Acoustically derived growth rates of sperm whales (*Physeter macrocephalus*) around Ischia and Ventotene Islands (Italy): preliminary results

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INTRODUCTION

Measuring the size of animals and quantifying their growth are fundamental to answering many ecological questions.

The sperm whale (*Physeter macrocephalus*) is the largest odontocete cetacean existing today. This animal emits almost exclusively one type of sound called "click", used in different circumstances and for different functions, including communication and echolocation. Clicks are multiple pulses (3 or more) at frequencies ranging from 5 to over 25 kHz, with high sound pressure level (greater than 223 dB) and high directionality. The type of the arrangement, frequency, intensity and duration of the clicks may provide insights on behavior, while the range of the pulses in the same click (Inter Pulse Interval - IPI) seems to be related to the size of the emitting animal.

Acoustic methods for estimate the size of sperm whales by measuring the IPI of their clicks have been applied in some different studies; however, very few data on the growth rate of sperm whale individuals in the Mediterranean Sea is available to date. We recently started to use to recordings collected around Ischia and Ventotene islands (Tyrrhenian Sea), Italy, in order to estimate the size and the growth of sperm whales that have been photo-identified and recorded at least two times in two different years between 2004 and 2012.

Here, we report the preliminary analysis on two individuals – one of unknown sex named PMODO.003 'Norma' (Figure 1) and one immature male named PMODO.015 'Brunone' (Figure 2) – over a three year period (2004, 2005 and 2006). The entire dataset counts 60 photo-identified individuals, 20 of which resighted in different years.

NORMA

Fig. 1

METHODS

We analyzed a total of 22:36:07 of recordings, 11:07:36 related to 'Norma' e 11:28:31 related to 'Brunone'.

The acoustic parameters used to characterize the sounds were:

1) Intensity of the acoustic wave (in dB), *i.e.* the amount of energy (P) which passes through, in a second, the unit of surface area (S).

2) Rhythm. A number of different parameters were taken into account to assess the rhythms, including:

- IPI - Inter Pulse Interval, *i.e.* the time intervals between pulses within a click.
- Cepstrum, i.e. according to the theory of the signals, the result of the "Fourier Transform" (FFT) applied to the spectrum (in dB) of a signal.
- ICI (Inter Click Interval), *i.e.* the time interval between two clicks.

Different types of acoustic signals emitted by the two sperm whales were classified according to ICI (usual click, creak, codas, etc.). Sequences of usual clicks were then selected to measure IPIs. Each click within a sequence was identified, numbered sequentially and saved in a separate file. A limited number of clicks (n=15 per year for each whale, *i.e.* 45 per whale), out of a total of 283.932 clicks for both whales, was sorted out through a simple random sampling. Selected clicks were initially 'clean' from background noises and then checked for their suitability for the IPI analysis by the means of Audacity 2.0.1 software. Finally, IPIs were manually derived through the 'cross correlation' function in Rainbow Click 4.06 and body length estimated using different polynomial formulas:

$TL=4,833+(1,453*IPI)-(0,001*IPI^2)$ (Gordon, 1991) (TL formula 1)

$TL=9,75-(0,521*SL)+(0,068*SL^2)+(0,0057*SL^3)$ (Gordon, 1991) (TL formula 2)

$TL=(1,258*IPI)+5,736$ (Growcott, 2011) (TL formula 3)

Where TL= total length in meters, IPI=Inter Pulse Interval in milliseconds, SL=spermaceti length in meters.

BRUNONE

Fig. 2

RESULTS

Table 1 and 2 report IPI values, spermaceti length and total body length estimates for Norma and Brunone, respectively.

Unconcernedly from the applied formula, both whales showed:

- Similar estimated length in 2004 and different ones in 2006 (Figure 3 and 4);
- An increasing derived IPI over time (Figure 5) as well as a growth of the spermaceti organ (Figure 6)
- A quicker growth rate between 2005 – 2006 than 2004 – 2005 (Table 3), with the immature male Brunone seeming to grow up significantly faster than the other whale Norma.

To proceed with the analysis of the other individuals of the dataset, we will use automatic methods to generate IPIs in order to match results with our manually derived preliminary finding.

