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BIOMASS ESTIMATION OF BLUEFIN TUNA IN SEA CAGES BY THE COMBINED USE OF ACOUSTIC AND OPTICAL TECHNIQUES

V. Puig[1], Victor Espinosa[1], Ester Soliveres[1], Aurelio Ortega[2],
Antonio Belmonte[3] and Fernando de la Gándara [2]

SUMMARY

*In this paper, an experimental setup to estimate the biomass of caged bluefin tuna (*Thunnus thynnus*) in the Spanish Mediterranean coast is presented. Aims are to monitor individual tuna during all stages of growth, to control the transfer of fish caught in purse seines to towing cages and to be able to estimate the total number of specimens and the biomass transferred. To do this, we propose a combined system of acoustic and optical techniques (both non-intrusive), in order to obtain direct values of acoustical target strength (TS) and information on the orientation of tuna inside the acoustic beam and their size. To achieve complete information, ventral and dorsal acoustic measurements are done using in a first attempt a multiplexed scientific echosounder with two 200 KHz split-beam transducers, while a stereoscopic video system provides optical information and allows estimating the size and the weight of the specimens. Preliminary results indicate that this combined use of techniques provides precise information to determine the TS as a function of fish orientation and for proper monitoring of tuna in floating cages.*

RÉSUMÉ

*Le présent document décrit une expérience visant à estimer la biomasse du thon rouge mis en cages (*Thunnus thynnus*) sur la côte méditerranéenne espagnole. Le but recherché est de faire un suivi de chaque thon pendant tous les stages de la croissance, de contrôler le transfert des poissons capturés par les senneurs vers les cages des remorqueurs et de pouvoir estimer le nombre total de spécimens et la biomasse transférée. A cette fin, nous proposons un système combiné de techniques acoustiques et optiques (les deux non invasives), en vue d'obtenir des valeurs directes de la force acoustique cible (TS) et des informations sur l'orientation des thons à l'intérieur du rayon acoustique, ainsi que sur leur taille. Afin d'obtenir des informations complètes, des mesures acoustiques ventrales et dorsales sont réalisées à l'aide, tout d'abord, d'un échosondeur scientifique multiplexe doté de deux transducteurs de type split beam de 200 KHz, tandis qu'un système vidéo stéréoscopique fournit des informations optiques et permet d'estimer la taille et le poids des spécimens. Les résultats préliminaires indiquent que cet emploi combiné de techniques fournit des informations précises visant à déterminer la force cible comme une fonction de l'orientation des poissons et à effectuer un suivi adéquat des thons dans les cages flottantes.*

RESUMEN

En este documento se presenta un diseño experimental para estimar la biomasa de atún rojo introducido en jaulas (Thunnus thynnus) en la costa española mediterránea. Los objetivos son realizar un seguimiento de los atunes a nivel individual, durante todas las fases de crecimiento, controlar la transferencia de ejemplares capturados por los cerqueros a las jaulas de remolque y estimar el número total de ejemplares y la biomasa transferida. Para ello, se propone un sistema combinado de técnicas acústicas y ópticas (ambas no intrusivas) con el fin de obtener valores directos de la fuerza de la señal acústica (TS) e información sobre la orientación de los atunes dentro del haz acústico y sobre su talla. Para conseguir información completa, las mediciones acústicas dorsales y ventrales se realizaron utilizando en un primer intento ecosonda científica multiplexeada con dos transductores de 200 KHz con haz dividido,

[1]I.G.I.C. (Instituto de Investigación para la Gestión Integrada de Zonas Costeras) - Polytechnic University of Valencia, C/ Paranimf, 1, 46730 Grao de Gandía (Valencia, Spain) vipuipon@epsg.upv.es, vespinos@fis.upv.es, essogon@epsg.upv.es.

