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Volume 7B Proposed Development (Offshore) Appendices

Appendix 7-3 Marine Mammals Piling Results (Auditory Injury and Disturbance)

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Table of Contents

List of Tables

Acronyms and Abbreviations

CES	Coastal East Scotland
CGNS	Celtic and Greater North Sea
EDR	Effective Deterrence Range
ES	East Scotland
GNS	Greater North Sea
km	Kilometres
MF	Moray Firth
MU	Management Unit
NC&O	North Coast and Orkney
NS	North Sea
PTS	Permanent Threshold Shift
SCANS	Small Cetaceans in European Atlantic waters and the North Sea
SEL	Sound Exposure Level
SMU	Seal Management Unit
SPL	Sound Pressure Level

1 Marine Mammals Piling Results (Auditory Injury and Disturbance)

1.1 Introduction

1.1.1 Overview

1.1.1.1 This appendix of the Environmental Impact Assessment Report (EIAR) provides a full set of quantitative results for the assessment of auditory injury (Permanent Threshold Shift; PTS) and disturbance to marine mammals as a result of the underwater noise during piling at the Proposed Development (Offshore) (including Caledonia OWF, Caledonia North Site and Caledonia South Site). These results form a basis for assessment of impacts associated with piling provided in Volumes 2, 3 and 4, Chapter 7: Marine Mammals.

1.1.1.2 The assessment methodology for marine mammals is consistent with that provided in the Offshore Scoping Report (Volume 7, Appendix 2) and is described in detail in Volume 7B, Appendix 7-2: Underwater Noise Assessment Methodology. The methodology applied in the assessment is based on current best practice and based on the worst-case scenario parameters detailed within the Volumes 2, 3 and 4, Chapter 7: Marine Mammals. The underwater noise modelling will be re-run when parameters of the Proposed Development (Offshore) are finalised post-consent. If available, alternative assessment methodologies will be considered and consulted upon with relevant stakeholders. The updated results with respect to impacts on marine mammals will be discussed and presented in the Piling Strategy.

1.1.2 Densities and Reference Populations

1.1.2.1 A comprehensive characterisation of the baseline environment to understand the abundance within respective Management Units (MUs) and the density of marine mammals are provided in Volume 7B, Appendix 7-1: Marine Mammals Baseline Characterisation. A summary of relevant Management Units (MUs), MU sizes and density sources are provided in Table 1-1. Note, the results presented in this document include comparisons against the MU population as a whole as well as the UK proportion of the population (Table 1-1), in line with Scoping Opinion (Volume 7, Appendix 3).

1.1.2.2 The tables in Section 1.2 and 1.3 presenting the results of auditory injury (PTS) and behavioural disturbance clearly denote which density estimate has been used in each assessment. Where available, two sets of densities were presented for species-specific assessments, however only the most precautionary ones were taken forward to the assessment in the Volumes 2, 3 and 4, Chapter 7: Marine Mammals.

Table 1-1: Marine mammal reference population and density taken forward to the assessment of auditory injury and disturbance.

Species	MU	MU Size	UK MU Size	Density Source
Harbour porpoise	North Sea (NS)	346,601	159,632	SCANS IV CS-K (Gilles *et al*., 2023[1])
				SCANS III surface (Lacey *et al*., 2022[2])
Bottlenose dolphin	Coastal East Scotland (CES)	245		Calculated (Quick *et al*., 2014[3], Thompson *et al*., 2015[4], Cheney *et al*., 2024[5])
	Greater North Sea (GNS)	2,022	1,885	Calculated (IAMMWG, 2023[6])
White-beaked dolphin	Celtic and Greater North Seas (CGNS)	43,951	34,025	SCANS IV CS-K (Gilles *et al*., 2023[1])
				SCANS III surface (Lacey *et al*., 2022[2])
Common dolphin	CGNS	102,656	57,417	SCANS III surface (Lacey *et al*., 2022[2])
Risso's dolphin	CGNS	12,262	8,687	SCANS IV CS-K (Gilles *et al*., 2023[1])
Minke whale	CGNS	20,118	10,288	SCANS IV CS-K (Gilles *et al*., 2023[1])
				SCANS III surface (Lacey *et al*., 2022[2])
Harbour seal	East Scotland (ES) Moray Firth (MF) North Coast and Orkney (NC&O)	364 958 1,951		Carter *et al*. (2020[7] ; 2022[8])
Grey seal	ES MF NC&O	10,783 7,380 34,191		Carter *et al*. (2020[7]; 2022[8])

1.1.3 Piling Parameters

1.1.3.1 The eight modelling locations include potential WTG locations within the Caledonia OWF, giving a spread of various water depths, distances to the shore and to the deeper water to the east into the North Sea and as a result different potential technology (fixed, floating). Table 1-2 explains which modelling locations fall within the Caledonia North Site (N) and Caledonia South Site (S) of the Caledonia OWF.

Table 1-2: Modelling locations within the Caledonia OWF.

Part of the Caledonia OWF	Modelling Locations
Caledonia North Site (N)	Bottom-fixed only: 1, 2, 3, 4
Caledonia South Site (S)	Bottom-fixed only: 3, 4 Floating only: 5, 6 Bottom-fixed and Floating: 7, 8

1.2 Auditory Injury (PTS)

1.2.1 Harbour Porpoise

1.2.1.1 The results for auditory injury (PTS) as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-3 based on peak sound pressure level (SPL_{peak}) and Table 1-4 based on cumulative sound exposure level (SEL_{cum}) metrics. The numbers of animals impacted were calculated based on uniform density across Small Cetaceans in European Atlantic waters and the North Sea (SCANS) IV blocks (Gilles *et al.*, 2023[1]) and SCANS III surface densities (Lacey *et al.*, 2022[2]).

Table 1-3: Piling underwater noise modelling results for auditory injury (PTS) to harbour porpoise based on SPL_{peak}.

Foundation Type	Modelling Location	Impact Range		Gilles *et al.* (2023[1])			Lacey *et al.* (2022[2])		
		Area (km^2)	Max Range (m)	# Animals	% NS MU	% NS UK MU	# Animals	% NS MU	% NS UK MU
Monopiles	1 (N)	2.2	840	1	0.0003	0.0006	1	0.0003	0.0006
	2 (N)	2.2	830	1	0.0003	0.0006	1	0.0003	0.0006
	3 (N&S)	2.2	840	1	0.0003	0.0006	1	0.0003	0.0006
	4 (N&S)	2.2	840	1	0.0003	0.0006	1	0.0003	0.0006
	7 (S)	2.3	850	1	0.0003	0.0006	1	0.0003	0.0006
	8 (S)	2.2	850	1	0.0003	0.0006	1	0.0003	0.0006
Jackets	1 (N)	1.7	750	<1	<0.0003	<0.0006	1	0.0003	0.0006
	2 (N)	1.7	750	<1	<0.0003	<0.0006	1	0.0003	0.0006
	3 (N&S)	1.7	750	<1	<0.0003	<0.0006	1	0.0003	0.0006
	4 (N&S)	1.7	750	<1	<0.0003	<0.0006	1	0.0003	0.0006
	7 (S)	1.8	770	1	0.0003	0.0006	1	0.0003	0.0006
	8 (S)	1.8	760	1	0.0003	0.0006	1	0.0003	0.0006
Anchors	5 (S)	1.0	570	<1	<0.0003	<0.0006	1	0.0003	0.0006
	6 (S)	1.0	570	<1	<0.0003	<0.0006	1	0.0003	0.0006

Foundation Type	Modelling Location	Impact Range		Gilles *et al.* (2023[1])			Lacey *et al.* (2022[2])		
		Area (km^2)	Max Range (m)	# Animals	% NS MU	% NS UK MU	# Animals	% NS MU	% NS UK MU
	7 (S)	1.0	580	<1	<0.0003	<0.0006	1	0.0003	0.0006
	8 (S)	1.0	580	<1	<0.0003	<0.0006	1	0.0003	0.0006

Note, there was no overlap of the PTS impact ranges during concurrent piling and therefore all results presented below are for single piling scenario.

(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-4: Piling underwater noise modelling results for auditory injury (PTS) to harbour porpoise based on SEL_{cum}.

