COMPARISON OF ACOUSTIC SIGNALS AMONG THREE ODONTOCETE SPECIES (*Grampus griseus*, *Physeter macrocephalus*, *Globicephala melas*) RECORDED IN A NATURAL ENVIRONMENT.

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Abstract:

The appearance of Risso's dolphin, pilot whale and sperm whale are very different each other and all the three species present striking contrast to the general notion of dolphin shape and form. Even their melons, that are believed to be sound projectors for echolocation, have peculiar anatomical structure in each of three species that differ significantly from the classic form of dolphin melon. It is possible, even if not yet demonstrated, that peculiar anatomical structure may create peculiar acoustic signals. Data were collected on board of StudioMare research vessel "Jean Gab", a 17.70 m wooden cutter equipped for underwater listening with towed hydrophones (system response 10 Hz, 20 kHz) and underwater vision (underwater Panasonic CCD Camera WV-KS152 anteriorly placed). Audio and video signals were synchronically recorded with a BETACAM support (BETACAM SP Sony). The audio signal is recorded also on an analogic support. All recording were kept in the water of Archipelago Pontino - Campano which has been the object of a long term study on cetaceans since 1991. Sperm whale recording concern a single individual encountered off from Ischia island. Risso's dolphin recording concern a school of approximately 20 individuals, dolphins appeared to be seasonally resident in Ischia waters based on photo-identification data collected between 1998-2000. Pilot whales recording concern a single stable pod of five individuals, whales have been photo identified and studied since 1995. The objective of this work is: (1) to present some features (spectrum and bandwidth, pulse duration, pulse repetition rate, pulse modulation) extracted by sequences of pulses emitted by each of three species in their habitat;(2) to compare these features among three species; (3) to make some comparison with the characteristic waveforms of bottlenose dolphin.

INTRODUCTION The appearances of Risso's dolphin, Pilot whale and Sperm whale are very different each other and all the three species present striking contrast to the general notion of dolphin shape and form. Even their melons, that are believed to be sound projector for echolocation, have peculiar anatomical structure in each of three species that differ significantly from the classic form of dolphin melon. It is possible, even if not yet demonstrated, that peculiar anatomical structure may create peculiar acoustic signals. The objective of this work is: (1) to present some features (spectrum and bandwidth, pulse duration, pulse repetition rate, pulse modulation) extracted by sequences of pulses emitted by each of three species in their habitat; (2) to compare these features among three species.

MATERIALS AND METHODS The observations were carried out on board of StudioMare research vessel "Jean Gab", a 17.70 m wooden cutter equipped for underwater listening with towed hydrophones (system response 10 Hz-20 kHz) and underwater vision (underwater Panasonic CCD Camera WV-KS152 previously placed). Audio and video signals are synchronically recorded with a BETACAM support (BETACAM SP Sony), that had a range-recording of 0/20 kHz; therefore the results about the clicks of Risso's dolphin (*Grampus griseus*) should be underestimated. The videos recorded were analysed by a Studio DC10 video bluster which allows to collect also single shots for further computer image analyses. The audio signal is recorded also on an analogic support.

The routes were chosen to optimise the sights and were determined daily on the basis of previous sightings, particular attention was paid to follow the bottom topography and depth profiles. No trip was performed in conditions greater than sea state 5 (Beaufort).
All recordings were kept in the waters of Archipelago Pontino-Campano which has been the object of a long term study on cetaceans since 1991. In such area from spring to autumn, in different periods, we have recorded almost regularly seven species of cetaceans: striped dolphin, *Stenella coeruleoalba*; bottlenose dolphin, *Tursiops truncatus*; common dolphin, *Delphinus delphis*; Risso's dolphin, *Grampus griseus*; long finned pilot whale, *Globicephala melas*; sperm whale, *Physeter macrocephalus* and fin whale, *Balaenoptera physalus* (Mussi *et al.*, 1998, 1999).
Sperm whale recording concerns a young (or a female) individual (12m long) encountered off from Ischia island in 3/8/00, the distance of the sighting point from the coast was 13.6 Km and the depth 850m.
Risso's dolphin concerns a school of approximately 20 individuals, they are seasonally resident in the coastal waters of Ischia, and have been photo identified and studied since 1998 (Miragliuolo, A. *et al.* In this vol.).
Pilot whales recording concerns a single stable pod of five individuals that are seasonally resident off of Ventotene island. All individuals have been photo identified and studied since 1995 (Mussi, B. *et al,* 1998, 2000).
The laboratory's analysis (Azzali *et al.*, 1999) was conducted in this way:

- the recorded signals were monitored with a H.P. digital oscilloscope 54520 A; every single signal was digitized on floppy disk;
- at a second time this digitized signals were processed using MATLAB m-file language to extract the statistic, time and frequency parameters of the single signals;
- using the statistical parameters, a matrix of the euclidean distances was calculated; the values in the matrix indicate the distance among the three species considered; the two nearest species (most similar) were combined to form one cluster, the third species formed a second cluster with one of precedent species;
- the clustering procedure was represented with a dendrogram.

