Cumulative Impact Assessment of East Coast Offshore Windfarm Construction on Bottlenose Dolphin and Grey Seals

Hazel Smith
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Introduction

Windfarm construction can impact marine mammals primarily as a result of the underwater noise generated by the installation of the foundation. Mitigation is available to prevent death and injury, but the wider constructions of disturbance is unclear. Potential consequences for extended or repeated disturbance for marine mammals include behavioural and physiological changes that can affect the health and vital rates of the individual animals which then could translate to population effects. There are two major clusters of windfarm development on the Scottish east coast. The Moray Firth has already seen the construction of the Beatrice Offshore wind farm this year and Moray East is progressing to build out. Other applications are anticipated and consented, leaving a question as to how cumulative impact assessment will be undertaken. These major developments, with hundreds of large offshore wind turbines, individually have the potential to input construction noise over tens of kilometres and taken cumulatively, potentially over a number of years for each project. Cumulative assessment of these projects is difficult. Each developer is required to consider the impact of their development in conjunction with all other developments (consented and proposed). Whilst we (SNH) have advised consistency in methods, often this is not realized, due to differing timeframes for submission and reluctance to share data due to commercial sensitivities. This means that the cumulative assessment is not always done consistently, which results in variable conclusions.

This project will assess cumulative assessment in an independent and as consistent an approach as is possible with the available data. Currently the only tool available to consider cumulative impact from disturbance is the Interim PCoD model developed by SMRU. This paper focusses on the cumulative potential population impacts to bottlenose dolphin (Moray Firth SAC) and grey seal (Isle of May SAC)

Methods

We carried out a cumulative impact assessment for the Coastal East Coast Management Unit bottlenose dolphin population using iPCoD ver 4.1. The following projects were considered within the Cumulative Impact Assessment

- Beatrice Offshore Wind Farm (BOWL)
- Aberdeen Harbour Expansion Plan
- Moray East Offshore Wind Farm
- Neart na Gaoithe Offshore Wind Farm
- Inch Cape Offshore Wind Farm
- Seagreen Offshore Wind Farm (Projects Alpha + Bravo)
- Moray West Offshore Wind Farm

We also carried out a cumulative impact assessment for grey seals, focussing on the grey seal population within the East Coast Management Area. This incorporates the Forth and Tay as shown in Figure 1. The cumulative impact assessment for grey seals only considered projects located within this region (Neart na Gaoithe, Inch Cape and Seagreen). Aberdeen Harbour Expansion Project was not included in the cumulative impact assessment for grey seals, despite being located in the East Coast Management Unit, due to the lack of data available for this project.

