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UNDERWATER NOISE AND THE NAVAL TRAFFIC FROM THE ROMANIAN BLACK SEA COAST AREA

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Abstract: *The Romanian Black Sea coast is an area with intense human activity, but also is an area with a large number of marine species. The regular measurement of the level of underwater noise is an important task in order to observe the evolution of the influence of human activities over the marine species. For a year and half, a team of professors from the Naval Academy „Mircea cel Batran“ and Ovidius University conducted a series of experiments regarding underwater noise. In this paper, a part of the results and conclusions are presented.*
Keywords: *Underwater noise, ship, fish*

1. INTRODUCTION

Human activity in the marine environment is an important component of the total sea acoustic background. Sound is used both as a tool for probing the sea and as a by-product of other activities.

Noise from artificial sources vary in space and time, but may be grouped into general categories:

a) large commercial ships;
b) military sonar;
c) ship-mounted sonar;
d) offshore drilling implements;
e) research sound sources;
f) small ships.

At low frequencies (5 to 500 Hz), commercial shipping is the major contributor to noise in the world’s seas. The distribution of ships contributes to the background noise over large geographic areas [1]. The sounds of individual vessels are often spatially and temporally indistinguishable in distant vessel traffic noise. Noise from vessel traffic at high latitudes is propagating over large distances because in these regions the sea sound channel (zone of most efficient sound propagation) reaches the sea surface.

Vessel operation statistics indicate steady growth in vessel traffic over the past few decades [2]. There has been an increase both in the number of vessels and in the tonnage of goods shipped.

Among the many human-induced sources of low frequency sound in the marine environment, marine vessels (and particularly large commercial ships) represent numerous, widespread, and relatively loud individual sources of underwater noise. The exact characteristics of which depend on ship type, size, mode of propulsion, operational characteristics, speed, and other factors.

First observations of the impact of the underwater noise over the environment came after noticeable changes in whales and dolphins populations because of military exercises.

The continuous intrusion of human activity in the nature was another factor to determine scientists to investigate the noise produced in the planet’s oceans and seas.

Ambient noise and underwater noise from shipping have continuously increased in the last decades (~ 3 dB per decade). This increase is valid for seas and oceans (high depths) and for shallow waters depends on local shipping [9].

One major source of underwater noise is the noise produced by the ships – around harbors and shipping lanes. In general, the noise produced by the ships is measured in areas with depths of hundreds of meters, while at the port entrance/exit the water depth is very small (~20m, shallow water). Often, when speaking of sea noise, the terms *deep sea noise* and *shallow sea noise* are encountered. It is usually understood that the shallow sea is the sea in coastal areas, and the deep sea is in regions distant from the coast.

The noise level depends on the type of ship, its speed and distance from the hydrophone, and varies with the speed of a passing ship relative to a measurement point. The spectrum is characterized by discrete components in a range below 200 Hz, generated by drive engines (engine noise) and propeller (rotational noise), as well as broadband cavitation noise, which decreases toward higher frequencies by – 6 dB/octave.

2. THE BLACK SEA MARINE WILDLIFE

At the Romanian Black Sea coast, due to the great diversity of substrata, and in accordance with the depth, there are some important biocoenoses.

Mytilus galloprovincialis (Lamarck, 1819) – the blue mussel or the Mediterranean mussel (length = 50-75 mm, height = 30-40 mm) is native to the Mediterranean coast and the Black and Adriatic Seas. *Mytilus galloprovincialis* is dark blue or brown to almost black. The two shells are equal and nearly quadrangular. The outside is black-violet colored; on one side the rim of the shell ends with a pointed and slightly bent umbo while the other side is rounded, although shell shape varies by region (Skolka, 2003).

