Seismic Survey in the area Jammerland Bay Near Shore Wind Farm European Energy

Modeling of underwater noise emissions during seismic survey

Oldenburg, 19.12.2024

Version 2

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Revision table

Version	Date	Comment
1	17.12.2024	First draft.
2	19.12.2024	Changed model input

The latest version replaces all previous versions.

Abbreviations:

COR - Corridor

ECC - Export Cable Corridor

HF - high-frequency

IAC - Intra Array Cable Corridor

LF - low-frequency

NS - Nearshore

OS - Offshore

PCW - phocid pinnipeds

SBP - Sub Bottom Profiler

USBL - Ultra Short Baseline

VHF - very-high-frequency

1. Project description and assignment of tasks

European Energy is planning seismic surveys in the area Jammerland Bay in Denmark, between Asnæs in the north and Rersø in the south in Kalundborg Municipality. These geotechnical investigations will be conducted in four different areas. Offshore (OS) , Cable Corridors (COR) for the Export Cable Corridor (ECC) and the Intra Array Cable Corridor (IAC), and Nearshore (NS).

The *itap – Institute for Technical and Applied Physics GmbH* was commissioned to carry out the modeling of the underwater seismic survey noise generated from the energy sources used during the surveys. For this purpose, four exemplary positions in the survey areas (Table 1) were selected with WSP, where the highest sound input is to be expected.

Table 1: Considered Locations for modeling

Location	Easting	Northing (UTM zone 32 U)
NS	628,276	6,165,704
COR-ECC	629,350	6,164,395
COR-IAC / OS-Deep	619,819	6,162,230
OS-Median	623,304	6,158,078

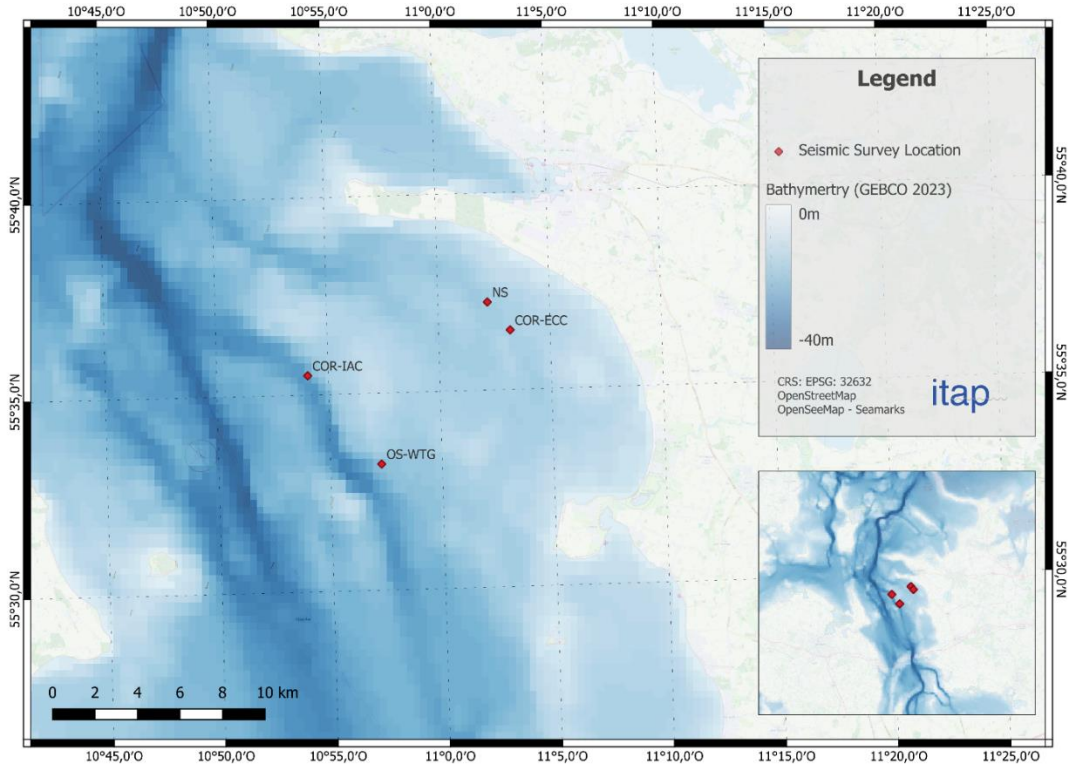

Figure 1: Considered Locations for modeling

Sub Bottom Profiler (SBP) surveys and Ultra Short Baseline (USBL) navigation systems are conducted in all four areas. In addition, Airgun measurements are performed in the NS area and Sparker measurements in the OS area.