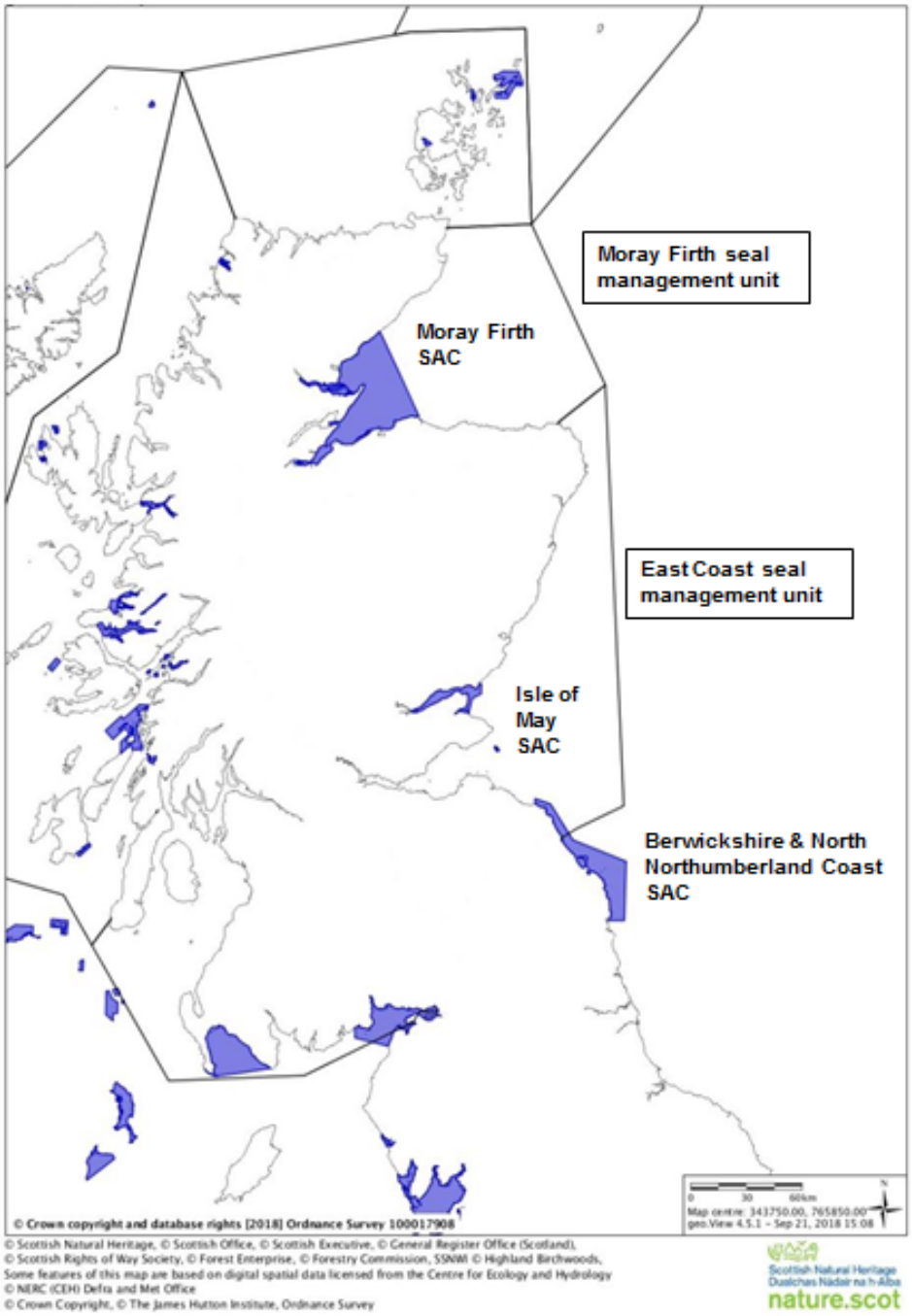

Figure 1: Map of grey seal management units

A pile-driving schedule was created for each project. The pile driving schedule for BOWL was created according to the actual construction timeline (Tables 1 & 2). Pile driving schedules for all other projects were based on the proposed development dates and the estimated number of days of piling.

The number of animals predicted to experience disturbance and PTS on each day of piling at each project were taken from the relevant impact assessment (Table 1). Each developer presents the number of animals experiencing disturbance under a number of different scenarios. Some developers present the number of animals disturbed using one vessel alone or two vessels concurrently. Some developers also present the number of animals disturbed using either monopiles or pinpiles.

The worst case scenario for each development was determined by carrying out an initial assessment for each individual project using the iPCoD model. The worst case scenarios for each project are shown in Table 1, alongside the number of individuals predicted to experience disturbance and PTS under each scenario.

It is important to note that different developers have assumed different density estimates of animals. The number of animals predicted to experience disturbance is therefore not directly comparable between all operations. However, it is difficult to convert all estimates on to the same scale. Values were therefore taken directly from the reports and no conversion factors were applied.