From scientific point of view, the fishes from the Black Sea belong to the Phylum Chondrichthyes (the shark, the thornback ray and the common stingray) and to the Phylum Osteichthyes – great taxonomical unit that includes sturgeons and bony fishes. From the ecological point of view, there are pelagial fishes, pre-eminently plankton feeders, living in shoals and demersal, carnivorous fishes. Some species, especially the pelagial ones (sprat, anchovy, horse mackerel and Black Sea shad) have great economical importance. Most species of sturgeons from the Black Sea are considered endangered or critically endangered species (Bănărescu, 1964).

At present, in the Black Sea there are only three species of Mammals: two species of dolphins (*Tursiops tursiops* Montagu, 1892 and *Dephinus delphis* Linnaeus, 1758 – the common dolphin) and the bottlenose dolphin (*Phocena phocena* Linnaeus, 1758).

In order to observe how organisms react to the sound, the subjects must be selected between species easy to collect and to keep in experimental conditions.

As benthic species, we consider mussels (*Mytilus galloprovincialis*) and round goby (*Neogobius* (*Apollonia*) *melanostomus*) appropriate for the experimental purpose. They can be found on rocky bottom, in shallow waters. They are euryhaline and eurythermic species. *Mytilus galloprovincialis* is a filter feeder and the round goby eat mussels, so both of them can be easily kept in aquaria (Skolka, 2003).

Pelagial organisms – fishes (sprat and anchovy) are quite difficult to keep for experimental purpose in laboratory aquaria, but it is convenient to led the observations in cages (used for marine aquaculture), submerged in marine water.

Man made noise can affect the gonad’s development, the filtering rate of *Mytilus* and the feeding rate of the round goby. Equally, it can affect the behaviour (swimming speed and rhythm) of fishes. For all organisms, oxidative stress enzymes can be determined.

The histology, physiology and comportment of the above-mentioned organisms are well studied and referential data are available.

3. EXPERIMENTS AND RESULTS

The experiments were conducted under the international project RO-NO-MAR (Romanian-Norwegian-Maritime Project) conducted in partnership with Aalesund Knowledge Park (NCE-Maritime) and The University College of Aalesund (AAUC) (contract No. 2747321), between 2009 and 2011.

The group of professors from Naval Academy performed measurements of underwater noise in the Black Sea and in collaboration with a team from Ovidius University, a series of tests regarding the impact of noise on oysters and gobies were conducted.

In the RoNoMar project equipment from Bruel&Kjaer was used to conduct the underwater noise measurements:

- 3 hydrophones type 8106;
- 2 hydrophones type 8104;
- Power amplifier type 2713;
- Data acquisition system LAN XI;
- Laptop with PULSE 14 software;
- Cables;
- Calibrator type 4229.

Several measurements were carried out at the entrance of Constanta North Port on the 8th of May and the 24th of May in two positions (as shown in figure 1), in order to determine the noise level caused by the vessel traffic at that point. On the 8th of May (from 11.05 till 13.40) the traffic on the port entrance was light, mainly tugs with barges and pilot boats. On the 24th of May, there were several noise sources, represented by 4 vessels, assisted by several tugs and pilot boats.

