Mariculture Research and Development in India - Frontier Areas

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Introduction

Mariculture contributes 36.5% of the global aquaculture production by quantity, producing a variety of high value finfish, crustaceans and molluscs. In the context of declining catch rate from capture fisheries on a global basis, the development and expansion of mariculture has the potential to augment seafood production. The present marine fisheries scenario in India is characterized by declining yields from the inshore waters and increasing conflicts among different stakeholders, whereas the growing demand for fish in domestic and export markets indicate good prospects for large scale sea-farming and coastal mariculture. India's share in the booming world trade of fish is less than 2%, which is

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Dr.G.Gopakumar, Head, Mariculture Division of Central Marine Fisheries Research Institute is specialised in Marine finfish breeding and seed production. He is the team leader for the development of seed production technologies of two marine foodfishes of high aquaculture potential in India viz. cobia and silver pompano for the first time in the country. He also pioneered in the breeding and seed production of a dozen species of marine ornamental fishes which can pave way for the development of hatchery produced trade of marine ornamental fishes in India. He has 35 years of research experience and has around 100 publications in marine fisheries and mariculture. Currently he is the Scientist-in-Charge of Mandapam Regional Centre of CMFRI.

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very low considering the huge potential for exports. The ever-expanding internal market also recorded the highest increase for fish and fishery products, among all the food products. The dwindling catch rates in capture fisheries and rampant unemployment in the coastal regions point towards the development of mariculture and coastal aquaculture as a remunerative alternate occupation. Recent estimates quantify the per capita fish consumption in India at around 8-10 kg per year and is likely to grow to 16.7 kg by 2015. Even though the capture fisheries will continue to be the mainstay of the Indian marine fisheries, it is evident that further increase in fishing pressure will not yield the required quantity of seafood to meet the increasing per capita requirement in the coming years. In India, till date, mariculture activities are confined to coastal brackishwater aquaculture, chiefly shrimp farming. The other coastal aquaculture activities are green mussel farming which is confined to the Malabar coast in Kerala, producing about 20,000t and seaweed farming along the Ramanathapuram and Tuticorin coasts of Tamil Nadu, producing about 10000t annually.

NEED FOR INTENSIFYING MARICULTURE R&D

India is still in the infancy in mariculture production, in the backdrop of the global scenario. In the Asia-Pacific Region also, a lot of advances have been made in the development and expansion of mariculture. Since mariculture is the only sunrise sector for increasing seafood production in the coming years, the research and development in this sector is of paramount importance. The Central Marine Fisheries Research Institute (CMFRI) is the pioneer in mariculture research in India, and many technologies have been developed by the Institute during the last four decades. Still, commercialization of mariculture has not yet taken place and it is high time that it is taken forward.

FRONTIER AREAS IN MARICULTURE RESEARCH

Marine Finfish Seed Production - Establishment of National Broodstock Centre

Mariculture of marine finfish has been growing rapidly on a global basis especially with the development and expansion of sea-cage farming. One of the major reasons for the growth of sea-cage farming is the availability of breeding techniques that can produce sufficient quantity of seeds of different high value marine finfish. Many countries in the Asia-Pacific region, like Australia, China, Japan, Taiwan, Philippines, Indonesia, Thailand, Malaysia and Vietnam have made substantial progress in the development of commercial level seed production technologies of high value finfish, suitable for sea farming. In all these countries, the success could be achieved due to the establishment of controlled broodstock development. In India, much research attention has not been given for developing seed production methods for high value finfishes suited for sea farming. At present, we have commercial seed production of only one species of marine finfish – sea bass (Lates calcarifer). Here also, private entrepreneurship has not yet been developed. The major bottlenecks in achieving commercial level seed production are the control of reproductive processes of fish in captivity and production of bio-secure and quality-certified fry. Broodstock management usually includes collection, selection and domestication of brooders as well as control of maturation, spawning and egg collection. The broodstock developed in sea-cages is susceptible to the changes in the water quality of the cage site, disease problems and impact of harmful algal blooms. Consequently, the broodstock developed in sea cages is not bio-secure and hence can lead to spreading of diseases, while farming is taken up on a commercial basis. If the broodstock development and larval production is practised in recirculation systems, it is possible to have control on the environment in which the broodstock and larvae are produced. Recirculation systems use land based units to pump water in a closed loop through fish-rearing tanks and include a series of sub-systems for water treatment, which include equipments for sterilization, heating or cooling, solid removal, water chemistry control, biological filtration and dissolved gas control. Sustainable production of bio-secure marine finfish seed all through the year, employing photo-thermal conditioning is possible only by recirculating systems and this facility can pave the way for the commercial level seed production.