[2] IEO (Instituto Español de Oceanografía) Centro Oceanográfico de Murcia Planta de Cultivos Marinos Ctra. de la Azohía s/n 30860, Puerto de Mazarrón (Murcia, Spain) aurelio.ortega@mu.ieo.es, fernando.delagandara@mu.ieo.es

[3] Caladeros del Mediterráneo, S.L., Carretera de la Palma Km 7, 30593 Cartagena (Spain) antonio.belmonte@taxon.es

mientras que el sistema de vídeo estereoscópico proporciona información óptica y permite estimar la talla y peso de los ejemplares. Los resultados preliminares indican que este uso combinado de técnicas proporciona información precisa para determinar la TS como una función de la orientación de los peces y para realizar un seguimiento adecuado de los atunes en las jaulas flotantes.

KEYWORDS

Biomass, biometrics, aquaculture, bluefin tuna, acoustics,
underwater, optical, target strength

1. Introduction

In order to alleviate the pressure on the wild fishery of the bluefin tuna and to aid in its preservation, the domestication of this fish and the development of a sustainable aquaculture industry are necessary. The SELFDOTT project (From capture based to self-sustained aquaculture and domestication of bluefin tuna (*Thunnus thynnus*) is implementing the knowledge on the reproduction of bluefin tuna in captivity. It aims to establish the knowledge-based required for controlled development of eggs, larvae and suitable and environmentally performing feeds. It was launched in January 2008 and is funded under the 7th FP Cooperation Work Programme: Food, Agriculture and Fisheries, and Biotechnology. While the life cycle is being close (De la Gandara, 2009), efforts should be addressed to design growth control mechanisms that make the process efficient and therefore ecologically and economical sustainable for breeders. Moreover to assure the sustainability of captured based aquaculture it is mandatory the development of reliable purse seiners caches estimation techniques. Only the exact knowledge of these data will allow effective control of the stock of bluefin tuna. To do this is necessary to characterize this species properly from the acoustic point of view, because hydroacoustic techniques have proven to be efficient tools for stock control in fisheries.

With this aim, this work proposes an experimental setup that combines acoustic measurements (dorsal and ventral) with optical techniques, to obtain biometric information on a non-intrusive concept, allowing monitoring of weight gain of specimens and optimizing of resources management. This experiment was conceived as a first approach to the problem and raises the expectations open so far in (De la Gandara, 2008) to obtain parameters showing the biometric behavior and state of the specimens in the aquaculture cages.

2. Material and methods

The measurements were conducted in cages installed in the Mediterranean Spanish coast in El Gorguel (Cartagena). As stated above we disposed both an acoustical and an optical system. The optical system (is a stereoscopic recording system) provides visual information of the specimens during measurement (behavior and orientation) as well as the length of the animals. The acoustic system consists of two split-beam transducers working at 200 kHz, and a multiplexer, to operate them simultaneously with a scientific echosounder, governed by the same field computer than the optical system, therefore providing the necessary synchronization through the internal computer clock.

The experimental scheme is shown in **Figure 1**. One of the transducers is placed 20 m from the surface (at the bottom of the cage) oriented upwards (to take ventral recordings) and the other aligned with the first, is placed on the surface oriented to the bottom, therefore providing dorsal information from specimens crossing the beam. Finally the VICASS systems placed 13 m from the surface, and aligned with the acoustical beams, with the objectives of both cameras oriented toward the surface. The equipment is not placed in the center of the cage but slightly displaced to one side (7 meters from the perimeter of the cage) so that the probability that a fish passes through the beam is larger because the specimens in captivity swim describing circles in the cage.

All the equipment is operated from a boat moored near the cage. The ping repetition rate is set to 200 milliseconds, what implies with a multiplexed signal, that a ping is sent by the same transducer every 400 milliseconds, being the output power 90 W. The optical system took a picture every 2 seconds. We took a total of 1200 images.

Acoustic and optical data are analyzed separately at first and then jointly. The processing of acoustic data is performed using software Sonar5_Pro (Balk 2008) (developed by Balk and Lindeman at the University of Oslo).

This program has sophisticated tools for the treatment of individual echoes (SED); we will make use of them for trace detection. Finally we relate these traces and the images taken by the optical system using the temporal information.

A high threshold is applied to reduce noise, and thus to have cleaner echograms for effective trace detection. The threshold is set at -40 dB, as it is known that for fishes of similar species and similar sizes TS varies between -40 and -15 dB (Bertrand 2000, Sainz-Pardo 2010). This software allows us the identification of tuna traces in the echogram related to the image of fish crossing the acoustic beam.

