Mariculture Technologies for Augmenting Marine Resources

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Introduction

A global review of the marine capture fisheries scenario reveals that 80% of the world's fish stocks for which assessment information is available are fully exploited and thus require effective and precautionary management. The maximum wild capture fisheries potential from world's oceans have almost been exploited and a more closely controlled approach to fisheries management is required (FAO, 2009). The current marine capture fisheries scenario in India is also characterized by increased and excessive fishing effort, overexploitation of certain resources from the inshore grounds and increased conflicts among the different stakeholders in the sector. Due to the larger dependency on inshore fisheries over the years, the production from near-shore waters has reached asymptotic level and hence ensuring sustainability is inevitable in our marine fisheries policy (Ayyappan and Srinath, 2005). The Comprehensive Marine Fishing Policy, 2004 (DAHD, 2004) underscores the need for a departure from the open access concept in the territorial waters and enforcing stringent management regimes. In this context, it is very much relevant to resort to resource augmentation methods through mariculture and allied techniques to enhance the seafood production.

Mariculture - Global scenario

It is well understood that aquaculture is the fastest growing animal food production sector with per capita supply increasing from 0.7 kg in 1970 to 7.8 kg in 2006 with an average annual growth rate of 6.9%. Most of the global aquaculture production of fish, crustaceans and molluscs continues to come from inland waters (61% by quantity and 53% by value). Mariculture contributes 34% of the total aquaculture production and 36% of the value. While much of the marine production is contributed by high value finfish, relatively low priced mussels and oysters are also widely farmed. While the overall share of farmed fish in marine finfish production has stayed much low, for the species that are farmed, cultured fish dominates the market. This is the case of Asian seabass, gilthead sea bream, red drum, bastard halibut and cobia. It is also a fact that for such species, the quantities now produced by aquaculture are often substantially higher than the past highest catch recorded by capture fisheries. In the last decade, salmonids have overtaken shrimp as the top aquaculture group in Latin America and the Caribbean as a result of outbreaks of disease in the major shrimp producing areas (FAO, 2009).

Aquaculture in the Asia-Pacific region has been growing steadily over the last few decades and to satisfy the demand of the local and export markets, many countries are expanding their aquaculture activities in the sea, including offshore areas where competition is less. Mariculture in this region is exceptionally biodiverse and relies on many species and hence the nature of mariculture is rapidly changing in this area (Rimmer, 2008). Some of the countries like China, Vietnam, Australia, Indonesia, Japan, Korea DPR, Korea Rep, Malaysia, Philippines and Thailand are much ahead in mariculture in this region and agencies like Network of Aquaculture Centres in Asia-Pacific (NACA) should take intergovernmental regional programmes so as to develop mariculture in the region as a whole.

Mariculture - Indian scenario

The dwindling catch rates in capture fisheries and rampant unemployment in the coastal region focus towards the development of mariculture and coastal aquaculture as a remunerative alternate occupation. Recent estimates quantify the per capita fish consumption in India around 8-10 kg per year and is likely to grow to 16.7 kg by 2015. Although about 1.2 million hectares are suitable for land based saline aquaculture in India, currently only 13% is utilized. Farmed shrimp contributes about 60% by volume and 82% by value of India's total shrimp export. Share of cultured shrimp export is 82,600 tonnes. The farming of shrimp is largely dependant on small holdings of less than 2 hectares and these farms account for over 90% of the total area utilized for shrimp culture. Coastal aquaculture is mainly concentrated in the states of Andhra Pradesh, Tamil Nadu, Orissa, West Bengal and Gujarat. In recent years, the demand for mussels, clams, edible oysters, crabs, lobsters, sea weeds and a few marine finfishes is continuously increasing and brings premium price in the international market. The long coastline of 8129 km along with the adjacent landward coastal agro climatic zone and the sea-ward inshore waters with large number of calm bays and lagoons offer good scope to develop mariculture in the country.

