Recording Cuvier's beaked whales (*Ziphius cavirostris)* with a wideband towed array.

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ABSTRACT
In September 2005 CIBRA participated to a wide research campaign organized in the Ligurian Sea by NURC (NATO Undersea Research Center) to study Cuvier's beaked whales, characterize their habitat, and possibly remotely record their acoustic signals. The CIBRA team, onboard the Krill, a 12 meters long catamaran, surveyed the area off the Western Ligurian coast with an advanced Passive Acoustic Monitoring (PAM) equipment based on a high quality towed array connected to a wideband low-noise front-end to allow digital recording with nearly 90 kHz bandwidth. On September 25th, a few minutes after two sighted animals started their dive, high frequencies clicks with features matching the description based on WHOI's D-TAG (Johnson et al. 2005, Zimmer et al. 2005) were recorded.
This was the first recording of *Ziphius cavirostris* clicks ever made with a sub-surface towed array that exactly match D-TAG data. The result is relevant for setting up affordable and easy to use equipment to be used for mitigation operations in areas where the presence of Cuvier's beaked whales must be estimated and monitored.

INTRODUCTION
The ability to detect marine mammals in a specific area is a fundamental requirement for the correct implementation of mitigation procedures aimed at reducing the impact of high power acoustic sources during either civil and military operations. Passive acoustic monitoring is one of the tools to be used for this task, but animals, to be detectable, must emit acoustic signals whose time-frequency structure and repetition rate are known and detectable with the used equipment. Cuvier's beaked whale, a critical species when sonar operations are concerned, is difficult to detect; its acoustic features have been discovered recently by using sophisticated digital recording tags, but sub-surface detection devices have never been proven reliable till now.

METHODS
In late September 2005 CIBRA was in charge of the bioacoustic part of a wide NURC (NATO Undersea Research Center) research campaign (Zifio '05) in the Ligurian Sea to study Cuvier's beaked whales, characterize their habitat, and possibly remotely record their acoustic signals. Up to five different platforms worked at the same time, with different tasks. CIBRA team was onboard the Krill, a 12 meters long catamaran, with the CIBRA PAM equipment based on a high quality towed array, now improved with a wideband low-noise front-end to allow digital recording with nearly 90 kHz bandwidth (192 kHz sampling rate).

RESULTS
On September 25th, the Krill quietly approached the location where three Cuvier's beaked whales were sighted by another vessel. Close to the location of the last sighting, the team saw the blows of two animals, immediately before their dive. No other animals of any species were observed before and after this sighting. The catamaran was stopped, the engines turned off and the array sank to more than 40 meters but not in a vertical orientation due to strong drifting conditions. A few minutes after the animals started their dive, high frequencies click trains on the real-time spectrogram display were noticed (SeaProUltra, two channels, 96 kHz bandwidth). Later analyses on the recorded files showed click series with features matching the description given by recent literature based on D-TAG recording (Johnson et al. 2005, Zimmer et al. 2005), but never matched the description given by Frantzis (2002). Recorded clicks show energy between 16 and 60 kHz, with a spectrum centered on 40 kHz; click duration about 300 μs; average ICI 380 ms (range 370-415).
Frequency center, bandwidth, waveform, repetition intervals and amplitude variations related with head scanning movements indicate that the recording captured the emissions of two *Ziphius cavirostris*.
Worthy to note that the amplitude of the clicks is not constant but oscillating, as it could be expected by a directional source swimming and scanning the environment with left-right movements of the head. In such a case, the hydrophones get the maximum amplitude only when in the beam axis.

CONCLUSION
This result proves feasible the development of a passive acoustic detection system to be used for mitigation operations in areas where the presence of Cuvier's beaked whales must be estimated an monitored. To increase detection probability, other than improving bandwidth and sensitivity, along with lowering self-noise, it is required to tow the hydrophones as deep as possible. According to D-TAG data, Cuvier's beaked whales do vocalize at great depth, at high frequency and with a narrow emission beam. Only little energy spreads toward the sea surface and this is why so many attempts to record these animals were unsuccessful in the past.

ACKNOWLEDGEMENTS

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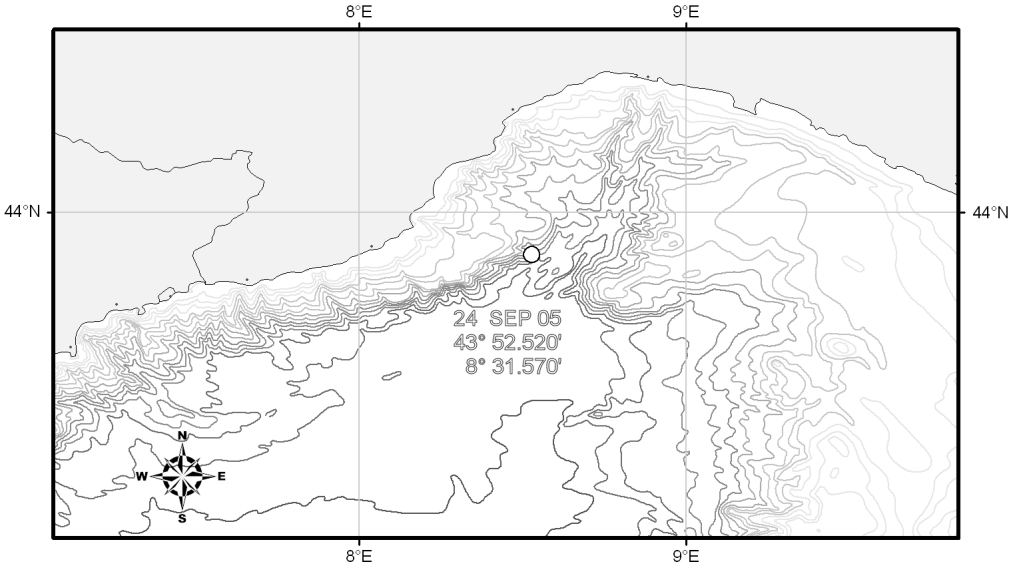

Fig. 1 – Map of the detection location (Ligurian Sea, Italy).