RESULTS At a first time the three species was analysed separately.
Sperm whale (*Physeter macrocephalus)*
We found two type of signals (Fig. 1 A). The first type (sperm whale 1) presents a low rhythm (one or two pulses per second) and a broad spectrum (1200-3000 Hz) with peak at 2100 Hz. The second type (sperm whale 2) presents a rhythm 3-4 times higher with the frequency distributed between 0-900 Hz (peak frequency at 100 - 200 Hz).
Long finned pilot whale, *Globicephala melas*
The signals analyzed (Fig. 1 B) for this species present a frequency distribution between 0-2000 Hz with a peak frequency at 250 Hz; but there are other two peaks: at 400 Hz and at 750 Hz.
Risso's dolphin, *Grampus griseus*
The signals considered (Fig. 1 C) for this species have a frequency distribution between 0-2000 Hz with a peak frequency at 400 Hz.
SIMILARITY MATRIX
The structure of the above mentioned signals has been analysed using the method described by Azzali *et al.* (1998, 1999). The first type of sperm whale's click (low rhythm) is very distant from the signals emitted by the other two species (Table 1); the maximum dissimilarity has been found with Risso' dolphin signals. The second type of sperm whale's click (high rhythm) is very similar to the signals emitted by the other two species (Table 2) but again Risso's dolphin signals result the most dissimilar. For the both set of signals the structure of the dendogram is the same (see Fig. 2). It is possible that the

first type of sperm whale's signal represents an echolocation click, whereas the second type represents a vocalization signal similar to thouse emitted by the other two odontocetes.

CONLUSIONS

This study seems to indicate that there is some relation between the size of animals and their acoustic features; indeed the two largest animals (sperm whale and long finned pilot whale) have acoustic signals more similar between them than the Risso's dolphin..

Moreover, this investigation points out that sperm whale is able to emit at the same time and for a long period two signals with very different structure.

This study represents a preliminary work of a long term project, during which will be utilized recorders with a wide bandwidth to obtain date more reliable.

