

IMPACT OF AQUACULTURE ON COASTAL MARINE ENVIRONMENT

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Since aquaculture is intimately linked with aquatic environmental quality, entry of pollutants to coastal waters constitutes the greatest threat to marine environmental quality and, hence, to long term viability of coastal aquaculture. Fish production through aquaculture is an old age traditional practice in southeast Asia and India. Aquaculture activities have increased rapidly during the last 20 years. Much concern is now being expressed over the environmental problems associated with rapidly expanding marine fish and shellfish farming, world over. Accelerated development in techniques and equipment in the last three decades has created negative environmental impact and the subject of increasing heated debate in the advanced countries. The proliferation of aquaculture structures and acute organic enrichment, usually accompanied by sedimentation and eutrophication of coastal water is a serious environmental problem today. The environmental implications of coastal aquaculture is viewed and discussed.

INTRODUCTION

The coastal aquaculture is a traditional practice well developed in Southeast Asia. There has been an accelerated development in the aquaculture activities during the last three decades world over. Such activities, although have increased the world fish production, created negative environmental impacts. It has been reported that large amount of artificial feed containing different nutrient salts, faeces, slaughter waste dead fish and significant quantities of chemicals, fertilizers and antibiotics are added every year, thus causing great deal of pollution to the coastal marine environment (Ackefors and Enell, 1990; Prakash, 1989).

The difficulties facing fish farmers and aquaculturists in the advanced countries as a result of environmental damage, are shared by other regions undergoing rapid development of intensive fish farming. Concern has been expressed by conservationists and fish farmers on extensive mangrove conversion to fish ponds and adverse effect on the economic viability of the farm due to interaction between a farm and its environment. The adverse environmental impacts of aquaculture development has now become a matter of urgency to the region of high aquaculture activity (Eng. *et al.*, 1989).

In this review an examination is made of the problem of pollution hypernutrition/eutrophication caused by the disposal of suspended solids, high levels of organic matter and organically enriched sludges from aquaculture systems.

THE FLUX OF MATERIAL THROUGH AQUACULTURE SYSTEM

In aquaculture water quality criteria are of crucial importance since the cultivable organisms have to grow and develop in a minimum span of time. To assess the impact of fish farming on marine environment it is necessary to know the types, composition and quantities of waste material released. Further more, for any predictions to be made prior to the establishment of a farm, in a particular location, the flux of waste material generated through the aquaculture has to be quantified.

The anthropogenic substances produced for different utilitarian purposes, ultimately reach water bodies and the impact of such toxicants have drawn considerable attention both from aquaculturists and environmental experts. In the past two decades, fish farmers using advanced technique of extensive and intensive culture and net cages have developed in the coastal waters throughout the world. Such farming has allowed the production of large amount of valuable fish and their supply to the markets in major cities on a regular basis. However, fish farming is often followed by serious organic pollution of the water and bottom sediment in the vicinity of the cages since approximately 90% of the food for the fishes results on organic discharge to the environment around the fish farm (Tsutsumi *et al.*, 1991).

The composition and physical nature of the fish farm waste reflects the composition of the diet and the digestibility of its components. Basically three types of food (dry, moist, wet) are used widely today in aquaculture by farmers. The dry food components are protein, carbohydrate and lipid, in different proportion. In addition these diets include nutrients, vitamins and pigments. All these components together with metabolic by products are potential waste products in the aquaculture system. Therefore the composition of the waste from an aquaculture system will include organic carbon, organic nitrogen, ammonium, urea, bicarbonates, phosphate, vitamins, therapeutants and pigments (Gowen and Bradbury, 1987).

The fish farm represent a gradient of accumulating organic waste on the sea bottom. Organic carbon and nitrogen compounds form the bulk of the waste food and faeces. They are denser than the sea water and sink to the bottom in the immediate vicinity of the fish farm. Large inputs of such particulate organic matter (POC) will have a considerable effect on the fauna and flora (Anonymous, 1983). Fish farms also release dissolved nutrient into the sea. This can lead to an increase in phytoplankton growth. This process is called eutrophication and will be dealt here. Similarly the soluble nitrogenous compounds (ammonium, urea) may cause hypernutrition of the coastal water. The loading of nitrogen and phosphorus from fish farms has been studied in details (Foy and Rossell, 1991). In the past few years debate has arisen on the issue of self pollution of ponds from fertilizers and nutrients. Vitamins, antibiotics and pigments impact, although have been poorly understood but could be significant. Antibiotics are not thought to accumulate in the marine environment (Anonymous, 1983). The fate of pigment is not known.