Stereoscopic vision allows determining biometric parameters of fish without handling them (Ruff, 1995). Several studies suggest that the use of these systems is useful for estimating the length and weight of specimens and thus to improve the efficiency in the feeding of this species in captivity (Aguado, 2009). The proposed experimental system is based in the innovative ventral measurement of images. For this reason, in this work a new procedure of image measurement is developed to estimate the tuna fork length, and a validation of this new method for measuring ventral images in connection with the usual configuration of a stereoscopic system (lateral) is performed.

But software that provides the Vicass system is not able to calculate the length of most of the pairs of images. For this reason, we use, besides Vicass software, our own application developed in Matlab ®. This application doesn´t use stereoscopy laws, only takes into account only one of the images of each pair and the distance between the fish and the camera lens is provided by the echogram (with an increase 20% of measured fishes). In **Figure 2** we can see the images taken by the two camera system VICASS (left and right, respectively) and traces found at the instant in time at which images are made marked in the echogram. (22/01/2010 at 15:10:40 day hours. Mean TS is -29.3 dB and the distance to the center of gravity of the transducer is 12.1 m).

3. Results

Dorsal TS measurements offer a bimodal distribution, which can be explained by the detection of the main lobe and two lateral lobes of the swimbladder scattering directivity, as the tuna crosses the acoustic beam, what has been described for other species (Knudsen, 2004). When a fish swim across the sound beam, the echoes from side lobes and main lobe of the swimbladder can be detected, producing multimodal distributions. It is known that for a fish with large fork length, swim bladder can be likened to a cylinder more accurately than for smaller species, the main lobe of the same becomes narrower, and therefore the possibility to be detected decreases. For this reason, for a long fish, unimodal distributions tend to increase (Knudsen, 2004).

Ventral data tend also to be unimodal, because the morphometry of the swimblader, more rounded than the dorsal side, reduces the directivity. In dorsal measurements, the effect of skeleton alters the effect of the bladder. This may also explain what TS in ventral measurements is greater than in dorsal aspect, since the bladder is responsible for 90% of the acoustic energy reflected by the fish (**Figure 3**).

Another critical point to consider is the relationship between tuna and size of the acoustic beam, and the fact that many measures in cages are affected by near field effects. When making measurements of large fish in cages, it is assumed that the fish is not far enough to consider the dispersed acoustic field as a far-field and it can not be asumed as punctually located inside the beam. Recalling that the transducers also have a near-field area to be avoided, the combination of both can lead us to obtain unreliable values of TS .

The main problem is the difficulty to obtain the correct TVG function (Time Varying Gain) to be applied when the fish is large compared with the area of the beam. For this reason, we expect an error associated with measuring the phase split-beam echo sounder, previous to the compensation of the received signal with TVG function.

For this reason, we studied the dependence of the TS with distance from the transducer as shown in **Figure 4**. We can see that for a defined number of traces, which comprises this preliminary study, the values of mean ventral TS evolves with distance to an apparent stable value. In the case of the dorsal measures, the literature indicates that for a tuna in the wild, the value of TS medium should vary with depth (Bertrand, 1999).But in our experiment, the scale used is far from that used in the literature on the subject, because we only can use few detections that are in the space between the surface and the position of the cameras. Therefore, our dorsal data exhibit a more complex dependence with transducer distance than the ventral ones what can be related to the near field effects described above.

With the combined use of biometric information obtained from optical equipment and acoustical data, we can plot first ventral TS to length relationship for bluefin tuna. The mean TS of each traces is calculated and depicted for every measured length in the corresponding image. This must be considered just a methodological description but very promising results are shown (**Figure 5**).

For the amount of data handled, which are few in order to perform a statistical treatment, we can only infer that the measurement methodology can be implemented effectively to the aim marked for this work: a non-intrusive monitoring of the growth of tuna in fattening cages.

