EIS Predictions of Marine Mammal Behavioural Response to Equinor's Bay du Nord Project Activities

1.0 Background

During the regulatory review of Equinor's Bay du Nord Environmental Impact Statement (EIS) and in follow-up discussions with the Impact Assessment Agency of Canada (IAAC) and Fisheries and Oceans Canada (DFO) it was determined that the provision of supplemental information and clarification for effects predictions of marine mammal behavioural response to Project activities would be beneficial. This document provides clarification on the conservative nature of effects predictions, and supplemental information related to acoustic modelling data, the likely concept for Project activities, and the Floating, Production, Storage, and Offloading (FPSO) vessel. It is important to note that this information is not meant to supersede the EIS but only to elaborate on the acoustic modelling and project description previously provided. The information presented here is intended to assist IAAC with preparation of the Environmental Assessment Review (EAR) document.

2.0 Effects Predictions

The effects assessment for marine mammals was based on an approach that has been used in numerous recent offshore drilling Environmental Assessments (EAs) for Newfoundland. The methodology for significance determination followed standard categories of magnitude, duration, and geographic extent (see Chapter 4 of the Equinor EIS) and used a conservative approach when assigning these categories to effects predictions. See Section 3.1 below for further discussion regarding geographic extent predictions associated with underwater sound emissions.

2.1 Information Used in the Effects Assessment

Several tools were used to guide the predictions of underwater sound effects on marine mammals. Acoustic modelling, conducted by JASCO Applied Sciences (Appendix D of the EIS; Zykov 2019), was one tool used to assist with effects predictions. Another key tool was studies of marine mammal response to oil and gas activities like seismic surveys, vessel transits, and drilling. The EIS cited approximately 200 references with information on marine mammal response to oil and gas and/or related activities (see Section 11.8 of the EIS). The acoustic modelling provides estimates of sound levels for a snapshot in time based on conservative assumptions (see Section 2.2 below). Then generic sound level thresholds for behavioural responses were applied to assist with predictions of the potential extent of effects on marine mammals. The use of these generic thresholds of 120 dB rms for non-impulsive sound and 160 dB rms for impulsive sound comes with many caveats, which were pointed out in several places in Chapter 11 of the EIS (i.e., see pages 11-12, 11-18, 11-24). It is important for the reader of IAAC's EAR to be aware that the EIS does not rely solely on the predictions of the acoustic model and that there are many caveats with using acoustic thresholds for predicting behavioural responses by marine mammals and that the results should serve as a guide only for effects predictions.

Furthermore, it would be beneficial to the reader of the EAR to highlight the following from Section 11.1.4 of the EIS "Behavioural reactions of marine mammals to sound are difficult to predict in the absence of site and context-specific data. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors."

2.2 Conservative Nature of Effects Predictions

The acoustic model provides estimates of sound levels for a snapshot in time based on conservative assumptions. In the EIS, we present both R_{max} and $R_{95\%}$ distances (ranges) as a guide for effects predictions. R_{max} is the worst-case sound level—i.e., the maximum predicted distance in the water column where a specific sound level threshold is likely to occur. In some cases, a sound level contour might have small protrusions or anomalous isolated fringes in some directions (for example see Figure 2.1). The isolated fringes can be located at substantial distances from the central "blob" of the threshold contour. In such cases, R_{max} can misrepresent the area of the region exposed to such effects. R_{max} ranges (and areas) are not very representative of a sound source in many cases but are useful when examining more acute effects like auditory injury or Permanent Threshold Shift (PTS) in hearing. $R_{95\%}$ is calculated as the range of the given sound level threshold after the 5% farthest grid points (5% of the outer area) were excluded and is considered more representative of the sound source in terms of practical application. In case of a perfectly circular threshold contour, $R_{95\%}$ is about 2.5% less than R_{max}. A large difference between R_{max} and $R_{95\%}$ is an indicator of strong asymmetry in the acoustic field, due to strong directivity of either the sound source or environment (bathymetry). $R_{95\%}$ is considered more representative for behavioural responses but still is precautionary because it only excludes 5% of maximum distances where a given sound level occurs in the water column.

