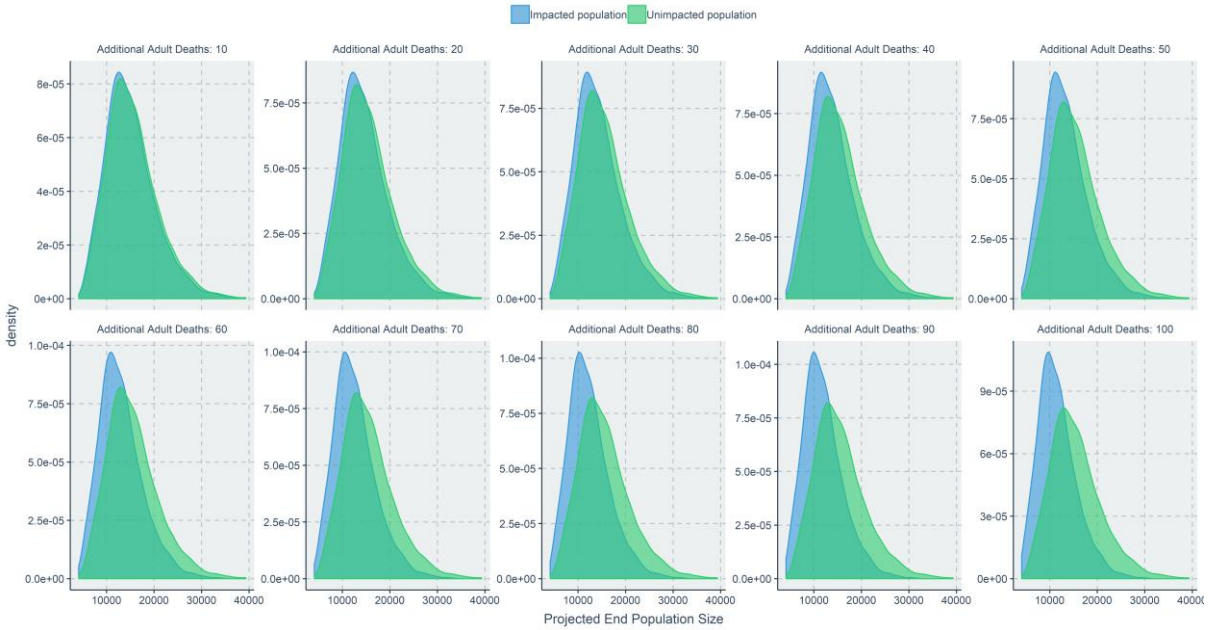

Figure 16: Razorbill at Fowlsheugh SPA – Density distributions of simulated population sizes after a 25-year post-construction period. Each plot represents a different impact scenario in terms of additional adult mortalities, together with the distribution of predicted unimpacted population sizes after 25 years.

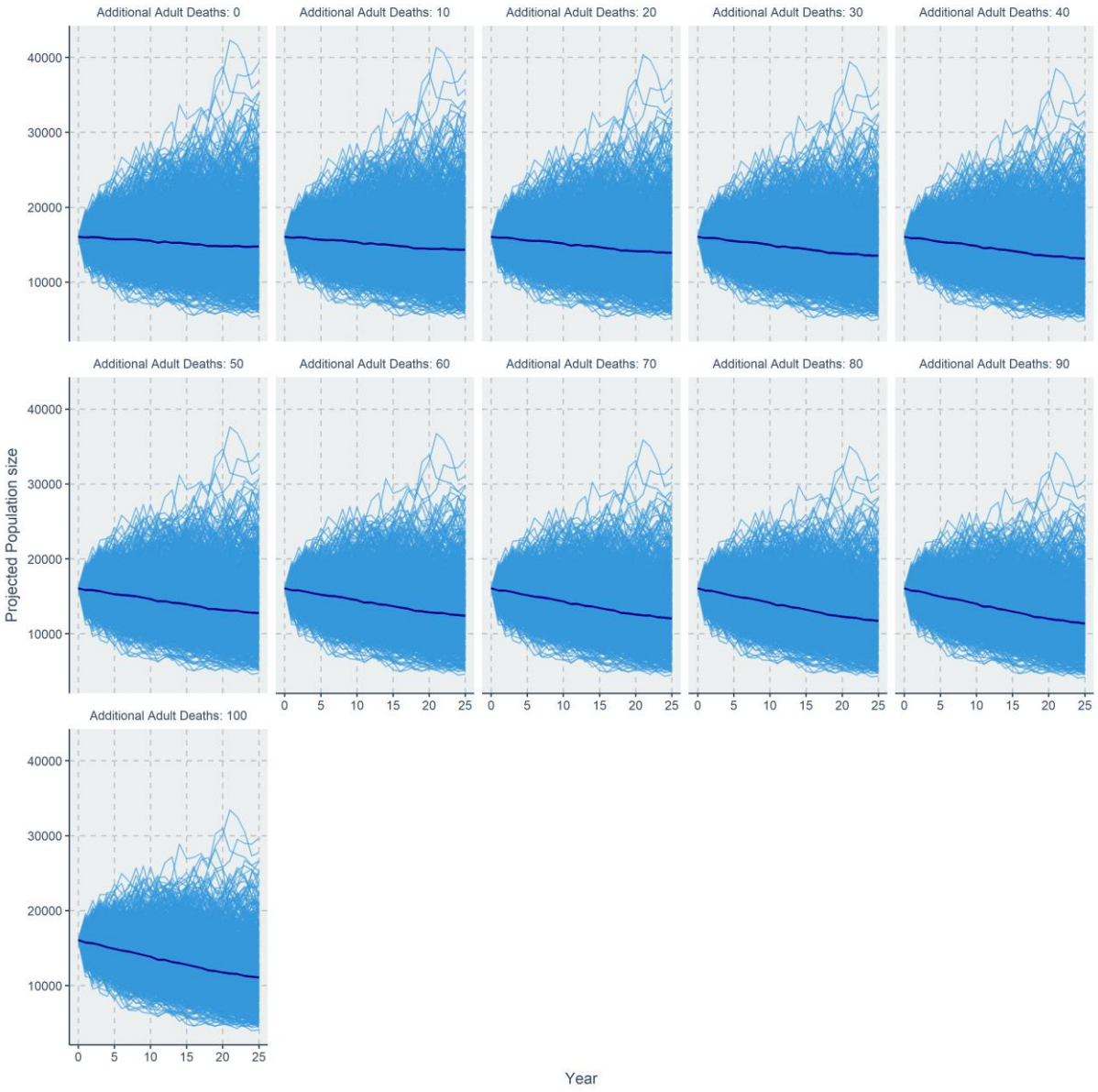

Figure 17: Razorbill at Fowlsheugh SPA – Projections of population sizes over a 25-year time-frame. Each plot represents a different impact scenario in terms of additional adult mortalities (starting at 0 i.e. unimpacted). Individual blue lines are different realisations of the population trajectory, when population parameters are sampled from their distributions. The dark blue line is the median at each time point.

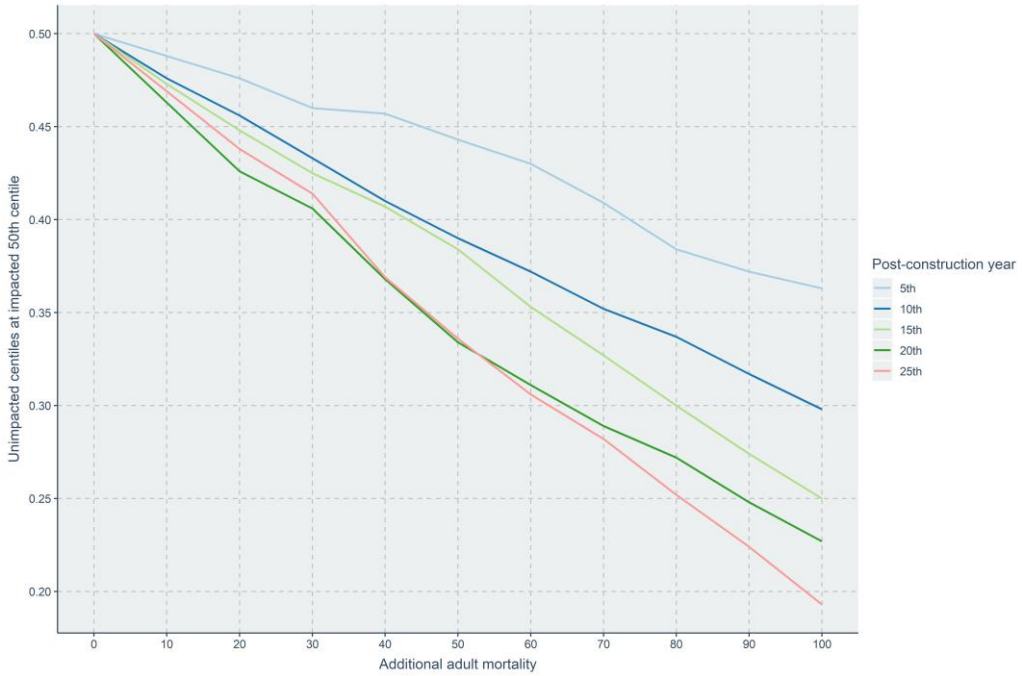

Figure 18: Razorbill at Fowlsheugh SPA – The median of the impacted population size as a centile of the unimpacted population size, under a range of impact scenarios (incremental additional adult deaths – x-axis). For example, 0.3 means the median (50th percentile) of the impacted projections sits at the 30th percentile of the unimpacted projections. Individual lines represent years post-construction (0-25 years).

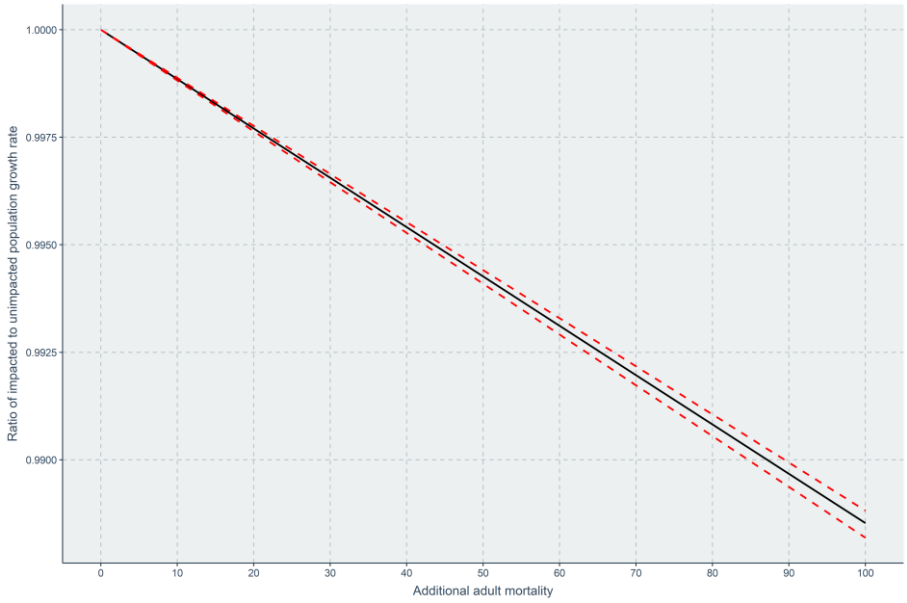

Figure 19: Razorbill at Fowlsheugh SPA – Ratio of impacted to unimpacted growth rates under a range of impact scenarios (incremental additional adult deaths – x-axis) i.e. 0.9 means a 10% decrease in the growth rate under the impact scenario. Figures are based on paired simulations for the impacted and unimpacted populations i.e. based on the same sampled population parameters. The black line represents the 50th percentile (median), red lines give the central 95% of simulated values (2.5% and 97.5% reference points).

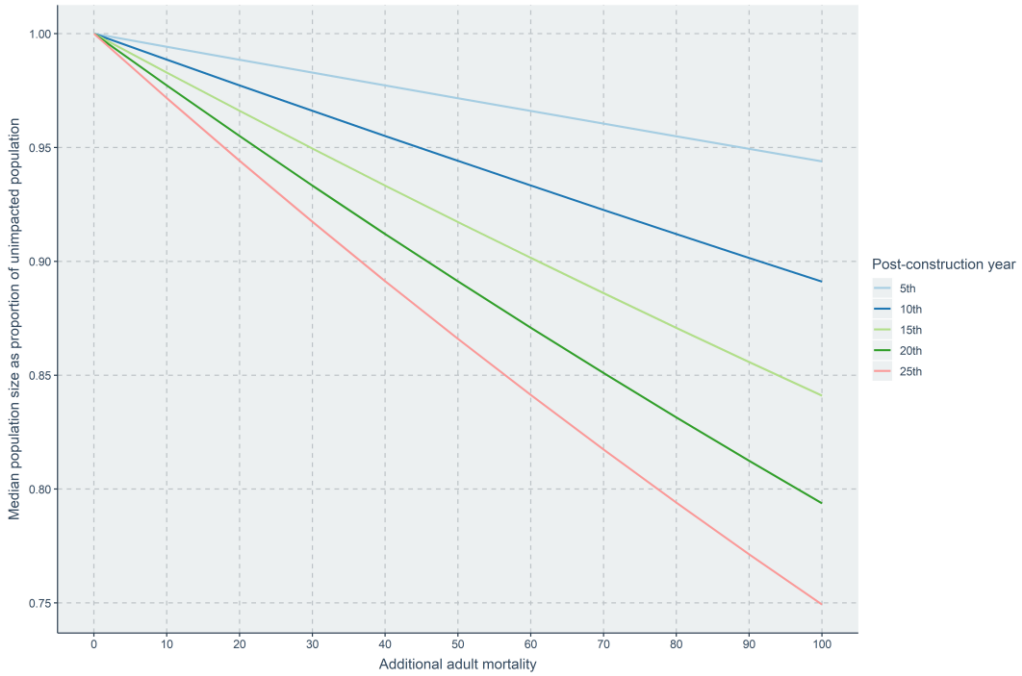

Figure 20: Razorbill at Fowlsheugh SPA – The median of the ratio of impacted to unimpacted population sizes from the simulations, for a range of impact scenarios i.e. 0.5 means the impacted population size is one-half the unimpacted population size. Impact scenarios, in terms of incremental additional adult deaths, are given on the x-axis. Individual lines represent post-construction time points (projected 5 – 25 years).

