Underwater Noise Modelling of Wave Energy Devices

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Wave Energy and Environmental Impact Studies

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Pre-mature stage

Future large-scale implementation of WECs

and

Pilot Zones / Test Sites

Opportunity to Monitor

(Positive and Negative Impacts)

Wave Energy and Underwater Noise

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Effects of underwater noise on marine life

Marine Mammals ➡ Use sound as their primary sense

Any change in the underwater noise has the potential to disturb these species

Wave Energy and Underwater Noise

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Wave Energy Devices may prove to be one addittional anthropogenic noise source

Single WEC Vs Several Devices in a Wave Farm

Scarce information on the sound levels produced by different project phases

Acoustical data not available yet

Wave Energy Acoustic Monitoring - WEAM

Objectives:

- To characterize noise generation by wave energy prototypes and farms
- To develop a plan or guideline to perform acoustic monitoring
- To develop a fixed hydrophone calibrated system for long time series measurements

Partner:

CINTAL
(Technological Research Centre of Algarve University)

Wave Energy Acoustic Monitoring - WEAM

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- No experimental work at sea has been carried out
- Implementation of acoustic modeling software;
- State-of-the art bibliography review on the evaluation of noise impact on marine mammals is being undertaken;
- Simulation results on acoustic propagation and impact evaluation

Acoustic Approach

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Assessing the acoustic impact – steps:

- Performing in-situ recording of noise generated by the WECs;
- Maximum and average broadband sound pressure level (SPL);
- The amplitude spectrum in the frequency domain over different phases of operation;
- Noise recordings performed over the area of interest at a certain range of distances;
- What extend an animal may be affected by a given noise source.

Audiogram - Represents the lowest sound level as a function of frequency that it can perceive

Acoustic Approach

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However:

- In –situ measurements may be sufficient for a minimal impact assessment;
- A complete spatial and time coverage via in-situ measurements - time consuming and expensive;
- Variations with time and space due to several factors: operating conditions – sea state; the sound pressure level (range, depth, bearing, etc.);

Solution: ACOUSTIC MODEL

Acoustic Approach

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Advantages /Possibilities:

- To estimate the SPL over a area needs the amplitude spectrum and validation of the transmission loss (TL) calculated by the acoustic model;
- Multiple noise sources that do not produce noise in a synchronized mode; or under sea states that do not allow the collection of in-situ acoustic data;
- Setting up the layout of wave energy farms (geometry, number of devices, distance, etc).

Acoustic Modelling

KRAKEN normal modes code

- Computationally efficient and relatively easy to use;
- Permits a 3D field calculation through triangulation of the environment

A Matlab interface to Kraken is being developed.

This software reads an input file that sets up the model with:

- the emitter and receiver geometries,
- environmental properties of the acoustic propagation channel,
- frequency range,
- and other KRAKEN input parameters.
- Simultaneously routines that yield plots on the influence zones are being implemented.

Marine Mammals and Influence Zones

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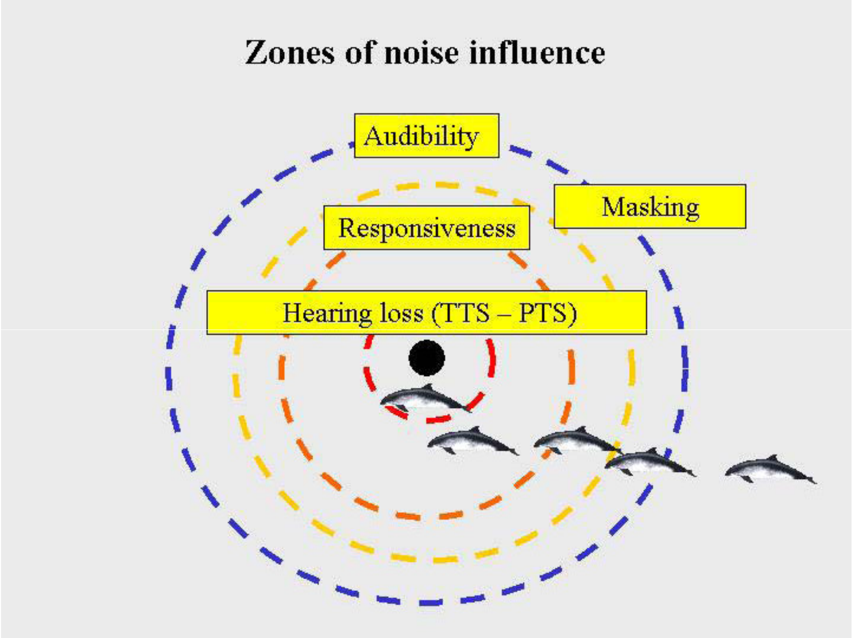

Zones of noise influence , Richardson, 1995
(Thomsen, *et al*, 2006)

Marine Mammals and Influence Zones

Each marine mammals species – specific audiogram

Calculate and define the influence zones:

- Zone of audibility is defined as the area within which the animal is able to detect the sound;
- Zone of responsiveness is the region in which the animal reacts behaviourally or physiologically;
- Zone of masking is highly variable in size, usually somewhere between audibility and responsiveness and defines the region within which noise is strong enough to interfere with detection of other sounds;
- Zone of hearing loss is the area near the noise source where the received sound level is high enough to cause tissue damage resulting in either temporary threshold shift (TTS) or permanent threshold shift (PTS) or even more severe damage.