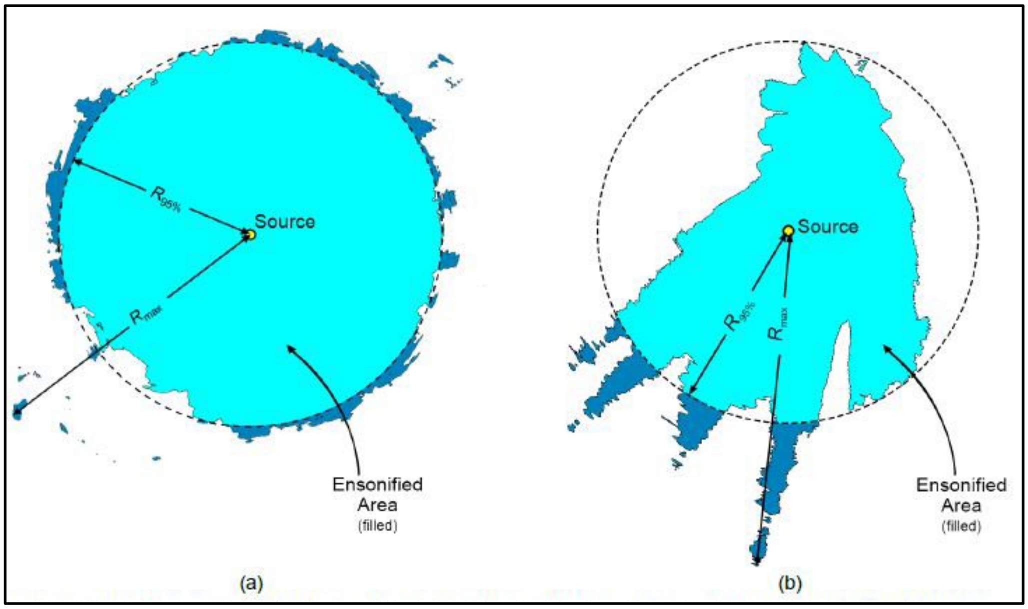

Figure 2.1. Two scenarios depicting variability in ensonified areas using an arbitrary sound level with R_{max} and $R_{95\%}$ ranges: (a) a primarily radially symmetric sound level contour with small "protrusions", for which $R_{95\%}$ best represents the ensonified area; and (b) a strongly asymmetric sound level contour with relatively long "protrusions, for which R_{max} best represents the ensonfied areas in some directs. Light blue shading indicates the ensonified areas bounded by $R_{95\%}$ whereas darker blue indicates the ensonified areas beyond $R_{95\%}$ that determine R_{max}. [source: JASCO]

3.0 Supplemental Information

Equinor has provided additional information on acoustical modelling and seasonal variation in sound propagation. Also provided below are updated information on scheduling of Project activities and an overview of new scientific information on the use of acoustic thresholds for predicting behavioural responses in marine mammals, which has come to light since submission of the EIS.

3.1 Acoustic Modelling

Based on feedback from IAAC, Equinor requested that JASCO provide areas and volumes where sound levels are predicted to exceed behavioural thresholds. Provided below is an overview of the method used to prepare area (km^2) and volume (km^3) estimates and summary tables of results for both R_{max} and $R_{95\%}$ values (Tables 3.1 and 3.2). Note that the maximum areal extent where modelled sound levels are predicted to exceed the behavioural response threshold for a single sound source is approximately 1400 km^2 (i.e, R_{max} value for a MODU at Site 2 in February). The maximum areal extent where modelled sound levels are predicted to exceed the behavioural response threshold for multiple sound sources operating simultaneously is approximately 2100 km^2 (i.e, R_{max} value for 2 MODUs plus the FPSO in February). In most situations (Section 3.3) and during most of the year (Section 3.2), areal extents where sound levels (see Table 3.3) are predicted to exceed behavioural response thresholds are much reduced. Regardless, all estimates of areal extent provided here are more reflective of potential areas of effects on marine mammals relative to the broad range of areas encompassed by the geographic extent category predictions presented in the EIS (see Tables 11.9 and 11.10).

Table 3.1. Estimated areas where generic behavioural sound thresholds are exceeded for Project sound sources modelled at Site 1 and Site 2 within the Bay du Nord Project Area in February and August.

Sound Source	Behavoural Threshold (dB re 1 uPa rms)	Area (km^2)							
		Site 1 (Feb)		Site 1 (Aug)		Site 2 (Feb)		Site 2 (Aug)	
		$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}
Multi-beam echosounder	160	0.018	0.019	--	--	--	--	--	--
Sub-bottom profiler	160	0.003	0.003	--	--	--	--	--	--
Airgun array	160	188.4	198.3	123.1	129.6	199.0	209.5	117.1	123.3
MODU	120	1301.5	1370.0	106.4	112.0	1320.5	1390.0	183.4	193.0
FPSO	120	330.6	348.0	37.8	39.8	--	--	--	--
FPSO + 1 MODU	120	1310.0	1380.0	128.0	133.0	--	--	--	--
FPSO + 2 MODU	120	2015.0	2110.0	235.0	245.0	--	--	--	--

Note: Where modelled sound fields from multiple sources (FPSO, MODU) overlap, the area of overlap is only included once in the calculation.

Table 3.2. Estimated volumes where generic behavioural sound thresholds are exceeded for Project sound sources modelled at Site 1 and Site 2 within the Bay du Nord Project Area in February and August.

Sound Source	Behavoural Threshold (dB re 1 uPa rms)	Volume (km^3)							
		Site 1 (Feb)		Site 1 (Aug)		Site 2 (Feb)		Site 2 (Aug)	
		$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}
Multi-beam echosounder	160	0.005	0.005	--	--	--	--	--	--
Sub-bottom profiler	160	0.000	0.000	--	--	--	--	--	--
Airgun array	160	71.1	74.8	56.3	59.3	49.3	51.9	40.5	42.6
MODU	120	74.4	78.3	46.9	49.4	78.3	82.4	33.3	35.1
FPSO	120	20.0	21.0	13.8	14.5	--	--	--	--
FPSO + 1 MODU	120	90.2	90.6	61.8	62.4	--	--	--	--
FPSO + 2 MODU	120	156.0	156.0	111.0	112.0	--	--	--	--

Note: Where modelled sound fields from multiple sources (FPSO, MODU) overlap, the volume of overlap is only included once in the calculation.

The calculations of the exposed area are based on a 2D cartesian grid which is derived from a 3D modelling result by applying maximum-over-depth operation. The total area exposed to the levels above a specific threshold is calculated by multiplying the number of grid nodes that register levels above that threshold by the area of a grid cell. The $R_{95\%}$ area is exactly 95% of the total area. Note that the ranges presented in Table 3.3 should not be considered as radii of a circle and then used to calculate area. The exposure level function with distance from the sound source is not monotonic (particularly in February) and there are areas around the source where sound levels go above and below the threshold level several times; i.e. there are areas within the illustrated polygons where sound is not above exposure thresholds.

