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Do benthic biofilters contribute to sustainability and restoration of the benthic environment impacted by offshore cage finfish aquaculture?

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ABSTRACT

Benthic biofilters were deployed under a cage fish farm and in two reference locations to assess the influence of the farm on the biofilters and the surroundings, as well as to verify the usefulness of this technology as a mitigation tool. The biofilters underneath the farm recruited a fouling community practically identical to that of the control biofilters, which included a variety of trophic strategies. The former showed a higher ^{15}N enrichment, indicating that fouling beneath the farm was benefiting from the farm waste. The waste retention efficiency was low (0.02 g N m^{-2} $month^{-1}$) beneath the farm. Benthic biofilters aggregated demersal wild fish around and within them. Pelagic wild fish also frequently used the biofilters beneath the farm, forming compact shoals around them. The increased complexity of the habitat below the fish farm enhanced biodiversity, but this improvement did not lead to the recovery of the sediments around the biofilters.

1. Introduction

The influence of organic waste derived from marine fish cage aquaculture on the benthic environment has always been considered as the main concern in aquaculture–environment interactions (Brooks et al., 2002). Several attempts have been made to prevent, ameliorate or remedy these effects, e.g. air-lift systems to collect waste, sediment dredging, the dispersal of waste by mean of submersed mixers, harrowing the seafloor, etc. (Beveridge, 1987 and references therein), but none of these methods can normally be considered acceptable under offshore conditions (Angel and Spanier, 2002).

Increased nutrient and food availability in cage aquaculture areas stimulate the proliferation of high diversity hard-substrata epibenthic communities attached to infrastructures such as cages, nets, ropes and buoys (Bongiorni et al., 2003; Sarà et al., 2007). Also, wild fish aggregate around fish farms due to food and shelter availability, which has been postulated as an "ecosystem service" (Dempster et al., 2009), since both benthic organisms and wild fish consume dissolved nutrients, surplus feed and feces, recycling waste and reducing particulate sedimentation around farms. In view of these facts, the use of artificial structures as biofilters in the pelagic (Cook et al., 2006; Tsemel et al., 2006) and benthic (Angel et al., 2002; Gao et al., 2008) environments has been investigated for the purpose of mitigating a farm's environmental impact.

The deployment of artificial structures on the seafloor can stimulate biological productivity around them (Bohnsack and Sutherland, 1985; Bombace, 1989), even in the surrounding soft bottom infaunal communities (Ambrose and Anderson, 1990; Barros et al., 2001; Danovaro et al., 2002). The application of artificial reefs to cage aquaculture for the purpose of mitigating the environmental impact has been evaluated in the Red Sea (Angel et al., 2002) and in the China Sea (Gao et al., 2008). Angel et al. (2002) found a greater wild fish aggregation around artificial reefs deployed under the cages as compared to control reefs. They also found a huge fouling biomass attached to the reefs, but the differences between farm and control reefs were inconsistent. In addition, these authors did not find significant changes in the organic matter content of the sediments around the reefs. Conversely, Gao et al. (2008) reported a slight but significant improvement in the sediment biotic and abiotic conditions around artificial reefs deployed beneath a fish farm.

In light of these findings, we planned the present work under the assumption that the presence of a fish farm will influence the aggregation of fauna on benthic artificial structures deployed underneath. Increased structural and trophic complexity of the benthic habitat around an offshore finfish aquaculture facility should favor the colonization of benthic and nektonic organisms, which could participate in the reutilization of fish culture-derived waste, thereby improving the benthic environment and mitigating the environmental impact. To this end, benthic biofilter-like artificial reefs were deployed in a Mediterranean fish farming area. The

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aim was to ascertain the influence of cage fish farming on these benthic biofilters and their immediate surroundings, and to assess whether this technology could be effective in reducing seabed degradation, enhancing the recycling of waste as a result of increased biodiversity.

2. Material and methods

2.1. Manufacture of benthic biofilters

The design of the benthic biofilters (hereafter BBs) was closely based on those of Angel et al. (2002). Each BB was formed by 28 cylinders (40 cm diameter, 210 cm length) arranged in a triangular pyramid formation. Each cylinder was made from a roll of 5 mm-thick 50 mm black mesh high-density polyethylene (HDPE), reinforced with 6 polyvinyl chloride (PVC) rings. The cylinders were held together with plastic tie-wraps and 1.5 mm cotton string. The pyramid was placed on a reinforced-concrete base (250 × 250 × 20 cm) so that the final dimensions were 250 × 250 × 240 cm (Fig. 1). Six BBs were constructed in our workshop.

