Aquaculture 420–421 (2014) 171–179

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aqua-online

Review

Food and faeces settling velocities of meagre (*Argyrosomus regius*) and its application for modelling waste dispersion from sea cage aquaculture

Óscar Pérez [a,*], Eduardo Almansa [b], Rodrigo Riera [a], Myriam Rodriguez [a], Eva Ramos [a], Janina Costa [a], Óscar Monterroso [a]

[a] Centro de Investigaciones Medioambientales del Atlántico (CIMA SL), Arzobispo Elías Yanes, 44, 38206 La Laguna, Tenerife, Canary Islands, Spain
[b] Instituto Español de Oceanografía, Centro Oceanográfico de Canarias, Avenida 3 de Mayo 73, Apdo. 1373, 38005, Santa Cruz de Tenerife, Canary Islands, Spain

ARTICLE INFO

Article history:
Received 27 August 2012
Received in revised form 5 November 2013
Accepted 6 November 2013
Available online 14 November 2013

Keywords:
Meagre
Argyrosomus regius
Settling velocity
Faeces
Food
Dispersion model

ABSTRACT

Particulate wastes (uneaten feed and faeces) are assumed to cause the most intense impact on the benthic community beneath aquaculture cages. Settling velocity of uneaten feed pellets and faecal material, required as model input data, represents a key parameter for waste dispersion models. In this study, settling velocity rates of two commercial meagre (*Argyrosomus regius*) feed pellets (EFICO Sigma 578 — Biomar 9 and 12 mm) and faecal material from two size categories of cultured meagre (small: 0.821 ± 0.157 kg; large: 1.663 ± 0.371 kg) were determined. Settling velocity for Biomar 9 and 12 pellets followed a normal distribution, with mean values of 9.83 ± 0.17 cm s^{-1} (n = 78) and 9.67 ± 0.28 cm s^{-1} (n = 76) respectively and 9.75 ± 0.24 cm s^{-1} for all data (n = 154). On the contrary, faecal particle settling velocity data did not comply with normal distribution assumptions. Settling rates were not significantly different ($P = 0.37$) between the two meagre size categories, but significant variation ($P < 0.001$) in settling velocity between all interval categories was found. Settling velocities generally increase with particle size. Particles with slow settling velocities (<1 cm s^{-1}) dominated samples (87.0%) and fast settling velocities (2–3 cm s^{-1}) were uncommon, with values of 1.1%. Yet, particles with small settling velocities (<1 cm s^{-1}) only account for 38% of the mass. Particles with medium settling velocities (1–2 cm s^{-1}), in which frequency distribution was much lower (12%) had the highest mass distribution, 51%. Waste dispersion modelling scenarios based on specific meagre settling feed and faeces settling velocity data, resulted in a wider dispersion area and lower flux values, hence in a smaller severity of predicted deposition, when compared with model output scenarios based on non-specific sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus aurata*) settling velocity data.

Contents

1. Introduction

There are many forms of wastes produced in marine fish cage aquaculture, however particulate waste in the form of uneaten feed and faeces (undigested fraction of feed) is believe to be the primary cause of

* Corresponding author.
E-mail address: oscarperez@cimacanarias.com (Ó. Pérez).

0044-8486/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.aquaculture.2013.11.001

ecological impact on the benthic community beneath cages (Beveridge, 2004; Riera et al., 2011; Vezzulli et al., 2003). This material, which generally settles on the seabed near the cages, provides a net input of organic carbon and nitrogen to sediments, thus waste accumulation can cause major changes in the benthic community and may exceed environment's capacity to bioprocess this material (Kalantzi and Karakassis, 2006; Papageorgiou et al., 2009, 2010; Telfer et al., 2009).

Modelling waste input and seabed distribution is a cost-effective tool that has been widely used to assist in the prediction of future impacts and aid decision-makers. Regulatory authorities are increasingly turning to predictive models to make informed decisions when licencing new marine fish farm and granting consents to discharge waste (Chamberlain and Stucchi, 2007; Dudley et al., 2000; Henderson et al., 2001; Read et al., 2001). However, outside the academic field, models have been sometimes indiscriminately used without knowledge of its real capabilities and limitations and hence, making results not reliable and of very limited or not use to environmental managers and regulators. This is mainly because most used models are general hydrodynamic models coupled with a Lagrangian particle module, which are not specifically developed and validated for fish cage aquaculture and their correct parametrization and setup are very complex. The use of these models within the private sector and administrations normally does not include important factors which describe dispersion and fate of particulate wastes from sea cages (Tironi et al., 2010), such as specific settling velocity for different pellet sizes, specific settling velocity for different faeces fraction and for different culture species, horizontal and vertical starting position of feed pellets and faeces within the cages (surface, middle, bottom, random, etc.), cage size (diameter and depth), cage shape, culture species within each cage, amount of feed input and hence faecal material individualised for each cage. On the other hand, the few available dispersion models for fin fish aquaculture (i.e. DEPOMOD, MERAMOD, CODMOD, MOM, etc.) are built for a specific geographical area, such as Scotland, Norway or the Mediterranean, thus have been parameterized with data to suit environments and fish species grown in that particular region (Cromey et al., 2012). As pointed out by Cromey et al. (2009), in order to utilise these models to predict impacts of new culture species, measurements of species-specific model parameters are required, but it is not necessary to re-validate the physical processes e.g. particle advection, which are non-species specific. Settling velocity of uneaten feed pellets and faecal material required as model input data, has shown to be a key parameter for the prediction accuracy. Settling characteristics are different depending on fish species, size and feed composition (Chen et al., 1999a,b). Most available data refers to species that have been extensively grown, such as Atlantic salmon (*Salmo salar*) (Chen et al., 1999a,b, 2003; Cromey et al., 2002; Elberizon and Kelly, 1998; Panchang et al., 1997). Recently, several studies have carried out detailed settling rate experiments in new species, such as gilthead sea bream (*Sparus aurata*), sea bass (*Dicentrarchus labrax*) (Magill et al., 2006; Piedecausa et al., 2009; Vassallo et al., 2006) and cod (*Gadus morhua*) (Cromey et al., 2009).

