In-situ measurements of the individual acoustic backscatter of European anchovy (Engraulis encrasicolus) and sardine (Sardina Pilchardus), with concurrent optical identification.

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Abstract

The lack of specific Target Strength (TS) values for European anchovy (Engraulis encrasicolus) and sardine (Sardina Pilchardus) in the literature has been pointed out by the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX. The need for specific small pelagics TS measurements conducted in controlled environments was recognized by the group, to further investigate the adequacy of TS length equation used to derive fish stock estimates for clupeids in European waters. TS is a stochastic variable which largely varies in the wild, in response to changes in physical (tilt angle, depth) or biological (physiology) single fish attributes. The first requirement to make sound TS measurement is to accurately identify of the species comprising fish targets. Fish target identification is usually carried out by fishing. The comparison between fishing and acoustic data may be biased by the large differences in sampling volume and selectivity between acoustic and fishing devices. Optical systems can improve target identification, by providing images of the fish simultaneously insonified by the echosounder. We used Ifremer's towed body 'EROC', fitted with an optical-acoustic system, to conduct in-situ TS measurements of Biscay anchovy and sardine, with concurrent optical identification. Its combination with an "open" pelagic trawl termed "ENROL" allowed for the recording of small pelagic fish TS, while controlling for the prominent factors known to influence fish TS distribution: species, length and tilt angle. Repeating EROC/ENROL-based TS measurements on monospecific schools should then allow for the definition of accurate TS~length equations for near horizontal small European pelagic fish species.

Introduction

The lack of specific Target Strength (TS) values for European anchovy (*Engraulis encrasicolus*) and sardine (*Sardina Pilchardus*) in the literature has been pointed out by the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (ICES 2008). The need for specific small pelagics TS measurements conducted in controlled environments was recognized by the group, to further investigate the adequacy of TS length equation used to derive fish stock estimates for clupeids in European waters (ICES 2008).

We present here a methodology developed to measure the TS of small pelagic in their natural environment, with near-synoptic identification. The methodology combines pelagic fishing conducted by a research vessel and acoustics and video observations made by the Ifremer's Remotely Operated Towed Vehicle (ROTV) EROC.

Materials and Methods

ROV EROC has originally been designed by Ifremer's Research and Technological Development Department for in-situ trawl observation purposes. It is towed behind the vessel at the end of a 1000 m cable fitted with optic fibre. It can be moved in real time in the vertical and horizontal planes thanks to 4 Magnus effect rotors. Its positive buoyancy housing allows for deployments as deep as 300 m, at a nominal speed of 3 knots (min/max speed: 2/4 knots). It is enclosed in a protective cage that ensures safe deployment and retrieval through the ramp of stern trawlers. The ROV EROC is equipped with a pressure sensor and a black and white, high definition, pan and tilt camera, whose images are displayed in real time for the pilot to locate and manoeuvre the ROV. The camera outputs are recorded in real time by a DVD recorder. A Simrad deep water 200 kHz splitbeam ER60 echosounder (nominal beam angle: 7°) was added to the system.

The EROC was deployed onboard Ifremer's RV Thalassa during the PELGAS survey from May, 27th to June, 6th 2011 in the Bay of Biscay. The EROC was first deployed at low speed (2 knots) in the Gironde zone, in an area with high density of pure anchovy schools, in an attempt to measure anchovy TS inside or around schools.

The codend of Thalassa's pelagic trawl (2 doors, headline: 57 m, foot rope: 52 m) was removed and the extremity of the net was fitted with a metallic cylindric tunnel called the “ENROL”, turning it into an"open trawl" (Figure 1). The idea was to canalise fish through the trawl and to record TS of fish exiting the ENROL. The methodology can be summarized as follow: i) shoot the open trawl equipped with ENROL, ii) deploy EROC, iii) find the open trawl using acoustics at the surface, iv) position EROC above (~5 m) ENROL with the camera, v) record TS, vi) bring EROC closer to the trawl to identify and observe fish. This methodology was tried an area near the Landes coast.

TS were extracted using parameters presented in Table 1. The Movies+ TS track procedure was applied on single echoes data to retain only targets observed on several successive pings.

Results

A total of 12 EROC dives were performed, including 8 EROC/ENROL dives (>32 hours). The average total dive duration was 3 hours, including 1-2 hours of TS recording.

No TS were recorded around or in schools observed at low speed in the Gironde area, because the schools were too dense (Figure 2). After some trials, the EROC/ENROL combination proved to be efficient for recording in-situ TS of pelagic fish from 5 to 90 m depth.