The following devices are intended for use:

USBL: Easytrak Nexus 2 USBL, Model 2692

SBP: Innomar Medium SBP

Sparker: 3x UHD Duraspark 400

Airgun: 60 cu.in. (GUNDALF)

Modeling scenarios, including different locations, noise sources and their respective frequency weightings, and sound speed profiles in the area, were defined to reflect the current project status to the highest possible extent with the objective to determine the expected noise levels, allowing an accurate assessment of the environmental impact of the seismic surveys. The modeling aimed to calculate the impact ranges (distances to thresholds derived from single-strike and cumulative Sound Exposure Levels) resulting from the energy sources used in the survey, considering different scenarios. In addition to unweighted noise levels, hearing sensitivities of relevant species were taken into account for the underwater noise prognosis according to Energistyrelsen (2022) and Southall et al. (2019). The model assumes that all

devices operate for 24 hours without interruption. The sources are modelled as stationary locations, while the considered marine mammal is assumed to have a constant fleeing speed.

The calculations were performed according to the requirements of the guideline for underwater noise, Energistyrelsen (2022). However, this report only summarizes the relevant results and does not provide extensive results and model descriptions as required by the guideline for underwater noise, Energistyrelsen (2022).

2. Model approaches

2.1 Spectrums and source level

The estimations of the broadband Sound Exposure Level (SEL) and Sound Pressure Level (SPL) are based on Manufacturer information and the broadband measuring data of different studies. However, the impact of noise survey equipment is frequency-dependent. For this reason, estimations of the frequency composition of the respective source levels[1] have to be made for the calculations. For the USBL and the Sparker only the Frequency range was given. Therefore a spectral flat distribution over the given frequency range is assumed. For the Airgun model two variants are used, an itap regression model based on measurements and literature data and data from the GUNDALF report (2009).

The manufacturer's specifications include a source level at 1 m distance. This is calculated with $20\ \log_{10} R$ with the distance R to a fictitious distance of 50 m and is matched to an acoustic transmission loss model that takes into account the local conditions at each position, see chapter 0. The reference distance of that model is 300 m. The 50 m level values are fitted to the median in 50 m distance.

Figure 2 shows the spectral distribution of the Sound Exposure Level (SEL) or Sound Pressure Level (SPL) of different seismic assessment equipment used for the survey. The SPL in case of the SBP and Sparker.

[1] "Source level" means the Sound Exposure Level (SEL) or zero-to-peak Sound Pressure Level ($L_{p,}$) at a fictive distance 750 m to an imagined point sound source.