The calculations of the exposed volume are based on a 3D cartesian grid. The total volume exposed to the levels above a specific threshold is calculated by multiplying the number of grid nodes that register levels above that threshold by the area of the grid cell and by the height of the grid cell. The 95% volume is calculated by dropping the 5% farthest vertical columns of grid cells that feature levels above a specific threshold at any depth. In most cases, the $V_{95\%}$ volume is more than 95% of the total volume. Estimates of volume were not provided in the EIS as this metric was not used to guide effects predictions.[1]

3.2 Seasonal Variation in Sound Propagation

Sound propagation is strongly affected by the sound speed profile in the water column, which varies seasonally. The EIS provided estimates of distances to acoustic thresholds based on two sound speed profiles –one for February and one for August, representing conditions with the most and least sound propagation, respectively (see Appendix D of the EIS). A sound channel is formed if the sound speed profile features a positive gradient. The sound channel traps acoustic energy within, increasing the acoustic energy flux density, and therefore the received levels inside the channel. This also prevents the acoustic wave from interacting with the bottom which effectively decreases the propagation loss. On the other hand, a strong negative gradient directs acoustic waves downward, increasing the interaction of the acoustic wave with the bottom and effectively increasing propagation loss. The sound speed profile in the Project Area features a strong surface channel in winter months and downward refracting conditions in the summer (Figure 3.1). Figure 3.2 shows vertical slices of the acoustic field depicting the differences in vertical distribution of the acoustic energy with season (using the FPSO as an example). Based on the comparison of the sound speed profiles for different months, it can be predicted that propagation conditions and, consequently, the distances to acoustic thresholds, in July, September, October, and November are about the same as in August and in January and March as in February. April, May, June, and December are transitional with ranges in between threshold ranges for February and August, likely closer to August. About 75% of the year has sound propagation conditions that do not reflect worst-case conditions (i.e., sound spreads farther from the source). This is important for the reader to realize when presenting distances and areas for acoustic thresholds – February is the worst-case scenario and sound speed profile conditions in this month best represent only three months of the year.

[1] If volumes of water where acoustic thresholds are predicted to be exceeded are presented in the EAR, it is important to highlight that most marine mammal species that occur in the Project Area do not dive to the maximum water depth (i.e., 1100 m). Without necessary background information on variability on diving depth ranges, the reader could assume that all marine mammals within the volume of water presented would exhibit a behavioural response.

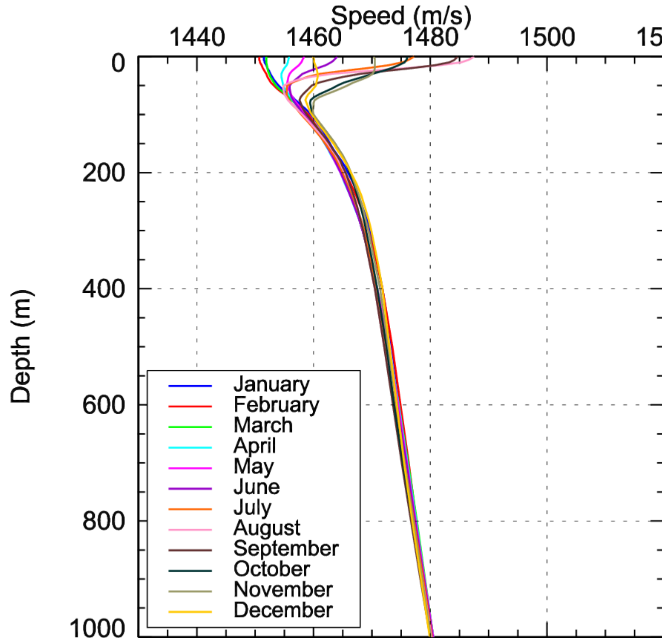

Figure 3.1. Monthly average sound speed profiles for the Equinor Project Area. [Sound speed profiles for February and August were shown in Figure 6 of Appendix D in the EIS.]