				Predicted number of animals that will experience PTS on each days of piling		**Predicted number of animals that will experience disturbance on each day of piling**	
Project	**Start Date**	**End Date**	**Number of Days of Piling**	**BND**	**GS (Forth and Tay Only)**	**BND**	**GS (Forth and Tay Only)**
BOWL	02/04/2017	02/12/2017	102	0	NA	19	NA
AHEP	15/09/2018	18/06/2019	36	0	NA	4	NA
Moray East - Single Vessel	01/04/2019	10/06/2020	134	0	NA	17	NA
Neart na Gaoithe - Single Vessel	01/07/2021	30/09/2022	54	0	1	2	821
Inch Cape - Monopiles - Single Vessel	12/03/2021	17/10/2021	74	0	0	7	1058
Seagreen Alpha - Pinpiles - Single Vessel	03/01/2022	29/12/2022	140	0	0	3	27
Seagreen Bravo - Pinpiles - Single Vessel	06/01/2023	29/12/2023	100	0	0	2	14
Moray West - Pin Piles - Single Vessel	01/04/2022	05/02/2023	133	0	NA	10	NA

Table 1: Construction timeline and number of individuals predicted to experience PTS and disturbance for each project. The table shows the worst case scenario for each project, determined by carrying out an initial assessment for each individual project using the iPCoD model.

Date		BOWL	AHEP	**Moray East -** Single Vessel	**NNG -** Single Vessel	**Inch Cape** - Monopiles - Single Vessel	**Seagreen A** - Pinpile - Single Vessel	**Seagreen B** - Pinpile - Single Vessel	**Moray West** - Pinpiles - Single Vessel
2017	**Q1**								
	Q2								
	Q3								
	Q4								
2018	**Q1**								
	Q2								
	Q3								
	Q4								
2019	**Q1**								
	Q2								
	Q3								
	Q4								
2020	**Q1**								
	Q2								
	Q3								
	Q4								
2021	**Q1**								
	Q2								
	Q3								
	Q4								
2022	**Q1**								
	Q2								
	Q3								
	Q4								
2023	**Q1**								
	Q2								
	Q3								
	Q4								

Table 2: Chart illustrating the construction period for each project

Sensitivity Analysis

We carried out a number of different cumulative impact assessments in order to allow us to examine the impact of unknown parameters.

Key Unknowns:

- Whether animals experience 0 or 1 day of residual disturbance.
- Whether animals avoid operations whilst experiencing residual disturbance or if animals can be re-disturbed within a period of residual disturbance.
- For bottlenose dolphins, whether it is worst case to assume 100% population is vulnerable to disturbance from all developments, or if the population should be split 50% vulnerable to the Moray Firth developments and 50% to the Forth and Tay developments.

In order to allow us to determine the effect of these unknown parameters on the model results, a total of 6 cumulative impact assessments were run for bottlenose dolphins and 3 for grey seals. A summary of the main differences between each scenario is provided in Tables 3 and 4 for bottlenose dolphins and grey seals respectively. Full sets of parameters used in each scenario are shown in the Appendix.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Number of Days of Residual Disturbance	1	1	0	1	1	0
Do animals avoid operations during a period of residual disturbance?	No	Yes	No	No	Yes	No
Population Structure	All individuals vulnerable to disturbance from all operations	All individuals vulnerable to disturbance from all operations	All individuals vulnerable to disturbance from all operations	50% of individuals vulnerable to operations in the Moray Firth and 50% vulnerable to operations in the Forth and Tay	50% of individuals vulnerable to operations in the Moray Firth and 50% vulnerable to operations in the Forth and Tay	50% of individuals vulnerable to operations in the Moray Firth and 50% vulnerable to operations in the Forth and Tay

Table 3: Summary of the scenarios included in the sensitivity analysis for Bottlenose Dolphins

	Scenario 1	Scenario 2	Scenario 3
Number of Days of Residual Disturbance	1	1	0
Do animals avoid operations during a period of residual disturbance?	No	Yes	No
Population Structure	All individuals vulnerable to disturbance from operations in the Forth and Tay	All individuals vulnerable to disturbance from operations in the Forth and Tay	All individuals vulnerable to disturbance from operations in the Forth and Tay

Table 4: Summary of the scenarios included in the sensitivity analysis for Grey Seals

Results

Results of the iPCoD modelling for all scenarios are presented in Tables 5 and 6. For each scenario a number of different metrics are used to assess the impact on the population. This includes:

1) The predicted mean population size at the end of 24 years
2) The mean of the ratio of the impacted to un-impacted population size, using the population sizes at the end of years 1, 6, 12, 18 and 24
3) The mean of the ratio of the impacted to un-impacted annual growth rate at the end of years 1, 6, 12, 18 and 24
4) The centile for the un-impacted population that matches the 50th centile for the impacted population at the end of years 1, 6, 12, 18 and 24.

