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IMAFISH_ML: A fully-automated image analysis software for assessing fish morphometric traits on gilthead seabream (*Sparus aurata* L.), meagre (*Argyrosomus regius*) and red porgy (*Pagrus pagrus*)

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ABSTRACT

A fast and fully automated software for image analysis (named *IMAFISH_ML)* was developed to measure 27 fish morphometric traits (technological traits) on three commercially relevant fish species: gilthead seabream (*Sparus aurata* L., from 12.5 to 36.6 cm length), meagre (*Argyrosomus regius*, from 17.5 to 58.4 cm length) and red porgy (*Pagrus pagrus*, from 16.3 to 29 cm length). This analysis was performed by using two images of each fish from different angles (lateral and dorsal). The computer vision algorithm was programmed in MATLAB® v.7.5 and is freely available to aquaculture industry and research, and it is possible to modify or combine traits in order to obtain new ones, according to specific interests and competence. Additionally, an appropriate, easy-to-perform and reproducible protocol to take photographs was also described. In order to validate the software, 500 fish of each species were laterally and dorsally photographed, and the images were processed by using the *IMAFISH_ML*. Each fish was manually processed to measure its fork length, body weight and fillet weight (phenotypic traits). Correlation coefficients between each fish technological and phenotypic traits were calculated, all of them were statistically significant ($P < 0.01$). Fork length measured by technological and phenotypic methods showed correlation coefficients between 0.98 and 0.99. The average photograph processing time was 10 s and 9.7 s for lateral and dorsal images, respectively. *IMAFISH_ML* software provides fish farmers and researchers with an efficient, fast and automatic tool to objectively asses morphological and growth traits. It is a practical and economical way to evaluate products for industrial purposes. Moreover, it is an especially useful tool to be included within genetic breeding programs, as it provides a high number of fast, easy-to-perform and non-invasive traits measurements, which additionally can be correlated to other production traits.

1. Introduction

According to the UN Food and Agriculture Organization (FAO), the global production of food must continue increasing in order to satisfy the increasing demand (APROMAR, 2014). Food from marine origin is an important part of people protein demand; and, currently, more than the half of this food comes from aquaculture. In addition, consumers' awareness is also increasing, and they demand high quality food. Gilthead seabream (*Sparus aurata* L.), meagre (*Argyrosomus regius*) and red porgy (*Pagrus pagrus*) are marine species well established in consumers' eating habits. Gilthead seabream is the most important Mediterranean aquaculture marine species: its total production reached 179,924 tons in 2013 (APROMAR, 2014). Meagre and red porgy constitute new aquaculture species and have been recently cultured in the European area, since they are well known and appreciated species among consumers and, additionally, their production systems are well adapted to farming conditions.

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There is an increasing need for aquaculture companies' to improve their competitiveness by optimizing their production and/or by increasing their products quality. The standardization of non-invasive measurement methods and their application on industrial processes minimizes costs, increases the fish measurement rate and maximizes their products added value. This challenge can be partly addressed by investing on scientific knowledge and technological innovation. In that context, biotechnology, together with genetic improvement, plays an especially relevant role. The positive results of considering genetic improvement programs in domestic animal species are remarkable, as annual rates of genetic improvement of 1–3% have been described (López-Fanjul and Toro, 2007). In aquaculture, genetic improvement programs have been successfully implemented in seawater fish, such as salmonids, cyprinids, tilapia, catfish (Gjedrem, 2012). In marine aquaculture, the first genetic breeding program in Spain for gilthead seabream (PROGENSA®) has been developed in collaboration with six Spanish aquaculture companies and four research centers (Afonso et al., 2012; Lee-Montero et al., 2015). In meagre, the first genetic parameters for growth traits have been estimated (Soula et al., 2012a); and, in red porgy, physical tagging systems and multiplex PCRs for the genetic identification have been developed to be introduced in breeding programs (Navarro et al., 2008; Soula et al., 2012b). However, to improve selection efficiency, traits information must be recorded in an objective and precise manner (without personal bias) and at a low cost (Gjedrem, 1997).

Image analysis technologies allow the objective measurement of lineal and dimensional morphological traits, as well as a fast report of reproducible and reliable information. This is useful for genetic improvement programs, which require large number of samples. Another advantage of using image analysis is the availability of images. Collections of digital images can be posted online and serve as easily accessed and sharable archives for researchers and fish farmers (Petrtýl et al., 2014). During the image analysis process, objects are distinguished from background, and numerical information is produced from the captured image. This process includes the following steps: image acquisition, image digitalization, image improvement, image segmentation and measurement operation (Dowlati et al., 2012). Computer vision is the construction of explicit and meaningful descriptions of physical objects from images. A computer vision system generally consists of illumination, a camera, computer hardware and software.

