Experimental setup for monitoring the growth of tuna in cages by the combined use of acoustic and optical cages

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In the frame of the European project SELFDOTT (From capture based to self-sustained aquaculture and domestication of bluefin tuna, *Thunnus thynnus*) an experimental setup to estimate the biomass of caged bluefin tuna (*Thunnus thynnus*) farms in the Spanish Mediterranean coast is presented. The aim is to monitor individuals during all stages of growth. To do this, we propose a combined system of acoustic and optical techniques (both non-intrusive), in order to obtain values of target strength of the specimens and information on the orientation of tuna in the acoustic beam and the fish size. To achieve a complete information, an experiment has been designed that allows us to get the acoustic measurements ventral and dorsal individuals accommodated in the cage (using in a first attempt a multiplexed echosounder with two 200KHz split-beam transducers), while stereoscopic systems provides visual information and allows estimate the size and weight of the specimens captured by the system. Preliminary results indicate that combined use of both techniques provides more precise values of the parameters needed to determine the TS as a function of fish orientation and for proper monitoring of tuna in floating cages.

1 Introduction

In order to alleviate the pressure on the wild fishery of the bluefin tuna and aid in its conservation, 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-base 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 to be closed [1] [2] [3], efforts should joined to design growth control mechanisms that make the process efficient and ecologically and economical sustainable for breeders.

Whit this aim, this paper 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.

Different aspects must be evaluated, like the capability of synchronizing scientific echosounders and commercial biometric video-based systems, the correspondence of images and acoustical traces in echograms, the consistency of TS measurements in a near range configuration (given the big size of animals related to the acoustic beam volume), the feasibility of relating TS (dorsal or ventral) versus tuna size, etc.

This experiment was conceived as a first approach to the problem and rises the expectations open so far in[4] to obtain parameters showing the biometric behavior and state of the specimens in the aquaculture cages.

2 Material and methods

2.1 Experimental setup

The measurements were conducted in cages (depth of 20 m and 25 m in diameter) installed in the Mediterranean Spanish coast in El Gorguel (Cartagena), and tuna in them are at different stages of growth. The tests were carried out in the cage R5 that houses reproductive tuna. These scientific breeding cages are coordinated by the IEO (Spanish Institute of Oceanography).

As stated above we disposed an acoustical and an optical system. The optical system (AkvaSmart Vicass) provides visual information of the specimens during measurement (behavior and orientation) as well as the length of the same (it is a stereoscopic recording system designed for use in fish farming composed of two identical cameras mounted on a metal frame and whose optical centers are aligned and separated 15"; a field computer allows the manipulation of the cameras and image acquisition manually or automatically). The acoustic system consists of two split-beam transducers of 200 kHz, and a multiplexer to operate them simultaneously with a Simrad EK60 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 to the surface (to take ventral recordings) and the other aligned with the first, is placed on the surface oriented to the bottom so that provide us dorsal information from specimens that pass through the beam. Finally the Vicass is 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 edge (7 meters from the perimeter of the cage) so that the probability that a fish pass through the beam is larger because the specimens in captivity swim describing circular motion near the perimeter of the cage.

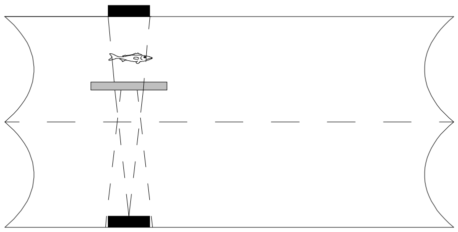

Fig. 1 Measurement system, echo-sounders in black Vicass in gray

All equipment is operated from a boat moored near the cage. For the echosounder we choose an interval of 0.2 s between pings, and we captured images with the Vicass system every 2 seconds.

2.2 Procedure

The pictures and echograms obtained during the measurement process are stored for later analysis.

On one hand the analysis begins with the selection of images. The temporal information of the selected ones is recorded for later comparison with the echograms traces. On the other hand, the processing of acoustic data is performed using software Sonar5_Pro [5] and sophisticated tools that the program provides for the treatment of individual echoes (SED). A high threshold (of -35 dB) is applied to the sonograms, thereby disposing of echograms cleaner for manual detection of traces, and the identification of events in the echogram related to the image of fish crossing the acoustic beam, marking these detections as possible acoustical tuna traces.

