

Noise Data

OpenHydro turbine at EMEC (Polagye 2012):

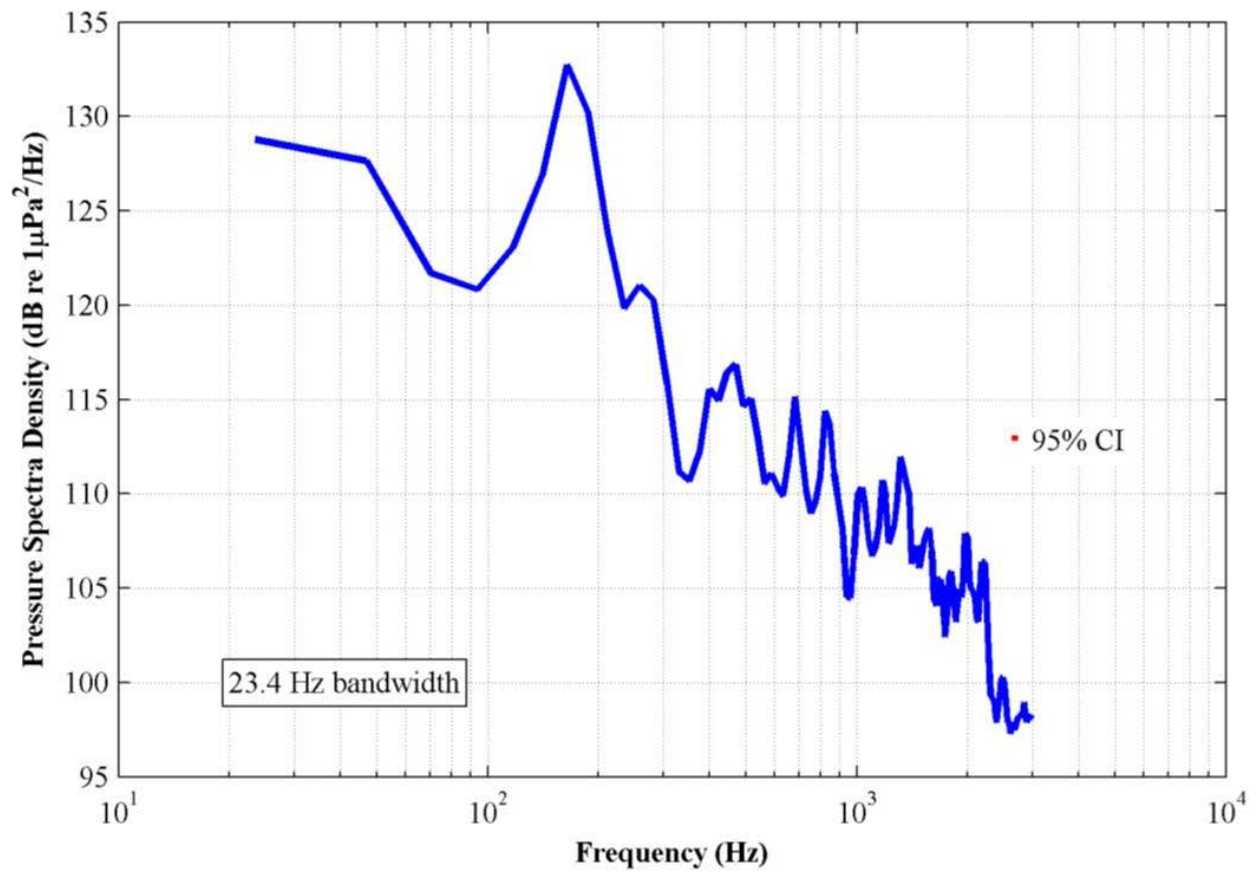


Figure 1. Characterization of the noise profile of the OpenHydro turbine at EMEC, Fall of Warness, Orkney.