Cobia brooders at Mandapam Regional Centre of CMFRI

Cobia seed produced at Mandapam Regional Centre of CMFRI

Cobia and Pompano Aquaculture

Cobia (Rachycentron canadum) and silver pompano (Trach-inotus blochii) are two marine finfish species with very high potential for aqua-culture in India. Fast growth rate, adaptability to captive breeding, lowest cost of production, good meat quality and high market demand, especially for sashimi industry, are some of the attributes that make cobia an excellent species for aquaculture. In recent years, the seed production and farming of cobia is rapidly gaining momentum in many Asian countries. Envisaging the prospects of cobia farming in India, broodstock development was initiated at the Mandapam Regional Centre of CMFRI in sea-cages during 2008 and the first successful induced breeding and seed production was achieved in March – April 2010. Trials on sea-cage farming carried out at Mandapam showed that the fishes attained an average weight of 2.5 kg in six months and 7.3 kg in twelve months. The species can be grown in low salinity and experiments revealed that up to 15 ppt, the growth and survival is comparable to that in seawater. These results point out the possibility of developing a lucrative cobia aquaculture enterprise in the country. However, standardization of technologies for seed production and farming of cobiato suit our environmental conditions have to be further pursued on a priority basis so that India can also emerge as a contributor for cobia production in the near future.

Similarly, among the many high value marine tropical finfish that could be farmed in India, the silver pompano is also one of the topmost, mainly due to its fast growth rate, good meat quality and high market demand. The spe-cies is able to acclimatize and grow well even at a lower salinity of about 10 ppt and hence is suitable for farming in the vast low saline waters of our country besides its potential for sea-cagefarming. At the Mandapam Regional Centre of CMFRI, successful broodstock development and induction of spawning and fingerling production of silver pompano was achieved during July 2011, for the first time in India. Subsequently, two more seed production experiments were also done successfully and now farming trials are progressing. This can be considered as a milestone towards the development of pompano aquaculture in the country. The current achievements in cobia and pompano can be considered as the first step towards the aquaculture development of the two species. The establishment of biosecure broodstock centres, standardisation of breeding, larviculture and nursery rearing protocols and farming demon-strations in pond and sea-cages are the steps to the way forward. Hence it is essential to establish infrastructure for the different phases from seed to product development viz., i) broodstock facility for the production of viable fertilised eggs throughout the year, (ii) hatchery facility for meeting the seed requirements, (iii) grow out facilities and (iv) product processing and distribution system. It appears that both cobia and pompano are potential aquaculture giants having vast domestic and global business prospects.

Fingerlings of silver pompano produced at Mandapam RC of CMFRI

Sea-cage farming

Sea-cage farming is globally recognised as the efficient farming system of the millennium. When compared to many countries in the Asia-Pacific Region, India is still in its infancy in sea-cage farming. For the first time in India, as part of R&D, a marine cage of 15m diameter with HDPE frame was successfully launched and operated at Visakhapatnam, in the east coast of India by the Central Marine Fisheries Research Institute. Even though it cannot be taken as a commercially successful venture, a lot of lessons were learnt on designing and fabrication of cages and mooring systems. This has led to the development of better designs of cages of 6m diameter with improved mooring systems that can withstand rough sea conditions. Subsequent demonstrations of cage farming were undertaken along different parts of the Indian coast under participatory mode with the local coastal fishermen. It is worth noting that one 6m dia sea-cage can easily produce fish that can be harvested from 1ha pond in land based system. Successful sea-cage farming demonstrations were conducted by CMFRI at Kanyakumari, Vizhinjam, Kochi, Mangalore, Karwar,

Sea-cagefarm of CMFRI at Karwar

Red snapper produced in sea-cageby capture based aquaculture

Veraval, Mandapam, Chennai and Balasore. Sea bass and spiny lobsters were the major groups employed for farming. Red snapper is another important species being attempted for sea-cage farming with promising results.