Foundation Type	Scenario	Location	Impact Range		Gilles *et al.* (2023[1])			Lacey *et al.* (2022[2])		
			Area (km^2)	Max Range (m)	# Animals	% NS MU	% NS UK MU	# Animals	% NS MU	% NS UK MU
Monopiles	Single piling	1 (N)	480	13,000	134	0.04	0.08	150	0.04	0.09
		2 (N)	440	13,000	126	0.04	0.08	134	0.04	0.08
		3 (N&S)	490	13,000	139	0.04	0.09	164	0.05	0.10
		4 (N&S)	480	14,000	136	0.04	0.09	148	0.04	0.09
		7 (S)	560	15,000	158	0.05	0.10	200	0.06	0.13
		8 (S)	580	15,000	165	0.05	0.10	186	0.05	0.12
	Concurrent	1 (N) and 4 (N&S)	1,700	15,000	465	0.13	0.29	508	0.15	0.32
		1 (N) and 8 (S)	2,200	22,000	618	0.18	0.39	688	0.20	0.43
		3 (N&S) and 8 (S)	1,800	15,000	496	0.14	0.31	577	0.17	0.36
Jackets	Single piling	1 (N)	420	13,000	120	0.03	0.08	133	0.04	0.08
		2 (N)	390	13,000	111	0.03	0.07	119	0.03	0.07
		3 (N&S)	450	13,000	128	0.04	0.08	151	0.04	0.09
		4 (N&S)	440	14,000	125	0.04	0.08	137	0.04	0.09
		7 (S)	530	15,000	149	0.04	0.09	190	0.05	0.12

Foundation Type	Scenario	Location	Impact Range		Gilles *et al.* (2023[1])			Lacey *et al.* (2022[2])		
			Area (km^2)	Max Range (m)	# Animals	% NS MU	% NS UK MU	# Animals	% NS MU	% NS UK MU
		8 (S)	530	15,000	149	0.04	0.09	169	0.05	0.11
	Concurrent piling	1 (N) and 4 (N&S)	1,600	15,000	457	0.13	0.29	501	0.14	0.31
		1 (N) and 8 (S)	2,200	22,000	617	0.18	0.39	691	0.20	0.43
		3 (N&S) and 8 (S)	1,700	15,000	489	0.14	0.31	570	0.16	0.36
Anchors	Single piling	5 (S)	130	7,000	36	0.01	0.02	45	0.01	0.03
		6 (S)	120	6,700	35	0.01	0.02	40	0.01	0.03
		7 (S)	130	7,100	38	0.01	0.02	48	0.01	0.03
		8 (S)	140	7,100	39	0.01	0.02	45	0.01	0.03
	Concurrent piling	5 (S) and 8 (S)	700	11,500	198	0.06	0.12	237	0.07	0.15
(N) = Caledonia North Site; (S) = Caledonia South Site.										

1.2.2 Bottlenose Dolphin

1.2.2.1 Density estimates for the assessment of impacts associated with piling and bottlenose dolphins were derived based on studies with local focus. It was assumed that all bottlenose dolphins present within the Moray Firth are from the CES MU population and the probability of bottlenose dolphin occurrence within the Moray Firth (based on Thompson *et al.,* 2015[4]) was scaled to the 50% of the current CES MU population size (Arso Civil *et al*., 2021[9]; Cheney *et al*., 2024[5]). Outside of the Moray Firth, all bottlenose dolphins within 2 km of the mainland coastline were assigned to CES MU (Quick *et al*., 2014) and this area assumed a density of 0.142 dolphins/km^2 (value derived by assuming the remaining 50% of the CES population is distributed uniformly within this 2km buffer). The areas further offshore assigned bottlenose dolphins to the GNS MU and assumed a density of 0.003 dolphins/km^2 (IAMMWG, 2023[6]). See Volume 7B, Appendix 7-1: Marine Mammals Baseline Characterisation for more details on how bottlenose dolphin densities were derived.

1.2.2.2 The results for auditory injury (PTS) as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 7-4. The maximum injury range to bottlenose dolphin based on SPL_{peak} and SEL_{cum} are less than 50m and less than 100m, respectively (Table 1-5). Based on Thompson et al. (2015[4]) data, the likelihood of encountering bottlenose dolphin further offshore, where the Caledonia OWF is located, is low. As such, there will not be any risk of auditory injury to bottlenose dolphins due to piling at locations 1, 2, 3, 4, 5, 6 and 7. Modelling location 8 is located at the southern edge of the Caledonia OWF and therefore there is a risk of auditory injury to less than one individual (0.45% CES MU population), based on both, SPL_{peak} and SEL_{cum} metrics. The assessment assumed that all bottlenose dolphins within the Moray Firth are assigned to CES MU and due to localised range of impact there will be no risk of injury to individuals from GNS MU.

Table 1-5: Piling underwater noise modelling results for auditory injury (PTS) to bottlenose dolphin based on SPL_{peak} and SEL_{cum}.

Foundation Type	Location	SPL_{peak}		SEL_{cum}	
		Area (km^2)	Max Range (m)	Area (km^2)	Max Range (m)
Monopiles	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.01	<50	<0.1	<100
Jackets	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.01	<50	<0.1	<100
Anchors	5, 6, 7, 8 (S)	<0.01	<50	<0.1	<100

Note, there was no overlap of the PTS impact ranges during concurrent piling and therefore all results presented below are for single piling scenario.

(N) = Caledonia North Site; (S) = Caledonia South Site.

1.2.3 White-beaked Dolphin

1.2.3.1 The results for auditory injury (PTS) as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-6 based on SPL_{peak} and Table 1-7 based on SEL_{cum} metrics. The numbers of animals impacted were calculated based on uniform density across SCANS IV blocks (Gilles *et al.*, 2023[1]) and SCANS III surface densities (Lacey *et al.*, 2022[2]).

Table 1-6: Piling underwater noise modelling results for auditory injury (PTS) to white-beaked dolphin based on SPL_{peak}.

Foundation Type	Location	Impact Range		Gilles *et al.* (2023[1])			Lacey *et al.* (2022[2])		
		Area (km^2)	Max Range (m)	# Animals	% CGNS MU	% CGNS UK MU	# Animals	% CGNS MU	% CGNS UK MU
Monopiles	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.01	<50	<1	<0.002	<0.003	<1	<0.002	<0.003
Jackets	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.01	<50	<1	<0.002	<0.003	<1	<0.002	<0.003
Anchors	5, 6, 7, 8 (S)	<0.01	<50	<1	<0.002	<0.003	<1	<0.002	<0.003

Note, there was no overlap of the PTS impact ranges during concurrent piling and therefore all results presented below are for single piling scenario.
(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-7: Piling underwater noise modelling results for auditory injury (PTS) to white-beaked dolphin based on SEL_{cum}.

Foundation Type	Location	Impact Range		Gilles *et al.* (2023[1])			Lacey *et al.* (2022[2])		
		Area (km²)	Max Range (m)	# Animals	% CGNS MU	% CGNS UK MU	# Animals	% CGNS MU	% CGNS UK MU
Monopiles	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.1	<100	<1	<0.002	<0.003	<1	<0.002	<0.003
Jackets	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.1	<100	<1	<0.002	<0.003	<1	<0.002	<0.003
Anchors	5, 6, 7, 8 (S)	<0.01	<100	<1	<0.002	<0.003	<1	<0.002	<0.003

Note, there was no overlap of the PTS impact ranges during concurrent piling and therefore all results presented below are for single piling scenario.

(N) = Caledonia North Site; (S) = Caledonia South Site.

1.2.4 Common Dolphin

1.2.4.1 The results for auditory injury (PTS) as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-8 based on SPL_{peak} and Table 1-9 based on SEL_{cum} metrics.

1.2.4.2 The numbers of animals impacted were calculated based on SCANS III surface densities (Lacey *et al.*, 2022[2]). There were no sightings of common dolphins in SCANS IV block CS-K, where the Proposed Development (Offshore) will be located and therefore results based on SCANS IV are not provided for common dolphins.

Table 1-8: Piling underwater noise modelling results for auditory injury (PTS) to common dolphin based on SPL_{peak}.

