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Mariculture Technologies for enhancing livelihood options in the Coastal Sector

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Introduction

Aquaculture, the fastest growing food-producing sector, is perceived as having the greatest potential to meet the growing demand for aquatic food. The contribution of aquaculture to global supplies of fish, crustaceans, molluscs and other aquatic animals for human consumption continues to grow, and reached 52.5 million tonnes in 2008. The contribution of aquaculture to the total global fish production continues to increase, rising from 34.5% in 2006 to 36.9% in 2008. The average annual per capita supply of food fish from aquaculture has increased by ten times from 0.7kg in 1970 to 7.8 kg in 2008 at an average rate of 6.6 % per year. Worldwide, the sector has grown at an average rate of 8.3 percent per year since 1970, compared with only 1.2 percent for capture fisheries and 2.8 percent for terrestrial farmed meat production systems over the same period.

Mariculture- the farming and husbandry of marine plants and animals in the marine environment - has contributed 32.3% of the global aquaculture production by quantity and 30.7% of the total value. Mariculture produces many high value finfish, crustaceans, and molluskcs like oysters, mussels and clams. Hence it is evident that 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.

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 8-10kg per year and is likely to grow to 16.7kg 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 the major share in the total shrimp export. The farming of shrimp is largely dependent on small holdings of less than 2 hectares, as 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 and West Bengal. In recent years, the demand for mussels, clams, edible oysters, crabs, lobsters, sea weeds and marine finfishes is continuously increasing and brings premium price in the national and international markets. 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.

Coastal aquaculture is a significant contributor to sea food production, constituting mainly the shrimps like *Penaeus monodon* and *Litopenaeus vannamei* .However, vast water bodies highly 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, sea bass, cobia, pompano, groupers, ornamental fishes and sea weeds in the new aquaculture scenario 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. In India till date mariculture activities are confined only to coastal brackish water aquaculture, chiefly shrimp farming. The other coastal aquaculture activities are green mussel farming which is confined to Malabar Coast in Kerala producing more than 15,000 tonnes and seaweed farming along Ramanathapuram and Tuticorin coasts of Tamil Nadu producing about 5000 tonnes annually.

The potentially cultivable candidate species 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, eco-friendly 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 and coastal areas are free from pollution and suited 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 etc., all of which are in high demand in the export market. In addition a fast growing trade of marine ornamental fishes and other tropical marines has also emerged in the recent years which open up the possibility of culture and trade of these organisms.

Existing major mariculture species and farming technologies Shrimp seed production and culture

Shrimps being a highly valued export commodity, shrimp farming is considered a lucrative industry. Depending on the area of the pond, inputs like seed, feed and management measures like predator control, water exchange through tidal effects or pumping, etc., farming systems have been classified into four groups: extensive, modified extensive, semi-intensive and intensive. The farming community has now become more responsive to the concepts of environment-friendliness and sustainable aquaculture. Disease problems are being overcome 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. Currently, farming of the white shrimp *Litopenaeus vannamei* has gained momentum in India and is contributing to the bulk of farmed shrimp production.

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 to marketable size in ponds and tanks by feeding trash fishes and other discards. In many maritime states juvenile lobsters of *Panulirus homarus, P. ornatus* and *P. poyphagus* are grown in captivity and the eyestalk ablated lobsters attained 180 – 200 g in 5 – 6 months period. 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, *Thenus orientalis* and *Petrarctus rugosus* was achieved. Successful hatchery production of seeds of *T. orientalis* and its compatibility with *F. indicus* at high density race way culture system with very high production rates of 3-5kg/sq.m is highly promising.

Crab farming / fattening

Live mud crabs (*Scylla serrata*, *S. tranquebarica)* being a much sought after export commodity, mud crab fattening is considered the best alternative. Seed stock consist of freshly moulted crabs (water crabs) of 550 g which are stocked in small brackishwater ponds at a stocking density of 1/sq. m or in individual cages for a period of 3-4 weeks while being fed thrice daily with low value fish @ 5-10 per cent 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 methods for breeding and seed production of the blue swimming crab, *Portunus pelagicus*, have 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 with a production rate of 8-10 tonnes/ha. Oyster shells are also in demand by local cement and lime industry.