A total of 124, 225 and 25 TS tracks were recorded during 3 dives. Species composition and size distribution of fish observed during these dives were inferred from: i) direct video observations, and ii) measurements of fish gilled in the trawl during EROC/ENROL dives. The first two dives were made amidst a mixture of small pelagic species whereas the last one allowed for the observation of pure schools of 20.5 cm sardines (Table 2).

TS distributions were multimodal in the multispecies case, and bimodal in the sardine area (Figure 3). TS distributions were recorded in areas and depth layers where no fish marks were present. This "background TS noise" was represented together with fish distributions recorded during EROC/ENROL experiments

(Figure 3).

Striking behavioural traits were observed during EROC/ENROL experiments. All fish species tended to swim upcurrent, toward the mouth of the trawl, even if they already escaped through the trawl through the open codend. Most fish kept swimming upcurrent until exhaustion, some escaped through the mesh. When fish reached exhaustion, they were washed out toward the codend.

Small pelagic fish showed very strong school fidelity, sometimes swimming outside the trawl alongside with their conspecifics inside the trawl. All small pelagic fish species inside and outside the trawl showed a strong attraction to light, leading sometimes to escapement, when the EROC lights were switched on at close range.

Discussion

Multimodal TS distributions observed in the the multispecies case probably originates from the combination of the TS distributions of the different species/size class observed in the catches and on video footages. In the sardine area, one can assume that the bimodal track distribution results from differences in the fish tilt angle.

In fact, variations of fish TS according to tilt angle can be theoretically investigated using Kirchoff-ray-mode (KRM) approximation from a detailed swimbladder shape (Clay and Horne 1994)(Jech and Horne 2002). Outputs of such a model simulating the acoustic backscatter of a 20cm sardine swimbladder are shown in Figure 4. The model outputs suggest that variations in the fish tilt angle can produce TS variations of the same order of magnitude as those observed in the TS distributions recorded in the sardine area.

According to these modelling results, the first TS mode could have been produced by near-horizontal sardines, yielding a mean TS value of -50dB. This value is in good agreement with Foote's (1987) TS~length (L in cm) equation for physostomous fish: TS=20*log10(L)-71.2 (Foote 1987). Further, the second TS mode could have been produced by sardine swimming up or down with high or low tilt angles, yielding lower TS values (-57.5 dB).

Fish tilt angle distribution can be assessed using either the video or acoustic data collected by the EROC. On one hand, videos of fish escaping the trawl can be recorded by stabilizing the EROC on the side of the ENROL, with the camera looking sidewards. This allows for the visual assessment of escaping fish tilt angle distribution. On the other hand, fish tilt angle distributions can be acoustically inferred from the fish depth variations recorded during TS tracks. Using in-situ fish tilt angle distributions as inputs in KRM TS models, one can compute theoretical TS distributions for each EROC dive, and compare them to in-situ ones. This should allow for the selection of the in-situ TS mode that was more likely produced by near horizontal fish. Assuming that fish are on average near horizontal at the scale of an acoustic cruise, one could then use these values to derive accurate TS~length equations for near horizontal fish.

In a nutshell, the EROC/ENROL methodology allows for the in-situ recording of small pelagic fish TS, while controlling for the prominent factors known to influence fish TS distribution: species, length and tilt angle. Repeating EROC/ENROL-based TS measurements on monospecific schools should then allow for the definition of accurate TS~length equations for near horizontal small European pelagic fish species.

Acknowledgments: we thank the Thalassa crew for their invaluable assistance in designing and building the ENROL open trawl.

References

Clay, C S, and J K Horne. 1994. “Acoustic models of fish: the Atlantic cod (Gadus morhua).” *J. Acoust. Soc. Am.* 96: 1661-1668.

Foote, K G. 1987. “Fish target strengths for use in echo integrator surveys.” *J. Acoust. Soc. Am* 82 (3): 981-987.

ICES. 2008. “Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG).” *ICES CM* 2008/LRC:17: 183.

Jech, J M, and J K Horne. 2002. “Three-dimensional visualization of fish morphometry and acoustic backscatter.” *Acoust. Res. Lett. Online* 3: 35-40.

Tables

Table 1.

