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Impact of sea-cage fish farms on intertidal macrobenthic assemblages

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The influence of two sea-cage fish farms at Gran Canaria Island (Canary Islands, central east Atlantic Ocean) on the intertidal macrobenthic assemblages was studied. Two controls and two impact locations were established at each farm. The composition and coverage of the macrobenthic assemblages were surveyed every three months using image processing analyses. Significant dissimilarities were found between control and impact locations at both sea-cage fish farms. The presence of: (1) algal species tolerant to pollution (*Caulerpa racemosa* and *Corallina elongata*); and (2) filter-feeding fauna (*Anemonia sulcata*) at impact locations, indicate that the fish farming activity is causing an effect on the surrounding intertidal macrobenthic assemblages of both sea-cage fish farms.

INTRODUCTION

Coastal communities are highly susceptible to sea-cage fish farms' impacts, especially as sea-cages are frequently installed in sheltered areas in shallow waters (Rönenberg et al., 1992). Sessile intertidal organisms, because of their sedentary nature, tend to integrate the effects of long-term exposure to adverse conditions. Their distribution reflects ecological and nutritional preferences and their dependence on specific habitat conditions can identify environmental changes, as possible impacts caused by fish farming pollution on the marine coastal environment (Nedwell et al., 2002).

Since the initial development of sea-cage aquaculture in the early 1980s, the number of sea-cage fish farms has increased rapidly throughout the world. Due to the Archipelago's favourable conditions, marine aquaculture has experienced fast growth in the Canary Islands as an alternative to overexploited industrial and traditional fisheries (Boyra et al., 2002). As a result of its development, the need for a sustainable development of this sector is an essential key factor to be considered by both local farmers and administration authorities (Boyra et al., 2002).

Fish farming is now considered as a potential source of pollution in the marine environment (Ruiz et al., 2001). Intensive aquaculture production systems produce considerable amounts of nutrients in dissolved forms such as ammonia and urea, as well as in faeces and uneaten food pellets. Although these waste products are diluted and dispersed in the surrounding environment, the input of

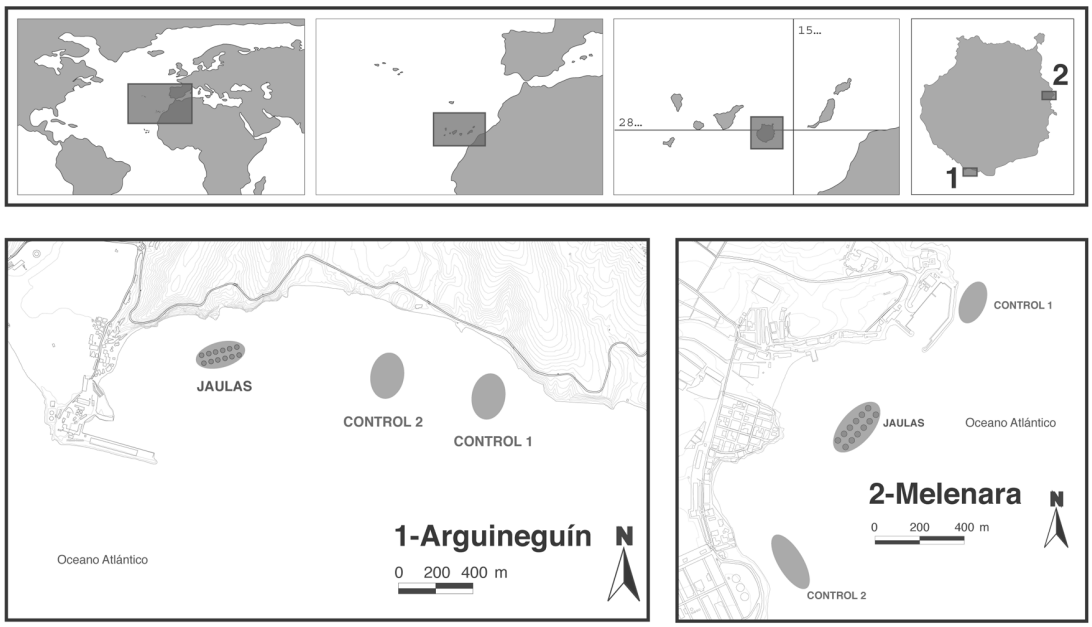

Figure 1. Map of studied sea-cage fish farms indicating control and impact study locations. I, impact locations; C, control locations.

