First description of the sound pressure and particle velocity components of the ambient noise and boat noise recorded at the WWF- Miramare Natural Marine Reserve (Trieste, Italy)

Angelo Farina[1], Adriano Farina[5], Enrico Armelloni[1], Linda Sebastianutto[2], Carlo Franzosini[3], Marta Picciulin* [3,4]

[1] University of Parma, Ind. Eng. Dept., Parco Area delle Scienze 181/A, 43100 Parma, Italy;

[2] SISSA, Cognitive Neuroscience Sector, Via Lionello Stock 2/2 34135 Trieste, Italy;

[3] WWF-Natural Marine Reserve of Miramare, viale Miramare 349, 34014 Trieste, Italy;

[4] University of Trieste, CSEE - Department of Life Sciences, via Giorgieri 7, 34127 Trieste, Italy; marta.picciulin@gmail.com

[5] University of York, Department of Electronics, Heslington, York, UK. YO10 5DD.

1 Introduction

Boat noise represents a chronic source of harassment for fish species, whose communication for inter- and intra-sexual selection is mainly based on low frequency sound signals (Amorim 2006). Investigating the impact of boat noise on target fish species is particularly relevant for coastal MPAs, which are biologically rich locations deserving protection from anthropogenic pollutants. Although many fish species are primarily sensitive to the kinematic components of the sound field (Popper and Fay 1999), namely to particle acceleration, boat noises have been characterized so far mostly by means of sound pressure measurement. In this work, the underwater acoustic background noise, and the noise produced by a small outboard-engine boat moving at 6 knots, were recorded inside the WWF-Natural Marine Reserve of Miramare (Trieste, Italy) by using a novel hydrophonic probe ("*Soundfish*") placed on the sea bottom (8 meters depth). This allowed for characterization of the sound field not just in terms of sound pressure, but also of the three Cartesian components of the particle velocity.

2 Description of the “*Soundfish*” probe and of the digital signal processing

The system is based on a modified ZOOM H2 digital sound recorder, re-named *Brahma*, capable of recording the signals coming from a probe consisting of 4 hydrophones, placed at the vertexes of a tetrahedron: this is the underwater equivalent of a Soundfield™ microphone. The recorder operates at 48 kHz, 24 bits and records standard uncompressed WAV files over a 16Gb SD card, which can be easily processed later on a PC. A software tool, named *Brahmavolver*, was developed for converting the raw signals coming form the 4 hydrophones to output signals, representing respectively the sound pressure and the three Cartesian components of particle velocity. The processing is based on the use of a matrix of 4x4 FIR filters, currently 2048 points long. In our approach (Farina et al. 2007) the filter coefficients are computed numerically, inverting a matrix of measured impulse responses, obtained with the sound source placed at a large number *D* of positions all around the probe, as shown in fig. 1.

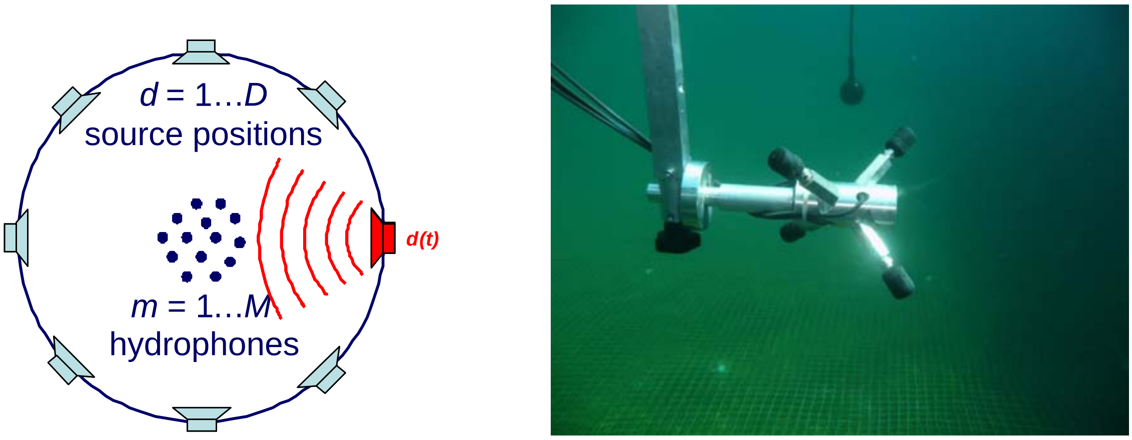

Fig. 1: impulse response measurements, performed inside a pool.

3 Preliminary tests in pool

A suitable number of impulse response measurements were performed on the Soundfish probe inside the test pool kindly made available by WASS in Livorno, Italy, as shown in fig. 1. A turntable, controlled by our Aurora software, was employed for automatically rotating the probe in steps of 30 degrees both along azimuth and elevation, yielding a set of 6x12 impulse responses. Fig. 2 shows some of the results of these preliminary tests: the polar patterns of the pressure and particle velocity in two octave bands.