Foundation Type	Location	Impact Range		Lacey *et al.* (2022[2])		
		Area (km^2)	Max Range (m)	# Animals	% CGNS MU	% CGNS UK MU
Monopiles	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.01	<50	<1	<0.001	<0.002
Jackets	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.01	<50	<1	<0.001	<0.002
Anchors	5, 6, 7, 8 (S)	<0.01	<50	<1	<0.001	<0.002

Note, there was no overlap of the PTS impact ranges during concurrent piling and therefore all results presented below are for single piling scenario.

(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-9: Piling underwater noise modelling results for auditory injury (PTS) to common dolphin based on SEL_{cum}.

Foundation Type	Location	Impact Range		Lacey *et al.* (2022[2])		
		Area (km^2)	Max Range (m)	# Animals	% CGNS MU	% CGNS UK MU
Monopiles	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.1	<100	<1	<0.001	<0.002
Jackets	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.1	<100	<1	<0.001	<0.002
Anchors	5, 6, 7, 8 (S)	<0.01	<100	<1	<0.001	<0.002

Note, there was no overlap of the PTS impact ranges during concurrent piling and therefore all results presented below are for single piling scenario.

(N) = Caledonia North Site; (S) = Caledonia South Site.

1.2.5 Risso's Dolphin

1.2.5.1 The results for auditory injury (PTS) as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-10 based on SPL_{peak} and Table 1-11 based on SEL_{cum} metrics.

1.2.5.2 The numbers of animals impacted were calculated based on uniform density across SCANS IV blocks (Gilles *et al.*, 2023[1]). Please note that Lacey *et al.* (2022[2]) did not report density values for Risso's dolphins and therefore results based on SCANS III surface densities are not provided.

Table 1-10: Piling underwater noise modelling results for auditory injury (PTS) to Risso's dolphin based on SPL_{peak}.

Foundation Type	Location	Impact Range		Gilles *et al.* (2023[1])		
		Area (km^2)	Max Range (m)	# Animals	% CGNS MU	% CGNS UK MU
Monopiles	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.01	<50	<1	<0.008	<0.01
Jackets	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.01	<50	<1	<0.008	<0.01
Anchors	5, 6, 7, 8 (S)	<0.01	<50	<1	<0.008	<0.01

Note, there was no overlap of the PTS impact ranges during concurrent piling and therefore all results presented below are for single piling scenario.

(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-11: Piling underwater noise modelling results for auditory injury (PTS) to Risso's dolphin based on SEL_{cum}.

Foundation Type	Location	Impact Range		Gilles *et al.* (2023[1])		
		Area (km^2)	Max Range (m)	# Animals	% CGNS MU	% CGNS UK MU
Monopiles	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.1	<100	<1	<0.008	<0.012
Jackets	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	<0.1	<100	<1	<0.008	<0.01
Anchors	5, 6, 7, 8 (S)	<0.01	<100	<1	<0.008	<0.01

Note, there was no overlap of the PTS impact ranges during concurrent piling and therefore all results presented below are for single piling scenario.

(N) = Caledonia North Site; (S) = Caledonia South Site.

1.2.6 Minke Whale

1.2.6.1 The results for auditory injury (PTS) as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-12 based on SPL_{peak} and Table 1-13 based on SEL_{cum} metrics. The numbers of animals impacted were calculated based on uniform density across SCANS IV blocks (Gilles *et al.*, 2023[1]) and SCANS III surface densities (Lacey *et al.*, 2022[2]).

Table 1-12: Piling underwater noise modelling results for auditory injury (PTS) to minke whale based on SPL_{peak}.

Foundation Type	Location	Impact Range		Gilles *et al.* (2023[1])			Lacey *et al.* (2022[2])		
		Area (km^2)	Max Range (m)	# Animals	% CGNS MU	% CGNS UK MU	# Animals	% CGNS MU	% CGNS UK MU
Monopiles	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	0.01	50	<1	<0.005	<0.01	<1	<0.005	<0.01
Jackets	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	0.01	<50	<1	<0.005	<0.01	<1	<0.005	<0.01
Anchors	5, 6, 7, 8 (S)	<0.01	<50	<1	<0.005	<0.01	<1	<0.005	<0.01

Note, there was no overlap of the PTS impact ranges during concurrent piling and therefore all results presented below are for single piling scenario.

(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-13: Piling underwater noise modelling results for auditory injury (PTS) to minke whale based on SEL_{cum}.

Foundation Type	Scenario	Location	Impact Range		Gilles *et al.* (2023[1])			Lacey *et al.* (2022[2])		
			Area (km^2)	Max Range (m)	# Animals	% CGNS MU	% CGNS UK MU	# Animals	% CGNS MU	% CGNS UK MU
Monopiles	Single piling	1 (N)	2,000	30,000	24	0.12	0.23	61	0.30	0.59
		2 (N)	1,900	28,000	22	0.11	0.21	59	0.29	0.57
		3 (N&S)	2,400	32,000	28	0.14	0.27	70	0.35	0.68
		4 (N&S)	2,200	32,000	26	0.13	0.25	73	0.36	0.71
		7 (S)	2,700	35,000	32	0.16	0.31	77	0.38	0.75
		8 (S)	2,500	34,000	29	0.14	0.28	75	0.37	0.73
	Concurrent piling	1 (N) and 4 (N&S)	4,900	32,000	57	0.28	0.55	150	0.75	1.46
		1 (N) and 8 (S)	5,800	34,000	67	0.33	0.65	172	0.85	1.67
		3 (N&S) and 8 (S)	5,300	34,000	62	0.31	0.60	156	0.78	1.52
Jackets	Single piling	1 (N)	1,900	30,000	22	0.11	0.21	56	0.28	0.54
		2 (N)	1,700	28,000	20	0.10	0.19	53	0.26	0.52
		3 (N&S)	2,200	32,000	25	0.12	0.24	63	0.31	0.61
		4 (N&S)	1,900	31,000	23	0.11	0.22	64	0.32	0.62

Foundation Type	Scenario	Location	Impact Range		Gilles *et al.* (2023[1])			Lacey *et al.* (2022[2])		
			Area (km^2)	Max Range (m)	# Animals	% CGNS MU	% CGNS UK MU	# Animals	% CGNS MU	% CGNS UK MU
		7 (S)	2,500	36,000	30	0.15	0.29	70	0.35	0.68
		8 (S)	2,300	34,000	26	0.13	0.25	68	0.34	0.66
	Concurrent piling	1 (N) and 4 (N&S)	4,700	31,000	54	0.27	0.52	141	0.70	1.37
		1 (N) and 8 (S)	5,600	34,000	65	0.32	0.63	166	0.83	1.61
		3 (N&S) and 8 (S)	5,100	34,000	60	0.30	0.58	149	0.74	1.45
Anchors	Single piling	5 (S)	850	19,000	10	0.05	0.10	24	0.12	0.23
		6 (S)	780	19,000	9	0.04	0.09	26	0.13	0.25
		7 (S)	880	19,000	10	0.05	0.10	25	0.12	0.24
		8 (S)	890	20,000	10	0.05	0.10	28	0.14	0.27
	Concurrent piling	5 (S) and 8 (S)	2,400	20,000	28	0.14	0.27	73	0.36	0.71

(N) = Caledonia North Site; (S) = Caledonia South Site.

1.2.7 Harbour Seal

1.2.7.1 The results for auditory injury (PTS) as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-14 based on SPL_{peak} and Table 1-15 based on SEL_{cum} metrics. The numbers of animals impacted were calculated based on mean at-sea densities (Carter *et al.*, 2020[7]). It should be also noted that all impacted seals were located in the Moray Firth MU.

Table 1-14: Piling underwater noise modelling results for auditory injury (PTS) to harbour seal based on SPL_{peak}.

Foundation Type	Location	Impact Range		Carter *et al.* (2020[7])	
		Area (km^2)	Max Range (m)	# Animals	% Moray Firth MU
Monopiles	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	0.01	60	<1	<0.1
Jackets	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	0.01	60	<1	<0.1
Anchors	5, 6, 7, 8 (S)	0.01	60	<1	<0.1

Note, there was no overlap of the PTS impact ranges during concurrent piling and therefore all results presented below are for single piling scenario.

(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-15: Piling underwater noise modelling results for auditory injury (PTS) to harbour seal based on SEL_{cum}.