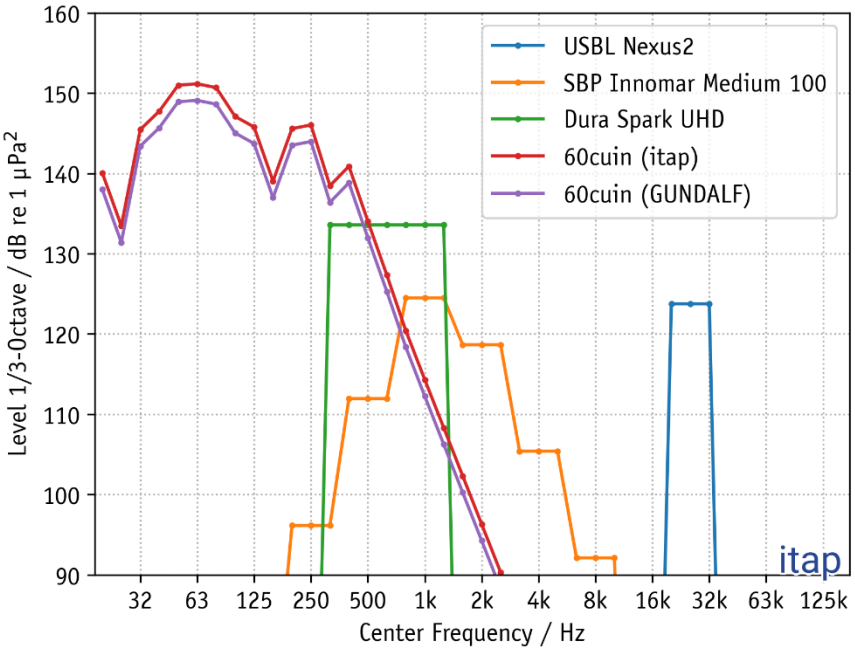

Figure 2: Considered input spectra in 300 m reference distance for all sources.

To assess the impact from underwater noise on marine mammals, the frequency weighted root-mean-square Sound Pressure Level over 125 ms ($SPL_{125ms,VHF}$) and the cumulative Sound Exposure Level (SEL_{cum}) was modelled in different starting distances and compared with PTS and TTS threshold levels for approval according to Energistyrelsen (2022), presented in Table 2. Pertaining to threshold levels for auditory injury of marine mammals, frequency weighted threshold levels are modelled. The frequency weighting functions are based on the audiograms for generalized hearing groups according to the recommendations by Southall et al. (2019). By means of hearing group specific weighting functions, frequencies outside the optimal hearing range are given less weight than frequencies within the hearing range. Figure 3 shows the weighting functions provided by Southall et al. (2019) for very-high-frequency cetaceans (VHF) (e. g. harbour porpoise, *Phocena phocena*), high-frequency cetaceans (HF) (e. g. White beaked dolphin, *Lagenorhynchus albirostris*), low-frequency cetaceans (LF) (e. g. Minke whale, *Balaenoptera acutorostrata*) and phocid pinnipeds (PCW) (e. g. harbour seal, *Phoca vitulina*). For modeling of cumulative Sound Exposure Levels (SEL_{cum}), an accumulation period of 24 hours as recommend by the Southall et al. (2019) is applied in line with Energistyrelsen (2022).

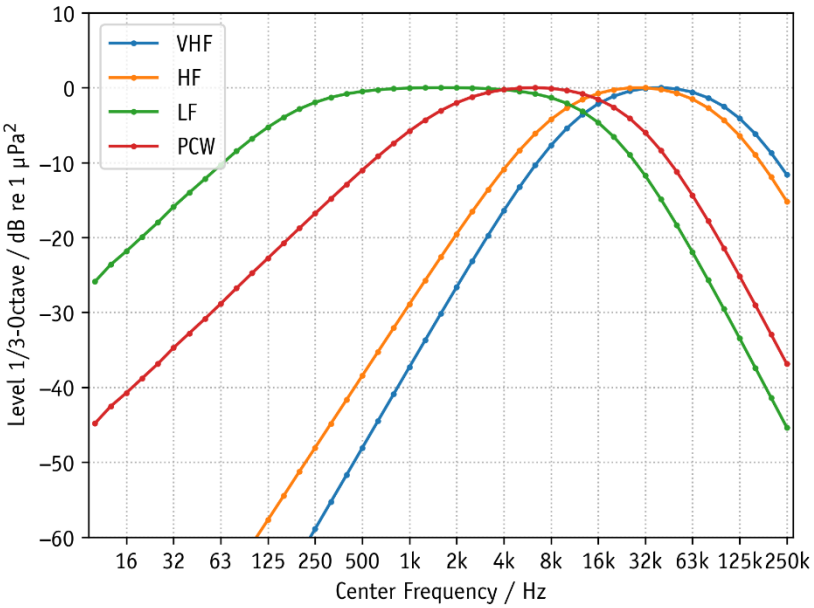

Figure 3: Weighting functions for very-high, high- and low-frequency cetaceans (VHF, HF and LF) and phocid seals (PCW) according to Southall et al. (2019).

Table 2: Noise modeling threshold criteria and considered fleeing speeds for different animals according to Energistyrelsen (2022). PTS: Permanent Threshold Shift, TTS: Temporary Threshold Shift.

