

Effects of Fish Farming on Marine Ecosystems in the Mediterranean: New Tools and Prospects

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Disturbance effects of fish farming on the seabed are well known for salmonids (Brown *et al.* 1987; Gowen & Bradbury 1987) as well as for the Mediterranean Sea bream and sea bass farming industry (Karakassis *et al.* 1998, 1999, 2000). These effects are in general similar to the model of macrobenthic succession along gradients of organic enrichment (Pearson & Rosenberg 1978). During the last 20 years, the fish farming industry in the Mediterranean has grown at an almost exponential rate facing strong local reactions by other users of the coastal zone. Three EU funded research projects namely MERAMED (Modelling environmental response to Aquaculture in the Mediterranean), AQCESS (Aquaculture and Coastal Economic and Social Sustainability) and MedVeg (Effects of nutrient release from Mediterranean fish farms on benthic vegetation in coastal ecosystems) have been carried out addressing the problem of environmental impacts of aquaculture. Results from these projects and reanalysis of data from different experiments pooled together have been used to derive quality indicators and to assess the reliability of benthic data as a means to assess environmental health of the sedimentary environment along with cost-effectiveness of the sampling protocols used. This type of data are very suitable for testing hypotheses on benthic indicators since they involve strong environmental gradients over relatively short distances thereby allowing for detection of impacts on benthic communities without the confounding effects of multiple gradients that could be present in large spatial scales.

Benthic samples were sequentially sieved through 1 and 0.5 mm sieves. The biomass fractionation ratio (biomass having passed through 1mm and retained only on 0.5 mm sieve/ total biomass > 0.5 mm) provides a simple and inexpensive method for assessing the effects of fish farming on benthic communities. The ratio was found to decrease consistently with distance from fish cages and particularly after 10m from the edge of the cages. The ratio at all the sites investigated was found to be significantly correlated with redox potential and distance. Multiple regression analysis showed that this index incorporates various components of sediment geochemistry (MD and TOC) as well as distance and feeding rates.

Sampling by means of different samplers, taxonomic resolution, and sieving size were compared in respect of information loss regarding the community structure as described through multivariate analysis as well as in respect of estimates of univariate metrics of macrofauna (Lampadariou *et al.*, submitted). The results clearly showed that information loss was relatively low as data were aggregated at higher taxonomic levels, particularly up to the level of family or even order. It was also found that the extra information gained by sieving samples through a 0.5 mm sieve did not improve the ability to distinguish the potentially impacted sites from the control stations.

Finally it was found that, a relatively large proportion of the available information concerning the community structure such as abundance, biomass or diversity is lost when sampling is carried out with corers. A cost/benefit analysis for the two sampling and the two sieving methods

showed minimal values for the van Veen samples (for both sieve fractions) at the family level, indicating that analysis at this level gives the best balance between precision of the results and decrease in taxonomic effort. However, if the time needed to sort the samples is included in the analysis, then, samples taken with corers using a 0.5 mm sieve and identified to families seems like a good compromise between precision and cost.

The overall TOC-E(S_{10}) relationship was very similar to the predictions provided by Hyland *et al.* (2005) regardless of sieve-size or sampler type. However, when samples were divided into coarse and fine sediment groups the curves obtained were substantially different among the two groups indicating that coarse sediment communities can maintain fairly high diversity even when TOC increases above 30 mg g⁻¹.

In the framework of the AQCESS project, sampling was carried out across different communities (macro-, mega-, and ichthyofauna) at large spatial scales in search of subtle effects of fish farming zones at far fields affected by nutrient release. Although the analysis of macrofaunal samples showed no signs of environmental change (Karakassis *et al.*, 2004) it was found that large animals (such as demersal fish) with longer life spans are more likely to show response to subtle effects (Machias *et al.*, 2004; 2005). It has also been found that in oligotrophic waters fish farming wastes could have a positive effect on local fisheries.

Finally, in coarse sediments, such as those inhabited by *Posidonia oceanica*, the monitoring of benthic fauna could give a false impression of “health” showing high abundance, biomass and diversity although monitoring results regarding density of *Posidonia* meadows carried out in parallel to these benthic surveys showed severe effects on the health of the seagrass which is an important habitat for the Mediterranean.

All the above indicate that the paradigm of benthic succession described by Pearson & Rosenberg (1978) should not be used as the one and only measure of environmental health since it works well only with disturbance of macrofaunal communities in muddy sediments. Effects on coarse sediments as well as on different communities could vary considerably depending on the type of disturbance and the specific attributes of the biota.

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