Table 16: Razorbill at Fowlsheugh SPA – Annual growth rates of simulated populations under a range of impact scenarios, for projections over 25 years. Reference points are the 2.5th, 50th (median) and 97.5th percentiles of the distribution of simulated growth rates. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median growth rates	2.5 percentile of simulated growth rates	97.5 percentile of simulated growth rates
0	0	0.997	0.964	1.028
10	16	0.996	0.963	1.026
20	32	0.995	0.962	1.025
30	48	0.994	0.961	1.024
40	65	0.992	0.960	1.023
50	81	0.991	0.958	1.022
60	97	0.990	0.957	1.021
70	113	0.989	0.956	1.019
80	129	0.988	0.955	1.018
90	145	0.987	0.954	1.017
100	162	0.986	0.953	1.016

Table 17: Razorbill at Fowlsheugh SPA – Median of predicted population sizes after a 25-year post-construction period for a range of impact scenarios. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median end-point population size at 25 years
0	0	14740
10	16	14323
20	32	13917
30	48	13523
40	65	13139
50	81	12769
60	97	12409
70	113	12060
80	129	11719
90	145	11388
100	162	11064

3.4.2 Specific mortality scenarios

Table 18: Razorbill at Fowlsheugh SPA - Relevant PVA metrics from models with impact scenarios for specific additional mortalities due to collisions and/or displacement effects

Impact	Scenario	Adults	Sub-Adults	Median Growth rate	Median end size at 25 years (individuals)	Median counterfactual of growth rates	Median counterfactual of population size at 25 years	Centile of unimpactacted matching the 50th centile of impacted
Baseline	**Unimpacted**	0	0	0.996	14544	1.000	1.000	0.500
Displacement	**Alpha**	10	7	0.995	14115	0.999	0.971	0.469
Displacement	**Bravo**	7	5	0.995	14240	0.999	0.979	0.476
Displacement	**A+B**	13	10	0.995	13970	0.998	0.961	0.457
Displacement	**A+B+F & T 2018**	22	19	0.993	13541	0.997	0.931	0.426

3.5 Guillemot – Forth Islands SPA

3.5.1 Incremental mortality scenarios

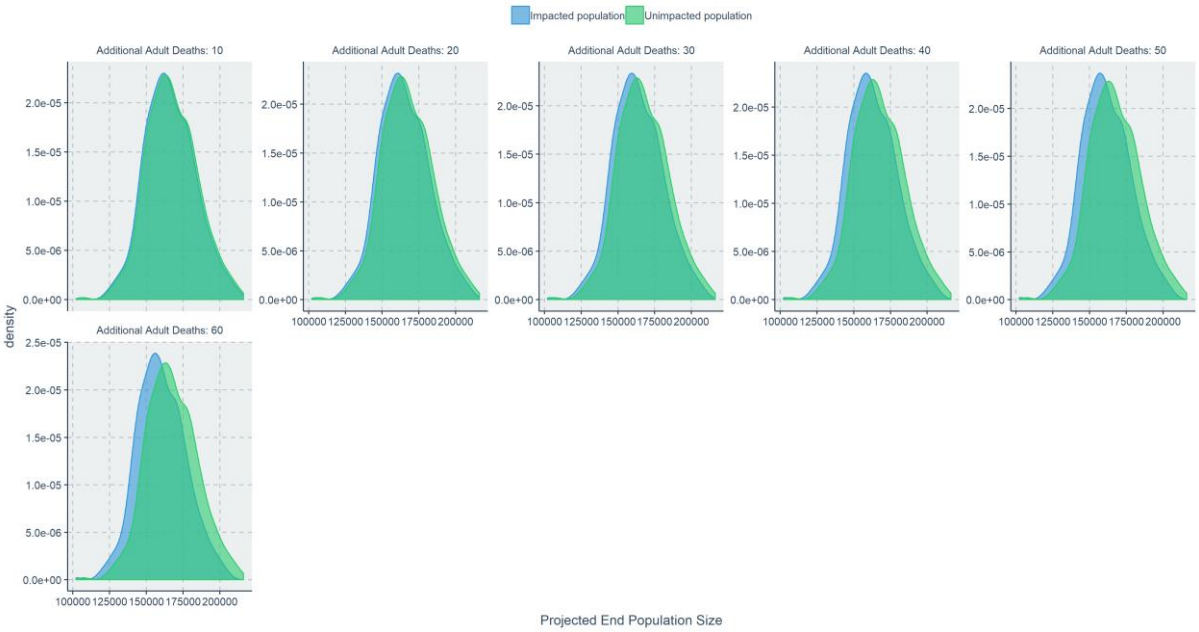

Figure 21: Guillemot at Forth Islands SPA – Density distributions of simulated population sizes after a 25-year post-construction period. Each plot represents a different impact scenario in terms of additional adult mortalities, together with the distribution of predicted unimpacted population sizes after 25 years.

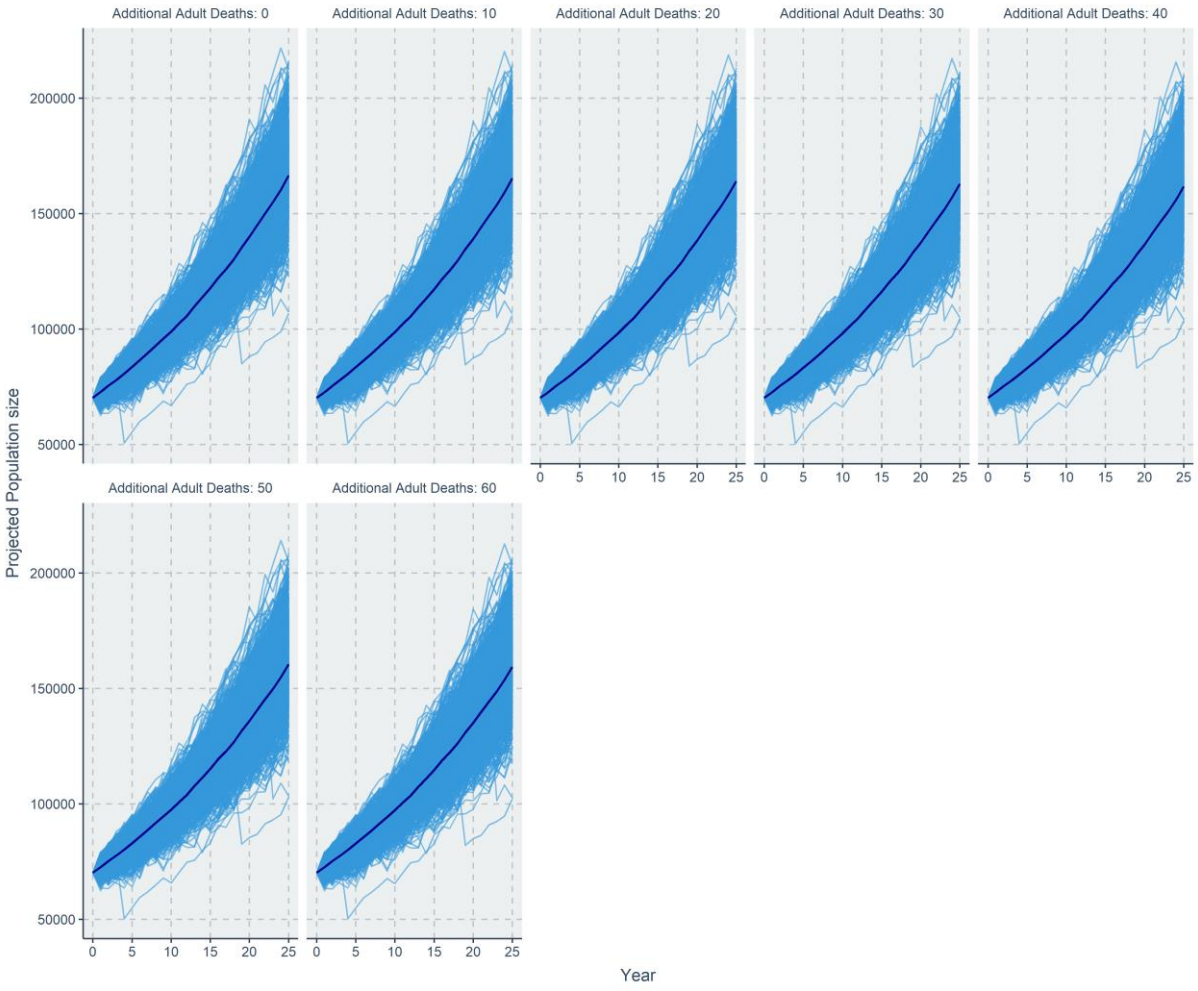

Figure 22: Guillemot at Forth Islands SPA – Projections of population sizes over a 25-year time-frame. Each plot represents a different impact scenario in terms of additional adult mortalities (starting at 0 i.e. unimpacted). Individual blue lines are different realisations of the population trajectory, when population parameters are sampled from their distributions. The dark blue line is the median at each time point.

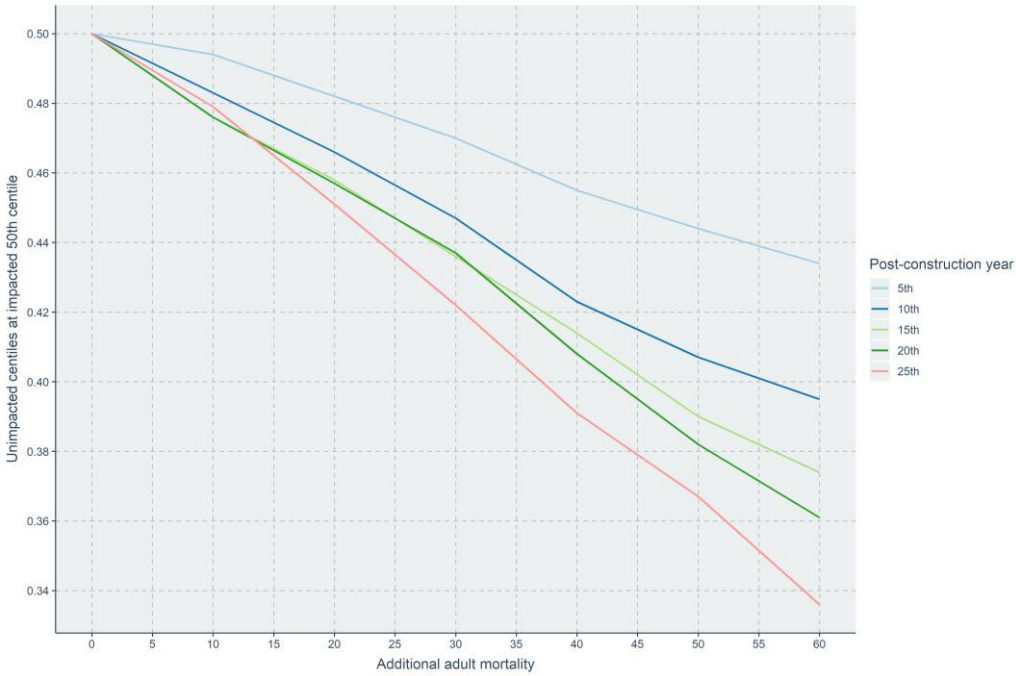

Figure 23: Guillemot at Forth Islands SPA – The median of the impacted population size as a centile of the unimpacted population size, under a range of impact scenarios (incremental additional adult deaths – x-axis). For example, 0.3 means the median (50th percentile) of the impacted projections sits at the 30th percentile of the unimpacted projections. Individual lines represent years post-construction (0-25 years).

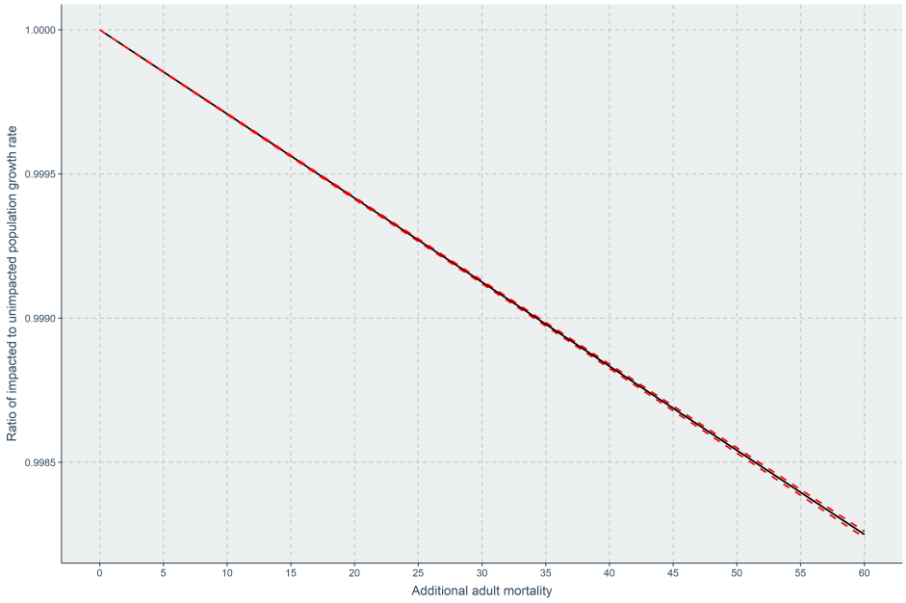

Figure 24: Guillemot at Forth Islands SPA – Ratio of impacted to unimpacted growth rates under a range of impact scenarios (incremental additional adult deaths – x-axis) i.e. 0.9 means a 10% decrease in the growth rate under the impact scenario. Figures are based on paired simulations for the impacted and unimpacted populations i.e. based on the same sampled population parameters. The black line represents the 50th percentile (median), red lines give the central 95% of simulated values (2.5% and 97.5% reference points).

