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Assessment of site specific benthic impact of floating cage farming in the eastern Hios island, Eastern Aegean Sea, Greece

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Abstract

The site specific impact on the benthic fauna was assessed within a 4.64 km^2 area of intensive aquaculture situated on the eastern side of Hios island (Aegean Sea, Greece) at 11 stations seasonally between November 2000 and October 2001. The benthic fauna showed marked changes in species numbers, diversity and faunal abundance between farm and control sites. The polychaetes *Nereis diversicolor*, *Scolelepis fuliginosa* and *Capitella capitata* were the most dominant species at the farm sites (35% of the total abundance), whilst the most dominant species at the control sites were the polychaete *Hyalinoecia brementi* and the sipunculid *Aspidosiphon muelleri* (23% of the total abundance). Species richness, diversity and evenness were higher at the control sites whereas numerical abundance was higher at the farm sites. K-dominance curves suggest a minor impact on the benthic community at the farm sites and temporal changes on macrobenthic assemblages.

Keywords: Aegean Sea; Aquaculture; Benthos; Environmental impact

1. Introduction

Fish farming was once considered an environmentally benign practice, but is now viewed as a potential polluter of the marine environment (Findlay et al., 1995). The rapid expansion of aquaculture activities in coastal marine areas during the past twenty years has induced a general concern for the impact on critical environmental variables (Klaoudatos, 2002; Mazzola et al., 2000; Wu, 1995). Only a small proportion of the carbon supplied to the fish via the feed is retrieved through harvest, whereas a considerable amount reaches the seabed in the form of uneaten food and faeces (Hall et al., 1990; Hall et al., 1992; Karakassis et al., 2000). This may cause organic enrichment of the sediments beneath the cages (Gowen and Bradbury, 1987; Findlay et al., 1995), thereby affecting the benthic community regarding macrofaunal succession with large differences in the spatial extend of the impacts (Hall et al., 1990; Stewart, 1997; Mazzola et al., 1999; Pergent et al., 1999; Delgado et al., 1999; McGhie et al., 2000; Naylor et al., 2000; Nordvarg and Johansson, 2002).

The most evident effects of fish cages on bottom sediments are the accumulation of organic matter and the progressive transformation of the substrate into a flocculent anoxic environment (Gowen and Bradbury,

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1987; Holmer, 1991; Iwama, 1991; Henderson et al., 1997; Karakassis et al., 1998). Such changes in the physical and chemical characteristics of the sediment are in temperate latitudes restricted to the immediate vicinities of the farm (Wu et al., 1994; Karakassis et al., 1998) and generally have a strong impact on the structure and characteristics of the benthic assemblages (Brown et al., 1987; Pocklington et al., 1994; Wu et al., 1994).

Gowen and Bradbury (1987) estimated that the deposition of organic waste beneath a fish farm might be as high as 10 kg m^{-2} yr^{-1} directly beneath the cages and 3 kg m^{-2} yr^{-1} in the immediate vicinity of the farm. This level of deposition might be expected to result in changes in the ecology of macrobenthic organisms comparable with changes arising from other forms of organic enrichment such as domestic sewage and wood pulp effluent (Pearson and Rosenberg, 1978).

Changes in benthic macrofaunal community structure have been widely used to detect organic enrichment (Pearson and Rosenberg, 1978). The effects on benthic community structure of organic loading originating from fish farms are most pronounced under and in the immediate vicinity of fish cages but less so at increasing distances from farming operations (Pohle et al., 1994). The measurement of changes in the structure of marine communities in combination with appropriate environmental variables is widely used for the detection and monitoring of human impact on the marine environment (Pearson and Rosenberg, 1978; Warwick et al., 1990; Agard et al., 1993). Among the different biota the soft-bottom macrobenthos is the most widely utilised constituent for community structure analysis to study environmental impacts (Warwick, 1993). Community and sediments (Hansen, 1994) represent an integrative measure of impact over time. Enrichment effects reflect the cumulative impact from all contributing sources over large areas. Benthic community structure reflects environmental conditions, and its dynamics depend on the frequency of perturbations (Langton and Auster, 1999).

The severity of the impact of an aquaculture farm on the marine environment appears to be closely dependent upon coastal hydrology and geomorphology (Wu et al., 1994; Gillibrand and Turell, 1997; Dudley et al., 2000; Nordvarg and Hakanson, 2002; Alongi et al., 2003). Thus in some coastal areas the fish farm impacts mentioned above can become significant, whereas in others they may be insignificant. However environmental preservation is difficult since aquaculture inevitably contaminates the aquatic ecosystem due to the high fish densities and artificial feeding regimes (Loayzu, 1992; Wallace, 1993; Barton, 1997). The effects of cage farming are more apparent in semi-enclosed estuaries or fjords where water exchange and tides are limited (Wallin and Hakanson, 1991). The extent of the affected area and the recovery speed of the benthic assemblages after the fish farm removal is crucial for planning a rational use of the coastal areas for aquaculture activities.

Little is known of the fish farming impacts in the Mediterranean (Munday et al., 1994; Karakassis et al., 2000), where fish farming of marine species, particularly sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*), has grown exponentially during the last 25 years. The objective of the current study was to assess site specific impact on the benthic fauna within one area of intensive aquaculture in the eastern Hios island, Greece over time, whilst monitoring sites devoid of farming activities.

2. Materials and methods

Chios Island is geographically located in the central Aegean Sea in eastern Greece (Fig. 1). The study site covers included an area of 4.64 km^2 on the eastern side of the island with a steep seabed reaching 40 m depth within a short distance of the coastline. Physiochemical parameters of the sea water were recorded and macrozoobenthic samples were obtained. In addition the water currents were also recorded at three stations (S1, S3 and S8) for the period between November 2000 and October 2001 for stations S3 and S8 and October 2001 and January 2002 for station S1.

Sampling took place at 11 stations located throughout the sampling area eight of which included intensive culture floating cage farm sites (S1, S2, S3, S4, S5, S6, S7 and S8) and the remaining 3 were control sites (C1, C2 and C3) (Table 1, Fig. 1). The choice of control sampling stations was based on their distance from aquaculture farms substrate type and depth. These sites allow for comparisons with farm sites of similar depth and substrate type as different species inhabit different substrates and occur at different depths. Control sites C1 and C2 were chosen to be adjacent to the coastline, close to aquaculture farms and representative of benthic environments with minimal degree of stress from the adjacent aquaculture farm effluents. Control site C3 was chosen to be in the middle of the bay with a higher distance from the coastline, at a greater depth and further away from aquaculture farms as close as possible to natural environmental conditions. Sampling was carried out seasonally between November 2000 and October 2001. Five replicate samples were taken from each site according to the results of a pre-study 'power analysis' (Clarke et al., 1997). Each replicate sample of sediment