Receptor	Impact type	metric	Fleeing speed [m/s]	Criteria [dB]
HF	PTS	$SEL_{cum,HF}$	1.5	185
HF	TTS	$SEL_{cum,HF}$	1.5	170
LF	PTS	$SEL_{cum,LF}$	1.5	183
LF	TTS	$SEL_{cum,LF}$	1.5	168
PCW	PTS	$SEL_{cum,PCW}$	1.5	185
PCW	TTS	$SEL_{cum,PCW}$	1.5	170
VHF	PTS	$SEL_{cum,VHF}$	1.5	155
VHF	TTS	$SEL_{cum,VHF}$	1.5	140
VHF	Avoidance	$SPL_{125ms,VHF}$	0	103

2.2 Transmission loss

The transmission loss was estimated for 24 transects in 15°-steps from the source using numerical model approaches and the bathymetry from GEBCO 2023 of a 100 km x 100 km grid quantized in 1 m steps. A frequency range between 20 Hz and 125 kHz was considered. For frequencies below 3 kHz the Range-dependent Acoustic Model (RAM) according to Micheal D Collins (1995) and above 3 kHz the BELLHOP Beam tracing approach (Porter 2011) was used.

Both models calculates the Transmission loss over the depth and distance. In this report, the transmission loss is only considered over the distance, a water depth dependent assessment is omitted. Therefore, a constant source depth and receiver depth of 9 m is considered.

Strong modes (local wave peaks and valleys) were smoothed when necessary. This is done by interpolating the amplitudes of local wave peaks. Figure 4 shows the transmission loss over distance and frequency.

