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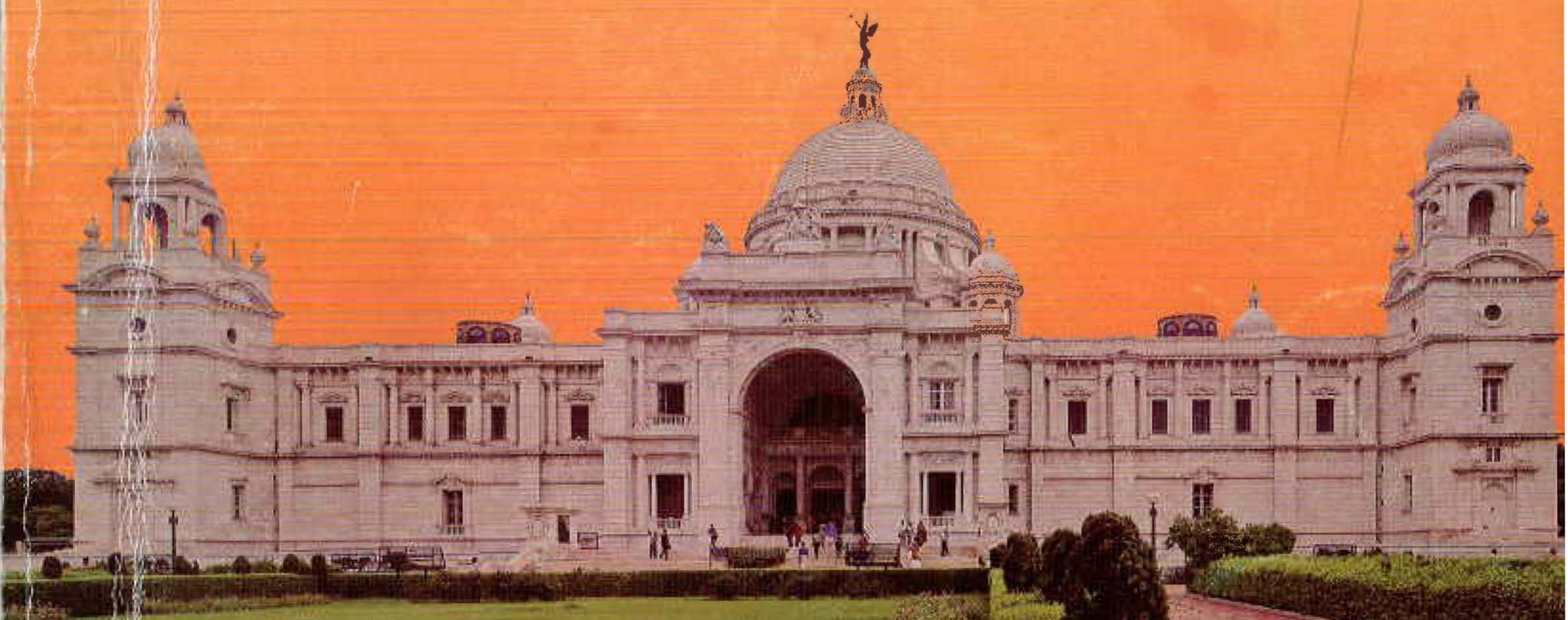

Development of Sustainable Capture Based Aquaculture : A Profitable Option for High Value Sea Food Production

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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 marine fish production was 2.81 million tonnes for the year 2005-06 which form 42.78% of the total fish production. With continued human pressure on marine fisheries and ocean resources, aquaculture has become one of the most promising avenues for increasing marine fish production in the future. On a global scale, the decline of fish stocks has been a motivating factor for expanding the role of aquaculture in the fishing industry. It is well known that the ready availability of seed in adequate quantities is one of the major constraints in the development and expansion of mariculture. In this context, the concept of capture based aquaculture/ mariculture can be considered as a viable option for augmenting the production of high value species.

