Acoustic observations for automatic size estimation of whales

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Abstract

The Physeter macrocephalus whale (PM) produces clicks of few milliseconds for echolocation, composed by a sequence of short pulses. The spacing of some pulses (called IPI) is a key parameter to assess the size (length) of the emitting whale. The IPI is usually estimated by auto-correlation, cepstrum or waveform averaging, but shows some variability to the whale orientation, and fails in the case of multiple emitting whales. To tackle these issues, we propose here an algorithm which allows to segregate, count precisely the whales, and estimate their size using only passive acoustics. Validation experiments are conducted on PELAGOS whale sanctuary recordings.

1. Introduction

The click multi-pulse structure is a consequence of their particular sound production system ([8, 7]) starting by an initial pulse generated in the nose, by the phonic lips, and following pulses generated by reflections inside the spermaceti organ; the inter-pulse interval (IPI), determines the time of the sound travelling twice the spermaceti organ. Using allometric rules, a nominal IPI assesses the size (length) of the whale [3, 5, 4].
Nevertheless, the orientation between the PM and the hydrophone, hardly known, has a strong influence on the click structure [6, 2, 8]. When the animal axis is not aligned with the recorder (the majority cases), some intermediate reflections are present in the recorded signal and mask the sequence of the pulses that carries the useful information [4]. This, explains why usually the IPI evaluation requires an experienced operator in order to select the right clicks and measure their IPI [5, 2].

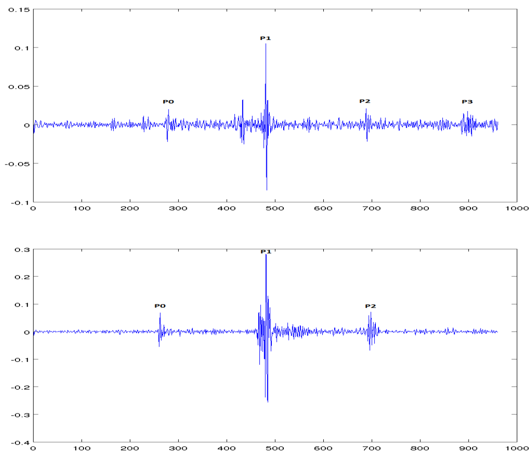

Figure 1. Two clicks from different whales emitting together in the same recordings the 26.01.2012 at 10h52. The pulses P_i are labeled after our algorithm. IPI=date(P2)-date(P1)=208 (top), =217 (Bottom). Abscissa in bin, FS=48kHz

Automatic or semiautomatic techniques to measure IPI have been investigated [5, 6, 4], based on waveform, autocorrelation, cesptral averaging, but they need single whale recording [2], because they fail when different IPIs (*i.e.* whales) are present into the same recording. Here we propose an algorithm which overcomes these issues, and thus determines the IPI of each emitting whales.

2. Materials and Methods

The National Park of Port-Cros (PNPC) is included into the sanctuary for marine mammals (PELAGOS). As PNPC is responsible for whale observing, we started a bioacoustic project (DECAV) conducted with the PNPC from May 2011 to October 2012, resulting

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into an effort of 26 days. These 77 recordings are 5 minutes each, mono-channel, using CR55 hydrophone at 30 meters depth, sampling frequency 48 kHz, 16 bits, localised by GPS.

The first step of our algorithm is a high pass filter (5 kHz cut-off) to avoid ship and environmental noise (*i.e* shrimp, etc). The second step is the click detection by selecting highest local maxima.

Finally, due to the multi intra-head reflections of the pulse, our algorithm computes the nominal IPI from a pulse selection among the seven highest pulses composing each click, and generating the recurrent IPIs. Then the mode(s) of the IPI distribution from a recording give(s) the IPI(s) of each whale recorded in it. If required, the IPI is transformed into a whale size by the Growcott's relation [4].