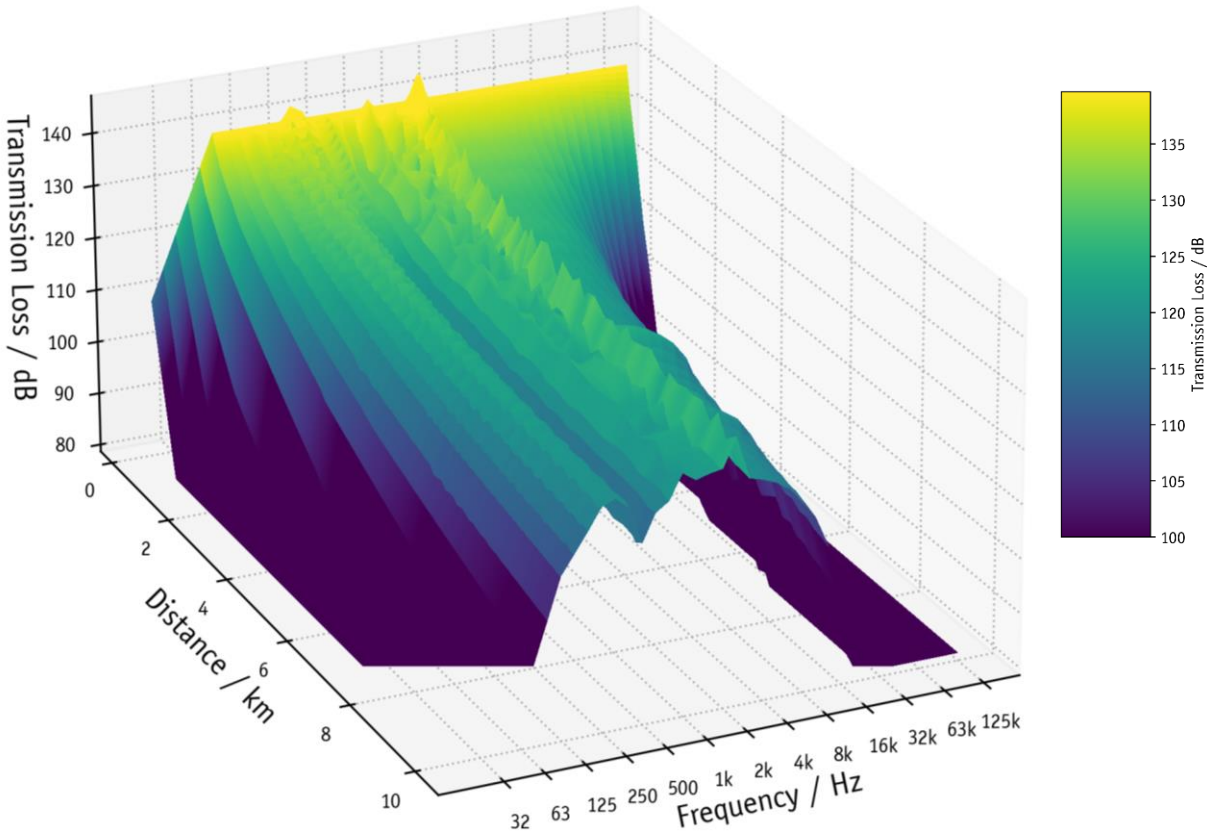

Figure 4: Transmission loss example for the OS location in 285 m direction. The absolute level values are presented as examples, as the transmission loss is adjusted to the respective source spectrum.

2.3 Model uncertainties

The main influencing parameter regarding model uncertainty is the transmission loss (TL) since this parameter significantly depends on the weather (wind and waves). This means that uncertainties regarding the transmission loss increase with increasing distance.
The source level based on literature and manufactures data. It is not possible to make statements about the uncertainty.

3. Modeling scenarios

3.1 Considered Scenarios

For the modeling, four locations were chosen in the survey area. For each Location, the transmission loss for two time periods (annual and January) were calculated as well as for the seismic survey equipment shown in Figure 5. The model assumes that all devices operate for 24 hours without interruption. The sources are modelled as stationary locations, while the animal is assumed to have a constant fleeing speed of 1.5 m/s for cumulative calculations.

Sub Bottom Profiler (SBP) surveys and Ultra Short Baseline (USBL) navigation systems are conducted in all four areas. In addition, Airgun measurements are performed in the NS area and Sparker measurements in the OS area.

The following devices are intended for use:

USBL: Easytrak Nexus 2 USBL, Model 2692

SBP: Innomar Medium SBP

Sparker: 3x UHD Duraspark 400

Airgun: 60 cu.in. (GUNDALF)

3.2 Used model

The transmission loss in water depends on the composition of the water, the spatial extent (water depth) and the attenuation at the boundary layer to the sediment. These are accounted for in the model as follows:

Table 3: Input parameter for transmission loss model.

Parameter	Value
Water depth across all survey locations:	Up to 21 m
Water temperature:	Annual: approx. 9.6°C January: approx. 4°C
Salinity	Approx. 20 ‰
Sound speed in water	Annual: 1,468 m/s January: 1,445 m/s
Seabed density	1.6 g/cm^3
Seabed Attenuation	0.8 dB

The model does not consider any background level. It will be assumed that the signal-to-noise-ratio between the seismic survey noise and the background noise will always be ≥ 10 dB.

The speed of sound in water is primarily influenced by changes in in salinity and temperature. For this prognosis report, the underwater sound speed was calculated using data from the National Oceanic and Atmospheric Administration (NOAA). Specifically, the latest available dataset (World Ocean Atlas 2013 V2) was used, which provides statistical mean values of salinity and temperature interpolated to standard depth levels on 0.25° grids. This high-resolution data allowed for precise modeling of underwater sound speed variations. Figure 5 show the annual temperature, salinity and sound speed profiles for the water depth in the project area for two time periods (annual and January).