AREAS OF R& D FOCUS IN SEA-CAGE FARMING

Site Selection

Site selection through its influence on capital outlay and operational costs, production and mortality is a key determinant of the economic viability of a cage farming operation. Even though we have provisionally selected certain sites for cage farming demonstrations, it is felt that scientific site selection protocols have to be followed for identifying suitable sites for commercial level operations. A brief outline of the site requirement is as follows:

A number of factors directly or indirectly affect the viability of cage culture. It is normally difficult to fulfil all of these and they will depend also on the cage technology used, for example, the extent of wave tolerance. There are three categories of site selection criteria that must be addressed. The first is primarily concerned with physico-chemical conditions that dictate whether the species can thrive in an environment; the second comprises those factors that must be considered in order to install a cage system successfully, like weather, shelter, depth etc., while the third is the availability of logistic support for cage farming, and it must be given careful consideration if a profitable business is to be established. Further, areas with frequent shipping traffic should be avoided because of disturbance to the fish and creation of waves. When selecting a site, good infrastructure, for example, proximity to roads, availability of electricity, etc. need to be considered. In addition, the legal requirement for fish farming in the proposed site must be satisfied. There may be areas publicly designated for other purposes, or where cage farming is unwanted from an environmental point of view.

Lakes, bays, lagoons, straits and inland seas are ideal sites for cage-culture, provided these sites are protected from strong winds and rough weather and have sufficient water movements. Before the start of the venture, it is also important to have a baseline data on the seasonal variations in salinity, temperature, water current, turbidity, dissolved oxygen and primary productivity. Whenever possible, suitable areas should also be free from potential predators.

Seed Availability of Suitable Species

Knowledge of the biology of each fish species is crucial in optimizing production from cages. The selection of fish should be based on a number of biological criteria (omnivore or carnivore, efficient food conversion ability, hardiness, fast growing, availability of eggs and juveniles, and disease resistance), economic marketability and demand, as well as prevailing conditions of culture sites, influence of species selected for aquaculture. Environmental factors such as water current, salinity, temperature, dissolved oxygen and pH affect the target species and hence are also important considerations.

The demonstrations conducted in India were mainly with seabass and spiny lobsters. Hatchery seed production technology is available for sea bass and seeds are sold mainly from RGCA and CIBA. However, the seed availability limited. In the private sector, no sea bass hatchery has come up. In the case of other suitable groups of marine finfish like groupers, snappers and cobia and high-value shellfishes like spiny lobsters, commercial level seed production technologies still remain to be standardised. The dependence on seed entirely from the wild is uncertain and may not prove to be viable. Hence, it is felt that there is an urgent need to focus R&D efforts on the development and standardisation of commercially viable seed production technologies. The availability of hatchery-produced seed is the basic need for the commercialization of sea-cage farming in India.

Feed

The cage culture demonstrations carried out by CMFRI were entirely dependent on trash fishes for feeding. The availability of trash fish can affect the farming operations. The dependence on trash fish should be reduced. This could be done in stages by (i) initially demonstrating to the farmers, ways and means of increasing the efficacy of using trash fish, such as through the adoption of better feeding management strategies (ii) using trash fish to prepare suitable on farm moist feed using other agricultural products such as soybean meal, rice bran etc. (iii) demonstrating the efficacy of dry pelleted feeds through demonstration farms, and (iv) providing market incentives for farmers to adopt more environmentally sound feeding methods using formulated diets. Appropriate cost-effective pelleted feeds have to be formulated and commercial level feed production is needed for the expansion of cage farming practices.

Cost Effectiveness of Cage and Mooring System

The demonstrations we conducted were mostly with cages of HDPE frame and comparatively expensive mooring systems.

The cost of such cages and labour involved in the installation of the same is higher and the same is a limiting factor for its adoption by small-scale entrepreneurs. Hence, it is felt that at the initial level we may have to go for artisanal type cheap cages. When we look into the current scenario of sea-cage farming in Asia, it is evident that large scale capital intensive, vertically integrated marine cage farming practices are not practised. Artisanal family based cluster farming is the predominant system in Asian countries. Clusters of small artisanal farms are likely to be the immediate future scenario for India also. Hence, research and developmental thrust in this aspect is warranted.