		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Median Population Size Year 24	Baseline Mean	304	304	303	303	303	304
	Impacted Mean	287	287	293	289	289	295
	Difference in Population Size	17	17	10	14	14	9
	Impacted as a % of Un-impacted	94.41	94.41	96.70	95.38	95.38	97.04
Ratio of the impacted to un-impacted population size	Year 1 Mean	0.992	0.992	0.996	0.991	0.992	0.995
	Year 6 Mean	0.947	0.947	0.966	0.953	0.956	0.967
	Year 12 Mean	0.948	0.948	0.966	0.953	0.955	0.968
	Year 18 Mean	0.945	0.945	0.964	0.950	0.953	0.967
	Year 24 Mean	0.946	0.946	0.964	0.951	0.954	0.967
Ratio of the impacted to un-impacted annual growth rate	Year 1 Mean	0.992	0.992	0.996	0.991	0.992	0.995
	Year 6 Mean	0.990	0.990	0.994	0.991	0.992	0.994
	Year 12 Mean	0.995	0.995	0.997	0.996	0.996	0.997
	Year 18 Mean	0.996	0.996	0.998	0.997	0.997	0.998
	Year 24 Mean	0.997	0.997	0.998	0.998	0.998	0.998
Centile for un-impacted population which matches the 50th centile for the impacted population	Year 1	43%	45%	45%	45%	45%	45%
	Year 6	50%	48%	48%	48%	48%	47%
	Year 12	49%	49%	49%	49%	49%	50%
	Year 18	49%	50%	49%	50%	50%	49%
	Year 24	50%	50%	50%	50%	50%	50%

Table 5: Bottlenose Dolphin Metrics for all 6 scenarios tested in the sensitivity analysis

		Scenario 1	Scenario 2	Scenario 3
Median Population Size Year 24	**Baseline Mean**	18683	18704	18707
	Impacted Mean	18665	18688	18699
	Difference in Population Size	18	16	8
	Impacted as a % of Un-impacted	99.90	99.91	99.96
Ratio of the impacted to un-impacted population size	**Year 1 Mean**	1.000	1.000	1.000
	Year 6 Mean	0.999	0.999	1.000
	Year 12 Mean	0.999	0.999	1.000
	Year 18 Mean	0.999	0.999	1.001
	Year 24 Mean	0.999	0.999	1.001
Ratio of the impacted to un-impacted annual growth rate	**Year 1 Mean**	1.000	1.000	1.000
	Year 6 Mean	1.000	1.000	1.000
	Year 12 Mean	1.000	1.000	1.000
	Year 18 Mean	1.000	1.000	1.000
	Year 24 Mean	1.000	1.000	1.000
Centile for un-impacted population which matches the 50th centile for the impacted population	**Year 1**	50%	50%	50%
	Year 6	50%	50%	50%
	Year 12	50%	50%	50%
	Year 18	50%	50%	50%
	Year 24	50%	50%	50%

Table 6: Grey Seal metrics for all 3 scenarios tested in the sensitivity analysis.

The results show that there is no difference between scenarios in which individuals avoid operations during residual disturbance and scenarios in which they do not. The results show a small difference between scenarios in which the number of residual days of disturbance is set to 1 and scenarios in which the number of residual days of disturbance is set to 0. Scenarios in which the number of residual days of disturbance is 1 have slightly more impact on the population.

The results also show that there may be a very small difference between scenarios in which the whole bottlenose dolphin population is vulnerable to disturbance from all operations and scenarios in which 50% of the population is vulnerable to disturbance in the Moray Firth and the other 50% is vulnerable to disturbance in the Forth and Tay. Scenarios in which all individuals are vulnerable to disturbance from all operations have marginally more impact on the population.