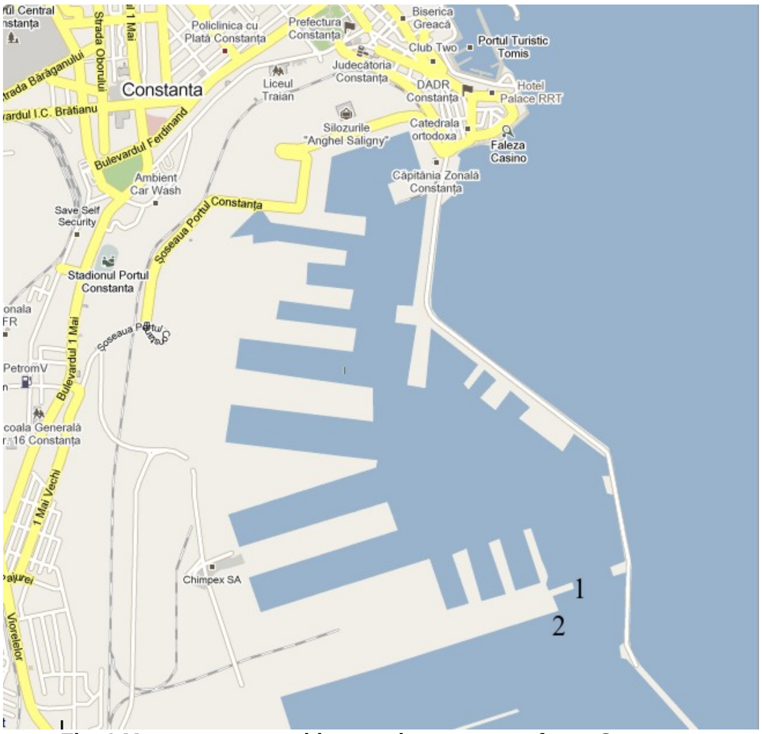

Fig. 1 Measurement positions at the entrance of port Constanta

The next figures present the underwater noise determined for each passing vessel.

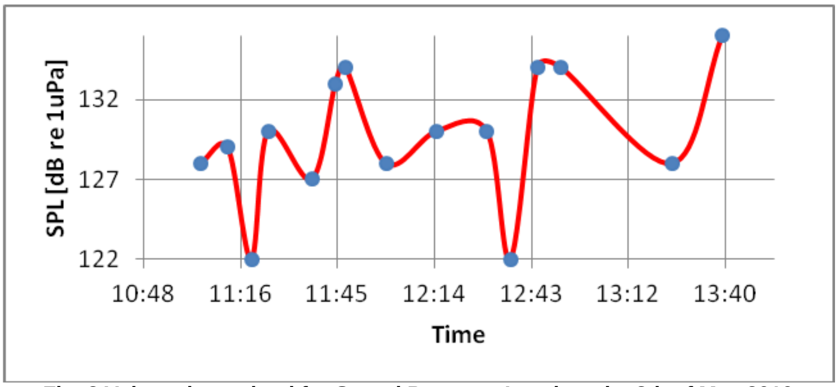

Fig. 2 Values determined for Sound Pressure Level on the 8th of May 2010

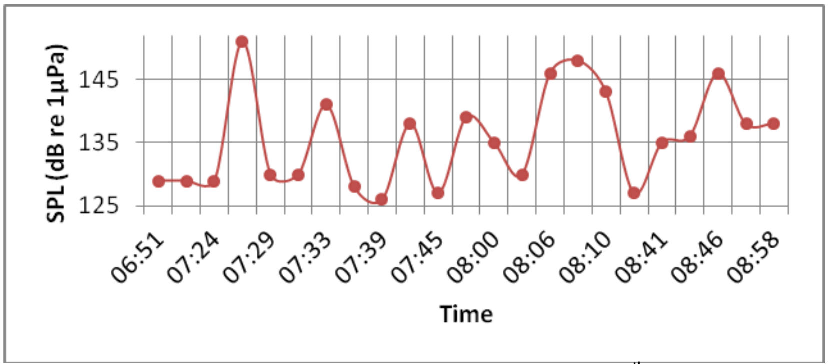

Fig. 3 Values determined for Sound Pressure Level on 24th of May 2010

Other underwater noise measurements were conducted on the west coast of the Black Sea between 14th and 26th of May 2010 on board of the *Mare Nigrum*, a research ship from the National Research Institute GeoEcoMar.