3. Results & Conclusion

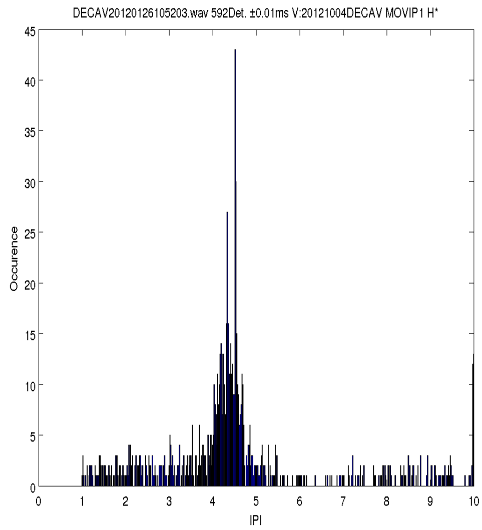
We have sum up all our results by date of recordings in the table 1.

Date	Seen/Heard	IPI(+-0.01ms)	Size(m)	Hours	Place
2011/05/06	0/2	4,88	11,88	11h57	Stoechades Canyon (Head)
2011/05/19	0/1	5,66	12,86	10h49	Port-Cros (4km South)
2011/06/07	0/0	-	-	-	-
2011/07/12	0/0	-	-	-	-
2011/07/28	0/0	-	-	-	-
2011/08/02	1/1	4,54	11,45	9h45	Levant (8km South-East)
2011/08/31	0/1	5,38	12.50	10h52	Porquerolles (7.5km South)
2011/09/16	0/0	-	-	-	-
2012/01/26	0/2	4,35 et 4,55	11,21 et 11,46	10h47	Porquerolles (9km South)
2012/03/16	0/0	-	-	-	-
2012/03/26	0/0	-	-	-	-
2012/05/04	0/1	-	-	-	Porquerolles (15km South-West)
2012/05/30	1/2	4,40 et 4,45	11,27 et 11,33	10h53 et 11h27	Stoechades Canyon
2012/06/06	0/1	-	-	-	Levant (3km East)
2012/06/07	0/0	-	-	-	-
2012/06/15	0/0	-	-	-	-
2012/06/28	0/0	-	-	-	-
2012/07/10	1/2	4,86	11,85	9h52	Cap Sicié
2012/07/23	0/0	-	-	-	-
2012/08/02	0/2	4,90 et 4,78	11,90 et 11,74	10h16	Levant (8km South-East)
2012/08/23	0/1	-	-	-	-
2012/09/09	0/0	-	-	-	-
2012/09/16	0/0	-	-	-	-
2012/09/17	1/3	4,6 et 4,66	11.52 et 11.60	14h04 et 14h09	Cassis South - Bec de l'aigle
2012/09/23	0/1	5,72	12.93	13h58	Cassis South - Bec de l'aigle
2012/10/06	1/2	4,44 et 5,62	11.32 et 12.80	17h23 et 17h56	Cap sicié

Table 1. Results by date for DECAV recordings.

Only 23% of the recorded whales during our DECAV project were seen, thus passive acoustic appears to be more consistent for studying this diving whale. We give (fig. 3) the probability of PM detection in the area according to our results, showing higher presence in large cayon.

The multi-whale case represents 5*2 PM, while we noted 6 cases of single PM. Thus, state of the art methods would have conducted to only 6 estimations of whale size, instead of 16 with our.



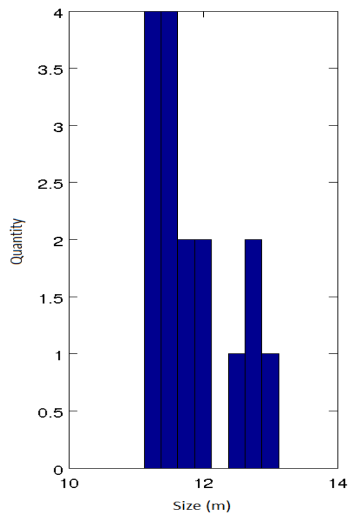


Figure 2. (Top) IPI distribution of the 5 minutes of the recording illustrated in fig 1 showing two pics, one for each present whale (IPI=208 vs. 217). (Bottom) Sizes distribution on the 16 analysed whales from 77 recordings.

