FISH TANK RESEARCH FACILITY FOR SOUND-VIDEO RECORDING AND SOUND EMISSION EXPERIMENTS

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Abstract

The sounds produced by fish fall into several categories. There are sounds like constant whistles, moans or purrs, simple pulsed (of knocking nature) sounds or series of pulsed sounds. Gilthead seabream and European seabass (Sparus aurata & Dicentrarchus labrax), are among the most commercial fish species that are raised massively in fish farms in Greece and abroad. In order to investigate the sound production capability of these species as well as studying their response to various emitted underwater sounds, a medium size tank (1.2 × 1.1 × 1.48 m) and a smaller size tank (1.14 × 0.45 × 0.30 m) have been designed and constructed. In this study, the supporting hardware and software will be discussed along with issues concerning the tanks' acoustics. Calculated values of eigenfrequencies and cutoff frequencies along with pressure field images obtained through the finite element method will also be presented. Problems encountered when developing an automated recording system for functioning in an environment where other fish supporting devices are operating will be mentioned and general guidelines for handling these problems will be discussed.

Keywords: *Tank experiments, Bioacoustics.*

1. INTRODUCTION

Several fish species produce sounds using different mechanisms. They are using their teeth, pharynx, fins and swimbladder, [1,2]. Although the sound production is limited to certain species of fish, it is obvious that all fish are able to perceive some kind of auditory stimuli. In order to investigate if some particular species are soniferous, record the sounds and also study their responses to various sounds in a laboratory environment, customized tanks for this purpose should be built. In this paper, description of a medium size tank for studying primarily Gilthead seabream and European seabass, of a smaller size tank for studying smaller fish (zebra fish), and of the supporting hardware and software for audio and video recordings. Several concerns that affect the methodology because of the tanks' acoustics and other problems that arise will be discussed.

2. TANK FACILITIES

In this section we will refer to the tanks that were built and to the problems that arise when trying to collect sounds from various fish in tanks. Two separate cases will be described: A) A medium size fish tank along with the appropriate equipment for sound and video recordings B) A small size fish tank for sound and video monitoring of smaller fish.

A) The main experimental facility for underwater sound recordings and video monitoring consists of a tank constructed from scratch. Using molds, two fiberglass pieces were built and attached face to face. One of the pieces carries a transparent thermoplastic Polymethyl methacrylate, (PMMA), window. The tank (Tank 1) is a rectangular parallelepiped (Fig.1), with dimensions: 1.1 x 1.2 x 1.48 m (Volume=1.95 m^3).

The structural vibration isolation of the aquarium was achieved by resting the whole tank on a special elastic base. The tank was placed in a small room on the ground floor of the Biology Department (U. of Crete) building. The sound pressure level inside this room was measured and found to be less than 35 dB (re 20 μPa), during all day or night hours. The equipment which is an integral part of this experimental aquarium consists of the following components/devices:

1. Water purification filter (EHEIM, model 2217, 1000 *l/hour*)
2. Air pump RESUN (model AC-9602, 1.5 *l/hour*).
3. Depending on the application three hydrophones were used:
   a) HS / 150 (company SRD) 1Hz-150kHz, Receiving sensitivity -204dB (100 kHz).
   b) Teledyne Reson, TC 4033, spherical reference hydrophone.
   c) Aquarian Audio Products, Model H2.
4. Two hydrophone preamps-filters, Reson EC6081 and Reson EC6067.
5. Data acquisition module, National Instruments NI 9215.
6. Desktop PC, Dell Precision T1650.
7. Three video cameras (a USB, an IP and an underwater camera), with appropriate stands.
8. Underwater speaker, Lubell 3400 U/W PA System, (Model LL916R).

9. Audio amplifier for driving the underwater speaker (TOA CA160, PA amplifier).
10. Special supports on top of the tank will give the potential to adjust the horizontal placement and depth of the hydrophones in the tank.