The overall worst case from the sensitivity analysis was taken to be Scenario 1 for both bottlenose dolphins and grey seals. Plots of the iPCoD model output for these two scenarios are presented in the following section.

Overall Worst Case: Bottlenose Dolphins

The mean population size and 95% CI for the impacted and un-impacted population are shown in Figure 2. The mean population size for the impacted population is smaller than the mean population size for the un-impacted population across all years in the simulation. It is important to note that the disturbed population follows the same trajectory as the undisturbed population in the years following construction. However, it is also important to note that the size of the impacted population after 24 years is significantly smaller than the size of the un-impacted population according to a two sample T test ($t = -16.86$, $p < 0.01$). After 24 years, the mean predicted population size for the un-impacted population was 304. The mean predicted population size for the impacted population after 24 years was 287, which is 94.4% of the size of the un-impacted population.

Figure 2: Mean population size for bottlenose dolphins under Scenario 1.

Histograms of the ratio of the impacted population size to the un-impacted population size across all paired simulations are shown in Figure 3 for the end of years 1, 6, 12, 18 and 24. At the end of 24 years, the mean ratio of the impacted and un-impacted population size was 0.946, indicating that the impacted population is generally smaller than the paired un-impacted population.

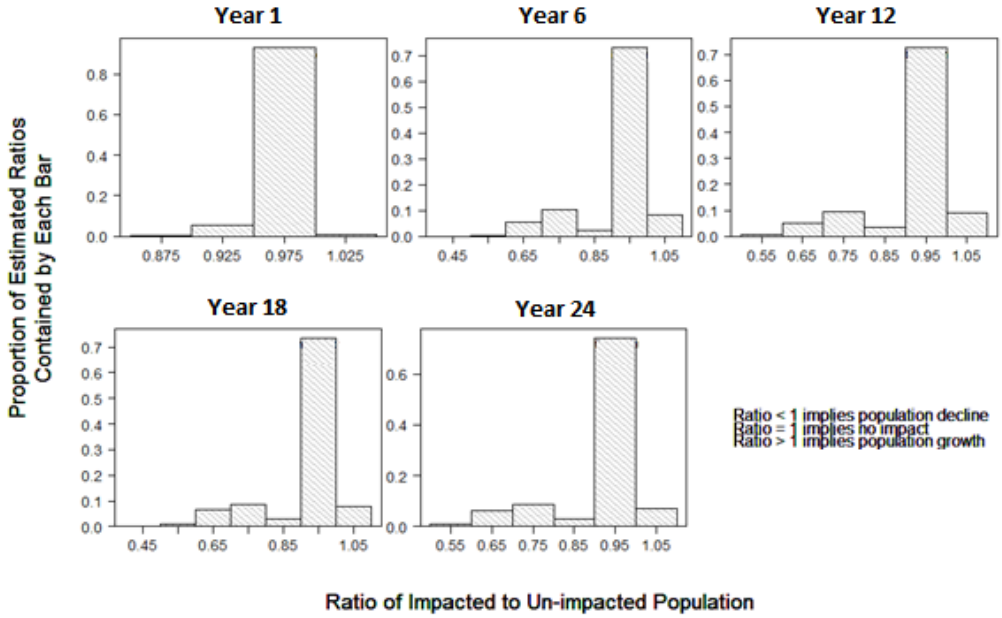

Figure 3: Ratio of impacted to un-impacted population size at the end of years 1, 6, 12, 18 and 24 for bottlenose dolphins in Scenario 1.

Histograms of the ratio of the impacted population growth rate to the un-impacted population growth rate across all paired simulations are shown in Figure 4 for the end of years 1, 6, 12, 18 and 24. The mean ratio of the impacted and un-impacted population annual growth rate at the end of 24 years was 0.997. A small number of simulations therefore resulted in a change in growth rate that was lower for the impacted population compared to the paired un-impacted population. However, this difference is very small.