Foundation Type	Scenario	Location	Impact Range		Carter *et al.* (2020[7])	
			Area (km^2)	Max Range (m)	# Animals	% Moray Firth MU
Monopiles	Single piling	1 (N)	4.00	1,200	<1	<0.1
		2 (N)	3.80	1,200	<1	<0.1
		3 (N&S)	4.00	1,200	<1	<0.1
		4 (N&S)	4.10	1,200	<1	<0.1
		7 (S)	5.40	1,500	<1	<0.1
		8 (S)	5.40	1,400	<1	<0.1
	Concurrent piling	1 (N) and 4 (N&S)	240.00	15,000	<1	<0.1
		1 (N) and 8 (S)	13.00	22,000	<1	<0.1
		3 (N&S) and 8 (S)	250.00	14,500	<1	<0.1
Jackets	Single piling	1 (N)	1.70	830	<1	<0.1
		2 (N)	1.60	780	<1	<0.1
		3 (N&S)	1.80	830	<1	<0.1
		4 (N&S)	1.80	850	<1	<0.1
		7 (S)	2.60	1,000	<1	<0.1

Foundation Type	Scenario	Location	Impact Range		Carter *et al.* (2020[7])	
			Area (km^2)	Max Range (m)	# Animals	% Moray Firth MU
		8 (S)	2.60	1,000	<1	<0.1
	Concurrent piling	1 (N) and 4 (N&S)	240.00	15,000	<1	<0.1
		1 (N) and 8 (S)	380.00	22,000	1	0.1
		3 (N&S) and 8 (S)	240.00	14,500	<1	<0.1
Anchors	Single piling	5 (S)	0.01	<100	<1	<0.1
		6 (S)	0.01	<100	<1	<0.1
		7 (S)	0.01	<100	<1	<0.1
		8 (S)	0.01	<100	<1	<0.1
	Concurrent piling	5 (S) and 8 (S)	95	11,500	<1	<0.1

Note, there was no overlap of the PTS impact ranges during concurrent piling at anchors.
(N) = Caledonia North Site; (S) = Caledonia South Site.

1.2.8 Grey Seal

1.2.8.1 The results for auditory injury (PTS) as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-16 based on SPL_{peak} and Table 1-17 based on SEL_{cum}. The numbers of animals impacted were calculated based on mean at-sea densities (Carter *et al.*, 2020[7]). It should be also noted that all impacted seals were located in the Moray Firth MU.

Table 1-16: Piling underwater noise modelling results for auditory injury (PTS) to grey seal based on SPL_{peak}.

Foundation Type	Location	Impact Range		Carter *et al.* (2020[7])	
		Area (km^2)	Max Range (m)	# Animals	% Moray Firth MU
Monopiles	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	0.01	60	<1	<0.01
Jackets	1, 2 (N) 3, 4 (N&S) 7, 8 (S)	0.01	60	<1	<0.01
Anchors	5, 6, 7, 8 (S)	0.01	60	<1	<0.01

Note, there was no overlap of the PTS impact ranges during concurrent piling and therefore all results presented below are for single piling scenario.

(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-17: Piling underwater noise modelling results for auditory injury (PTS) to grey seal based on SEL_{cum}.

Foundation Type	Scenario	Location	Impact Range		Carter *et al.* (2020[7])	
			Area (km^2)	Max Range (m)	# Animals	% Moray Firth MU
Monopiles	Single piling	1 (N)	4.00	1,200	1	0.01
		2 (N)	3.80	1,200	1	0.01
		3 (N&S)	4.00	1,200	2	0.03
		4 (N&S)	4.10	1,200	2	0.03
		7 (S)	5.40	1,500	<1	<0.01
		8 (S)	5.40	1,400	<1	<0.01
	Concurrent piling	1 (N) and 4 (N&S)	240.00	15,000	103	1.40
		1 (N) and 8 (S)	13.00	22,000	2	0.03
		3 (N&S) and 8 (S)	250.00	14,500	58	0.79
Jackets	Single piling	1 (N)	1.70	830	<1	<0.01
		2 (N)	1.60	780	<1	<0.01
		3 (N&S)	1.80	830	1	0.01
		4 (N&S)	1.80	850	1	0.01
		7 (S)	2.60	1,000	1	0.01
		8 (S)	2.60	1,000	2	0.03

Foundation Type	Scenario	Location	Impact Range		Carter *et al.* (2020[7])	
			Area (km^2)	Max Range (m)	# Animals	% Moray Firth MU
	Concurrent piling	1 (N) and 4 (N&S)	240.00	15,000	100	1.36
		1 (N) and 8 (S)	380.00	22,000	132	1.79
		3 (N&S) and 8 (S)	240.00	14,500	54	0.73
Anchors	Single piling	5 (S)	0.01	<100	<1	<0.01
		6 (S)	0.01	<100	<1	<0.01
		7 (S)	0.01	<100	1	0.01
		8 (S)	0.01	<100	1	0.01
	Concurrent piling	5 (S) and 8 (S)	95	11,500	17	0.23

Note, there was no overlap of the PTS impact ranges during concurrent piling at anchors.
(N) = Caledonia North Site; (S) = Caledonia South Site.

1.3 Behavioural Disturbance

1.3.1 Harbour Porpoise

1.3.1.1 The results for behavioural disturbance as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-18 using dose-response approach. The numbers of animals impacted were calculated based on uniform density across SCANS IV blocks (Gilles *et al.*, 2023[1]) and SCANS III surface densities (Lacey *et al.*, 2022[2]).

Table 1-18: Predicted impact of disturbance as a result of underwater noise during piling on harbour porpoise using dose-response approach.

Foundation Type	Scenario	Modelling Location	Giles *et al*. (2023[1])				Lacey *et al*. (2022[2])			
			# Animals NS MU	% NS MU	# Animals UK NS MU	% UK NS MU	# Animals NS MU	% NS MU	# Animals UK NS MU	% UK NS MU
Monopiles	Single piling	1 (N)	6,713	1.94	6,666	4.18	6,434	1.86	6,392	4.00
		2 (N)	6,057	1.75	6,028	3.78	5,848	1.69	5,822	3.65
		3 (N&S)	8,002	2.31	7,918	4.96	7,639	2.20	7,569	4.74
		4 (N&S)	6,683	1.93	6,647	4.16	6,480	1.87	6,448	4.04
		7 (S)	8,942	2.58	8,827	5.53	8,505	2.45	8,411	5.27
		8 (S)	7,317	2.11	7,267	4.55	7,063	2.04	7,020	4.40
	Concurrent piling	1 (N) and 4 (N&S)	7,823	2.26	7,776	4.87	7,557	2.18	7,515	4.71
		1 (N) and 8 (S)	8,602	2.48	8,545	5.35	8,318	2.40	8,268	5.18
		3 (N&S) and 8 (S)	8,881	2.56	8,797	5.51	8,529	2.46	8,458	5.30
Jackets	Single piling	1 (N)	6,088	1.76	6,056	3.79	5,856	1.69	5,827	3.65
		2 (N)	5,482	1.58	5,462	3.42	5,316	1.53	5,298	3.32
		3 (N&S)	7,274	2.10	7,213	4.52	6,966	2.01	6,914	4.33

Foundation Type	Scenario	Modelling Location	Giles *et al*. (2023[1])				Lacey *et al*. (2022[2])			
			# Animals NS MU	% NS MU	# Animals UK NS MU	% UK NS MU	# Animals NS MU	% NS MU	# Animals UK NS MU	% UK NS MU
		4 (N&S)	6,078	1.75	6,054	3.79	5,910	1.71	5,887	3.69
		7 (S)	8,201	2.37	8,111	5.08	7,818	2.26	7,743	4.85
		8 (S)	6,685	1.93	6,649	4.17	6,471	1.87	6,440	4.03
	Concurrent piling	1 (N) and 4 (N&S)	7,157	2.06	7,124	4.46	6,936	2.00	6,906	4.33
		1 (N) and 8 (S)	7,898	2.28	7,856	4.92	7,664	2.21	7,628	4.78
		3 (N&S) and 8 (S)	8,132	2.35	8,071	5.06	7,834	2.26	7,782	4.87
Anchors	Single piling	5 (S)	6,530	1.88	6,487	4.06	6,266	1.81	6,230	3.90
		6 (S)	5,094	1.47	5,083	3.18	4,978	1.44	4,967	3.11
		7 (S)	6,648	1.92	6,604	4.14	6,357	1.84	6,337	3.97
		8 (S)	5,431	1.57	5,417	3.39	5,287	1.53	5,273	3.30
	Concurrent piling	5 (S) and 8 (S)	6,990	2.02	6,947	4.35	6,734	1.94	6,679	4.20

(N) = Caledonia North Site; (S) = Caledonia South Site.