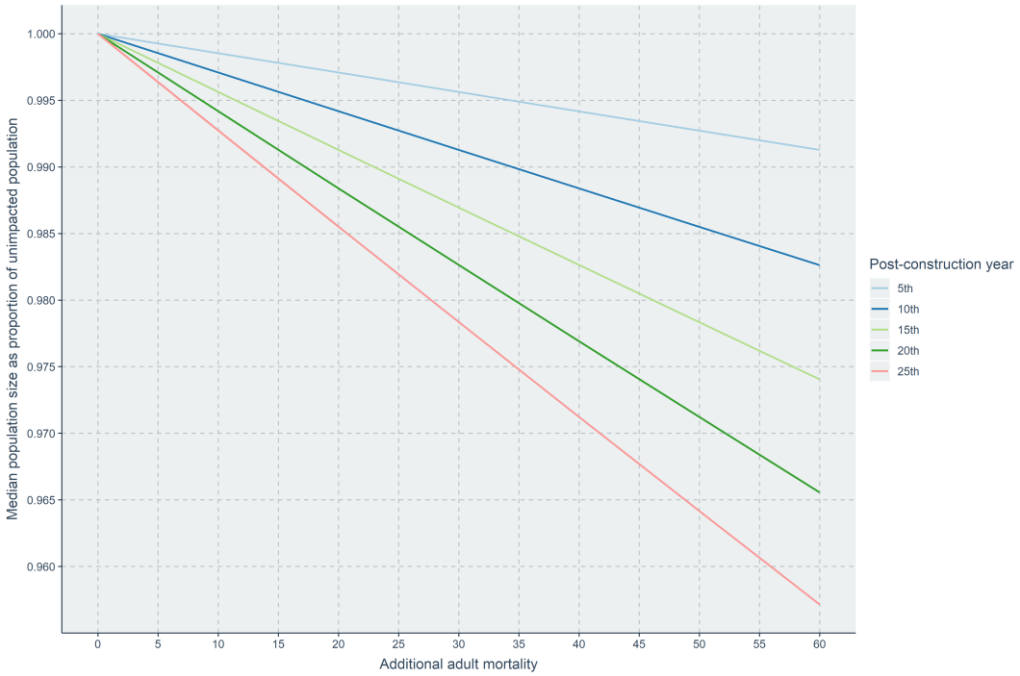

Figure 25: Guillemot at Forth Islands SPA – The median of the ratio of impacted to unimpacted population sizes from the simulations, for a range of impact scenarios i.e. 0.5 means the impacted population size is one-half the unimpacted population size. Impact scenarios, in terms of incremental additional adult deaths, are given on the x-axis. Individual lines represent post-construction time points (projected 5 – 25 years).

Table 19: Guillemot at Forth Islands SPA – Annual growth rates of simulated populations under a range of impact scenarios, for projections over 25 years. Reference points are the 2.5th, 50th (median) and 97.5th percentiles of the distribution of simulated growth rates. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median growth rates	2.5 percentile of simulated growth rates	97.5 percentile of simulated growth rates
0	0	1.036	1.026	1.044
10	18	1.035	1.026	1.044
20	36	1.035	1.025	1.044
30	55	1.035	1.025	1.043
40	73	1.034	1.025	1.043
50	91	1.034	1.024	1.043
60	109	1.034	1.024	1.042

Table 20: Guillemot at Forth Islands SPA – Median of predicted population sizes after a 25-year post-construction period for a range of impact scenarios. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median end-point population size at 25 years
0	0	166477
10	18	165268
20	36	164067
30	55	162875
40	73	161691
50	91	160513
60	109	159344

3.5.2 Specific mortality scenarios

Table 21: Guillemot at Forth Islands SPA - Relevant PVA metrics from models with impact scenarios for specific additional mortalities due to collisions and/or displacement effects

Impact	Scenario	Adults	Sub-Adults	Median Growth rate	Median end size at 25 years (individuals)	Median counterfactual of growth rates	Median counterfactual of population size at 25 years	Centile of unimpactacted matching the 50th centile of impacted
Baseline	**Unimpacted**	0	0	1.035	167661	1.000	1.000	0.500
Displacement	**Alpha**	11	10	1.035	166264	1.000	0.992	0.466
Displacement	**Bravo**	9	7	1.035	166581	1.000	0.994	0.473
Displacement	**A+B**	17	15	1.035	165532	0.999	0.987	0.449
Displacement	**A+B+F & T 2018**	46	53	1.034	161325	0.998	0.962	0.345

3.6 Guillemot – Fowlsheugh SPA

3.6.1 Incremental mortality scenarios

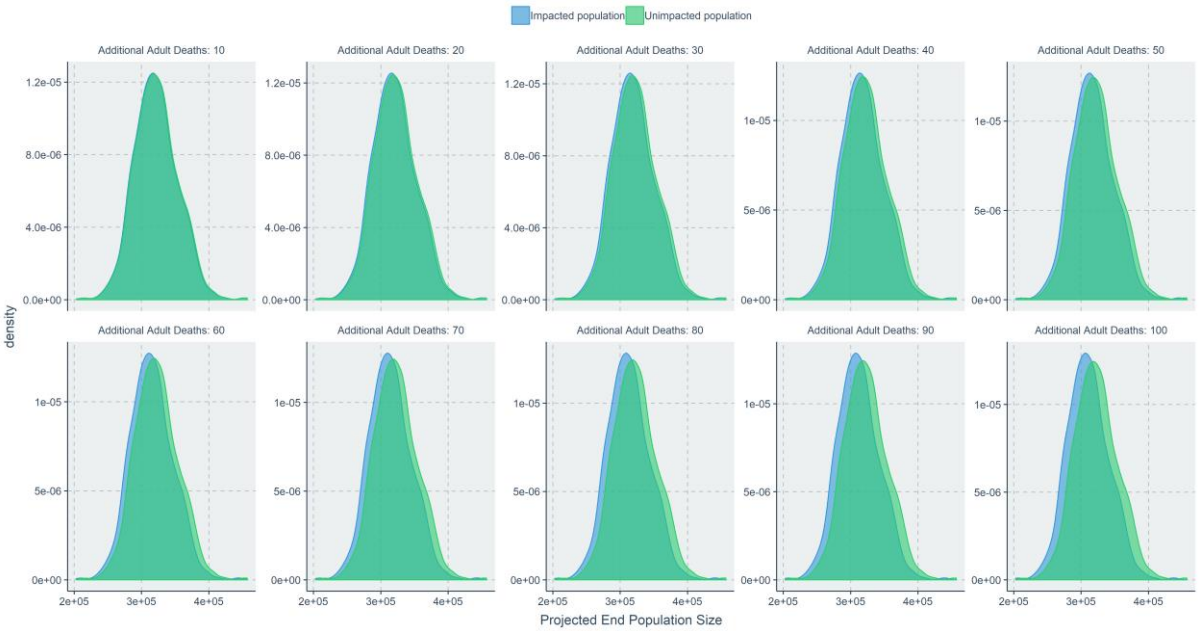

Figure 26: Guillemot at Fowlsheugh SPA – Density distributions of simulated population sizes after a 25-year post-construction period. Each plot represents a different impact scenario in terms of additional adult mortalities, together with the distribution of predicted unimpacted population sizes after 25 years.

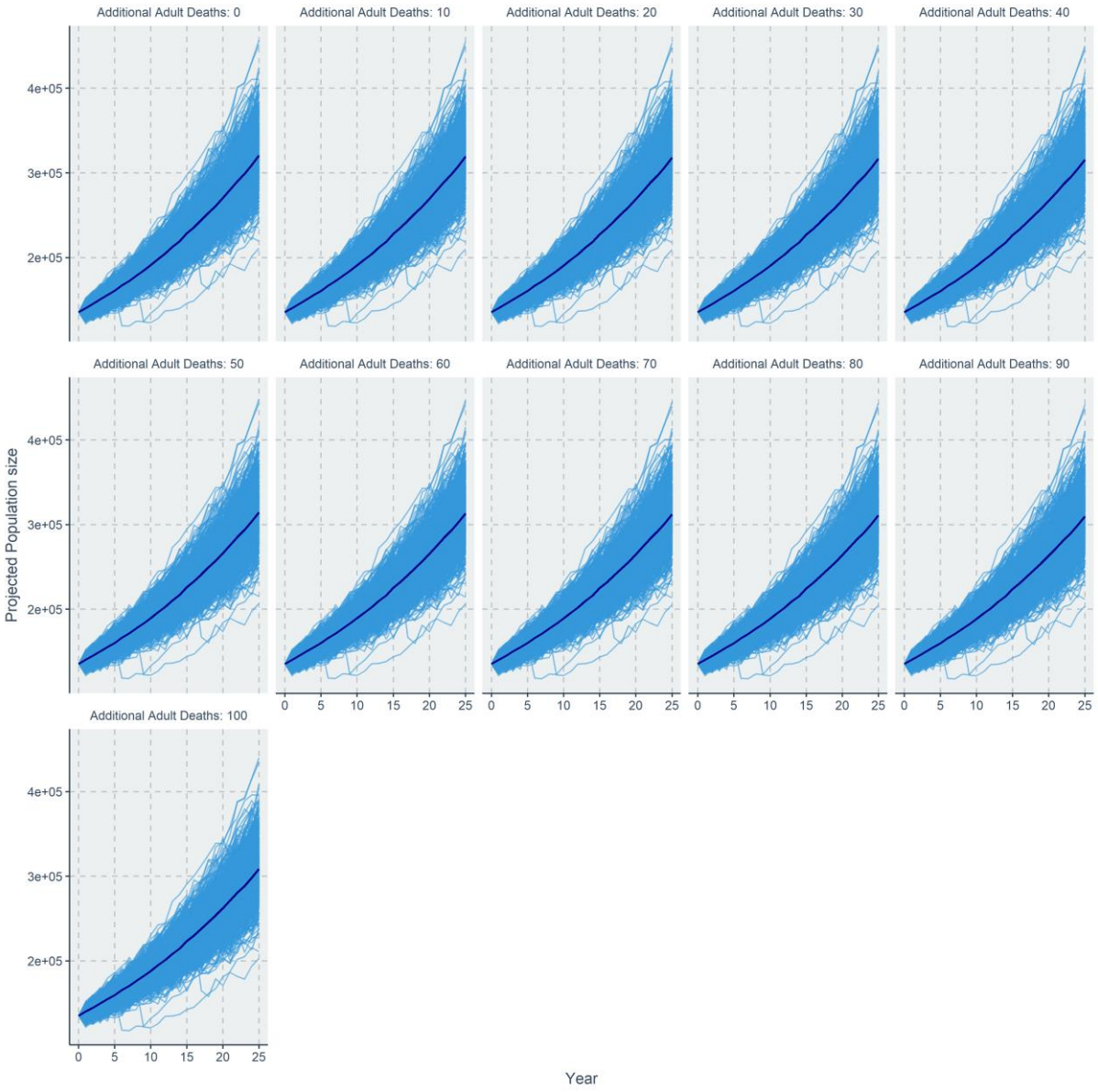

Figure 27: Guillemot at Fowlsheugh SPA – Projections of population sizes over a 25-year time-frame. Each plot represents a different impact scenario in terms of additional adult mortalities (starting at 0 i.e. unimpacted). Individual blue lines are different realisations of the population trajectory, when population parameters are sampled from their distributions. The dark blue line is the median at each time point.

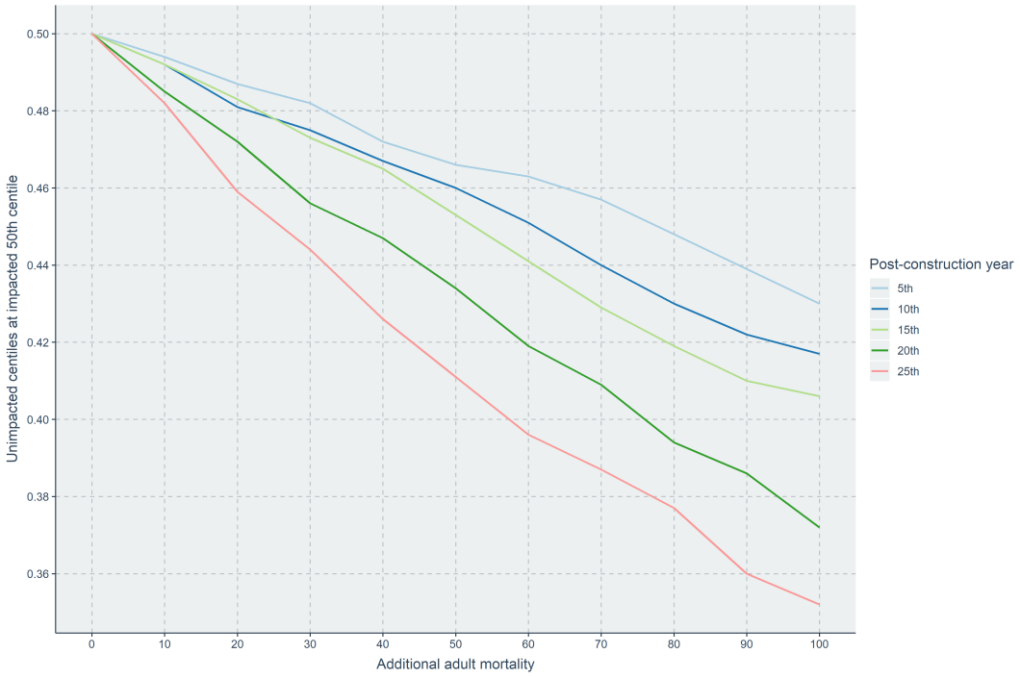

Figure 28: Guillemot at Fowlsheugh SPA – The median of the impacted population size as a centile of the unimpacted population size, under a range of impact scenarios (incremental additional adult deaths – x-axis). For example, 0.3 means the median (50th percentile) of the impacted projections sits at the 30th percentile of the unimpacted projections. Individual lines represent years post-construction (0-25 years).