Fred Olsen Lifesaver at WETS (Polagye et al. 2017):

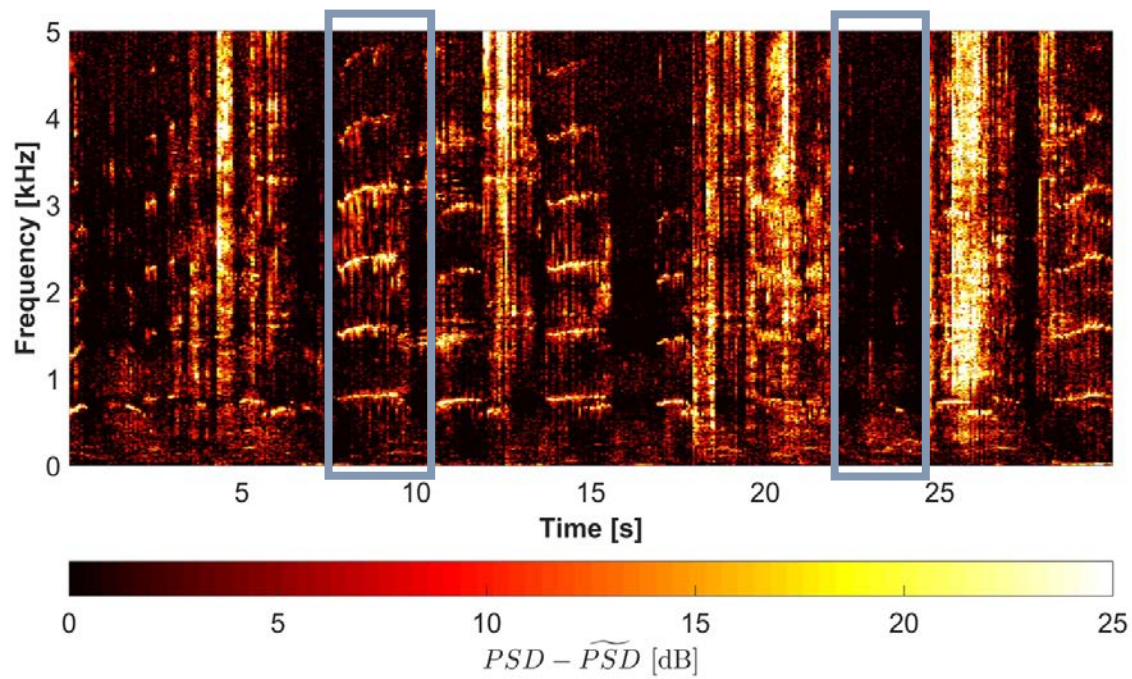


Figure 2. Characterization of the noise profile of the Fred Olsen Lifesaver at WETS.