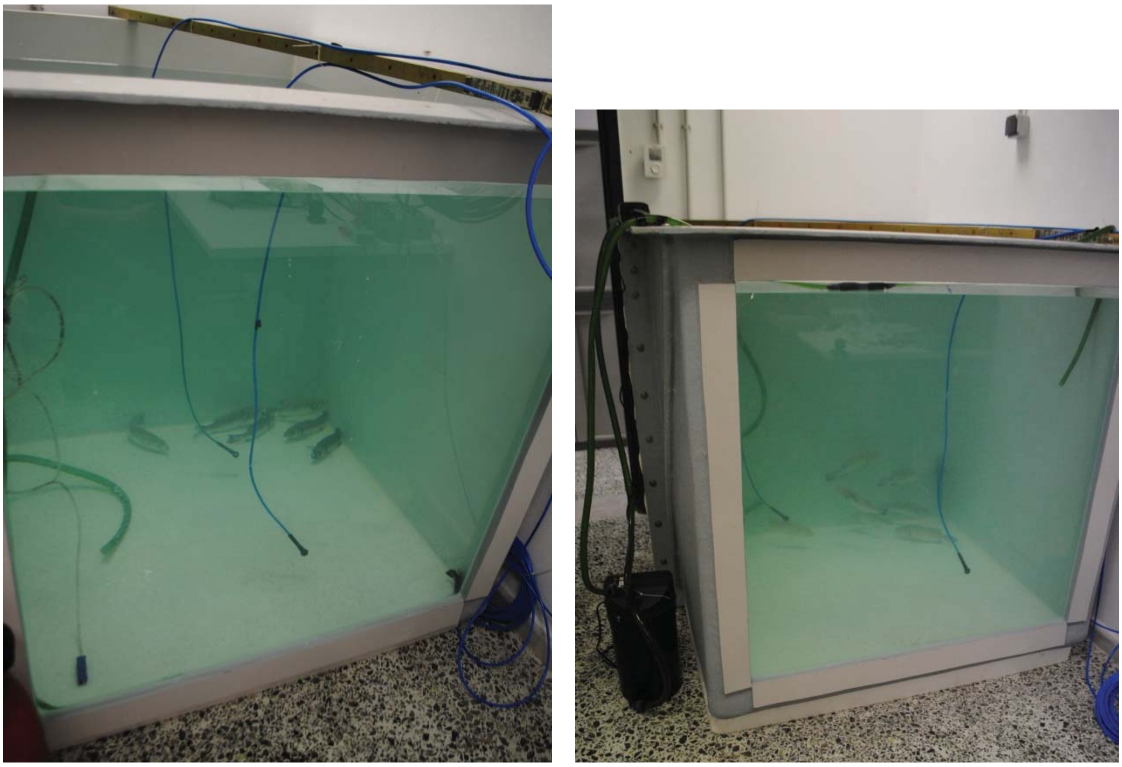

Fig. 1: The primary fish tank (Tank 1).

Several software applications were developed for capturing one or two audio signals from the hydrophones along with the video signal from the camera. The application is based on the MATLAB language and can be set to automatically start capturing and saving all signals. The recordings' starting times and durations can be adjusted in advance, so that fish can remain undisturbed from any human presence. Several recordings were made for 5-6 successive days, spanning several day and night hours. Usually each experimental session lasted for 5-6 days involving fish of different age or species in each session. Our undertaken research aims to investigate both the sound production and the mechanisms involved in it, [3], concerning primarily two fish species: Gilthead seabream (Sparus aurata) and European seabass (Dicentrarchus labrax). All recordings made in Tank 1 so far, involve these two fish species.

Experiments were also performed for studying the behaviour of the fish in response to various sounds played by the underwater speaker. A collection of 10 sound files were played at certain intervals. The collection consisted of files with sinusoidal wavetrains at different frequencies, slowly sweeping sinusoidal sounds, compilations of fish sounds from other species or of the same species as the ones tested and compilations of synthesized fish like knocking sounds. During the sound reproduction, the audio and video signals from the hydrophone(s) and the camera were recorded.

B) A smaller fish tank for experiments involving small size fish (i.e. zebra fish) was also constructed. This set up can also be used for experiments with medium size fish and is handier than bigger tanks. It can also be used for informing and educating pupils, students and the general public on acoustic ecology issues. For this purpose, it is proposed to use freshwater fish of the species that are known to produce sounds. The fish tank was made from fiberglass. Only one side was made transparent by attaching a transparent thermoplastic (plexiglass) window (Fig. 2).