2.2. Study area and fish farm facilities

The study area is located off the coast of San Pedro del Pinatar (Murcia, SE Spain). The seabed consists of a detrital sedimentary floor with a very low slope (<2%) and 37–38 m depth. A cage fish farm (Fig. 1) was located 4.8 km east of the coast (37°48.941′ N; 00°41.731′ W), a site with a high degree of exposure to dominant wind and wave regimes. It consisted of 18 offshore sea cages, with a diameter of 16 m and a net depth of 15 m (approximately 3000 m^3 per cage) and a maximum authorized production of 810 tons of gilthead seabream (*Sparus aurata*) and meagre (*Argyrosomus regius*) per year. Fig. 2 shows the evolution of fish biomass and food supplied during the study period.

2.3. Experimental and sampling design

An asymmetrical design (Underwood, 1993, 1997; Glasby, 1997) was used with one impacted and two control locations. Two BBs were deployed in May 2006 in each sampling location: under the seacages (hereafter BI: BI-1 and BI-2) and in two control locations (hereafter BC: BC1 and BC2) situated 1 and 1.3 km downstream from the fish farm. BBs within a given pair were placed 150 m apart (Fig. 1), a distance considered sufficient for them to be independent from one another. Sampling was restricted by financial resources and as a result, only one BB in each pair was monitored (always the same one: BI-1, BC-1.1 and BC-2.1, as shown in Fig. 1), except for in the case of wild fish assemblage monitoring, for which both BBs in each location were sampled. We planned for a three-year study, but in autumn 2007, the company changed ownership and the facilities were progressively remodeled and the cages emptied; as a result, the study finished earlier than expected (summer 2007). All samples were taken by scuba divers. The following four aspects were studied in each area.

2.3.1. Particulate matter

Starting in the summer of 2006, and then at six-month intervals, four sediment traps were suspended from one BB in each study area. Each sediment trap consisted of four vertical PVC pipes

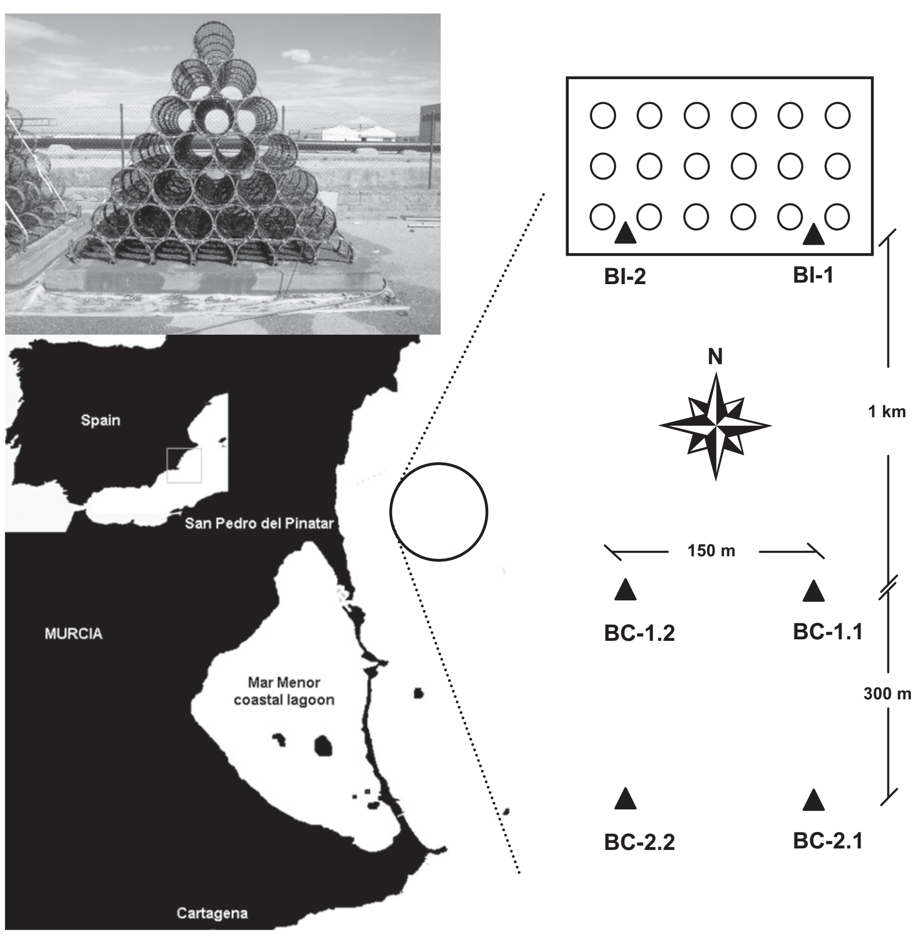

Fig. 1. Benthic biofilter design, localization of the study area and layout of the sampling stations.