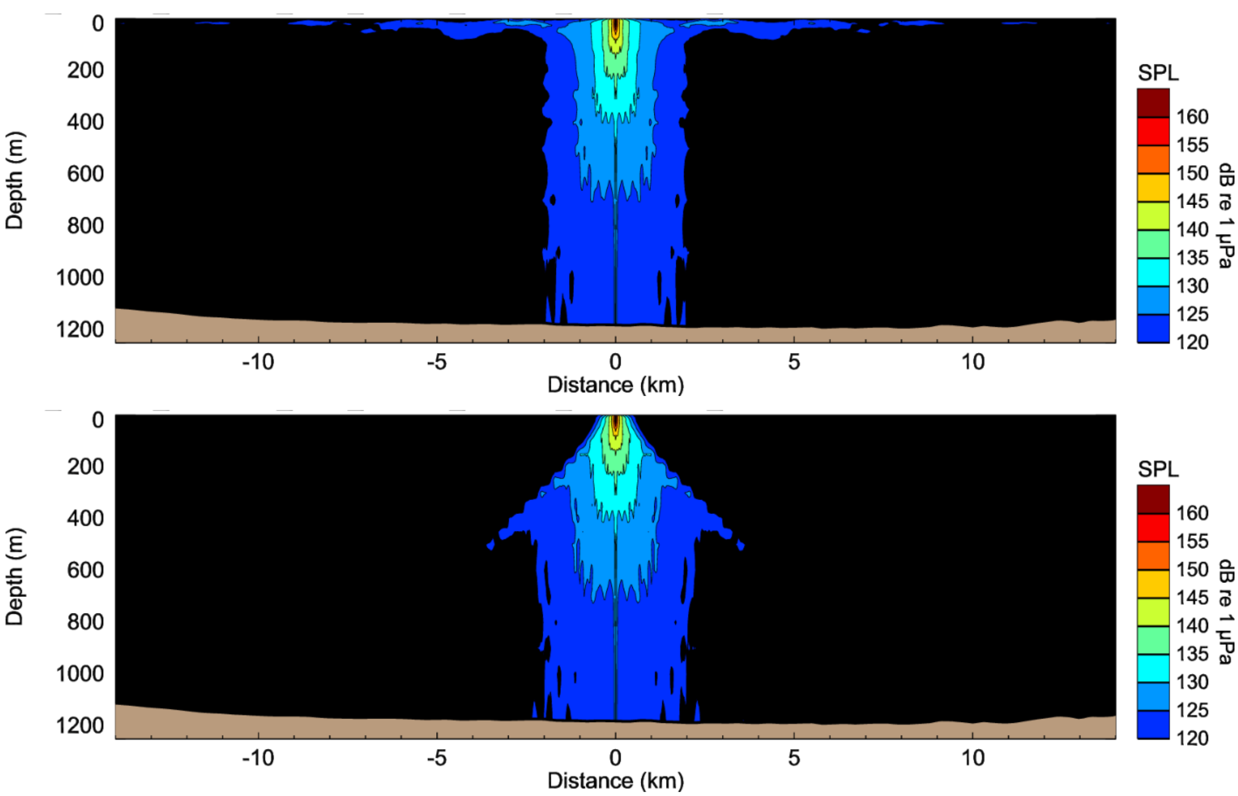

Figure 3.2. Vertical slice of the acoustic field for the FPSO at Site S1 for February (top panel) and August (bottom panel) propagation conditions.

3.3 Operational Scenarios

For the purposes of the EIS, Equinor provided an operational scenario for maximum simultaneous Project activities. This included consideration of 9 sound sources in the Core Development Area: 2 MODUs, 1 FPSO, 1 seismic survey, 1 multi-beam echosounder (MBES), 1 sub-bottom profiler (SBP), and 3 support vessels. However, the most likely scenario is to conduct most or all proposed drilling operations with 1 MODU (Core BdN and Project Area Tiebacks). As described in Section 2.6.3 of the EIS the proposed scope is estimated to be up to 60 wells. A plausible scenario where a second MODU would be simultaneously planned for in the field include the contingency to safeguard against unforeseen Project delay for the Drilling Activities phase. These scenarios are not predicable and are contingent on external factors such as market conditions, rig availability, characteristics of the drilled wells, well operations and maintenance requirements, among others. Scenarios where a second MODU is required will be to supplement the 1 MODU operations described herein and therefore will be for some subset of the overall Drilling Activities scope. Simulations for potential 2 MODU operations undertaken during the Project planning phase suggest a range of roughly 6 to 24 months. Other examples of scenarios where Equinor may require short-term deployments of a second MODU include to undertake well workover, well intervention and well completion activities on already drilled wells. The key consideration with respect to the effects of underwater sound emissions is that it can be assumed that in the case where 2 MODUs are concurrently conducting planned drilling operations the timeline for those operations will be reduced by approximately half.

Given it is likely that 1 MODU is deployed for most or all drilling activities, a probable conservative scenario would entail 1 MODU, 1 FPSO, 1 seismic survey, 1 MBES, 1 SBP, and 2 support vessels operating simultaneously within the BdN Core Development Area, although these simultaneous operations of all sound sources would occur only for a period of days to weeks over the life of the Project. Based on planning phase simulations, a probable average case scenario and regular operations would be 1 MODU, 1 FPSO, and 2 support vessels for approximately 3 years and 1 FPSO and 1 support vessel thereafter. In this probable average case scenario, Project Area Tiebacks and Improved Oil Recovery could result in approximately 4 additional years of drilling operations. Figure 3.3 illustrates a potential drilling schedule for the noted average case scenario. The scenarios described here are based on current information and provide context but may change to some degree with detailed engineering in future Project phases.

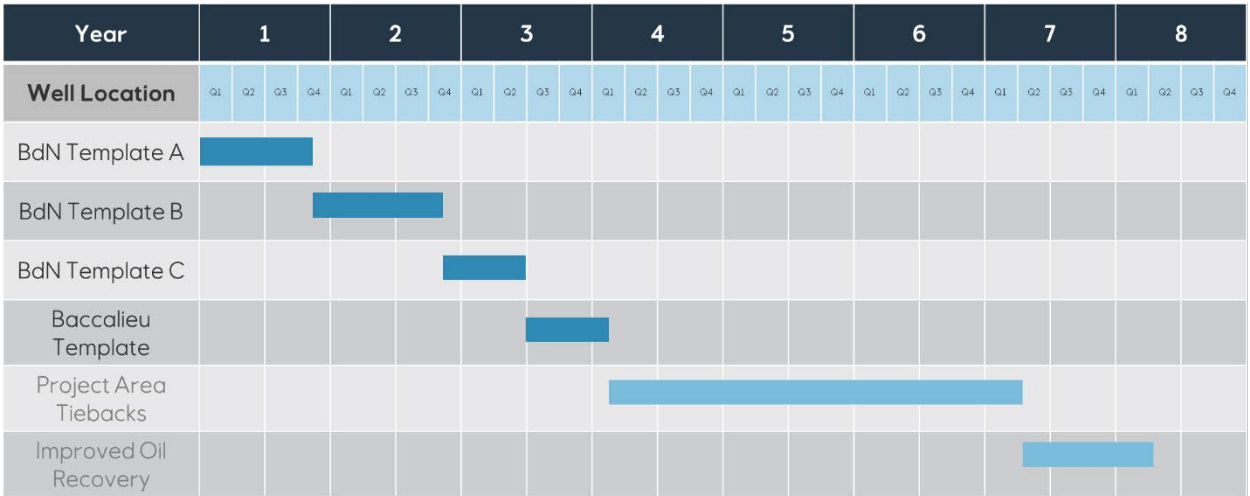

Figure 3.3. Sample drilling schedule based on simulation of a 1 MODU scenario where the MODU and support vessel will be on site.