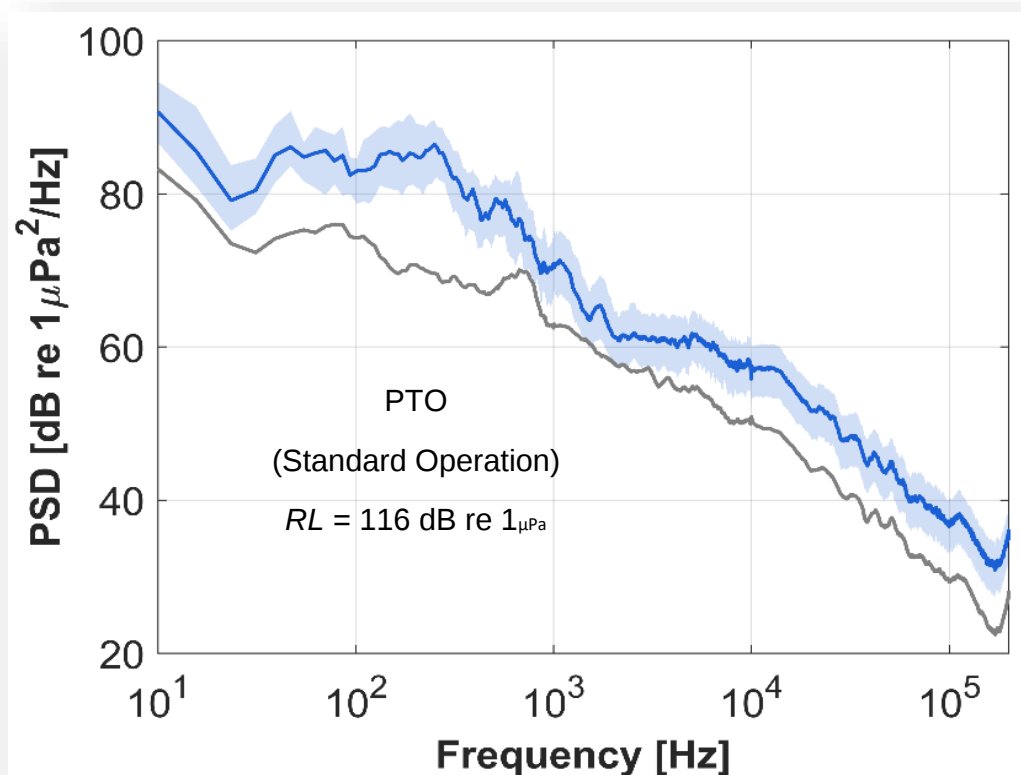


Figure 3. Power spectral density (PSD) of the Fred Olsen Lifesaver PTO under standard operation.

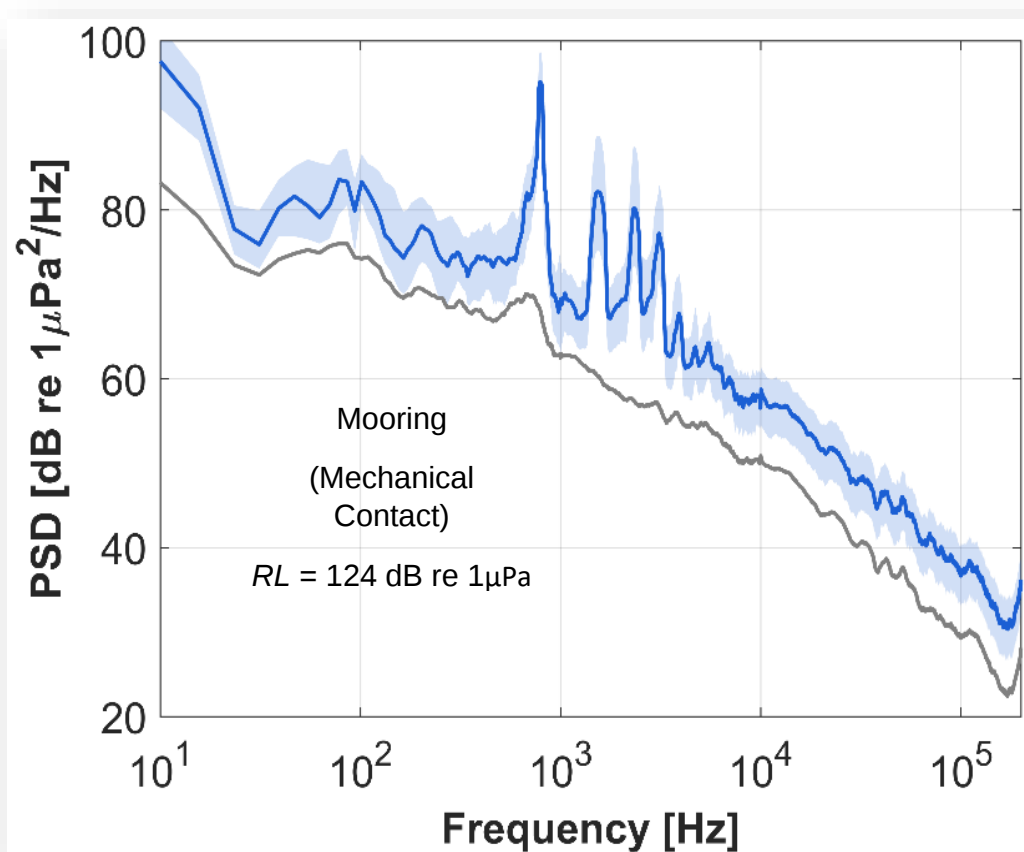


Figure 4. Power spectral density (PSD) of the Fred Olsen Lifesaver mooring noise.