Once Once the manual selection of traces has been accomplished, the program can do automatic detection using the parameters stored during the manual process. Due to the parameters chosen to perform the test (frequency of the transducers, the interval between pings, beam width, distance to the transducers ...) and the size and speed of the specimens, in this particular case, we had to fix that each trace should contain at least three echoes (pings).

2.3 Optical information processing

Stereoscopic vision allows to determine biometric parameters of fish without handling them [6]. Akvasmart Vicass is one of the few available commercial systems that, through image analysis, is optimized to obtain size information of farmed fish.

In recent years it has extended the use of such systems in floating cages in the sea, in particular those where bluefin tuna (*Thunnus thynnus*) is fattened. 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 breeding of this species in captivity [7] [8].

The image processing software developed by Akvasmart needs a lateral image to estimate biometric parameters like the fork length, the maximum height and weight. For the specific case of bluefin tuna, this system shows absolute errors of around 4% compared with manual measurements of the length [7].

The proposed experimental system is based in the alternate ventral measurement of images. For this reason, before conducting the test, it was necessary to validate (compare) the ventral image measurements with the usual configuration of a stereoscopic system (lateral), estimating the deviation that occurs when the fork length is calculated from ventral images instead of dorsal images. From images obtained by the two measurement procedures (lateral and ventral), the fork length and mean absolute error is calculated (Table 1).

Configuration	Mean fork length (cm)	Ɛ (%)
Lateral	164 ± 7	4,3
Ventral	165 ± 13	7,9

Table 1

These size values will be correlated to the mean TS of bluefin tuna. The aim of this work is to obtain a methodological approach to obtain this relationship.

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3 Results

After finding the echogram-image relationship, as shown in Fig. 2, mean TS is calculated for each of the traces found.

Figure 3 shows the TS distribution of all the detected acoustical traces, for ventral and dorsal aspects. We can see that the dorsal TS measurements offer a bi-or trimodal distribution, which can be explained by the detection of the main lobe and two lateral lobes of the swimblader, crossing the acoustic beam, what has been described for other species [8]. For bluefin tuna at this stage, because of its length, the distribution tends to be more unimodal than smaller ones. Ventral data tend also to be unimodal, because the morphometry of the swimblader, more rounded tan the dorsal side, reducing directivity. In any case these distributions and the TS absolute values must be carefully considered since we offer preliminary results of the validation of a experimental setup. However, the distributions reflect the paradigmatic characteristics shown by other species at lower frequencies. This leads us to believe that the implemented monitoring method can be effective for this case study.

