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Detection and target strength measurements of uneaten feed pellets with a single beam echosounder

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ABSTRACT

The possibility of detecting uneaten food pellets in aquaculture floating cages using a scientific single beam echosounder is demonstrated. The applied methodology is based in a basic scheme with the ultrasonic beam facing upwards the sea surface from the cage bottom. The target strength of single pellets is measured resulting in a linear relationship between target strength and pellet size. These results are the basis to quantify the uneaten food falling and to develop an automated feeding system based on demand.

1. Introduction

There is a great variety of fish farming in marine aquaculture in which feeding is mainly based on commercial pelleted food. Nowadays much of the economic investment of a fish farm is due to feeding costs, which can reach 60% of expenditure on salmon farming (Acker et al., 2002). It is not easy to know, during the feeding process, when the individuals in a cage have ingested the optimum amount for their adequate growth. Usually, the moment to stop food supply is determined by observation, so that, when there are not or there are few individuals near the surface, it is considered that these are satiated. This method is inaccurate and it gets more complicated due to the high fish density and turbidity in sea cages (Mallekh et al., 2003). Because of this inaccuracy, feed is often provided in excess; near 8% of the total feed is lost (García et al., 2011), which carries a high economic waste and adds environmental impact because the extra organic matter that is deposited on the seabed producing a nutrient enrichment (Pearson, 1991).

Therefore, due to economic and environmental reasons, there is an obvious interest in developing methods to supply the optimal amount of food for marine cage farming. Different studies have been carried out with this objective, from calculating the amount of feed needed for a culture by collecting the uneaten pellets (Helland et al., 1996) to a mechanism of self-feeding in which fish regulate the level of feeding by activating (through presses or bites) a trigger of a feed dispenser (Alanärä et al., 2001). Indirect process control mechanisms have been carried out too, such as interactive feedback systems, based on the feed amount adjustment either by means of uneaten pellets detection or evaluation of fish feeding activity. Juell (1991) developed an acoustic method to detect the accumulated uneaten feed and the individual pellets, and (Blyth and Purser, 1993) used infrared sensors to detect pellets (Mallekh et al., 2003). Later image analysis softwares orientated to uneaten pellets detection and quantification were developed (Foster et al., 1995; Ang and Petrell, 1997). Acker et al. (2002) designed a system of detection, quantity and direction monitoring of waste food pellets by a digital scanning sonar, besides capable of predict the sinking trajectory. Also there have been used echosounders in combination with video cameras to determine the position of individuals(Alanärä et al., 2001) and the swimming speed as appetite indicators (García et al., 2011). Mallekh et al. (2003) developed a method to determine the moment of supply stop in the turbot culture by means of passive acoustic, based on the sounds produced by the individuals during the feeding, a decrease in the feeding sounds indicates lack of demand. Therefore the required amount of feed can be fixed for a determined culture, but it cannot be extrapolated to other species.

The aim of this work is to investigate the application of the echo integration method initiated by Juell (1991) to estimate the falling pellet abundance, based on the assumption that the total integrated echo intensity returned from randomly distributed targets inside the acoustic beam is proportional to the quantity of those targets and to the echo intensity returned by an average scatterer.

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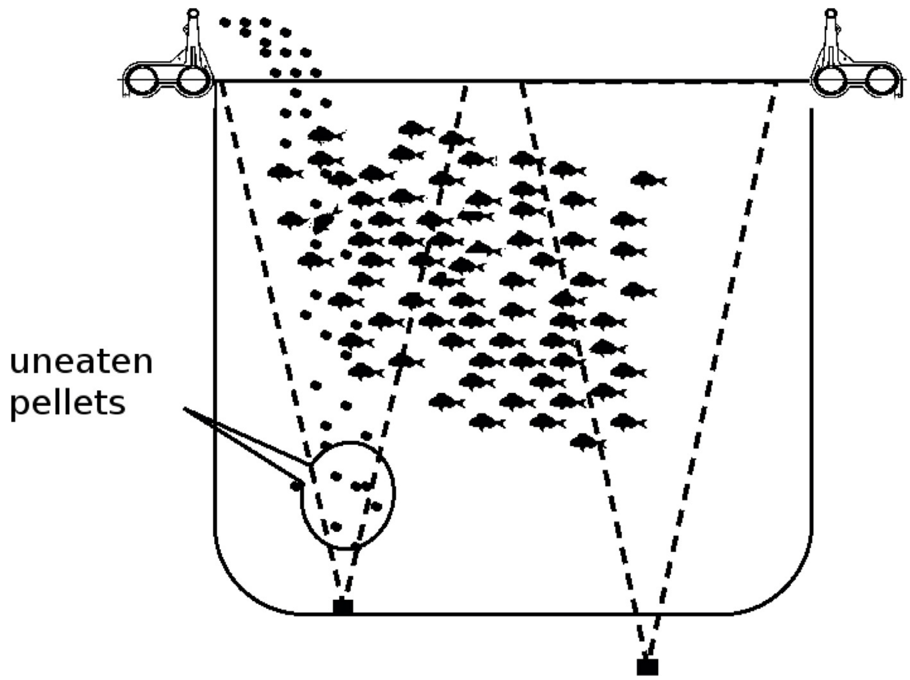

Fig. 1. Schema of the proposed pellet detection system. The transducer can be placed at the net bottom (left) or below the pen (right).