IAAC requested that Equinor provide maps of areas where the acoustic thresholds for potential behavioural response in marine mammals would be exceeded for Project activities based on acoustic modelling predictions. Four figures each with four panels representing sound propagation conditions in August (best representative of most of the year) and February (considered worst-case sound propagation, i.e., sound travels farther) with areas depicted for $R_{95\%}$ and R_{max} sound metrics are provided below (Figures 3.4-3.7). Sound levels from support vessels were not modelled. A 10 km value was selected as a conservative distance (i.e., precautionary) for potential marine mammal behavioural effects based on a review of the literature on marine mammal response to vessels (see Section 11.1.1 of the EIS). It is important once again to note the variability and difficulties in predicting behavioural responses by marine mammals, without presenting necessary background information the reader is left to assume that all marine mammals within the areal extents depicted in these maps will exhibit a behavioural response, which is inaccurate.

Note that the exposure level function with distance from the sound source is not monotonic (particularly in February) and there are areas around the source (within the illustrated polygons) where sound levels go above and below the threshold level several times. As such, the ranges (distances) to the behavioural response thresholds provided in the EIS (see Section 11.3 and Appendix D) should not be considered radii of a circle.

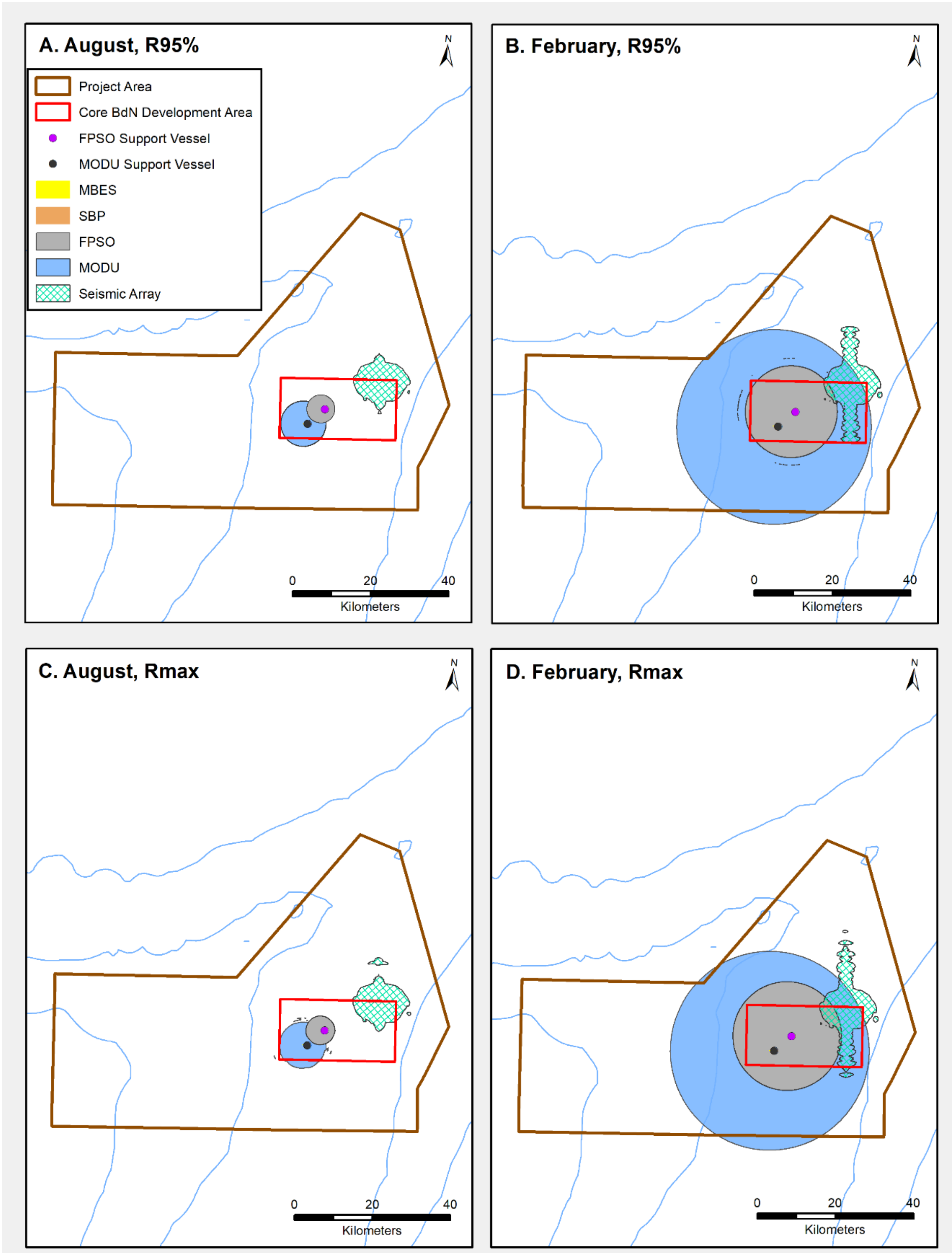

Figure 3.4. Areas around Project sound sources representing a credible conservative scenario where sound levels are estimated to exceed the generic behavioural acoustic thresholds for marine mammals: (A) $R_{95\%}$, August, (B) $R_{95\%}$, February, (C) R_{max}, August, and (D), R_{max}, February. Note 1 - the relatively small areas for MBES (≤0.019 km^2) and SBP (≤0.003 km^2) are not visible on the map—these areas (if visible) are located near the MODU. Note 2 - Assumed that FPSO thruster system is engaged at 50% power which is expected to only occur during noted operational conditions.

