Overview on mariculture and the opportunities and challenges of cage culture in India

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India is the fourth largest producer of fish in the world and the total fish production is around 6 Mt per year and its share in the GDP is around 1.4%. The world annual growth rate in aquaculture production has been 7.05% since 1971 (FAO 2008). In 2006, aquaculture comprised 41.8% of total seafood supply. Indian aquaculture has demonstrated a six and half fold growth over the last two decades, with freshwater aquaculture contributing over 95 percent of the total aquaculture production. Given the status of global fisheries, with most large fish stocks being fully exploited or over-exploited, aquaculture production must increase in order to maintain or increase the global seafood supply per capita. Fortunately, the aquaculture sector seems well positioned to succeed in this respect. By obtaining control over the production process and closing the production cycle for an increasing number of species, research and innovation similar to what has taken place in agriculture is rapidly improving the competitiveness of aquaculture, and the blue revolution is following the green revolution.

India utilises only about 40 percent of the available 2.36 million hectares of ponds and tanks for freshwater aquaculture and 13 percent of a total potential brackishwater resource of 1.2 million hectares; in other words, there is room for both horizontal and vertical expansion of these sectors. With over 8000 km of coastline there is immense potential for the development of mariculture which has taken roots only in recent years.

CMFRI has developed several mariculture technologies during last 25 years and concentrated mainly on non finfish like green mussel, edible oyster clams pearl oysters sea cucumbers, several species of ornamental fish, as the scarcity or need for edible marine fish culture was not felt. The demand for cultured marine fish is of recent development in India.

CMFRI initiated a pearl culture program in 1972 and successfully developed the technology for pearl production in Indian pearl oysters. Success in controlled breeding and spat production of the Japanese pearl oyster (*Pinctada fucata*) in 1981 and the blacklip pearl oyster (*P. margaritifera*) in 1984 was another important breakthrough. CMFRI also took the lead in the development of the technology required for edible oyster farming during the 1970s. Intensive research on various aspects of the culture of the Indian backwater oyster (*Crassostrea madrasensis*) has been made and the technology has also been developed for the hatchery production of seed.

In India, two species of marine mussels namely the green mussel (*Perna viridis*) and the Indian brown mussel (*P.*

indica) are found in rocky coastal areas. Investigation of the culture possibilities for mussels was initiated in early 1970s by CMFRI which resulted in the development of a range of practices for the culture of these species. Among maritime States, Kerala was the first to recognise the advantages of utilizing mussel farming technology in rural development, from a meagre production in 1997 cultured mussel production rose to 1250 tonnes in 2002 with over 250 mussel farms being established in the estuaries of Kerala.

Considering the substantial contribution aquaculture makes towards socio-economic development in terms of income and employment through the use of unutilised and underutilised resources in several regions of the country, environmentally friendly aquaculture has been accepted as a vehicle for rural development, food and nutritional security for the rural masses. It also has immense potential as a foreign exchange earner.

Aquaculture- a challenging task

Aquaculture ranks among the most risky businesses to enter as an entrepreneur, farmer, or investor. The risk begins with the production process, as farms face several substantial biophysical uncertainties related to disease, water environment, environmental, and climatic conditions. For many species a long production cycle from fingerlings to harvest contributes to the production risk. Market prices for most aquaculture species exhibit significant volatility; market access is often restricted by changing trade regulations; and new competitors continuously enter the market. There are many causes of market risk. Obvious sources are shifts in total supply from farmers and consumer demand that is not fully anticipated when production decisions are made. When aquaculture products are marketed in the international arena, which is the case for most aquaculture species, producers face risks related to exchange rate, antidumping, sanitary and veterinary regulatory changes, and other trade barriers. Finally, aquaculture products are increasingly marketed through large retail chains, where there are risks related to retailers' bargaining power and extensive requirements to suppliers in terms of deliveries (volume, timing,), documentation, certification, Despite high economic risks, the global aquaculture industry continues to attract new production capacity, new entrepreneurs, and new investors. This is a clear sign of the profitability of the industry, as high returns are the market's signal to attract more investors and to increase production. There are two main explanations for this development. The first is a strong underlying growth in the global demand for seafood. This primarily benefits aquaculture as fisheries production cannot grow much above current levels. As an increasing number of the world's people, particularly in Asia, climb from poverty to the middle class, further growth driven by the demand for variety in protein intake and health concerns is expected. The second is rapid development in the technologies on which aquaculture depend, leading to an almost continuous increase in productivity and quality over time. There is still much room for improvement, *e.g.*, in genetic material, feed formulations, disease-control, logistics, distribution, and marketing. With large differences in technological sophistication between different species and regions, one can expect productivity development in aquaculture to continue to improve the competitiveness of aquaculture species, and with increased demand the production will be profitable. However, as new technologies are adopted, the cyclical and risky nature of the industry will also continue.