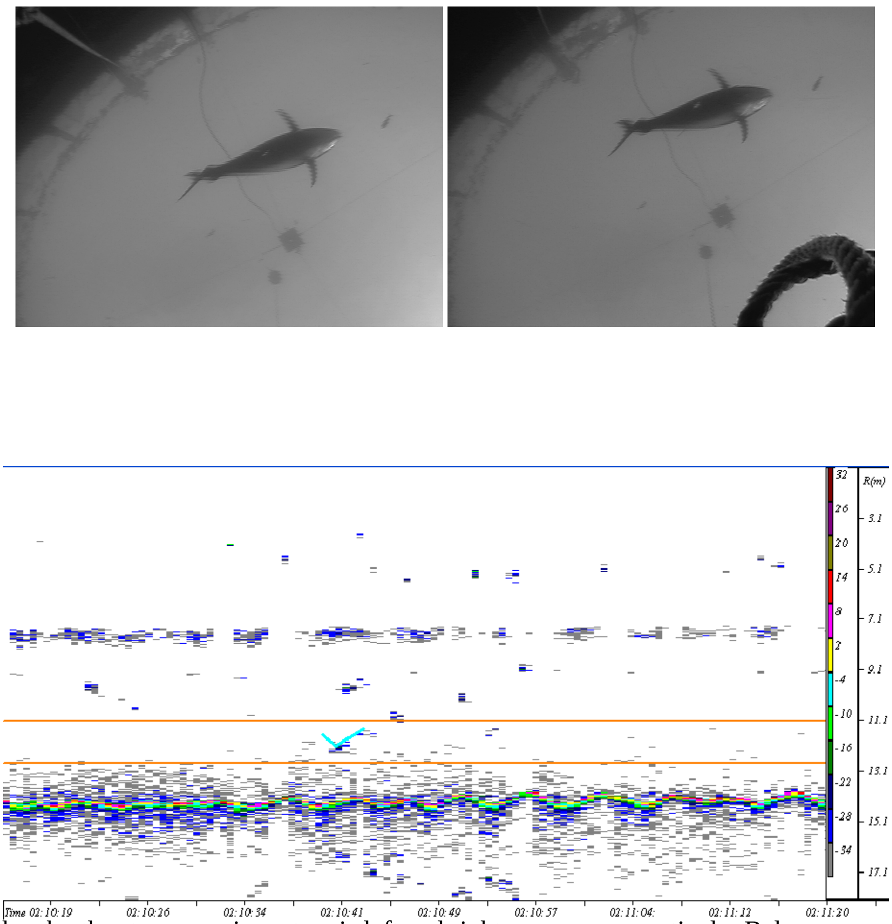

Fig. 2: Images taken by the stereoscopic system is left and right cameras respectively. Below sonogram obtained wit Sonar5_Pro, which shows the trace that corresponds to the image

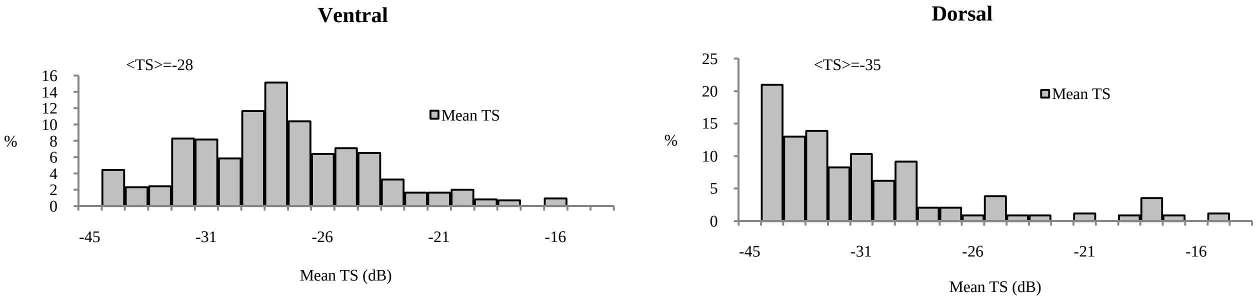

Fig. 3: Target strength distribution for dorsal and ventral recordings.

Another critical point to be taken into account is the relationship between the tuna and beam area size, and the fact most cage measurements are affected by a near range error related to different non realistic assumptions: the fish are not far enough to consider the dispersed acoustic field as a far-field, and/or they can not be taken as punctually located inside the beam, with the corresponding error in the phase determination performed by the split-beam echosounder previous to the beam compensation gain. For these reasons we have studied the dependence of the TS values with transducer distance (Figure 4).