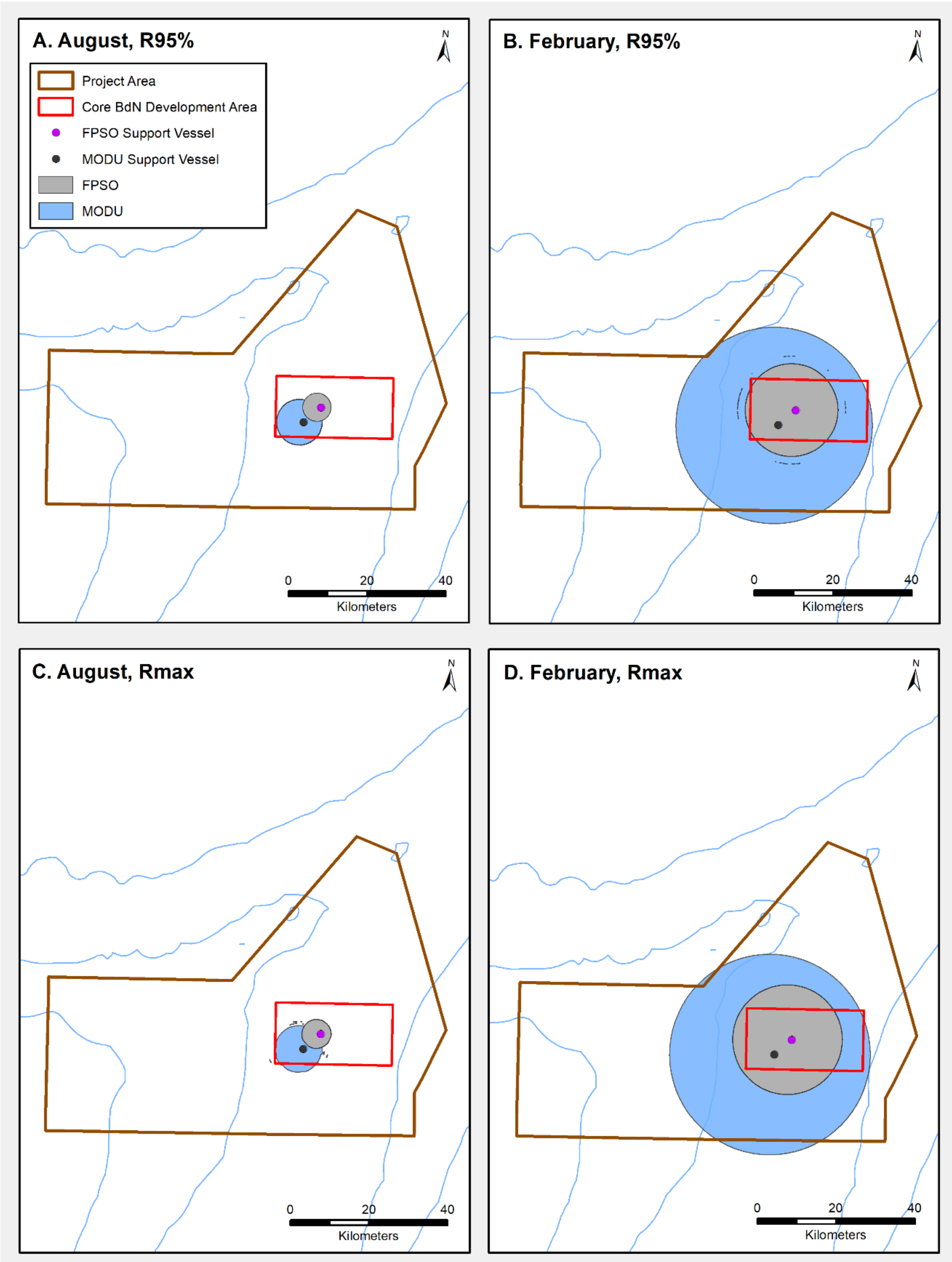

Figure 3.5. Areas around Project sound sources representing an average-case scenario for Years 1-8 of the Core BdN and Potential Future Tiebacks drilling phases of the Project where sound levels are estimated to exceed the generic behavioural acoustic threshold for marine mammals: (A) $R_{95\%}$, August, (B) $R_{95\%}$, February, (C) R_{max}, August, and (D), R_{max}, February. Note - Assumed that FPSO thruster system is engaged at 50% power which is expected to only occur during noted operational conditions.

