APPENDIX 10E PILING NOISE IMPACT ASSESSMENT USING A 1% ACOUSTIC ENERGY CONVERSION FACTOR AND USE OF ADD

INTRODUCTION

1.1. The assessment of piling noise impacts on marine mammals, presented in Appendix 10B (Noise Modelling Technical Report), is supported by underwater noise modelling undertaken by the Centre for Environment, Fisheries and Aquaculture Science (Cefas). The Cefas model uses a range of parameters, as advised by Cefas, to predict the propagation of underwater noise. This includes the use of a 0.5% acoustic energy conversion factor (the 'conversion factor'). This conversion factor is used by Cefas as a standard variable in their modelling of the underwater noise generated by pile-driving.

1.2. There is currently ongoing discussion on the most suitable conversion factor to be used to assess piling noise impacts on marine mammals, following the development of the Beatrice Offshore Wind Farm Ltd. (BOWL) piling strategy, which adopted the use of a 1% conversion factor. This was to support precautionary modelling of near field effects to support development of the piling mitigation strategy. Consequently, Marine Scotland Licensing and Operations Team (MS-LOT) have advised Seagreen to provide modelling results, to demonstrate any potential differences in the assessments when using a 0.5% and 1% conversion factor. MS-LOT have also advised Seagreen to model piling impacts on marine mammals using an Acoustic Deterrent Device (ADD) as embedded mitigation, as well as scenarios where an ADD is not used.

1.3. In response to MS-LOT's advice, Seagreen has provided this appendix which sets out the results of underwater noise modelling and potential impact significance for marine mammals when using a 1% conversion factor with and without ADDs as embedded mitigation. Model runs were completed for each scenario presented in Chapter 10 (Marine Mammals). The sections below describe the results from this analysis. The worst case scenario for each species is described, and the results for each scenario are listed in tables. For comparison, the tables also provide the modelling results using the 0.5% conversion factor and with ADD as embedded mitigation.

1.4. It is highlighted that with the use of a 1% conversion factor and the removal of ADDs as embedded mitigation there are no changes to the predicted impact significance across the majority of species assessed, when considering PTS, as well as disturbance effects. The exception to this is Minke whale which demonstrates a change from Negligible significance to Minor significance for PTS impacts, for one of the seven scenarios modelled (concurrent pin piling at Project Alpha and Project Bravo). It is further highlighted that the significance of residual effects (using the 1% conversion factor and use of pre-piling ADD) is Negligible or Minor across all species assessed, when considering PTS as well as disturbance effects. Therefore, the results presented within this Appendix are unchanged when compared to the conclusions of Chapter 10 (Marine Mammals).

1.5. Impacts for all species remain Negligible or Minor and therefore Not Significant in EIA terms.

PTS

1.6. Following the methodology adopted in Chapter 10 (Marine Mammals), PTS ranges have been modelled using the National Marine Fisheries Service (2016) weighted SEL_{cum} and unweighted SPL_{peak} PTS thresholds for each marine mammal hearing group. A comparison of the SPL_{peak} and SEL_{cum} PTS impact ranges determined that for all species/hearing groups, the worst case SEL_{cum} impact ranges were either equal to, or larger than the worst case SPL_{peak} PTS impact ranges. Therefore, only the SEL_{cum} PTS thresholds are presented in this appendix (Table 1.1).

Table 1.1 . National Marine Fisheries Service (2016) weighted SEL_{cum} PTS thresholds for each marine mammal hearing group.

Species Group	PTS Threshold
Pinnipeds in water (harbour and grey seals)	NMFS weighted SEL_{cum} 185 dB re 1 µPa²s
High frequency cetaceans (harbour porpoise)	NMFS weighted SEL_{cum} 155 dB re 1 µPa²s
Mid frequency cetaceans (bottlenose and white-beaked dolphins)	NMFS weighted SEL_{cum} 185 dB re 1 µPa²s
Low frequency cetaceans (minke whale)	NMFS weighted SEL_{cum} 183 dB re 1 µPa²s

Harbour and Grey Seal

1.7. The predicted PTS impact ranges for both harbour and grey seals were all <50 m for each piling scenario when modelled using a 1% conversion factor both with and without the use of pre-piling ADD incorporated into the modelling. This is identical to the impact ranges for the 0.5% conversion factor with ADD use (Table 1.2). Assuming an appropriate piling strategy and including best practice mitigation measures, these are unlikely to result in a risk of PTS to any individual harbour or grey seal.

Table 1.2 Predicted PTS impact ranges for harbour and grey seals from the different piling scenarios.

Scenario	Build Scenario	0.5% conversion factor, with pre-piling ADD	1% conversion factor, with pre-piling ADD	1% conversion factor, without pre-piling ADD
		Maximum Range (m)	Maximum Range (m)	Maximum Range (m)
Monopiles at Alpha	5	<50 m	<50 m	<50 m
Monopiles at Bravo	6	<50 m	<50 m	<50 m
Pin pile jackets at Alpha	1	<50 m	<50 m	<50 m
Pin pile jackets at Bravo	2	<50 m	<50 m	<50 m
Concurrent Monopile and Pin pile jackets at Alpha	9	<50 m and <50 m	<50 m and <50 m	<50 m and <50 m
Concurrent Monopile and Pin pile jackets at Bravo	11	<50 m and <50 m	<50 m and <50 m	<50 m and <50 m
Concurrent Pin pile jackets at Alpha and Bravo	4	<50 m and <50 m	<50 m and <50 m	<50 m and <50 m

1.8. Based on the PTS ranges presented in Table 1.2, including the worst case scenario for a 1% conversion factor without the use of pre-piling ADD mitigation, the magnitude of impact of PTS on harbour and grey seals is predicted to be **Negligible.** As described in Chapter 10 (Marine Mammals), the sensitivity of harbour and grey seals to PTS is **Low.** The impact of PTS on harbour and grey seals is predicted to be **Negligible** and therefore **Not Significant** in EIA terms.

Harbour Porpoise

1.9. As detailed in Table 1.3, the maximum predicted PTS range for harbour porpoise was 474 m from a Pin pile jacket foundation when modelled concurrently with a Monopile foundation at Project Alpha, using a 1% conversion factor without the use of pre-piling ADD incorporated into the modelling. Assuming an appropriate piling strategy and including best practice mitigation measures, these are unlikely to result in a risk of PTS to any harbour porpoise.

Table 1.3 Predicted PTS impact ranges for harbour porpoise from the different piling scenarios.