Technological Challenges

The demonstrations conducted revealed the need for standardisation of many technological challenges in relation to cage farming operations. The major aspects are the following:

Stocking: The stocking density depends on the carrying capacity of the cages and feeding habits of the cultured species. For those species which are low in the food chain, stocking will also depend on the primary and secondary productivity of the sites. The optimal stocking density varies with the species and size of fish and ensures optimum yield and low disease prevalence.

Feeding: Feeding is affected by many biological, climatic, environmental and economic factors. Growth rate is affected by feeding intensity and feeding time. Each species varies in maximum food intake, feeding frequency, digestibility and conversion efficiency. These in turn affect the net yield, survival rates, size of fish and overall production form the cage. The shortage of trash fish is a major problem with large scale cage farming.

Farm management: Farm management must optimize production at minimum cost. Efficient management depends heavily on the competence and efficiency of the farm operator with regard to feeding rate, stocking density, minimizing loss due to diseases and predators, monitoring environmental parameters and maintaining efficiency in technical facilities. Maintenance works are also very vital in cage culture. The entire structure must be routinely inspected and necessary repairs and adjustments to anchor ropes mooring system and net-cages should be done immediately. Monthly replacement of net structures should also be considered as it ensures good water exchange in the net.

Biofouling: Biofouling is an important and common problem in cage culture. The rate of biofouling in tropical waters is faster than other regions. The net walls as well as the firm structures such as the floats can be covered with biofouling organisms. Common fouling organism includes barnacles, mussels, oysters, algae and tunicates. Biofouling clogs the mesh of the net, reducing the rate of water exchange thereby causing stress to fish due to low oxygen and accumulated wastes. The rate of fouling depends on the mesh size of the net, temperature of the water and productivity of the sites. Small mesh sized nets (0.7-1.3 cm) can easily be fouled within 7-14 days while larger mesh sized nets (2.5-3.8 cm) may get fouled in 1-2 months. In tropical waters, net cages have to be replaced at least once a month. Boring organisms frequently damage the wooden structures of the cage unit.

A fouled net will be heavier, thereby

increasing drag and this results in the loss of net and fish. Mechanical cleaning of fouled net is still the most efficient and cheapest method of removing biofouling organisms, using hard bristle brushes above and below water line to dislodge weeds and accumulated debris. Routine checking of moorings is inevitable. In addition, regular lifting of the net to check for predators and damage caused by poachers has to be carried out. Air or sun drying of nets at regular intervals will allow the removal of debris and other materials that clog the mesh and block water exchange.

Regulation of fish growth and production: An important aspect of farm management is the skilled manipulation of operational functions such as stocking density and feeding. The main purpose is to regulate fish growth to attain the desired size for the targeted market and season.

Grading: Grading of fish is management process to maintain uniform size of the product. Greater size uniformity improves feed conversion rates and overall growth, especially in meeting marketing and processing requirements. Frequency of grading depends on individual fish species and size requirement at harvest.

Diseases : Disease outbreaks can occur and cause problems in cage culture. Increased stocking, pressures on faster growth and high density can create conditions conducive to outbreaks of infectious diseases and an increase in prevalence of parasites. Infectious diseases are mainly due to waste pollution, crowding, handling, temperature and biofouling. The most common fish disease in cages is vibriosis caused by Vibrio spp. Abrasions cause fin and skin damage to cultured stocks. Occurrence of infections/disease can be minimized by selecting good sites, proper mooring, optimal stocking densities and careful handling of stocks. Adequate spacing between cages and farms are also essential management tools to reduce the spread of disease.

Water quality: Monitoring of water quality is routinely required. The farmer should be sensitive to threats such as pollutants, or indicators of occurrence of algal blooms such as red tide.

Pollution: Cage culture systems contributes wastes to the aquatic environment from uneaten food, dust, fish faeces, scales, mucus and other debris. These may accumulate beneath the cages or downstream and result in a reduction in dissolved oxygen and a build up of waste in water. These lead to the formation of hydrogen sulphide and high levels may cause fish mortality. Improper use of antibiotics and their release into aquatic environment may result in the development of antibiotic resistant bacteria. Cage culture can also introduce disease and parasitic transmission, cause changes in aquatic flora and fauna and may even alter the behaviour of the local fish community (Woo et al., 2002).