Categories of finfish farming include hatchery-based rearing from egg to adult ("closed cycle aquaculture" or "true aquaculture") and capture-based aquaculture (CBA), which involves capturing "seed" material from the wild, then growing it to marketable size in captivity, using aquaculture techniques (FAO, 2004). CBA is an interface between capture fisheries and true aquaculture and provides an alternative income for local coastal communities in developing and several industrialized countries. It has been estimated that CBA accounts for about 20 percent of the total quantity of food fish production through aquaculture, which is about 7.5 million tonnes per year, mostly molluscs. The production of finfish, especially carnivorous species (including milkfish, groupers, tunas, yellowtails and eels), through CBA, is currently receiving the most attention. CBA has developed due to the market demand for some high value species for which seed production technology is not yet standardized. Many of the environmental concerns associated with the grow out of juveniles produced in hatcheries like transfer of diseases and 'genetic pollution' of wild stocks are not encountered in CBA. As CBA potentially generates higher profits than other aquaculture systems, the market demand for the products and species cultured is high and it is likely that efforts to promote this activity in future will increase significantly.

Species selection

Potential marketatability, economic value, growth rate, performance under captive conditions *etc.* are the main criteria to be considered for species selection in CBA. Most species farmed under CBA are carnivorous due to their better market demand and higher value. CBA is practiced for finfish (eels, groupers, bluefin tuna, yellowfin tuna, yellow tail *etc.*), molluscs (oysters, mussels, scallops) and crustaceans (shrimps, crabs) (Pillay, 1995). Eels, groupers, yellow tail and tunas are of special significance due to their fast growth and high market demand.

Yellow tail

Under the genus *Seriola* (Family: Carangidae), three species are widely used for CBA: the Japanese amberjack *S. quinqueradiata*, greater amberjack *S. dumerili*, and gold striped amberjack *S .talandi.* Yellow tails are cultured in Asian countries and in the Mediterranean. Fish aggregating devices (FAD) set along transects extending from shallow coastal waters to offshore (up to 500 m) are used for wild seed collection. For the past 30 years, yellowtail culture has developed in Japan due to its high market demand and growth performance. The global production of *S. quinqueradiata* is about 1,38,000 tonnes and is mainly from floating or submersible marine cages in Japan. Yellowtail are marketed fresh, chilled or frozen at price ranging from US \$ 5-18 kg^{-1} depending on the region and season. The constraints in increasing production are limited seed availability, feed, and occasional 'red tides'.

Tuna

In the recent past there has been a rapid increase in the CBA of bluefin tunas, *Thunnus thynnus thynnus* (North Atlantic and Mediterranean) and *Thunnus thynnus orientalis* (North pacific) and *Thunnus maccoyi* (Australia). Individual 'rod fishing' with single hook has been adapted for catching juveniles and sub adults. Barbless hooks are used for capturing specimens weighing several kilos. Purse seine fishery is the most important provider of live tuna for CBA. Tuna traps placed in the course of its trophic migration also provide specimens for CBA. The main CBA producers of tuna are Australia, Spain, Croatia, Malta and Mexico. In Japan juveniles of 150-500 g are reared in net cages for 3- 4 years until they reach 30-70 kg when they are harvested and marketed. The major problem encountered in Japan is in obtaining juveniles for culture. In the Mediterranean region, bluefin tuna fattening is a major industry, where live catches taken from wild are reared in offshore HDPE floating cages (30- 50 m diameter) and kept for variable periods ranging from a few months to years depending on the farming location and fish size. In Morocco, 120 x 40 x 30 m HDPE floating net cages moored in open sea at a depth of 55 m are used for tuna farming. In Australia, 50 m diameter floating cages, partially anchored are employed for tuna farming, for its convenient shifting from one location to another. Irrespective of its high production cost, tuna farming is highly profitable due to the heavy demand for 'sushi' and 'sashimi' products in Japan. The price is up to US \$600 kg^{-1}. The fish raised by CBA are not only gaining weight, but also adds on the fat content which makes it more valuable.