The sizes distribution from our algorithm (fig. 3) shows two modes : the *A* mode between 11 to 12 meters, and *B* mode for longer whales. According to the sexual dimorphism [2], we assess that *A* concerns adult females, young females, young males ; and *B* only concerns adult males. Then we roughly assume in a first approximation that the mesured population was composed of 4 PM for each class.

No correlation between GPS localization and size is observed. This study demonstrates the interest of passive acoustics contrary to a visual observation (low detection rate, imprecize size estimation). Moreover this study provides evidences which helped us to finance (IUF, USTV and TPM) a sono-buoy (BOMBYX) for marine mammals monitoring in south of Port-Cros.

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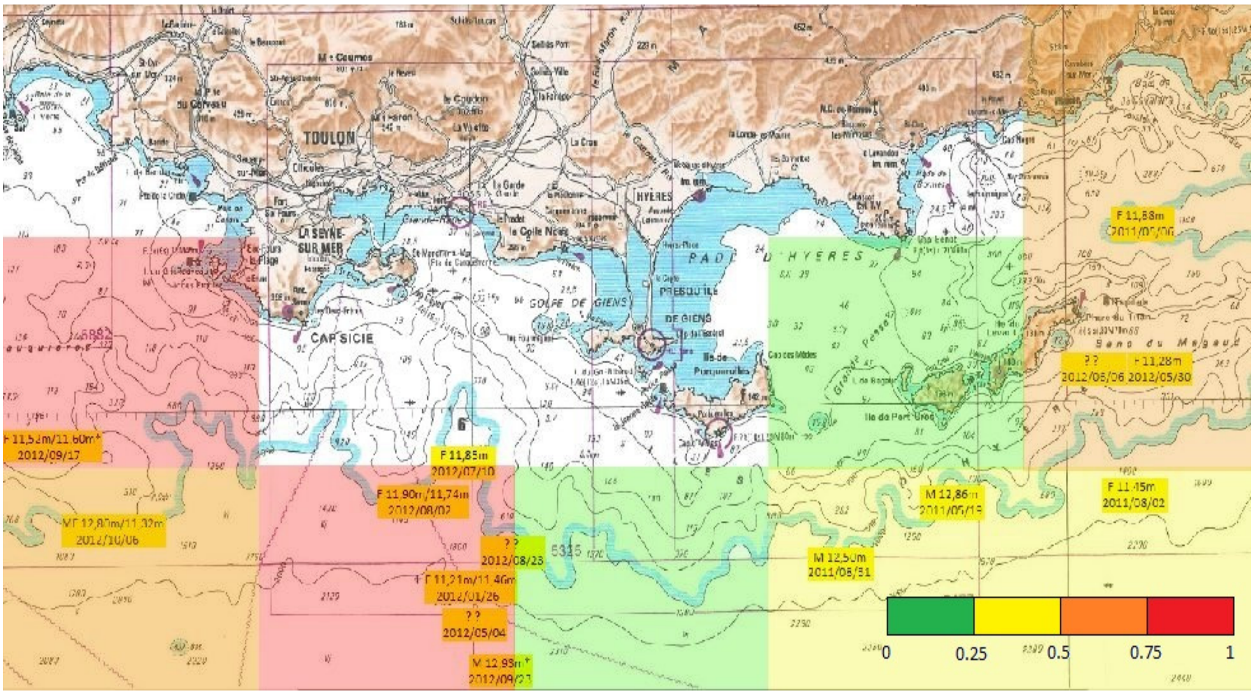

Figure 3. Probability of sperm whale detection. See [1] for details.