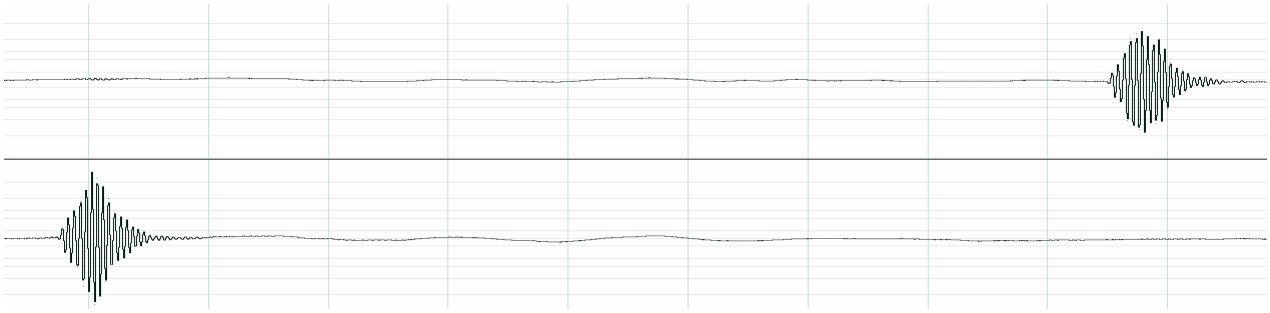

Fig. 2 – Waveform of a click received on the two hydrophones of the towed array. X-tic 500 µs.

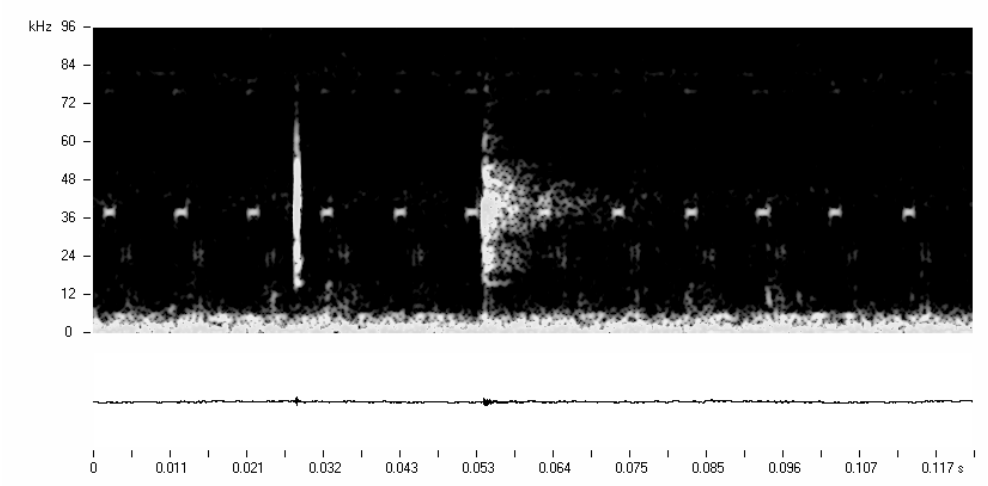

Fig. 3 – Spectrogram of a click and its echo.

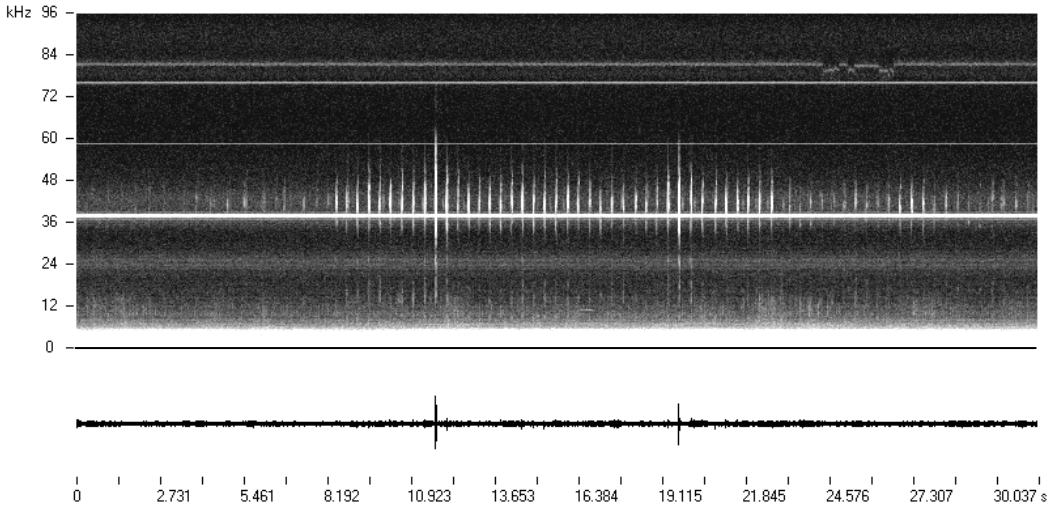

Fig. 4 - A 30 seconds spectrogram of the detection. The horizontal lines are due to electric interferences. Worthy to note that the amplitude of the clicks is not constant but oscillating, as it could be expected by a directional source swimming and scanning the environment with left-right movements of the head. The two loudest clicks were probably recorded when the hydrophone was in beam axis.