In this context, the Central marine Fisheries Research Institute (CMFRI) is the pioneering institution in the country which has initiated mariculture research and has been developing appropriate mariculture technologies in India (Devaraj *et al.*, 1999; ICAR, 2000; Pillai and Menon, 2000; Pillai *et al*, 2003; Modayil, 2004; Modayil *et al.* 2008; Gopakumar *et al.,* 2007). In India, till date mariculture activities have been confined to coastal brackish water aquaculture, mainly shrimp farming. The other coastal aquaculture activities are green mussel farming which is confined to Malabar coast in Kerala producing more than 10,000 t and seaweed farming along Ramanathapuram and Tuticorin coasts of Tamil Nadu producing about 5000 t annually.

The potentially cultivable candidate species for mariculture in India include about 20 species of finfishes, 29 crustaceans, 17 molluscs, 7 seaweeds and many other species of ornamental and therapeutic value. Many mariculture technologies are very simple, ecofriendly and use only locally available infrastructure facilities for construction of farm, feed and seed and hence the entire farming can be practiced by traditional fishermen. Another advantage is that most of our brackish water and coastal areas are free from pollution and are suitable for aquaculture. But hardly 10% of the potential cultivable area is presently used for aquaculture in spite of growing demand for cultured shrimp, bivalves, crabs and lobsters. In addition, a fast growing trade in marine ornamental organisms has also emerged in the recent years which opens up the possibility of culture and trade. Employment in aquaculture (inland and marine) has been increasing and is now estimated to account for about 25% of the total (GOI, 2001).

Coastal aquaculture is a significant contributor to marine fish production, constituting mainly the shrimps like *Penaeus monodon* and *Fenneropenaeus indicus.* However, vast water bodies suitable for aquaculture and the varied biodiversity that has the potential to capture new markets with a wide range of seafood products, have prompted consideration of other candidate species like oysters, mussels, crabs, lobsters, scampi, seabass, groupers, sea cucumber, ornamental fishes and sea weeds in the new aquaculture scenario in the country. Hatchery and rearing techniques have also been standardised for many of these organisms (ICAR, 2000).

Existing major mariculture species and farming technologies

Shrimp seed production and culture

Shrimps being a highly valued export commodity, shrimp farming is considered as a lucrative industry. Production-wise *Penaeus monodon* contributed 75% and *Fenneropenaeus indicus* 20%. Depending on the area of the pond, inputs like seed, feed and management measures like predator control and water exchange through tidal effects or pumping, farming systems have been classified into four groups: extensive, modified extensive, semi-intensive and intensive. Currently, 80% of the shrimp production comes from small and marginal holdings. Shrimp farms of less than 2 ha constitute 49.2%, between 2-5 ha 15.8%, 5-10 ha 13% and >10 ha 22% of the total area under culture (ICAR, 2000). The farming community has now become more responsive to the concepts of environment-friendliness and sustainable aquaculture. Disease problems are being tackled through adoption of closed system of farming (recirculation system, zero water exchange) in grow outs, application of probiotics, secondary aquaculture of selected fishes like mullets, milkfish, molluscs and seaweeds in reservoirs and drain canals, adoption of indigenous, good quality seed and feed and reduction in stocking density.

Lobster farming and fattening

Increasing demand for live lobsters in the export market led the farmers and entrepreneurs to collect juvenile lobsters from the wild and grow them to marketable size in ponds and tanks by feeding trash fishes. In many maritime states, juvenile lobsters of *Panulirus homarus, P. ornatus* and *P. poyphagus* are grown in captivity and the eyestalk ablated lobsters attained a weight of 180-200 g in 5-6 months. This type of lobster fattening at a stocking density of 10-15 young ones per square meter yielded appreciable growth rates with a profit margin of Rs. 50,000/- from a pond of 70 m^2. Fattening and grow out trials with artificial pellet feeds has been successfully completed. Cage farming of spiny lobsters was successfully demonstrated by CMFRI at Vizhinjam, Veravel and Mandapam. Recently major breakthrough in breeding and hatchery production of two species of scyllarid lobsters, *viz., Thenus orientalis* and *Petrarctus rugosus* was achieved. Successful hatchery production of seeds of *Thenus orientalis* and its compatibility with *Fenneropenaeus indicus* at high density race way culture system with very high production rates of 3-5 $kg.m^{-2}$ is highly promising.