Scenario	Build Scenario	0.5 % conversion factor, with pre-piling ADD	1% conversion factor, with pre-piling ADD	1% conversion factor, without pre-piling ADD
		Maximum Range (m)	Maximum Range (m)	Maximum Range (m)
Monopiles at Alpha	5	<50 m	<50 m	<50 m
Monopiles at Bravo	6	<50 m	<50 m	<50 m
Pin pile jackets at Alpha	1	<50 m	<50 m	349 m
Pin pile jackets at Bravo	2	<50 m	<50 m	364 m
Concurrent Monopile and Pin pile jackets at Alpha	9	<50 m and <50 m	<50 m and <50 m	<50 m and 474 m
Concurrent Monopile and Pin pile jackets at Bravo	11	<50 m and <50 m	<50 m and <50 m	<50 m and 276 m
Concurrent Pin pile jackets at Alpha and Bravo	4	<50 m and <50 m	<50 m and <50 m	322 m and 365 m

1.10. Based on the maximum ranges presented in Table 1.3, the magnitude of impact of PTS on harbour porpoise is predicted to be **Negligible.** As discussed Chapter 10 (Marine Mammals), the sensitivity of harbour porpoise to PTS is **Medium**. The impact of PTS on harbour porpoise is predicted to be **Negligible** and therefore **Not Significant** in EIA terms.

Bottlenose and white-beaked dolphins

1.11. The predicted PTS impact ranges for bottlenose and white-beaked dolphins were all <50 m for each piling scenario when modelled using a 1% conversion factor both with and without the use of pre-piling ADDs. This is identical to the impact ranges for a 0.5% conversion factor with ADD use (Table 1.4).

Table 1.4 Predicted PTS impact ranges for bottlenose dolphins and white-beaked dolphins from the different piling scenarios.

Scenario	Build Scenario	0.5 % conversion factor, with pre-piling ADD	1% conversion factor, with pre-piling ADD	1% conversion factor, without pre-piling ADD
		Maximum Range (m)	Maximum Range (m)	Maximum Range (m)
Monopiles at Alpha	5	<50 m	<50 m	<50 m

Scenario	Build Scenario	0.5 % conversion factor, with pre-piling ADD	1% conversion factor, with pre-piling ADD	1% conversion factor, without pre-piling ADD
		Maximum Range (m)	Maximum Range (m)	Maximum Range (m)
Monopiles at Bravo	6	<50 m	<50 m	<50 m
Pin pile jackets at Alpha	1	<50 m	<50 m	<50 m
Pin pile jackets at Bravo	2	<50 m	<50 m	<50 m
Concurrent Monopile and Pin pile jackets at Alpha	9	<50 m and <50 m	<50 m and <50 m	<50 m and <50 m
Concurrent Monopile and Pin pile jackets at Bravo	11	<50 m and <50 m	<50 m and <50 m	<50 m and <50 m
Concurrent Pin pile jackets at Alpha and Bravo	4	<50 m and <50 m	<50 m and <50 m	<50 m and <50 m

1.12. Based on these ranges the magnitude of impact of PTS on bottlenose and white beaked dolphins is predicted to be **Negligible**. As described in Chapter 10 (Marine Mammals), the sensitivity of bottlenose and white-beaked dolphins to PTS is **Medium**. The impact of PTS on bottlenose and white-beaked dolphins is predicted to be **Negligible** and therefore **Not Significant** in EIA terms.

Minke whales

1.13. As detailed in Table 1.5, the maximum predicted PTS range for minke whales was 25.8 km (total area 679.6 km^2) from concurrent pin pile jackets at Project Alpha and Project Bravo using a 1% conversion factor without the use of pre-piling ADD (Figure 1.1). This equates to a maximum of 26.5 animals (6.1 – 71.4) or 0.11% (0.03 – 0.30) of the Management Unit predicted to experience PTS on a single piling day. This compares to a total of <1 animal from the same scenario using a 0.5% conversion factor, with the use of pre-piling ADD (Table 1.6).

1.14. The inclusion of pre-piling ADD use with the 1% conversion factor, reduces the predicted maximum PTS impact range to 25.6 km (total area 559.4 km^2). This equates to a maximum of 21.8 animals (5.0 – 58.7) or 0.09% (0.02 – 0.25) of the Management Unit predicted to experience PTS on a single piling day (Table 1.6).

Table 1.5 Predicted PTS impact ranges for minke whales from the different piling scenarios using the 1% conversion factor and without pre-piling ADD.

Scenario	Build Scenario	1% conversion factor, without pre-piling ADD			
		Maximum Range	Total Area (km^2)	Number of Animals	% of MU
Monopiles at Alpha	5	1.5 km	4.0	0.2 (0.0 – 0.4)	0.00 (0.00 – 0.00)
Monopiles at Bravo	6	1.4 km	4.8	0.2 (0.0 – 0.5)	0.00 (0.00 – 0.00)
Pin pile jackets at Alpha	1	6.3 km	57.7	2.3 (0.5 – 6.1)	0.01 (0.00 – 0.03)
Pin pile jackets at Bravo	2	6.1 km	69.0	2.7 (0.6 – 7.2)	0.01 (0.00 – 0.03)

Scenario	Build Scenario	1% conversion factor, without pre-piling ADD			
		Maximum Range	Total Area (km²)	Number of Animals	% of MU
Concurrent Monopile and Pin pile jackets at Alpha	9	9 km	189.2	7.4 (1.7 – 19.9)	0.03 (0.01 – 0.08)
Concurrent Monopile and Pin pile jackets at Bravo	11	12.75 km	149.5	5.8 (1.3 – 15.7)	0.02 (0.01 – 0.07)
Concurrent Pin pile jackets at Alpha and Bravo	13	25.8 km	679.6	26.5 (6.1 – 71.4)	0.11 (0.03 – 0.30)

Table 1.6 Predicted PTS impact ranges for minke whales from the different piling scenarios using the 1% conversion factor with pre-piling ADD compared with 0.5% with pre-piling ADD.

Scenario	Build Scenario	Conversion factor	With pre-piling ADD			
			Maximum Range	Total Area (km²)	Number of Animals	% of MU
Monopiles at Alpha	5	1%	<50 m	-	<1	-
		0.5%	<50 m	-	<1	-
Monopiles at Bravo	6	1%	<50 m	-	<1	-
		0.5%	<50 m	-	<1	-
Pin pile jackets at Alpha	1	1%	4.3 km	18.9	0.7 (0.2 – 2.0)	0.00 (0.00 – 0.01)
		0.5%	<50 m	-	<1	-
Pin pile jackets at Bravo	2	1%	4.2 km	24.7	1.0 (0.2 – 2.6)	0.00 (0.00 – 0.01)
		0.5%	<50 m	-	<1	-
Concurrent Monopile and Pin pile jackets at Alpha	9	1%	9 km	100.3	3.9 (0.9 – 10.5)	0.02 (0.00 – 0.04)
		0.5%	<50 m	-	<1	-
Concurrent Monopile and Pin pile jackets at Bravo	1	1%	12.75 km	51.5	2.0 (0.5 – 5.4)	0.01 (0.00 – 0.02)
		0.5%	<50 m	-	<1	-
Concurrent Pin pile jackets at Alpha and Bravo	4	1%	25.6 km	559.4	21.8 (5.0 – 58.7)	0.09 (0.02 – 0.25)
		0.5%	<50 m	-	<1	-