Mussel Farming

The Institute has developed technologies for culture of bivalves like raft method (in bays, inshore waters), rack method (in brackishwater, estuaries) or long line method (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/nylon ropes of 1-6 m length and enveloped by mosquito or cotton netting. Seeds get attached to rope within a few days while the netting disintegrates. The seeded ropes are hung from rafts, racks or long lines. 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. Commercial level mussel farming is being practiced at Malabar Coast, Kerala which produces around 15,000 t annually.

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 nearshore 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 labs, 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. 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 as part of technology transfer programme along the Valinokkam Bay on the east coast. 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. Research efforts are being carried out for the production of tissue culture pearls. Mabe pearl production was standardised for production of base images . Technology for production of jewellery from Mabe pearl was also standardised. However, marine pearl production still remains to be commercialized in India.

Clam Culture

Package of clam culture practices has been developed for the blood clam *Anadara granosa* and *Paphia malabarica*, where production of 40 tonnes/ ha/6 months and 15-25 tonnes/ha/4-5 months have been achieved in field trials. Induced spawning and larval rearing to setting of spat has been perfected for clams like *P. 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.

Marine Finfish Culture

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 only be possible due to the establishment of controlled broodstock development. In India much research attention is not yet given for developing seed production methods for high value finfishes suited for sea farming. At present, we have commercial seed production of only one 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 and 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 practiced 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 and pompano aquaculture

Cobia (*Rachycentron canadum*) and silver pompano (*Trachinotus blochii*) are two marine finfish species with very high potential for aquaculture in India. Fast growth rate, adaptability for 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 Central Marine Fisheries Research Institute 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 upto 15ppt 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 cobia to 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 species 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 cage farming. At Mandapam Regional Centre of CMFRI, successful broodstock development, induction of spawning and fingering 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 demonstrations in pond and sea cages are the steps to the way forward. Hence it is required to invest and establish infrastructure for the different phases from seed to product development *viz.* Required 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 is felt that both cobia and pompano are potential aquaculture giants having vast domestic and global business prospects.

Marine Ornamental Fish Culture

On a global basis a lucrative marine ornamental fish trade has emerged in recent years which have 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 a sizeable foreign exchange. A long term sustainable trade of marine ornamental fishes could be developed only through hatchery produced fish.

The Central Marine Fisheries Research Institute 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 Success was also obtained on the broodstock development, larval rearing and seed production of 7 species of damsel fishes. The marine ornamental fishes for which breeding and seed production technologies were developed by CMFRI are the following.

1) *Amphiprion sebae*
2) *Amphiprion percula*
3) *Amphiprion ocellaris*
4) *A.nigripes*
5) *A.ephippeum*
6) *Premnas biaculeatus*
7) *Pomacentrus pavo*
8) *Neopomacentrus nemurus*
9) *Dascyllus aruanus*
10) *Dascyllus trimaculatus*

11) *Pomacentrus caeruleus*
12) *Chrysiptera cyanea*

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 price per unit of ornamental fish. The clown fishes and damselfishes of the family Pomacentridae offer immediate scope for hatchery production due to the availability of seed production methodologies.

Development of a Sustainable Trade

A critical analysis of current global trade of the marine ornamentals from wild collections reveals many ecological concerns which require policy interventions. The major aspect that should receive top most priority is for taking appropriate action to ensure that the development of the trade should not threaten the sustainability of the coral reef ecosystem. The following measures are suggested.