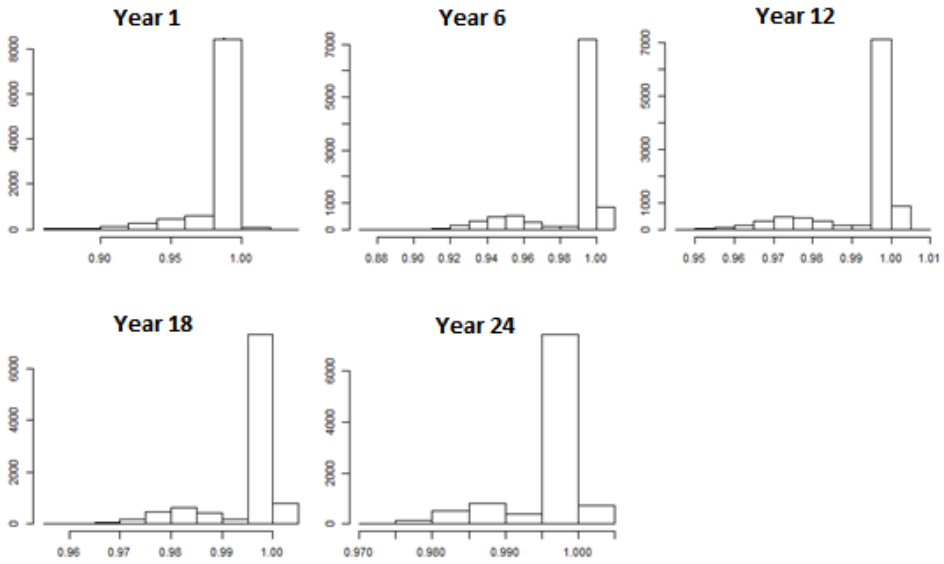

Figure 4: Ratio of impacted to un-impacted annual growth rate at the end of years 1, 6, 12, 18 and 24 for bottlenose dolphins in Scenario 1.

Overall Worst Case: Grey Seals

The mean population size and 95% CI for the impacted and un-impacted population are shown in Figure 5. There is a very large overlap in confidence intervals for the impacted and un-impacted population. The results of a two-sample T test show no significant difference between the size of the impacted and un-impacted population after 24 years (t =-0.43, p = 0.66). The mean predicted population size for the un-impacted population after 24 years was 18,683. The mean predicted population size for the impacted population after 24 years was 18,665, which is 99.9% of the size of the un-impacted population.

Figure 5: Mean population size for grey seals under Scenario 1.

Histograms of the ratio of the impacted population size to the un-impacted population size across all paired simulations are shown in Figure 6 for the end of years 1, 6, 12, 18 and 24. The mean ratio of the impacted population size to un-impacted population size is very close to 1 across all years examined, indicating that the differences between the two population sizes are very small.