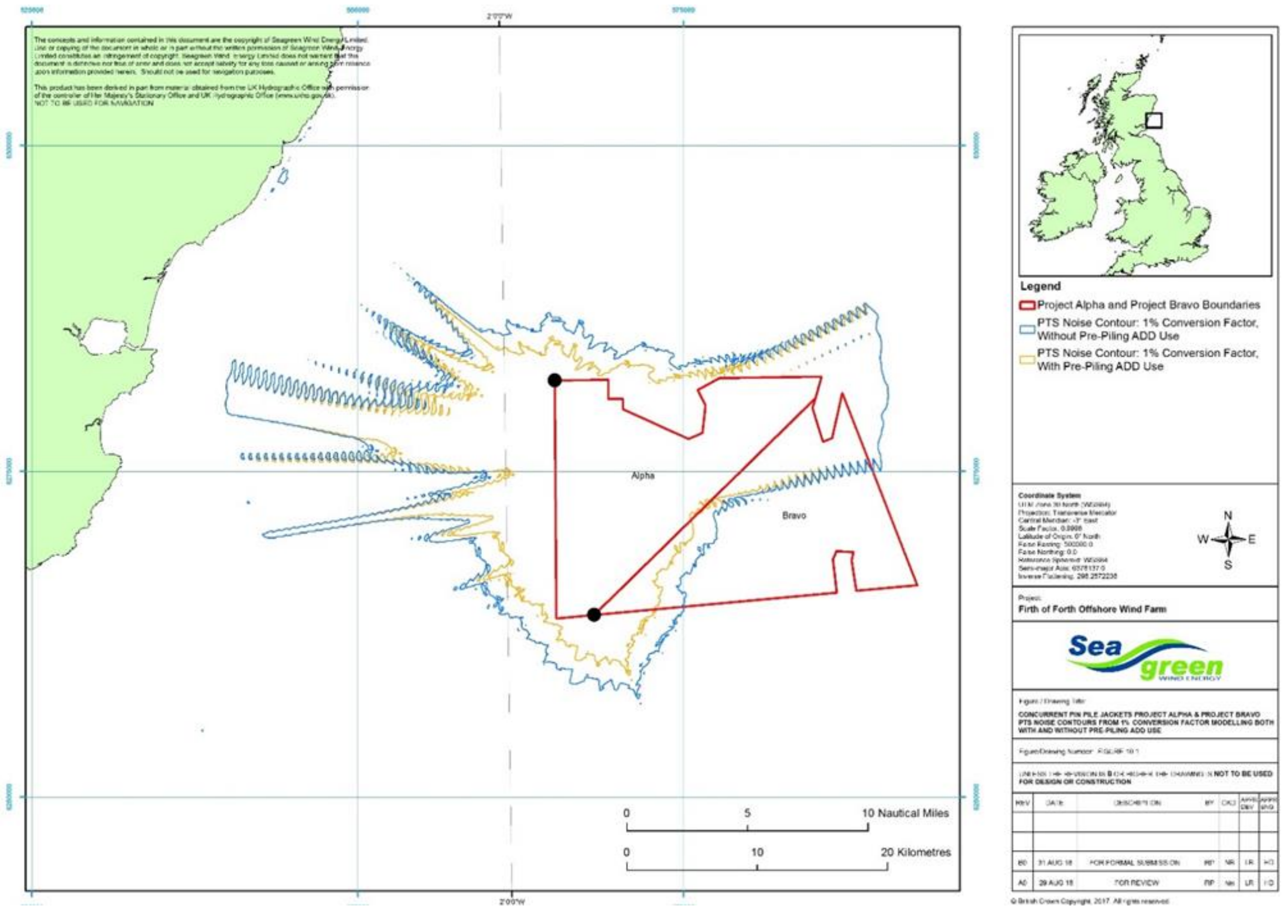

Figure 1.1 PTS noise impact contours for minke whales during the concurrent installation of pin pile jackets at Project Alpha and Project Bravo using the 1% conversion factor both with and without pre-piling ADD use.

Minke whales iPCoD Analysis

1.15. In order to assess if this predicted level of PTS would result in population level impacts, the absolute worst case scenario of **concurrent pin pile jackets at Project Alpha and Project Bravo using a 1% conversion factor and no pre-piling ADD mitigation** was modelled with iPCoD. Given that minke whales are present in the area only seasonally, the iPCoD modelling only included piling activity in the piling schedule when minke whales are expected to be the area and therefore available to be impacted. Sightings data from the Seagreen Firth of Forth Round 3 Zone Marine Mammal Surveys (Appendix 10Ai) demonstrated that minke whales were only recorded in the area between April and November inclusive; therefore only piling events during this time frame were included in the piling schedule.

1.16. The median predicted population size for the un-impacted minke whale population after 25 years was 23,076 (95% CI 17,561 – 32,403). The median predicted population size for the impacted population after 25 years was 21,464 (95% CI 16,072 – 30,253) which is 93% of the size of the un-impacted population. This means that after a simulated 25 years the size difference between the median un-impacted and impacted population was 1,612 animals, with a large overlap in confidence intervals.

1.17. The population trajectory for both the un-impacted and the impacted populations (the mean and each individual 1,000 simulated outcomes) are presented in Figure 1.2. This demonstrates that the mean impacted population is predicted to experience a decline in growth rate and population size relative to the un-impacted population, after which it then returns to almost the same growth rate as the un-impacted population and continues to increase at almost the same rate as the un-impacted population for the remainder of the simulation (see Table 1.7 and Table 1.8). The median ratio of the impacted to un-impacted minke whale population size after the 25-year simulation is 0.9265 (Table 1.7) and the median ratio of impacted to un-impacted minke whale population growth rate after the 25 year simulation is 0.9968 (Table 1.8).