(i) Regulation for Collection from the wild

The destructive collection practices such as use of cyanide should be banned by legislation and enforced. Results from a recent study demonstrated that colonies of commonly traded species of corals and soft corals to varying concentrations of cyanide over different periods of time caused mortality in all corals. *Acropora,* the genus which is specifically targeted by fishers for collection of fish as they tend to hide amongst its braches is most vulnerable to cyanide exposure, showing rapid signs of stress and bleaching (Cervino, *et.al.* 2003). Another aspect of concern is the impact of exploitation on population due to selective harvesting of species which are of high demand in the trade. Here also policy intervention through legislation has to play a key role. Several countries in Asia and South America have begun to implement collection restrictions on certain ornamental fish species (Corbin and Young, 1995; Friedlander, 2001; Ogawa and Brown, 2001). Although no marine species collected for the aquarium trade have been driven to global extinction, studies carried out in Sri Lanka, Kenya, the Philippines, Indonesia, Hawaii and Australia have reported localized depletion of a number of targeted aquarium species due to heavy collection pressure. Studies have also shown that removal of larger quantities of cleaner wrasses and cleaner shrimps which play key roles in reef health creates negative impacts on reef diversity. The third aspect of concern is the exploitation of species which are not suited for aquarium. This also needs to be avoided by legislation. The fourth aspect which demands regulations is regarding the post harvest mortality. Research on marine ornamental trade between Sri Lanka and the United Kingdom demonstrated that in mid 1980's about 50% fish died during and immediately after collection another 10% during transport and 5% in holding facilities (Wood, 1985). As a result of such mortally more fish often need to be collected for meeting the market demand. Where organisms are collected, stored and handled by adequately trained individuals and transported in suitable containers fish mortality have been very low. The post harvest conditioning facilities should include modern gadgets such as UV lighting system, protein skimmers and carbon filters.

(ii) Introduction of certification for wild collected species

Marine Aquarium Council (MAC) has developed a certification scheme that will track an animal from collector to hobbyist. Established in 1996, the goals of MAC are to develop standards for quality products and sustainable practices and a system to certify compliance with these standards, and create consumer demand for certified products. With a net work of 2600 stakeholders in more than 60 countries, it is recognized as the lead organization for developing and coordinating efforts to ensure that the international trade in ornamental marine organisms is sustainable. MAC certification covers both practices and products.(Bunting *et al,* 2003)

Industry operators can be certified through an evaluation for compliance with the appropriate MAC standard for the certification of practices. For certification of products MAC certified marine ornamentals must be harvested from a certified collection area and pass from are certified operations to another. MAC – certified marine organisms bear the "MAC-certified" label on the tanks and boxes in which they are kept and shipped.

Concept of a small-scale hatchery

Small-scale hatcheries for marine ornamental fish are those where the capital costs and technologies are accessible for relatively low cost which focuses on broodstock development, larviculture, nursery rearing and grow-out to marketable size. The small-scale hatcheries can be easily adapted to culture a range of different species.

Advantages of small-scale hatcheries

1. Low capital inputs
2. Simple construction
3. Ease of operation and management
4. Flexibility
5. Quick economic returns.

A typical small-scale hatchery for marine ornamental fish consists of the following units.

1. Broodstock tanks
2. Larviculture tanks
3. Nursery rearing and grow-out tanks
4. One sand filter
5. Outdoor live feed (Phyto and zooplankton) production tanks
6. Seawater and freshwater supply system.

Technical assumptions for production

It is assumed to be an indoor system located in a coastal area with access to both salt and freshwater and easy transportation access to market.

The analysis will focus on an integrated culture system of broodstock, hatchery, larval rearing/nursery and grow-out.

There are 12 broodstock pairs. At any time there are 10 active spawning pairs. Each pair will spawn 2 times per month. An average of 400 larvae is produced during each spawn. The survival rate of the larvae to transfer to grow out phase is 50%. The period from larvae to juvenile is 30 days.

There is a 60% survival rate for juveniles to market size, which are saleable. The period from nursery to market size is 120 days. In a month, 240 saleable sized fishes can be produced from one pair of clown fish. Each fish can be sold at a rate of Rs.100.

The sale of the fishes will start from second year onwards. The first year of operation will be construction and set up of the building, procurement of equipment and collection and maintenance of brooders. The first spawning is expected in eighth month of first year. The first harvest and sale will occur at the first month of second year.