Crab farming and fattening

Live mud crabs (*Scylla serrata, S. tranquebarica)* being a much sought after export commodity, mud crab fattening has gained popularity. Seed stock consists of freshly moulted crabs (water crabs) of 550 g which are stocked in small brackish water ponds at a stocking density of 1 per sq.m or in individual cages for a period of 3-4 weeks while being fed thrice daily with low value fish @ 5-10% of their biomass. Selective harvesting is done according to size, growth and demand and the venture is profitable because of low operating costs and fast turnover. Monoculture (with single size and multiple sizes stocking) and polyculture with milkfish and mullets are being carried out on a small scale, as the seed supply is still mainly from the wild. Hatchery technology for breeding and seed production of the blue swimming crab, *Portunus pelagicus*, has also been developed. Fattening and grow out trials with artificial pellet feeds has been successfully completed.

Edible oyster farming

CMFRI has developed methods for edible oyster (*Crassostrea madrasensis*) culture and has produced a complete package of technology, which is presently being widely adopted by small scale farmers in shallow estuaries, bays and backwaters all along the coast. In the adopted rack and ren method, a series of vertical poles are driven into the bottom in rows, on top of which horizontal bars are placed. Spat collection is done either from the wild or produced in hatcheries, on suitable cultch materials. Spat collectors consist of clean oyster shells (5-6 nos.) suspended on a 3 mm nylon rope at spaced intervals of 15-20 cm and suspended from racks, close to natural oyster beds. Spat collection and further rearing is carried out at the same farm site and harvestable size of 80 mm is reached in 8-10 months. Harvesting is done manually and production rate obtained is in the range of 8-10 $t.ha^{-1}$. Oyster shells are also in demand by local cement and lime industry.

Mussel farming

The technologies developed by CMFRI for culture of bivalves such as raft method (in bays and inshore waters), rack method (in brackish waters and estuaries) or long line method (in open sea) are commonly adopted for mussel farming (*Perna indica* and *P. viridis*). Mussel seeds of 15-25 mm size collected from intertidal and sub-tidal beds are attached to coir or nylon ropes of 1-6 m length and enveloped by netting. Seeds get attached to the rope within a few days while the netting disintegrates.

The seeded ropes are hung from rafts, racks or longlines. A harvestable size of 70-80 mm is reached in 5-7 months and production of 12-14 kg mussel (shell on) per metre of rope can be obtained. Attempts to demonstrate the economic feasibility of mussel culture has led to the development of group farming activities in the coastal communities (especially rural women groups) with active support from local administration and developmental agencies like Brackishwater Fish Farmers Development Agency (BFFDA) and Kerala State Fisheries Department. Cultured mussel production has increased from 20 tonnes in 1996 to above 10,000 tonnes in 2008, mainly through the raft culture system in estuarine area.

Pearl oyster farming and pearl production

In India, the marine pearls are obtained from the pearl oyster, *Pinctada fucata*. Success in the production of cultured pearls was achieved for the first time in 1973 by CMFRI. Raft culture and rack culture in near-shore areas are the two methods commonly adopted for rearing pearl oysters and recently attempts have been made to develop onshore culture methods. Shell bead nucleus (3-8 mm) implantation is done in the gonads of the oyster through surgical incision while graft tissues are prepared from donor oysters of the same size and age group. Implanted oysters are kept under observation for 3-4 days in the laboratory, under flow-through system and then shifted to the farm in suitable cages for rearing. Periodic monitoring is done and harvest is carried out after 3-12 months. Pearls are categorized into A, B and C types depending on colour, luster and iridescence. 25% pearl production has been successfully demonstrated in a series of farm trials at various locations along the Indian coast. Research is also directed towards development of a technology for *in vitro* pearl production using mantle tissue culture of pearl oyster. The technology for mass production of pearl oyster seed has also been developed. Village level pearl oyster farming and pearl production, through direct involvement of small scale fishermen have been carried out successfully as part of technology transfer programme along the Valinokkam Bay, Tamil Nadu. Recently success has been obtained in the production of Mabe pearls and tissue culture of pearls. Success was achieved in the organ culture of mantle of pearl oyster and abalone. A breakthrough has been achieved by developing a tissue culture technology for marine pearl production using the pearl oyster *Pinctada fucata* and abalone *Haliotis varia* for the first time in the world. This technology can be easily extended to other pearl producing molluscs and gives ample scope for manipulation of pearl quality and also increased pearl production. Mabe pearl production was standardised for production of base images with ten different types of moulds. Technology for production of jewellery from Mabe pearl was also standardised.

