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PRELIMINARY ANALYSIS OF CJM TARGET STRENGTH

Francois Gerlotto – Mariano Gutierrez

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Francois Gerlotto[1] and Mariano Gutierrez[2]

[1]IREA, Montpellier, France
[2] Universidad Nacional Federico Villareal, Lima, Peru

INTRODUCTION

Abundance estimates using underwater fisheries acoustics is basically obtained applying echo-integration methods. The principle of echo-integration consists in integrating and summing all the fish echoes received along transects. Assuming the statistical scheme of the survey design is satisfactory, the abundance is obtained by transforming the total echo in number of fish of a given individual weights by dividing the total echo by the individual echo, then multiply the number of fish by the mean weight of the fish. The value of this individual echo represents the key and the most critical point in the method, because any error on the measurement of this index of individual echo will directly affect the total biomass. This index is represented in decibel units by the Target Strength. Therefore knowing the real value of TS for a species is a priority.

METHOD

The biomass estimate (for the simple case of a single species) is:

$$B = W \, . \, S_A / (1852^2 \, . \, 4\pi \, . \, 10^{TS/10}) \quad \text{in g.m}^{-2}$$

where

B: total biomass
S_A : total backscattering coefficient (total echo)
TS: target strength of fish

This specific value of backscattering coefficient of a fish depends on its geometry and physical reflectivity. It is represented ion decibel units by the Target Strength (TS), which is_the logarithmic representation of $\sigma_{bs.}$

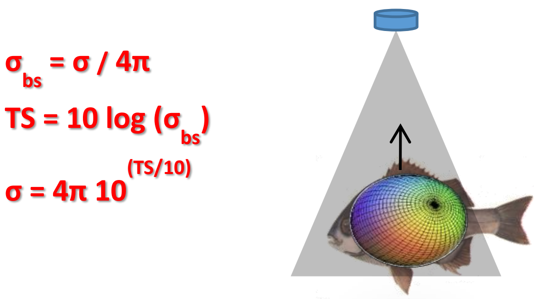

Figure 1. Backscattering properties of a fish

The TS is a decibel transformation of the backscattering coefficient σ_{bs} of a target. The backscattering coefficient characteristics σ_{bs} of the fish is usually assumed as represented by the surface of the backscattering cross section (perpendicular to the beam axis).

The practical measurement of the TS is obtained through:

$$\mathbf{ts = I_r/I_i} \qquad \text{or in dB:} \qquad \mathbf{TS = 10 \log (I_r/I_i)}$$

where

I_i: intensity of incident wave
I_r: intensity of reflected wave

Foote (1987; 1997) proposed a standard equation for the TS, based on the assumption that the echo of a fish is proportional to the backscattering cross section, which is assimilated to a surface, i.e. proportional to the square length L^2 (or 20.log L in decibel units). This standard TS equation (named equation b_{20}) was adopted by the Fisheries Acoustics community:

$$TS = 20 \log L + b$$

Each Institutes performed experiments for measuring the fish target strength. Some of these results have been published (see bibliographical list below). We give as an example in table 1 the list of TS adopted by IMARPE for the main resources inside Peru's jurisdictional zone.

Table 1. TS equations for the main species used by IMARPE for abundance estimates.

Especie	Ecuación TS	Rango	Fecha
Krill	TS_{120} = 20 Log L – 92.7	20 a 50 mm	1998
Anchoveta	TS_{120} = 20 Log L - 77,5	Moda 13.5 cm	1997
	TS_{38} = 20 Log L – 78.9	10-16 cm	1998
	TS_{120} = 20 log L – 76.25	10-13 cm	1998
	TS_{120} = 20 Log L – 78.5	11.5 a 14.5 cm	1999
	TS_{38} = 20 Log L – 77.35	13.5 a 16 cm	2001
	TS_{38}= 20 Log T – 81.2	5.5 a 10.5 cm	2000
	TS_{120} = 20 Log L – 82,2	5.5 a 9.5 cm	2000
	TS_{120} = 20 Log L – 81.8	6 a 8.5 cm	1999
	TS_{38} = 29.15 Log L – 88.98	5.5 a 18 cm	2002
	TS_{120} = 20 Log L – 77.95	11 a 13 cm	2001
	TS_{120} = 33.38 Log L – 92.93	5 a 18 cm	2002
	TS_{120} = 30.25 Log L – 89.35	5 a 18 cm	2003
Merluza	TS_{38} = 20 Log L – 67.6		1979-1999
	TS_{120} = 20 Log L – 65.1		1979-1999
	TS_{38} = 20 Log L – 65.05	21 a 30 cm	2001
Calamar Gigante	TS_{38} = 20 Log L – 87.2	12 a 24 cm manto	2000
	TS_{120} = 12.57 Log L – 72.85	13 a 28 cm manto	2002
	TS_{120} = 20 Log L – 83.5	19 a 28 cm manto	2001
	TS_{120} = 20 Log L – 81.20	14 a 21 cm manto	2001
	TS_{120} = 20 Log L – 82.65	15 a 25 cm manto	2001
	TS_{120} = 20 Log L – 77.40	13 a 16 cm manto	2001
Bregmaceros sp	TS_{120} = 20 Log L – 80.25	5.5 a 8 cm	1999
Pez cinta	TS_{120} = 20 Log L – 70.95	29 a 42 cm	1999