Legal and other developmental challenges

Currently there is no leasing policy for cage sites and no regulatory measures for farming. Leasing policies have to be formulated for development and expansion of cage farming. Regulatory measures are also needed to prevent the use of available inshore sites beyond their carrying capacities. More governmental intervention in streamlining cage farming activities is desirable especially for financing the sector and to develop firmer market chains and vertically integrate the different sectors and to bring about more efficacy and cost-effectiveness

Way forward

Cage culture has great development potential as exemplified by the family-scale cage farming which is highly successful in many parts of Asia. It will play an important role in the overall process of providing enough (and acceptable) fish for all, particularly because of the opportunities for the integration of species and production systems in near shore areas as well as the possibilities for expansion with installation of cages far from the coast.

Even though the sea-cage farming has been advancing in many Asia-Pacific countries such as China, Indonesia, Japan, Philippines, Taiwan, Vietnam and Korea in recent years, it still remains to be commercialised in India. The Central Marine Fisheries Research Institute has been taking pioneering and massive steps towards this direction currently. The major constraint for popularization of cage farming in India is the scarcity of sheltered areas that are ideally suited for sea-cage farming. In this context, the development of cost effective types of mooring, anchor and floating systems which can withstand the impact of adverse weather and currents will help us to venture into more unsheltered open-sea areas. Hence, it is felt that more technological and engineering interventions in cage farming along with large-scale hatchery seed production of high value and fast growing finfishes, development of cost effective pelleted feeds and formulation of appropriate legal and regulatory measures can pave the way for the development of sea-cage farming industry in our country in the near future.

INTEGRATED MULTITROPHIC AQUACULTURE (IMTA)

On a global basis, the mariculture practices are denominated by intensive monoculture which have led to sustainability problems, environmental degradation and consequent disease problems. In this context, the idea of bio-mitigation of the environment along with increased biomass production integrating commercially important species of different trophic levels is emerging as a sunrise sector in aquaculture. Integrated multitrophic aquaculture (IMTA) is the practice which combines in appropriate proportions the cultivation of fed aquaculture species (e.g. fin fish / shrimp) with organic extractive aquaculture species (e.g. shell/herbivorous fish) and inorganic extractive aquaculture species (e.g. seaweed), to create balanced systems for environmental stability (bio-mitigation), economic stability (product diversification and risk reduction) and social acceptability (better management practices). IMTA is well recognized as a mitigation approach against the excess nutrients/organic matter generated by intensive aquaculture activities especially in marine waters, since it incorporates species from trophic position or nutritional levels in the same systems. In addition, it is also relevant in the implementation of the Ecosystem Approach to Aquaculture (EAA), propagated by FAO. IMTA can also increase the production capacity of the particular site. It is well understood that increasing use of coastal waters worldwide, coupled with rapid growth and expansion of mariculture demand for more sustainable practices and hence the concept of IMTA has much relevance and scope.

The concept of IMTA is feasible and the system has included such combinations as shellfish /shrimp, fish/seaweed/shellfish, fish/shrimp /seaweed. It is important that appropriate organisms have to be chosen based on the functions they have in the ecosystems, their economic value or potential and their acceptance by consumers. Currently, the existing major IMTA systems in the world are generally simplified with finfish/shellfish/seaweed. The aim is to increase long term sustainability and profitability for the cultivation unit, as the waste of one crop is converted into fertilizer, food and energy for the other crops, which can in turn be sold in the market. For example, uneaten fish food, fish faeces and excreted nitrogen and phosphorus can be assimilated by shellfish (organic processors) and seaweed (inorganic processors), thereby reducing the amount of waste expulsion from a fish farm, and turning it into fodder for another species which is also of commercial value. This practice of IMTA can help to reduce environmental impacts while also producing economically viable products at the same time. It is this dual benefit that makes IMTA attractive to fish farmers.

The development of IMTA in marine and coastal environments has not been demonstrated as a viable enterprise in India and research focus is needed to make this practice a reality by establishing farms on scientific grounds and to conduct front-line demonstrations on this potential sector of mariculture to different stakeholders including officers of fisheries department of maritime states, fisheries developmental agencies, industry, self-help groups and NGOs.