Fig. 2: Small size fish tank (Tank 2).

The tank's capacity is 104 *l* with dimensions: 1.14 x 0.45 x 0.30 m (water depth 0.26m). In tests conducted in our laboratory, recordings were made using the following freshwater fish species: Pterophyllum Scalare, Pimelodus Pictus, Trichogaster leeri, Paracheirodon simulans and Ancistrus cirrhosus. The Pimelodus Pictus species was studied more thoroughly, (far more sound recording time was captured). Recordings were made using the following saltwater fish species: Oblada melanura, Sarpa salpa, Balistes capriscus, Diplodus sargus sargus, and Sparus aurata. It should be noted that even for species with known sound producing potential, very lengthy recordings had to be made for a sound to be captured. A typical stridulatory sound followed by a knock sound from a *Pimelodus Pictus,* is shown in Fig. 3.

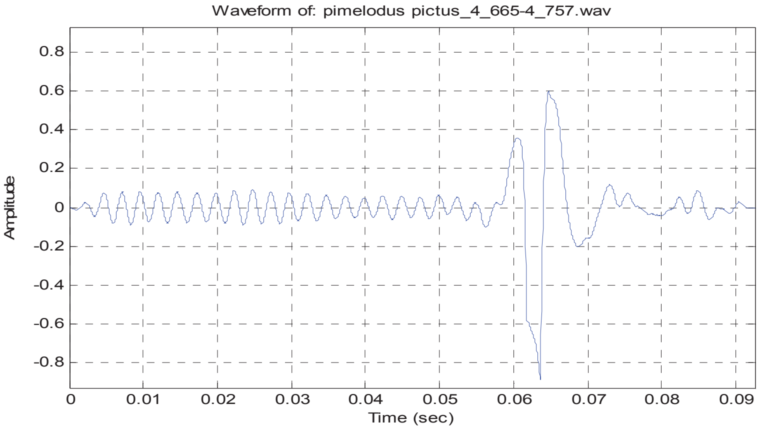

Fig. 3: Characteristic sound waveform from Pimelodus Pictus, recorded in Tank 2.

3. THEORETICAL AND NUMERICAL APPROACH OF TANKS' ACOUSTICS

The shape of both tanks constructed, was rectangular parallelepiped. In the small tank (Tank 2), one dimension is remarkably larger than the rest of them. In cases where the tank wall material is lightweight and it is thin (as it is the case with the small tank), it can be shown both experimentally and theoretically that the boundary surfaces of the aquarium behave as if they were free [4,5]. Since the small tank was made out of plastic (fiberglass) with its bottom surface resting on the floor, it is more reasonable to assume a different boundary condition only for this surface. We consider the bottom surface as hard and all other surfaces as being free. The resonance frequencies in this case will be given by the relationship,

$$f_{lmn} = \frac{c}{2}\sqrt{\left(\frac{l}{L_x}\right)^2 + \left(\frac{m}{L_y}\right)^2 + \left(\frac{2n+1}{2L_z}\right)^2} \tag{1}$$

Where the sound speed in water c=1500 m/sec, L_x, L_y, L_z the dimensions of the tank in meters, while *l, m, n* take the values: *l, m = 1,2,3….* and *n = 0,1,2,3…* The lowest eigenfrequency corresponds to: *(l,m,n)=(1,1,0).* Considering the small tank as a waveguide with the boundary conditions mentioned above, the cutoff frequency for this kind of tank (rectangular parallelepiped), is given by the relation:

$$f_{cutoff} = \frac{c}{2}\sqrt{\left(\frac{1}{L_y}\right)^2 + \left(\frac{1}{2L_z}\right)^2} \tag{2}$$

We can define the attenuation distance, as the frequency dependent distance, for which the sound is reduced by 20 dB, [5]. In Fig. 4 the attenuation distance is plotted with respect to frequency, in the case where the water depth is 0.26 m and the bottom is considered hard (fixed). We notice that up to 1800 Hz the attenuation distance is below 30 cm.

The cutoff frequencies and lowest eigenfrequencies for the small tank but for different water depths are summarized in Table 1. The length L_x and the width L_y of the tank, are 1.14 and 0.35 m respectively, while L_z corresponds to the water height (depth).