Table 1. *Composition of macrobenthic assemblages per intertidal belt within each impact and control location at both sea-cage fish farms.*

Arguineguín Farm				Melenara Farm			
C1	C2	I1	I2	C1	C2	I1	I2
Littorina striata				*Littorina striata*			
Chthamalus stellatus				*Chthamalus stellatus*			
Algal mat				*Fucus spiralis*			
Padina pavonica		*Anemonia sulcata*		Cyanophyta beds			
		Caulerpa racemosa				*Corallina elongata*	

organic matter into the water column and the consequent nutritional enrichment of the seabed can disturb the local benthic flora and fauna (Iwama, 1991; Rönenberg et al., 1992; Karakassis et al., 1999; Ruiz et al., 2001).

Environmental impacts of fish farming on the subtidal environment have been documented on issues concerning: (1) water quality; (2) dynamics of sediment accumulation beneath fish farms and benthic enrichment (Gowen & Bradbury, 1987; Iwama, 1991); (3) biological assemblages, as sea grass meadows (Delgado et al., 1999; Ruiz et al., 2001) and filter-feeding populations; and (4) the recovery of benthic organisms after cessation of fish farming activities (Karakassis et al., 1999). However, information on the effects of sea-cage aquaculture on intertidal communities is still scarce with a lack of relevant scientific contributions.

The aim of this paper is to assess the impact caused by sea-cage fish farm activities on the surrounding intertidal assemblages. The study compares the composition and cover of the macrobenthic intertidal assemblages near two sea-cage fish farms with established control locations.

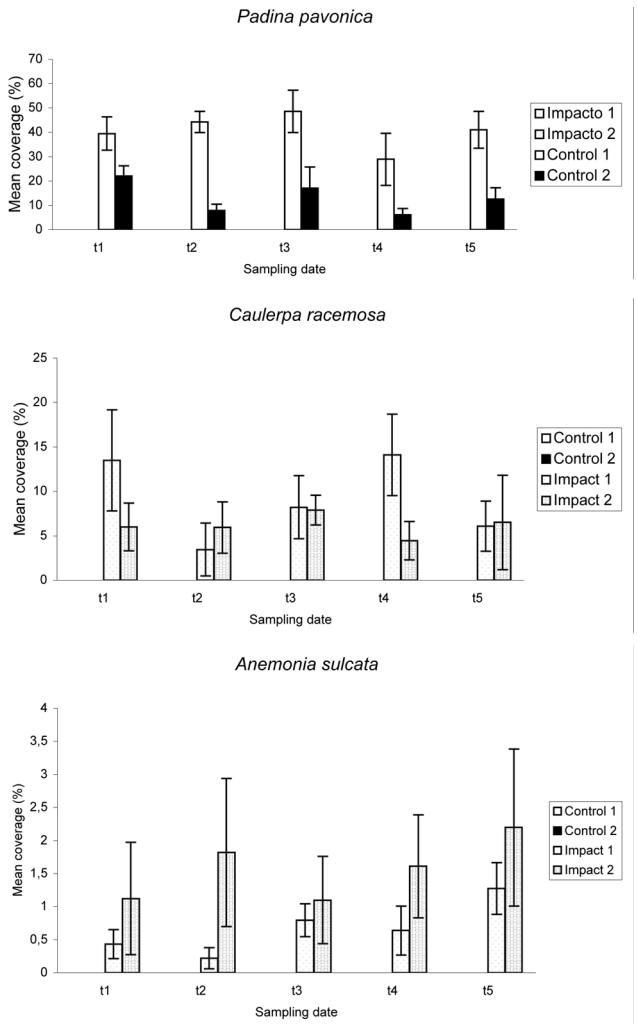

Figure 2. Mean coverage (%) of *Padina pavonica*, *Caulerpa racemosa* and *Anemonia sulcata* in the 4th intertidal belt on impact and control locations studied around Arguineguín Farm throughout the studied period (t1, May 2000; t2, August 2000; t3, November 2000; t4, February 2001; t5, May 2001). Error bars represent SE of mean values.