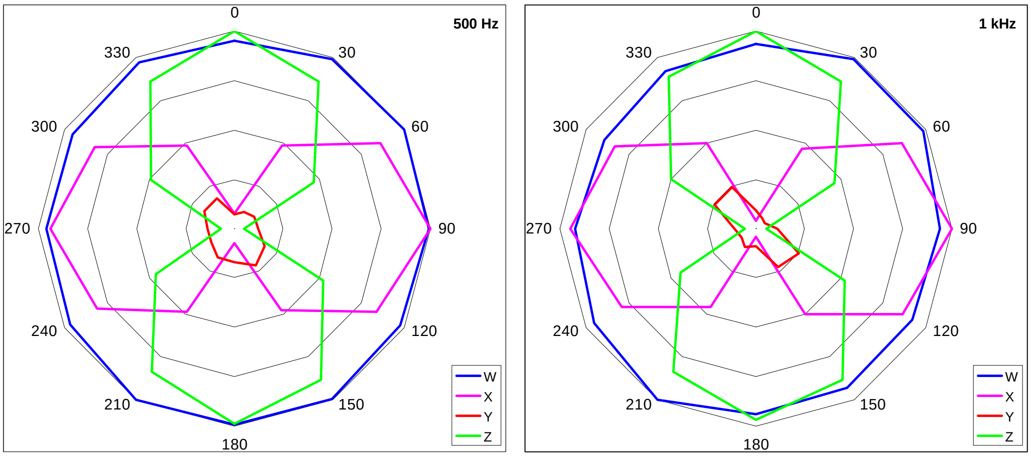

Fig. 2: polar patterns of the Soundfish probe at 500 and 1000 Hz

4 Field recordings

The probe and the Brahma recorder were placed on the sea bottom, at a depth of 8m, in the centre of the protected area of the Miramare Reserve. A 30 minutes long recording of the Sea Ambient Noise (SAN) was performed, followed by recordings of a boat passing near the probe. The analysis of these recordings allowed for the computation of 1/3 octave band spectra of both sound pressure level (SPL) and particle velocity level (PVL), computed with reference to the standard quantities for underwater acoustics (1 μPa and 1nm/s). Furthermore, the particle acceleration levels (PAL) can be easily derived from the values of particle velocity levels, following the procedure described in Picciulin et al. (2010).

Fig. 3 presents the analysis of the recordings, showing the 1/3 octave band spectra in terms of SPL and PVL of the SAN and of the boat passage.

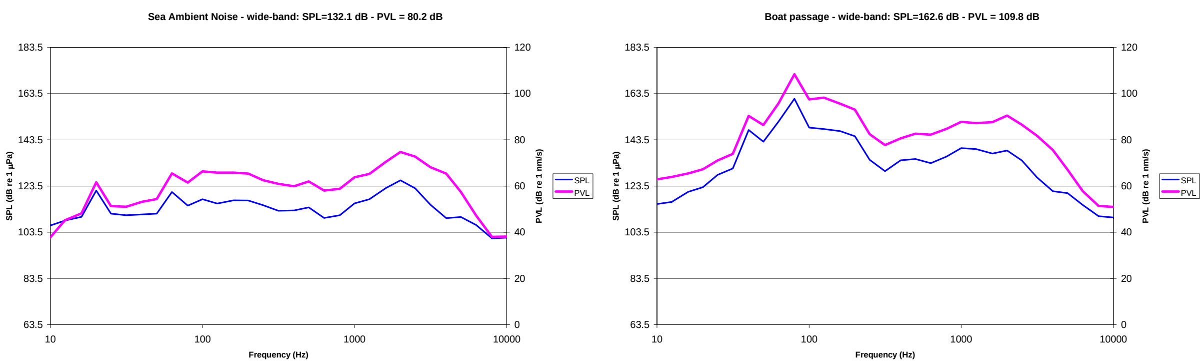

Fig. 3: SPL and PVL spectra: Sea Ambient Noise (left) and boat passage above the probe (right).

Albeit only the overall magnitude of the particle velocity vector is reported here, the data obtained allow for computation of the direction of the vector, making it possible to know, at any instant, the position of the sound source, which resulted in good agreement with the real trajectory of the boat.

5 Conclusions

The new *Soundfish* probe can be employed for an analysis of the cause-effect relationship, as at every instant the position of the source, relative to the receiver, is known, alongside with the quantities relevant for assessing the impact of human-produced noise over marine species, either sensitive to sound pressure or to particle motion. The reliability of the new measurement system must now be assessed by employing it in a number of surveys, under different sea conditions, at different depths, and with various kinds of noise sources. It could also be advisable to repeat the calibration in the pool, employing narrower angular steps, for ensuring computation of even better digital filters.

References

Amorim MCP (2006) Diversity of sound production in fish. In: Ladich SP et al (eds) Communication in fishes. Science Publishers, Enfield. pp. 71-104.

Farina A., Capra, L., Conti, L. Martignon, P., Fazi, F. Measuring spatial impulse responses in concert halls and opera houses employing a spherical microphone array. In 19th International Congress on Acoustics (ICA) - Madrid (Spain), 2-7 September 2007.

Picciulin M, Sebastianutto L, Codarin A, Farina A, Spoto M, Ferrero EA (2010) In-situ behavioral responses to boat noise exposure of *Gobius cruentatus* (Gmelin, 1789; fam. Gobiidae) and *Chromis chromis* (Linnaeus, 1758; fam. Pomacentridae) living in a Marine Protected Area. J. Exp. Mar. Biol. Ecol. 386(1-2), 125-132.

Popper AN, Fay RR (1999) The auditory periphery in fishes. In: Fay RR and Popper AN (eds.) Comparative Hearing: Fish and Amphibian. Springer-Verlag, New York, pp. 43–100.