Cage culture

The cage culture which initiated in Norway during 70s got developed into a high tech industry in many countries all over the world for high value fishes. The major advantage in countries where cage culture has been commercialised is that they have large, calm and protected bays to accommodate the cages safely against any unfavourable weather conditions. But in India, such areas are very few and the sea conditions are unpredictable during monsoon seasons leaving the safety of structures uncertain. Also, the Government of India or any maritime States have no policies regarding commercial mariculture and leave alone open sea cage farming. Many countries try to venture into Indian arena to sell aquaculture equipments including cage related products which are suitable for their environment and may not be to Indian conditions. But, all are reluctant to transfer technologies suitable to Indian conditions and foreign consultants charge exorbitantly for consultancy. Fish farming in cages is a lucrative business for otherwise poor coastal communities and it is an industry that is growing rapidly in many Asian countries. In some countries and locations, cage farming provides an important source of fish production and income for farmers, other industry stakeholders and investors. Of the estimated one million tonnes of marine fish cultured in Asia, probably 80-90 % is from cage farming. Most of the research relates to cage aquaculture in temperate waters, an industry that has been well established for more than 30 years, particularly for salmon. In modern times, cage culture is also seen as an alternate livelihood, for example, for persons displaced by the construction of reservoirs or acquisition of land for other developmental activities. In such a situation, cage aquaculture has emerged as a promising venture and offers the farmer a chance for optimal utilization of the existing water resources which in most cases have only limited use for other purposes.

Cage is an aquaculture production system made of a floating frame, net materials and mooring system (with synthetic mooring rope, buoy, and anchor) as a round or square shape floating net pen to hold and culture large number of fishes and can be installed in reservoir, river, lake or sea. The design of the cage and its accessories can be tailor-made in accordance to the individual farmer's requirements. HDPE float frames installed in open unprotected water can withstand wave conditions. Round cage (volume depends on diameter) with floatation system made of butt-welded HDPE pipes, designed for the culture of fishes such as milkfish, mullet, cobia or pompano seabass, koth, ghol lobsters are used in many countries.

By integrating the cage culture system into the marine aquatic ecosystem, the carrying capacity per unit area is optimized because the free flow of current brings in instantaneous exchange of water and removes metabolic waste and excess feed. Thus economically speaking, cage culture is a low impact farming practice with high economic returns and with least carbon emission activity. In view of the high production attainable in cage culture system and the presence of large sheltered coastal waters in many countries, marine cage farming can play a significant role in increasing fish production.

Success of open sea cage farming in India

For the first time in India a marine cage was successfully launched at Visakhapatnam, in the east coast of India by CMFRI in 2007. The indigenously designed and fabricated HDPE cage was provided with a cat walk for free working on board and stabilization. The cage net was 15 m diameter and 6 m deep. An outer HDPE predator net protected the cage net from damage by large predators. On top of the cage railing, a bird net was provided to prevent bird attacks. The entire structure was kept in position by ballast and ropes tied to the mooring chains. The cage was provided with a shock absorber on the mooring chain to withstand and absorb the pressure of winds, currents and was moored at a depth of 11 m about 300 m from the shore line. The total net volume was 850 cubic meters. This area being under the influence of high water currents, strong waves, and winds and generally rough, the cage was intact. Limited number of Asian seabass, *Lates calcarifer,* was stocked during the first trial and successful harvesting was carried out after four months during the trawl ban period in the east coast. The economic analyses of the operation have revealed the viability of cage culture in Indian waters. Other successful models are lobster

(*Panulirus homarus*) at Trivandrum, Kerala and seabass at Balasore, Orissa. At Balasore, culture of seabass in cage was undertaken during 2009 and despite of several odds, a catch of 3.1 t was harvested with the active cooperation of fishermen.

Opportunities for cage culture in India

General

The Indian sub continent presents open sea aquaculture producers with a number of opportunities:

A huge area to convert to mariculture farm: The Indian coastline is extending up to 8129 kilometres and has a continental shelf area of 5.3 lakh km^2. With numerous creeks and saline water areas the opportunities for cage culture are tremendous in India.