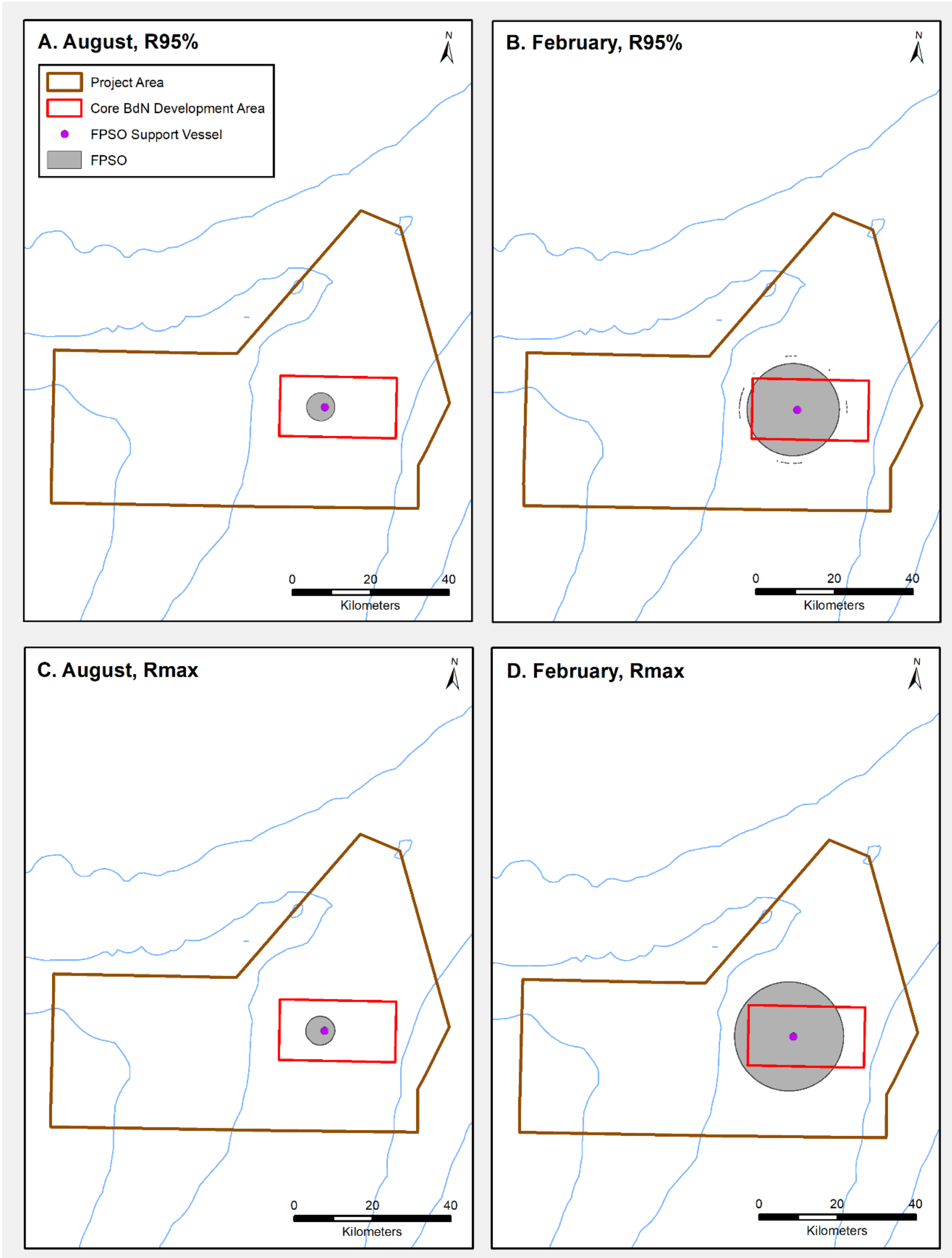

Figure 3.6. Areas around Project sound sources representing an average-case scenario for Years 9-onwards of the Project when there is no MODU on site where sound levels are estimated to exceed the generic behavioural acoustic threshold for marine mammals: (A) $R_{95\%}$, August, (B) $R_{95\%}$, February, (C) R_{max}, August, and (D), R_{max}, February. Note - Assumed that FPSO thruster system is engaged at 50% power which is expected to only occur during noted operational conditions.

