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Comparison between some procedures for monitoring offshore cage culture in western Mediterranean Sea: Sampling methods and impact indicators in soft substrata

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Abstract

Two sampling methods, an array of physical–chemical and biological indicators, and uni-multivariate statistical procedures were compared on the basis of sensitivity to detect any impact and cost-effectiveness criteria, applied to environmental monitoring of fish farming. Sampling was conducted in a western Mediterranean gilthead seabream (*Sparus aurata*) and meagre (*Argyrosomus regius*) farm (San Pedro del Pinatar, SE Spain). Both sampling methods (Van Veen grab vs SCUBA diving) provided similar results for all the parameters except redox potential. The most sensitive chemical parameters of the sediment were total phosphorus, total ammonium nitrogen and acid volatile sulphide, but the latter was the only one which correlated with the macrobenthic community structure. The application of univariate methods to biological indicators only showed a clear trend in two (AMBI and BENTIX) of the five indices used. Both biotic indices, although statistically correlated with the spatial pattern of the macrobenthic community, provided different quality status categorization that could lead to misinterpretation and so, validation in offshore conditions is required. Nevertheless, multivariate analysis of macrofauna confirmed a noticeable spatial pattern, at the same time that this statistical strategy has been proven and validated in a wide range of marine community studies.

Keywords: Cage aquaculture; Monitoring; Biological indicators; Physical–chemical indicators; Sampling methods; Multivariate analysis

1. Introduction

The overall objective of the European Water Framework Directive (WFD, 2000/60/EC) is to achieve a “good ecological quality status” for all water bodies (including inland surface waters, transitional (= estuarine) waters, coastal waters and ground-waters) by 2015. Likewise, WFD urges the development of tools that allow the ecological quality status to be established and monitored, based upon biological, hydromorphological and physical–chemical criteria, and under the premise of simplicity but accuracy. Since cage mariculture uses seawater and the surrounding environment as resources, these WFD criteria can be directly applied to monitoring aquaculture environment interaction and the ecological status of the influenced area.

As regards the effects of fish farming on the benthic environment, the aquaculture environment interaction is well documented (Costa-Pierce, 1996; Brooks et al.,

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2002), and in recent years, a great number of scientific papers have been published with respect to the application of chemical criteria (Hargrave et al., 1997; Chou et al., 2002; Aguado-Giménez and García-García, 2004; Hyland et al., 2005; Yokoyama et al., 2006), biomarkers (Vezzulli et al., 2002; Focardi et al., 2005), microbiological indicators (La Rosa et al., 2004; Caruso et al., 2003; Zaccone et al., 2005) macrobenthic indicators (Karakassis and Hatziyanni, 2000; Edgar et al., 2005; Lee et al., 2006; Mallet et al., 2006) and modelling (Henderson et al., 2001; Cromey et al., 2002) for the assessment and monitoring of fish farm impacts. The selection of an indicator depends on both sensitivity and cost-effectiveness, and from a rigorous monitoring programme point of view, the selected parameters should be coupled so that any clear cause–effect relationships can be deduced (Hodson, 2002).

A diverse array of sampling methods are currently available to study soft-sediment habitats and their biological assemblages, and selection of a method will depend very closely on the objectives of the study, the logistical and economic resources available and the physical nature of the study area (Morrisey et al., 1998). The most frequently used sampling methods in aquaculture monitoring programmes on soft substrata are benthic grabs (particularly Van Veen grab) and diver-operated hand grabs or cores (Aguado-Giménez et al., 2004). The cost-effectiveness balance between the sensitivity of a set of quality indicators and the sampling method in a monitoring programme is often a source of conflict between aquaculture businessmen and environmental managers. There are very few studies on cost-effective monitoring directly applied to marine cage culture (Wildish et al., 2001), although many works attempt to determine the optimum effort applicable to several ecological disciplines that are also applicable in mariculture monitoring programmes (Warwick and Clarke, 1991; Olsgard et al., 1998; Ferraro and Cole, 2004).

The aim of this work was to assess the suitability of two sampling methods comparing them in terms of cost-effectiveness (sampling costs and data reliability), and of several biotic and abiotic parameters for deducing cause–effect relationships in the cage aquaculture environment interaction in soft substrata, and their potential use as tools to monitor the ecological status of the surrounding area.

2. Materials and methods

2.1. Fish farm facilities

The cage fish farm (A in Fig. 1) was located 4.8 km east off the coast of San Pedro del Pinatar (Murcia, SE Spain: 37° 48.941′ N; 00° 41.731′ W). It was composed of 18 offshore sea cages, 16 m diameter and 15 m net depth (approximately 3000 m^3 per cage), with a total production of 400 tonnes per year of gilthead seabream (*Sparus aurata*) and meagre (*Argyrosomus regius*). The fish farm started its activity in October 2000, reaching its maximum production level in May 2001. The fish were fed manually once a day with extruded diets, and the estimated feed conversion ratio (supplied food/weight increase) was 2.6. Three fish farms (B, C and D in Fig. 1) and a floodway stream and a sewage emissary are located 2 km east and 7 km north, respectively.

2.2. Study area

The seabed has a very slight slope and the depth ranges from 36 to 38 m. During the study, the water temperature ranged from 15.1 °C at the bottom to 26 °C at the surface, salinity was around 37‰ and dissolved oxygen was always close to 100% saturation. The average and maximum current speeds were 26.9 and 48.7 cm s^{-1} respectively at −5 m depth, 11.3 and 13.7 cm s^{-1} at −15 m depth, and 8.7 and 10.6 cm s^{-1} at −35 m depth. The prevailing current directions were NNW and SSE, but predominantly towards SSE and the potentially affected zone would be within a radius of less than 1 km in the prevailing directions (Aguado-Giménez and García-García, 2004). Sampling stations were placed along a transect following the main current stream and dispersion of wastes (Fig. 2): below the cages (0), 100, 200 and 500 m north and south (N 100, N 200, N 500, S 100, S 200 and S 500), and one control station (C) located 1.8 km to the south. Four replicates were randomly taken in each sampling station. Sampling was carried out in July 2004 coinciding with the period of greatest growth and food supply, and maximum biomass stocked.

2.3. Sampling methods

Samples were taken in two different ways. First, sampling was made with a stainless steel Van Veen grab (VV) with a surface area of 0.04 m^2 and a maximum penetration of 10 cm, provided with top opening flaps for access and visual examination, and inner marks for volume estimate. Once the VV sample was on board, the sample volume was estimated and the pH and Eh were measured; sub-samples were taken with small PVC cores (5 cm diameter × 5 cm depth) and transferred into labelled plastic containers, being cooled-transported to the laboratory for analysis. The other sampling method was SCUBA-diver-operated (SD) samplers: hand grabs and cores. The hand grab consisted of a stainless steel box (20 × 20 × 8 cm: approximately the same maximum