In situ measurements of lateral target strength (TS) of Atlantic bluefin tuna (*Thunnus thynnus*) from purse seiners

Vicente Puig-Pons[1], Sergio Morell-Monzó[1], Héctor Peña[2], Isabel Pérez-Arjona[1] and Victor Espinosa[1]

[1]Institut d'Investigació per a la Gestió Integrada de Zones Costaneres (IGIC), Universitat Politècnica de València (UPV), C/Paranimf 1, 46730 Gandia, Spain
[2]Pelagic fish group, Institute of Marine Research P. O. Box 1870 Nordnes, Bergen, Norway

Vicente Puig-Pons, Institut d'Investigació per a la Gestió Integrada de Zones Costaneres (IGIC), Universitat Politècnica de València (UPV), C/Paranimf 1, 46730 Gandia, Spain.
vipupon@upvnet.upv.es

Abstract: *Atlantic bluefin tuna (Thunnus thynnus) is a species of high economic and environmental value. To ensure its sustainable management, the International Commission for the Conservation of Atlantic Tunas (ICCAT) has established fishing quotas and a limited fishing season from May to July. The purse-seine fleet has only 40 days to catch its allocated quota, making it essential for fishermen to use efficient tools for estimating school biomass. This study proposes the simultaneous use of a calibrated omnidirectional sonar (Furuno FSV-25) and a scientific echosounder (Furuno FCV-38) to enhance biomass estimation. The results present lateral target strength (TS) measurements obtained from the scientific echosounder during the 2024 fishing season. Acoustic data were compared with length estimates derived from a stereoscopic video system used during fish transfer operations. A bimodal length distribution was observed; however, this pattern did not appear in the TS distributions. The use of a clustering algorithm to establish a relationship between acoustic energy and fish size for two distinct fish group is being explored.*

Keywords: *Bluefin tuna, target strength, scientific echosounder, underwater acoustics*

1. INTRODUCTION

Atlantic bluefin tuna is a highly valued species that achieves premium prices in international markets, particularly in Japan. However, during the last decades of the 20th century, bluefin tuna populations were severely impacted by overfishing. In response, the International Commission for the Conservation of Atlantic Tunas (ICCAT) implemented strict fishing quotas and a limited fishing season, confined to the months of May through July. As a result, the purse-seine fleet is allowed only 40 days to catch its allocated quota [1]. To optimize fishing operations and promote sustainable practices, it is essential for fishers to use accurate tools to estimate the biomass of tuna schools. Biomass estimation requires determining the total acoustic energy backscattered by the school, known as volume backscattering strength (Sv). This value is then divided by the acoustic energy backscattered by a single fish, known as the target strength (TS). The TS used is typically the average TS value calculated from all individually detected targets. The number of fish is estimated by dividing Sv by TS, and then multiplying this by the average fish weight and the estimated school volume. The final result, is the school biomass, expressed in tons [2]. The volume backscattering strength (Sv) and the school volume can be obtained from the calibrated omnidirectional sonar [3]. The average fish weight is estimated using a stereoscopic video system, as required by ICCAT regulations [1]. Finally, the mean target strength (TS) is calculated from echosounder data. As omnidirectional sonars beams insonify the fish schools horizontally, is required to have lateral TS of the target fish TS provides information about fish size, while single target detection from echosounder data also enable the assessment of fish orientation, that is, whether the fish are swimming toward or away from the vessel.

In-situ biomass estimation is one of the main objectives of the *ACTTHUN* project (ref. PID2021-127426OB-C21, funded by MICIU/AEI/10.13039/501100011033). To achieve this, we propose the simultaneous use of an omnidirectional sonar and a scientific echosounder. The ACTTHUN project is ongoing, and here we present lateral target strength (TS) measurements obtained from Atlantic bluefin tuna during the 2024 fishing season.

2. MATERIAL AND METHODS

Measurements were carried out during the 2024 bluefin tuna fishing season, between May 26 and June 13. A Furuno FCV-38 scientific echosounder was used to obtain lateral TS measurements. The echosounder operated at 38 kHz, and its transducer was mounted on the starboard side of the boat to ensure overlap between the echosounder and the omnidirectional sonar (Furuno FSV-25) beams.