Tab. 1

Year	Whale	Selected clicks	IPI	Spermaceti lenght (m)	Whale lenght (m) Formula 1 (Gordon, 1991)	Whale lenght (m) Formula 2 (Gordon, 1991)	Whale lenght (m) Formula 3 (Growcott, 2011)
2004	Norma	5210	3,99	2,85	10,137	10,615	10,755
2004	Norma	13129	3,99	2,85	10,137	10,615	10,755
2004	Norma	13831	3,86	2,85	10,137	10,427	10,592
2004	Norma	15391	3,69	2,76	10,028	10,181	10,378
2004	Norma	15957	3,88	2,64	9,897	10,456	10,617
2004	Norma	17225	3,38	2,77	10,040	9,733	9,988
2004	Norma	18356	3,47	2,42	9,695	9,863	10,101
2004	Norma	20053	4,17	2,48	9,746	10,875	10,982
2004	Norma	26840	3,86	2,98	10,310	10,427	10,592
2004	Norma	34193	3,58	2,76	10,028	10,022	10,240
2004	Norma	34408	4,08	2,98	10,310	10,745	10,869
2004	Norma	39284	4,08	2,76	10,028	10,745	10,869
2004	Norma	42677	3,58	2,76	10,028	10,022	10,240
2004	Norma	44726	3,45	2,76	10,028	9,834	10,076
2004	Norma	50596	3,86	2,56	9,818	10,427	10,592
2004 AVERAGE±SD			**3,79±0,25**	**2,75±0,16**	**10,01±0,18**	**10,33±0,37**	**10,51±0,32**
2005	Norma	478	4,08	2,92	10,228	10,745	10,869
2005	Norma	3853	4,08	2,92	10,228	10,745	10,869
2005	Norma	12037	4,31	3,08	10,456	11,077	11,158
2005	Norma	16661	3,79	2,71	9,972	10,326	10,504
2005	Norma	22347	3,99	2,85	10,137	10,615	10,755
2005	Norma	22639	3,74	2,67	9,929	10,253	10,441
2005	Norma	29761	3,97	2,84	10,124	10,586	10,730
2005	Norma	36218	3,85	2,75	10,017	10,412	10,579
2005	Norma	37759	3,65	2,61	9,867	10,123	10,328
2005	Norma	38238	4,08	2,92	10,228	10,745	10,869
2005	Norma	41612	4,08	2,92	10,228	10,745	10,869
2005	Norma	51047	4,29	3,06	10,426	11,048	11,133
2005	Norma	55191	3,61	2,58	9,837	10,065	10,277
2005	Norma	58274	3,9	2,79	10,064	10,484	10,642
2005	Norma	70895	3,88	2,77	10,040	10,456	10,617
2005 AVERAGE±SD			**3,95±0,21**	**2,83±0,15**	**10,12±0,19**	**10,56±0,30**	**10,71±0,26**
2006	Norma	2068	4,08	2,92	10,228	10,745	10,869
2006	Norma	2153	4,08	2,92	10,228	10,745	10,869
2006	Norma	4171	4,22	3,02	10,367	10,947	11,045
2006	Norma	6413	4,4	3,15	10,565	11,207	11,271
2006	Norma	8121	4,08	2,92	10,228	10,745	10,869
2006	Norma	11569	4,08	2,92	10,228	10,745	10,869
2006	Norma	11793	4,08	2,92	10,228	10,745	10,869
2006	Norma	13138	4,08	2,92	10,228	10,745	10,869
2006	Norma	13950	4,31	3,08	10,456	11,077	11,158
2006	Norma	14707	4,31	3,08	10,456	11,077	11,158
2006	Norma	15604	4,24	3,03	10,381	10,976	11,070
2006	Norma	16276	4,08	2,92	10,228	10,745	10,869
2006	Norma	16331	4,4	3,15	10,565	11,207	11,271
2006	Norma	16779	3,89	2,78	10,052	10,470	10,630
2006	Norma	18573	4,13	2,95	10,268	10,817	10,932
2006 AVERAGE±SD			**4,16±0,14**	**2,98±0,10**	**10,31±0,14**	**10,87±0,21**	**10,97±0,18**