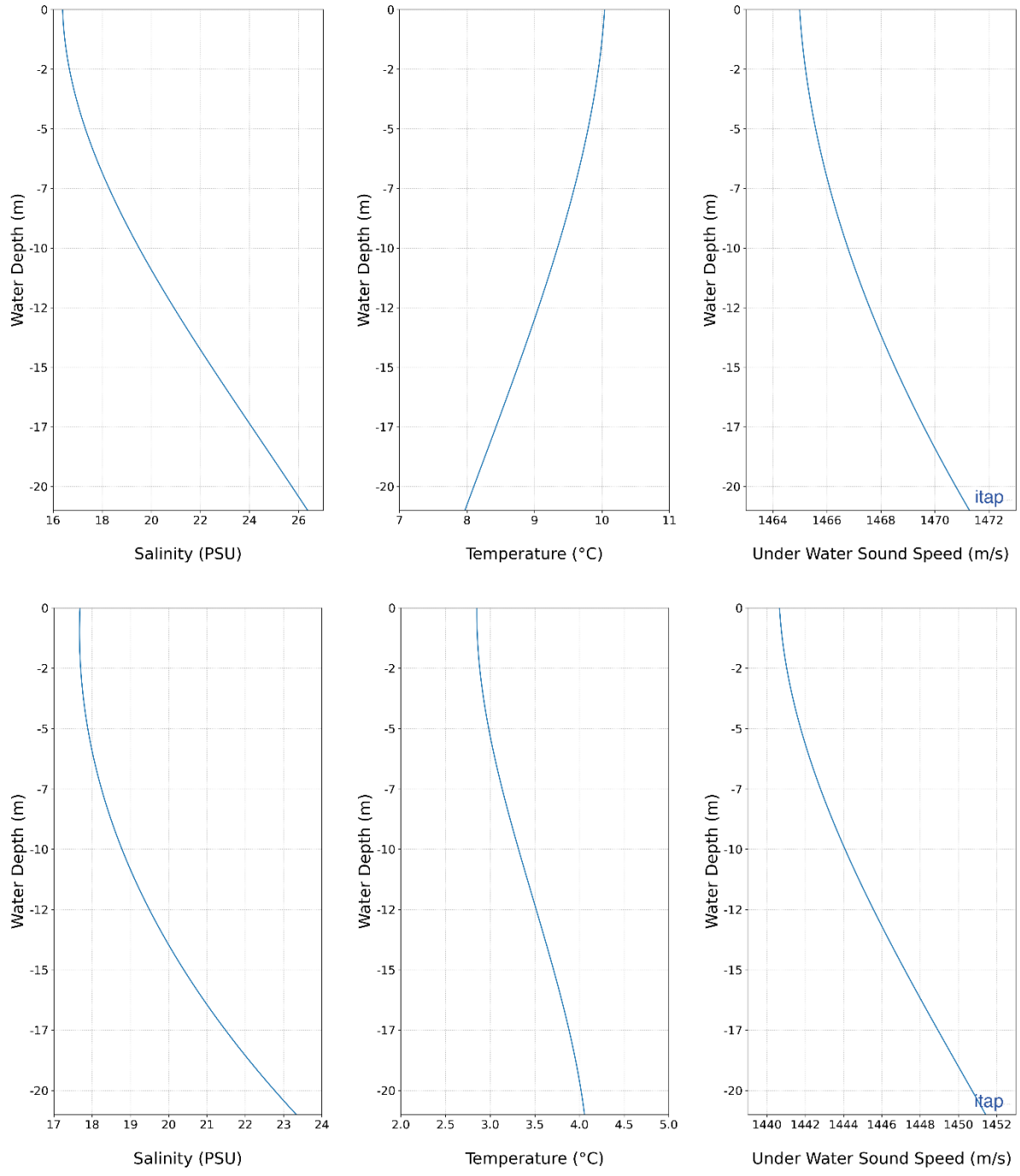

Figure 5: Salinity, temperature and sound speed profiles in the project area. Top: Annual. Bottom: January.

4. Model results

Considering the model approaches in chapter 2, the single Strike, peak and cumulative Sound Exposure are calculated for each modelled location and possible noise mitigation measures as well as the impact ranges. The impact ranges are presented in tables below as minimum, median, 95%percentile and maximum Distances to thresholds, for the different relevant receptors and their respective TTS/PTS-threshold criteria according to the guidelines.

A detailed result presentation of all single strike and cumulative metrics as well as the impact ranges for each direction and for all locations can be found in the enclosed excel tables. The overview sheets in those enclosed tables present the metrics summarizing all 24 directions for each case as minimum, median and maximum values.