Well experienced fishermen work force: India has a huge human resource of about 14.66 million fishermen population including adult fishermen (8.7 million), full time (0.93 million), part time (1.07 million),and those who are involved in ancillary activities like net making, processing and fish vending (3.96 million). Development of mariculture through cage farming can be taken up with a focus on sustainability through empowering the fishermen by achieving employment generation, social security and increased food security and augmenting sea food exports. Many of these wild fish harvesters represent a highly trained workforce that have extensive knowledge of the ocean, boat handling, net mending and maintenance, fish harvesting and quality control that aquaculture companies can easily adapt to their own operations. In these cases, previous wild fish harvesters would require only some basic training associated with standard farm operations and fish health management.

Strong domestic and export markets: It is a major advantage of Indian sub-continent that it has an excellent domestic market for fish and if supply is assured during fishing ban seasons, the returns to the farmer will be very attractive. Similarly export also can be enhanced for fish if adequate post harvest measures are adopted for live fish export to countries where such fish fetch good market price. At present only shellfish is leading Indian export and the scenario can be changed if we can assure post production quality for harvested marine fishes.

An educated workforce and people with excellent animal husbandry skills: sufficient number of fisheries graduates and specialists in different areas of fish farming (Nutrition, pathology, environment) are available in India to make the cage farming sector technically fool proof.

Local availability of trash fish: There are 3827 fishing villages and 1914 traditional fish landing centers in India and if proper effort is put in preserving the trash fish, they can be utilised for feed, feed ingredient for compounded feed. Availability of local feed manufacturers and suppliers also are added advantage.

Strong research and extension capabilities: In India there are 8 National Fisheries Research Institutes, equipped with well experienced researchers and infrastructure facilities. CMFRI and CIBA are doing extensive research in marine and brackishwater aquaculture and since CMFRI has pioneered in open sea cage farming, it will be an added strength for entrepreneurs to have consultants within the country rather than spending on foreign experts. There are extension researchers as well as officers in different national and state level organisations and it is also helpful when new and novel technologies are introduced to aquaculture sector.

Marine cage culture also presents an excellent opportunity to maintain coastal communities that are presently reliant upon over-harvested commercial fisheries (In the simplest terms one 6 m diameter cage is equivalent to one ha pond on land with regard to production and with less work).

Challenges or constraints

Lack of clear regulations for use of open sea waters: The Indian seas are open to all Indians and the lack of any policy in utilisation of open waters has to be tackled in a positive manner. By allocating areas for cage farming, by means amicable to fishermen and other users of the sea (navigation, tourism) this can be overcome.

Competition arises from other uses of coastal and offshore waters such as recreational boating, commercial fishing and shipping

Rising costs of inputs such as energy and feed: Demand and supply are not matching in many cases and therefore cost escalation in aquaculture operations also inevitable.

Concerns by fishermen about competition from aquaculture: due to lack of awareness and insecure feeling, fishermen resist on any venture in the sea. Only solution is to get them involved in cage culture operations also. By experience in the field they will also change their mind set.

Concerns about environmental effects of aquaculture: Before starting any new venture, it is of no concern about environment or sustainability. But over the years, that becomes the major concern. So before initiating cage culture, it is better to plan out a scheme for environmental concern over the years which will help in flourishing aquaculture rather than killing it.

Technological challenges: Since the industry is new to India, many stake holders will come with many offers, but no proven technology is available so far.

Other challenges

Site selection

Site selection is the biggest challenge in determining commercial viability of cage culture. Identifying a location that has the optimum water quality (temperature, oxygen, light and nutrient levels), current movements and other infrastructure facilities is the most critical factor in cage culture.

Criteria to be considered before selecting a site for cage culture are:

- Site should be at least 6- 8m (depending on the net depth) deep over a sizable area, with sandy or rocky bottom
- Site must have good water quality and should be located away from sources of pollution
- Wind and wave action should be at moderate levels
- Site should not be a regular fishing ground or a navigation channel so that interference would be hindrance for the operation
- Site should have an all weather access
- Nearest beach should have required low valued fish source to be used as feed
- There should be adequate availability of labour and materials
- Cages should be easily monitorable

Cage models

Another challenge to tackle over is in selection of cage models and the design of the cage is directly related to the chosen site, inshore or offshore. According to the analysis of Loverich and Gace (1997) on the effect of currents and waves on several classes of cages for offshore, the most suitable cage is a self-supporting cage. However, for inshore or sheltered sites the conditions change and gravity cages can be used. Some countries tend to move the cages offshore due to legal and possible pollution problems, but the open sea cages face other problem like rough sea. In all the cases, whether inshore, offshore, or sheltered, the cage structures must withstand the forces of the currents, waves and winds, while holding the stock securely. There are a number of types of cages. Beveridge (1996) proposed four basic types: a) fixed; b) floating; c) submersible; d) submerged.

