Integrated mariculture: its role in future aquaculture development

Max Troell
The Royal Swedish Academy of Sciences
Beijer International Institute of Ecological Economics
Stockholm, Sweden
E-mail: max@beijer.kva.se

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Looking at the present growth of aquaculture production, it seems feasible that the sector will be able to meet the future challenge and double its production within 30 years. Thus, the interesting question is not if this expansion will take place, but rather how it will be achieved and what the resulting environmental and socio-economic consequences will be. Besides increased inland production from freshwater fish aquaculture, which is traditionally an integral part of agriculture production, a large part of the expansion is also anticipated to take place along the coasts of both developing and developed countries (FAO, 2006). Fish will be the main farmed aquaculture species, but production of more extensive species like bivalves and seaweeds will increase. Coastal areas, especially in developing countries, already experience high pressure from e.g. urbanization and industrialization that has resulted in both terrestrial and marine ecosystem degradation. Potential impacts from any aquaculture development will mainly be determined by culture system characteristics (species, intensity, technology, etc.) and site characteristics (nature of the landscape and seascape, waste assimilating capacity, waste loadings, social structures, etc.). Generally, some aquaculture systems can be identified as being more sustainable as compared to others. However, in each case of aquaculture development, local constraints from environmental and socio-economic perspectives need to be considered. Under some circumstances, more "environmentally friendly" species may fail to meet some important aspects of sustainability.

To meet future protein demand, increased aquaculture production should come from species not dependent upon high-food-grade raw materials, i.e. fishmeal and fish oil produced from fish species suitable for human consumption. This implies a focus on species able to utilize vegetarian diets and on extractive species (filter feeders and seaweeds). Development of alternative protein feed sources will also play a role in production of fish species that today depend on fishmeal-based feeds (see Tacon, Hasan and Subasinghe (2006) for a review on feed development). The rapid-scale increase now seen in human activities in coastal areas puts further pressure on the already impoverished functions of coastal ecosystems. Therefore, legislative guidelines, standards and controls regarding the discharge of nutrient wastes from various sources (including aquaculture operations) are starting to become more stringent in many countries. Development of integrated mariculture, i.e. bioremediation via integrated concepts with a capacity to improve the quality of the discharged water, may facilitate the aquaculture industry to avoid non-compliance and gain both direct and indirect benefits from improving water quality and coastal ecosystem health.

The findings from many recent studies on both land-based and open marine culture systems show the potential for adopting integrated mariculture systems (see reviews in Troell *et al.*, 1999, 2003; Chopin *et al.*, 2001; Neori *et al.*, 2004). The European Aquaculture Society meeting "Beyond Monoculture", held in Trondheim, Norway in 2003, concluded that we now have accumulated enough data to support the biological demonstration of the concept of integrated aquaculture. Further conclusions were that no universal integrated system exists, the choice of technology and species is different for different regions and different socio-economic conditions and that we now need to demonstrate its applicability at commercial scales, including analyses of both biological and economic performance.

Despite some 20 years of research, today only a few commercial integrated mariculture systems exist. Most recent marine integrated systems have been experimental and small scale, which implies difficulties when extrapolating the results (efficiency and economic performance) to commercial scales (Troell *et al.*, 2003). There are, however, integrated systems that are operating at larger scale and being commercial. The best examples can be found in China where suspended multi-species aquaculture operates at scales of whole bays. For example in Sungo Bay, east of the Shandong Peninsula, scallops are cultivated together with kelp, abalone and fish, in cultures extending 8 km offshore. Another integrated open-water culture of kelp with salmon and mussels operates in the Bay of Fundy, Canada. Abalone farming in South Africa and Israel are other examples of integrated mariculture systems performed at larger scales on land. Abalones are cultured in land-based flow-through tank systems and seaweeds are cultured in the wastewaters from the abalones (Troell *et al.*, 2006). In Israel the integration also includes fish (Neori *et al.*, 2004).

The general benefits from integrated practices are additional income from co-cultured crops and reduction of nutrient release to the environment. There are other benefits such as facilitation for recirculation of waters (i.e. through ammonium removal and oxygenation by seaweeds), which also could result in reduced pumping costs and increased water temperature (resulting in higher growth) (Troell *et al.*, 2006). The ability to operate in recirculation mode may be important in cases where intake water may need to be shut off for a limited period (e.g. during red tides or oil spills). The cultivated additional crop, i.e. the extractive organism, can in itself generate an economic value (marketable product) or be used as input to co-cultured species. Seaweeds cultivated with abalones are used as abalone feeds, and their quality has been proven to increase when cultured in abalone wastewater. For species like abalones that in some countries depend to a large extent on wild-harvested kelp, future expansion may depend on increased cultivation of seaweeds when wild kelp resources become exhausted (Troell *et al.*, 2006). Additional arguments for integrated mariculture include possible social benefits and diversified production (risk reduction – i.e. increased portfolio).

The practice of integrated farming also generates additional costs that may impact negatively on overall farm economy. These costs could include additional investments, maintenance and the need for increased and complementary skills. There might also be an increased risk for negative interactions between species (i.e. spread of diseases, parasites, chemicals, etc.). These potential costs and interactions may only be revealed when practicing integration at large scales. Scale is also important, as many beneficial interactions probably are limited by scale (i.e. spread of dissolved nutrients and particulate matter) (Troell and Norberg, 1998; Troell *et al.*, 2003).

The fact that few integrated mariculture systems exist could indicate that the incentives for their practice are weak. It is important to acknowledge that present aquaculture business models do not consider and recognize the economic value of the biomitigation services provided by biofilters, as there is no cost associated with aquaculture discharge/effluent in mariculture systems. Regulatory and financial incentives may therefore be required to clearly recognize the benefits of the extractive components in a culture system (shellfish and seaweed). A better estimate of the overall cost/benefits to nature and society of aquaculture waste and its mitigation would create powerful financial and regulatory incentives to governments and the industry to jointly invest in integrated approaches.

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The future of mariculture: a regional approach for responsible development in the Asia-Pacific region

FAO/NACA Regional Workshop
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Aquaculture in the Southeast Asian region has been growing steadily over the last few decades, requiring more space to accommodate it. The search for additional areas to expand the aquaculture industry as a whole and the identification of new farming species of commercial value to satisfy the growing local and export markets are pushing the sector in some countries to broaden activities in the sea, including further offshore where more space is available and where, to a lesser extent, competition is currently not so intense. The Fisheries and Aquaculture Department of the Food and Agriculture Organization of the United Nations (FAO) in collaboration with the Network of Aquaculture Centres in Asia-Pacific (NACA) organized the regional workshop entitled "The Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific Region" from 7 to 11 March 2006. The workshop was conducted in collaboration with the Ministry of Fisheries of the People's Republic of China and the Guangdong Ocean and Fisheries Administration.

The workshop was convened in response to requests from FAO and NACA member countries to identify key trends and issues affecting mariculture growth in the Asia-Pacific region and to strengthen regional collaboration for future responsible development of mariculture.

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