Clam culture

Package of clam culture practices has been developed for the blood clam *Anadara granosa* and *Paphia malabarica*, where production of 40 $t.ha^{-1}$ for culture duration of 6 months and 15-25 $t.ha^{-1}$ for a culture duration of 4-5 months have been achieved in field trials. Induced spawning and larval rearing to setting of spat have been perfected for clams like *Paphia malabarica*, *Meretrix meretrix* and *Marcia opima*.

Abalone culture

Abalones are marine gastropods of the genus *Haliotis*. They are known for the production of gem quality pearls and also for their succulent meat. *Haliotis varia* is the commercially important species along the Indian coast. CMFRI has developed methods for the seed production and culture of this species.

Cephalopod culture

CMFRI has developed methods for the culture of the cuttlefish *Sepiella inermis, Sepioteuthis lessoniana* and *Sepia pharaonis* in experimental conditions. However, scaling up of the methodologies for commercial level production remains to be demonstrated.

Marine finfish culture

In the area of marine fish seed production and culture, the country is still in the experimental phase only. Seed production technology is available only for the Asian seabass, *Lates calcarifer*. The Central Institute of Brackishwater Aquaculture (CIBA) has developed an indigenous hatchery technology for Asian seabass. The Rajiv Gandhi Centre for Aquaculture (RGCA) has also been propagating the seed production and farming techniques in the country. Recently CMFRI has successfully demonstrated the cage farming of sea bass at different parts of the coast. The broodstock development and spawning of the grouper *Epinephelus tauvina* was achieved at CMFRI. Attempts are being made to develop suitable hatchery and farming technology for cobia, mullets, pearl spot, rabbitfish, groupers, snappers, breams and pompano. The latest achievement in this regard is the successful broodstock development, breeding and fingerling production of cobia (*Rachycentron canadum*) at Mandapam Regional Centre of CMFRI.

Ornamental fish culture

On a global basis a lucrative marine ornamental fish trade has emerged in recent years which has become a low volume high value industry. There are a wide variety of ornamental fishes in the vast water bodies and coral reef ecosystems along the Indian coast which, if judiciously used, can earn sizeable foreign exchange. A long term sustainable trade of marine ornamental fishes could be developed only through hatchery produced fish.

The CMFRI has intensified its research on breeding, seed production and culture of marine ornamental fishes. One of the milestones in this programme is the recent success in the hatchery production technology of clown fish (Gopakumar *et al.*, 2001a; Ignatius *et al.*, 2001; Madhu an Madhu, 2002, Madhu *et al.*, 2006). Success was also obtained on the broodstock development, larval rearing and seed production of 7 species of damsel fishes (Gopakumar *et al.*, 2001b; Gopakumar, 2005). Breeding and seed production technologies have been developed for 12 marine ornamental fishes *viz.*, *Amphiprion sebae*, *Amphiprion percula*, *Amphiprion ocellaris*, *Premnas biaculeatus*, *Pomacentrus pavo*, *Neopomacentrus filamentosus*, *Neopomacentrus nemurus*, *Dascyllus aruanus*, *Dascyllus trimaculatus*, *Chromis viridis*, *Pomacentrus caeruleus*, and *Chrysiptera cyanea* by CMFRI.

The technologies developed have to be scaled up and demonstrated for commercial level production. Hatchery production and culture of marine tropical ornamental fish can prove to be more economically feasible than that of marine food fish culture, due to the high unit price of ornamental fishes. The clown fishes and damselfishes of the family Pomacentridae offer immediate scope for hatchery production due to the availability of seed production methodologies.

