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The laser scanner is a reliable method to estimate the biomass of a Senegalese sole (*Solea senegalensis*) population in a tank

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ABSTRACT

The measurement of total fish biomass is an essential practice in the aquaculture management. The method commonly used which involves removing a sub-sample of fish from a tank, weighing it and extrapolating the result to the whole tank, carries a large error, is intense labor and causes great stress. Here, we tested a laser scanning method to estimate the total fish biomass from the total fish volume of a sole population (*Solea senegalensis*) in a tank. The ratio FB/FLV of fish biomass (FB), weighing the 100% of soles, versus the fish layer volume (FLV) measured by the laser scanning, is calculated. Different fish size (small and large) and stocking densities (very low, low, medium and high) were tested. To test the method in the worst conditions, in very low stocking density, fish were 3.0 g ± 1.1 (individual mean weight ± SD); but in low, medium and high stocking density fish were 234.0 g ± 84.6 (individual mean weight ± SD). The fish layer volume included the fish biomass and the interstitial water present among them, which can be estimated from the ratio FB/FLV. In medium and high rearing densities with larger fish the ratio takes values very close to 1 (0.957 ± 0.021 and 0.967 ± 0.011) giving percentages of interstitial water lower than 5%. But in very low stocking density (0.4 kg/m^2) with smaller fish (3.0 g ± 1.1), the ratio FB/FLV was much lower, giving a non-realistic percentage of interstitial water estimation. The low ratios obtained at very low stocking densities are due to the resolution of the image catching process, which is aggravated when working with small fish, since the error of a pixel from a digital image represents a larger percentage of error than with larger fish and higher stocking density. It should be noted that the coefficient of variation (CV) obtained was very low (in all cases lower than 7.2%) and decreased as the stocking density increased achieving the lowest value (1.1%) at high stocking density. The laser scanning has proven to be a useful tool to estimate the total fish layer volume of flatfish, and thus fish biomass, in an aquaculture tank with a usual grow-out stocking density for sole, reducing the labor involved and the stress commonly associated to manual sampling.

1. Introduction

One of the most common and important practice in the aquaculture management is the measure of total fish biomass. It is important to enable effective management of feeding regimes, oxygen consumption calculation, antibiotic dose, grading times and the optimum time of harvest. Nowadays, in aquaculture facilities, the most common way to estimate total fish biomass is by removing a sub-sample of fish from a tank, weighing it and extrapolating the result to the whole tank. However, it is labor intense and a human action is necessary on the fish or on the tank. Furthermore, an inaccuracy of 15–25% is inherent in this method (Klontz, 1993), the value may vary depending on many factors like fish and sample size as well as frequency of sampling and even the fish species can affect the results. Finally, any operation which involves disturbing and handling fish, like weighing fish manually, can cause physical damage or stress that is a major factor in the growth and health of farmed fish (Ashley, 2007).

The possibility to measure the fish in a tank without human intervention is therefore of great interest for the aquaculture community. This has lead to the emergence of other innovative technologies such as acoustic methods (Løvik, 1987; Conti et al., 2006), model-based methods (Alver et al., 2005), or, the most remarkable, computer vision techniques (Zion, 2012). Computer-imaging techniques in aquaculture are widely used to monitor behavior and welfare of fish (Cordero et al., 1994; Kato et al., 1996;

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Conte, 2004; Kristiansen et al., 2004; Stien et al., 2007; Duarte et al., 2009), to counting fish (Costa et al., 2009), to stock identification (Cadrin and Friedland, 1999; White et al., 2006), and to estimate size and weight (Ruff et al., 1995; Bedow et al., 1996; Sheih and Petrell, 1998; Tillett et al., 2000; Lines et al., 2001; Martinez-de Dios et al., 2003; Costa et al., 2006, 2009; Hufschmied et al., 2011).

Most of the techniques that use the stereo-vision methodology consist in two views of a fish to estimate the fish dimensions in 3-D (Ruff et al., 1995; Bedow et al., 1996; Tillett et al., 2000; Lines et al., 2001; Martinez-de Dios et al., 2003; Costa et al., 2006, 2009). Based on this methodology, AQ1 Systems developed commercially the *AQ1 AM100* to measure and count fish in cages (AQ1 Systems, 2013). The main advantage of these methods is that they are able to measure the fish remotely avoiding the stress caused by the sampling handling. Otherwise the usual conditions in commercial facilities can limit their use because limited visibility, variations in lighting, varying distances and relative orientations between cameras and fish, and motion and density of the monitored fish. Another methodology used nowadays is the commercial development by *Vaki Aquaculture Systems Ltd*. (VAKI, 2009) that provides good dimensional information, although only a single fish can be analyzed and it has to swim through a frame.