The echosounder was calibrated in the harbor of L'Ametlla de Mar, prior data collection. The boat was docked, with the water depth at 5 meters. The transducer was positioned mid-water, directed toward the opposite side of the harbor, providing a 60-meter unobstructed acoustic path. Calibration followed the standard target procedure using a 38.1 mm tungsten carbide sphere. A rig was employed to position the sphere in the center of the acoustic beam during calibration [4].

Fig.1: Left: image of echosounder transducer mounted on the starboard side of the boat. Centre: image of rig during sonar calibration. Right: image of rig during echosounder calibration.

The purse-seine vessel carried out five sets between May 26 and June 10. Data were recorded in netCDF4 format. After each catch, the tuna were transferred to a transport cage, which was then towed to a fattening cages anchored near the Spanish coast. During the transfer process, tuna lengths were measured using a stereoscopic video system, following ICCAT guidelines [1].

The data were analysed using two methods (Fig.2). First, a single echo detection (SED) algorithm and a tracking algorithm were applied to process the data. The resulting traces were analysed statistically, and the outcomes were compared with the length data obtained from the stereoscopic video system during the transfer operations. In the second approach, a ping-by-ping analysis was conducted using the SED algorithm. The results from this analysis were also compared with the length measurements provided by the stereoscopic system.

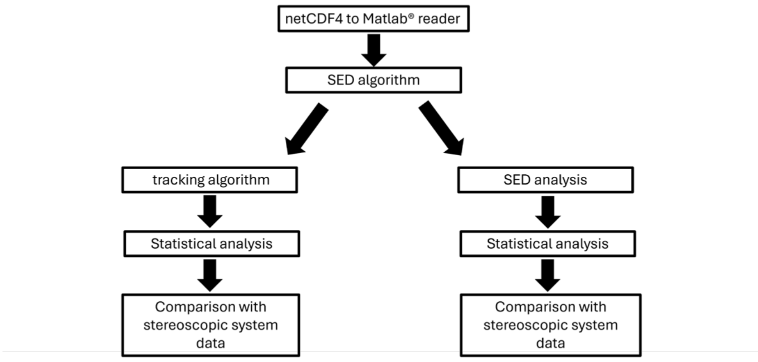

Fig.2: Flowchart for two analysis methods. Tracking method on the left and SED method on the right.

3. RESULTS AND DISCUSSION

The mean length for each catch was calculated using stereoscopic video recordings. Likewise, the mean and maximum target strength (TS) values were obtained through both trace-based and ping-by-ping analyses. The mean swimming tilt angle of the tuna was estimated from isolated traces. The results are summarized in Table 1. Typically, the mean TS is expected to correlate with the mean fish length to establish a TS-versus-length relationship. However, in this study, catches with greater mean lengths exhibited lower TS values, as seen on May 27 and May 29. As a result, it was not possible to establish a reliable TS–length relationship.

Several factors may explain this outcome: the catches on May 27 and 29 showed higher average swimming yaw angles; the number of isolated traces and analyzed pings varied between catches; and the school may have not been fully insonified in all cases.

To better understand this phenomenon, numerical simulations were performed using the Method of Fundamental Solutions (MFS) [5][6]. Being the swimbladder the most important contributor to the backscattering of the BFT, we characterized its anatomical features to develop the geometry considered in the numerical model (Fig. 3). Considering the size and swimming orientation present in the previous fishing seasons, the numerical model estimated a TS vs length relationship, to be compared with the experimental data, to better understand the *insitu* results.

	Date	*May 26*	May 27	May 29	June 1	*June 10*
	Mean length (cm)	205	206	214	178	195
TS from tracking	*Mean TS (dB)*	-19.2	-22.9	-22.2	-18.9	-20.9
	Max TS (dB)	-15.7	-19.5	-19.1	-15.8	-16.3
	Isolated traces	277	59	252	125	940
	Mean tilt angle (°)	93	108	98	96	92
TS from SED	*Mean TS (dB)*	-20.3	-21.3	-23.2	-21.2	-21.4
	Max TS (dB)	-15.6	-16.8	-18.4	-16.5	-16.2
	Pings analysed	328	158	526	449	1542

Table 1: Results from statistical analysis using two analysis methods.

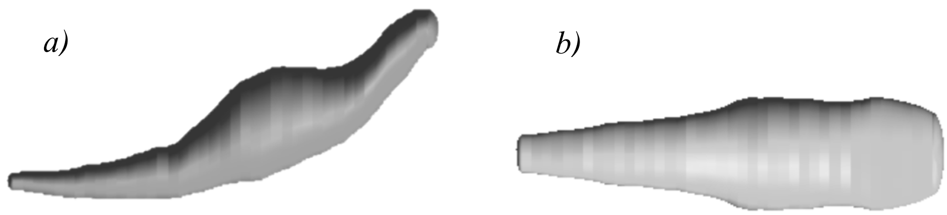

Fig. 3: a) Lateral and b) dorsal view of the BFT swimbladder model.