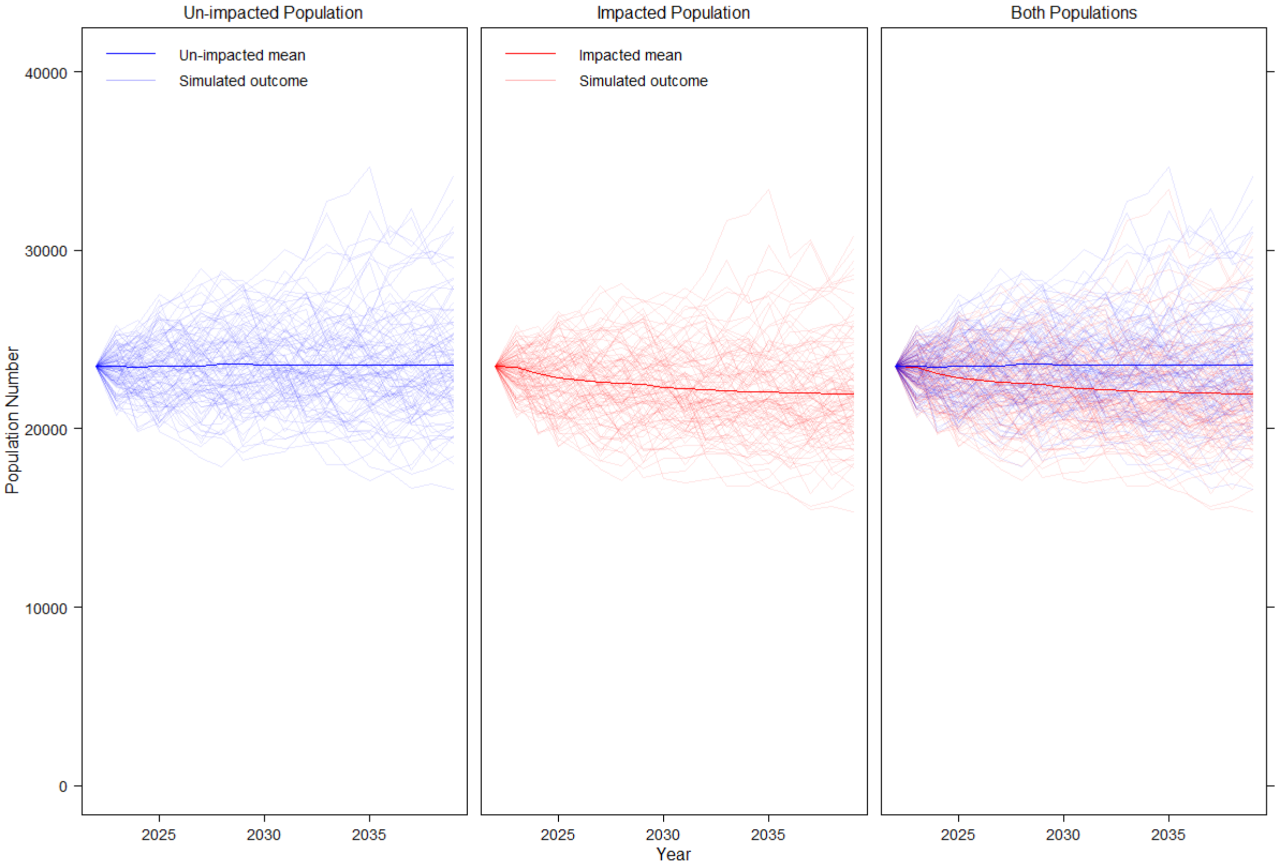

Figure 1.2 Simulated minke whale population sizes for both the un-impacted and the impacted populations resulting from concurrent pin pile installation at Project Alpha and Project Bravo using 1% conversion factor and no pre-piling ADD use.

Table 1.7 The ratio of impacted to un-impacted minke whale population size resulting from concurrent pin pile installation at Project Alpha and Project Bravo using 1% conversion factor without the use of pre-piling ADD.

Time.point	Years after start of simulation	Min	1st Qu.	Median	Mean	3rd Qu.	Max
Time.point 2	1	0.983106	0.995355	0.997243	0.996242	0.99821	0.99984
Time.point 7	6	0.905815	0.940906	0.957068	0.95495	0.967567	0.994328
Time.point 13	12	0.894513	0.922348	0.934929	0.937135	0.947726	0.989597
Time.point 19	18	0.89319	0.918675	0.928475	0.931437	0.940179	0.985448
Time.point 25	24	0.891478	0.917419	0.926471	0.929311	0.936612	0.982831

Table 1.8 The ratio of impacted to un-impacted minke whale population growth rate resulting from concurrent pin pile installation at Project Alpha and Project Bravo using 1% conversion factor without the use of pre-piling ADD.

Time.point	Years after start of simulation	Mean	Median	1st Qu.	3rd Qu.
Time.point 2	1	0.996242	0.997243	0.995355	0.99821
Time.point 7	6	0.992318	0.992713	0.989899	0.99452
Time.point 13	12	0.994586	0.994409	0.993287	0.995536
Time.point 19	18	0.996052	0.995886	0.995299	0.996579
Time.point 25	24	0.996943	0.996823	0.996415	0.997275

1.18. It is important to note that this is a precautionary assessment for a number of reasons. Firstly this assumes the higher energy conversion factor of 1% and does not include embedded mitigation in the form of an ADD prior to any piling. In addition, the maximum hammer energies will only be reached for a small proportion of the time and at only a proportion of piling locations.

1.19. Previous experience has shown that in practice, lower hammer energies than those assessed are required. For example, the pile driving at Beatrice OWF was assessed in the ES, based on a defined maximum hammer energy of 2,300 kJ. During the actual construction, mean maximum hammer energy across all piles was 1,088 kJ and modal maximum hammer energy was between 900 and 1,000 kJ. Only six out of the total 84 locations required the use of hammer energies above 1,800 kJ (BOWL, pers. com.). In addition, piling at the full hammer energy only occurred for 14% of the overall piling duration, not including any breaks in activity. On average, the maximum hammer energy at each location was only maintained for approximately 10 minutes. Therefore, it is unlikely that the maximum hammer energy will be reached at every pile location during the piling at Seagreen. The iPCoD modelling however, assumes that on each day of concurrent installation of pin piles at Project Alpha and Project Bravo, the full hammer energy is reached and therefore the maximum predicted number of animals are modelled to experience PTS. This iPCoD modelling is therefore highly precautionary and likely results in an overestimate of the true number of minke whales that will experience PTS. Thus, the resulting population consequences represent the worst case scenario and the true population consequences are likely to be much lower.

1.20. The inclusion of all piling days between April and November in the piling schedule for iPCoD is also likely overestimating the number of piling events in which minke whales are actually likely to be present in the area. Of the 57 minke whale sightings from the Seagreen Firth of Forth Round 3 Zone Marine Mammal Surveys (Appendix 10Ai), 77% of the sightings were in May and June and 93% of the sightings were between April and August inclusive. Therefore, including piling months between April and November is likely to overestimate the number of months in which minke whales are expected to be present at the site and available to be impacted. Thus, the true number of piling events where minke whales are likely available to be impacted will be much less than that modelled, which means that the population consequences are an overestimate.

1.21. These simulations are based on the maximum prediction of 27 individuals potentially being at risk during a single pile driving event. Based on this, the iPCoD simulations of individual exposure results in a median of 178 animals with PTS at the end of the simulated piling period. This is based on the assumption of an average density which is equal to the uniform average density based on summer surveys over a wider area (SCANS III surveys in July). This density actually occurring across the whole pile driving period is highly unlikely, given the low sightings rates of minke whales from the site based surveys detailed in Appendix 10Ai.