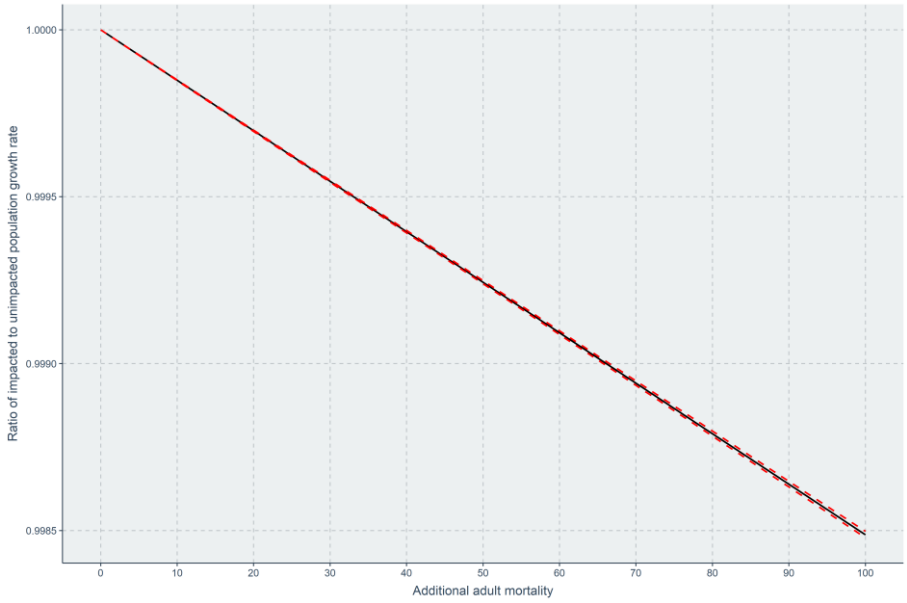

Figure 29: Guillemot at Fowlsheugh SPA – Ratio of impacted to unimpacted growth rates under a range of impact scenarios (incremental additional adult deaths – x-axis) i.e. 0.9 means a 10% decrease in the growth rate under the impact scenario. Figures are based on paired simulations for the impacted and unimpacted populations i.e. based on the same sampled population parameters. The black line represents the 50th percentile (median), red lines give the central 95% of simulated values (2.5% and 97.5% reference points).

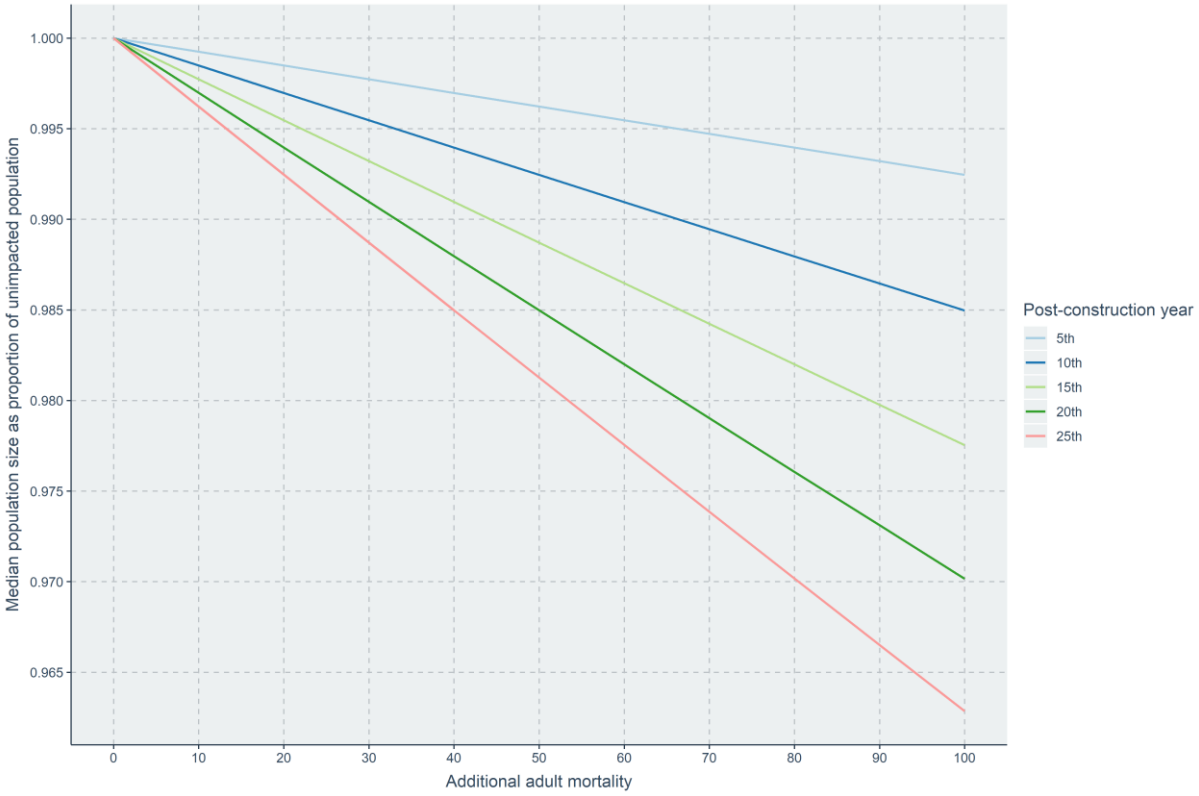

Figure 30: Guillemot at Fowlsheugh SPA – The median of the ratio of impacted to unimpacted population sizes from the simulations, for a range of impact scenarios i.e. 0.5 means the impacted population size is one-half the unimpacted population size. Impact scenarios, in terms of incremental additional adult deaths, are given on the x-axis. Individual lines represent post-construction time points (projected 5 – 25 years).

Table 22: Guillemot at Fowlsheugh SPA – Annual growth rates of simulated populations under a range of impact scenarios, for projections over 25 years. Reference points are the 2.5th, 50th (median) and 97.5th percentiles of the distribution of simulated growth rates. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median growth rates	2.5 percentile of simulated growth rates	97.5 percentile of simulated growth rates
0	0	1.035	1.026	1.044
10	18	1.035	1.026	1.044
20	36	1.035	1.026	1.044
30	55	1.035	1.025	1.044
40	73	1.035	1.025	1.044
50	91	1.035	1.025	1.044
60	109	1.034	1.025	1.043
70	127	1.034	1.025	1.043
80	146	1.034	1.025	1.043
90	164	1.034	1.025	1.043
100	182	1.034	1.024	1.043

Table 23: Guillemot at Fowlsheugh SPA – Median of predicted population sizes after a 25-year post-construction period for a range of impact scenarios. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median end-point population size at 25 years
0	0	320428
10	18	319218
20	36	318012
30	55	316811
40	73	315614
50	91	314422
60	109	313233
70	127	312050
80	146	310870
90	164	309695
100	182	308524

3.6.2 Specific mortality scenarios

Table 24: Guillemot at Fowlsheugh SPA - Relevant PVA metrics from models with impact scenarios for specific additional mortalities due to collisions and/or displacement effects

Impact	Scenario	Adults	Sub-Adults	Median Growth rate	Median end size at 25 years (individuals)	Median counterfactual of growth rates	Median counterfactual of population size at 25 years	Centile of unimpactacted matching the 50th centile of impacted
Baseline	**Unimpacted**	0	0	1.035	323713	1.000	1.000	0.500
Displacement	**Alpha**	38	32	1.035	319055	0.999	0.986	0.451
Displacement	**Bravo**	30	26	1.035	319992	1.000	0.988	0.457
Displacement	**A+B**	58	49	1.034	316621	0.999	0.978	0.407
Displacement	**A+B+F & T 2018**	89	88	1.034	312249	0.999	0.964	0.366

3.7 Guillemot –St Abb's Head to Fast Castle SPA

3.7.1 Incremental mortality scenarios

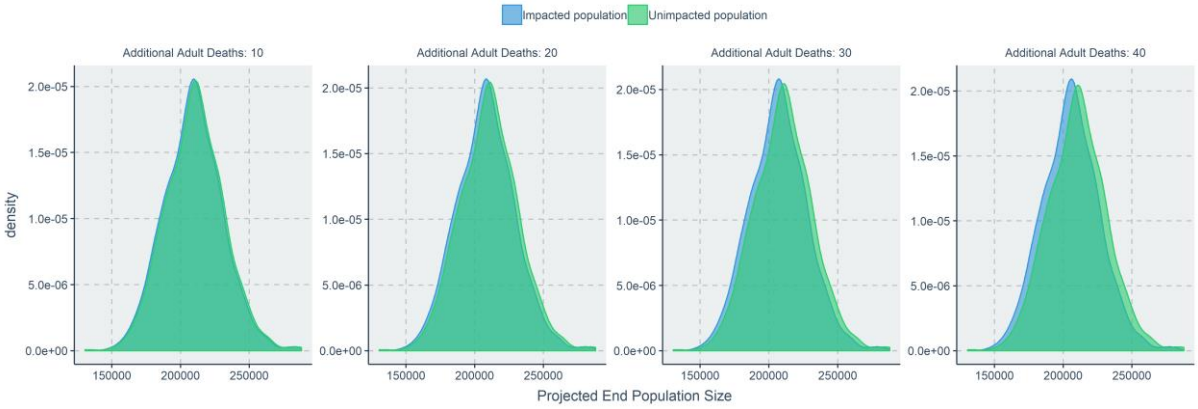

Figure 31: Guillemot at St Abb's Head to Fast Castle SPA – Density distributions of simulated population sizes after a 25-year post-construction period. Each plot represents a different impact scenario in terms of additional adult mortalities, together with the distribution of predicted unimpacted population sizes after 25 years.

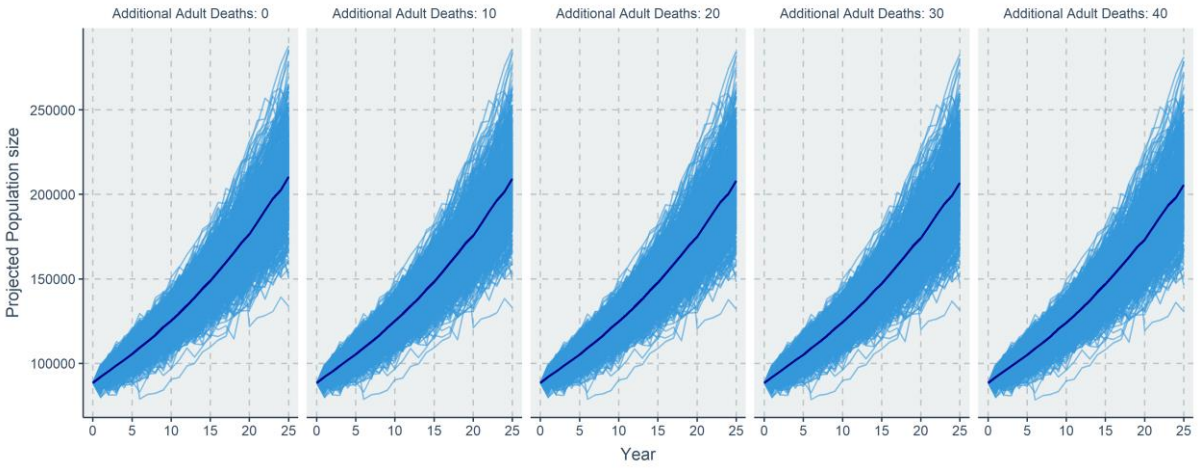

Figure 32: Guillemot at St Abb's Head to Fast Castle SPA – Projections of population sizes over a 25-year time-frame. Each plot represents a different impact scenario in terms of additional adult mortalities (starting at 0 i.e. unimpacted). Individual blue lines are different realisations of the population trajectory, when population parameters are sampled from their distributions. The dark blue line is the median at each time point.

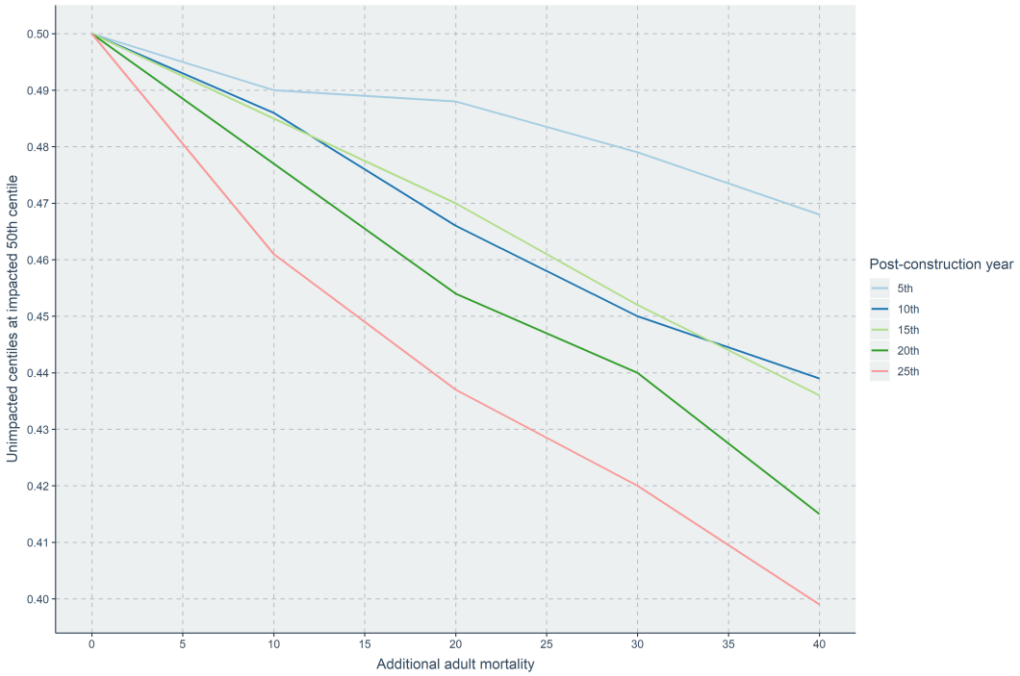

Figure 33: Guillemot at St Abb's Head to Fast Castle SPA – The median of the impacted population size as a centile of the unimpacted population size, under a range of impact scenarios (incremental additional adult deaths – x-axis). For example, 0.3 means the median (50th percentile) of the impacted projections sits at the 30th percentile of the unimpacted projections. Individual lines represent years post-construction (0-25 years).