Acoustic Simulation - Example

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To Compute the influence zones.

- Audiogram of the Harbour Porpoise (*Phocoena phocoena*)

Note:

It is only an indicative example where the noise used as input does not come from real measurements or data.

Acoustic Simulation - Example

- The synthetic noise spectrum consists of a superposition of four discrete tones at frequencies of 200, 400, 600, and 800 Hz, and a continuous noise spectrum in the band 200 to 1000 Hz, and the broadband SPL is 175 dB

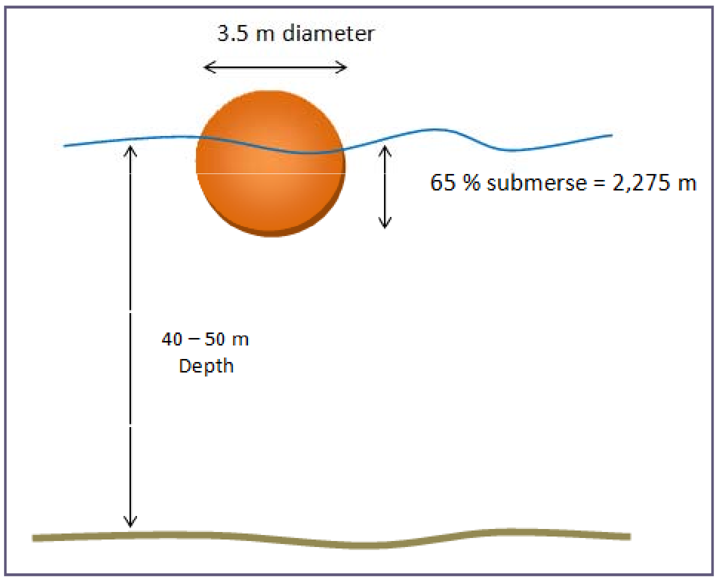


Figure 1: WEC deployment in depth

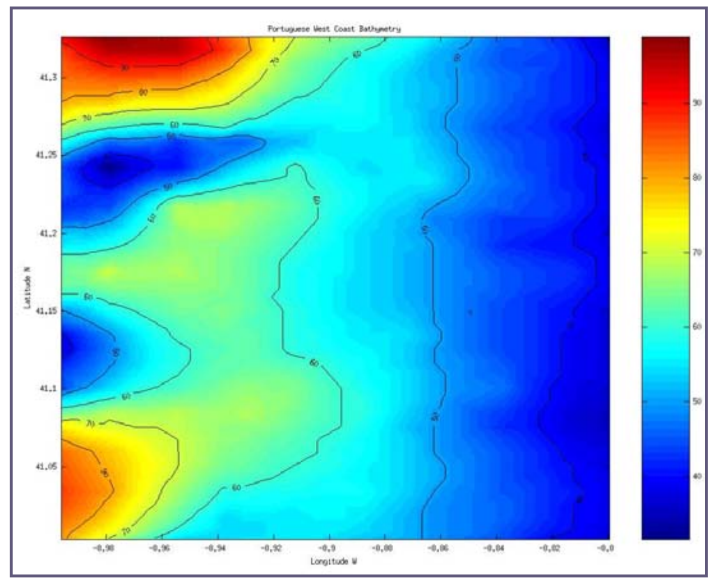


Figure 2: Bathymetry of Portuguese West Coast

Acoustic Simulation - Example

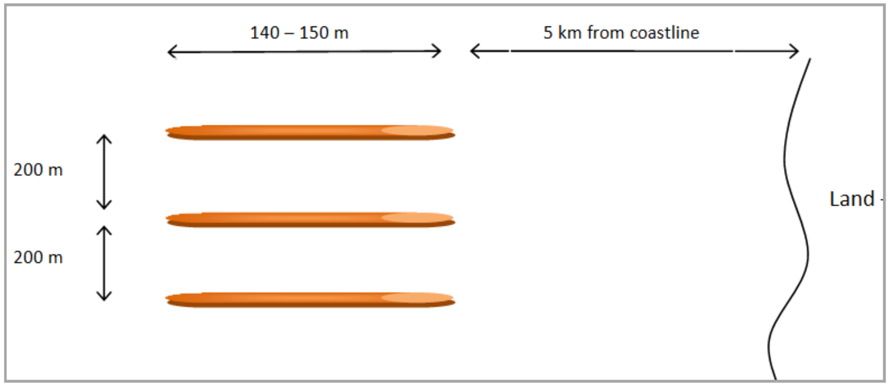


Figure 3: Case A: Three equidistance rows of WEC corresponding to each one as a single source