Seaweed culture

Around 60 species of commercially important seaweeds with a standing crop of one lakh tonne occur along the Indian coast from which, nearly 880 tonnes dry agarophytes and 3,600 tonnes dry alginophytes are exploited annually from the wild. Seaweed products like agar, algin, carrageenan and liquid fertilizer are in demand in global markets and some economically viable seaweed cultivation technologies have been developed in India by CMFRI and Central Salt and Marine Chemical Research Institute (CSMCRI, Bhavnagar). CMFRI has developed technology to culture seaweeds by either vegetative propagation using fragments of seaweeds collected from natural beds or spores (tetraspores or carpospores). It has the potential to develop in large productive coastal belts and also in onshore culture tanks, ponds and raceways. The rate of production of *Gelidiella acerosa* from culture amounts to 5 tonnes dry weight per hectare, while *Gracilaria edulis* and *Hypnea* production is about 15 tonnes dry weight per hectare. Recently the culture of the carageenan yielding seaweed *Kappaphycus alvarezii* has become very popular due to its fast growth and less susceptibility to grazing by fishes and is being cultivated extensively along the Ramanathapuram and Tuticorin coasts of Tamil Nadu producing about 5000 t dry weight annually.

Open sea cage culture

For the first time in India, a marine cage was successfully launched and operated at Visakhapatnam, in the east coast of India by CMFRI. Asian seabass (*Lates calcarifer*) was stocked during the first stocking as a trial. Successful harvesting was done after four months. A few demonstration cages have been deployed in different parts of the coast with fishermen participation and successful harvests could be made at many places.

Indicators from mariculture development in Asia–Pacific region

Many countries in the Asia-Pacific Region like Australia, China, Japan, Taiwan, Philippines, Indonesia, Thailand, Malaysia and Vietnam have made substantial progress in the commercialisation of many seed production and farming technologies of marine species. However, there are several issues to be addressed and opportunities to be exploited (FAO/NACA 2008). A knowledge about the issues involved and the opportunities for further mariculture development in the region will provide much insight and guidelines for progress towards this direction in India.

Major issues

Seed stock supply

There is limited supply of seeds of high value species desired by the farmers. More information is needed especially on growth rates to allow farmers to make informed choices. Cheaper seed stock would help to reduce production cost. Application of extensive larval rearing technology has to be tried for desired species to reduce cost-efficiency of production. The quality of seed stock has to be ensured by evolving of specific-pathogen-free (SPF) certification for seedstock. The quality and management of broodstock and the impacts of domestication of hatchery broodstock have to be ascertained. Research and development on seed production and nursery rearing technologies for high value finfish needs to be intensified.

Feeds

It is well known that aquaculture feed in the Asia-Pacific Region is largely dependent on trash fish. Cost of feeds is the key factor to reduce the production costs. Even though pellet feeds are available for some cultured species the diversity of species cultured in the area acts as a barrier for the development of specific feeds. Farmers are also reluctant to use pellet feeds as the product quality of pellet feeds are not well documented.

Environmental impacts

In the integrated coastal zone management, there should be zoning for areas for mariculture. There is a general lack of information on the impacts of aquaculture on the environment.

Health management

In many areas there is a lack of diagnostic support for mariculture and farmers may not appreciate environment-disease interactions, so that they may not realize that the negative environmental impacts affect their productions. An SPF certification is essentially needed.

Chemicals

The widespread use of unregistered and inappropriate chemicals to treat diseases has environmental impacts as well as food safety implications. There is a need for better education of farmers and extension agencies on chemicals approved for use in aqualculture.

Production technologies

Current production technologies such as cage design restrict mariculture largely to inshore areas. Improved cage designs and mooring systems are to be developed for extending mariculture to deeper waters. There is a need to continue support to the development of small-scale farms using artisanal cages with appropriate infrastructure and materials. Mariculture development needs to focus on reducing production costs while increasing production. For capture based aquaculture better knowledge of the seed resources and the impacts of their harvests on resources are required.

Better management practices

Site selection for mariculture has to be done with clear definitions. A guide for site selection is needed. Carrying capacities of coastal tropical environments have to be well assessed.

Opportunities

The increasing affluence in Asian countries is expanding the markets for seafood. Opportunities for developing information services and networking will support this sector. Mariculture in the region is notable for the high diversity of production as compared with that of Europe or North America and this provides opportunities for farmers to switch between commodities in response to factors such as price and risk.

Constraints

Intense competition exists in the global market for seafood. In some Asian countries, aquaculture is less attractive to young people as a career. Market chains in many countries are poorly developed which decreases the profitability of mariculture enterprises. Environmental degradation leads to less efficient production because of water quality induced stress and increased prevalence of disease. Mariculture in the Asia-Pacific Region still relies mainly on trash fish as a feed source.