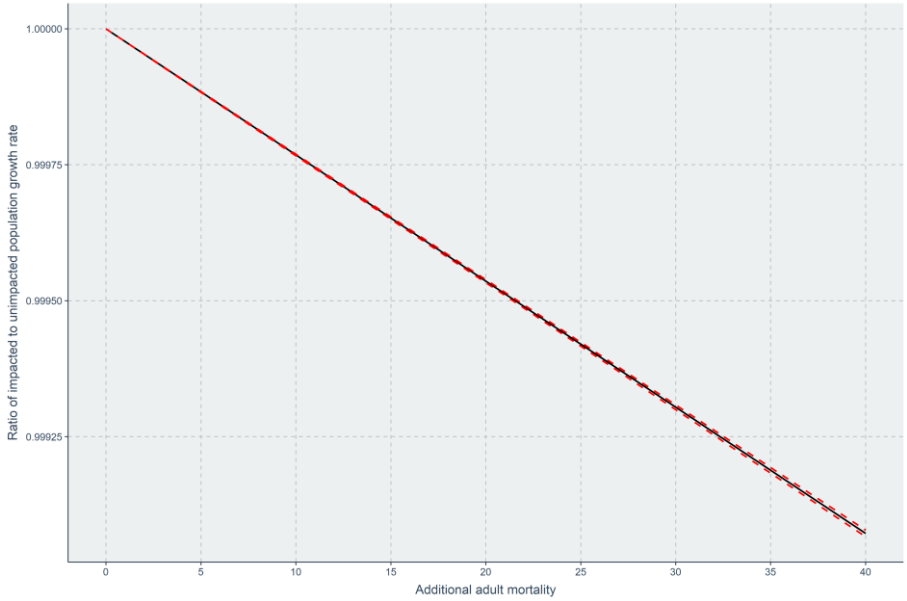

Figure 34: Guillemot at St Abb's Head to Fast Castle SPA – Ratio of impacted to unimpacted growth rates under a range of impact scenarios (incremental additional adult deaths – x-axis) i.e. 0.9 means a 10% decrease in the growth rate under the impact scenario. Figures are based on paired simulations for the impacted and unimpacted populations i.e. based on the same sampled population parameters. The black line represents the 50th percentile (median), red lines give the central 95% of simulated values (2.5% and 97.5% reference points).

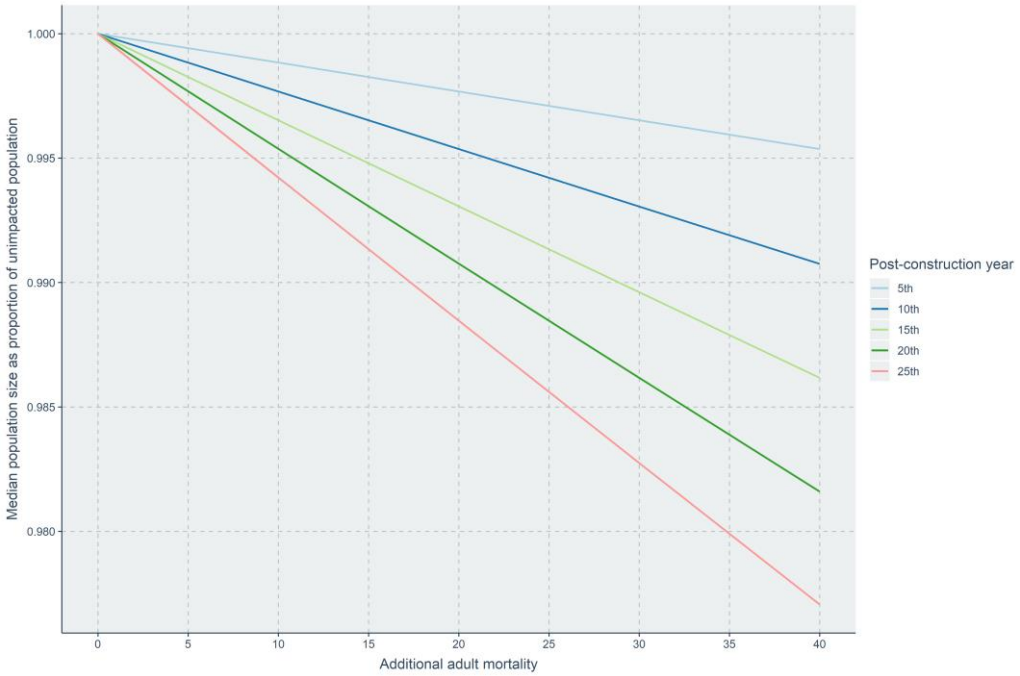

Figure 35: Guillemot at St Abb's Head to Fast Castle SPA – The median of the ratio of impacted to unimpacted population sizes from the simulations, for a range of impact scenarios i.e. 0.5 means the impacted population size is one-half the unimpacted population size. Impact scenarios, in terms of incremental additional adult deaths, are given on the x-axis. Individual lines represent post-construction time points (projected 5 – 25 years).

Table 25: Guillemot at St Abb's Head to Fast Castle SPA – Annual growth rates of simulated populations under a range of impact scenarios, for projections over 25 years. Reference points are the 2.5th, 50th (median) and 97.5th percentiles of the distribution of simulated growth rates. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median growth rates	2.5 percentile of simulated growth rates	97.5 percentile of simulated growth rates
0	0	1.035	1.025	1.044
10	18	1.035	1.024	1.044
20	36	1.035	1.024	1.044
30	55	1.034	1.024	1.043
40	73	1.034	1.024	1.043

Table 26: Guillemot at St Abb's Head to Fast Castle SPA – Median of predicted population sizes after a 25-year post-construction period for a range of impact scenarios. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median end-point population size at 25 years
0	0	210385
10	18	209168
20	36	207958
30	55	206754
40	73	205557

3.7.2 Specific mortality scenarios

Guillemot at St Abb's Head to Fast Castle SPA - Relevant PVA metrics from models with impact scenarios for specific additional mortalities due to collisions and/or displacement effects

Impact	Scenario	Adults	Sub-Adults	Median Growth rate	Median end size at 25 years (individuals)	Median counterfactual of growth rates	Median counterfactual of population size at 25 years	Centile of unimpactacted matching the 50th centile of impacted
Baseline	**Unimpacted**	0	0	1.035	209563	1.000	1.000	0.500
Displacement	**Alpha**	8	8	1.035	208517	1.000	0.995	0.486
Displacement	**Bravo**	7	5	1.035	208752	1.000	0.996	0.489
Displacement	**A+B**	13	11	1.035	207969	1.000	0.992	0.471
Displacement	**A+B+F & T 2018**	24	24	1.035	206439	0.999	0.985	0.440

3.8 Kittiwake – Forth Islands SPA

3.8.1 Incremental mortality scenarios

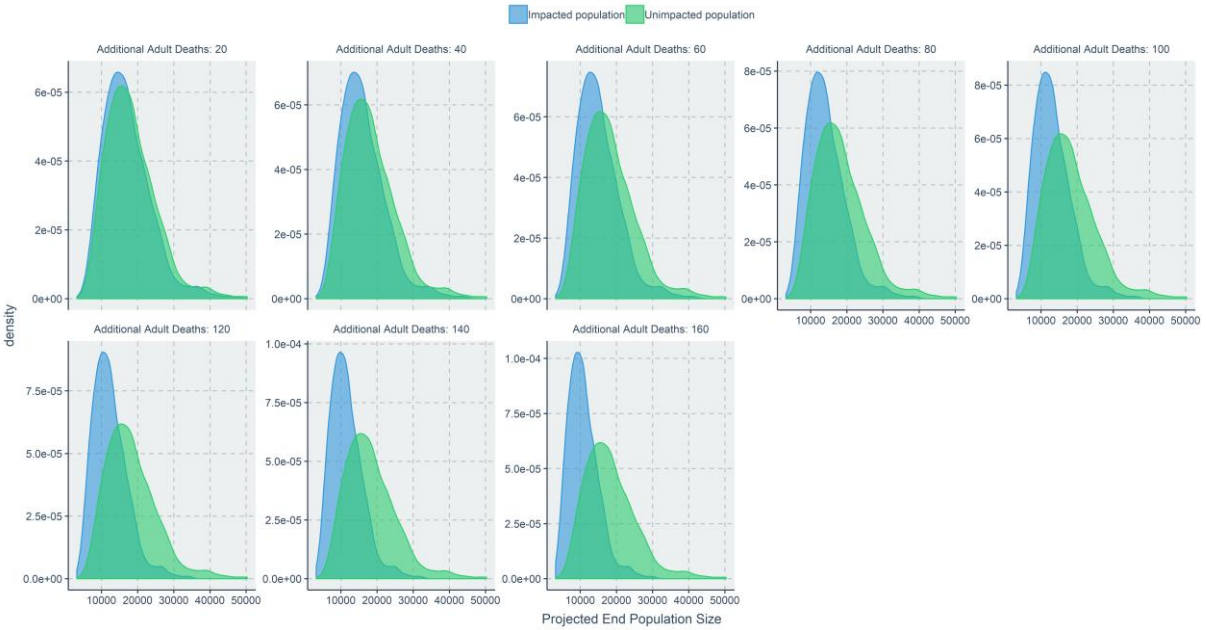

Figure 36: Kittiwake at Forth Islands SPA – Density distributions of simulated population sizes after a 25-year post-construction period. Each plot represents a different impact scenario in terms of additional adult mortalities, together with the distribution of predicted unimpacted population sizes after 25 years.

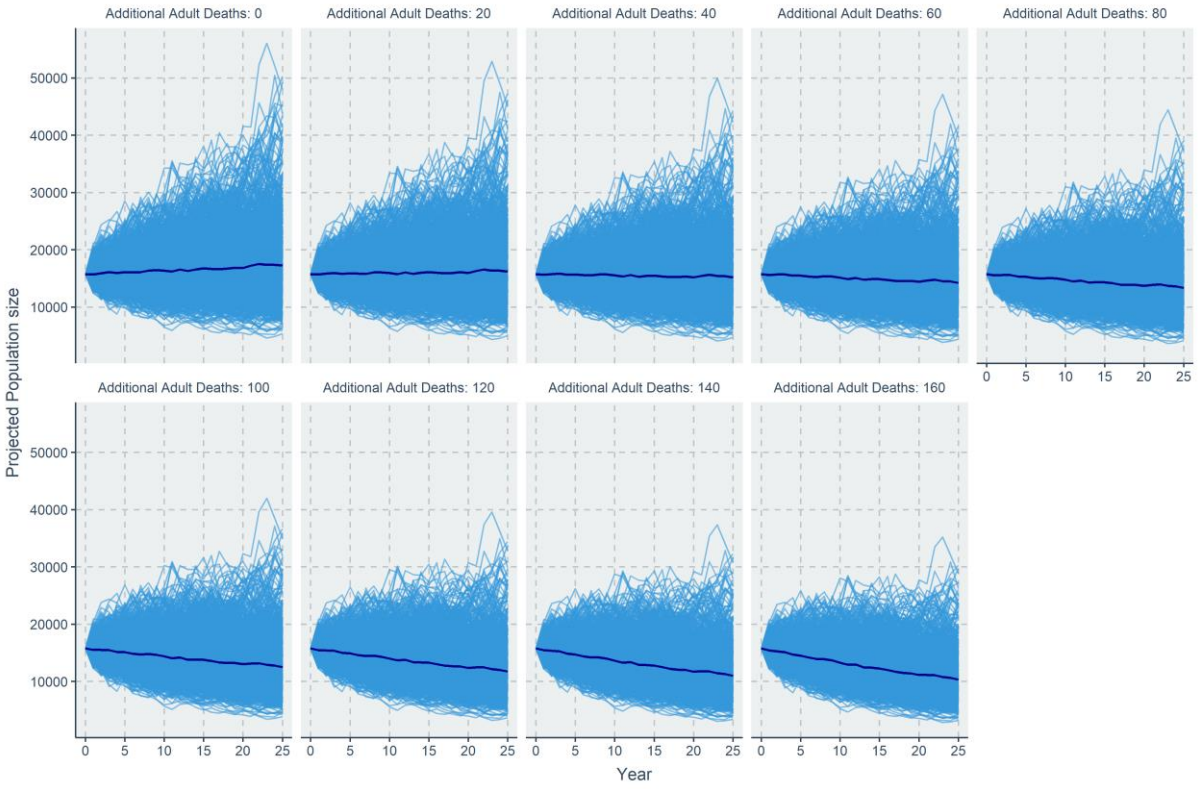

Figure 37: Kittiwake at Forth Islands SPA – Projections of population sizes over a 25-year time-frame. Each plot represents a different impact scenario in terms of additional adult mortalities (starting at 0 i.e. unimpacted). Individual blue lines are different realisations of the population trajectory, when population parameters are sampled from their distributions. The dark blue line is the median at each time point.

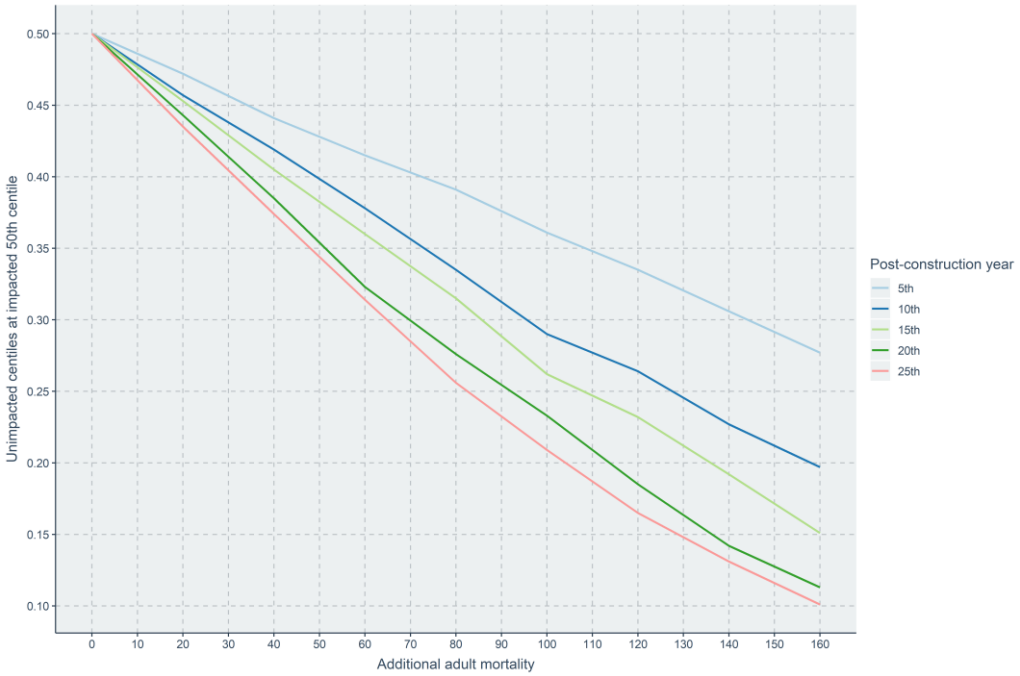

Figure 38: Kittiwake at Forth Islands SPA – The median of the impacted population size as a centile of the unimpacted population size, under a range of impact scenarios (incremental additional adult deaths – x-axis). For example, 0.3 means the median (50th percentile) of the impacted projections sits at the 30th percentile of the unimpacted projections. Individual lines represent years post-construction (0-25 years).