This paper shows preliminary results of work in progress. Nowadays we are working on the implementation of a system composed of an IP camera and a singlebeam echosounder to have a greater beamwidth provides a greater number of echoes for each acoustical trace. Moreover, a wireless communication system is being implemented in order to access remotely the information stream (acoustic and optical) that our system offers. This communication systems will be installed in cages at sea and will allow to investigate the biometrics and also behavior of bluefin tuna.

4. Conclusions

The work described in this document represents the first characterization of bluefin tuna in captivity made by acoustic and optical techniques. As indicated throughout the document, the aim of this study is to provide the information technology to achieve a sustainable tuna industry and effective control of catches.

The combined use of acoustic and optical techniques allows to assign correspondences between the values of target Strength (TS) and the size of a particular fish. This fact will also improve the monitoring of tuna in captivity and also to develope a biomass estimation method during tuna transfer from seiners nets to towing cages.

The experiment shows that the ventral TS measures allows to monitor tuna growth in captivity. However, the dorsal measures show, as in other experiments (Knudsen 2004) more ambiguous results.

There is not a clear dependence of the TS with distance at short distances. A first equation, that relates the TS and fork length of bluefin tuna in sea cages, is obtained as already exists for other (Knudsen 2004).

This paper presents preliminary results of an ongoing project; in this moment we are developing a new campaign to extend the statistical validity of the conclusions. For this reason, quantitative values shown throughout these pages, must be reviewed and adjusted in order to obtain higher correlations between the values of TS and fish length.

5. References

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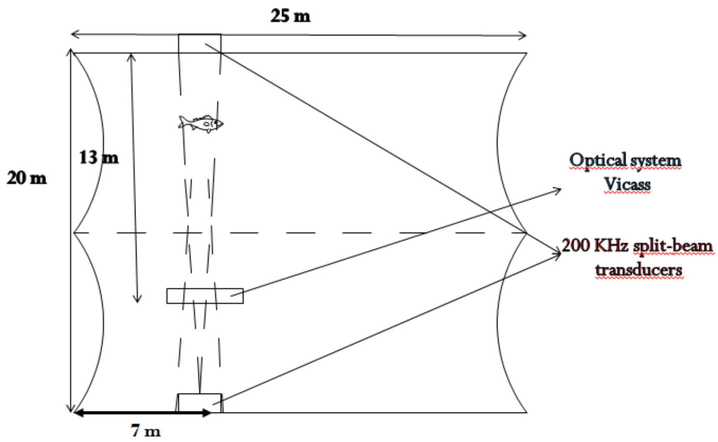


Figure.1. Experimental scheme.

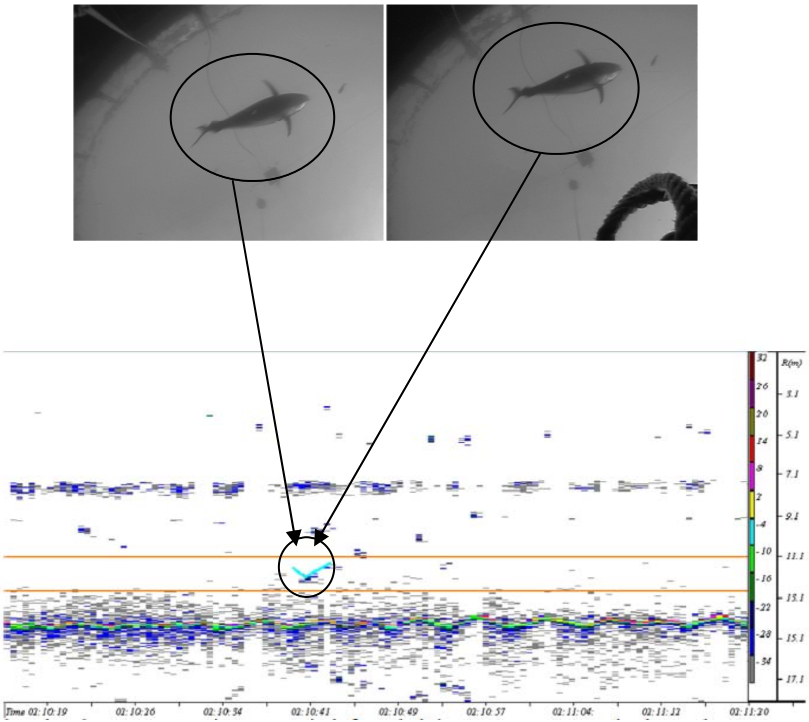


Figure 2. Images taken by the two camera system VICASS (left and right, respectively) and traces found at the instant in time at which images are made marked in the echogram. (22/01/2010 at 15:10:40 day hours. Mean TS is -29.3 dB and the distance to the center of gravity of the transducer is 12.1 m)