1.3.2 Bottlenose Dolphin

1.3.2.1 The results for behavioural disturbance as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-19 and Table 1-20, for CES MU and GNS MU, respectively. Details regarding bottlenose dolphin densities are summarised in Section 1.2.2 and provided in more detail in Volume 7B, Appendix 7-1: Marine Mammals Baseline Characterisation.

Table 1-19: Predicted impact of disturbance as a result of underwater noise during piling on bottlenose dolphin for the CES MU using dose-response approach.

Foundation Type	Scenario	Modelling Location	Dose-response	
			# Animals CES MU	% CES MU
Monopiles	Single piling	1 (N)	30	12.24
		2 (N)	32	13.06
		3 (N&S)	38	15.51
		4 (N&S)	51	20.82
		7 (S)	41	16.73
		8 (S)	56	22.86
	Concurrent piling	1 (N) and 4 (N&S)	52	21.22
		1 (N) and 8 (S)	58	23.67
		3 (N&S) and 8 (S)	57	23.27
Jackets	Single piling	1 (N)	28	11.43
		2 (N)	30	12.24
		3 (N&S)	36	14.69
		4 (N&S)	48	19.59
		7 (S)	38	15.51
		8 (S)	52	21.22

Foundation Type	Scenario	Modelling Location	Dose-response	
			# Animals CES MU	% CES MU
	Concurrent piling	1 (N) and 4 (N&S)	49	20.00
		1 (N) and 8 (S)	54	22.04
		3 (N&S) and 8 (S)	53	21.63
Anchors	Single piling	5 (S)	32	13.06
		6 (S)	41	16.73
		7 (S)	33	13.47
		8 (S)	46	18.78
	Concurrent piling	5 (S) and 8 (S)	47	19.18

(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-20: Predicted impact of disturbance as a result of underwater noise during piling on bottlenose dolphin within the GNS MU using dose-response approach.

Foundation Type	Scenario	Modelling Location	Dose-response	
			# Animals GNS MU	% GNS MU
Monopiles	Single piling	1 (N)	29	1.43
		2 (N)	25	1.24
		3 (N&S)	34	1.68
		4 (N&S)	25	1.24
		7 (S)	39	1.93
		8 (S)	28	1.38
	Concurrent piling	1 (N) and 4 (N&S)	32	1.58
		1 (N) and 8 (S)	36	1.78
		3 (N&S) and 8 (S)	37	1.83
Jackets	Single piling	1 (N)	26	1.29
		2 (N)	22	1.09
		3 (N&S)	30	1.48
		4 (N&S)	22	1.09
		7 (S)	35	1.73

Foundation Type	Scenario	Modelling Location	Dose-response	
			# Animals GNS MU	% GNS MU
		8 (S)	25	1.24
	Concurrent piling	1 (N) and 4 (N&S)	29	1.43
		1 (N) and 8 (S)	32	1.58
		3 (N&S) and 8 (S)	33	1.63
Anchors	Single piling	5 (S)	27	1.34
		6 (S)	18	0.89
		7 (S)	27	1.34
		8 (S)	19	0.94
	Concurrent piling	5 (S) and 8 (S)	28	1.38
(N) = Caledonia North Site; (S) = Caledonia South Site.				

1.3.3 White-beaked Dolphin

1.3.3.1 The results for behavioural disturbance as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-21 using dose-response approach.

1.3.3.2 The numbers of animals impacted were calculated based on uniform density across SCANS IV blocks (Gilles *et al.*, 2023[1]) and SCANS III surface densities (Lacey *et al.*, 2022[2]).

Table 1-21: Predicted impact of disturbance as a result of underwater noise during piling on white-beaked dolphin using dose-response approach.

Foundation Type	Scenario	Modelling Location	Gilles *et al.* (2023[1])				Lacey *et al.* (2022[2])			
			# animals CGNS MU	% CGNS MU	# animals UK CGNS MU	% UK CGNS MU	# animals CGNS MU	% CGNS MU	# animals UK CGNS MU	% UK CGNS MU
Monopiles	Single piling	1 (N)	2,526	5.75	2,499	7.34	1,384	3.15	1,384	4.07
		2 (N)	2,297	5.23	2,281	6.70	1,218	2.77	1,218	3.58
		3 (N&S)	2,867	6.52	2,824	8.30	2,010	4.57	2,008	5.90
		4 (N&S)	2,398	5.46	2,378	6.99	1,752	3.99	1,751	5.15
		7 (S)	3,114	7.09	3,057	8.98	2,442	5.56	2,440	7.17
		8 (S)	2,507	5.70	2,481	7.29	2,197	5.00	2,197	6.46
	Concurrent piling	1 (N) and 4 (N&S)	2,857	6.50	2,831	8.32	1,800	4.10	1,800	5.29
		1 (N) and 8 (S)	3,037	6.91	3,007	8.84	2,249	5.12	2,248	6.61
		3 (N&S) and 8 (S)	3,113	7.08	3,070	9.02	2,372	5.40	2,370	6.97
Jackets	Single piling	1 (N)	2,306	5.25	2,287	6.72	1,220	2.78	1,219	3.58
		2 (N)	2,098	4.77	2,086	6.13	1,064	2.42	1,064	3.13
		3 (N&S)	2,624	5.97	2,592	7.62	1,792	4.08	1,791	5.26

Foundation Type	Scenario	Modelling Location	Gilles *et al.* (2023[1])				Lacey *et al.* (2022[2])			
			# animals CGNS MU	% CGNS MU	# animals UK CGNS MU	% UK CGNS MU	# animals CGNS MU	% CGNS MU	# animals UK CGNS MU	% UK CGNS MU
		4 (N&S)	2,199	5.00	2,186	6.42	1,559	3.55	1,558	4.58
		7 (S)	2,873	6.54	2,828	8.31	2,210	5.03	2,208	6.49
		8 (S)	2,308	5.25	2,290	6.73	1,983	4.51	1,983	5.83
	Concurrent piling	1 (N) and 4 (N&S)	2,634	5.99	2,615	7.69	1,605	3.65	1,605	4.72
		1 (N) and 8 (S)	2,810	6.39	2,788	8.19	2,031	4.62	2,030	5.97
		3 (N&S) and 8 (S)	2,871	6.53	2,839	8.34	2,138	4.86	2,137	6.28
Anchors	Single piling	5 (S)	2,329	5.30	2,307	6.78	1,682	3.83	1,681	4.94
		6 (S)	1,862	4.24	1,855	5.45	1,276	2.90	1,276	3.75
		7 (S)	2,363	5.38	2,340	6.88	1,729	3.93	1,729	5.08
		8 (S)	1,909	4.34	1,901	5.59	1,555	3.54	1,554	4.57
	Concurrent piling	5 (S) and 8 (S)	2,488	5.66	2,466	7.25	1,818	4.14	1,817	5.34

(N) = Caledonia North Site; (S) = Caledonia South Site.

1.3.4 Common Dolphin

1.3.4.1 The results for behavioural disturbance as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-22 using dose-response approach.

1.3.4.2 The numbers of animals impacted were calculated based on SCANS III surface densities (Lacey *et al.*, 2022[2]). There were no sightings of common dolphins in SCANS IV block CS-K, where the Proposed Development will be located and therefore results based on SCANS IV are not provided for common dolphins.

Table 1-22: Predicted impact of disturbance as a result of underwater noise during piling on common dolphin using dose-response approach.