MATERIALS AND METHODS

Sea-cage fish farms

The study was conducted at two mixed *Sparus aurata* and *Dicentrarchus labrax* sea-cage fish farms located 60 km from each other at Gran Canaria Island, namely (1) Melenara Farm (MF) and (2) Arguineguín Farm (AF) (Canary Islands, central east Atlantic Ocean; Figure 1). Melenara Farm is located on the eastern coast, while AF is on the southern coast of the island. Both farms are situated above a sandy seabed covered by sparse patches of the sea grass *Cymodocea nodosa* and the green algae *Caulerpa* spp. Distance from the coast ranges from 200 to 300 m and depth varies from 15 to 23 m. The numbers of cages (15 m diameter, net depth=10–15 m) were 12 for each farm. Preliminary sampling was used to identify intertidal belts along coastal areas near to both study fish farms.

Experimental design and estimation of coverage

Two controls and two impact locations were established at each farm (Figure 1), following a symmetrical sampling design. Four $50 \times 50\ cm^2$ quadrats were randomly deployed per intertidal belt within each sampled location along a transect perpendicular to the shoreline. Photographs encompassing sampling quadrats were taken to assess the coverage occupied by assemblages by means of image processing analysis with the software Image Pro Plus.

Temporal replication was included by sampling five times, from May 2000 until May 2001 (1=May 2000, 2=August 2000, 3=November 2000, 4=February 2001, 5=May 2001).

Differences in species composition and coverage between control and impact locations at each studied farm are so clear and large there can be little doubt that there is a real effect. Therefore, the data can be easily interpreted visually, without the need of statistical analysis tools.

RESULTS

Arguineguín Farm

A clear difference in species composition between control and impact locations (Table 1) was found. The 4th

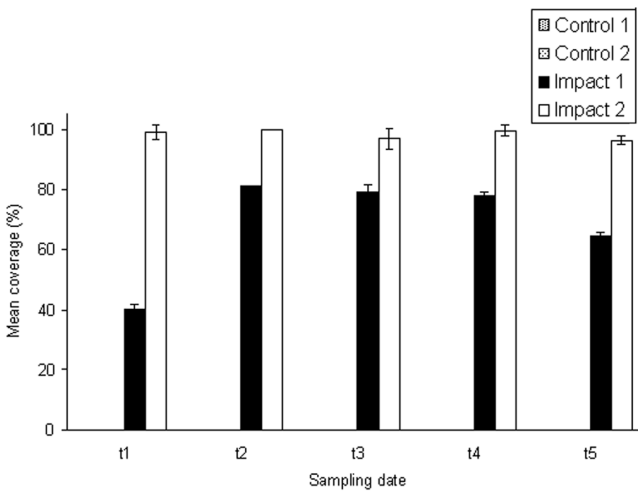

Figure 3. Mean coverage (%) of *Corallina elongata* in the 5th intertidal belt on impact and control locations studied around Melenara Farm throughout the studied period (t1, May 2000; t2, August 2000; t3, November 2000; t4, February 2001; t5, May 2001). Error bars represent SE of mean values.

intertidal belt (low intertidal zone) in both control locations was dominated throughout the study period by the brown algae *Padina pavonica*, which was otherwise absent in the low intertidal zone at both impact locations (Figure 2), where it was replaced by the green algae *Caulerpa racemosa* (Figure 2). In addition, we observed the presence in both impact locations of the sea-anemone *Anemonia sulcata*, which was not recorded in the control locations for the overall study (Figure 2).