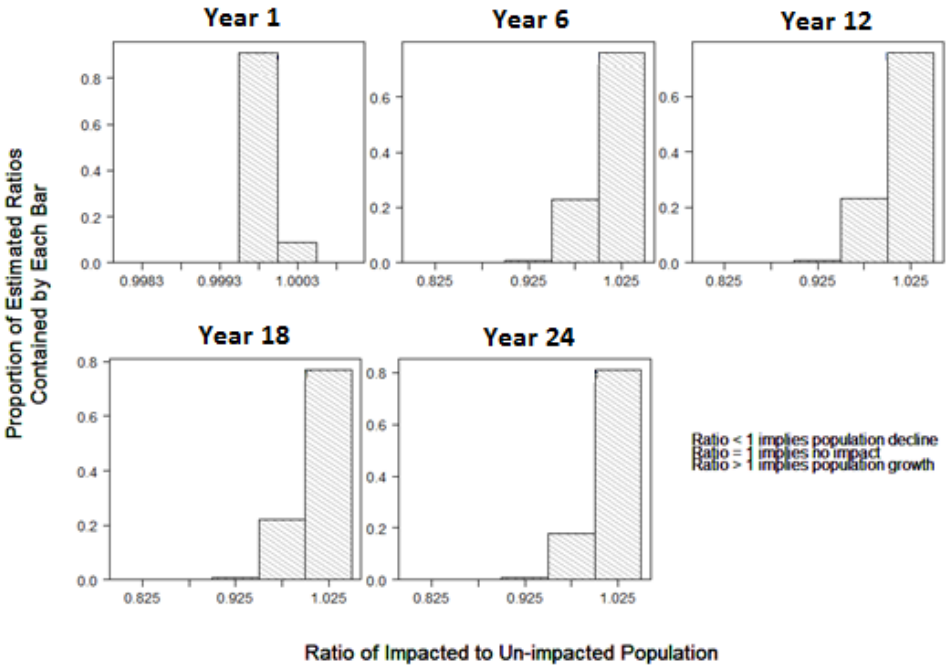

Figure 6: Ratio of impacted to un-impacted population size at the end of years 1, 6, 12, 18 and 24 for grey seals in Scenario 1.

Histograms of the ratio of the impacted population growth rate to the un-impacted population growth rate across all paired simulations are shown in Figure 7 for the end of years 1, 6, 12, 18 and 24. The mean ratio of the impacted and un-impacted population annual growth rate was equal to 1 across all years examined. This indicates that there is no difference in the growth rate between the impacted and un-impacted population.

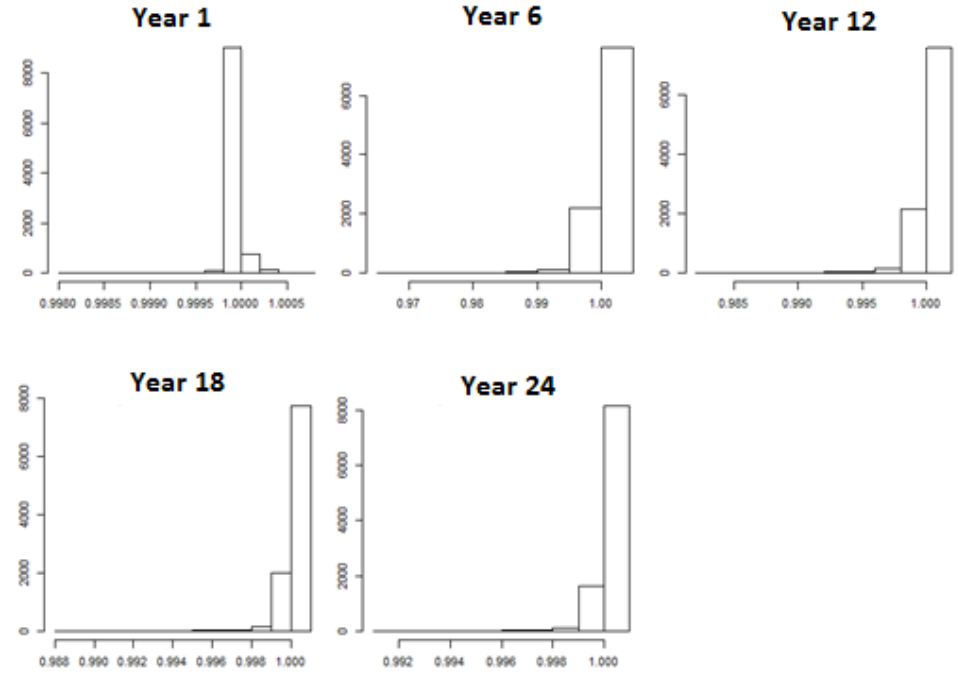

Figure 7: Ratio of impacted to un-impacted annual growth rate at the end of years 1, 6, 12, 18 and 24 for grey seals in Scenario 1.