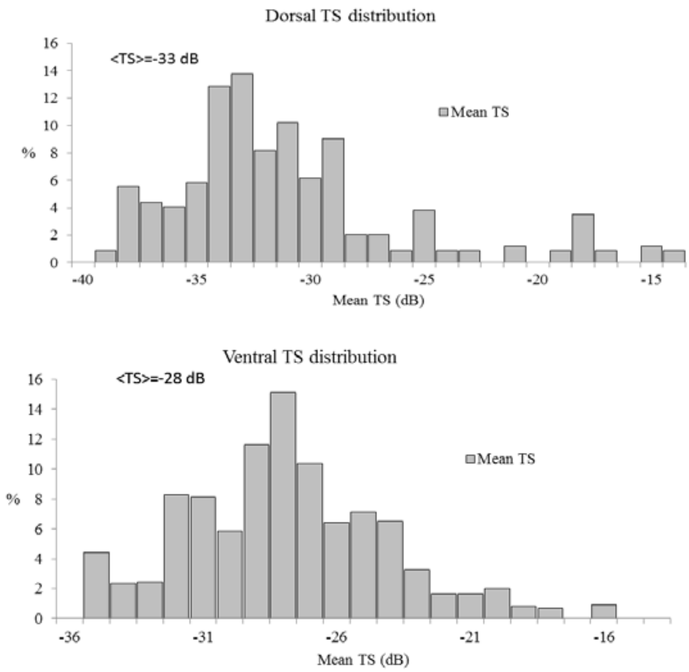
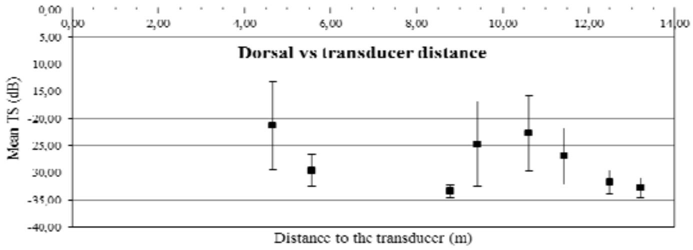


Figure. 3. TS distribution to dorsal and ventral measures.



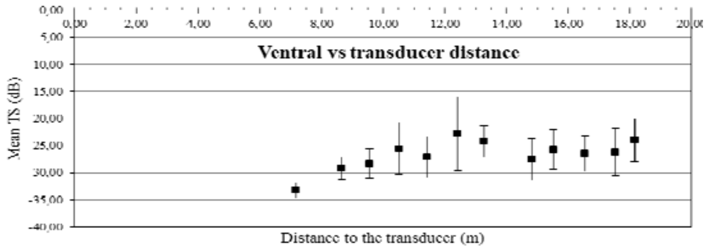


Figure 4. Mean TS measurement in relation to distance to the transducer from ventral and dorsal recordings.

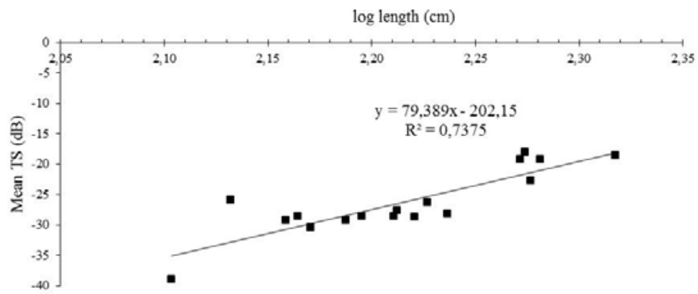


Figure 5. TS to fork length relationship.