SHELLFISH MARICULTURE

Small-scale bivalve farming is already being practised in India especially along the Malabar coast, Kerala, where green mussel farming has been established as a commercial activity. The practise can be further extended towards Karnataka, Goa and Maharashtra coasts. Edible oyster farming practised on a very small scale at certain locations in Kerala also requires to be expanded. Here, the two major concerns which have to be addressed are the low value - high volume production of spat to cater to the seed availability and the development of suitable marketing channel. Among crustaceans, the two promising species for farming appears to be the blue swimmer crab Portunus pelagicus and the sand lobster Thenus orientalis. However, standardisation of seed production technology of both the species have to be achieved before initiation of commercial level farming operations.

HATCHERY TECHNOLOGY OF MARINE ORNAMENTAL FISHES

The marine ornamental fish industry has been expanding globally in recent years and about 20 to 25 million marine ornamental fishes are traded annually. Nearly 98% of the marine ornamental species marketed are wild, collected mainly from coral reefs of tropical developing countries. This has been threatening the long term sustainability of the trade due mainly to indiscriminate exploitation of coral reef areas, leading to degradation of coral reef habitat and overexploitation of desired species. In this context, the hatchery production of selected marine ornamental fishes is the ultimate option for the development of a long-term sustainable trade. The Central Marine Fisheries Research Institute has been focusing on this vital aspect for the past few years. Techniques for broodstock development, breeding and seed production of 12 species of pomacentrids viz., Amphiprion percula (Orange clown), A. ocellaris (False clown), A. sebae (Sebae clown), Premnas biaculeatus (Maroon clown, spine cheek anemonefish), Pomacentrus cearuleus (Blue damsel), Dascyllus trimaculatus (Three spot damsel), Dascyllus aruanus (Humbug damsel), Chromis viridis (Bluegreen damsel) and Neopomacentrus nemurus (Yellowtail damsel), Pomacentrus pavo (Peacock damsel), Neopomacentrus filamentosus (Filamentous tail damsel) and Chrysiptera cyanea (Sapphiredevil damsel) were developed and standardized in India. The major constraint in the hatchery production of these fishes is the small size of the newly hatched larvae and the consequent problems in the first feeding. However, the newly hatched larvae of clownfishes are comparatively larger and hence initial phase of larviculture is carried out by employing enriched rotifers as live feed. But, the larvae of the damselfishes are very small and hence the nauplii of selected species of copepods formed the first feed of the larvae. Greenwater technique was adopted for the larviculture of all the species. The metamorphosis period of clownfishes ranged from 15 to 20 days whereas the same for the damselfish species ranged from 25 to 40 days. Further research efforts are being focused in the breeding and seed production of pseudochromids, gobiids and angelfishes. The way forward for the development of a hatchery produced marine ornamental fish trade in the country include imparting necessary training to prospective entrepreneurs, promoting the establishment of a few small-scale hatcheries and establishing an appropriate marketing channel.

Conclusion

It is well recognised that many of our exploited marine fishery resources have already reached the maximum sustainable levels and hence, increasing the fishing pressure to augment the marine fishery resources from Indian seas may not be a viable proposition. In this context, for meeting our future additional demand for seafood, it is inevitable to venture into mariculture practises. The development and standardisation of commercially viable mariculture activities is the major prerequisite. Hence, a technology oriented research and development in the frontier areas of mariculture, coupled with the establishment of state of the art infrastructure and capacity building are the immediate needs of the hour. In this regard, it is felt that international collaboration for establishing the state of the art infrastructure for seed production and farming of finfish and shellfish and HRD is essential. At the national level, collaborative research among institutions like CMFRI, NFDB and MPEDA will accelerate the developments. Mariculture R&D is capital-intensive and India has not made substantial investments in this sector. Hence, massive investment in this sector is warranted. Priority should be given to the development of lucrative and less capital-intensive farming technologies, which can be easily adopted by the coastal fisherfolk. Extension research for adoption of the technologies developed should also be given priority. A mission-oriented research and development approach, coupled with appropriate policy formulations can lead to the emergence of mariculture as a substantial contributor to the sea food production of the country.