Tab. 2

Year	Whale	Selected clicks	IPI	Spermaceti lenght (m)	Whale lenght (m) Formula 1 (Gordon, 1991)	Whale lenght (m) Formula 2 (Gordon, 1991)	Whale lenght (m) Formula 3 (Growcott, 2011)
2004	Brunone	931	3,88	2,77	10,040	10,456	10,617
2004	Brunone	1458	3,70	2,64	9,897	10,195	10,391
2004	Brunone	3564	3,72	2,66	9,918	10,224	10,416
2004	Brunone	3673	3,90	2,79	10,064	10,484	10,642
2004	Brunone	3806	3,87	2,77	10,040	10,441	10,604
2004	Brunone	4375	3,72	2,66	9,918	10,224	10,416
2004	Brunone	4551	3,87	2,77	10,040	10,441	10,604
2004	Brunone	5846	3,88	2,77	10,040	10,456	10,617
2004	Brunone	5913	3,88	2,77	10,040	10,456	10,617
2004	Brunone	7426	3,88	2,77	10,040	10,456	10,617
2004	Brunone	9115	3,72	2,66	9,918	10,224	10,416
2004	Brunone	10870	3,90	2,79	10,064	10,484	10,642
2004	Brunone	11638	3,90	2,79	10,064	10,484	10,642
2004	Brunone	14841	3,88	2,77	10,040	10,456	10,617
2004	Brunone	15960	3,85	2,75	10,017	10,412	10,579
2004 AVERAGE±SD			**3,84±0,08**	**2,74±0,05**	**10,01±0,08**	**10,39±0,11**	**10,56±0,10**
2005	Brunone	1098	4,20	3,00	10,338	10,918	11,020
2005	Brunone	2134	3,86	2,76	10,028	10,427	10,592
2005	Brunone	2381	4,01	2,87	10,162	10,643	10,781
2005	Brunone	2458	4,08	2,92	10,228	10,745	10,869
2005	Brunone	2876	4,04	2,89	10,188	10,687	10,818
2005	Brunone	3029	4,01	2,87	10,162	10,643	10,781
2005	Brunone	4512	4,08	2,92	10,228	10,745	10,869
2005	Brunone	5177	3,88	2,77	10,040	10,456	10,617
2005	Brunone	5671	3,88	2,77	10,040	10,456	10,617
2005	Brunone	8344	4,17	2,98	10,310	10,875	10,982
2005	Brunone	9580	3,99	2,85	10,137	10,615	10,755
2005	Brunone	9656	4,08	2,91	10,214	10,745	10,869
2005	Brunone	9827	4,04	2,89	10,188	10,687	10,818
2005	Brunone	10568	3,88	2,77	10,040	10,456	10,617
2005	Brunone	11480	4,13	2,95	10,268	10,817	10,932
2005 AVERAGE±SD			**4,02±0,11**	**2,87±0,08**	**10,17±0,10**	**10,66±0,16**	**10,80±0,14**
2006	Brunone	10220	4,39	3,14	10,549	11,192	11,259
2006	Brunone	24299	4,38	3,13	10,533	11,178	11,246
2006	Brunone	30895	4,17	2,98	10,310	10,875	10,982
2006	Brunone	61399	4,35	3,11	10,502	11,135	11,208
2006	Brunone	66821	4,35	3,11	10,502	11,135	11,208
2006	Brunone	76207	4,12	2,95	10,268	10,802	10,919
2006	Brunone	78110	4,17	2,98	10,310	10,875	10,982
2006	Brunone	79283	4,31	3,08	10,456	11,077	11,158
2006	Brunone	94535	4,35	3,11	10,502	11,135	11,208
2006	Brunone	95424	4,35	3,11	10,502	11,135	11,208
2006	Brunone	99228	4,33	3,1	10,486	11,106	11,183
2006	Brunone	102748	4,33	3,1	10,486	11,106	11,183
2006	Brunone	107441	4,26	3,05	10,411	11,005	11,095
2006	Brunone	109059	4,11	2,94	10,255	10,788	10,906
2006	Brunone	109503	4,33	3,1	10,486	11,106	11,183
2006 AVERAGE±SD			**4,29±0,10**	**3,07±0,07**	**10,44±0,10**	**11,04±0,14**	**10,13±0,12**