Groupers

Epinephilus coides , *E. tauvina* and *E. malabaricus* are the most abundant species caught for CBA. Grouper seed are caught by artisanal methods from coastal areas, particularly around seagrass beds, mangroves and shallow brackishwater areas. Large fixed nets, traps and shelters, hook and line, artificial reefs *etc.* are employed for catching the seed (1-4 cm). Groupers are cultured in South East Asian countries including Indonesia, Malaysia, Philippines, Taiwan Province of China and Viet Nam. Groupers can grow into 600 g in 12 months and marketable size is attained in 8 months (>500 g). Wooden cages are employed for grouper farming. The demand for live groupers has considerably increased in the South East Asian countries over the past two decades, with its price ranging from US \$ 8-31 kg^{-1}. The market is dominated by trade through Hong Kong. The future development in CBA of groupers is likely to be influenced by factors like (i) development of markets outside the specialist live markets, (ii) cost effective production methods so that 'non live' markets can be accessed at a profit, (iii) development of formulated feeds to avoid using trash fish, (iv) better management practices for disease control and (v) development of new culture systems to move beyond the existing congested/ polluted sites.

Eels

The eel catch comprise of the European eel *Anguilla anguilla*, Japanese eel *A. japonica*, American eel *A. rostrata* and shortfin eel *A. australis*. Global eel culture is totally dependent on the availability of glass eels and elvers. Japanese and European glass eels supply the international eel market. Juvenile eels are captured by hand nets, traps, trawlers using wing net, dip net *etc.* Eel farming employs a variety of reliable well established systems from relatively low density flow- through pond culture, semi intensive pond and tank culture to super high density closed recirculation tank culture. Intensive eel farms rely on artificial feed in the form of moist paste for glass eels and steam pressed or extruded pellets for later developmental stages. Advantage of eel culture is that they can be stocked at very high densities. Traditionally Western Europe and Japan are the major markets for eel and it can fetch up to US $ 32 kg^{-1}. Global demand for eels exceeds 2,00,000 tonnes annually and hence CBA for eels has developed into a specialized industry (Frost *et al.*, 2000). Seed costs can be as much as 505 of the total production costs and in future it could limit the profitability of eel farming industry.

The Indian scenario

Irrespective of its vast potential, the marine/ brackishwater culture production in India is only about 80,000-1,00,000 tonnes annually, which is almost entirely from shrimp production. Even though many Asian countries are leading in mariculture, India is yet to make an impact in this sector. Constraints are many in this line. However, it is time that India should focus on these issues and make a change in the present scenario of mariculture production. Commercial level seed production techniques are to be standardized for many species except Asian seabass. In many non selective gears, and shore seines juveniles of high value fish are caught which are either discarded or sold for nominal prices. If suitable measures are followed, these juveniles could be used for CBA for resource conservation as well as for increased seafood production.

Research and Development on CBA in India

Shrimp farming

During the first half of the 20th century, prawn filtration in traditional paddy fields in Kerala involved only trapping young ones brought in by high tide and holding it for few days and harvest by filtration during the lowest low tide. Menon (1954) was the pioneer in prawn farming in India and he has reported a production of 400 lbs/ acre/ crop of *Penaeus indicus* in 2-3 months and Muthu (1978) has modified the culture system by stocking with fast growing species and adoption of scientific farming for achieving higher productivity. Central Marine Fisheries Research Institute (CMFRI) has given elaborate guidelines for utilizing a variety of wet lands, in addition to the traditional prawn filtration areas, such as backwater and estuarine areas, brackishwater canals in coconut groves and derelict water bodies along the coastlines. The two candidate species recommended for shrimp farming in India were *P. indicus* and *P. monodon* (Alagarsami, 1981). The availability of shrimp seed, shrimp seed collection, identification and transport *etc.* were recorded by many researchers of CMFRI over the years. Now except for the few traditional farms, the shrimp culture industry is entirely dependent on hatchery raised seeds from India as well as imported from other countries.