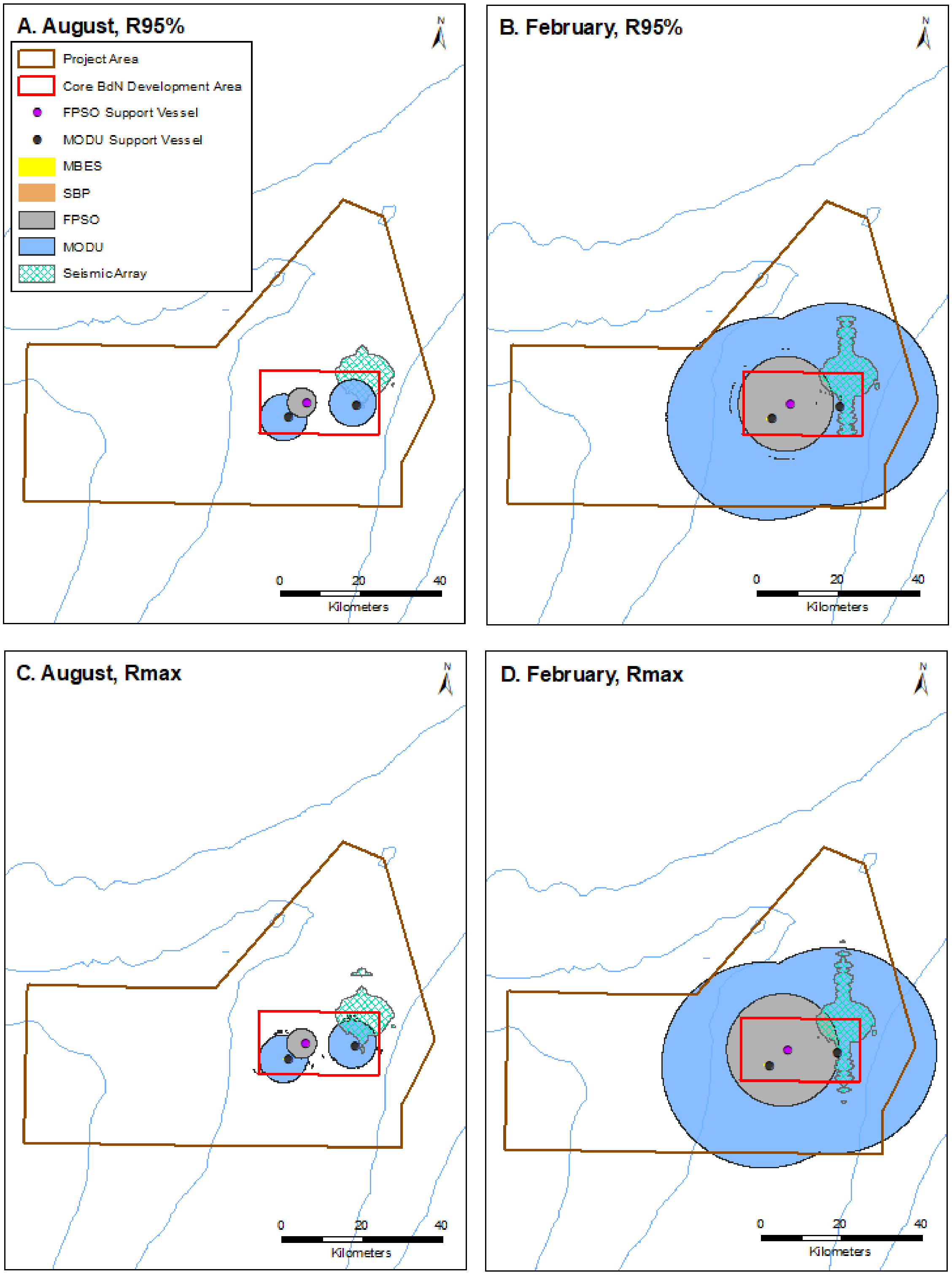

Figure 3.7. Areas around Project sound sources representing a worst-case scenario, which may occur for some subset of Years 1-9 of the Project when there are 2 MODUs on site, where sound levels are estimated to exceed the generic behavioural acoustic thresholds for marine mammals: (A) $R_{95\%}$, August, (B) $R_{95\%}$, February, (C) R_{max}, August, and (D), R_{max}, February. Note 1 - the relatively small areas for MBES (≤0.019 km^2) and SBP (≤0.003 km^2) are not visible on the

map—these areas (if visible) are located near the MODU. Note 2 - Assumed that FPSO thruster system is engaged at 50% power which is expected to only occur during noted operational conditions.

3.4 New Literature on the Use of Acoustic Thresholds for Behavioural Response

Since the EIS was submitted to IAAC, scientific experts have prepared a journal publication (Southall et al. in prep.), which serves as an update to the behavioural exposure criteria review presented in Southall et al. (2007). The new paper further stresses that there is considerable variability in the type and magnitude of behavioural response of marine mammals to similar underwater sound exposures as a function of species, age/sex class, individual behavioural state, and a suite of interacting biological and ecological factors. The authors highlight that using simple all-or-nothing behavioural thresholds (i.e., like the 120 dB rms and 160 dB rms put forward by the U.S. NMFS) and applying these thresholds across broad taxonomic groups of marine mammals and sound types can lead to much uncertainty in predicting effects. Once again, the use of behavioural thresholds and predicted distances to these sound levels in the EIS is a simple tool to highlight what is considered a likely worst-case scenario for potential behavioural effects on marine mammals in the Project Area (and Local Study Area). The area around the sound sources, particularly the stationary FPSO and MODU(s) where marine mammals may exhibit a behavioural response like avoidance, would be smaller than the worst-case distances predicted by acoustic modelling undertaken for the EIS (see Chapter 11, Section 11.3 and Appendix D).

4.0 Mitigating Factors

Since submission of the EIS, Equinor has advanced the design of the FPSO. The thrusters are a safety related system that are expected to be engaged only for necessary operational or emergency conditions. While engaged, the system will typically use between 30% and 50% power. As the project progresses, the thruster design will be optimised for sound output, energy efficiency and as a safety critical system. The thruster system is required for active heading control under certain circumstances, such as maintaining position during crew transfer ("walk to work" via gangway), to optimize heading in case of severe storm conditions, or to make a safer heading for helicopter operations. These circumstances collectively make up a fraction of total operational time.

The conditions under which the thrusters will be used for propulsion, position control, or heading control as appropriate will be described in various manuals that will be submitted to C-NLOPB for the Operations Authorization. These manuals include as a minimum:

- the Operations Manual,
- the Safety Plan,
- the Contingency Plans / Emergency Response Plan, and
- the Ice Management Plan

The acoustic modelling for the FPSO conducted for the EIS assumed the thrusters were continuously operational (at 50% power; see Appendix D of the EIS). Relative to modelling predictions for the FPSO, when the vessel is moored and does not use thrusters at all, its sound emissions will decrease substantially as the sound source level from the internal machinery is significantly lower than the source level from the thruster propellers. This is an important consideration related to the effects assessment given the FPSO is the only sound source to be on site for the entire operational life of the Project.

In the modelling of the acoustic field from vessels, the source level is the variable that contributes most to the uncertainty of the predictions. For the best results with highest possible accuracy, the field measurements of the sound from the same vessel are required. This is often not possible given that the specific vessel to be used in the project is not known at the time of the acoustic modelling. In such cases available measured data on a similar class/size vessel are used to derive the source level of the vessel for the project. The broad band source level of the FPSO used in acoustic modelling for the EIS was assessed at 183.7 dB re µPa m SPL. Table 4.1 provides R_{max} and $R_{95\%}$ distances to modelled maximum-over-depth 120 dB re µPa SPL thresholds for various reduced source levels of the FPSO. A relatively small reduction in source level results in substantially smaller distances to the 120 dB rms threshold.

Other Project optimization concepts are under investigation that would reduce sound emissions and improve energy efficiency. Some examples of these concepts include the maintenance excellence program that will reduce support vessel requirements and a shared support vessel approach for FPSO and drilling operations. If implemented this would decrease the number of vessels on site simultaneously.

Table 4.1. Maximum (R_{max}, m) and 95% ($R_{95\%}$, m) horizontal distances to modelled maximum-over-depth 120 dB re µPa SPL threshold for various reduced source levels (SL) of the FPSO. The source level used in the EIS was 183.7 dB re µPa m SPL.

SL (dB re µPa m)	Site S1				Site S2			
	February		August		February		August	
	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$	R_{max}	$R_{95\%}$
183.7	14000	13700	3750	3600	14000	13800	8190	7190
182.0	8980	8450	3180	3090	11100	8640	7740	3930
180.0	5800	5690	2470	2410	6150	5800	3700	3230
178.0	5500	3310	2100	2060	5540	3400	2440	2070
176.0	2920	2900	1710	1680	2960	2920	1720	1680
174.0	730	712	996	970	747	717	1320	973

5.0 References

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, Jr., D. Lastal, D.R. Ketten, J.H. Miller, and P.E. Nachitgall. 2007. Special Issue: Marine mammal noise exposure criteria: Initial scientific recommendations. Aquatic Mammals 33(4): 411-521.

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