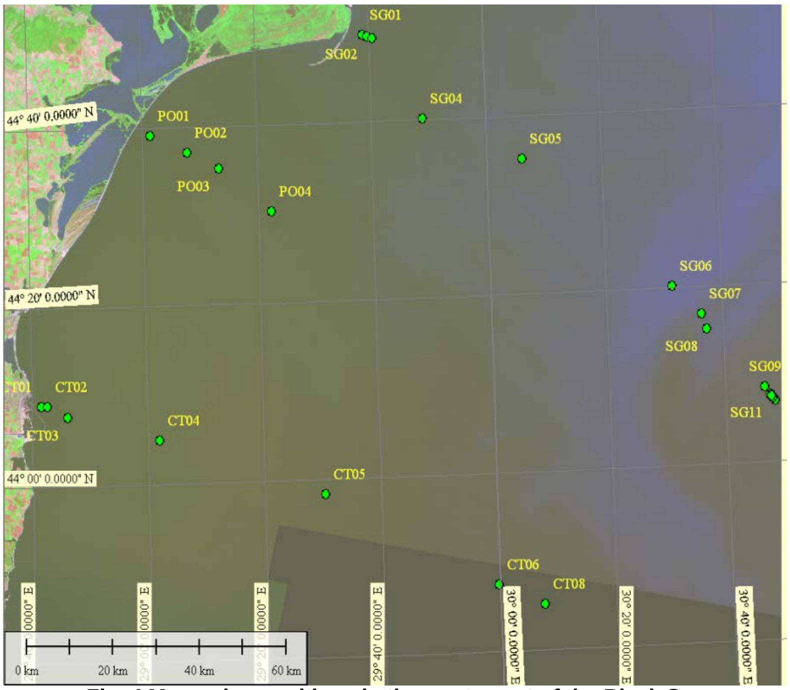

Fig. 4 Measuring positions in the west coast of the Black Sea

Measurements were conducted using three hydrophones in the same time deployed from the ship.

In this way we could record the acoustic signal on three depths simultaneously (figure 5). In order to minimize the effect of waves and current an array was constructed using a weight, a rope and a buoy.

The weight was tied onto the rope and the buoy at the other end; the cables and hydrophones were attached on the rope; the weight was about 15 kg and the buoy, bicone shape, was chosen to ensure that the hydrophones would not move horizontally, but in the same time they would not be pulled out of the water (calculus were done to determine the buoyancy of the entire system).

A second buoy, ball shape, is used to indicate the array position.

In the positions indicated in the map we conducted three types of recordings:

- first we measured the noise generated by the ship in the proximity of the ship (2 to 5 meters from the hull); these recordings were made in a variety of situations: measuring only the noise generated by the diesel generators, either generators and the main engines; we have the opportunity to record the activity of a multibeam sonar;

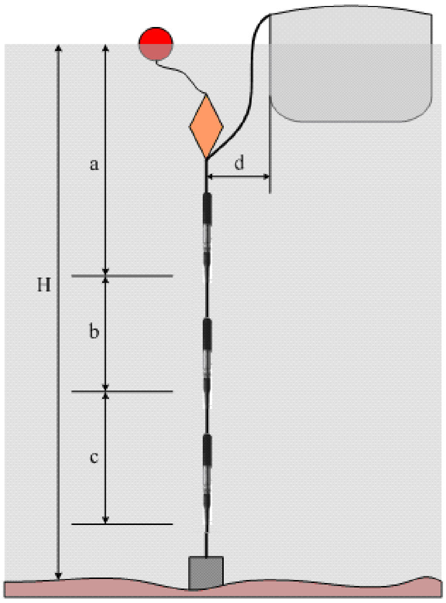

Fig. 5 Array used for sound recording

- second we measured the noise created by the ship’s machineries at distances of 1Nm and 1.5Nm from the ship; this was possible using the service boat. The equipment has autonomy of 4 hours which permitted us to make several recordings at different distances;

These recordings gave us information on sound propagation and acoustic signal attenuation.

- third we made measurements to determine the ambient noise level; these were made in open sea with no artificial noise source in presence.

The significant results from these measurements are synthesized in the next table.