4.1 Location NS January

4.1.1 USBL

Table 4: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the USBL at location NS (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.088	0.074	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0.635	0.617	0.477	0.072
VHF	TTS	$SEL_{cum,VHF}$	140	1.279	1.010	0.882	0.404
VHF	Avoidance	$SPL_{125ms,VHF}$	103	2.316	1.972	1.517	0.960
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0.200	0.190	0.077	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0	0	0	0

4.1.2 SBP

Table 5: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the SBP at location NS (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0	0	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0.170	0.154	0	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	1.626	0.942	0.762	0.667
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0.124	0.110	0	0

4.1.3 Airgun

Table 6: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the 60 cu.in. Airgun (itap regression model) at location NS (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.548	0.547	0.507	0.398
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0	0	0	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	0.305	0.305	0.304	0.302
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0.473	0.471	0.434	0.348
LF	TTS	$SEL_{cum,LF}$	170	3.285	3.040	2.145	1.004

Table 7: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the 60 cu.in. Airgun (GUNDALF data) at location NS (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.403	0.402	0.373	0.294
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0	0	0	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	0.228	0.218	0.203	0.172
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0.333	0.331	0.298	0.234
LF	TTS	$SEL_{cum,LF}$	170	2.480	2.358	1.783	1.002

4.2 Location NS Annual

4.2.1 USBL

Table 8: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the USBL at location NS (Annual sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.178	0.096	0.094	0
VHF	PTS	$SEL_{cum,VHF}$	155	0.672	0.640	0.630	0.064
VHF	TTS	$SEL_{cum,VHF}$	140	1.350	1.346	1.102	0.376
VHF	Avoidance	$SPL_{125ms,VHF}$	103	2.335	2.332	2.073	1.000
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0.279	0.208	0.204	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0.054	0	0	0

4.2.2 SBP

Table 9: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the SBP at location NS (Annual sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0	0	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0.306	0.297	0.070	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	1.841	1.626	0.801	0.691
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0.120	0.117	0.047	0

4.2.3 Airgun

Table 10: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the 60 cu.in. Airgun (itap regression model) at location NS (Annual sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.556	0.545	0.508	0.390
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0	0	0	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	0.305	0.305	0.304	0.302
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0.468	0.467	0.432	0.334
LF	TTS	$SEL_{cum,LF}$	170	2.801	2.718	1.993	1.005

Table 11: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the 60 cu.in. Airgun (GUNDALF data) at location NS (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.408	0.406	0.374	0.292
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0	0	0	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	0.223	0.219	0.206	0.176
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0.334	0.332	0.301	0.240
LF	TTS	$SEL_{cum,LF}$	170	2.171	2.157	1.648	1.003

4.3 Location COR-ECC January

4.3.1 USBL

Table 12: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the USBL at location COR-ECC (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.102	0.102	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0.617	0.614	0.304	0.070
VHF	TTS	$SEL_{cum,VHF}$	140	1.068	1.057	0.675	0.399
VHF	Avoidance	$SPL_{125ms,VHF}$	103	1.863	1.857	1.001	0.859
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0.227	0.226	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0	0	0	0

4.3.2 SBP

Table 13: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the SBP at location COR-ECC (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0	0	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0.133	0.102	0.004	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	0.848	0.842	0.772	0.534
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0.095	0.095	0.053	0

4.4 Location COR-ECC Annual

4.4.1 USBL

Table 14: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the USBL at location COR-ECC (Annual sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.175	0.174	0.107	0
VHF	PTS	$SEL_{cum,VHF}$	155	0.671	0.669	0.609	0.069
VHF	TTS	$SEL_{cum,VHF}$	140	1.359	1.337	1.002	0.407
VHF	Avoidance	$SPL_{125ms,VHF}$	103	2.462	2.461	1.859	1.000
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0.275	0.275	0.228	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0.050	0.050	0	0

4.4.2 SBP

Table 15: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the SBP at location COR-EEC (Annual sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0	0	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0.025	0.007	0	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	1.704	0.960	0.782	0.605
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0.062	0.055	0.030	0

4.5 Location COR-IAC / OS-Deep January

4.5.1 USBL

Table 16: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the USBL at location COR-IAC/OS-Deep (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0	0	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0.457	0.387	0.110	0.077
VHF	TTS	$SEL_{cum,VHF}$	140	1.553	1.054	0.466	0.452
VHF	Avoidance	$SPL_{125ms,VHF}$	103	2.745	1.983	1.000	0.856
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0	0	0	0