1.22. It is also important to note that the iPCoD model used to generate the predictions of long term population consequence has not been updated with any revised transfer functions for the effects of PTS on vital rates. The recent expert elicitation process detailed in Booth and Heinis (2018) and discussed in Chapter 10 (Marine Mammals), did not explicitly revisit the expert elicitation process for minke whales, due to time constraints, but it is recognised that the information presented at the workshop and discussed in Booth and Heinis (2018) would result in reduced predictions of effects of PTS on minke whale vital rates and therefore this modelling presents a real overestimate of the effects of the defined magnitude of PTS.

1.23. There are also a number of uncertainties in relation to the modelling of SEL_{cum} and the potential for PTS where the modelling will always take a precautionary approach to the prediction of PTS. These predictions rely heavily on the assumptions of the equal energy hypothesis. The equal energy hypothesis predicts that the effect of PTS is the same regardless of how the exposure is accumulated, i.e. whether the exposure was in one continuous bout, or split up into periods of exposure, with gaps in between. However, there is some evidence for marine mammals that the equal energy hypothesis may not hold (e.g. Kastelein *et al.* 2013). If this holds true for exposure to piling noise, which will have several gaps (in particular breaks between each jacket pin pile) this will allow for hearing recovery and PTS risk will be significantly lower than estimated.

1.24. It is important to note that the thresholds defined by National Marine Fisheries Service (2016) indicate PTS-onset thresholds below which PTS can be ruled out. This means that not every animal within these ranges will actually experience PTS, only a proportion will and the probability of any individual experiencing PTS will likely decrease rapidly with distance from the piling location. Work by Finneran *et al.* (2005) suggests that at the threshold level, the probability of experiencing PTS is about 0.18-0.19. It is also highly unlikely that animals are within close range of the piling operation at the very beginning of the piling event, due to vessel activity in preparation for piling. Therefore, the majority of the risk will be at ranges of much lower PTS-onset probability.

1.25. Furthermore, the fleeing speed used in the model was 2.1 m/s for minke whales, however, there is evidence that minke whales may respond faster than this to noise they find aversive. For example a recent study on the responses of minke whales to ADDs found that animals moved at a mean speed of 4.2 m/s (range 1.8 m/s to 5.9 m/s) (McGarry *et al.* 2017). Although this was in relation to ADD rather than pile driving, it is reasonable to assume that the response to pile driving noise may be similar. Therefore, the fleeing swim speed of 2.1 m/s in the model should also be considered an underestimate of the true fleeing swim speed of minke whales and as such will result in precautionary PTS impact ranges.

1.26. Based on the assessment of magnitude detailed above, the magnitude of impact of PTS on minke whales is predicted to be **Low**. As described Chapter 10 (Marine Mammals), the sensitivity of minke whales to PTS is **Medium**. Based on the worst case scenario of a 1% conversion factor and without the use of ADD, the impact of PTS on minke whales is predicted to be **Minor** and therefore **Not Significant** in EIA terms.

PTS Summary

1.27. In summary, no significant impacts of PTS were predicted for any marine mammal receptor during any of the piling scenarios using the 1% conversion factor both with and without the use of pre-piling ADD (Table 1.9).

Table 1.9 Summary of predicted PTS impact significance on marine mammal receptors using a 1% conversion factor with and without ADD and 0.5% conversion factor with ADD.

Species	Conv. factor	Magnitude	Sensitivity	Impact Significance
Harbour Seal	1% No ADD	Negligible	Low	Negligible (not significant)
	1% with ADD	Negligible	Low	Negligible (not significant)
	0.5% with ADD	Negligible	Low	Negligible (not significant)
Grey Seal	1% No ADD	Negligible	Low	Negligible (not significant)
	1% with ADD	Negligible	Low	Negligible (not significant)
	0.5% with ADD	Negligible	Low	Negligible (not significant)
Harbour Porpoise	1% No ADD	Negligible	Medium	Negligible (not significant)
	1% with ADD	Negligible	Medium	Negligible (not significant)
	0.5% with ADD	Negligible	Medium	Negligible (not significant)
Bottlenose Dolphin	1% No ADD	Negligible	Medium	Negligible (not significant)
	1% with ADD	Negligible	Medium	Negligible (not significant)
	0.5% with ADD	Negligible	Medium	Negligible (not significant)
White-beaked Dolphin	1% No ADD	Negligible	Medium	Negligible (not significant)
	1% with ADD	Negligible	Medium	Negligible (not significant)
	0.5% with ADD	Negligible	Medium	Negligible (not significant)
Minke Whale	1% No ADD	Low	Medium	Minor (not significant)
	1% with ADD	Low	Medium	Minor (not significant)
	0.5% with ADD	Negligible	Medium	Negligible (not significant)

DISTURBANCE

1.28. The assessment of potential for disturbance followed the same approach as described in Chapter 10 (Marine Mammals). This combines predictions of a series of contours of predicted unweighted single strike SEL noise levels, with species specific density estimates and a behavioural dose response curve, to determine the number of animals potentially displaced during pile driving activity. Because the assessment of disturbance is based on predicted levels of noise at the maximum hammer energies for each scenario, the use of ADDs has no bearing on the noise modelling on which the predictions of numbers of animals disturbed are based.

Harbour Seal

1.29. The use of the 1% conversion factor results in a maximum of 0.57 animals (0.11% of the MU) predicted to experience disturbance during the installation of Monopiles at Project Alpha (Table 1.10). The number of animals disturbed per piling day and the proportion of the MU disturbed per piling day is assessed as Negligible.

1.30. The magnitude of disturbance on harbour seals is predicted to be **Negligible** using both the 0.5% and the 1% conversion factor models. As described in Chapter 10 (Marine Mammals), the sensitivity of harbour seals to disturbance is assessed as **Medium**. The impact of disturbance on harbour seals is predicted to be **Negligible** and therefore **Not Significant** in EIA terms.

Table 1.10 Number of harbour seals predicted to be disturbed during the different piling scenarios using the 0.5% or the 1% conversion factor.

