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Substrate vibro-scape of a high ship traffic density area

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Waterborne sound has been the main phenomenon considered when sound impact on marine fauna have been addressed. However, few studies have considered seismic waves (acoustic waves that propagates through the seafloor and normally expressed as vibration levels) as a possible source of negative effects on marina fauna. Levels of seafloor vibrations are not well documented, neither how these vibrations can affect seafloor fauna (crustaceans, molluscs…etc.). In the present study, the ship-induced vibro-acoustic (substrate-vibration) soundscape of a high ship traffic density area is characterized and the correlation between ship induced waterborne and seismic sound in shallow waters is studied. For this purpose, long-term measurements performed with the **Multi-Influence Range System (MIRS)** are used. Additional results regarding environmental underwater acoustic and seismic levels are provided.

Data Collection - MIRS

Fig 1. Multi-Influence Ranging System before and after deployment

The operational zone where the data set was compiled is the area of the Cartagena Harbour. This is an area of particularly intense human activity, with relevant maritime traffic in its two docks: Escombreras and Cartagena, that together configure as one of the ten biggest commercial and industrial harbours in Spain. Additionally, Cartagena is one of the most important military harbours in Spain. This intense activity makes especially worth to record long term underwater acoustic measurements, as a basis for further studies on its variation levels and potential impacts on marine fauna.

Measurements have been collected using the SAES' manufactured MIRS system (Fig.1). This last-generation portable and light system incorporates a set of sensors to provide underwater acoustic, electric, magnetic, pressure and seismic measurements during long periods of time. MIRS incorporates among its set of sensors a calibrated omnidirectional hydrophone with a measurement range of acoustic data of up to 8 kHz.

SOUND PRESSURE AND ACCELERATION LEVELS

Spectrograms of passing vessel and ambient noise recording

During 2013 and 2014, a set of underwater multiinfluece measurements were carreid out at the sea harbour of Cartagena. Tracking of AIS data was used in order to triguer the onset of the different measurements.. All influences (electric, magnetic, acoustic, pressure and seismic) start and end at the same time. The duration of the signals were vessel position dependent, however, for this study, only measurements larger than 30 seconds have been used. Ambient noise measurements were also carried out right after a vessel measurement except when other vessel was predicted to pass over the location of the MIRS station. Military vessels were left out from the measurement campaign.

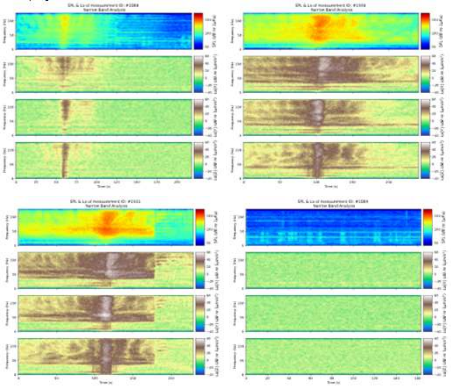

Fig 2. Narrowband Spectrograms

Two typical Narrow-Band spectrograms are shown. Acoustic, and Seismic (3-axis) signals are depicted. Sound Pressure Levels - SPLs (Ac.) and Accleration levels - La (Seismic) expressed as dB re 1μPa and 1μ ms^{-2} respectively. Fig. 2 shows typical examples of acoustic and triaxial seismic spectrograms of passing vessels except for the bottom right spectrogram which corresponds to an ambient sound recording.

Vibro-Acoutic scape

A total of 2175 vessel and 1736 ambient noise recordings have been analyzed. SPLs and La were extracted arithmetically averaged for each different day when multi-influence recordings were performed.

SPLs and Las for each day were arithmetically averaged. Max, L95 and L5 percentiles were also extracted and are presented.