WaveRoller at WavEC (Cruz et al. 2015)

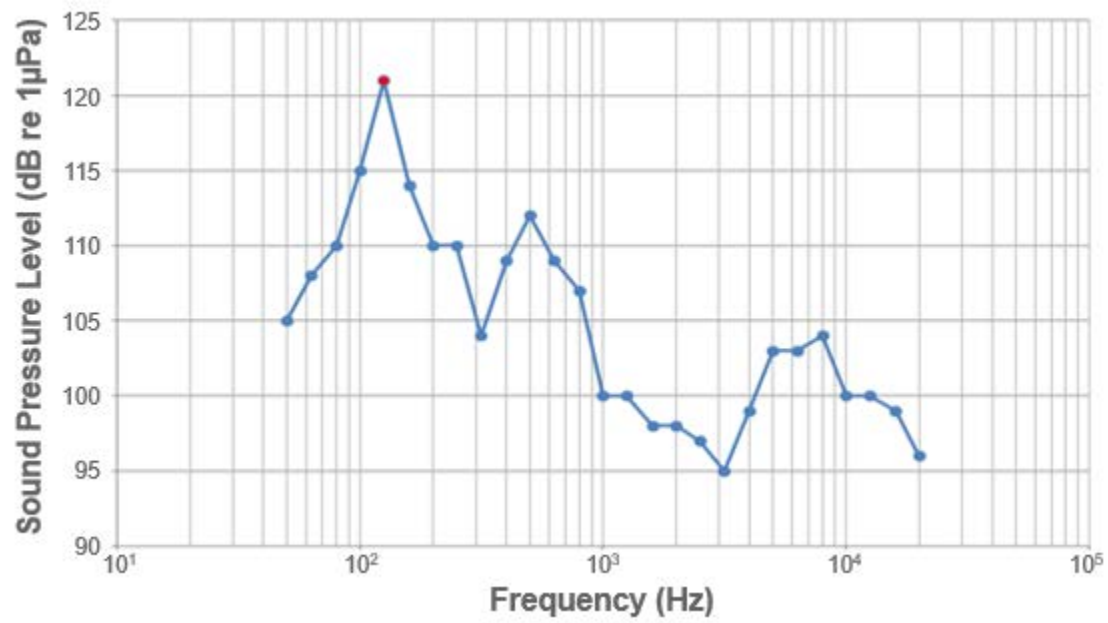


Figure 5. 1/3 octave band spectrum of the noise radiated by the WaveRoller.

Hearing thresholds for marine animals and underwater noise levels (Scholik-Schlomer 2015):