Scenario	Build Scenario	0.5% conversion factor		1% conversion factor	
		Number of animals	% of MU	Number of animals	% of MU
Monopiles at Alpha	5	0.28 (0.07 – 0.49)	0.05% (0.01 – 0.10)	0.57 (0.14 – 1.00)	0.11% (0.03 – 0.20)
Monopiles at Bravo	6	0.18 (0.01 – 0.37)	0.03% (0.00 – 0.07)	0.37 (0.05 – 0.75)	0.07% (0.01 – 0.15)
Pin pile jackets at Alpha	1	0.13 (0.04 – 0.22)	0.03% (0.01 – 0.04)	0.33 (0.08 – 0.59)	0.07% (0.02 – 0.11)
Pin pile jackets at Bravo	2	0.09 (0.00 – 0.19)	0.02% (0.00 – 0.04)	0.20 (0.01 – 0.43)	0.04% (0.00 – 0.08)
Concurrent Monopile and Pin pile jackets at Alpha	9	0.29 (0.07 – 0.51)	0.06% (0.01 – 0.10)	0.56 (0.13 – 1.00)	0.11% (0.03 – 0.20)
Concurrent Monopile and Pin pile jackets at Bravo	11	0.21 (0.05 – 0.38)	0.04% (0.01 – 0.07)	0.47 (0.10 – 0.88)	0.09% (0.02 – 0.17)
Concurrent Pin pile jackets at Alpha and Bravo	4	0.18 (0.05 – 0.30)	0.03% (0.01 – 0.06)	0.41 (0.10 – 0.72)	0.08% (0.02 – 0.14)

Grey Seal

1.31. The use of the 1% conversion factor results in a maximum of 95 animals (0.87% of the MU) predicted to experience disturbance during the installation of Monopiles at Project Alpha (Table 1.11). The number of animals disturbed per piling day and the proportion of the MU disturbed per piling day is assessed as Low.

1.32. The magnitude of disturbance on grey seals is predicted to be **Low** under both the 0.5% and the 1% conversion factor models. As described in Chapter 10 (Marine Mammals), the sensitivity of grey seals to disturbance is **Low**. The impact of disturbance on grey seals is predicted to be **Negligible** and therefore **Not Significant** in EIA terms.

Table 1.11 Number of grey seals predicted to be disturbed during the different piling scenarios using the 0.5% or the 1% conversion factor.

Scenario	Build Scenario	0.5% conversion factor		1% conversion factor	
		Number of animals	% of MU	Number of animals	% of MU
Monopiles at Alpha	5	51 (16 – 86)	0.47% (0.15 – 0.79)	95 (32 – 159)	0.87% (0.29 – 1.46)
Monopiles at Bravo	6	29 (13 – 45)	0.27% (0.12 – 0.42)	69 (28 – 109)	0.63% (0.26 – 1.00)

Scenario	Build Scenario	0.5% conversion factor		1% conversion factor	
		Number of animals	% of MU	Number of animals	% of MU
Pin pile jackets at Alpha	1	27 (8 – 46)	0.25% (0.07 – 0.42)	60 (19 – 100)	0.55% (0.18 – 0.92)
Pin pile jackets at Bravo	2	14 (6 – 21)	0.13% (0.06 – 0.19)	35 (15 - 54)	0.32% (0.14 – 0.50)
Concurrent Monopile and Pin pile jackets at Alpha	9	42 (14 – 70)	0.38% (0.13 – 0.64)	91 (30 – 151)	0.83% (0.28 – 1.39)
Concurrent Monopile and Pin pile jackets at Bravo	11	27 (12 – 43)	0.25% (0.11 – 0.39)	71 (30 – 112)	0.65% (0.28 – 1.03)
Concurrent Pin pile jackets at Alpha and Bravo	4	24 (8 – 39)	0.22% (0.08 – 0.36)	63 (22 – 105)	0.58% (0.20 – 0.96)

Harbour Porpoise

1.33. The use of the 1% conversion factor results in a maximum of 2,391 animals (0.69% of the MU) predicted to experience disturbance. This is predicted for the installation of Monopiles at Project Bravo (Table 1.12). The number of animals disturbed per piling day and the proportion of the MU disturbed per piling day is assessed as Low.

1.34. The magnitude of disturbance on harbour porpoise is predicted to be **Low** under both the 0.5% and the 1% conversion factor models. As described in Chapter 10 (Marine Mammals), the sensitivity of harbour porpoise to disturbance is **Medium**. The impact of disturbance on harbour porpoise is predicted to be **Minor** and therefore **Not Significant** in EIA terms.

Table 1.12 Number of harbour porpoise predicted to be disturbed during the different piling scenarios using the 0.5% or the 1% conversion factor.

Scenario	Build Scenario	0.5% conversion factor		1% conversion factor	
		Number of animals	% of MU	Number of animals	% of MU
Monopiles at Alpha	5	1,403 (747 – 2,415)	0.41% (0.22 – 0.70)	2,113 (1,125 – 3,637)	0.61% (0.33 – 1.05)
Monopiles at Bravo	6	1,613 (859 – 2,776)	0.47% (0.25 – 0.80)	2,391 (1,274 – 4,116)	0.69% (0.37 – 1.19)
Pin pile jackets at Alpha	1	971 (517 – 1,671)	0.28% (0.15 – 0.48)	1,523 (811 – 2,622)	0.44% (0.23 – 0.76)
Pin pile jackets at Bravo	2	1,103 (587 – 1,898)	0.32% (0.17 – 0.55)	2,087 (1,112 – 3,592)	0.60% (0.32 – 1.04)
Concurrent Monopile and Pin pile jackets at Alpha	9	1,452 (773 – 2,499)	0.42% (0.22 – 0.72)	2,157 (1,149 – 3,713)	0.62% (0.33 – 1.08)

Scenario	Build Scenario	0.5% conversion factor		1% conversion factor	
		Number of animals	% of MU	Number of animals	% of MU
Concurrent Monopile and Pin pile jackets at Bravo	11	1,598 (851 – 2,751)	0.46% (0.25 – 0.80)	2,361 (1,258 – 4,065)	0.68% (0.36 – 1.18)
Concurrent Pin pile jackets at Alpha and Bravo	4	1,177 (627 – 2,027)	0.34% (0.18 – 0.59)	1,789 (953 – 3,080)	0.52% (0.28 – 0.89)

Bottlenose dolphin

1.35. The use of the 1% conversion factor results in a maximum of 6.8 animals (3.47% of the MU) predicted to experience disturbance. This is predicted for the installation of Monopiles at Project Alpha (Table 1.13). The number of animals disturbed per piling day and the proportion of the MU disturbed per piling day is assessed as Low.

Table 1.13 Number of bottlenose dolphins predicted to be disturbed during the different piling scenarios using the 0.5% or the 1% conversion factor.

Scenario	Build Scenario	0.5% conversion factor		1% conversion factor	
		Number of animals	% of MU	Number of animals	% of MU
Monopiles at Alpha	5	4.1	2.11%	6.8	3.47%
Monopiles at Bravo	6	3.1	1.58%	5.1	2.62%
Pin pile jackets at Alpha	1	3	1.52%	4.5	2.31%
Pin pile jackets at Bravo	2	2	1.01%	3.4	1.72%
Concurrent Monopile and Pin pile jackets at Alpha	9	4.5	2.30%	6.5	3.31%
Concurrent Monopile and Pin pile jackets at Bravo	11	3.8	1.93%	6	3.10%
Concurrent Pin pile jackets at Alpha and Bravo	4	3.2	1.64%	5.4	2.75%

Bottlenose dolphin iPCoD Analysis

1.36. The iPCoD modelling presented in Chapter 10 (Marine Mammals) concluded that the worst case disturbance scenario for the bottlenose dolphin population was the installation of monopiles at Project Alpha, followed sequentially by the installation of pin pile jackets at Project Bravo. Therefore, this sequential scenario has been re-modelled using the predicted disturbance levels from the 1% conversion factor model.