Site Selection

A site suitable for a small-scale marine ornamental fish hatchery should have the following characteristics:

(i) Good water source – both seawater and access to freshwater

(ii) Good infrastructure such as road, electricity, etc.

(iii) Free from industrial and other pollution

Hatchery lay out

The hatchery should be laid out in such a way that it provides for ease of operation and it should also be free from work hazards. The essential types of tanks required for a small-scale hatchery are the following:

i) Sand filter tank:

Small-scale hatcheries may use a gravity sand filter to initially remove coarse particles and organisms from the source water. Such filter tanks are usually made of concrete and the filter medium comprises a layer of coarse material such as stones at the bottom and gravel and sand layers respectively. The water inlet to this filter is at the top of the tank to allow water to filter from top down before going to the larval rearing tank.

ii) Broodstock tanks

Broodstock tanks are generally cement tanks, rectangular or square in shape. They range in size from 0.3 to 0.5 m^3 capacity. Usually, the depth of broodstock rearing tanks is 0.6m in depth. Cement tanks should be painted internally with food grade epoxy paint to prevent the leaching of cement and other chemicals into water.. It is better to paint the inside of the tanks with dark colours.

ii) Larval rearing tanks:

Larval rearing tanks are generally cement tanks, rectangular or square in shape. They range in size from 0.3 to 0.5 m^3 capacity. Usually, larval rearing tanks are 0.5m in depth, but nursery tank can range between 0.5-1 m deep. All cement tanks used in hatcheries need to be finished internally with food grade epoxy paint to prevent the water from coming in direct contact with the cement. It is better to paint the inside of the tanks with blue or green colour.

iii) Live feed production tanks

Microalgae production tanks normally make up about 30% of the total production volume of a small-scale hatchery. These tanks are usually located outside the hatchery and are not roofed. Capacity varies from 1.0m^3 to 2.0m^3.

Generally the rotifer culture area will take up about 10% of the total hatchery area. Rotifer tanks can be 1.0 -2.0 m^3.

Artemia are hatched in fiberglass or plastic tanks. These tanks range from 20 to 500 litres.

Hatchery equipment and accessories:

i) Water Pump:

Two types of pumps are required for the small-scale hatchery operation. A pump of 5HP is required to pump seawater to the hatchery's sand filter tank. A separate submersible pump is required to distribute water within the hatchery system.

ii) Generator:

A generator of 1 KVA is essential as backup electricity supply for the hatchery.

iii) Aeration system:

Small 100 watt air pump with at least one backup is needed.

iv) Other hatchery equipments

1. An ordinary microscope.
2. Thermometer
3. Salinometer
4. pH meter
5. Water analysis kit
6. Hand nets
7. Plastic wares like buckets, bins, hoses etc.

v) Manpower:

The small scale hatchery can be managed by two full time staff – One technician and two workers. Basic training on technical aspects is needed for day-to-day hatchery operation. Daily routine works include cleaning broodstock and larval tanks, feeding broodstock and larval tanks, harvesting microalgae, rotifers, *Artemia* etc.

Economic Assessment

The candidate species selected for economic analysis is the true clown *Amphiprion percula.*

Capital Investment

This component involves all the expenditure on the infrastructure and establishment of the hatchery. The items included in this component generally have a life span larger than one year and they are used to generate the future income from the hatchery. The items include

Capital Investment items	**Quantum**	**Cost in Rupees**
Temporary Shed	144m^2 (12 X 12m)	1,10,000
Cement tanks for		3,40,000
i. Broodstock	12	
ii. Larval rearing	12	
iii. Nursery and grow out	18	
iv. Microalgae (outdoor)	4	
v. Rotifer (outdoor)	3	
vi. Sand filter /Over head tank	1	

Artemia hatching tanks (Transparent Perspex)	3	10,000
Power installation		10,000
4 HP diesel pump	1	19,000
1/2 HP submersible pump	1	6,000
Generator 2 KVA	1	30,000
Air pumps	2	40,000
PVC piping, plastic wares (water supply/aeration/drainage)		45,000
Netting, miscellaneous etc.		40,000
TOTAL COST		**6,50,000**

Operating expenses

This component is for the expenses that are spent during each production cycle and are essential for the routine operation of the hatchery.