Regional cooperation

Cooperation in the technological, marketing and other aspects among the different countries is of paramount importance for the development and expansion of mariculture in the Asia-Pacific Region. The Asia-Pacific Marine Finfish Aquaculture Network (APMFAN) can be taken as a model for further cooperation in this regard. APMFAN uses website mechanisms such as website (www.enaca.org/marinefish), electronic publications, print publications, training courses, regional technical workshops and technical advice. The proposed cooperation should include (i) support to develop sustainable growth of the mariculture industry in the Asia-Pacific Region, (ii) promote the production of quality products to consumers addressing human health issues, (iii) promote knowledge transfer and (iv) ensure that mariculture development contributes to sustainable livelihoods in coastal communities.

Approaches for regional cooperation in enhancing aquaculture production may include the following short term and long term work packages:

Short term packages

Development of low cost cages

Cooperation on low cost cage technology could be undertaken by linking with existing projects in Vietnam and Phillippines. Aspects of the work could include economic evaluation and engineering aspects of cage design.

Low cost hatchery system for bivalves

Low cost and high volume technology for bivalves as is practised in Hainan (China) can be adopted.

Live feeds

This programme is to improve the culture densities and reliability of live feeds such as micro-algae, rotifers and copepods. Copepod culture is particularly important for marine finfish larval rearing, including cobia.

Aquatic animal health

This package is to develop and implement a training programme for extension staff to support improved aquatic animal health in the region.

Long line culture of bivalves

This is to extend the long line culture techniques for bivalves to countries not currently practicing these techniques. Potential source countries are China, New Zealand, the Republic of Korea and Japan.

Recirculation technology

The most obvious application of this technology is to support improved biosecurity in hatcheries and nurseries.

Long term packages

Vaccine development

Ongoing research and development in Vietnam and Taiwan Province of China to evolve vaccines for finfish diseases should be linked.

Ecosystem approach to aquaculture

The ecosystem approach should involve all the stakeholders to ensure ecological, social and economic sustainability, thus assuring the farmers their immediate and future livelihood business. The objectives would be (i) to collate the information needed to develop an ecosystem approach to mariculture (EAMAR), (ii) to develop and implement coastal management and zoning plans based on EAMAR, (iii) training on best management practices and EAMAR for cage based mariculture, and (iv) integrated monitoring of environmental conditions to reduce environmental impacts of mariculture.

Genetic improvement

There are plans to undertake selective breeding work on cobia in Vietnam. Collaborative investigations on the potential of triploidy for mollusc production can be done.

Future thrust areas for mariculture research and development in India

Seed production of crabs, lobsters, cephalopods and marine finfish

The major constraint for the development and expansion of mariculture in India is the lack of availability of seed for commercial level farming. Hence, maximum research thrust is required for the development of commercial level seed production technologies for the suitable species of crabs, lobsters and marine finfishes. Even though, seed production of the swimming crab *Portunus pelagicus* is achieved, the survival rate to seed stage is only about 5%. Technology upgradation is required to achieve commercial level seed production. Similarly, the success in the seed production of the sand lobster *Thenus orientalis* also needs scaling up to commercial level production. In the case of spiny lobsters, the larval rearing of phyllosoma VIII still remains as a challenge due to the prolonged larval phase of spiny lobsters. The experimental success obtained in the seed production of squids and cuttlefishes (*Doryteuthis singhalensis, Sepia pharaonis, Sepioteuthis lessoniana* and *Sepiella inermis*) have to be scaled up. Massive research input is required for development of seed production technologies for many species of marine finfishes which are suitable for open sea cage farming. The current success in the seed production of cobia has to be standardised.

Establishment of seed banks for mariculture

At present, except for a few species of shrimps, commercial level seed availability is lacking for other suitable species for mariculture. Hence the establishment of seed banks at appropriate locations is the basic requirement for the development of mariculture. Seed banks for all the mariculture candidate species need to be developed at appropriate locations. For those species in which hatchery produced seed is not economically viable as for instance in bivalve molluscs and for those species in which hatchery production technologies are not available, seed banks could be developed from wild collected seeds.