It is reported that increased wastage in fish farm is associated with decreasing stability in water and organic pollution of the soft bottom. It is often followed by the development of reducing conditions and deoxydization of the bottom water, as a result of the decomposition of the abundant POC. There are reports of increased sulphide contents, chemical oxygen demand (COD), ignition loss and mass mortality of benthic organisms during mariculture practices in semienclosed areas of bays and estuaries (Pearson and Rosenberg, 1978; Anonymous, 1983). It is felt that the good estimates of the flux of POC and other waste from aquaculture system are required if the impact is to be modelled accurately.

MARICULTURE AND THE ENVIRONMENT

Fish production through mariculture has increased considerably during the last two decades. Majority of the fish farms, net cages, sea pens are located in the brackish water areas of enclosed bays and estuaries. The excess of nutrient salt from fish farms find their way into the coastal marine environment. In Finland, for example, rapid increase in net cage forming has contributed an estimated 140 t of phosphorus and 950 t of nitrogen to the total input to the environment (Maekinen, 1989). The eutrophication of sea due to release of high organic matter from aquaculture system is a serious environmental problem today in Baltic proper, the Sound, the Kattegat and also to some extent the Skagerrak (Enell and Ackefors, 1991).

One of the first effects of enrichment is an increase in oxygen consumption by heterotrophic organisms within the sediment. When the demand for oxygen exceeds the supply, the sediment becomes anoxic and at this point there are major changes in the sediment chemistry and the ecology of benthic organisms (Pearson and Rosenberg, 1978; Ansari *et al.*, 1986). In the absence of oxygen anaerobic processes predominate and the sediment becomes reducing. The reducing capacity of the sediment depends on the degree of enrichment and can be assessed by measuring the redox potential (oxygen/reduction level) of the sediment. Redox potential as low as -150mv has been recorded in the sediment beneath fish cages (Brown *et al.*, 1987) indicating that amount of fish farm wastes are sufficient to cause the sediment to become highly reducing. Anaerobic processes result in the production of reduced compounds such as ammonia, hydrogen sulphide and methane. These gaseous forms, when produced in sufficient quantities, can be released from the sediment. It is clear that in sheltered, shallow water sites, levels of enrichment which result in highly reducing sediment and outgassing does pose a threat to the fish.

AQUACULTURE AND EUTROPHICATION

It is evident that considerable amount of waste is produced by fish farm. The consequences of any hypernutrition in terms of enhanced primary production and phytoplankton standing crop are complex. Sometimes the phytoplankton production is stimulated by eutrophication while in other cases

it is not affected. There are other factors which restrict the phytoplankton production in the marine environment. Enhanced phytoplankton growth could be threat to fish held in cages if additional growth was in the form of toxic phytoplankton species. There are a number of toxic dinoflagellates stimulated by the addition of ammonia. Red tides have become a synonym with eutrophication and mass killing of the fish. In larger semienclosed water bodies vertical stratifications and limited horizontal advection would reduce the volume into which the nitrogenous waste is dispersed and this could lead to localized hypereutrophication.

The intensive cultivation method involving high stocking density and feeding rates, results in an organic enrichment of the sea bed which can affect both natural communities and farmed stock (Frid and Mercar, 1989). In the sheltered and enclosed waters in which most fish farming takes place, effects are likely to be greater. In a study of 57 fish farms in Scotland Lumb (1989) has shown that acute organic enrichment, usually accompanied by sediment outgassing, occurred beneath most cages. Development of these conditions is likely to result in self pollution of the fish farm bodies besides affecting the adjoining areas. This leads to a classic organic enrichment gradient extending from the fish farm far upto 50 m down current (Brown *et al.*, 1987). Significant benthic enrichment is known to occur at these sites (Ansari *et al.*, 1986), but the effect is highly localised. Fish farming in the macrotidal environment may reduce the impact on benthic communities but there exists the potential for accumulation of farm waste in nearby sedimentary sinks. Loading of organic material to the sediment from extensive fish farm is of the same order of magnitude as that of sewage dumping ground and pulpmill effluents (Pearson and Rosenberg, 1978; Brown *et al.*, 1987) and it would be thought that the magnitude of effects on benthos would be similar.