The items included are:

	Items	1st year	2nd year	3rd year
1.	Broodstock fishes/Anemone	25,000	5,000	5,000
2.	Feeds	12,000	12,000	12,000
3.	Artemia	4,000	12,000	12,000
4.	Chemicals for microalgal culture	6,000	6,000	6,000
5.	Electricity	36,000	36,000	36,000
6.	Diesel	24,000	24,000	24,000
7.	Maintenance	12,000	18,000	18,000
8.	Workers salaries (1xRs. 5000; 2xRs.3000)	1,32,000	1,32,000	1,32,000
9.	Miscellaneous expenditures	12,000	12,000	12,000
	TOTAL	**2,63,000**	**2,57,000**	**2,57,000**

Non-operational expenses

These are related to the capital cost and investments write off. There are two items under this component for small-scale hatcheries.

i) Depreciation

ii) Interest on capital investment

The sale of the fishes will start from second year onwards. The first year of operation will be construction and set up of the building, procurement of equipment and collection and maintenance of brooders. The first spawning is expected in eighth month of first year. The first harvest and sale will occur at the first month of second year.

	Amount in Rs.		
	Year 1	Year 2	Year 3
Revenue Sale of clownfish fingerlings @ Rs.100/fingerlings (240 juveniles x 10 pair x12 month =28,800 numbers 28800 x Rs 100 = Rs. 2880000)		28,80,000	28,80,000
Non operating expenses a. Depreciation (20%)	1,30,000	1,30,000	1,30,000
b. Interest rate on capital investment @12%	78,000	78,000	78,000
Operating cost	2,63,000	2,57,000	2,57,000
TOTAL EXPENSES	4,71,000	4,65,000	4,65,000
Profit	--------	**24,15,000**	**24,15,000**
Pay back period	**5.28 months**		

Profit and Loss

This consists of the revenue generated from sales of clownfish young ones minus all the operating and non-operating expenses. The payback period can be used to measure how rapidly to small-scale hatchery can provide a return to the farmers or investors.

Payback period (PP) = (Capital Investment / Profit) x 12 months

= (6.5/14.53)*12 = 5.28

Return on investment or payback period for the small-scale hatchery based on the above calculations is about six months. It is evident that the capital invested for the small-scale hatchery can be recovered fully within six months from the start of earning. The only assumptions made are that the hatchery operations are running smoothly and the price of *A.percula* juveniles remain stable during the period.

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). CMFRI has developed technology to culture seaweeds by either vegetative propagation using fragments of seaweeds collected from natural beds or spores (tetraspores/ 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 sea weed *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 .

Culture Techniques

In Tamil Nadu coast, floating raft method was found to be commercially viable method in *K. alvarezii* farming. Floating raft is made of bamboo with 12′ × 12′ for mainframe and 4′ x 4′ for diagonals. In each raft, 20 polypropylene-twisted ropes are used for plantation. The fragments (approximately 150 grams) are tied at a spacing of 15 cm in a rope. Totally, at 20 points the fragments are tied in a rope. Thus, for one raft the plantation requirement is 60 kgs. To protect the *Kappaphycus* from grazing, fishing net of 4m x 4m size is tied at the bottom of the raft. One anchor of 15 kg can hold a cluster of 10 rafts. During rough season two to three anchors are required to hold a cluster of 10 rafts. The unit cost per bamboo raft for seaweed cultivation **is** Rs.1000/-The farming is taken up for nine months (i.e., February to October) in an year. The crop is ready for harvest after 45 days from planting. From the 45^{th} day, one raft is harvested every day and subsequently planted and floated in the sea. Hence, one crop / cycle duration is 45 days. In the first year, four crops are harvested. During the second and third year, three crops are harvested. On an average three to four crops are harvested in a year.