Foundation Type	Scenario	Modelling Location	Lacey *et al.* (2022[2])			
			# Animals CGNS MU	% CGNS MU	# Animals UK CGNS MU	% UK CGNS MU
Monopiles	Single piling	1 (N), 2 (N), 3 (N&S), 4 (N&S), 8 (S)	3	0.003	3	0.005
		7 (S)	4	0.004	4	0.007
	Concurrent piling	1 (N) and 4 (N&S)	4	0.004	4	0.007
		1 (N) and 8 (S)	4	0.004	4	0.007
		3 (N&S) and 8 (S)	4	0.004	4	0.007
Jackets	Single piling	1 (N), 2 (N), 3 (N&S), 4 (N&S), 7 (S), 8 (S)	3	0.003	3	0.005
	Concurrent piling	1 (N) and 4 (N&S)	4	0.004	4	0.007
		1 (N) and 8 (S)	4	0.004	4	0.007
		3 (N&S) and 8 (S)	4	0.004	4	0.007
Anchors	Single piling	5 (S), 6 (S), 7 (S), 8 (S)	3	0.003	3	0.005
	Concurrent piling	5 (S) and 8 (S)	3	0.003	3	0.005
(N) = Caledonia North Site; (S) = Caledonia South Site.						

1.3.5 Risso's Dolphin

1.3.5.1 The results for behavioural disturbance as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-23 using dose-response approach.

1.3.5.2 The numbers of animals impacted were calculated based on uniform density across SCANS IV blocks (Gilles *et al.*, 2023[1]). Please note that Lacey *et al.* (2022[2]) did not report density values for Risso's dolphins and therefore results based on SCANS III surface densities are not provided.

Table 1-23: Predicted impact of disturbance as a result of underwater noise during piling on Risso's dolphin using dose-response approach.

Foundation Type	Scenario	Modelling Location	Gilles *et al.* (2023[1])			
			# Animals CGNS MU	% CGNS MU	# Animals UK CGNS MU	% UK CGNS MU
Monopiles	Single piling	1 (N), 2 (N), 3 (N&S), 4 (N&S), 7 (S), 8 (S)	<1	<0.008	<1	<0.01
	Concurrent piling	1 (N) and 4 (N&S)	<1	<0.008	<1	<0.01
		1 (N) and 8 (S)	<1	<0.008	<1	<0.01
		3 (N&S) and 8 (S)	<1	<0.008	<1	<0.01
Jackets	Single piling	1 (N), 2 (N), 3 (N&S), 4 (N&S), 7 (S), 8 (S)	<1	<0.008	<1	<0.01
	Concurrent piling	1 (N) and 4 (N&S)	<1	<0.008	<1	<0.01
		1 (N) and 8 (S)	<1	<0.008	<1	<0.01
		3 (N&S) and 8 (S)	<1	<0.008	<1	<0.01
Anchors	Single piling	5 (S), 6 (S), 7 (S), 8 (S)	<1	<0.008	<1	<0.01
	Concurrent piling	5 (S) and 8 (S)	<1	<0.008	<1	<0.01
(N) = Caledonia North Site; (S) = Caledonia South Site.						

1.3.6 Minke Whale

1.3.6.1 The results for behavioural disturbance as a result of underwater noise during piling at various locations across the Caledonia OWF are provided in Table 1-24 using dose-response approach.

1.3.6.2 The numbers of animals impacted were calculated based on uniform density across SCANS IV blocks (Gilles *et al.*, 2023[1]) and SCANS III surface densities (Lacey *et al.*, 2022[2]).

Table 1-24: Predicted impact of disturbance as a result of underwater noise during piling on minke whale using dose-response approach.

Foundation Type	Scenario	Modelling Location	Giles *et al*. (2023[1])				Lacey *et al*. (2022[2])			
			# Animals CGNS MU	% CGNS MU	# Animals UK CGNS MU	% UK CGNS MU	# Animals CGNS MU	% CGNS MU	# Animals UK CGNS MU	% UK CGNS MU
Monopiles	Single piling	1 (N)	231	1.15	229	2.23	434	2.16	432	4.20
		2 (N)	211	1.05	210	2.04	405	2.01	403	3.92
		3 (N&S)	286	1.42	282	2.74	498	2.48	493	4.79
		4 (N&S)	250	1.24	248	2.41	441	2.19	439	4.27
		7 (S)	326	1.62	321	3.12	543	2.70	536	5.21
		8 (S)	207	1.03	278	2.70	466	2.32	463	4.50
	Concurrent piling	1 (N) and 4 (N&S)	286	1.42	284	2.76	508	2.53	505	4.91
		1 (N) and 8 (S)	324	1.61	321	3.12	547	2.72	543	5.28
		3 (N&S) and 8 (S)	332	1.65	328	3.19	556	2.76	551	5.36
Jackets	Single piling	1 (N)	209	1.04	207	2.01	399	1.98	397	3.86
		2 (N)	191	0.95	190	1.85	373	1.85	371	3.61
		3 (N&S)	259	1.29	257	2.50	458	2.28	455	4.42

Foundation Type	Scenario	Modelling Location	Giles *et al*. (2023[1])				Lacey *et al*. (2022[2])			
			# Animals CGNS MU	% CGNS MU	# Animals UK CGNS MU	% UK CGNS MU	# Animals CGNS MU	% CGNS MU	# Animals UK CGNS MU	% UK CGNS MU
		4 (N&S)	227	1.13	225	2.19	407	2.02	406	3.95
		7 (S)	298	1.48	294	2.86	502	2.50	496	4.82
		8 (S)	281	1.40	255	2.48	431	2.14	428	4.16
	Concurrent piling	1 (N) and 4 (N&S)	261	1.30	259	2.52	471	2.34	469	4.56
		1 (N) and 8 (S)	297	1.48	295	2.87	508	2.53	506	4.92
		3 (N&S) and 8 (S)	303	1.51	301	2.93	516	2.56	512	4.98
Anchors	Single piling	5 (S)	235	1.17	233	2.26	410	2.04	407	3.96
		6 (S)	190	0.94	190	1.85	349	1.73	348	3.38
		7 (S)	240	1.19	238	2.31	415	2.06	413	4.01
		8 (S)	256	1.27	207	2.01	359	1.78	358	3.48
	Concurrent piling	5 (S) and 8 (S)	257	1.28	255	2.48	448	2.23	445	4.33

(N) = Caledonia North Site; (S) = Caledonia South Site.

1.3.7 Harbour Seal

1.3.7.1 The results for behavioural disturbance as a result of underwater noise during piling at various locations across the Caledonia OWF are provided based on the Whyte (2021[11]) dose-response function separately for Moray Firth MU, North Coast and Orkney MU as well as East Scotland MU in Table 1-25, Table 1-26, and Table 1-27, respectively. The numbers of animals impacted were calculated based on mean at-sea densities from Carter *et al.* (2020[7]).

1.3.7.2 A total number of harbour seals potentially impacted is presented in Table 1-28. The population size within each MU (Table 1-1) were added to result in a total population of 3,385 harbour seals across three MUs. Given the large confidence intervals on the data, the assessment presents the mean number of seals predicted to be disturbed using both the mean dose-response and the 95% confidence intervals (CI) (as advised by Whyte *et al.,* 2020[10]).

Table 1-25: Predicted impact of disturbance as a result of underwater noise during piling on harbour seal within the MF SMU using dose-response approach.

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# animals	% MU	# animals	% MU	# animals	% MU
Monopiles	Single piling	1 (N)	38	3.97	20	2.09	1	0.10
		2 (N)	52	5.43	27	2.82	2	0.21
		3 (N&S)	51	5.32	26	2.71	2	0.21
		4 (N&S)	122	12.73	61	6.37	4	0.42
		7 (S)	61	6.37	30	3.13	2	0.21
		8 (S)	142	14.82	71	7.41	5	0.52
	Concurrent piling	1 (N) and 4 (N&S)	124	12.94	63	6.58	5	0.52
		1 (N) and 8 (S)	152	15.87	77	8.04	5	0.52
		3 (N&S) and 8 (S)	148	15.45	75	7.83	5	0.52
Jackets	Single piling	1 (N)	31	3.24	16	1.67	1	0.10
		2 (N)	42	4.38	22	2.30	2	0.21
		3 (N&S)	43	4.49	21	2.19	1	0.10
		4 (N&S)	105	10.96	53	5.53	4	0.42
		7 (S)	51	5.32	25	2.61	1	0.10
		8 (S)	116	12.11	58	6.05	4	0.42

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# animals	% MU	# animals	% MU	# animals	% MU
	Concurrent piling	1 (N) and 4 (N&S)	108	11.27	55	5.74	4	0.42
		1 (N) and 8 (S)	127	13.26	65	6.78	5	0.52
		3 (N&S) and 8 (S)	124	12.94	62	6.47	4	0.42
Anchors	Single piling	5 (S)	32	3.34	15	1.57	1	0.10
		6 (S)	76	7.93	38	3.97	2	0.21
		7 (S)	32	3.34	16	1.67	1	0.10
		8 (S)	78	8.14	39	4.07	3	0.31
	Concurrent piling	5 (S) and 8 (S)	83	8.66	42	4.38	3	0.31

Note, confidence intervals are presented here due to the large confidence intervals in the dose-response function for harbour seals.