1.37. The median predicted population size for the un-impacted bottlenose dolphin population after 25 years was 306 (95% CI 190 - 462). The median predicted population size for the impacted population after 25 years was 302 (95% CI 184 - 462) which is 98.7% of the size of the un-impacted population. This means that after a simulated 25 years, the size difference between the median un-impacted and impacted population was four animals, with a large overlap in confidence intervals. Therefore, there was no significant difference between the predicted un-impacted and impacted population sizes, as a result of the predicted levels of disturbance.

1.38. None of the bottlenose dolphin impact scenarios resulted in a significant long term population effect. The population trajectory for both the un-impacted and the impacted populations (the mean and each individual 1,000 simulated outcomes) are presented in 0. This demonstrates that the mean impacted population is predicted to experience an initial slight decline in growth rate relative to the un-impacted population, after which it then returns to the same growth rate as the un-impacted population and continues to increase at the same rate as the un-impacted population for the remainder of the simulations (see Table 1.14 and Table 1.15).

1.39. The magnitude of impact of disturbance on bottlenose dolphins for the installation of monopiles at Project Alpha followed by pin pile jackets at Project Bravo (the worst case scenario for disturbance) is predicted to be **Low**. As described Chapter 10 (Marine Mammals), the sensitivity of bottlenose dolphins to disturbance is **Medium**. The impact of disturbance on bottlenose dolphins is predicted to be **Minor** and therefore **Not Significant** in EIA terms.

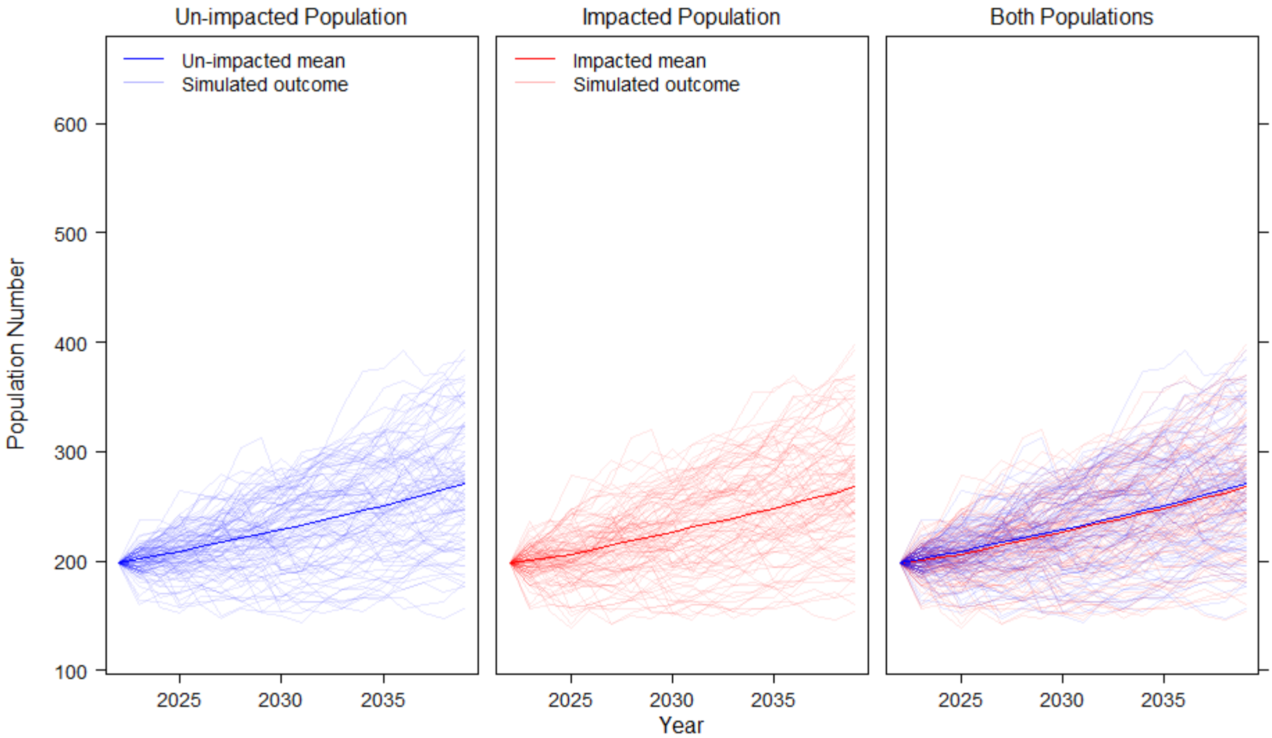

Figure 1.3 Simulated bottlenose dolphin population sizes for both the un-impacted and the impacted populations resulting from monopile installation at Project Alpha followed by pin pile jacket installation at Project Bravo using a 1% conversion factor.

Table 1.14 The ratio of impacted to un-impacted bottlenose dolphin population size resulting from monopile installation at Project Alpha followed by pin pile jacket installation at Project Bravo using a 1% conversion factor.

Time.point	Years after start of simulation	Min	1st Qu.	Median	Mean	3rd Qu.	Max
Time.point 2	1	0.914894	0.980723	1	0.996166	1.009733	1.07
Time.point 7	6	0.755556	0.965517	0.991228	0.987315	1.015095	1.076923
Time.point 13	12	0.783019	0.966315	0.993243	0.989322	1.015719	1.108333

Time.point	Years after start of simulation	Min	1st Qu.	Median	Mean	3rd Qu.	Max
Time.point 19	18	0.795918	0.966611	1	0.988919	1.014599	1.108108
Time.point 25	24	0.779661	0.965744	1	0.988848	1.014286	1.134615

Table 1.15 The ratio of impacted to un-impacted bottlenose dolphin population growth rate resulting from monopile installation at Project Alpha followed by pin pile jacket installation at Project Bravo using a 1% conversion factor.

Time.point	Years after start of simulation	Mean	Median	1st Qu.	3rd Qu.
Time.point 2	1	0.996165959	1	0.980722554	1.009732534
Time.point 7	6	0.997759769	0.998532639	0.994168516	1.002500152
Time.point 13	12	0.999041094	0.99943516	0.997148651	1.001300552
Time.point 19	18	0.999334109	1	0.998115144	1.000805491
Time.point 25	24	0.999495119	1	0.998548685	1.000591201

Minke Whale

1.40. The use of the 1% conversion factor results in a maximum of 155 animals (0.66% of the MU) predicted to experience disturbance. This is predicted for the installation of Monopiles at Project Bravo (Table 1.16). The number of animals disturbed per piling day and the proportion of the MU disturbed per piling day is assessed as Low.