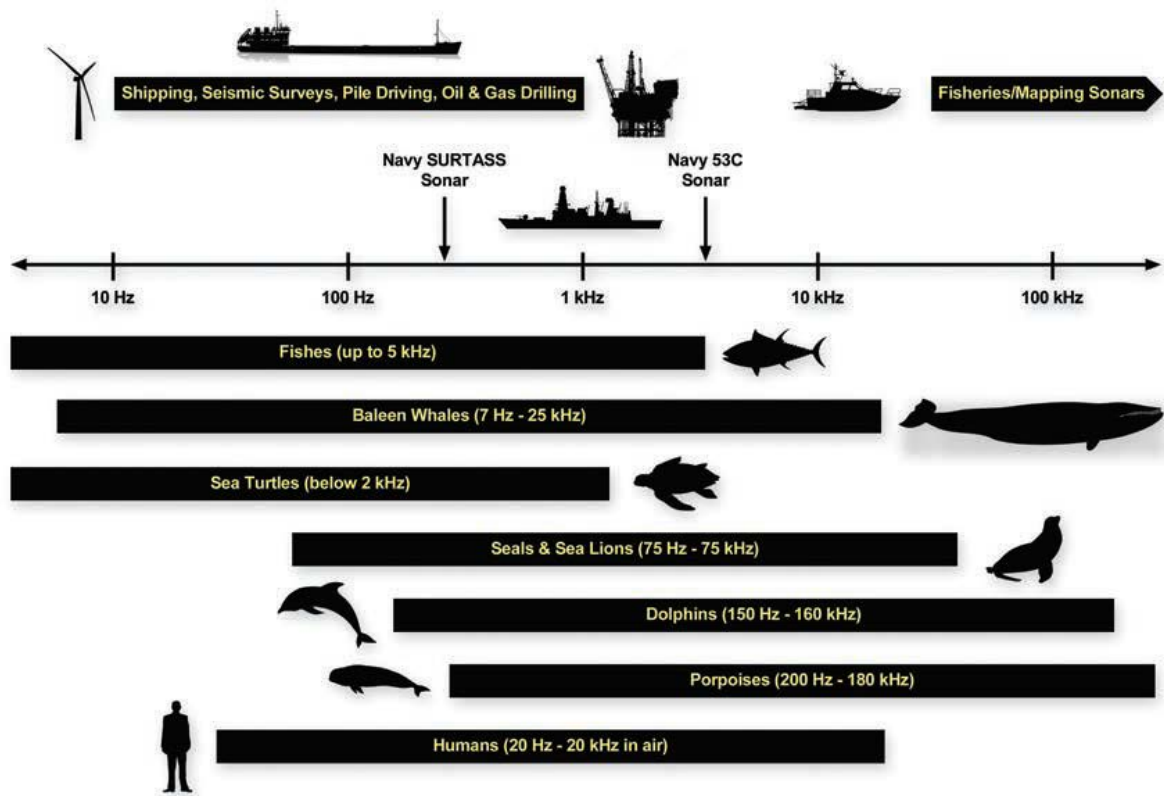


Figure 6. General overlap between the auditory range of marine species and frequencies produced by man-made underwater sound sources. Human hearing range is provided as a reference. Note: hearing thresholds are not available for all species (e.g., baleen whales) so other data are used to predict hearing ranges (e.g., anatomy, vocalizations, and behavioral responses to sound).

Regulatory Thresholds:

NOAA Technical Guidance (2018).

Table 4: Summary of PTS onset thresholds.

Hearing Group	PTS Onset Thresholds* (Received Level)	
	Impulsive	Non-impulsive
Low-Frequency (LF) Cetaceans	Cell 1 $L_{pk,flat}$: 219 dB $L_{E,LF,24h}$: 183 dB	Cell 2 $L_{E,LF,24h}$: 199 dB
Mid-Frequency (MF) Cetaceans	Cell 3 $L_{pk,flat}$: 230 dB $L_{E,MF,24h}$: 185 dB	Cell 4 $L_{E,MF,24h}$: 198 dB
High-Frequency (HF) Cetaceans	Cell 5 $L_{pk,flat}$: 202 dB $L_{E,HF,24h}$: 155 dB	Cell 6 $L_{E,HF,24h}$: 173 dB
Phocid Pinnipeds (PW) (Underwater)	Cell 7 $L_{pk,flat}$: 218 dB $L_{E,PW,24h}$: 185 dB	Cell 8 $L_{E,PW,24h}$: 201 dB
Otariid Pinnipeds (OW) (Underwater)	Cell 9 $L_{pk,flat}$: 232 dB $L_{E,OW,24h}$: 203 dB	Cell 10 $L_{E,OW,24h}$: 219 dB

Figure 7. Table of Permanent Threshold Shifts (PTS) for marine mammals.

Table 6: TTS onset thresholds for non-impulsive sounds.

Hearing Group	K (dB)	C (dB)	Weighted TTS onset acoustic threshold (SEL _{cum})
Low-frequency (LF) cetaceans	179	0.13	179 dB
Mid-frequency (MF) cetaceans	177	1.20	178 dB
High-frequency (HF) cetaceans	152	1.36	153 dB
Phocid pinnipeds (underwater)	180	0.75	181 dB
Otariid pinnipeds (underwater)	198	0.64	199 dB

Figure 8. Table of Temporary Threshold Shifts (TTS) for marine mammals.

BOEM Underwater Acoustic Modeling Report (2013).

Table 3. Interim Fisheries Cause and Effect Guidelines

	Criteria Level	Type
Physiological Effects	206 dBL re 1 μ Pa	Absolute Peak SPL
	187 dBL re 1 μ Pa ² s	SEL _{cum} , For fishes above 2 grams (0.07 ounces)
	183 dBL re 1 μ Pa ² s	SEL _{cum} , For fishes below 2 grams (0.07 ounces)
Behavioral Effects	150 dBL re 1 μ Pa (RMS)	Absolute
Reference: U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM). Effects of Noise on Fish, Fisheries, and Invertebrates in the U.S. Atlantic and Arctic from Energy Industry Sound-Generating Activities, Literature Synthesis, 2012		

Figure 9. Criteria for assessing the potential of pile driving activities to cause injury to fish, developed by an interagency work group that included U.S. Fish and Wildlife Service and the National Marine Fisheries Service.