SUSPENDED SOLID AND ORGANIC ENRICHMENT

The characteristic of one type of aquaculture, such as intensive throughput-based salmon cage farming and shrimp pond farming, are found to be similar to those of stressed ecosystems. In these systems there is a great deal of suspended solid used in the form of feed. Among these characteristics are a very inefficient resource use and generation of by-products that are stored or exported. The suspended unused feed and

excrement of the finfish is settled at the bottom. Example of this can be had from Seymour and Bergheim (1991) in which pollution was reported due to the use of dry feed and faeces. Others have also observed the phenomenon of settlement of suspended solids in fish farms. It has been estimated that the deposition of organic waste beneath a well fed fish farm might be as high as $10 \text{ kg. m}^{-2} \text{ y}^{-1}$ directly beneath the cages and $3 \text{ kg. m}^{-2} \text{ y}^{-1}$ in the immediate vicinity of the farm (Gowen and Baradbury, 1987).

A moderate intensity of mariculture management encourages the development of a rich benthic community, providing food for fish, assisting decomposition of organic wastes and lessening downstream environmental impact. However, in extensive mariculture areas greater sedimentation and higher nutrient densities in sedimenting material from fish ponds are recorded. The effluents from such fish ponds show statistically significant increment in BOD, ammonia, nitrites, phosphates and settleable solids and reduced dissolved oxygen. In general, relatively small amounts of suspended solids are washed out and mostly sedimented directly at the bottom of the pond.

REDUCING THE EFFECT OF FISH FARM WASTE

From the foregoing accounts it is very obvious that the use of modern techniques in mariculture in the last 20 years has generated lot of waste material, rich in organic content, while enhancing fish production (Eng *et al.*, 1989). Presence of such waste either at lethal or chronic level impairs the rate of production in aquatic environment. Sometimes the lethality may not be on the fish directly but on the fish food organisms and this affects the different links in the food chain. A number of techniques have been used to reduce the level of organic enrichment beneath the fish cages (Seymour and Bergheim, 1991; Rouhonen and Maekinen, 1991).

The waste food could account for 70% of the organic carbon sedimenting directly beneath fish farm. Thus any reduction in food waste would have a significant effect in reducing the level of enrichment. It seems likely that the only way of minimizing hypernutrition and eutrophication is to site farms in locations which are well flushed. This would also enhance the dispersal of solid waste. A harmful local impact on the environment

can be avoided by careful site selection based on sensitivity models, which ensure that the mariculture production does not exceed the carrying capacity of the environment. The aquaculture system should aim at increased efficiency, reduced resource use, avoidance of chemicals and medicals, less waste generation and the recycling of nutrients and materials. Based on the principle of ecological aquaculture, intensive mangrove destructing shrimp farming should be opposed to integrated shrimp farming.

CONCLUSION

We must keep in mind that the aquaculture is a dynamic process of coastal marine environment. It has created problems of pollution in enclosed bays and estuaries by generating byproducts. The waste from seafarming is composed of organic compounds, protein, carbohydrate, vitamins and inorganic ions like phosphate, ammonia and bicarbonate. The effects of enrichment of marine sediment by organic carbon and hypernutrition/eutrophication of coastal water are best studied. The flux of suspended solid (feed, faecal and nitrogenous waste) in fish farms and its deposition in fish farms and its deposition is likely to lead to the sediment becoming anoxic and a benthic macrofauna which is impoverished or absent. Existing techniques should be applied to reduce the input of organic waste and recycling of nutrients without wastage of energy. Efforts should be made to minimize the ecological impact of farm waste and reduce the risk of harmful feedback on the fish.

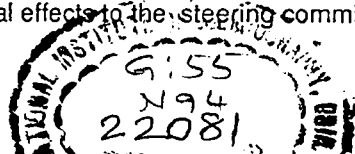
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