Parameter	Value
Pulse length	0.128 ms
Min. threshold	-60 dB
Min-Max echolength	[0.8 – 1.8]
Maximum Gain Compensation	6 dB
Max phase deviation	8

Table 2

Station	Species	Total catch	PoidsMoy	Mean length (cm)	% total catch
P0557	Engraulis encrasicolus	2.01	19.00	141.00	6%
P0557	Sardina pilchardus	5.57	77.00	212.64	16%
P0557	Scomber japonicus	4.10	273.00	294.67	12%
P0557	Scomber scombrus	1.34	112.00	235.00	4%
P0557	Trachurus trachurus	22.14	326.00	168.53	63%
P0557	TOTAL	35.16			
P0559	Engraulis encrasicolus	2.86	19.00	138.83	15%
P0559	Mola mola	6.36	6360.00	490.00	33%
P0559	Sardina pilchardus	2.94	73.00	204.63	15%
P0559	Scomber japonicus	0.22	108.00	230.00	1%
P0559	Scomber scombrus	0.34	67.00	170.00	2%
P0559	Squid	0.02	20.00	0.00	0%
P0559	Trachurus trachurus	6.48	41.00	165.00	34%
P0559	TOTAL	19.21			

Figures

Figure 1a – ENROL building

Figure 1b – Engin Non léthal Remorqué d'Observation par chaLutage: ENROL.

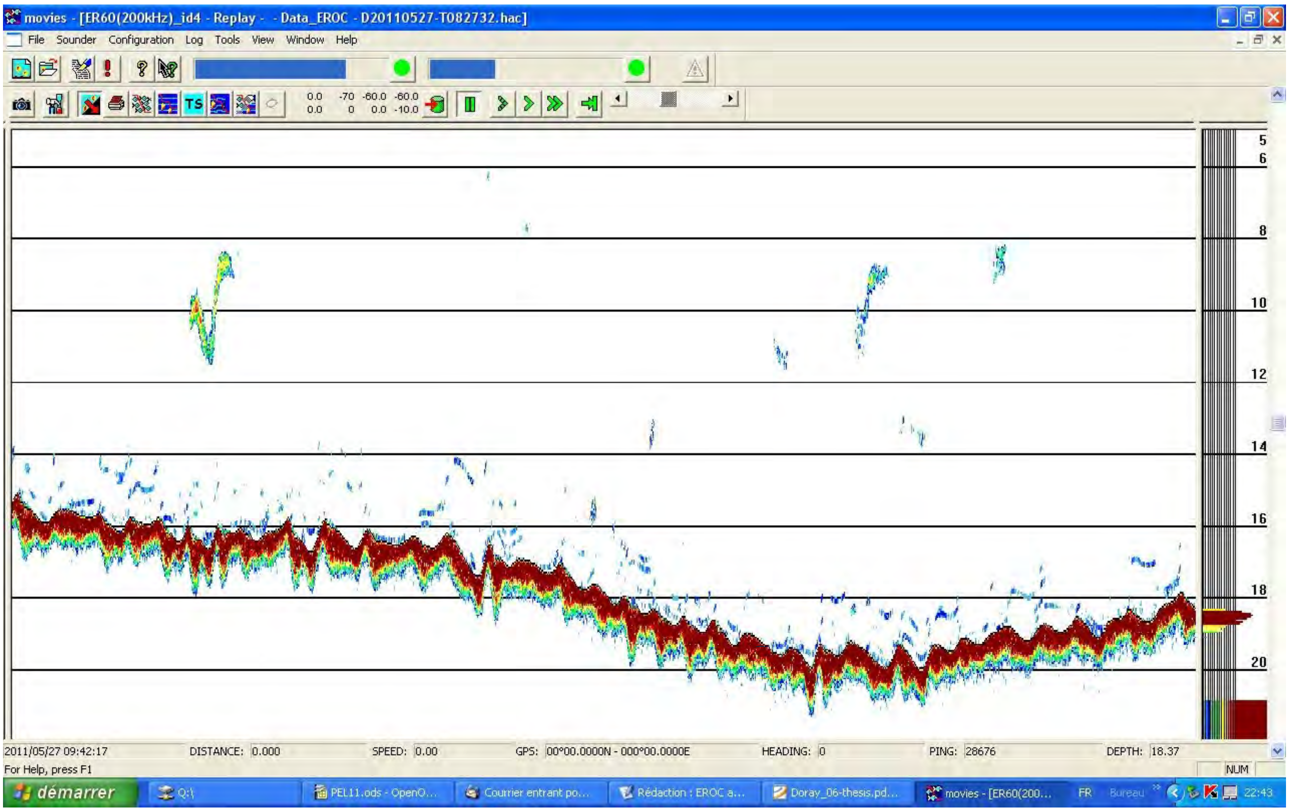

Figure 2 – 200kHz echogram showing anchovy schools observed at low speed by ROV EROC (27/05/11, Gironde area)