Water depth L_z (m)	Cutoff Frequency (Hz)	Lowest Eigenfrequency (Hz)
0.15	3292	3357
0.19	2913	2986
0.23	2692	2772
0.26	2583	2665
0.30	2480	2566

Table 1: *Cutoff frequencies and lowest eigenfrequencies for the small tank (Tank 2) for different water depths. Free boundary conditions are considered all around this tank, except for the bottom surface (considered hard).*

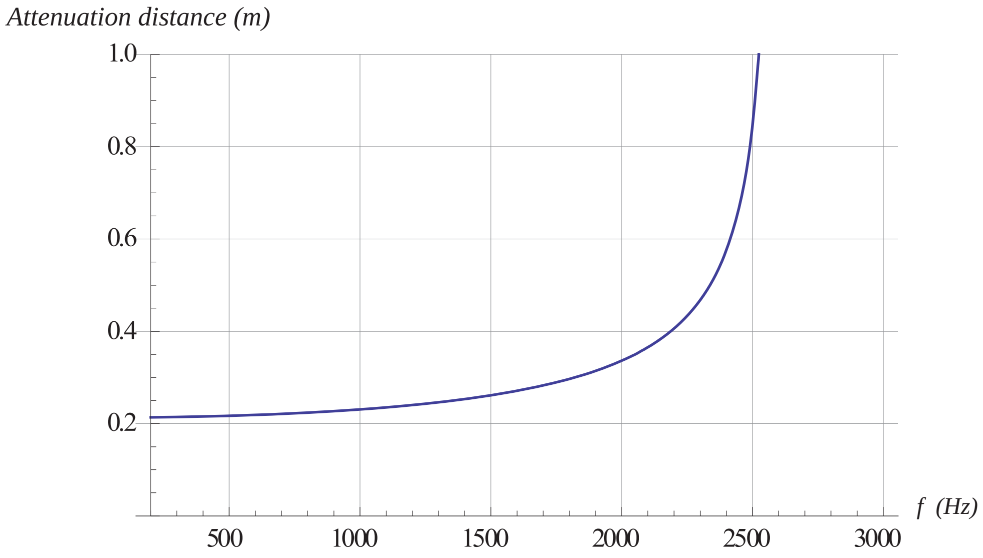

Fig. 4: Attenuation distance with respect to frequency for the small tank with a water depth of 0.26 m. For tank's boundary conditions and dimensions, see text.

Since the walls of primary tank (Tank 1) are much thicker than those of Tank 2, hard boundary conditions (BCs) can be considered for size and bottom surfaces, and free BC for the top water surface. Equation (1) can still be used to obtain the theoretical values for the eigenfrequencies, but in this case take the following values: *l,m,n=0,1,2,3…* . The lowest eigenfrequency corresponds to: *(l,m,n)=(0,0,0).* The corresponding eigenfrequencies for both tanks, as derived through commercial FEM program (*Comsol*) for the first 9 modes, are given in Table 2. In what follows some characteristic images of the basic acoustic pressure inside Tank 1, are presented (Fig. 5).

Modes	1	2	3	4	5	6	7	8	9
Tank 1 (Hz)	250	666	718	750	947	972	1008	1182	1251
Tank 2 (Hz)	3316	3502	3792	4164	4598	4945	5072	5079	5277

Table 2: The first ten eigenfrequencies for primary (Tank 1) and secondary (Tank 2).

4. DISCUSSION - CONCLUDING REMARKS

In this section some issues one has to face while trying to collect fish sounds that are not obvious at first, will be discussed. We should notice that even well known for the sound production capabilities fish species often they do not produce any sounds (especially under this artificial environment of captivity and possibly stress induced).

Therefore many hours of recordings are needed only to find out, after off line processing, that one or two fish sounds were detected.