Lower CI means higher response level, which means more animals are predicted to be impacted; Upper CI means lower response level, which means fewer animals are predicted to be impacted.

(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-26: Predicted impact of disturbance as a result of underwater noise during piling on harbour seal within the NC&O SMU using dose-response approach.

Foundation type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# animals	% MU	# animals	% MU	# animals	% MU
Monopiles	Single piling	1 (N)	180	11.31	95	5.97	11	0.69
		2 (N)	151	9.49	78	4.90	8	0.50
		3 (N&S)	113	7.10	54	3.39	2	0.13
		4 (N&S)	26	1.63	12	0.75	1	<0.06
		7 (S)	62	3.90	29	1.82	1	0.06
		8 (S)	3	0.19	1	0.06	<1	<0.06
	Concurrent piling	1 (N) and 4 (N&S)	180	11.31	95	5.97	11	0.69
		1 (N) and 8 (S)	180	11.31	95	5.97	11	0.69
		3 (N&S) and 8 (S)	113	7.10	54	3.39	2	0.13
Jackets	Single piling	1 (N)	165	10.37	86	5.41	9	0.57
		2 (N)	139	8.74	70	4.40	6	0.38
		3 (N&S)	90	5.66	43	2.70	1	0.06
		4 (N&S)	14	0.88	7	0.44	<1	<0.06
		7 (S)	39	2.45	18	1.13	<1	<0.06
		8 (S)	2	0.13	1	0.06	<1	<0.06

Foundation type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# animals	% MU	# animals	% MU	# animals	% MU
	Concurrent piling	1 (N) and 4 (N&S)	165	10.37	86	5.41	9	0.57
		1 (N) and 8 (S)	165	10.37	86	5.41	9	0.57
		3 (N&S) and 8 (S)	90	5.66	43	2.70	1	0.06
Anchors	Single piling	5 (S)	14	0.88	6	0.38	<1	<0.06
		6 (S)	2	0.13	1	0.06	<1	<0.06
		7 (S)	11	0.69	5	0.31	<1	<0.06
		8 (S)	<1	<0.06	1	<0.06	<1	<0.06
	Concurrent piling	5 (S) and 8 (S)	14	0.88	6	0.38	<1	<0.06

(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-27: Predicted impact of disturbance as a result of underwater noise during piling on harbour seal within the ES SMU using dose-response approach.

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# Animals	% MU	# Animals	% MU	# Animals	% MU
Monopiles	Single piling	1 (N), 2 (N), 3 (N&S), 4 (N&S), 7 (S), 8 (S)	<1	<0.27	<1	<0.27	<1	<0.06
	Concurrent piling	1 (N) and 4 (N&S)	<1	0.27	<1	<0.27	<1	<0.06
		1 (N) and 8 (S)	<1	0.27	<1	0.27	<1	<0.06
		3 (N&S) and 8 (S)	<1	0.27	<1	0.27	<1	<0.06
Jackets	Single piling	1 (N), 2 (N), 3 (N&S), 4 (N&S), 7 (S), 8 (S)	<1	<0.27	<1	<0.27	<1	<0.06
	Concurrent piling	1 (N) and 4 (N&S)	<1	0.27	<1	<0.27	<1	<0.06
		1 (N) and 8 (S)	<1	0.27	<1	0.27	<1	<0.06
		3 (N&S) and 8 (S)	<1	0.27	<1	0.27	<1	<0.06
Anchors	Single piling	5 (S), 6 (S), 7 (S), 8 (S)	<1	0.27	<1	<0.27	<1	<0.06
	Concurrent piling	5 (S) and 8 (S)	<1	0.27	<1	<0.27	<1	<0.06
(N) = Caledonia North Site; (S) = Caledonia South Site.								

Table 1-28: A total predicted impact of disturbance as a result of underwater noise during piling on harbour seal within three SMUs (MF, NC&O and ES) using dose-response approach.

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# Animals	% MU	# Animals	% MU	# Animals	% MU
Monopiles	Single piling	1 (N)	219	6.47	116	3.43	13	0.38
		2 (N)	204	6.03	106	3.13	11	0.32
		3 (N&S)	165	4.87	81	2.39	5	0.15
		4 (N&S)	149	4.40	74	2.19	6	0.18
		7 (S)	124	3.66	60	1.77	4	0.12
		8 (S)	146	4.31	73	2.16	7	0.21
	Concurrent piling	1 (N) and 4 (N&S)	305	9.01	159	4.70	17	0.50
		1 (N) and 8 (S)	333	9.84	173	5.11	17	0.50
		3 (N&S) and 8 (S)	262	7.74	130	3.84	8	0.24
Jackets	Single piling	Location 1 (N)	197	5.82	103	3.04	11	0.32
		Location 2 (N)	182	5.38	93	2.75	9	0.27
		Location 3 (N&S)	134	3.96	65	1.92	3	0.09
		Location 4 (N&S)	120	3.55	61	1.80	6	0.18
		Location 7 (S)	91	2.69	44	1.30	3	0.09

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# Animals	% MU	# Animals	% MU	# Animals	% MU
		8 (S)	119	3.52	60	1.77	6	0.18
	Concurrent piling	1 (N) and 4 (N&S)	274	8.09	142	4.19	14	0.41
		1 (N) and 8 (S)	293	8.66	152	4.49	15	0.44
		3 (N&S) and 8 (S)	215	6.35	106	3.13	6	0.18
Anchors	Single piling	5 (S)	47	1.39	22	0.65	3	0.09
		6 (S)	79	2.33	40	1.18	4	0.12
		7 (S)	44	1.30	22	0.65	3	0.09
		8 (S)	80	2.36	41	1.21	5	0.15
	Concurrent piling	5 (S) and 8 (S)	98	2.90	49	1.45	5	0.15
(N) = Caledonia North Site; (S) = Caledonia South Site.								

1.3.8 Grey Seal

1.3.8.1 The results for behavioural disturbance as a result of underwater noise during piling at various locations across the Caledonia OWF are provided based on the Whyte (2021[11]) dose-response function separately for Moray Firth MU, North Coast and Orkney MU as well as East Scotland MU in Table 1-29, Table 1-30, and Table 1-31, respectively. The numbers of animals impacted were calculated based on mean at-sea densities from Carter *et al.* (2020[7]).

1.3.8.2 A total number of grey seals potentially impacted is presented in Table 1-32. The population size within each MU (Table 1-1) were added to result in a total population of 52,354 grey seals across three MUs. Given the large confidence intervals on the data, the assessment presents the mean number of seals predicted to be disturbed using both the mean dose-response and the 95% confidence intervals (CI) (as advised by Whyte *et al*., 2020[10]).

Table 1-29: Predicted impact of disturbance as a result of underwater noise during piling on grey seal within the MF SMU using dose-response approach.