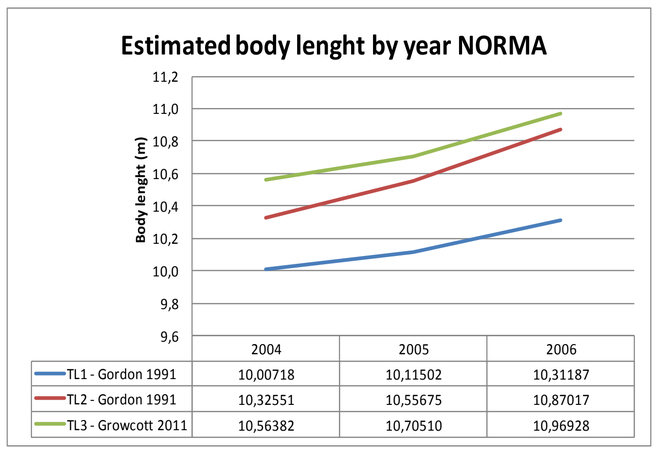

Fig. 3

Tab. 3

YEAR	NORMA			BRUNONE		
	TL Formula 1	TL Formula 2	TL Formula 3	TL Formula 1	TL Formula 2	TL Formula 3
2004-2005	10,77 cm	23,12 cm	14,13 cm	15,60 cm	26,01 cm	22,64 cm
2005-2006	19,70 cm	31,30 cm	26,42 cm	26,90 cm	39,01 cm	33,97 cm
TOT (2004-2006)	30,47 cm	54,42 cm	40,55 cm	42,50 cm	65,02 cm	56,61 cm
Growth rate	**0,10**	**0,18**	**0,13**	**0,14**	**0,21**	**0,19**

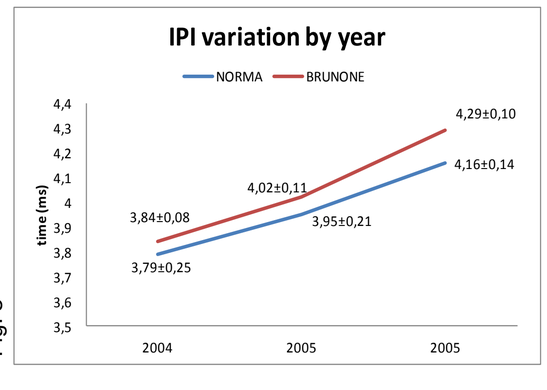

Fig. 5

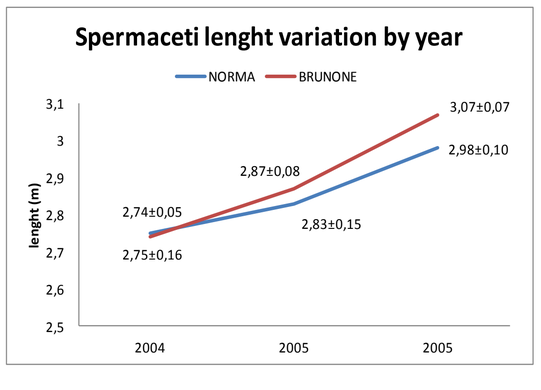

Fig. 6

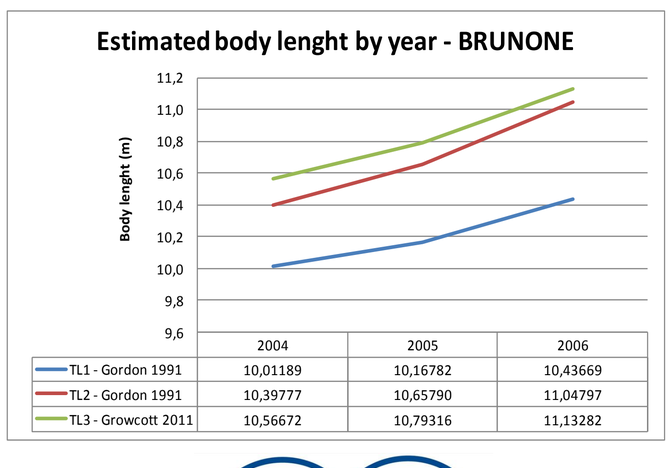

Fig. 4

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