Measuring point	*Underwater noise level (dB re 1μPa)*					
	Hydrophone 1		*Hydrophone 2*		*Hydrophone 3*	
3 m away from ship’s hull (turning on the main engines)	0 – 100 Hz	133	0 – 100 Hz	131	0 – 100 Hz	131
	0 – 200 Hz	136	0 – 200 Hz	132	0 – 200 Hz	132
3 m away from ship’s hull (5 minutes after the engines started)	0 – 100 Hz	145	0 – 100 Hz	144	0 – 100 Hz	142
	0 – 200 Hz	146	0 – 200 Hz	144	0 – 200 Hz	143
1 Nm away from the ship (1 diesel generator working onboard the ship)	0 – 100 Hz	101	0 – 100 Hz	101	0 – 100 Hz	101
	0 – 200 Hz	103	0 – 200 Hz	102	0 – 200 Hz	101
1.5 Nm away from the ship (1 diesel generator working onboard the ship)	0 – 100 Hz	101	0 – 100 Hz	101	0 – 100 Hz	98
	0 – 200 Hz	104	0 – 200 Hz	101	0 – 200 Hz	99
3 m away from ship’s hull (at the engines stop)	0 – 100 Hz	127	0 – 100 Hz	124	0 – 100 Hz	124
	0 – 200 Hz	127	0 – 200 Hz	125	0 – 200 Hz	125
3 m away from ship’s hull (1 diesel generator working onboard the ship)	0 – 100 Hz	124	0 – 100 Hz	118	0 – 100 Hz	122
	0 – 200 Hz	125	0 – 200 Hz	122	0 – 200 Hz	124

In another part of the project, oysters from Constanta harbor area were collected and they were the subject of monitoring and testing under captivity in small tanks. The oysters used in the experiment are a common type of oyster in the Romanian coastal region of the Black Sea. Professors from Ovidius University collected the oysters and prepared them for the experiment. Also, sea water was used in the tanks to replicate the natural conditions. Due to practical constraints, small glass tanks were used for the experiment. Of course, a lot of distortion of recorded noise is expected because of the boundary effects. Nevertheless, the goal was to prove that excessive noise can alter the internal structure of the oyster. In the figure below is represented the noise recorded in the tanks.

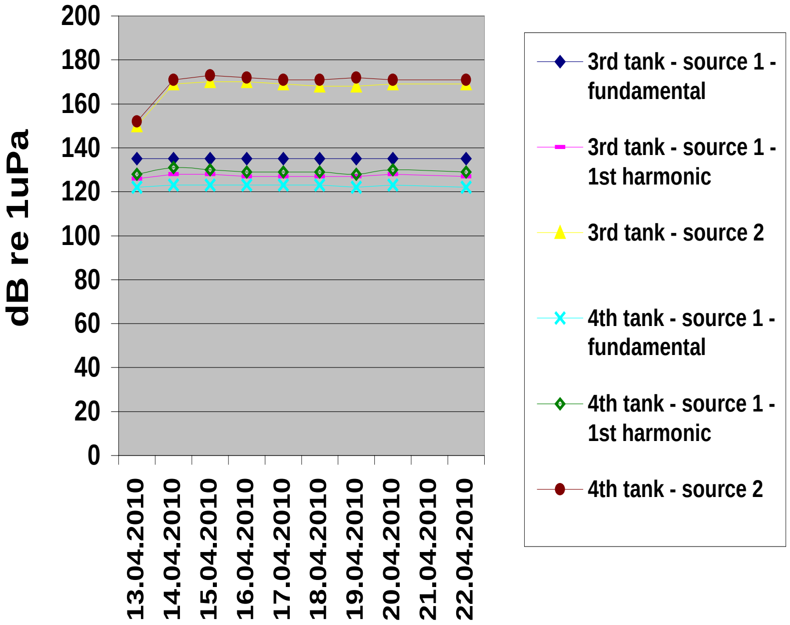

Fig. 6 Noise level in two tanks during oysters experiments

The second experiment involving species from the Black Sea was a study on the effect of antropogenic sound on gobies kept in cages. Healthy individuals of Round goby *Apollonia* (*Neogobius*) *melanostomus* Pallas 1814 were collected from the southern rocky shore of the Romanian littoral and transported in 100 l barrels with sea water at 16°C. The experiment took place in Constanta harbor, at the berth RoRo5 (Maritime Station area), where the ship «Noordkaap**»** was docked. There, three experimental cages were fasted on the ship board.