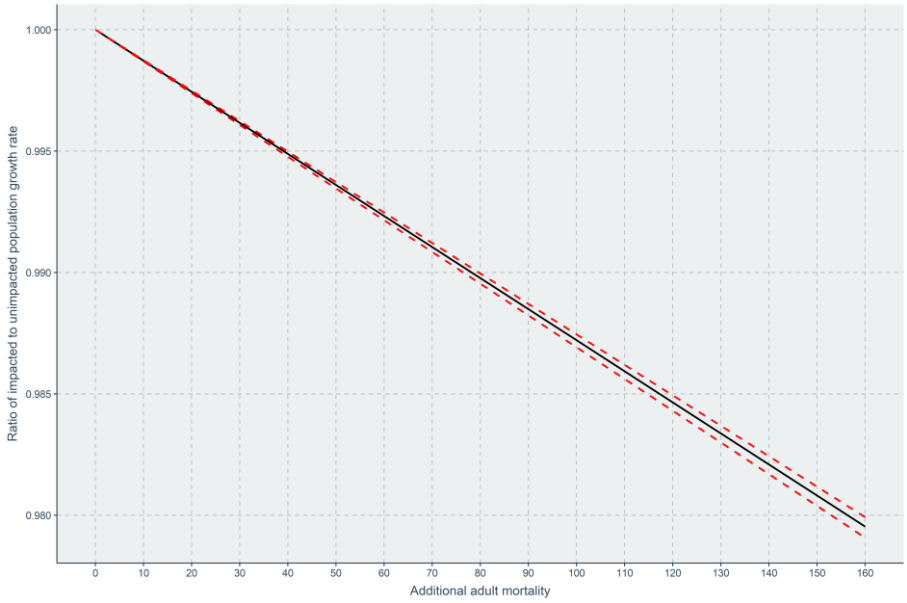

Figure 39: Kittiwake at Forth Islands SPA – Ratio of impacted to unimpacted growth rates under a range of impact scenarios (incremental additional adult deaths – x-axis) i.e. 0.9 means a 10% decrease in the growth rate under the impact scenario. Figures are based on paired simulations for the impacted and unimpacted populations i.e. based on the same sampled population parameters. The black line represents the 50th percentile (median), red lines give the central 95% of simulated values (2.5% and 97.5% reference points).

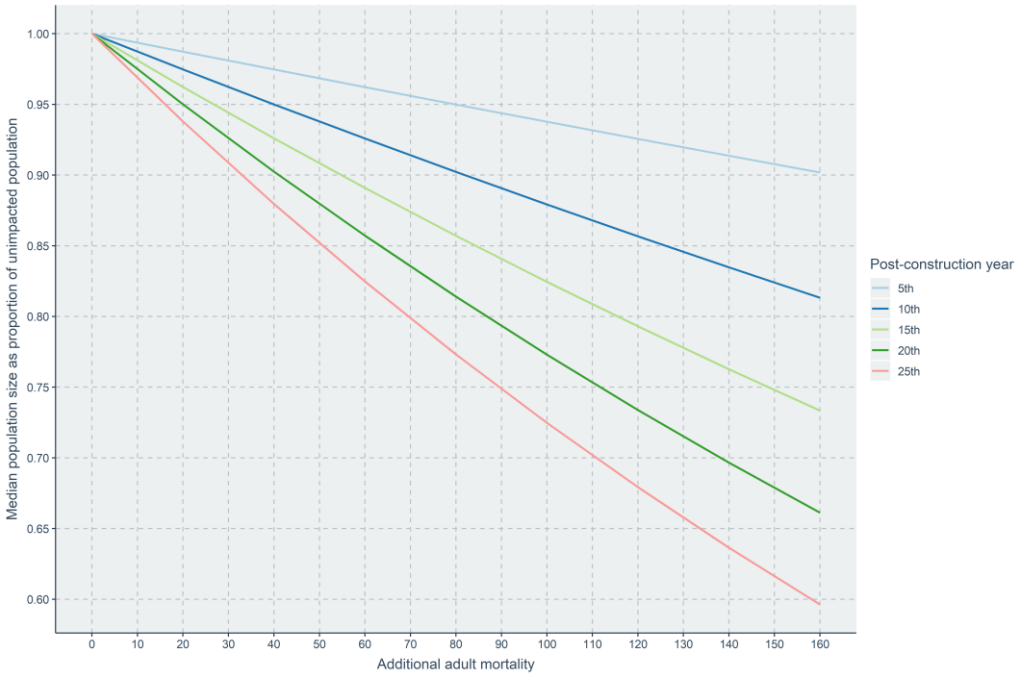

Figure 40: Kittiwake at Forth Islands SPA – The median of the ratio of impacted to unimpacted population sizes from the simulations, for a range of impact scenarios i.e. 0.5 means the impacted population size is one-half the unimpacted population size. Impact scenarios, in terms of incremental additional adult deaths, are given on the x-axis. Individual lines represent post-construction time points (projected 5 – 25 years).

Table 27: Kittiwake at Forth Islands SPA – Annual growth rates of simulated populations under a range of impact scenarios, for projections over 25 years. Reference points are the 2.5th, 50th (median) and 97.5th percentiles of the distribution of simulated growth rates. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median growth rates	2.5 percentile of simulated growth rates	97.5 percentile of simulated growth rates
0	0	1.003	0.972	1.036
20	34	1.000	0.969	1.034
40	68	0.998	0.967	1.031
60	101	0.995	0.964	1.029
80	135	0.992	0.962	1.026
100	169	0.990	0.959	1.023
120	203	0.987	0.957	1.021
140	236	0.985	0.954	1.018
160	270	0.982	0.951	1.015

Table 28: Kittiwake at Forth Islands SPA – Median of predicted population sizes after a 25-year post-construction period for a range of impact scenarios. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median end-point population size at 25 years
0	0	17245
20	34	16177
40	68	15174
60	101	14231
80	135	13345
100	169	12512
120	203	11729
140	236	10993
160	270	10301

3.8.2 Specific mortality scenarios

Table 29: Kittiwake at Forth Islands SPA - Relevant PVA metrics from models with impact scenarios for specific additional mortalities due to collisions and/or displacement effects

Impact	Scenario	Adults	Sub-Adults	Median Growth rate	Median end size at 25 years (individuals)	Median counterfactual of growth rates	Median counterfactual of population size at 25 years	Centile of unimpactacted matching the 50th centile of impacted
Baseline	**Unimpacted**	0	0	1.004	17131	1.000	1.000	0.500
Collision	**Alpha**	6	1	1.003	16882	0.999	0.986	0.479
Collision	**Bravo**	5	1	1.003	16919	1.000	0.988	0.480
Collision	**A+B**	9	1	1.003	16772	0.999	0.979	0.472
Collision	**A+B+F & T 2018**	20	3	1.002	16326	0.998	0.953	0.440
Collision	**A+B+F & T 2014**	49	4	0.999	15307	0.996	0.893	0.371
Collision	**A+B+F& T 2014 + NSea**	57	7	0.998	14974	0.995	0.874	0.348
Collision + Displacement	**Alpha**	8	1	1.003	16809	0.999	0.981	0.475
Collision + Displacement	**Bravo**	7	1	1.003	16845	0.999	0.983	0.478
Collision + Displacement	**A+B**	12	2	1.003	16637	0.999	0.971	0.463
Collision + Displacement	**A+B+F & T 2014**	64	5	0.998	14793	0.994	0.863	0.338
Collision + Displacement	**A+B+F & T 2014 + NSea**	70	8	0.997	14534	0.993	0.848	0.326

3.9 Kittiwake – Fowlsheugh SPA

3.9.1 Incremental mortality scenarios

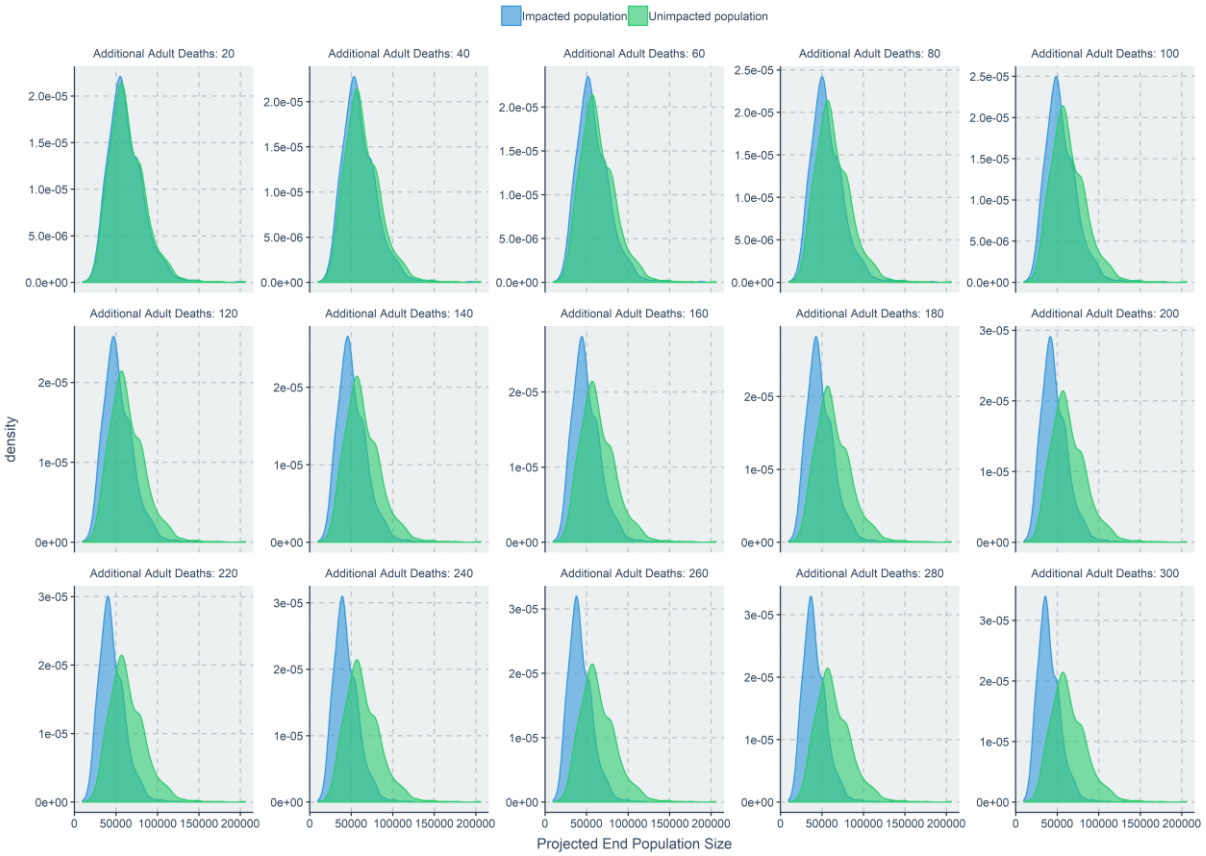

Figure 41: Kittiwake at Fowlsheugh SPA – Density distributions of simulated population sizes after a 25-year post-construction period. Each plot represents a different impact scenario in terms of additional adult mortalities, together with the distribution of predicted unimpacted population sizes after 25 years.