In Fig. 4, histograms of mean target strength (TS) values for each catch are shown. The TS distributions appear approximately normal, except for May 27 (Fig. 3b), likely due to the lower number of samples obtained. In contrast, the fish length histograms (Fig. 5) show a bimodal pattern across all catches.

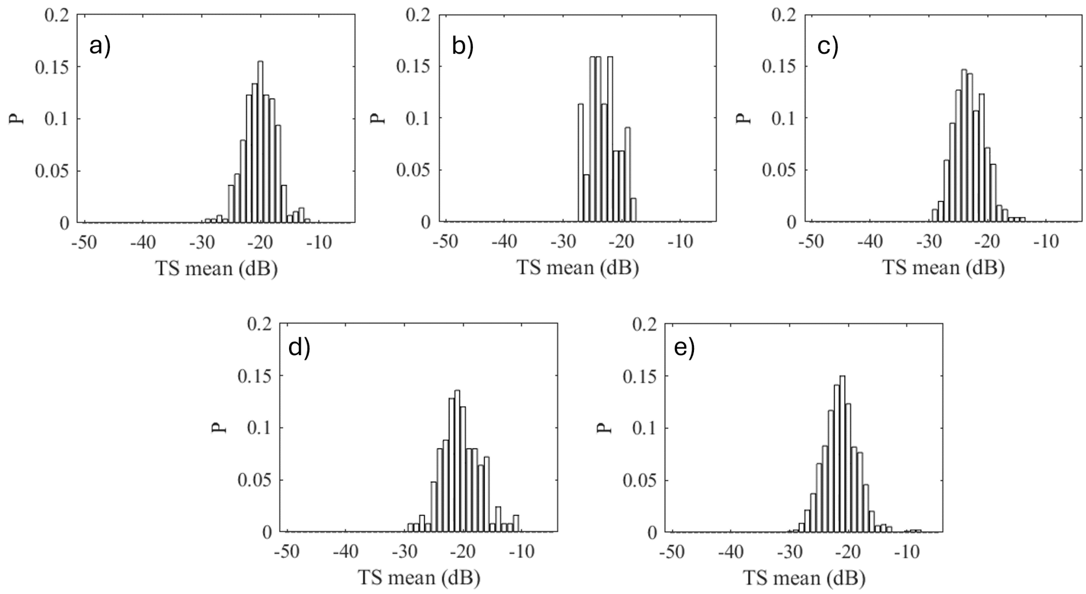

Fig.4: Histograms of mean target strength (TS) values for each catch: (a) May 26, (b) May 27, (c) May 29, (d) June 1, and (e) June 10.

To explore this further, we applied a clustering algorithm to divide the TS distributions into two groups, with the aim of associating each mode of the length distributions with one of these TS clusters. This analysis is ongoing and will be applied to the 2024 data and tested during the 2025 fishing season.