Average yield per raft (12 x 12 feet) is 240 to 260 kilogram. They retain 60 kilogram as planting material for the next crop. If 240 kg of seaweed is dried, it results in 24 kg dry weight. The current price is ` 3.50 per kilogram on wet weight basis and ` 26.50 per kilogram on dry weight basis. A fisherman family earns around ` 10,000 to15, 000 per month.

Sea cage Farming

The sea cage culture has been expanding in recent years on a global basis and it is viewed by many stakeholders 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 rising fish. The rapid growth of the industry in most countries can be attributed to (i) suitable sites for cage culture (ii) well established breeding techniques that yield a sufficient quantity of various marine and freshwater fish juveniles (iii) availability of supporting industries such and feed, net manufactures, fish processors etc. (iv)strong research and development initiatives from institutions, governments and universities and (v) the private sector ensuring refinement and improvement of techniques/ culture systems, thereby further developing the industry.

Commercial cage culture was pioneered in Norway in the 1970s with the rise and development of salmon farming. As in terrestrial agriculture, the move within aquaculture towards the development and use of intensive cage farming systems was driven by a combination of factors, including the increasing competition faced by the sector for available resources (including water, land, labour, energy) , the drive for increased productivity per unit area and the need for the sector to access and expand into new untapped open water culture sites such as lakes, reservoirs, rivers and coastal brackish and marine offshore waters. The cage aquaculture sector has grown very rapidly during the past 20 years and is presently undergoing rapid changes in response to pressures from globalization and growing demand for aquatic products. Currently on a global basis commercial cage culture has been restricted to the culture of high value, compound feed fed finfish species, including salmon, Japanese amberjack, red sea bream, yellow croaker, European sea bass, gilthead sea bream, cobia and groupers. Cage culture systems employed by farmers vary from traditional family owned cage farms (Asian countries) to modern commercial large scale salmon and trout cage farms in Northern Europe and Americas. The rapid rise and success of the salmon cage farming industry has been due to a combination of interlinked factors such as the development and use of an easily replicated and cost effective technology (including hatchery seed production), access to large areas of suitable waters, good species selection, market acceptability, increased corporate investment and a good and supportive government regulatory environment.

Marine cage farming is relatively new in Asia and was developed initially in Japan for species such as yellowtail (*Seriola quinqueradiata*) and red sea bream *Pagrus major*. Over the last twenty years the cage farming practice has spread almost throughout Asia. The major cage farming countries are China, Indonesia, Taiwan Province of China and Vietnam. A large number of finfish species are farmed in cages in Asia *viz*. groupers, snappers, carangids, seabass and cobia. In most countries individual operations are not large, and often a clustering of farming activities, which is due to limited site availability in coastal waters, is seen.

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 15 m diameter with HDPE frame was successfully launched and operated at Visakhapatnam, in the east coast of India by the Central Marine Fisheries Research Institute. Eventhough 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 a participatory mode with the local coastal fishermen. Successful sea cage farming demonstrations were conducted at Kanyakumari, Vizhinjam, Kochi, Mangalore, Karwar, Veraval, Mandapam, Chennai and Balasore. Sea bass and spiny lobsters were the major groups employed for farming. Recently successful sea cage farming demonstrations were conducted from hatchery produced seeds of cobia and silver pompano at Mandapam. The major steps for the way forward in the development of sea cage farming include (i) selection of suitable sites along our coast for cage farming (ii) establishment of hatcheries for high value finfishes like cobia, pompano, groupers and snappers (iii) development of cost effective cage designs suited to different areas (iv) Evolving appropriate species specific farm management protocols and (v) development of marketing strategies.

Conclusion

It is well recognized that many 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 sea food, it is inevitable to venture into mariculture practices to meet the additional requirement of sea food as well as for augmenting the income of the coastal fishermen. The development and standardization of commercially viable mariculture activities is the major prerequisite. The available technologies can be popularized by effective extension mechanisms such as participatory demonstration programmes. In this context, the bivalve farming practices, sea weed culture, marine ornamental fish culture and small-scale sea cage farming deserve prime attention. The initiation and expansion of mariculture practices can lead to the increased production of sea food and also augment the income generation of the coastal fishermen in the country.

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