Various cage types and systems are being used for finfish farms all over the world, the choice of which is usually determined by the following main factors:

Site: The most important aspect to be considered is the site in which the cages will be set up and their suitability with regard to (i) exposure to potential sea storms, (ii) seabed characteristics and depth, (iii) prevailing sea conditions, and (iv) visual impact. An exposed site and an increased risk of heavy storms will require cages, nets and mooring systems designed to resist the maximum registered storm strength. If the site is somewhat sheltered, a simplified mooring system and lighter rearing structure will reduce the cost of the initial investment. Should negative interactions be encountered with coastal tourism; submerged or low visual impact models are often considered and/or possibly recommended by the authorities responsible for the issuance of the farming license.

Cost of cages: The initial cost of the investment usually represents a limiting factor particularly for those investors with a fixed budget. However, the cheapest option may not take into consideration the suitability of the structures for the site.

Production plans: The size of the farm and cage model may vary depending on the target pursued by the investors. For instance, farmers aiming to produce a niche product, or attempting to diversify production with fish of various sizes, may prefer a large number of small cages rather than a few large ones so that only a reduced percentage of volume can be engaged in a selected production.

Species selection and seed availability

It is well known that availability of seed in adequate quantities is one of the major challenges in the development and expansion of mariculture. Though seed production technologies have been developed for many marine finfish and shellfish species, many of these technologies have not been scaled up to commercially viable levels. The hatchery seed production of many high value marine finfishes and shellfishes is complex and expensive due to the high costs involved in the establishment of broodstock and hatchery facilities and also to the complicated larviculture procedures involving culture of proper live feeds, their nutritional enrichment, feeding protocols, grading, water quality maintenance, nursery rearing and disease management. The production of seed of the concerned species by development of commercially viable technologies is essential for development of sustainable mariculture practices, but many of these technologies are still in the emerging state and may take several years for standardisation on a cost effective level. High value species like Asian sea bass for which hatchery seed as well as natural fingerlings available at different locations in India is ideal to be stocked in cages. More hatcheries are to be set up for seabass along the Indian coast for continuous supply of seed.

Capture based aquaculture (CBA) is an alternative for those species for which hatchery technology is not developed. As hatchery technologies remain to be perfected for many species, fish farmers have to depend on 'seed' available from the wild. CBA has developed due to the market demand for some high value species whose life cycles cannot currently be closed on a commercial scale. CBA is a world-wide aquaculture practice and has specific and peculiar characteristics for culture, depending on areas and species. The species/ groups that can be harvested as wild juveniles include shrimps, milkfish, seabass, mullets, pomfrets, groupers, red snappers, koth, lobsters It is generally considered that further development of marine aquaculture is possible only by the increase in mass production of juveniles in hatcheries. But it remains a fact that much of world's coastal aquaculture can still be expected to come only from the supply and availability of capture-based juveniles. The species include seer fish, pomfrets, mackerel, koth, shrimps Also, there exists a good fishery for live juveniles of different species of lobsters but very little are used for fattening. It is estimated conservatively that about one million of seer fish juveniles of 7-10 cm and two millions of mackerel juveniles of 5-8 cm land by shore seines in the month of April alone along the stretch of Visakhapatanam- Kalingapatnam. If only a small fraction of these seed/juveniles are induced to be brought in live condition, they form very good source of CBA without affecting the ecosystem and livelihood of fishermen. It will be more lucrative for the fishermen at the same time contributing to several fold increase in the mariculture production. Juvenile yellow fin tuna are available in plenty in and around Lakshadweep waters which can be used for farming in cages.

Feed

Availability of cost effective and nutritionally balanced feed is another constraint for high value fish culture in cages. As on today there is no indigenous scientifically developed marine finfish feed. The development of feed is also very complicated and need to look into nutritional balance for carnivorous fish, feed conversion and cost effectiveness. The imported feeds for seabass are sold at Rs 80/kg which is not economical for most of the farming operations.

Conclusion

With all the challenges to be faced, it is felt that with innovations in cage culture as suitable to Indian conditions can result in opening up a new horizon in Indian fisheries, especially in mariculture.