Lobster fattening/ farming

Spiny lobsters *Panulirus homarus, P. polyphagus, P. ornatus, P. Pencillatus, P. longiceps* and sand lobster *Thenus orientalis* are the different species available in India for farming or fattening. Farming/ fattening of sand lobster *T. orientalis* has been demonstrated by CMFRI and the technology has not been perfected to commercial level. Spiny lobster *P. polyphagus* fattening is being experimented by some NGO in Gujarat using wild caught juveniles. Radhakrishnan (1995) has detailed on the spiny lobster farming in India. CBA of lobster has potential in India because of its high value and demand from export market.

Crab

Mud crab *Scylla serrata* and *S. Tranquebarica* are the two candidate species for aquaculture in India. Even though seed production technology has been perfected for these species, adequate quantity of seed is not available for extended farming practices. For mud crab, fattening of wild collected crab is practiced in several states. About 300- 400 g size crab are kept in small brackishwater cages for two to three weeks by feeding trash fish and marketed live for export to South East Asian Countries.

Mussel farming

Perna indica and *P. viridis* are the two mussel species suitable for farming in Indian waters. CMFRI, National Institute of Oceanography, Goa, Konkan Krishi Vidyapeeth, Ratnagiri and Central Agricultural Research Institute (CARI), Port Blair, have implemented research programmes on mussel farming. From early 1970s itself, CMFRI has developed grow-out structures suitable for open sea farming, seeding method and farm management measures. The first commercial mussel farm in the country was set up at Padanna, Kasaragode, Kerala in the year 2000 (Appukuttan *et al.*, 2001). Mussel culture in India is entirely based on CBA and the total production of farmed mussel for the year 2005-06 was 10,600 tonnes.

Oyster farming

One of the first reports of oyster farming in India is that of Hornell (1910) who has attempted collection of oyster spat by placing lime- coated tiles in Pulicat Lake. Awaiti and Rai (1931) have reported oyster fattening at Kelwa, Navapur and Utsali in Maharashtra. However, the concerted efforts to develop farming methods were started at CMFRI in 1970s. Methods for spat collection and grow out culture methods (rack and tray, stake, rack and ren methods) were developed then onwards. Subsequent to this oyster spat was produced in the hatchery and methods for cultch-less spat production were also developed (Rao *et al.,* 1983).

Clam culture

The farming techniques and production rates of the blood clam *Anadara granosa, Meretrix meretrix, M. casta* and *Villorita cyprinoides* have been developed by CMFRI from 1980s. *Paphia malabarica* and *V. cyprinoides* are widely distributed in the major estuaries of west coast and in several regions semi- culture systems are developed wherein under sized clam caught in the fishery are stocked for further growth and for harvest after 2- 3 months.

Marine finfish culture

The major marine finfish species which are cultivable include Asian seabass (*Lates calcarifer*), rabbit fish (*Siganus* sp.), groupers (*Epinephiles* spp.), pompano (*Trachynotus* spp.), snappers (*Lutjanus* spp.), seabreams (*Lethrinus* sp., *Sparus* sp.), cobia (*Rachycentron canadum*), pomfrets and seer fishes. Currently mariculture of finfishes is almost entirely supported by the seed collected from wild. It has been reported that on a small stretch of 100 km of N. Andhra coast, shore seines land about 15 lakh juvenile seerfish in April, which can easily be conserved in live condition for CBA. Similarly good juvenile fishery for pomfrets exists along Orissa, Maharashtra and Gujarat which can be taken advantage for CBA till their seed production techniques are developed and standardized. Similar opportunities exist for many more marine fish seed along our inshore area and Andaman and Lakshadweep area through most seasons along the coasts. Survey on distribution and availability of fish seed resources has been carried out from estuaries, backwaters and coastal waters in India by CMFRI. CMFRI has carried out experimental pen and cage culture of different species of fishes like rabbit fish (*Siganus canaliculatus, S. javus*), groupers (*E. tauvina* and *E. hexagonatus*), and the sand whiting (*Sillago sihama*).

