

Effects of Aquaculture Activities on Microbial Assemblages

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In the last decades, aquaculture has experienced an exponential growth [1-3], but farming practices are expected to increase also in future years to cover the increased demand of products available for human consumption. Aquaculture development has raised issues of concern in terms of environmental impacts and ecosystem health [4]. Fish farming induces eutrophication processes near the sites where cages are located. Organic substances released from faeces, food residuals and other wastes related to fish farming cause the organic enrichment of seawater, leading to increased decomposition processes, water turbidity and oxygen consumption. Increasing organic matter inputs to the sediments close to the fish cages, marine fish farms may have a significant detrimental effect on sea floor integrity and benthic microorganisms [5-6].

Innovation in aquaculture is inspired to the principles of Sustainability or Eco-Friendly design, Responsibility, and Food Safety. Recent trends in this field aim at developing sustainable and environmental-friendly and cost-efficient off-shore production systems. The interest towards the environmental safeguard is documented by the proliferation of studies and research focusing on the reduction of possible aquaculture impacts (see for example MERMAID project funded by EU-FP7 under the framework of the program OCEAN.2011-1 "Multi-use offshore platforms" and the RITMARE Flagship project funded by Italian Ministry of University and Research, Sub-Project 2, WP4 Innovative aspects for Sustainable aquaculture. The development of ecosystem-based (i.e. polyculture) or eco-friendly systems (i.e. off-shore systems) represents the most interesting perspective to reply to the need of improving current fish farming systems and to support further development in aquaculture field.

Although the effects of fish farming on aquatic environment and fauna are well known [3 and references therein], there is a comparatively little knowledge of the effects on the microbial metabolism [6,7]. Microbial community is known to quickly react to environmental changes by modulating its structure and metabolic patterns [8-10]; heterotrophic bacterial communities benefit as a food source from the complex of dissolved and particulate substrates provided by aquaculture wastes. High organic inputs may determine a stimulation in the mineralisation process, more or less pronounced depending on their labile or refractory nature, so that microbial abundance and metabolic activities are expected to be enhanced in highly enriched environments such as intensive aquaculture farms [11] or in sites where mariculture plants are operating [12]. Therefore significant variations in the microbial community are expected to occur in correspondence of farming sites.

Particularly, degradation of high-molecular weight substrates by bacterial extracellular hydrolytic enzymes can be viewed as a rate-

limiting step in organic matter degradation by the microbial community, while only few low-molecular weight organic substances can be taken up directly by bacteria. Since extracellular hydrolytic enzyme activity is recognized to be a key step in the degradation of organic matter by microbes in natural aquatic environments, estimates of the potential ability of micro-organisms to degrade biopolymers such as proteins, polysaccharides and organic phosphates through specific enzymes (i.e. leucine aminopeptidase, beta-glucosidase and alkaline phosphatase, respectively) can provide an indication of the microflora ability to remineralize organic matter, so preventing its accumulation in natural environments.

In a previous study Caruso et al. [7] investigated the effects of off-shore fish farming on microbial enzyme activities and heterotrophic bacterial density in three Mediterranean sites before and after a mariculture experiment. Results showed that fish farming mainly affected the levels of microbial activities in seawater, which were significantly increased for alkaline phosphatase, while no significant variations were recorded in heterotrophic bacterial density. But generally the most evident effects are found in the benthic compartment, especially along an organic enrichment gradient [13] and with significant changes in its biogeochemistry [14]. Significant increases in prokaryotic abundance, biomass, carbon production and enzymatic activities are reported in the sediments beneath aquaculture cages [12,15-17].

Heavy supply of organic materials from fish farms might affect not only quantitatively but also qualitatively organic matter degradation processes in the sediment [18], as shown by the smaller ratio of leucine aminopeptidase to beta-glucosidase measured in farming sites compared to the others from the same aquaculture area. Besides the effects on Carbon cycle pathways, marked changes have also been observed in the Sulphur cycle and the relative importance of sulphate-reducing δ -Proteobacteria [13,19-21]. Studying the effects of biodeposition in several fish farming areas across the Mediterranean Sea, from Cyprus to Spain, Luna et al. [6] reported significantly higher prokaryotic and viral abundance and production, and rates of organic matter decomposition in the sediments beneath the cages although the differences between impact and control sediments were not consistent at all regions.

Both microbial abundance and enzyme activities may undergo substantial alterations in intensive aquaculture farms or in mariculture sites. The suitability of microbial extracellular enzymes as sensitive sentinels of aquaculture impact has recently been confirmed also in a Sicilian site, the Gulf of Castellammare, traditionally used for marine aquaculture [22]; there, a polyculture experiment has recently been performed as an eco-friendly alternative to conventional, near-shore, aquaculture systems to increase aquaculture productivity and sustainability, as well as to decrease the potential impact of productive systems on the environment. Increased levels of alkaline phosphatase

and leucine aminopeptidase have been measured at all the impacted stations, compared to control sites, proving their effectiveness as parameters to indirectly monitor aquaculture impact due to organic enrichment over the pelagic compartment [Caruso G., unpublished data].

The general conclusion of the above-reported studies is that the organic load from aquaculture activities can have a significant impact on prokaryotes and viruses, by stimulating prokaryotic metabolism and viral infections, reducing bacterial diversity and altering assemblage composition. However, the relevance of this impact may greatly vary depending upon the habitat characteristics. However, the development of systems for sustainable aquaculture and ecologically based design, coupled with rapid methods to detect variations in parameters related to microbial community (like enzymatic activity rates measurements or bacterial and counts) could be used as a useful tool of environmental disturbance ("early warning") for fish farmers and any aquaculture workers.

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