1.41. The magnitude of impact of disturbance on minke whales is predicted to be **Low** under both the 0.5% and the 1% conversion factor models. As described in Chapter 10 (Marine Mammals), the sensitivity of minke whales to disturbance is **Medium**. The impact of disturbance on minke whales is predicted to be **Minor** and therefore **Not Significant** in EIA terms.

Table 1.16 Number of minke whales predicted to be disturbed during the different piling scenarios using the 0.5% or the 1% conversion factor.

Scenario	Build Scenario	0.5% conversion factor		1% conversion factor	
		Number of animals	% of MU	Number of animals	% of MU
Monopiles at Alpha	5	91 (22 – 247)	0.39% (0.09 – 1.05)	137 (33 – 371)	0.58% (0.14 – 1.58)
Monopiles at Bravo	6	104 (25 – 283)	0.44% (0.11 – 1.20)	155 (37 – 420)	0.66% (0.16 – 1.79)
Pin pile jackets at Alpha	1	63 (15 – 171)	0.27% (0.06 – 0.73)	98 (24 – 268)	0.42% (0.10 – 1.14)
Pin pile jackets at Bravo	2	71 (17 – 194)	0.30% (0.07 – 0.82)	135 (33 – 367)	0.57% (0.14 – 1.56)
Concurrent Monopile and Pin pile jackets at Alpha	9	94 (23 – 255)	0.40% (0.10 – 1.08)	139 (34 – 379)	0.59% (0.14 – 1.61)

Scenario	Build Scenario	0.5% conversion factor		1% conversion factor	
		Number of animals	% of MU	Number of animals	% of MU
Concurrent Monopile and Pin pile jackets at Bravo	11	103 (25 – 281)	0.44% (0.11 – 1.19)	153 (37 – 415)	0.65% (0.16 – 1.76)
Concurrent Pin pile jackets at Alpha and Bravo	4	76 (18 – 207)	0.32% (0.08 – 0.88)	116 (28 – 314)	0.49% (0.12 – 1.34)

White-beaked Dolphin

1.42. The use of the 1% conversion factor results in a maximum of 971 animals (2.68% of the MU) predicted to experience disturbance during the installation of Monopiles at Project Bravo (Table 1.17). The number of animals disturbed per piling day and the proportion of the MU disturbed per piling day is assessed as Low.

1.43. The magnitude of impact of disturbance on white-beaked dolphins is predicted to be **Low** under both the 0.5% and the 1% conversion factor models. As described in Chapter 10 (Marine Mammals), the sensitivity of white-beaked dolphins to disturbance is **Medium**. The impact of disturbance on white-beaked dolphins is predicted to be **Minor** and therefore **Not Significant** in EIA terms.

Table 1.17 Number of white-beaked dolphins predicted to be disturbed during the different piling scenarios using the 0.5% or the 1% conversion factor.

Scenario	Build Scenario	0.5% conversion factor		1% conversion factor	
		Number of animals	% of MU	Number of animals	% of MU
Monopiles at Alpha	5	570 (110 – 1,120)	1.57% (0.69 – 7.61)	858 (165 – 1,823)	2.36% (0.46 – 5.02)
Monopiles at Bravo	6	655 (126 – 1,391)	1.80% (0.35 – 3.83)	971 (187 – 2,063)	2.68% (0.52 – 5.68)
Pin pile jackets at Alpha	1	394 (76 – 838)	1.09% (0.21 – 2.31)	618 (119 – 1,314)	1.70% (0.33 – 3.62)
Pin pile jackets at Bravo	2	448 (86 – 951)	1.23% (0.24 – 2.62)	847 (163 – 1,800)	2.34% (0.45 – 4.96)
Concurrent Monopile and Pin pile jackets at Alpha	9	590 (114 – 1,253)	1.62% (0.31 – 3.45)	876 (169 – 1,861)	2.41% (0.46 – 5.13)
Concurrent Monopile and Pin pile jackets at Bravo	11	649 (125 – 1,379)	1.79% (0.34 – 3.80)	959 (185 – 2,037)	2.64% (0.51 – 5.61)
Concurrent Pin pile jackets at Alpha and Bravo	4	478 (92 – 1,016)	1.32% (0.25 – 2.80)	727 (140 – 1,544)	2.00% (0.39 – 4.25)

Disturbance Summary

1.44. In summary, there was no significant predicted impact of disturbance on any marine mammal receptor during any of the piling scenarios using the 1% conversion factor. The outcomes of the assessment are the same when compared to the use of the 0.5% conversion factor (Table 1.18).

Table 1.18 Summary of predicted disturbance impact significance on marine mammal receptors using a 0.5% and a 1% conversion factor.

Species	Conv. Factor	Magnitude	Sensitivity	Impact Significance
Harbour Seal	1%	Negligible	Medium	Negligible (not significant)
	0.5%	Negligible	Medium	Negligible (not significant)
Grey Seal	1%	Low	Low	Negligible (not significant)
	0.5%	Low	Low	Negligible (not significant)
Harbour Porpoise	1%	Low	Medium	Minor (not significant)
	0.5%	Low	Medium	Minor (not significant)
Bottlenose Dolphin	1%	Low	Medium	Minor (not significant)
	0.5%	Low	Medium	Minor (not significant)
Minke Whale	1%	Low	Medium	Minor (not significant)
	0.5%	Low	Medium	Minor (not significant)
White-beaked Dolphin	1%	Low	Medium	Minor (not significant)
	0.5%	Low	Medium	Minor (not significant)

CONCLUSION

1.45. There is currently ongoing discussion on the most appropriate conversion factor to be used in underwater noise modelling, to assess piling noise impacts on marine mammals. In response to advice from MS-LOT, Seagreen has provided this appendix which has investigated potential impact significance for marine mammals using a 1% conversion factor, compared to a 0.5% conversion factor used by Cefas. Following advice from MS-LOT this appendix has also investigated potential PTS impacts without the use of ADD as embedded mitigation.

1.46. Modelling undertaken has demonstrated that the use of a 1% conversion factor without pre-piling ADD use as embedded mitigation results in no changes to the significance of predicted impacts for the majority of species assessed, when considering PTS as well as disturbance effects. The exception to this is for minke whales which demonstrated a change from Negligible significance to Minor significance for PTS impacts, and then only for one of the seven scenarios modelled (concurrent pin piling at Project Alpha and Project Bravo) and without the use of ADDs.

1.47. The significance of residual effects (using the 1% conversion factor and with the use of pre-piling ADD) is Negligible or Minor across all species assessed, when considering PTS as well as disturbance effects. Only minke whales demonstrated a Minor significance for residual PTS impacts, and then only for one of the seven scenarios modelled (concurrent pin piling at Project Alpha and Project).

1.48. Impacts for all species remain **Negligible** or **Minor** and are therefore **Not Significant** in EIA terms.

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