The application of image analysis technology is increasing in the food industry. It replaces the subjective human vision by automatic processes of image analysis for the evaluation of shapes and colors of fruits and vegetables (Du and Sun, 2004; Costa et al., 2011). In aquaculture, there are many potential applications for this technology, which could improve the product quality and the production efficiency (Zion, 2012). An increasing number of studies include image analysis for different purposes in fish farming (Zion, 2012). Several image-analysis-based softwares have been developed to evaluate color and fillet fat content in salmonids and cichlids production (Korel et al., 2001; Stien et al., 2006; Kong et al., 2007; Yagız et al., 2009). Many softwares have been developed in order to identify species (Storbeck and Daan, 2001; Trapani, 2003; White et al., 2006; Zion et al., 2007; Hosseini et al., 2008), to count living fish (Merz and Merz, 2004), to evaluate shape variation (Loy et al., 2000; Blonk et al., 2010; Costa et al., 2015) or to estimate the fish size (Martinez-de Dios et al., 2003; Costa et al., 2006; Balaban et al., 2010a; Balaban et al., 2010b; Torisawa et al., 2011). All these softwares have proven to be successful. However, many of these softwares do not offer the information in a totally automatic manner from image analysis, they require manual establishment of certain specific points. This is a great limitation in large scale studies, such as a genetic selection programs.

In view of the above, the main objective of this study was to develop a fully-automated software for image analysis, in order to determine morphometric traits in three commercially interesting fish species: gilthead seabream, meagre and red porgy; and to validate this software by analyzing 500 fish of each species (total 1500 fish). This would provide fish farmers and researchers with a highly efficient tool to be used within genetic breeding programs or in large scale assessments of fish product. Another additional objective was the development of an adequate and reproducible protocol to capture images.

2. Materials and methods

2.1. Image capture protocol

Two photographs from each fish were taken: one lateral image and one dorsal image. Photographs were taken without any outer light influence. To get that, a small dark room with metallic structures covered with black plastic film was used. An Olympus digital camera (FE230/X790, Olympus lens 6.3 to 18.9 mm, f3.1 to 5.9, equivalent to 38 to 114 mm on a 35 mm camera) was fixed to the table. The camera has a 3× optical zoom lens and the lens has a maximum aperture of f3.1 at wide angle. However, the zoom was fixed during the calibration step in order to maximize the area of the fish in the image. Once fixed, it remained unchanged during all the acquisitions of the database. In order to obtain a homogeneous illumination, two Tubular fluorescent lamps 16 mm HE 14 W/827 with 2700 K color temperature (HE 14 W/827 LUMILUX T5 HE Product Datasheet by OSRAM available at: http://www.osram.com/osram_com/products/lamps/fluorescent-lamps/fluorescent-lamps-t5/lumilux-t5-he/index.jsp) were used. They were placed equidistantly to the camera and perpendicularly to the fish anteroposterior axis (from head to tail) (Fig. 1). The front-light is chosen instead of the back-light (better for silhouette detection) in order to increase the quality of the texture inside the fish (e.g. fin details). This front-light illumination produces specular reflection but it appears in regions with moderate importance in our study (mainly in fish scales). This disposition reduces fish image shades formation and improves fish measures accuracy (fin detection) and reliability, since shadows formation and reflection affect negatively the segmentation process. In addition, the acquired images show a good contrast which allows the analysis of other regions such as eyes (not included in this work).

After conducting contrast tests in each species, a red background for lateral images and a white background for dorsal images were used. These backgrounds made easier to segment the fish. To get these differently colored backgrounds, two wood

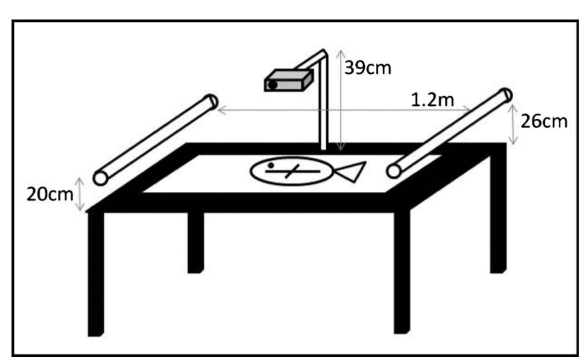

Fig. 1. Light source (two fluorescent tubes of 89.46 cm and 30 W), digital camera and fish positions for the capture of images. The background was red for lateral images and white for dorsal images, and it showed a small cross just under the camera in order to place the fish just under the camera objective.