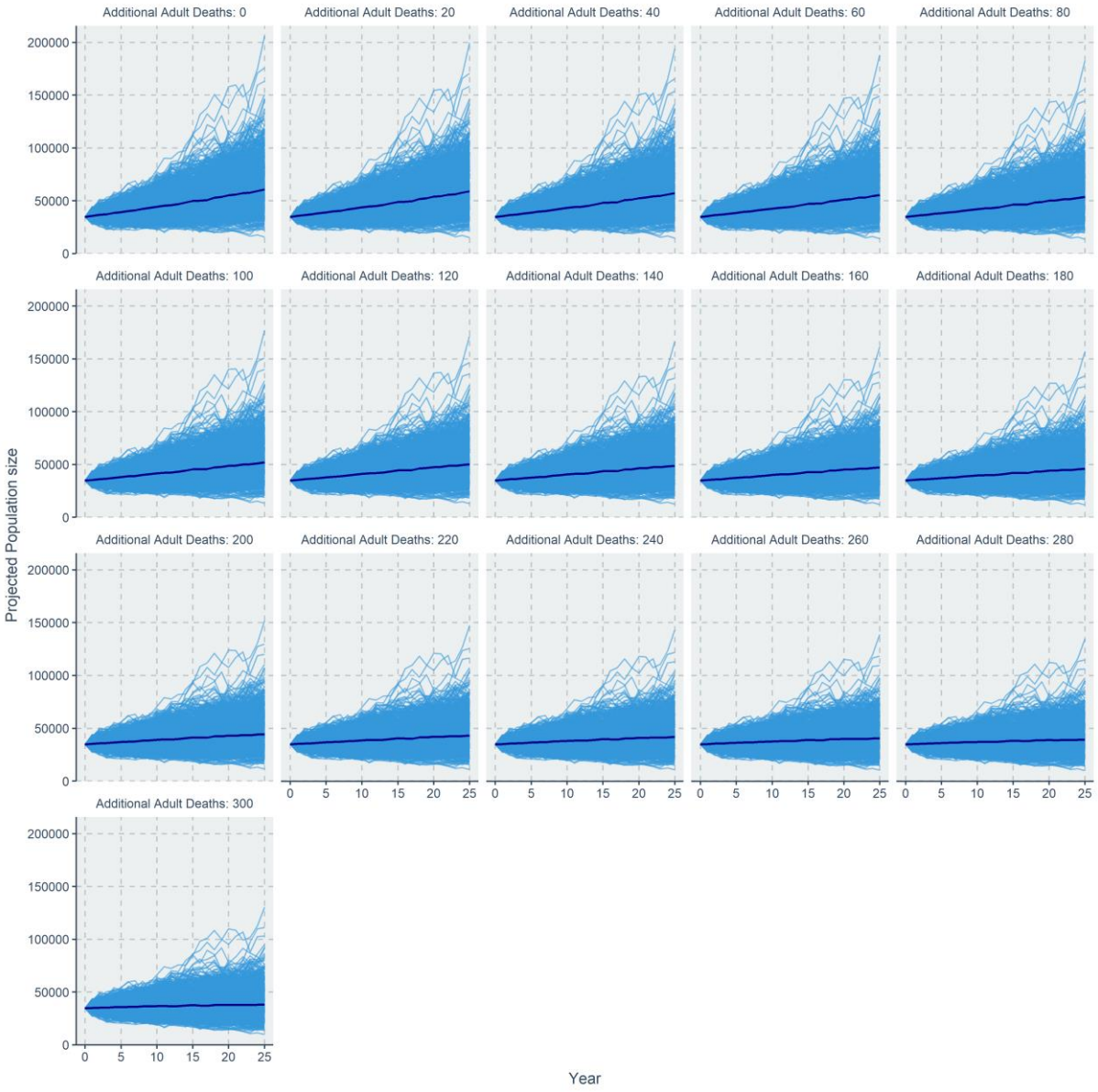

Figure 42: Kittiwake at Fowlsheugh SPA – Projections of population sizes over a 25-year time-frame. Each plot represents a different impact scenario in terms of additional adult mortalities (starting at 0 i.e. unimpacted). Individual blue lines are different realisations of the population trajectory, when population parameters are sampled from their distributions. The dark blue line is the median at each time point.

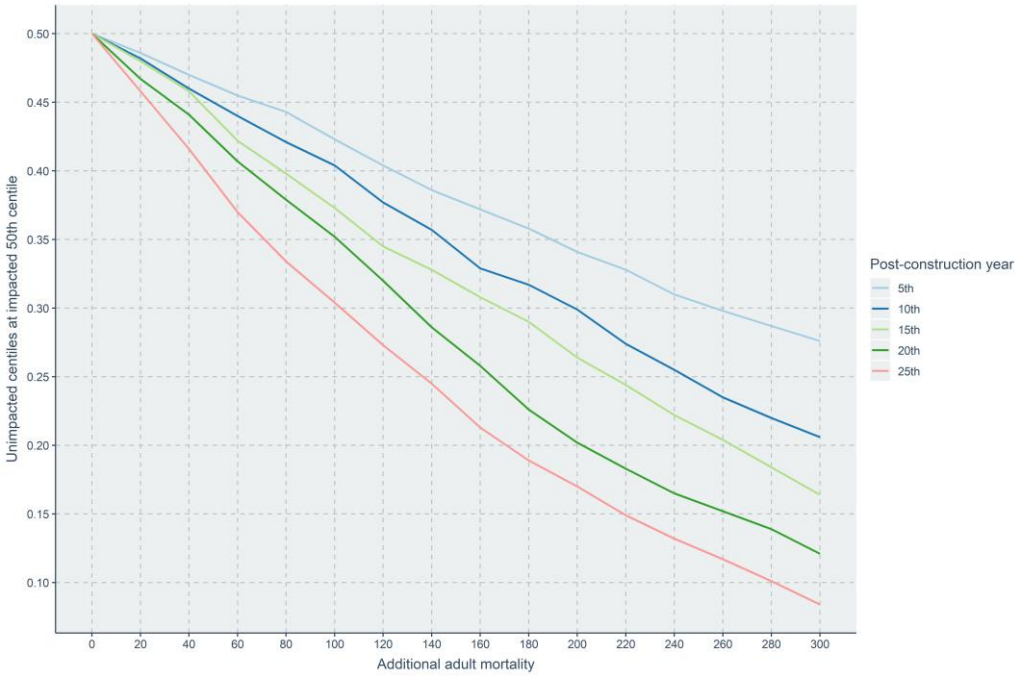

Figure 43: Kittiwake at Fowlsheugh SPA – The median of the impacted population size as a centile of the unimpacted population size, under a range of impact scenarios (incremental additional adult deaths – x-axis). For example, 0.3 means the median (50th percentile) of the impacted projections sits at the 30th percentile of the unimpacted projections. Individual lines represent years post-construction (0-25 years).

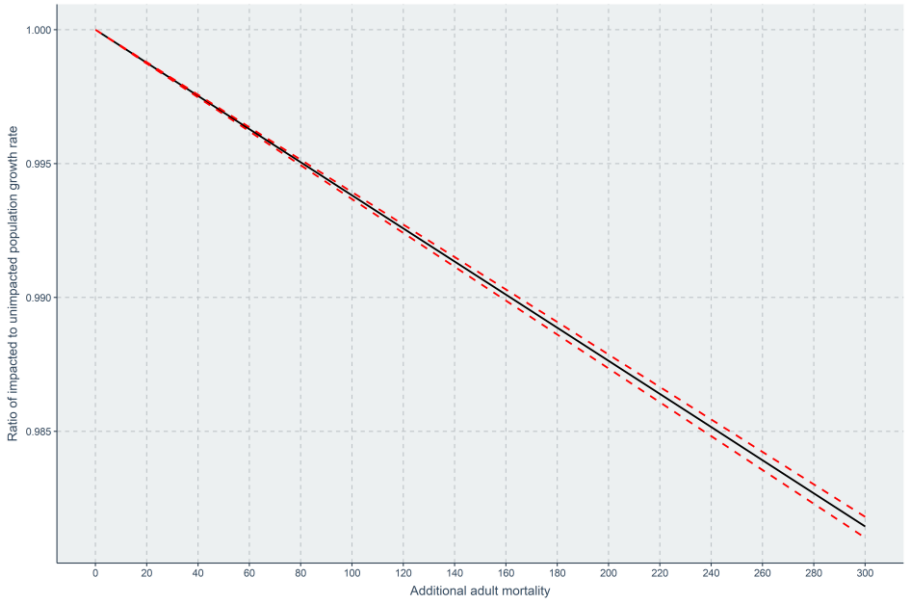

Figure 44: Kittiwake at Fowlsheugh SPA – Ratio of impacted to unimpacted growth rates under a range of impact scenarios (incremental additional adult deaths – x-axis) i.e. 0.9 means a 10% decrease in the growth rate under the impact scenario. Figures are based on paired simulations for the impacted and unimpacted populations i.e. based on the same sampled population parameters. The black line represents the 50th percentile (median), red lines give the central 95% of simulated values (2.5% and 97.5% reference points).

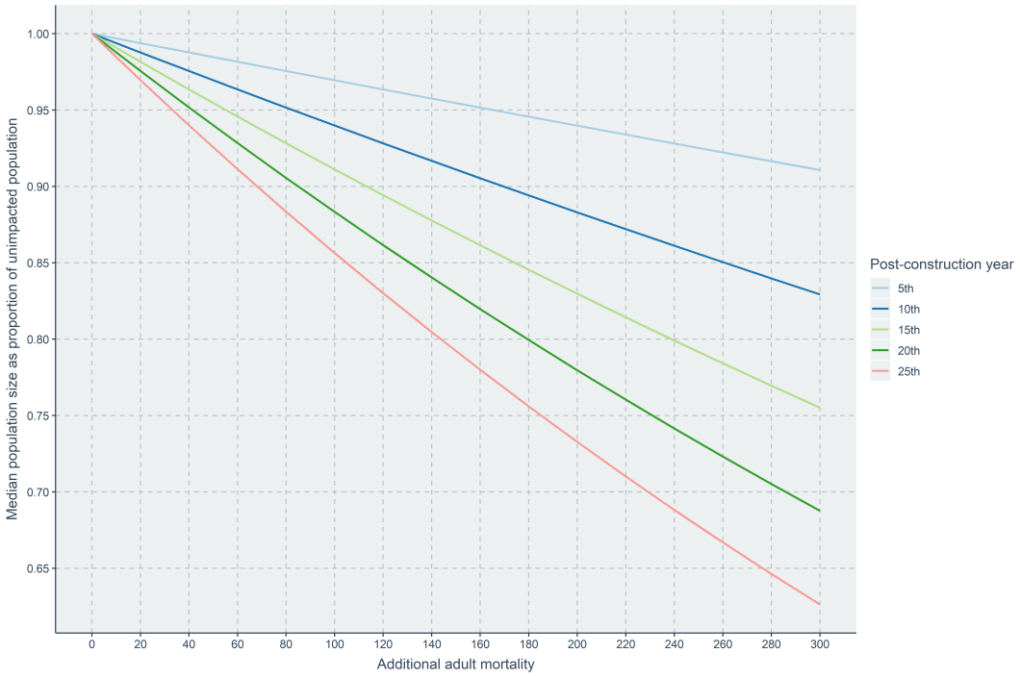

Figure 45: Kittiwake at Fowlsheugh SPA – The median of the ratio of impacted to unimpacted population sizes from the simulations, for a range of impact scenarios i.e. 0.5 means the impacted population size is one-half the unimpacted population size. Impact scenarios, in terms of incremental additional adult deaths, are given on the x-axis. Individual lines represent post-construction time points (projected 5 – 25 years).

Table 30: Kittiwake at Fowlsheugh SPA – Annual growth rates of simulated populations under a range of impact scenarios, for projections over 25 years. Reference points are the 2.5th, 50th (median) and 97.5th percentiles of the distribution of simulated growth rates. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median growth rates	2.5 percentile of simulated growth rates	97.5 percentile of simulated growth rates
0	0	1.023	0.992	1.053
20	36	1.022	0.991	1.052
40	72	1.021	0.990	1.051
60	108	1.019	0.988	1.049
80	144	1.018	0.987	1.048
100	180	1.017	0.986	1.047
120	216	1.016	0.984	1.045
140	251	1.014	0.983	1.044
160	287	1.013	0.982	1.043
180	323	1.012	0.981	1.042
200	359	1.011	0.979	1.040
220	395	1.009	0.978	1.039
240	431	1.008	0.977	1.038
260	467	1.007	0.976	1.037
280	503	1.005	0.974	1.035
300	539	1.004	0.973	1.034

Table 31: Kittiwake at Fowlsheugh SPA – Median of predicted population sizes after a 25-year post-construction period for a range of impact scenarios. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median end-point population size at 25 years
0	0	60640
20	36	58792
40	72	56999
60	108	55259
80	144	53550
100	180	51903
120	216	50304
140	251	48753
160	287	47254
180	323	45807
200	359	44390
220	395	43016
240	431	41682
260	467	40397
280	503	39144
300	539	37926

3.9.2 Specific mortality scenarios

Table 32: Kittiwake at Fowlsheugh SPA - Relevant PVA metrics from models with impact scenarios for specific additional mortalities due to collisions and/or displacement effects

Impact	Scenario	Adults	Sub-Adults	Median Growth rate	Median end size at 25 years (individuals)	Median counterfactual of growth rates	Median counterfactual of population size at 25 years	Centile of unimpactacted matching the 50th centile of impacted
Baseline	**Unimpacted**	0	0	1.023	60786	1.000	1.000	0.500
Collision	**Alpha**	28	3	1.022	58969	0.999	0.970	0.461
Collision	**Bravo**	24	2	1.022	59248	0.999	0.975	0.465
Collision	**A+B**	40	5	1.021	58179	0.998	0.957	0.445
Collision	**A+B+F & T 2018**	51	6	1.021	57496	0.998	0.946	0.428
Collision	**A+B+F & T 2014**	80	9	1.019	55719	0.997	0.916	0.406
Collision	**A+B+F& T 2014 + NSea**	98	17	1.018	54416	0.996	0.895	0.380
Collision + Displacement	**Alpha**	36	4	1.021	58455	0.998	0.961	0.452
Collision + Displacement	**Bravo**	31	3	1.022	58791	0.999	0.967	0.460
Collision + Displacement	**A+B**	52	6	1.021	57438	0.998	0.945	0.428
Collision + Displacement	**A+B+F & T 2014**	98	10	1.019	54674	0.996	0.899	0.388
Collision + Displacement	**A+B+F & T 2014 + NSea**	116	19	1.018	53359	0.995	0.877	0.368

3.10 Kittiwake – St Abb's Head to Fast Castle SPA

3.10.1 Incremental mortality scenarios

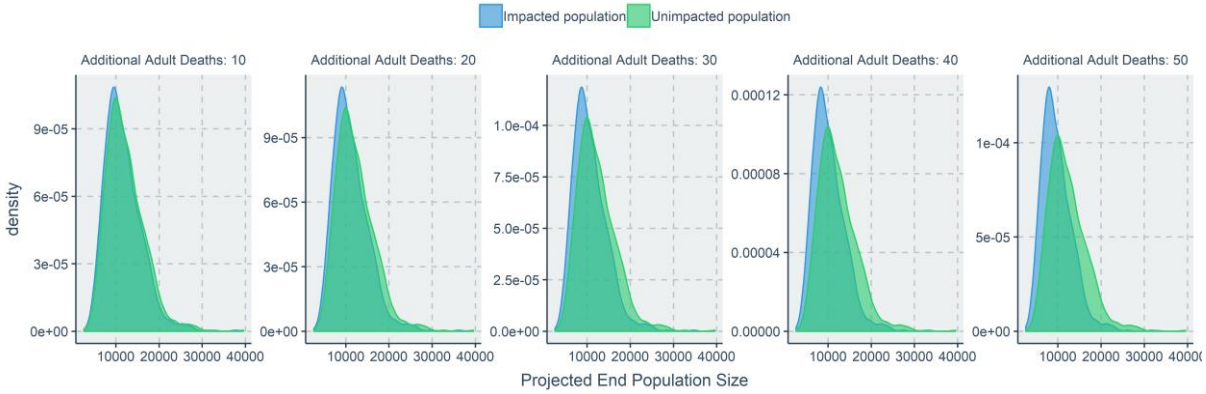

Figure 46: Kittiwake at St Abb's Head to Fast Castle SPA – Density distributions of simulated population sizes after a 25-year post-construction period. Each plot represents a different impact scenario in terms of additional adult mortalities, together with the distribution of predicted unimpacted population sizes after 25 years.