Cage culture

It has now been realized that further conversion of wetlands and mangroves into traditional aquaculture farms has to be limited. Cage culture has several advantages over other culture systems. The cage culture system can optimize the carrying capacity per unit area since the flow of current brings in freshwater and removes metabolic wastes, excess feed and faecal matter. Simple cage designs for inshore waters are relatively easy to construct with minimal skilled labour. Cage culture is a low input farming practice with high economic return and can be improved and expanded by extension and training programmes to the fisherman by Central and State Government fisheries development agencies.

Open sea cage culture

The open sea cage culture has been expanding in recent years on a global basis and it is viewed by many stake holders in the industry as the aquaculture system of the millennium. Cage culture has made possible the large scale production of commercial finfish in many parts of the world and can be considered as the most efficient and economical way of fish culture. The Indian coast offers many ideal locations for cage farming. Potential sites include bays in Ratnagiri, Goa, Karwar, Palk Bay, Larsons Bay, Gulf of Mannar, Lakshadweep Islands and Andaman and Nicobar Islands. The potential fishes for cage culture include groupers, snappers, seabass, rabbit fish and cobia. A few modern demonstration farms could be set up at suitable sites by entrusting the work with developmental agencies of Central and State Governments. Floating cage farming can be further expanded after the techno-economic viability under Indian conditions is established through the demonstration farms.

Integrated farming of finfish and shellfish with seaweed

In recent years, the Integrated Multi-trophic Aquaculture (IMTA) which combines the cultivation of fed aquaculture species such as finfishes and shrimps with organic extractive aquaculture species such as molluscs and macro-algae has been gaining momentum internationally. Integrated farming of fish and shellfish with seaweed can reduce the environmental impact of industrialized mariculture and at the same time improve the operational economics of culture system. Plants counteract the environmental effects of the heterotrophic fed fish and shrimp and restore water quality. A one hectare land based integrated sea bream – shellfish – seaweed farm can produce 25 t of fish, 50 t of bivalves and 30 t fresh weight of seaweeds, annually. Hence, modern integrated systems are bound to play a major role in the sustainable expansion of mariculture. A few frontline demonstration farms on integrated farming of fish and shellfish with seaweed can be established at suitable locations through Central and State Government fisheries development agencies to assess the techno-economic viability of such systems. The integrated farming approach can be adopted for cage farming also.

Popularisation of bivalve mariculture

Being in the lower part of the food chain, bivalves are energy efficient and cause least pollution to the culture system and the environment. It can be carried out as an artisanal mariculture programme and also as a large scale mariculture enterprise oriented towards export market. Artisanal mariculture of mussels, edible oyster and clams is being practiced on a small scale in certain parts of our coast. There is scope for bivalve farming along Kerala, Karnataka and Maharashtra coasts. State and Central Government developmental agencies can be entrusted for the expansion of bivalve farming in suitable areas along the coast by giving training and extension programmes. Mass scale industrial farming of bivalves can also be taken up with an export oriented market.

Expansion of seaweed culture

The seaweed industry provides a wide variety of products that have an estimated global annual production value of US$ 5.5–6 billion, of which food products for human consumption contribute about US$ 5 billion. Substances that are extracted from seaweeds account for a large part while miscellaneous uses such as fertilizers and animal feed additives make up the rest. The industry uses 7.5–8 million t of wet seaweed annually, originating from the wild or farmed seaweeds. The farming of seaweeds has expanded rapidly as demand has outstripped the supply available from natural resources. Commercial harvesting occurs in about 35 countries, spread between the northern and southern hemispheres, in waters ranging from cold, through temperate, to tropical.

Against this background, mariculture of seaweeds in the suitable areas of the Indian coast has to be promoted to achieve industrial level production. Suitable areas for seaweed culture include coasts of Tamil Nadu, Orissa, Okha-Veraval (Gujarat) and Konkan coast. Demonstration programmes for artisanal seaweed culture could be organised by developmental agencies in these areas. Large scale culture of seaweed can also be demonstrated at Palk Bay to assess the techno-economic viability for industrial level production of seaweeds. Production of good quality agar and carageenan and development of appropriate marketing system have to be taken up as priority programmes for the development of seaweed industries in India.

Demonstration farms for pearl culture

The techno-economic viability of pearl culture still remains to be demonstrated, in India. Hence establishment of one or two demonstration farms, through Central and State developmental agencies, is an immediate requirement before commercialisation of this programme.