4.5.2 SBP

Table 17: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the SBP at location COR-IAC /OS-Deep (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.067	0.003	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0.300	0.266	0.183	0.079
VHF	Avoidance	$SPL_{125ms,VHF}$	103	1.389	1.326	0.956	0.670
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0.393	0.354	0.245	0.167

4.5.3 Sparker

Table 18: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the Sparker at location COR-IAC/OS-Deep (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.198	0.089	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0.044	0	0	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	0.284	0.280	0.260	0.200
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0.648	0.635	0.549	0.411

4.6 Location COR-IAC Annual

4.6.1 USBL

Table 19: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the USBL at location COR-IAC/OS-Deep (Annual sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0	0	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0.505	0.459	0.089	0.078
VHF	TTS	$SEL_{cum,VHF}$	140	1.252	1.174	0.449	0.426
VHF	Avoidance	$SPL_{125ms,VHF}$	103	2.186	2.037	1.000	0.906
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0.119	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0	0	0	0

4.6.2 SBP

Table 20: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the SBP at location COR-IAC/OS-Deep (Annual sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0	0	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0.350	0.287	0.084	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	1.709	1.691	1.021	0.700
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0.211	0.205	0.127	0

4.6.3 Sparker

Table 21: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the Sparker at location COR-IAC/OS-Deep (Annual sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0	0	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0	0	0	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	0.287	0.272	0.235	0.037
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	1.281	1.090	0.493	0.349

4.7 Location OS-Median January

4.7.1 USBL

Table 22: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the USBL at location OS-Median (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.244	0.109	0.107	0
VHF	PTS	$SEL_{cum,VHF}$	155	0.730	0.662	0.659	0
VHF	TTS	$SEL_{cum,VHF}$	140	1.610	1.585	1.510	1.270
VHF	Avoidance	$SPL_{125ms,VHF}$	103	2.733	2.709	2.432	2.173
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0.342	0.222	0.220	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0.122	0	0	0

4.7.2 SBP

Table 23: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the SBP at location OS-Median (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0	0	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0.487	0.379	0.323	0.028
VHF	Avoidance	$SPL_{125ms,VHF}$	103	2.805	1.344	0.924	0.732
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0.318	0.258	0.088	0

4.7.3 Sparker

Table 24: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the Sparker at location OS-Median (January sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.224	0.065	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0.022	0	0	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	0.514	0.455	0.258	0
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	6.296	0.865	0.457	0.116

4.8 Location OS-Median Annual

4.8.1 USBL

Table 25: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the USBL at location OS-Median (Annual sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0.025	0	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0.489	0.476	0.152	0.109
VHF	TTS	$SEL_{cum,VHF}$	140	1.252	1.249	0.661	0.500
VHF	Avoidance	$SPL_{125ms,VHF}$	103	2.246	2.200	1.112	0.881
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0.119	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0	0	0	0

4.8.2 SBP

Table 26: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for the SBP at location OS-Median (Annual sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0	0	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0.186	0.070	0.006	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	2.487	1.263	1.001	0.633
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	0.102	0	0	0

4.8.3 Sparker

Table 27: *Distances to thresholds for marine mammals: min., median, max and 95th percentile across 24 directions for Sparker at location OS-Median (Annual sound speed profile).*

Weighting	Impact type	Metric	Criteria [dB]	Max. range [km]	95 % percentile range [km]	Median. range [km]	Min. range [km]
PCW	PTS	$SEL_{cum,PCW}$	185	0	0	0	0
PCW	TTS	$SEL_{cum,PCW}$	170	0	0	0	0
VHF	PTS	$SEL_{cum,VHF}$	155	0	0	0	0
VHF	TTS	$SEL_{cum,VHF}$	140	0	0	0	0
VHF	Avoidance	$SPL_{125ms,VHF}$	103	0.325	0.313	0.215	0.147
HF	PTS	$SEL_{cum,HF}$	185	0	0	0	0
HF	TTS	$SEL_{cum,HF}$	170	0	0	0	0
LF	PTS	$SEL_{cum,LF}$	185	0	0	0	0
LF	TTS	$SEL_{cum,LF}$	170	1.649	0.594	0.414	0.257

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