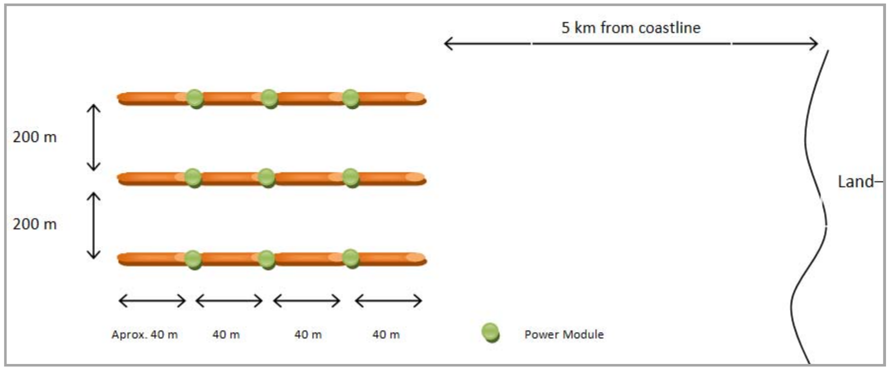


Figure 4: Scheme of 3 semi-submersible WECs deployment (each green point correspond to a power module)

Case B: Matrix of 9 noise sources in 3 parallel rows.

Acoustic Simulation - Example

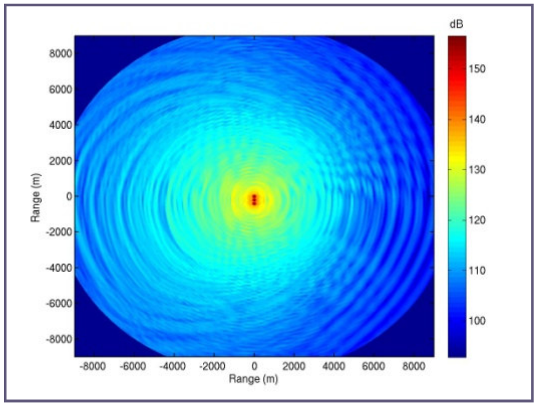


Figure 5: Case A **-** SPL over the distance from the wave farm with 3 simultaneous noise sources

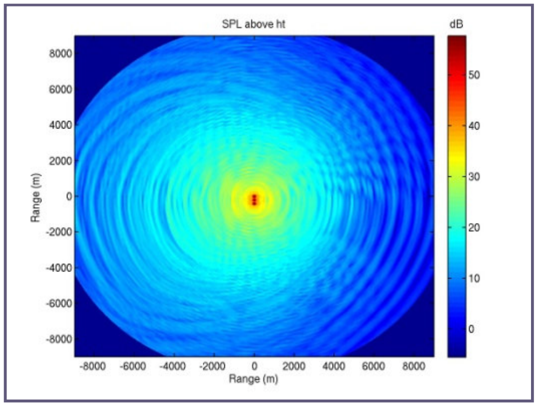
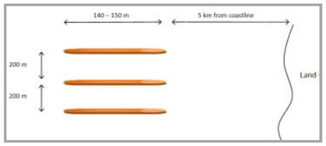


Figure 6: Case A - SPL above hearing threshold for Harbour Porpoise

Case A



Acoustic Simulation - Example

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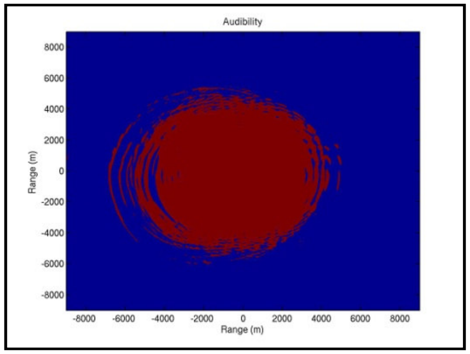


Figure 7: Case A - Audibility zone based on the SPL and the animal's audiogram. All points SPL more than 20 dB the hearing threshold are included in the audibility zone.

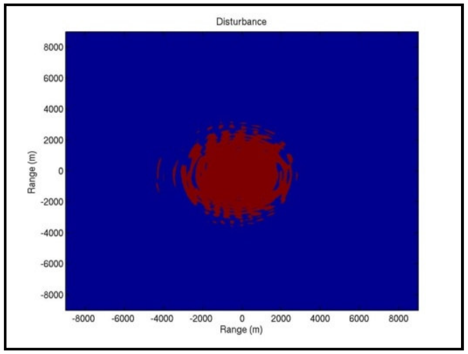


Figure 8: Case A **-** Zone of behavioural disturbance, considering every point with an SPL of more than 120 dB.