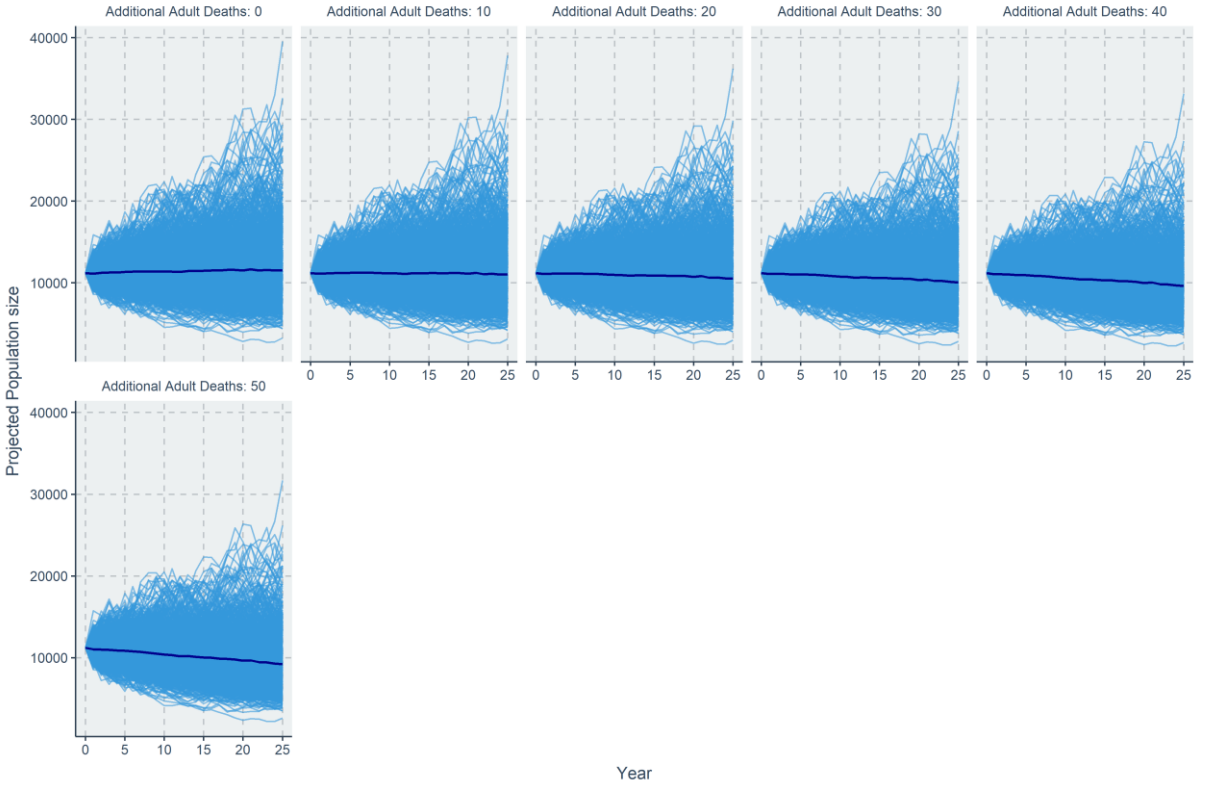

Figure 47: Kittiwake at St Abb's Head to Fast Castle SPA – Projections of population sizes over a 25-year time-frame. Each plot represents a different impact scenario in terms of additional adult mortalities (starting at 0 i.e. unimpacted). Individual blue lines are different realisations of the population trajectory, when population parameters are sampled from their distributions. The dark blue line is the median at each time point.

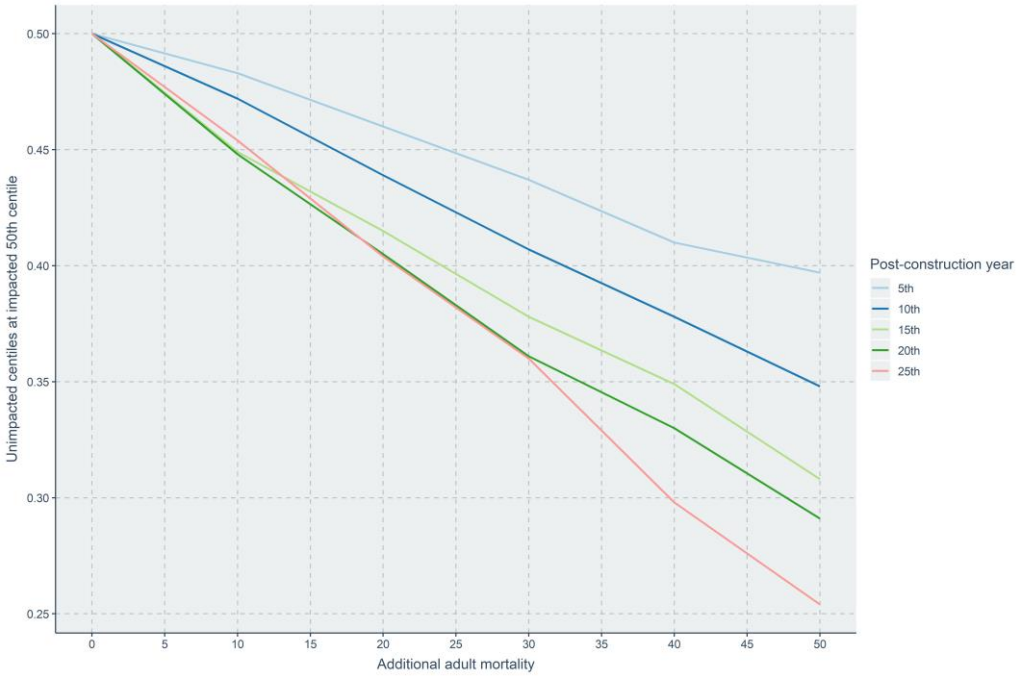

Figure 48: Kittiwake at St Abb's Head to Fast Castle SPA – The median of the impacted population size as a centile of the unimpacted population size, under a range of impact scenarios (incremental additional adult deaths – x-axis). For example, 0.3 means the median (50th percentile) of the impacted projections sits at the 30th percentile of the unimpacted projections. Individual lines represent years post-construction (0-25 years).

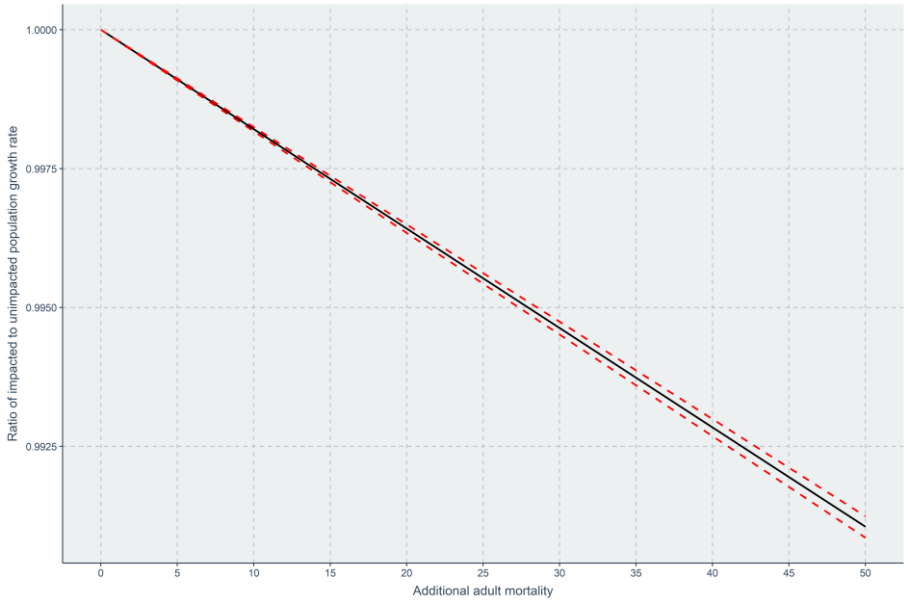

Figure 49: Kittiwake at St Abb's Head to Fast Castle SPA – Ratio of impacted to unimpacted growth rates under a range of impact scenarios (incremental additional adult deaths – x-axis) i.e. 0.9 means a 10% decrease in the growth rate under the impact scenario. Figures are based on paired simulations for the impacted and unimpacted populations i.e. based on the same sampled population parameters. The black line represents the 50th percentile (median), red lines give the central 95% of simulated values (2.5% and 97.5% reference points).

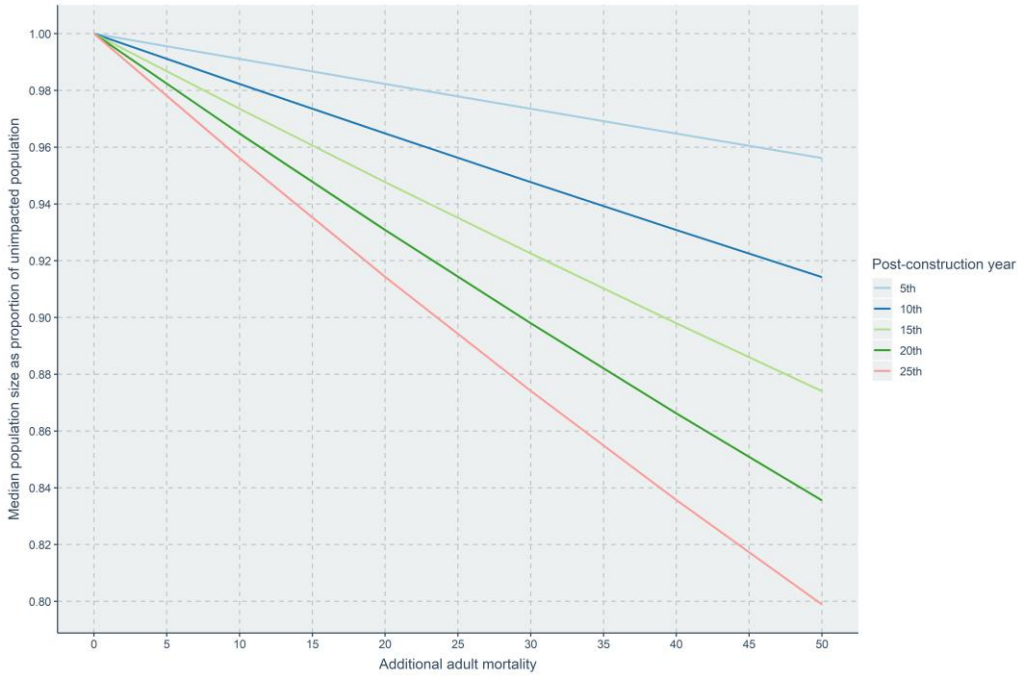

Figure 50: Kittiwake at St Abb's Head to Fast Castle SPA – The median of the ratio of impacted to unimpacted population sizes from the simulations, for a range of impact scenarios i.e. 0.5 means the impacted population size is one-half the unimpacted population size. Impact scenarios, in terms of incremental additional adult deaths, are given on the x-axis. Individual lines represent post-construction time points (projected 5 – 25 years).

Table 33: Kittiwake at St Abb's Head to Fast Castle SPA – Annual growth rates of simulated populations under a range of impact scenarios, for projections over 25 years. Reference points are the 2.5th, 50th (median) and 97.5th percentiles of the distribution of simulated growth rates. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median growth rates	2.5 percentile of simulated growth rates	97.5 percentile of simulated growth rates
0	0	1.000	0.971	1.032
10	17	0.999	0.969	1.030
20	34	0.997	0.967	1.028
30	50	0.995	0.966	1.027
40	67	0.993	0.964	1.025
50	84	0.991	0.962	1.023

Table 34: Kittiwake at St Abb's Head to Fast Castle SPA – Median of predicted population sizes after a 25-year post-construction period for a range of impact scenarios. Each impact scenario expressed as additional adult deaths, and corresponding additional total deaths, in the starting year.

Additional adult mortalities	Additional total mortalities	Median end-point population size at 25 years
0	0	11496
10	17	10992
20	34	10509
30	50	10047
40	67	9608
50	84	9187

3.10.2 Specific mortality scenarios

Table 35: Kittiwake at St Abb's Head to Fast Castle SPA - Relevant PVA metrics from models with impact scenarios for specific additional mortalities due to collisions and/or displacement effects

Impact	Scenario	Adults	Sub-Adults	Median Growth rate	Median end size at 25 years (individuals)	Median counterfactual of growth rates	Median counterfactual of population size at 25 years	Centile of unimpactacted matching the 50th centile of impacted
Baseline	**Unimpacted**	0	0	1.001	11358	1.000	1.000	0.500
Collision	**Alpha**	3	1	1.000	11231	1.000	0.989	0.485
Collision	**Bravo**	3	0	1.000	11254	1.000	0.991	0.491
Collision	**A+B**	4	1	1.000	11196	0.999	0.986	0.484
Collision	**A+B+F & T 2018**	8	1	1.000	11059	0.999	0.974	0.469
Collision	**A+B+F & T 2014**	16	3	0.998	10747	0.998	0.946	0.442
Collision	**A+B+F& T 2014 + NSea**	21	6	0.998	10518	0.997	0.926	0.413
Collision + Displacement	**Alpha**	4	1	1.000	11196	0.999	0.986	0.484
Collision + Displacement	**Bravo**	4	1	1.000	11196	0.999	0.986	0.484
Collision + Displacement	**A+B**	6	1	1.000	11127	0.999	0.980	0.475
Collision + Displacement	**A+B+F & T 2014**	19	2	0.998	10671	0.998	0.940	0.432
Collision + Displacement	**A+B+F & T 2014 + NSea**	25	6	0.997	10390	0.996	0.915	0.398

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