Development of artisanal mariculture programmes

Since the marine fish catch in recent years has been declining alternate small scale livelihood programmes have to be evolved for coastal fisherman. In this context, artisanal mariculture can play a vital role as an additional source of income. Artisanal mariculture of bivalve molluscs, seaweeds, crab and lobster fattening are being practiced in certain parts of the coast. Extensive training programmes could be organised along Kerala, Tamil Nadu, Karnataka, Konkan and Orissa coasts for promoting the artisanal mariculture practices.

Development of marine ornamental fish culture

In recent years, the marine ornamental fish trade is a global multi-million dollar industry worth an estimated US$ 200-330 million, annually. Even though, India is bestowed with ornamental fish resources, wild collection from coral reefs can lead to destruction of the reef habitats. Hence development of trade through hatchery production of fish offers good scope. In the recent past, CMFRI has developed technologies of hatchery production techniques for clownfish and a few species of damsel fishes. However, the techno-economic viability of commercial level production is yet to be demonstrated. Hence, establishment of one or two demonstration units at suitable areas like Lakshadweep Islands, Andaman and Nicobar Islands and Gulf of Mannar coast, through State and Central developmental agencies is an immediate requirement. In addition, research on development of seed production technologies for suitable species of marine angelfishes, gobiids and cardinal fishes deserve attention.

Development of capture based aquaculture

The harvesting of wild individuals from very early stages in the life cycle to large mature adults and their culture under confined and controlled conditions is referred to as capture-based aquaculture (CBA) (Lovatelli and Holthus, 2008). This category of farming includes the rearing of some species of finfish, most molluscs, and certain forms of the extensive culture of marine shrimp. It has been estimated that it accounts for about 20% of the total quantity of food fish production through aquaculture. Using FAO data from 2001, this is equivalent to over 7.5 million t per year, principally molluscs. The production of finfish, especially carnivorous species such as groupers, tunas, yellowtails and eels, through CBA is currently receiving the most attention. CBA is an interface between capture fisheries and true aquaculture and provides an alternative livelihood for local coastal communities in developing countries and several industrialized countries. In India, since the seed production technologies of many species are either not standardised or commercial viability is not demonstrated, the practice of CBA can be developed with proper management.

Installation of artificial reefs and FADs

Artificial reefs (AFs) and Fish Aggregating Devices (FADs) are known to attract fish. Hence, installation of AFs and FADs at suitable areas of the coast can enhance fish production. A few artificial reefs and FADs can be installed at suitable locations by Central and State developmental agencies by involving stakeholder participation. Regular assessment of the impact of AFs and FADs on enhancing fish production can be done with the involvement of research institutions.

Large scale sea ranching for stock enhancement

It is well known that many of our marine fisheries resources are overexploited leading to reduction of the concerned wild stock. In this context, large scale sea ranching programmes can play vital role in the natural stock enhancement. Already, sea ranching of *Penaeus semisulcatus* was demonstrated by CMFRI at Mandapam area. Massive sea ranching programme for *Penaeus semisulcatus* can be taken up along the east coast by developmental agencies with participation of fishers. Regular impact assessments of the sea ranching have to be conducted by involving research institutions.

Conservation mariculture

The populations of many marine species are constantly declining and are in the process of getting endangered. These include species of *Trochus, Turbo,* chank, sea cucumber and seahorse. Stock replenishment through large scale seed production and sea ranching will be a positive step towards the conservation of these species. CMFRI has successfully developed hatchery techniques for some of the species. However, additional thrust in research in this sector is required.

Conclusion

Research and development on commercial level seed production technologies of high value finfish and shellfish, popularisation of sea cage farming and evolving suitable policies for sea farming are the key areas to be focused, in order to make mariculture as a significant seafood production sector in India. Mariculture and allied post harvest technologies if scaled up to commercial level with community participation, the coastal productivity and economy can prosper. Intergovernmental cooperation with countries in the Asia-Pacific Region, where mariculture is technologically advanced, through agencies like NACA can play a key role in the development of mariculture in the country. A focused research and development thrust, technological demonstrations and extension programmes, along with enactment of appropriate legislation and enabling policy framework in marine farming sector can pave the way for India to emerge as one of the major producers of farmed marine fish in the world, in the foreseeable future.

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