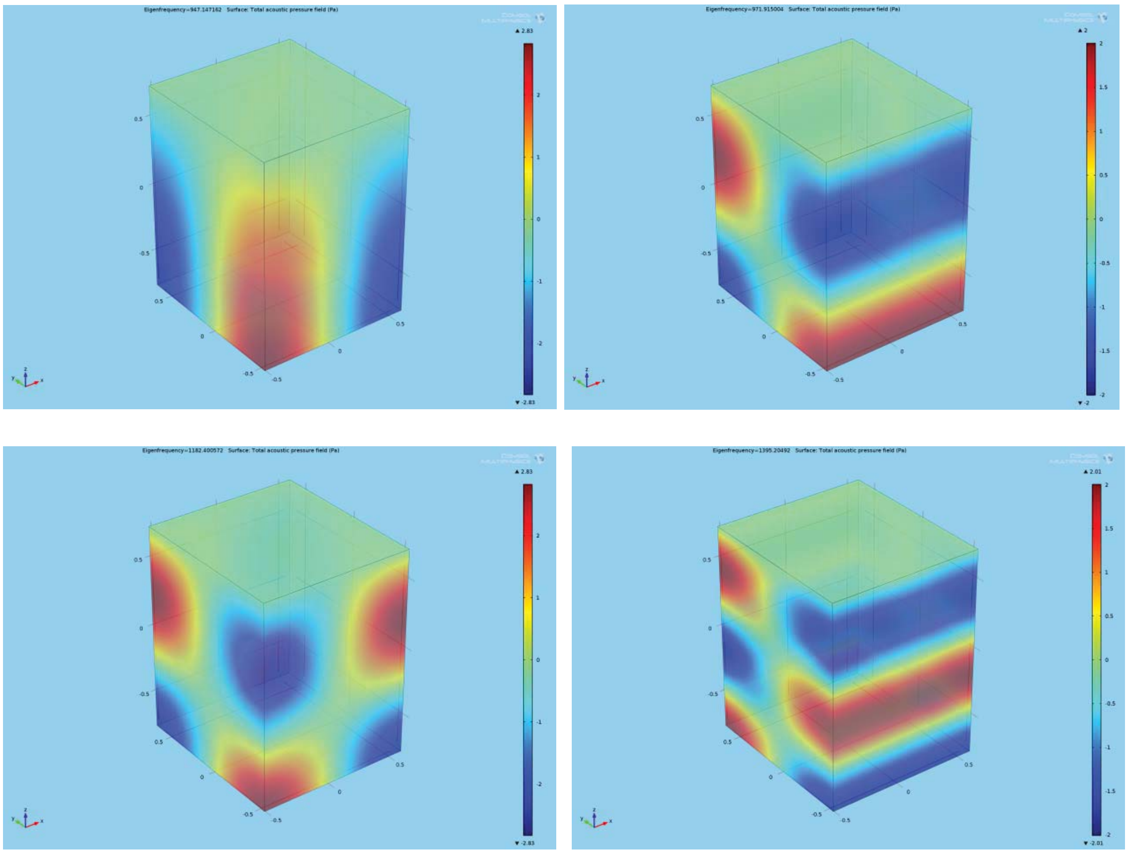

Fig. 5: Sound field representation in the primary tank for modes 5,6,8 and 12.

Moreover since the produced fish sounds are of very low intensity, for the fish sounds not to be buried in the noise produced by the circulating water filters and air pumps, all these noise making devices should be turned off for a recording to take place. This process reduces the recording's duration since the fish wellbeing cannot be maintained if these vital devices remain off for more than 5 hours. Furthermore, because of the long hydrophones cables along with the many devices (audio, video, computers, lighting, etc.) and power appliance outlets involved, interference noise and ground loops deteriorate the audio signal quality. In many cases all the equipment involved with audio and video recordings was battery operated resulting in a much cleaner sound signals.

As far as small sized tanks are concerned additional factors should be a concern when one is willing to record various types of fish. We should consider that the fish sound signature recorded in such a small tank could be remarkably different than the actual one. This is due to spectral morphing, because some fish waveform frequencies might be boosted when they coincide with tank eigenfrequencies and also, since the attenuation distance is frequency dependent, depending on the distance of the active fish from the hydrophone, the fish waveform might be distorted. Because of this and the weakness of fish sounds, it is then good practice to install more than one hydrophone in the tank, increasing this way the odds, the fish being close to a certain hydrophone at the moment it is vocalizing. This in turn, increases the equipment and processing requirements (more audio channels synchronized with the video signal).

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