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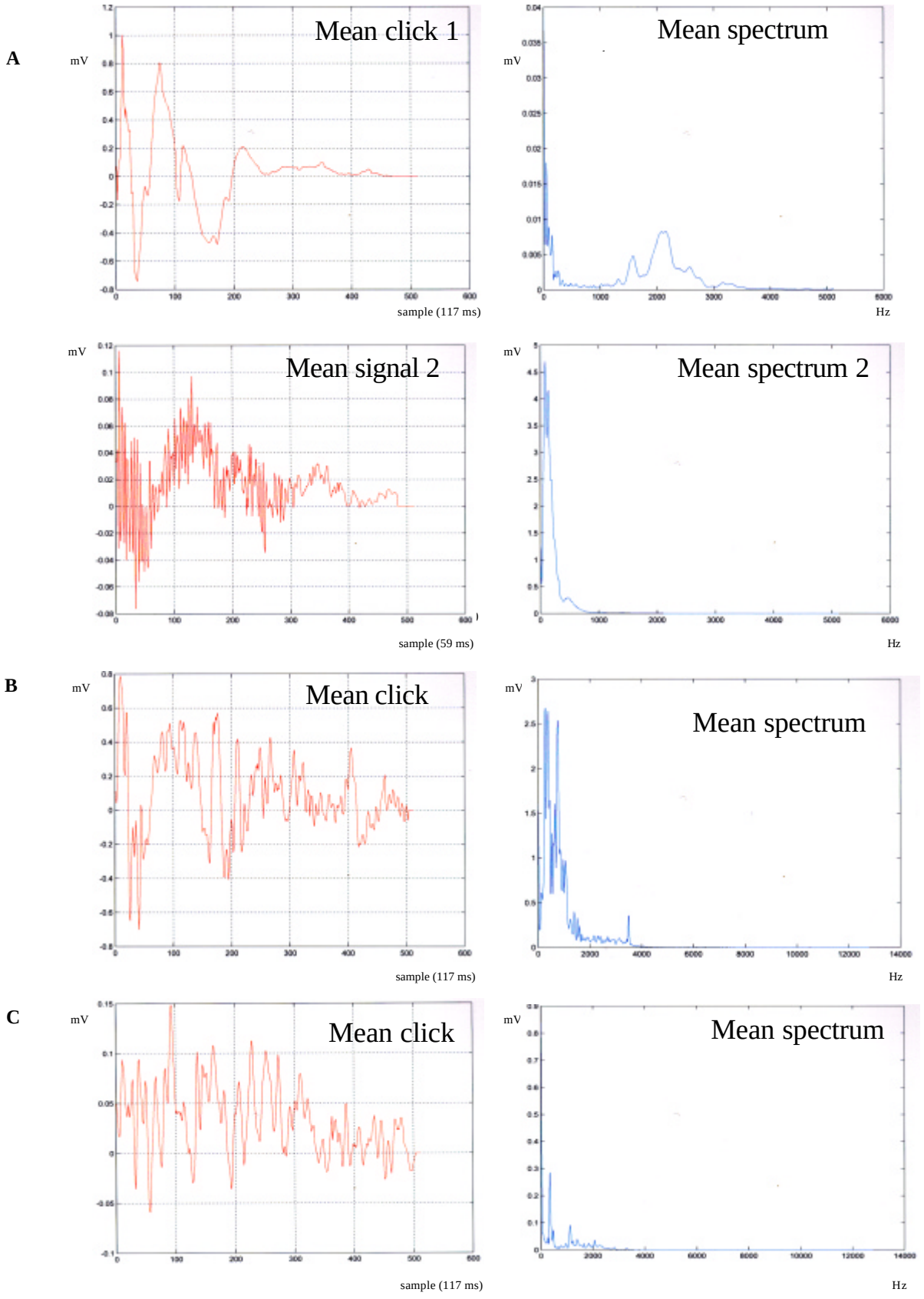

Fig. 1 - signal's mean waveform and mean spectrum of sperm whale (A), long finned pilot whale (B) and Risso's dolphin (C)

Table 1 - distance's matrix with first type of sperm whale's click

	SPERM WHALE 1	RISSO'S DOLPHIN	PILOT WHALE
SPERM WHALE 1	0	64.426	63.320
RISSO'S DOLPHIN		0	2.024
PILOT WHALE			0

Table 2 - distance's matrix with second type of sperm whale's click

	SPERM WHALE 2	RISSO'S DOLPHIN	PILOT WHALE
SPERM WHALE 2	0	2.870	1.817
RISSO'S DOLPHIN		0	2.024
PILOT WHALE			0

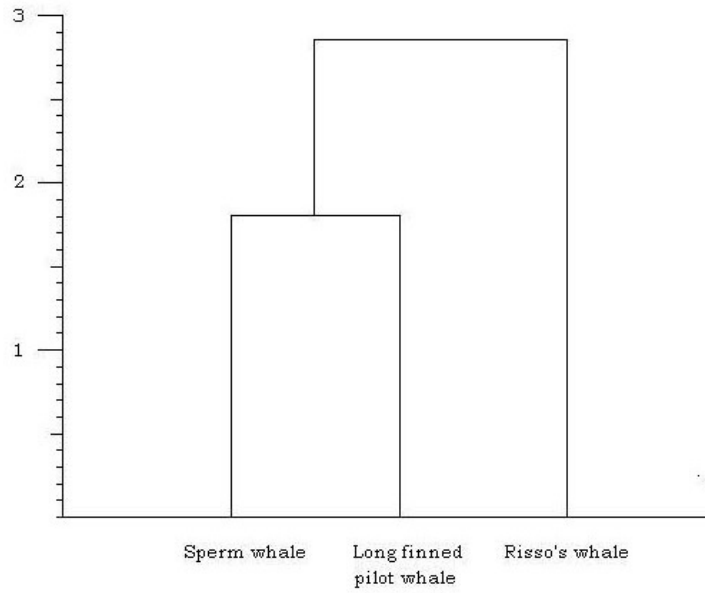

Fig. 2 - dendrogram; the sperm whale (*Physeter macrocephalus)* and the long finned pilot whale (*Globicephala melas*) have acoustic signals more similar between them than the Risso's dolphin (*Grampus griseus)* due to the considerable size of both these two species.