Marine cage farming

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 catwalk 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 *etc.* 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.

Impacts of CBA

Wild source of seed will be unsustainable in the short term and inadequate in the long term because the catch per unit of effort of seed- whether juveniles or adults- appears to be in decline. Overfishing of the target resources frequently occurs during normal fishing activities, but is exacerbated by the demand created by CBA. The collection of seed for CBA can also lead to mortalities in non-target species and the destruction and disturbance of habitats; it also generates discards, contributing further to the depletion of other resources. In addition, the transfer of seed to CBA farms is characterized by high mortality rates (and thus wastage of resources).

The culture of fish in cages can cause potential threat to the surrounding environment. Such impacts include distortion of local ecosystem, eutrophication, pollution, transmission of parasites and pathogens and aesthetic deterioration in coastal areas. The effects of CBA on environment can be significantly reduced by careful site selection, controlled stocking, good feeding regimes, good health management and accurate environment impact assessments.

CBA represents an alternative livelihood for coastal communities and have significant, positive economic returns in those economically backward areas. CBA can have significant economic multiplier effects, due to labour intensiveness associated with operating and infrastructure requirements, exporting of fresh, chilled and frozen products *etc.* Related activities can also generate significant number of jobs. It can also contribute to poverty alleviation in developing nations and enhance the standard of living of the poor.

Legal/institutional considerations for sustainable CBA

The application of responsible production methods must become the norm in CBA. In many cases, CBA represents the first step towards true aquaculture. However, this evolution will not affect the characteristics of certain forms of CBA as currently practised, such as the stocking of large bluefin tuna. Furthermore, the CBA of new species will emerge. It is therefore essential that governments explore and develop legal and institutional instruments that recognize CBA as a distinct sector. CBA also needs to be integrated into resource use and development planning. International agreements for specific actions in the CBA sector need to be drafted and signed by all the countries that share common resources. The management of CBA, particularly where the practice is currently unsustainable, needs to be improved. If governments are actively promoting CBA, it is likely that it will lead to the rearing of new aquaculture species, reducing the pressure on existing wild stocks.

Competitive Advantages and Disadvantages of CBA

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

- A huge area in which to farm (the Indian EEZ).
- Well experienced fishermen work force.
- Strong domestic and export markets.
- An educated workforce and people with excellent animal husbandry skills (Fisheries graduates and above).
- Local availability of feed ingredients and feed suppliers.
- Strong research and extension capabilities.

To put these advantages to good use, however, aquaculture producers must overcome several disadvantages or constraints, including the following:

- Lack of clear regulations for use of open sea waters.
- Competition 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.
- Concerns by fishermen about competition from aquaculture.
- Concerns about environmental effects of aquaculture.
- Technological challenges (since the industry is new to India).

Future Perspectives of CBA

CBA is to continue to expand in the short term, both with finfish species currently under exploitation likely and probably with others that will be selected for rearing in the future. In the case of non-finfish species, such as a variety of bivalves (e.g. mussels), CBA is certain to continue indefinitely in view of the very large number of seed released. However, the CBA of selected species of finfish is more uncertain; where it becomes a direct competitor of capture fisheries it is therefore critically important that economically viable means be found to rear the species concerned throughout their full life cycle. When that goal is achieved, not only will the future aquaculture production of those species be assured, but the feasibility of restocking programmes may be explored to enhance their capture fisheries. It is felt that with effective regulations and management practices, the CBA offers good scope and potential for the artisanal and industrial sectors in the years to come.