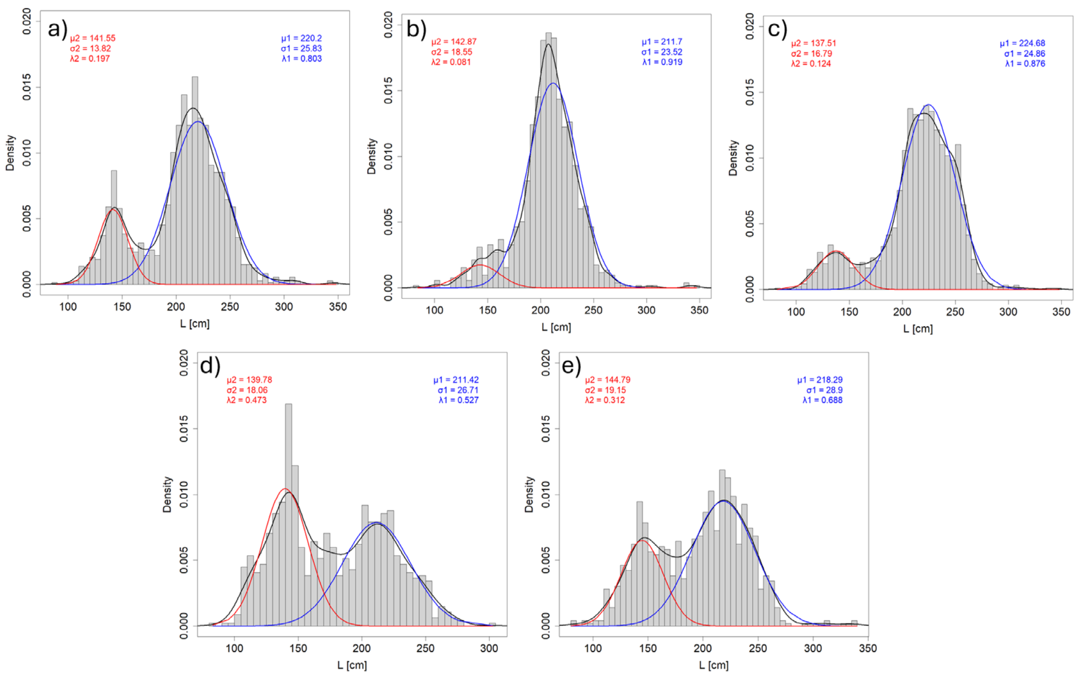

Fig.4: Histograms of fish length values for each catch: (a) May 26, (b) May 27, (c) May 29, (d) June 1, and (e) June 10.

4. CONCLUSIONS

This study presents *in situ* measurements of the lateral target strength (TS) of Atlantic bluefin tuna (*Thunnus thynnus*) obtained during the 2024 fishing season using a scientific echosounder. Two data analysis methods—trace-based tracking and ping-by-ping SED—were applied and compared against fish length measurements from a stereoscopic video system. Despite expectations, a consistent TS–length relationship could not be established, as longer fish exhibited lower TS values. This discrepancy may be attributed to varying swimming tilt angles, differences in sample sizes, and incomplete insonification of the schools. To further investigate these anomalies, numerical simulations were conducted using the Method of Fundamental Solutions (MFS), incorporating anatomical features of the swimbladder. In addition, histograms revealed a mismatch between unimodal TS distributions and bimodal length distributions. A clustering algorithm will be explored to separate TS values into two groups potentially corresponding to the observed length modes. This approach will be further evaluated during the 2025 fishing season.

5. ACKNOWLEDGEMENTS

This work was supported by funding from ACTHHUN project grant ref. PID2021-127426OB-C21 was funded by MICIU/AEI/10.13039/501100011033. The Institute of Marine Research are thanked for financial and technical support to H.P through their internal ICCAT-Atlantic bluefin tuna project 15615.

REFERENCES

[1] **ICCAT.** Recommendation by ICCAT amending the Recommendation 18-02 establishing a multi-annual management plan for Bluefin tuna in the eastern Atlantic and the Mediterranean.2019

[2] **Simonds J, MacLennan D.** Fisheries Acoustics: Theory and Practice Second Edition. Second edi. edited by D. Simonds, J, MacLennan. Blackwell Science. 2007.

[3] **Héctor Peña, Gavin J Macaulay, Egil Ona, Sindre Vatnehol, Arne J Holmin.** Estimating individual fish school biomass using digital omnidirectional sonars, applied to mackerel and herring, *ICES Journal of Marine Science*, Volume 78, Issue 3, July 2021, Pages 940–951, https://doi.org/10.1093/icesjms/fsaa237

[4] **Sindre Vatnehol, Atle Totland, Egil Ona**. Two mechanical rigs for field calibration of multi-beam fishery sonars, *Methods in Oceanography*,Volumes 13–14,2015,Pages 1-12,ISSN 2211-1220, https://doi.org/10.1016/j.mio.2016.02.001

[5] **[5] Pérez Arjona, I.; Godinho, L.; Espinosa Roselló, V.** Numerical simulation of target strength measurements from near to far field of fish using the method of fundamental solutions, Acta Acustica united with Acustica, 2018. 104(1):25-38. https://doi.org/10.3813/AAA.919142

[6] **I. Pérez-Arjona, L. Godinho, V. Espinosa**, Influence of fish backbone model geometrical features on the numerical target strength of swimbladdered fish, *ICES Journal of Marine Science*, Volume 77, Issue 7-8, December 2020, Pages 2870–2881, https://doi.org/10.1093/icesjms/fsaa160