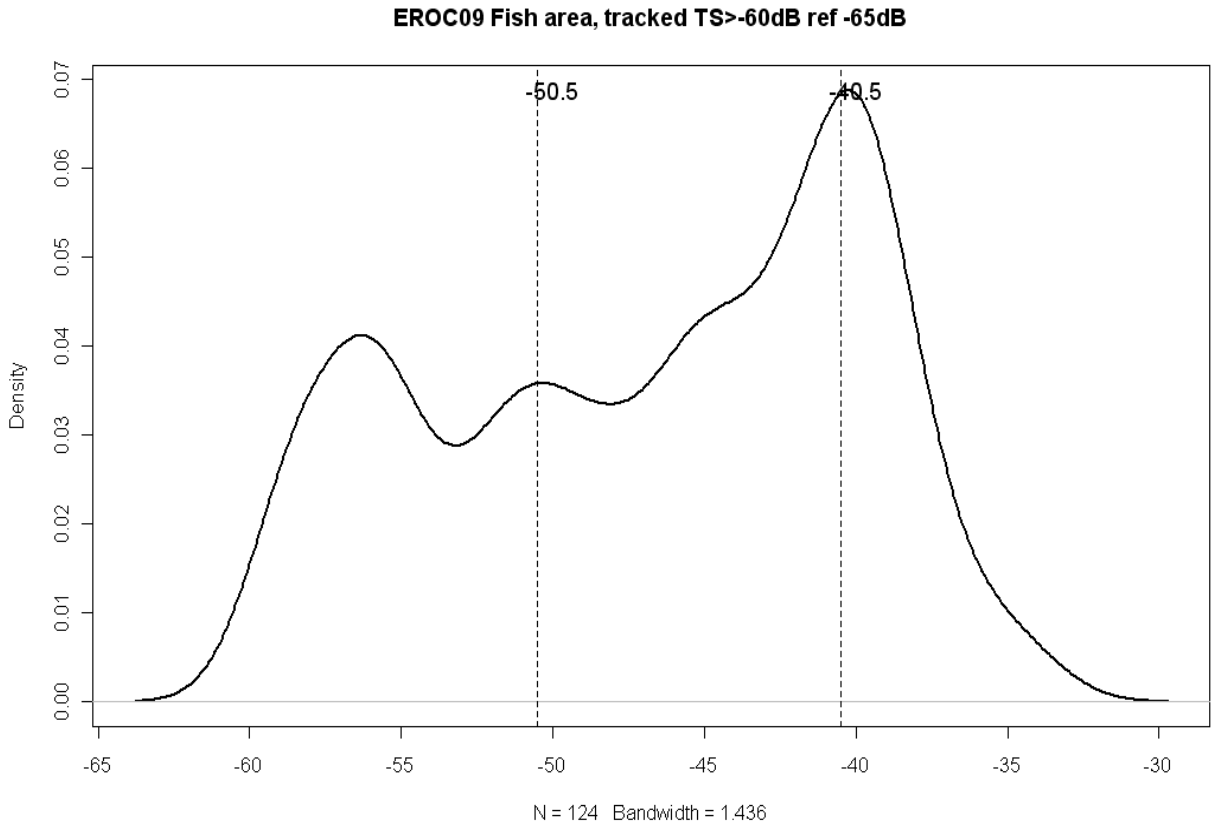

Figure 3a. Mean TS distribution of tracked fish in the mixed species area #1a

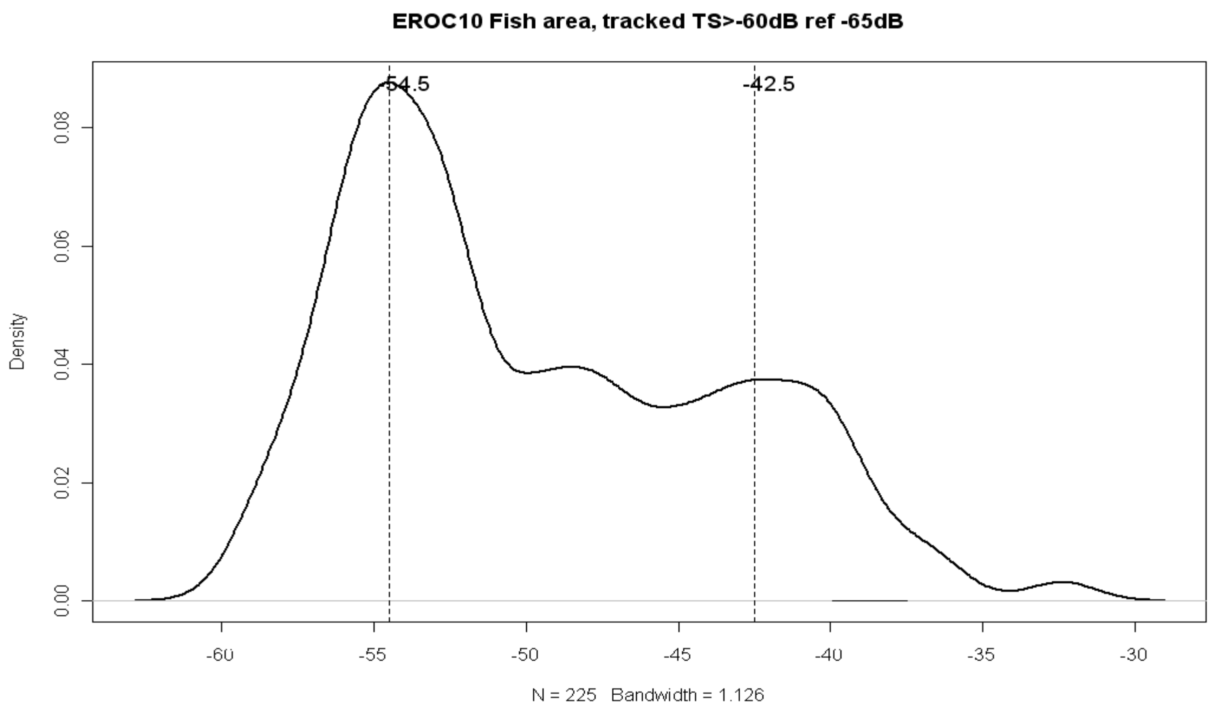

Figure 3b. Mean TS distribution of tracked fish in the mixed species area #2