Melenara Farm

A strong dominance of the red algae *Corallina elongata* within the 5th intertidal belt (low intertidal zone) of the two impact locations (Table 1, Figure 3) was observed. However, this macroalgae species was absent at the two control locations (Figure 3).

DISCUSSION

Arguineguín Farm

The presence of *Caulerpa racemosa* at both impact locations was recorded. This green alga is a weedy species that exhibits fast growth, with high dispersion and broad tolerance to physiological conditions. Other fast-growing green macroalgae species (e.g. *Ulva* spp., *Enteromorpha* spp.) are known to have high requirements for NO_3^- and NH_4^+ (Walentinus, 1984), caused by their high N content per unit biomass at maximum growth rates (Nedwell et al., 2002). The appearance of *C. racemosa* can therefore be related to the pollution caused by the release of waste products from animal metabolism, such as NH_4^+ and uneaten food pellets. Such input into the water column is thus capable of affecting and altering the intertidal algal communities and enables nitrofilous macroalgae (*C. racemosa*) to dominate the impacted locations.

The high level of organic matter input, caused by the waste products of fish farming activities, have been known to encourage the development of filter-feeding and detritivorous animals (Brown et al., 1990). The replacement of algae by filter-feeding animals can be considered as an indication of severe ecological disturbance (Diez et al., 1999). The presence of the filter-feeding *Anemonia sulcata*, a sea-anemone that occurs frequently in areas with a high content of organic matter in the water, seems to support additionally the suggestion that the fish farming activities are causing a disturbance on the intertidal areas around the fish farm.

Melenara Farm

The dominant presence of *Corallina elongata* has been observed at both impact locations and the complete absence of this species at the control locations. Moderate nutrient increments might favour the development of *C. elongata* (Diez et al., 1999), as this calcareous red algae has been implicated as a pollution tolerant species (Kindig & Littler, 1980), being associated with several types of environmental stresses. However, Diez et al. (1999), studying algal populations in a pollution gradient, have observed that *C. elongata* dominated sites subjected to moderate pollution, but was substituted by other, more opportunistic species, as pollution increased. Soltan et al. (2001) also found that *C. elongata* dominated moderate pollution zones, being substituted by turf-forming algae in areas with high levels of pollution. In addition, Brown et al. (1990) have noted this effect for a similar species (*Corallina officinalis*), which has shown a lower abundance in high polluted areas.

The dominance of *Corallina elongata* on the impact locations can also be influenced by the fact that this calcareous macroalgae is resistant to herbivorous grazing (Littler & Kauker, 1984). Several works have reported an intensification of grazing activity near areas exposed to high organic matter content (Wallentinus, 1991). In addition to this, sea-cages are known to attract wild fish populations (Dempster et al., 2002), since floating cages can provide structure in the pelagic environment, while the unused portion of feed that falls through the cages also enhances its attractive effect (Dempster et al., 2002). Therefore, it is possible that sea-cage fish farms can attract fish species that will increase grazing activity around the farms, granting *C. elongata* a competitive advantage over other species not so resistant to herbivores grazing.

The fact that *Corallina elongata* dominates the flora on both impact locations may therefore suggest that the fish farming activities are creating a moderate impact on the surrounding intertidal environment.

Conclusions

Clear differences have been recorded between the control and impact locations for both studied sea-cage fish farms in terms of: (1) species composition; and (2) coverage of the intertidal assemblages. Our results provide evidence of the impact that sea-cage fish farms have on intertidal assemblages. The results displayed by this work show that fish farming activities may have important ecological implications on the intertidal macrobenthic assemblages, although the role of other environmental factors leading to an overall increase of pollution in the coastal areas of the

Canary Islands should be determined. There is therefore a clear need to be carefully addressed for the planning of future development of the fish farming industry along the coastal waters of the Canarian Archipelago in relation to other anthropogenic activities and ecological value of selected areas.

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