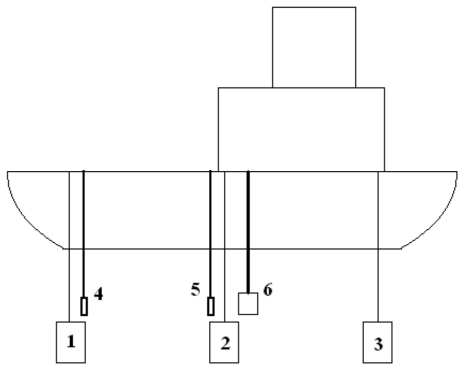

Fig. 7 Schematic of the display of cages (1, 2, 3), hydrophones (4, 5) and noise source (6)

A number of 30 individuals of Round goby were placed in each net cage. The cages were suspended in the water column, at 12 m depth, one meter above the sea floor. One cage, containing the control group (*CG*) was suspended at the starboard of another ship – a fire-fighter vessel («Pompier**»**), at about 200 m from the «Noordkaap**»** - the location of the three experimental groups of Round goby, directly affected by the noise. During the whole experimental period, also the test group – control group (*CG*) was affect by the ambient noise generated by the traffic in the harbour. The noise levels of the ambient noise are relatively constant, between 121 – 123 dB re 1µPa. The exposure to high levels of noise was made periodically, for 10 to 25 minutes and at 3 hours interval. During this exposure, the noise source emitted a noise level between 157 to 167 dB re 1µPa.

4. CONCLUSIONS

The measurement of underwater noise in shallow waters is not fully understood. The contribution of ship's noise to the background noise cannot be overlooked. The analysis (FFT, STFT, DWT) gives us qualitative information on the signals recorded in the Black Sea regarding the noise sources onboard ships (main engine, diesel generators etc.) and their contribution to the underwater noise. The achieved results enrich the data base over signal's shape and the determination of the time domain complementary numerical parameters.

The SPL recorded at the entrance of port Constanta varied from 135dB re 1µPa to 146dB re 1µPa. This represents a real increase of ambient underwater noise of approximately 45dB. High levels of noise were recorded, of course, in the range from 10 to 200Hz.

The ship traffic is not constant in time. There is no periodicity in the noise generated by the vessels entering and exiting the harbour. Also, ships are moving at approximately constant speed which means that ship's engines are running at constant RPM.

When the ships are closing to the hydrophone, they reach the CPA (Closest Point of Approach). In the range of the CPA the spectrograms present several peaks in the frequency band of 3 – 200Hz. These peaks represent different noise sources onboard ships: the main engine, diesel generators, pumps, propeller etc.

The processing method STFT is useful in identification of the shape signals which occur during ship operation. Furthermore, the spectrogram shapes calculated in the time-frequency domain are affected by the measurement equipment's power supply.

From the DWT analysis we can state that the energy is bigger at the engine stop than at start, and time distribution is very different.

Simple observations of the environment reveal that some species (like dolphins) in the coastal region of the Black Sea of Romania adapted somehow to the changes produced by human activities. On the other hand, intensive shipping traffic produced significant changes in fish population around the area of port Constanta. After the experiments on gobies, a few important conclusions can be drawn:

- the exposure to ambient noise has adverse effects on captive goby expressed by the values of biochemical indicators of the oxidative stress in liver tissue;
- after the exposure to various levels of noise, it was noticed the installation of oxidative stress after 72 hours, proved by the decrease of concentration of superoxide dismutase, catalase, reduced glutathione as a result of increased concentration of oxygen free radicals generated by stress; some captive fishes situated in the proximity of the noise source died after an exposure of 72 hour'

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