Vinciguerria	TS_{120} = 20 Log L – 83.29	4 a 6.5 cm	1999
	TS_{38} = 18.3 Log L – 81.06	4 a 8 cm	2002
	TS_{38} = 20 Log L – 82.60	5 a 8 cm	2001
Samasa	TS_{120} = 20 Log L – 86.57	10 a 14.5 cm	1999
	TS_{120} = 20 Log L – 74.60	12 a 15.5	2001
Caballa	TS_{120} = 20 Log L – 83.09	10 a 20 cm	1999
	TS_{38} = 20 Log L – 70.95	26-30 cm	1998
	TS_{120} = 20 Log L – 70.8	26-30 cm	1998
	TS_{120} = 51.91 Log L – 119.27	10 a 30 cm	2002
Pez cinta	TS = 20 Log L – 71.41	29 a 42 cm	1999
Vinciguerria	TS = 20 Log L – 82.04	3.5 a 6.5 cm	1999
Sardina	TS_{120} = 20 Log L – 74.1	12-20 cm	1998
Jurel (Jack Mackerel CJM)	TS_{38} = 20 Log L – 68.15	36-40 cm	1998
Múnida	TS_{120} = 40.68 Log L – 114.42	10 a 30 mm	2002
	TS_{120} = 20 Log L – 91.90	10 a 20 mm	2001

The definition and calculation of TS show clearly that there is a risk to obtain different results, which can dramatically transform the abundance estimates. We must keep in mind that these values are in dB, and that a 3 dB difference represent a factor 2 in arithmetic units, which would eventually affect the total biomass with the same factor. For instance, a TS calculated at -45 dB should represent a fish two times bigger than a fish with a TS calculated as -48 dB. Therefore it is essential to get good values of TS, and to produce an agreed common value or set of values in order to make the biomasses calculated by the different laboratories compatible.

RESULTS

A good example of such variability is given by Peña (2008) comparing the TS results from several experiments (fig. 2). Although in this particular figure the TS for the CJM show a good consistency, it is likely due to the small number of experiments.

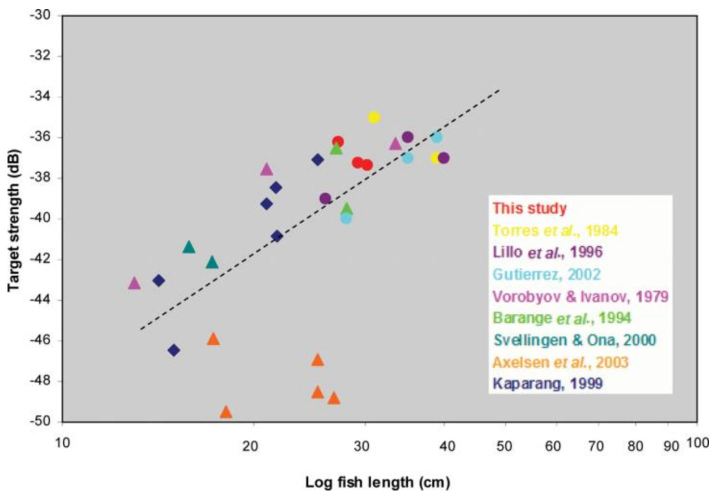

Figure 2. Target-strength values of Trachurus spp. available in the literature. Dots, *T. symmetricus murphyi*; triangles, *T. t. capensis*; diamonds, *T. japonicus*. The colours correspond to the references detailed in the figure. The dotted line represents the general relation for physoclists (TS ¼ 20 log (L) 268), according to Foote (1987). From Peña, 2008

For some other species, the figure shows that some inter-experiment differences for a fish with the same length can be above 10 dB (i.e. the biomass would be affected by a factor 10^1).

To give a very preliminary image of the magnitude of the question, we give here a few values of the equation [TS=20logL+B] from the literature (table 2; a more complete table is in construction).