As it is commonly applied in fisheries acoustics (Simmonds and Mac Lennan, 2005), the backscattered energy per unit volume *Sv* is proportional to the scatterer density ρ and to the backscattering cross-section of an average single scatterer σ, and therefore the scatterer density inside the acoustic beam is given by: $\rho = S_v/\sigma$. With the limitations of the available technology (an analogical echosounder), Juell (1991) demonstrated that the integrated echo energy was proportional to the total weight of food batches thrown at the surface inside the beam volume. Also an estimation of the target strength of relatively big size pellets were performed, comparing the integrated energy (over a certain period of time) when a suspended pellet or a calibration sphere were placed in the beam axis. The minimum quantity of falling pellets that could be detected with the electronics and transducers available at that time were between 5 and 10 g. We suggest to improve the acoustical method using the capabilities of modern quantitative echosounders to apply more adequately the linear superposition principle to automate an estimation of falling pellets density in the water column below the caged school. For such a purpose it is necessary the determination of the backscattering cross-section (or its equivalent logarithmic expression, known as target strength, *TS*) of individual pellets, for all the sizes used in every growing stage of a production cycle; this implies to detect individual pieces with weights below the milligram. This can be the beginning of the development of a method capable of determining, during the feeding process, when individuals in a sea cage have ingested the optimal amount of food for optimum growth by detecting and quantifying uneaten pellets. This would minimize economic and environmental impacts due to oversupply of food. Another key point is the use for this purpose of a quantitative single beam echosounder as a part of a cost-effective system installed permanently in every single floating cage in aquaculture farms. In spite of the relative high number of proposed systems to monitor the feeding process as we mentioned above, the fact is that nowadays no automated system has been implemented in a generalized way in intensive aquaculture, and only visual (human) inspection performed directly or with video cameras is commonly applied. We propose the use of a simple control set up like in Fig. 1 with a fixed upward looking ultrasonic transducer to monitor school behavior and to detect and to quantify uneaten pellet falling. This could be also a part of a more ambitious system to monitor fish biomass (Knudsen et al., 2004) boosting the benefits of the investment in control equipment.

2. Materials and methods

Five different sizes of cylindrical pellets (1, 2, 4, 6 and 8 mm of diameter equal to their length) of commercial dry-pelleted feed for sea bass were measured sinking from the surface with a single beam echosounder Simrad EK15. The measurements were taken inside a scaled floating cage which had 3 m of diameter and 3.5 m of depth. The cage was almost empty with the exception of the intrusion of tiny harbor fishes. The upward looking transducer of 30.3 degrees of aperture at −3 dB was placed on the net bottom on a support formed by two PVC tubes arranged crosswise, with a resulting distance to the sea surface of 3.3 m. The emission frequency of the echo sounder was 200 kHz, with a ping duration of 64 μs, a repetition rate of 2 pings per second, a bandwidth of 18.76 kHz, and the power set to 90 W. The experiment took place inside Gandia's harbor waters during the same day in the time interval of one and a half hour.

To guarantee the repeatability of the measurement of TS absolute values with the EK15, we used a 13 mm copper calibration sphere moved by a positioning system in a tank to obtain the maximum on-axis value. The difference with the theoretical value for the experimental conditions was introduced as an on-axis gain in the post-processing software used for data analysis. Data processing was carried out using the dedicated software Sonar5-Pro ® and Matlab ®. The first echogram processing was performed with Sonar5-Pro. In this step single echo detection (SED) algorithms based on echo length and amplitude were applied to isolate single targets, and echo traces corresponding to pellets were identified in the so-called "SED echogram"; only those with specific length, continuity and slope were taken into account. Fig. 2 shows an example of a recorded amplitude echogram and the resultant echogram after applying single echo detection (SED) algorithms and the selected layer for pellet trace identification. We selected for our analysis a layer of 1 m of vertical dimension, once the far field of the transducer is achieved, corresponding to a distance between 0.3 and 1.3 m. Parallel lines with negative slopes correspond to pellet echo