Although these methods have proven effective and non-intrusive, they have been used mainly with pelagic fish. These techniques are difficult to implement in flatfish facilities due to its behavior and morphological characteristics. They are relatively inactive species that remain most of the time motionless in the bottom of the tank, therefore they use mainly the surface area instead of the water column and usually they are kept at densities higher than 100% of coverage area. Taking advantage of the relative immobility and benthic behavior of flatfishes, Oca et al. (2007) proposed a laser scanning method based on image analysis. Laser scanning is a prosperous data acquisition method with rapid development since the mid 1990s because it allows an automated sampling of the object surface within a short time (Pfeifer and Briese, 2007). Structured light or laser scanning involves projecting a pattern of light onto the target acquiring a multitude of *XY* or *XYZ* coordinates (2D or 3D analysis, respectively) from the surface of the object. The laser scanning technique is used in a wide variety of industries, among others, in manufacturing, aerospace and electronic industries. Also in the healthcare sector, for instance, to manufacture prosthesis. In security industries, it is used in some airports for face recognition-based systems (Bogue, 2010), and increasingly, it is used in agriculture (Rosell et al., 2009; Igathinathane et al., 2010). In fisheries, Storbeck and Daan (1991) also used satisfactorily (±5% of error) the laser light combined with image analysis, to estimate individually weight of dead flatfish to sort them on board of the ship before they were stored.

Almansa et al. (2012) used the laser scanning method to evaluate turbot distribution in a raceway tank under different water conditions in a commercial facility with high stocking density (around 30 kg m^{-2}). In that work, the possibility to use the same methodology to estimate the fish volume of a turbot (*Scophthalmus maximus*) population with a low coefficient of variation (lower than 10%) in a non-invasive way was pointed out. The volume of fish was converted into total biomass assuming that fish density was equal to water density.

The aim of the present work is to validate the feasibility of the laser scanning technique to estimate the fish biomass of sole populations with different individual fish size and at different stocking densities.

Senegalese sole (*Solea senegalensis*) is a flatfish of high commercial value and demand in the European market (Morais et al., 2014) because of its fast growth rates and high market price (Imsland et al., 2003).

2. Material and methods

2.1. Rearing and fish conditions

The study was carried out in the facilities of the Escola Superior d'Agricultura de Barcelona at the Universitat Politècnica de Catalunya – BarcelonaTech. Fish were held in a raceway tank with a recirculation system. Four different fish densities of sole (*S. senegalensis*) were tested: very low (VL), low (L) medium (M) and high (H) (Table 1). Two different sizes of sole were used and kept in two different tanks. For VL fish density the individual weight was 3.0 g ± 1.1 (mean ± SD) and they were kept in a raceway tank measuring 16 cm wide, 100 cm long and 5 cm of water depth. For L, M, and H densities the fish had 234.0 g ± 84.6 (mean ± SD) of individual weight. The standard weighing of fish was carried out by removing the fish from the water and anesthetizing them (2-phenoxyetanol solution, 0.4 ml L^{-1}) to obtain their individual weight.

In these trials (L, M and H) the fish were kept in a raceway tank measuring 40 cm wide, 310 cm long and 10 cm water depth. To get the different rearing fish density, the number of fish and the rearing area for each treatment were adjusted. The size of the rearing area was limited avoiding the access of the fish to some part of the tank. The use of a net was discarded for this objective because it would have distorted the reflection of the laser in the area adjacent to the net, since the laser beam is projected at an angle. Different materials were tested to check the level of rejection by the soles. Finally the artificial grass was used because it prevented fish from staying in the area.

The dimensions of the tank, the number of fish, their individual weight, and the resulting stocking density are summarized in Table 1.

Fish were fed daily around 1% BW with a commercial pelleted diet for soles (Skretting Gemma Diamond 1.5 for smaller and Skretting Elite Le-7 for bigger fish). The water temperature was 22.5 °C ± 0.9; dissolved oxygen 8.0 mg L^{-1} (109.5% saturation ± 12.4); pH 7.34 ± 0.1; and salinity 38 g L^{-1}.

2.2. Laser scanning measures

2.2.1. Image acquisition

A laser lighting scanning technique described by Almansa et al. (2012), with some modifications, was used to measure the fish layer volume of *S. senegalensis*. On the ceiling on top of the tank, a system of mobile rails was set. A digital camera (Nikon Coolpix P6000, 4224 × 3168 pixel of image resolution) and a laser light device (Lasiris SNF 20 mW, with wavelength of 440–710 nm) were fixed in opposite directions with an inclination of 45 degrees (Fig. 1).

Table 1
Stocking conditions.

Qualitative fish density	Tank dimensions (cm × cm)	Number of fish	Mean fish weight ± SD (g)	Stocking density (kg m^{-2})
Very Low (VL)	100 × 16	22	3.0 ± 1.1	0.4
Low (L)	270 × 40	27	234.0 ± 84.6	5.8
Medium (M)	190 × 40	39	234.0 ± 84.6	12.0
High (H)	100 × 40	39	234.0 ± 84.6	22.8