Table 2. Values of CJM target strength from the literature

TS = 20 log L - 68.9	(Lillo et al 1998)
TS = 20 log L - 74.9	(Peña and Foote, 2008)
TS = 20 log L - 71.1	(Peña and Foote, 2008)
TS = 20.11 log L – 68.67	(Cordova et al. 1998; Cordova, 2008)
TS = 20 log L – 71.9	(value adopted by IMARPE from 1992 to 1998*)
TS = 20 Log L - 68.1	(value adopted by IMARPE since 1998)
TS = 20 Log L – 66	(Peña, 2008)
TS = 20 Log L – 67	(Torres et al. 1984)
TS = 20 Log L – 68	(Gutiérrez, 2002)

* Value calculated from the bibliography and especially Cordova 1998; Simmonds and MacLennan 2006)

A measurement was made in Peru in 1998 at 38 kHz (Gutierrez 2002), giving b_{20} intercept of the TS-Size regression as -68.15 dB. However all the calculations of CJM biomass in Peru have been made using Lillo et al (1995[1]) equation, where the b_{20} intercept is -68.91 dB. (Gutiérrez et al., 2016).

It is interesting to note the important difference between results by Peña (2008) and Peña and Foote (2008) with the other results (table 2). Gutiérrez et al (2016) give some comments on this situation: " In that study, the fish used for modelling were collected during in situ TS measurements of Chilean jack mackerel off Chile during 2003 (Peña, 2008[2]). As the range in mean lengths of the used three catches was so limited, only a single-parameter regression analysis was performed, namely TS = 20 log L +b_{20}, where TS is the mean in situ TS and L the mean length in centimetres. The value of the coefficient and intercept b_{20} was -66 dB, a value different from the obtained by Peña & Foote, in which b_{20} varied between -74.9 and -72.1 dB. Some reasons were accounted to explain such a difference (using the -72.1 dB value would represent a biomass 2 times higher than previous estimations) and a conclusion was made on testing other technological approaches such as multifrequency."

We may note also that some other works used another TS function, where TS represents a value per kilo. We give here as an example the equation calculated by Robotham and Castillo (2009):

$$TS = -32.5\ dB.kg^{-1}$$

We must also keep in mind that TS equations are given for particular frequencies. The most common frequency used by most of the research vessels are 38 and 120 kHz. It is therefore important to know what frequencies the experiments are performed with.

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[1] Lillo S, J Cordova, A. Paillaman.(1995). Target Strength measurements of hake and jack mackerel. ICES Journal of Marine Science, 53: 267-271.

[2] Peña, H. 2008. In situ target-strength measurements of Chilean jack mackerel (Trachurus symmetricus murphyi) collected with a scientific echosounder installed on a fishing vessel. ICES Journal of Marine Science, 65: 594–604.

For instance, Peña (2008) gave some examples of TS for different *Trachurus* species and different frequencies that are of interest (table 3)

Table 3. Values of b_{20} for available references for *Trachurus spp* (from Peña, 2008)

Table 5. Values of b_{20} from all available references for *Trachurus* spp.

References	b20	Frequency (kHz)	Species
Mukai *et al.* (1993)	−64	25	*T. japonicus*
Vorobyov and Ivanov (1981)	−65	20	*T. t. capensis*
Svellingen and Ona (1999)	−66	38	*T. t. capensis*
This study	−66	38	*T. symmetricus murphyi*
Kaparang (1999)	−67	70	*T. japonicus*
Barange and Hampton (1994)	−67	38	*T. t. capensis*
Torres *et al.* (1984)	−67	38	*T. symmetricus murphyi*
Lillo *et al.* (1996)	−68	38	*T. symmetricus murphyi*
Mukai *et al.* (1993)	−68	100	*T. japonicus*
Foote (1987)	−68	38	Physoclists
Gutierrez (2002)	−68	38	*T. symmetricus murphyi*
Misund *et al.* (1997)	−73	38	*T. trachurus*
Axelsen *et al.* (2003)	−75	38	*T. t. capensis*

RESEARCH PROJECT

It is important when several countries are sharing a common data base to get agreement on the TS equations to select. This is typically the case inside SPRFMO where at least 4 countries (Chile, Peru, EU, and Russia) are performing acoustic estimates. Therefore there is need to a workshop for establishing the state-of-the-art, defining the common equations already existing, and preparing common experiments in order to obtain reference TS values.

This has been recommended by the Scientific Committee in its 4th meeting in Port Vila in 2015, and the SPRFMO Task Group on Fisheries Acoustics was committed to organize this workshop. It was foreseen in the first semester of 2016, but due to the agendas of the scientists and the surveys at sea, it could not be organized prior to November, 2016. The program is given in annex. The workshop will be held from 7th to 11th November, in Lima, co-organized by IREA and IMARPE and sponsored by SNP.

Prior to the workshop, a small group of scientists is in charge of gathering most of the available information and produce a small document completing the present one, with the list of existing TS equations, their origins, their methodology, the frequencies, etc.

These results will be submitted to the SPRFMO Scientific Committee.

Provisional bibliography for Target Strength of *Trachurus* species.

(Some articles are referring to other *Trachurus* species than *T. murphyi*, but it seems interesting to compare these results with those obtained on CJM)

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