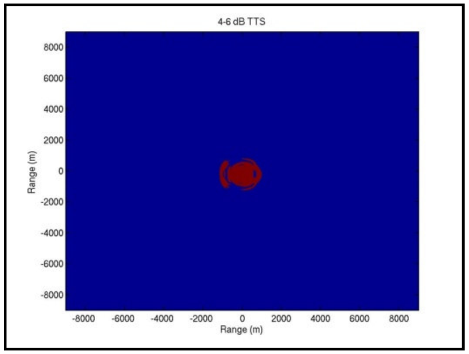
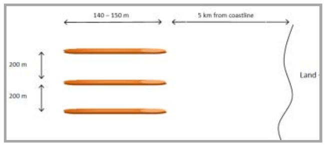


Figure 9: Case A - Zone of TTS of 6 dB considering a source level with 30 dB excess in the broadband SPL.

Case A



Acoustic Simulation - Example

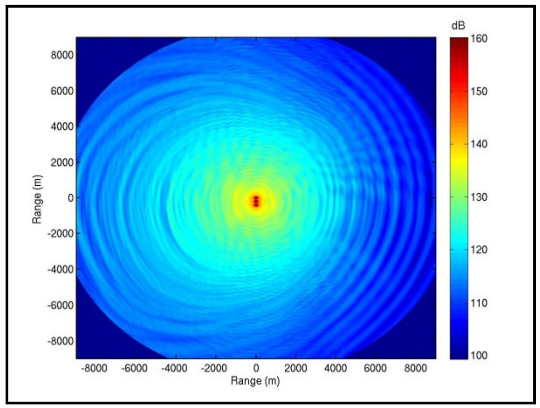
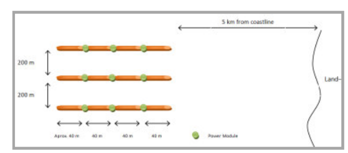


Figure 10: SPL over distance from the Wave Farm of Case B.

Case B



Acoustic Simulation - Example

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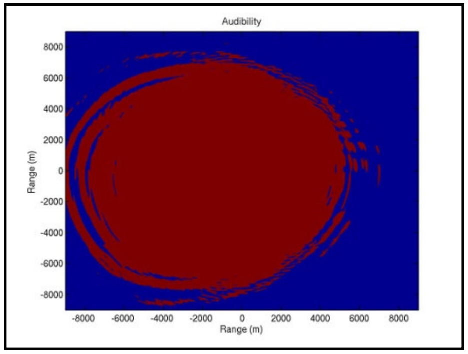


Figure 11: Case B - Audibility zone based on the SPL and the animal's audiogram. All points SPL more than 20 dB the hearing threshold are included in the audibility zone.

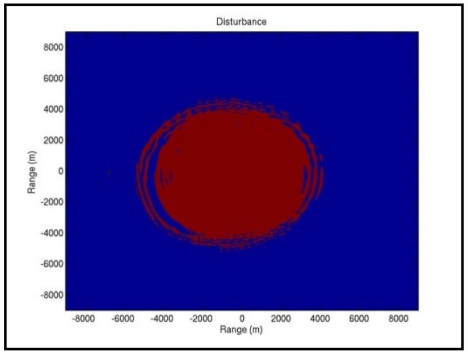


Figure 12: Case B **-** Zone of behavioural disturbance, considering every point with an SPL of more than 120 dB

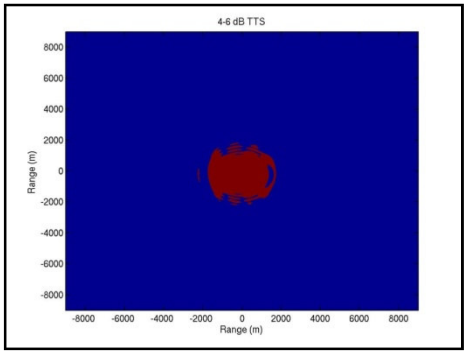
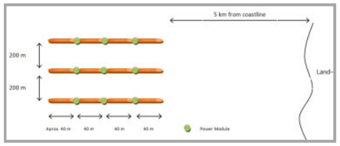


Figure 13: Case B - Zone of TTS of 6 dB considering a source level with 30 dB excess in the broadband SPL.

Case B



Conclusion

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- Models can help to analyse the sound propagation over space
- Helpful tool

The next steps are:

- Measure the frequency and duration of noise generated by WECs, under different sea states and ocean conditions;
- Validate the model;
- Development of a monitoring plan that is crucial