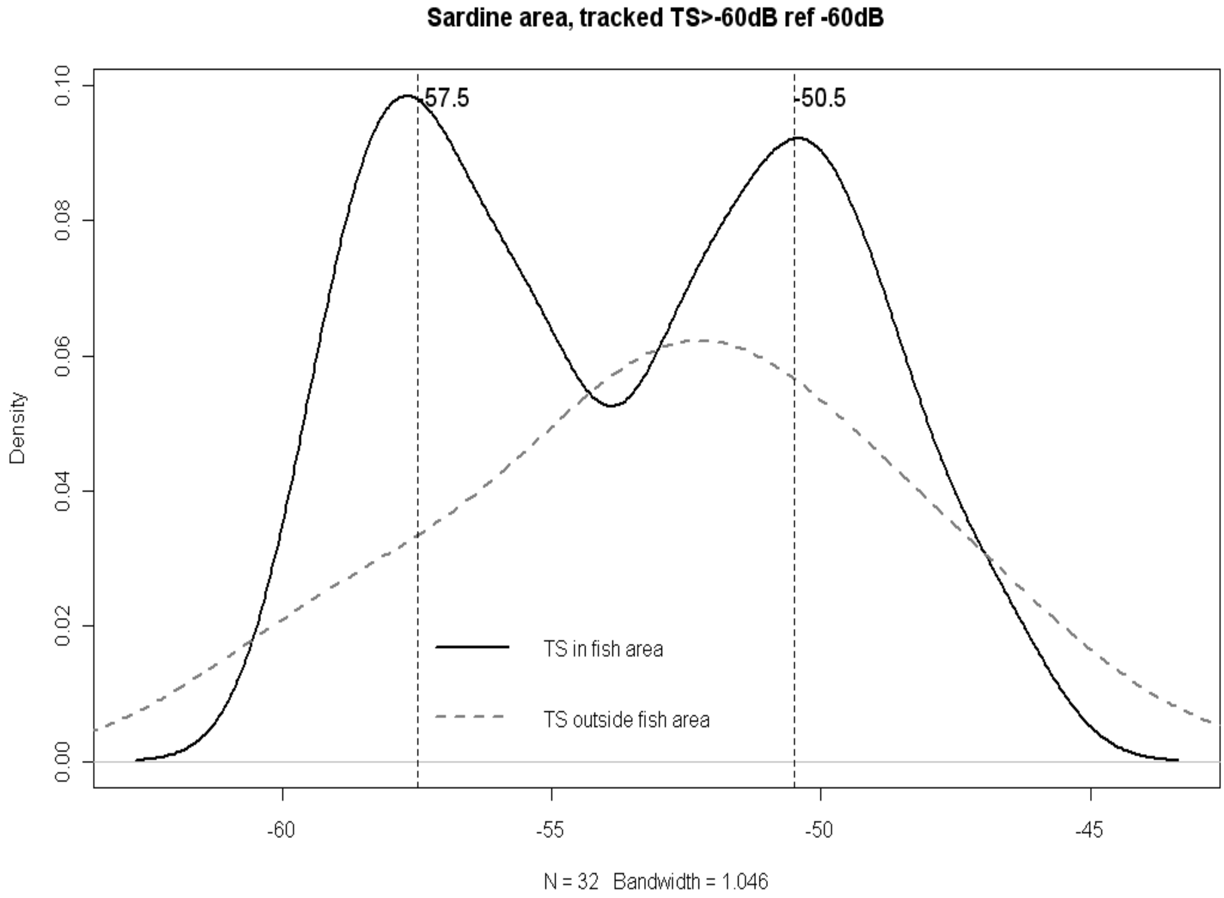

Figure 3b. Mean TS distribution of tracked fish in the 20cm sardine area (solid line) and « background TS noise » (dotted line).

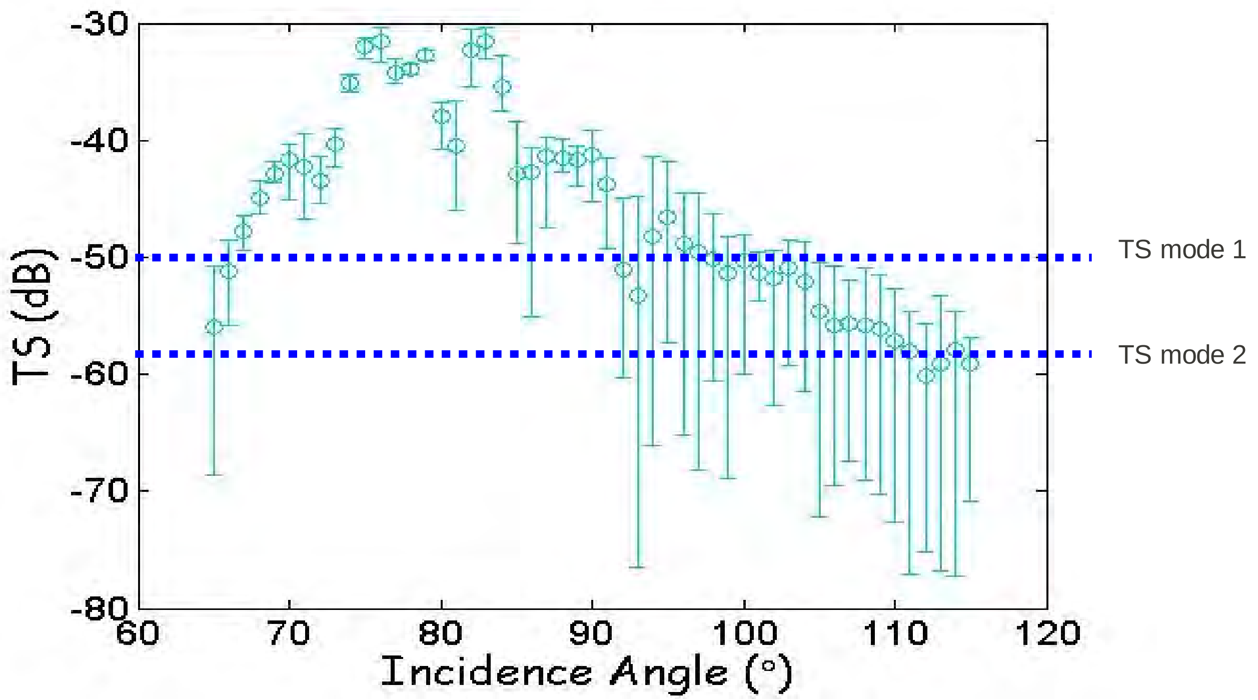

Figure 4. Outputs of a Kirchoff-ray-mode model simulating the acoustic backscatter of a 20cm sardine, as a function of fish tilt angle, relative vertical (dots : TS median, segment extremities : 10 and 90% percentiles of the TS distribution).