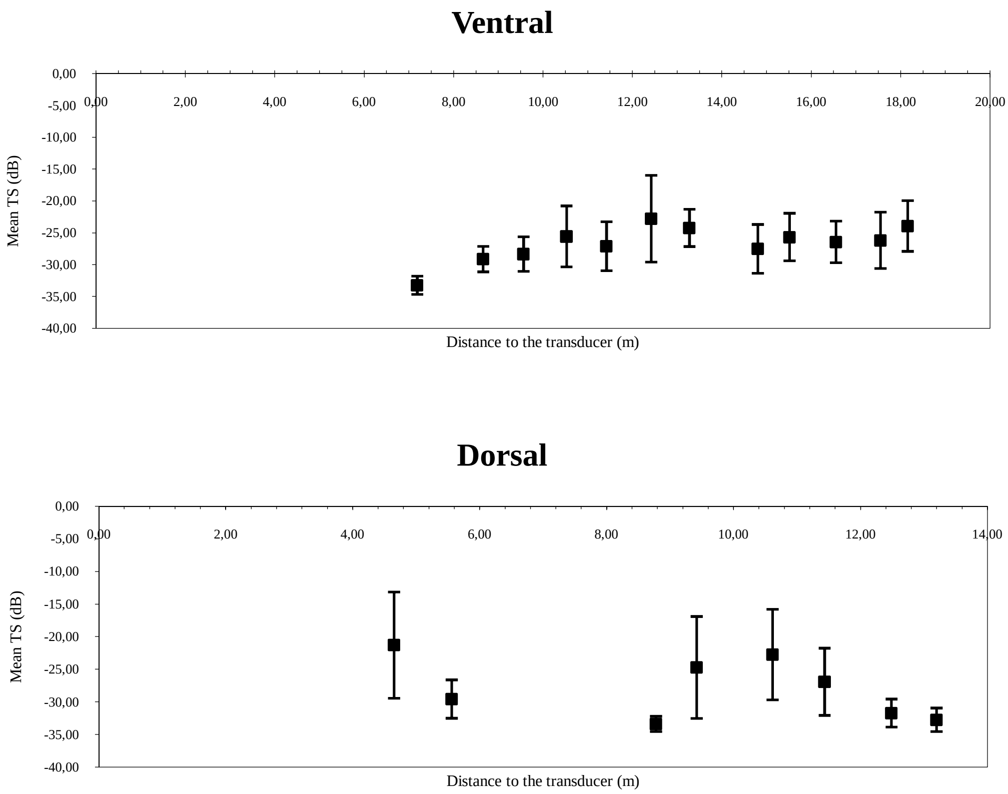

Fig. 4 Mean TS measurement in relation to distance to the transducer from Ventral and Dorsal recordings.

For the limited number of traces of this preliminary study, we can appreciate that mean ventral TS evolves with distance to an apparent stable value. In the case of dorsal measurements, the literature indicates that in the wild, varies with depth [9], but the scale of our experiment is far away from those of the reported data. 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. This considerations are crucial, to evaluate any TS versus size relationship based on optical biometric information, and in Fig. 5, we plot a 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 enforces.

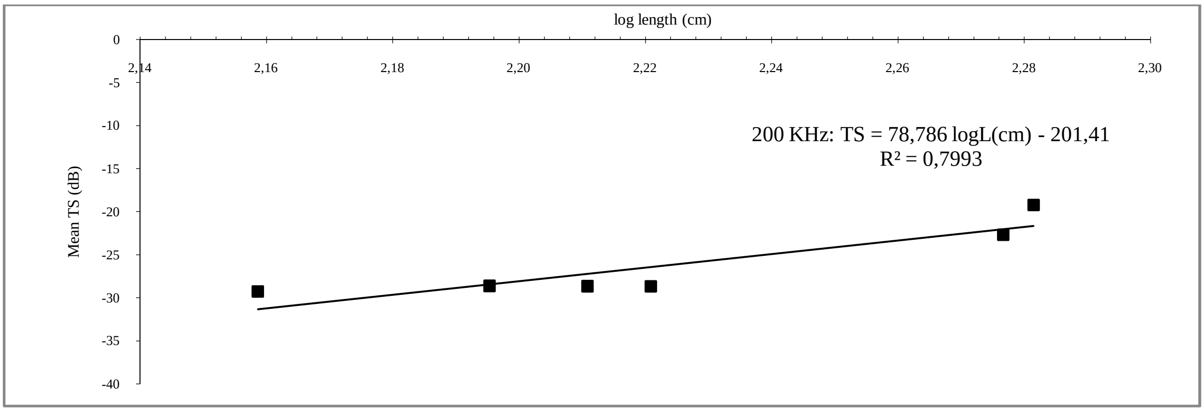

Fig.5 TS to fork length relationship

4 Conclusion

The combined use of acoustic and optical techniques permits to assign the correspondences between TS values and specific animal size. It can improve the monitoring conditions of captive bluefin tuna, with additional information to the established stereoscopic video systems.

The experiment showed that the ventral TS measurements provide information of the growing stage of specimens. However, dorsal measurements show, like in other experiments [8], poor results.

This paper shows preliminary results of work in progress, with new data collection campaigns. For this reason, the quantitative values provided will be reviewed and adjusted to achieve the highest correlations between TS and length.

Current works are also addressed to improve the methodology on different lines: implementing more automated and efficient image processing algorithms for the measurement of fork length and width of tuna from ventral images, and setting relationships between that value and weight of the fish. Also we develop the echogram processing algorithm for the automated assignment of traces and images.

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