Conclusion

In conclusion, displacement from pile driving/blasting may affect the size and growth of the bottlenose dolphin population off the east coast of Scotland in the short term. However, the outputs from iPCoD suggest that the size of this effect is likely to be small over the modelled period. Outputs from iPCoD suggest that there is likely to be no effect of pile driving/blasting on the grey seal population in the Forth and Tay.

Parameter Name	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
nboot	10000	10000	10000	10000	10000	10000
Spec	BND	BND	BND	BND	BND	BND
propfemale	0.5	0.5	0.5	0.5	0.5	0.5
pmean	195	195	195	195	195	195
threshold	500	500	500	500	500	500
Surv[1]	0.9	0.9	0.9	0.9	0.9	0.9
Surv[7]	0.94	0.94	0.94	0.94	0.94	0.94
Surv[13]	0.9497	0.9497	0.9497	0.9497	0.9497	0.9497
Fertility	0.3	0.3	0.3	0.3	0.3	0.3
age1	2	2	2	2	2	2
age2	9	9	9	9	9	9
pile_years	7	7	7	7	7	7
vulnmean	c(1)	c(1)	c(1)	c(0.5,0.5)	c(0.5,0.5)	c(0.5,0.5)
pilesx1	8	8	8	8	8	8
vulnpile[1,]	c(1,1,1,1,1,1,1,1)	c(1,1,1,1,1,1,1,1)	c(1,1,1,1,1,1,1,1)	c(1,0,1,0,0,0,0,1) c(0,1,0,1,1,1,1,0)	c(1,0,1,0,0,0,0,1) c(0,1,0,1,1,1,1,0)	c(1,0,1,0,0,0,0,1) c(0,1,0,1,1,1,1,0)
seasons	1	1	1	1	1	1
numDT	c(19,4,17,2,7,3,2,10)	c(19,4,17,2,7,3,2,10)	c(19,4,17,2,7,3,2,10)	c(19,4,17,2,7,3,2,10)	c(19,4,17,2,7,3,2,10)	c(19,4,17,2,7,3,2,10)
numPT	c(0,0,0,0,0,0,0,0)	c(0,0,0,0,0,0,0,0)	c(0,0,0,0,0,0,0,0)	c(0,0,0,0,0,0,0,0)	c(0,0,0,0,0,0,0,0)	c(0,0,0,0,0,0,0,0)
days	1	1	0	1	1	0
prop_dist_days	1	1	1	1	1	1
other_days	0	0	0	0	0	0
Avoid	FALSE	TRUE	FALSE	FALSE	TRUE	FALSE
years	25	25	25	25	25	25
Day1	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Ncollisions	0	0	0	0	0	0
z	0	0	0	0	0	0
K	NA	NA	NA	NA	NA	NA
Fert_0	NA	NA	NA	NA	NA	NA

Table A1: Parameter Values used for the Bottlenose Dolphin Simulations

Parameter Name	Scenario 1	Scenario 2	Scenario 3
nboot	10000	10000	10000
Spec	GS	GS	GS
propfemale	0.5	0.5	0.5
pmean	14714	14714	14714
threshold	500	500	500
Surv[1]	0.222	0.222	0.222
Surv[7]	0.94	0.94	0.94
Surv[13]	0.94	0.94	0.94
Fertility	0.84	0.84	0.84
age1	1	1	1
age2	5	5	5
pile_years	3	3	3
vulnmean	c(1)	c(1)	c(1)
pilesx1	4	4	4
vulnpile[1,]	c(1,1,1,1)	c(1,1,1,1)	c(1,1,1,1)
seasons	1	1	1
numDT	c(821,1058,27,14)	c(821,1058,27,14)	c(821,1058,27,14)
numPT	c(1,0,0,0)	c(1,0,0,0)	c(1,0,0,0)
days	1	1	0
prop_dist_days	1	1	1
other_days	0	0	0
Avoid	FALSE	TRUE	FALSE
years	25	25	25
Day1	FALSE	FALSE	FALSE
Ncollisions	0	0	0
z	0	0	0
K	NA	NA	NA
Fert_0	NA	NA	NA

Table A1: Parameter Values used in the Grey Seal Simulations