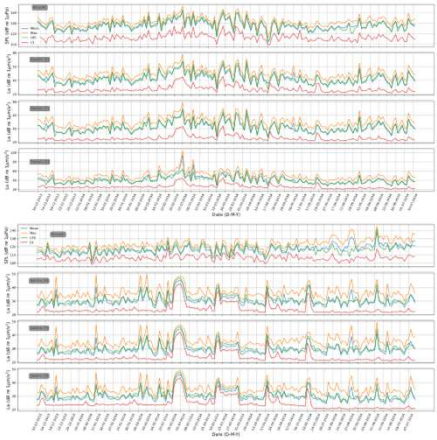

Fig 3. Acoustic and Acceleration levels

Mean SPL and La levels are about 135 dB re 1μPa and 42 dB re 1μms^{-2} for horizontal seismic axes, and 41 dB re 1μms^{-2} for vertical seismic axis. SNRs for acoustic signals are about 20-19 dB, meanwhile for seismic signals, SNR is a little bit lower and it is around 10-11 dB.
No levels trend was observed during 7 months of measurements.

Correlation between acoustic and seismic measurements

From Figure 2, it can be seen, as expected, that there is a correlation between the acoustic and seismic signals. A passing vessel, can be detected on a simple spectrogram by visual inspection of the acoustic and seismic signals acquired during the passing of the vessel. Acoustic-seismic correlation has been studied in third-octave bands (OTO) in the frequency range of 10 – 125 Hz. Only vessel measurements were taken into account for this section.

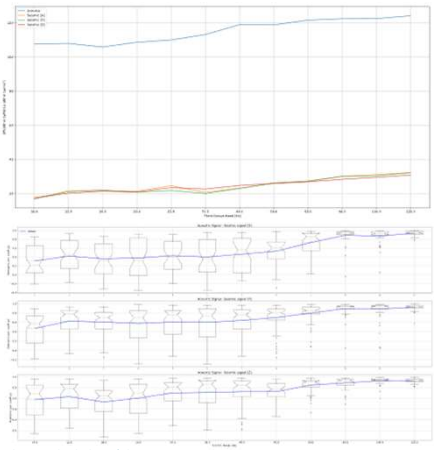

Fig 4. Acoustic-seismic correlation

In the upper plot (Fig 4.a) , the mean of all vessel measurements (1736) in the OTO spectrum for each influence, i.e. acoustic and three-axial seismic. Units are expressed in dB re 1μPa and 1μ ms^{-2} for acoustic and seismic signals respectively. Pearson's correlation coefficient have been computed for each third-octave band in SPL and La – [X], La - [Y] and La-[Z] along the entire measurement (1s time resolution). Mean P-value is about 0.6 for very low frequency with high standard deviation. P-value increases with frequency (~0.9 @ frequencies larger than 63 Hz) whereas standard deviation of P-value decreases.

CONCLUSIONS & DISCUSSION

The vibroscape of a high maritime traffic area has been analyzed. The system used for data acquiring is the Multi-Influence Ranging System (MIRS) which is able to acquire synchronous acoustic, magnetic, electric, pressure and seismic data.

Acoustic and Seismic data of about 1736 passing vessels and 2175 ambient noise recordings have been analyzed and their induced influence to the marine environment are computed. Narrowband and One-third octave band analysis in the frequency range of 10 – 125 Hz is performed. The time period in which these measurements were carried out was 7 months.

Mean acoustic SPL of about 135 dB re 1μPa and mean La 42-41 dB re 1μms^{-2} are found for vessel measurements. Ambient noise levels were about 20 dB and 10 dB lower for acoustic and seismic influence respectively.

In order to study the correlation between the acoustic and seismic influence of a vessel, one-third octave band analysis has been performed, and pearson's correlation between SPL and La levels for each third-octave band computed for each entire measurement with a time resolution of 1s is computed. Results suggest that stronger correlation exists in the frequency range of 63 – 125 Hz. They also suggest that this correlation present a large variability in the very low frequency range, and it decreases as the frequency increases. This might be produced by low SNR for low frequencies, specially in the seismic influence. Behaviour of the correlation within the frequency domain is found to be independent from the axis in which the seismic signal is measured.