As aquaculture industry expands, there are new species that are currently grown such as meagre *Argyrosomus regius* (Asso, 1801). Meagre is a very interesting species for aquaculture due to its high flesh quality and flavour, high commercial value over 2 kg, rapid growth and good feed conversion ratio (Monfort, 2010). Its commercial culture started in France in 1997, spreading through the Mediterranean area in the 2000s, starting in Italy and Spain and most recently in Cyprus. Reported production figures for 2010 (FAO, 2012) are 14.634 tonnes worldwide, corresponding to a market value of US$ 47.7 million. Egypt is the top country with 84% of the overall production, with a market value of 73%. On the contrary, Europe only counts for 16% of the overall production, but its market value is up to 27%. Within Europe, Spain is the largest producer, with 78%, followed by France with 17%. Nevertheless, to our knowledge there is no available data for food and faeces particle settling rates, therefore waste dispersion modelling for meagre has to be done using values for other species, such as salmon, sea bream or sea bass, which may not be representative.

The purpose of this study was to accurately determine settling velocities of food (fish pellets) and faecal material for the meagre *A. regius* culture in the Canary Islands. Furthermore, these values will be used in an existing tailor-made fish farm waste deposition model (MERAMOD), to assess the importance of different representations of these data when compared with the use of generic settling rates from other species (sea bass and sea bream).

2. Materials and methods

2.1. Food pellet settling velocity

Two commonly used meagre feed pellets were used in the settling velocity experiment, EFICO Sigma 578 (Biomar) 9 and 12 mm. Hereafter, we refer to feed types according to the brand and nominal diameter of the cylindrical feed pellets: Biomar 9 and Biomar 12. Diameter, length, weight and density were determined in a random sample of 100 pellets of each type. Diameter and length were determined using a precision gauge ($\pm$0.5 mm) and pellets were weighted using an analytical balance ($\pm$0.1 mg).

Using a methacrylate settling column ($l = 2$ m; internal $\Phi = 30$ cm), filled with non-filtered seawater (20.2–20.4 °C; 36.6 PSU), pellets were carefully placed with forceps in the centre and just below water surface, avoiding bubbles. A marked section of 10 cm, placed 40 cm up from the base of the column to allow particles to reach terminal velocity (after a period of initial acceleration, particle velocity will be constant, reflecting the balance between forces causing settling and forces resisting settling) and avoiding velocity interferences with the bottom, was filmed using a SONY HDV 1080i miniDV camcorder mounted on a tripod, fitted with zoom lens (F: 1.8/5.4 ~ 54 mm). To minimize perspective errors, the longest focal length or slightly less was used to adjust the field of view to the whole width of the column. The seawater volume was completely renewed between experiments to maintain similar water properties.

Digital settling food pellet footages were analysed on a desktop PC, enabling time and position of individual particles to be recorded as particles entered and exited the field of view and calculating accurate settling velocity (system accuracy: timing = 0.01 s). The methodology relied on visual detection of particles on screen, both entering and exiting the filmed 10 cm section. For each experiment, the total number of pellets was determined, except particles that came into contact with the tube wall during the fall, which were excluded.

2.2. Faecal material settling velocity

Settling velocity rates of two size categories (small and large) of cultured meagre were determined, using a modification of the method presented by Magill et al. (2006) and later revised by Cromey et al. (2009), for determining faecal settling rates of a large number of particles. A sample of 10 fishes per category (small: 0.821 $\pm$ 0.157 kg; large: 1.663 $\pm$ 0.371 kg) was obtained from a commercial fish farm in the south of Tenerife (Canary Islands, Spain) and transferred to rectangular 1000 m^3 tanks supplied with running seawater without filter, to simulate sea cage conditions. Fish were allowed to acclimate during two weeks before starting the trials. During all acclimatising period and experiment time, fish were fed ad libitum with commercial meagre pellets, Biomar 9 and Biomar 12 for small and large meagre respectively, in a 'commercial feeding regime', once per day during the morning. Tanks were completely cleaned before feeding. Faecal material was collected during 3 h after feeding by syphoning the faeces from the tanks. Collected material was transferred to a settling column and gently introduced at regular intervals sub-surface. Experiments were performed in the settling column described above, but filmed for longer periods (maximum of 30 min) allowing time for smallest particles to settle in the column.