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# Animals	% MU	# Animals	% MU	# Animals	% MU
Monopiles	Single piling	1 (N)	2,552	34.58	1,360	18.43	140	1.90
		2 (N)	2,886	39.11	1,529	20.72	156	2.11
		3 (N&S)	2,984	40.43	1,599	21.67	194	2.63
		4 (N&S)	3,756	50.89	2,038	27.62	235	3.18
		7 (S)	3,127	42.37	1,672	22.66	199	2.70
		8 (S)	3,757	50.91	2,023	27.41	206	2.79
	Concurrent piling	1 (N) and 4 (N&S)	3,815	51.69	2,120	28.73	274	3.71
		1 (N) and 8 (S)	4,024	54.53	2,236	30.30	272	3.69
		3 (N&S) and 8 (S)	3,985	54.00	2,195	29.74	272	3.69
Jackets	Single piling	1 (N)	2,260	30.62	1,207	16.36	122	1.65
		2 (N)	2,636	35.72	1,396	18.92	139	1.88
		3 (N&S)	2,860	38.75	1,510	20.46	166	2.25
		4 (N&S)	3,566	48.32	1,921	26.03	221	2.99
		7 (S)	2,958	40.08	1,562	21.17	168	2.28
		8 (S)	3,521	47.71	1,891	25.62	195	2.64

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# Animals	% MU	# Animals	% MU	# Animals	% MU
	Concurrent piling	1 (N) and 4 (N&S)	3,633	49.23	2,009	27.22	257	3.48
		1 (N) and 8 (S)	3,861	52.32	2,135	28.93	253	3.43
		3 (N&S) and 8 (S)	3,810	51.63	2,084	28.24	255	3.46
Anchors	Single piling	5 (S)	2,543	34.46	1,304	17.67	106	1.44
		6 (S)	3,104	42.06	1,650	22.36	184	2.49
		7 (S)	2,543	34.46	1,307	17.71	108	1.46
		8 (S)	2,911	39.44	1,561	21.15	174	2.36
	Concurrent piling	5 (S) and 8 (S)	3,245	43.97	1,742	23.60	194	2.63

Note, confidence intervals are presented here due to the large confidence intervals in the dose-response function for grey seals.

Lower CI means higher response level, which means more animals are predicted to be impacted; Upper CI means lower response level, which means fewer animals are predicted to be impacted.

(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-30: Predicted impact of disturbance as a result of underwater noise during piling on grey seal within the NC&O SMU using dose-response approach.

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# Animals	% MU	# Animals	% MU	# Animals	% MU
Monopiles	Single piling	1 (N)	6,320	18.48	3,401	9.95	361	1.06
		2 (N)	5,742	16.79	3,040	8.89	334	0.98
		3 (N&S)	5,507	16.11	2,835	8.29	263	0.77
		4 (N&S)	3,155	9.23	1,516	4.43	61	0.18
		7 (S)	4,715	13.79	2,383	6.97	181	0.53
		8 (S)	1,669	4.88	801	2.34	31	0.09
	Concurrent piling	1 (N) and 4 (N&S)	6,329	18.51	3,407	9.96	362	1.06
		1 (N) and 8 (S)	6,336	18.53	3,410	9.97	362	1.06
		3 (N&S) and 8 (S)	5,507	16.11	2,835	8.29	263	0.77
Jackets	Single piling	1 (N)	6,004	17.56	3,199	9.36	342	1.00
		2 (N)	5,429	15.88	2,840	8.31	302	0.88
		3 (N&S)	5,021	14.69	2,558	7.48	222	0.65
		4 (N&S)	2,542	7.43	1,212	3.54	39	0.11
		7 (S)	4,106	12.01	2,051	6.00	138	0.40

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# Animals	% MU	# Animals	% MU	# Animals	% MU
		8 (S)	1,185	3.47	565	1.65	18	0.05
	Concurrent piling	1 (N) and 4 (N&S)	6,012	17.58	3,204	9.37	343	1.00
		1 (N) and 8 (S)	6,018	17.60	3,206	9.38	343	1.00
		3 (N&S) and 8 (S)	5,021	14.69	2,558	7.48	222	0.65
Anchors	Single piling	5 (S)	3,054	8.93	1,496	4.38	80	0.23
		6 (S)	1,055	3.09	498	1.46	11	0.03
		7 (S)	2,957	8.65	1,450	4.24	79	0.23
		8 (S)	580	1.70	272	0.80	4	0.01
	Concurrent piling	5 (S) and 8 (S)	3,054	8.93	1,496	4.38	80	0.23

(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-31: Predicted impact of disturbance as a result of underwater noise during piling on grey seal within the ES SMU using dose-response approach.

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# Animals	% MU	# Animals	% MU	# Animals	% MU
Monopiles	Single piling	1 (N)	78	0.72	36	0.33	0	0.00
		2 (N)	49	0.45	23	0.21	0	0.00
		3 (N&S)	397	3.68	190	1.76	7	0.06
		4 (N&S)	397	3.68	191	1.77	8	0.07
		7 (S)	546	5.06	274	2.54	23	0.21
		8 (S)	576	5.34	294	2.73	28	0.26
	Concurrent piling	1 (N) and 4 (N&S)	397	3.68	191	1.77	8	0.07
		1 (N) and 8 (S)	576	5.34	157	1.46	28	0.26
		3 (N&S) and 8 (S)	584	5.42	299	2.77	29	0.27
Jackets	Single piling	1 (N)	42	0.39	20	0.19	0	0.00
		2 (N)	16	0.15	8	0.07	0	0.00
		3 (N&S)	331	3.07	157	1.46	4	0.04
		4 (N&S)	333	3.09	157	1.46	4	0.04
		7 (S)	489	4.53	241	2.23	15	0.14
		8 (S)	515	4.78	261	2.42	24	0.22

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# Animals	% MU	# Animals	% MU	# Animals	% MU
	Concurrent piling	1 (N) and 4 (N&S)	333	3.09	294	2.73	4	0.04
		1 (N) and 8 (S)	515	4.78	261	2.42	24	0.22
		3 (N&S) and 8 (S)	527	4.89	267	2.48	24	0.22
Anchors	Single piling	(S)	337	3.13	160	1.48	5	0.05
		6 (S)	235	2.18	109	1.01	1	0.01
		7 (S)	361	3.35	173	1.60	6	0.06
		8 (S)	390	3.62	191	1.77	12	0.11
	Concurrent piling	5 (S) and 8 (S)	435	4.03	214	1.98	13	0.12

(N) = Caledonia North Site; (S) = Caledonia South Site.

Table 1-32: A total predicted impact of disturbance as a result of underwater noise during piling on grey seal within three SMUs (MF, C&O and ES) using dose-response approach.

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# Animals	% MU	# Animals	% MU	# Animals	% MU
Monopiles	Single piling	1 (N)	8,950	17.10	4,797	9.16	501	0.96
		2 (N)	8,677	16.57	4,592	8.77	490	0.94
		3 (N&S)	8,888	16.98	4,624	8.83	464	0.89
		4 (N&S)	7,308	13.96	3,745	7.15	304	0.58
		7 (S)	8,388	16.02	4,329	8.27	403	0.77
		(S)	6,002	11.46	3,118	5.96	265	0.51
	Concurrent piling	1 (N) and 4 (N&S)	10,541	20.13	5,718	10.92	644	1.23
		1 (N) and 8 (S)	10,936	20.89	5,803	11.08	662	1.26
		3 (N&S) and 8 (S)	10,076	19.25	5,329	10.18	564	1.08
Jackets	Single piling	1 (N)	8,306	15.87	4,426	8.45	464	0.89
		2 (N)	8,081	15.44	4,244	8.11	441	0.84
		3 (N&S)	8,212	15.69	4,225	8.07	392	0.75
		4 (N&S)	6,441	12.30	3,290	6.28	264	0.50
		7 (S)	7,553	14.43	3,854	7.36	321	0.61

Foundation Type	Scenario	Modelling Location	Lower CI		Mean		Upper CI	
			# Animals	% MU	# Animals	% MU	# Animals	% MU
		8 (S)	5,221	9.97	2,717	5.19	237	0.45
	Concurrent piling	1 (N) and 4 (N&S)	9,978	19.06	5,507	10.52	604	1.15
		1 (N) and 8 (S)	10,394	19.85	5,602	10.70	620	1.18
		3 (N&S) and 8 (S)	9,358	17.87	4,909	9.38	501	0.96
Anchors	Single piling	5 (S)	5,934	11.33	2,960	5.65	191	0.36
		6 (S)	4,394	8.39	2,257	4.31	196	0.37
		7 (S)	5,861	11.19	2,930	5.60	193	0.37
		8 (S)	3,881	7.41	2,024	3.87	190	0.36
	Concurrent piling	5 (S) and 8 (S)	6,734	12.86	3,452	6.59	287	0.55
(N) = Caledonia North Site; (S) = Caledonia South Site.								

1.4 References

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