TRAINING MANUAL

On

Capture Based Aquaculture Practices

2- 4, December, 2013

Mangalore Research Centre of

Central Marine Fisheries Research Institute

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**Mangalore Research Centre of
Central Marine Fisheries Research Institute**

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Training schedule

Day 1	2nd August, 2013
09.30-10.00	**Registration**
10.00-10.30	**Inauguration**
11.00-12.00	**Overview of mariculture in India** Dr. Prathibha Rohit
12.00-13.0 0	**Water quality criteria for aquaculture** Dr. Bindu Sulochanan, Senior Scientist
14.00-15.00	**Technologies for fisheries enhancement** Dr. A. P. Dineshbabu, Principal Scientist
15.30-16.30	**Concept of Capture Based Aquaculture and practices** Dr. Sujitha Thomas, Senior Scientist

Day 2	3rd August, 2013
7.00-16.30	**Field trip to small scale cage culture sites** **Hands on training in cage fabrication at Kundapur**

Day 3	4th August, 2013
10.00-11.00	**Bivalve farming practices** Dr. Geetha Sasikumar, Senior Scientist
11.30-12.30	**Open sea cage culture for marine finfish and shell fishes** Dr. K. K. Philipose , Principal Scientist
12.30-13.30	**Development initiatives in Aquaculture** Dr. K.M. Rajesh, Senior Scientist
14.00-15.00	**General session on cage culture, Feedback from participants**
15.30-16.30	**Valedictory Session** Distribution of Certificates

1. Overview of Mariculture in India

Prathibha Rohit, , Mangalore Research Centre of CMFRI

Introduction:

The fish production from capture has registered an increase over the years but the rate of increase has stabilized globally. Aquaculture on the other hand has progressively increased. In India though the capture fish production has steadily increased, production from the present grounds has reached its maximum and several problems such as increase in fishing intensity, declining stocks, conflict between the fishing sectors, decreasing catch rate, decreasing recruitment, inappropriate exploitation pattern, habitat degradation and resource degradation have been identified. Further scope for increased production lies in exploitation of resources from deeper waters which necessitates introduction of bigger vessels, trained manpower, better handling facilities, etc. Aquaculture on the other hand has progressively increased and production through mariculture is the best way to increase overall marine fish production. Mariculture contributes to the production of protein rich food and has been the source of livelihood of millions of coastal villagers. Global production from the marine environment increased from 21.6 million tonnes in 1999 to 27.6 million tonnes in 2003.

Mariculture is defined as the cultivation of marine organisms in their natural environment (Webster's Dictionary). In other words mariculture is the rearing of the aquatic organisms under controlled or semi-controlled conditions in coastal and offshore waters. The mariculture environment thus includes sea, backwaters, estuaries and coastal lagoons. Marine organisms include both migratory species to estuaries/backwaters and non-migratory species confined only to the sea. Mariculture today includes predominantly migratory marine fishes such as seabass, shrimps,lobsters, cobia, snappers, mullets, pearlspot, milkfish etc. Most of these species are capable of tolerating variations in the environment.

Potential areas for mariculture in India:

The near shore coastal waters, creeks and backwaters in all the maritime states are suitable for mariculture adopting different culture practices. The creeks and backwater area have been extensively used for shrimp culture. Some area has also taken up crab fattening. The backwaters too have been used for culture practices and culture of mussels in a large scale is being practiced in Kerala for several years. Mussel culture in the estuarine waters has been taken up in Karnataka, Goa and Maharashtra. The potential sites for open sea mariculture have been identified by CMFRI at Palk Bay and Gulf of Mannar in Tamil Nadu, Lawsons Bay near Visakhapatnam in Andhra Pradesh, Balasore in Odisha, Marine bay's in Karwar, Near shore areas in Goa and off Ratnagiri in Maharashtra. The open seas around the Andaman & Nicobar Islands and Lakshadweep too have high potential to take up mariculture activities.

Mariculture

i. Brackishwater aquaculture

Aquaculture in brackishwaters in India is an age old practice and has been carried out in bheries of West Bengal and *pokkali* fields of Kerala. However, scientific farming in the country is just a decade old. The country possesses huge brackishwater resources of over 1.2 million hectares suitable for farming and presently (2001-02) only 13% of the potential water area available i.e. 157,400 ha in is utilized. Shrimp is the single commodity that contributes almost the total production of the sector. The production levels of shrimp recorded marked increase from 28,000 tonnes in 1988 89 to 127,170 tonnes in 2001-2002. The black tiger prawn, *Penaeus monodon*, is the most abundantly cultivated prawn species followed by other shrimp species such *as P. indicus*, *P. penicillatus*, *P. merguiensis*, *P.semisulcatus* and *Metapenaeus* sp.

Induced breeding of shrimps was initiated by the Central Marine Fisheries Research Institute as early as in the early 70s'; an experimental hatchery was established by the Institute in 1975 at Narakkal, Kerala, MPEDA took the lead for establishment of two large scale hatcheries viz., TASPARC and OSPARC in 80's that gave a boost for the establishment of a number of commercial hatcheries in the private sector. The technology of hatchery production of shrimp seed involving broodstock development, induced maturation and spawning, larval-rearing and post-larval (nursery) rearing has been standardized. At present about 226 shrimp hatcheries are operational with a total production capacity of 10.5 billion PL20/year. Semi-intensive culture practices mainly with black tiger prawn have demonstrated production levels of 4-6 t/ ha in a crop of 4-5 months. The high return coupled with credit facilities from commercial banks and subsidies from MPEDA have helped in the development of shrimp farming in the country to a multi-billion dollar industrial sector. In spite of disease problem that has been plaguing the sector since 1994-1995 the industry has learnt to live with certain modifications in pond management, which has resulted in sustaining the shrimp production of the country during last two years. During the year 2000-2001 the shrimp production of the country from aquaculture has witnessed a record production of 97,100 tonnes valued as Rs. 3,620 crores.

Culture of crab species like *Scylla serrata* and *S. tranquebarica* has also been taken up by few entrepreneurs. Crab fattening and demand for soft crabs and berried crabs has induced several aquafarmers to take up culture of these species on a commercial scale. Seed production techniques too are available.

Several finfish species of mullets (*Mugil cephalus*, *Liza parsia, L. macrolepis*, *L. tade),* milkfish *(Chanos chanos),* seabass *(Lates calcarifer),* cobia *(Rachycentron canadum)* pearlspot *(Etroplus suratensis)* and rockcod *(Epinephelus tauvina),* snappers (*Lutjanus* sp), pompano (*Trachinotus blochii*) and rabbitfish (*Siganus* sp.), possess great potential for farming. Commercial production of most of these species on a small scale has been taken up by some entrepreneurs in Andhra Pradesh, Karnataka, Kerala and Tamil Nadu. Seed production technology of seabass, cobia, pearlspot, pompano and rockcod is available.

ii. Aquaculture in seawater

The Central Marine Fisheries Research Institute has been the pioneering fisheries organization to initiate research in this area and have developed of several viable technologies with regard to seed production and culture of important marine crustaceans, molluscs, finfishes and seaweeds. Several programmes on sea ranching of exploited stocks such as pearl oysters (*Pinctada* spp.), mussels (*Perna viridis*), sacred chanks (*Xancus pyrum*), topshells (*Trochus* sp.), turbanshells (*Turbo* sp.) and clam (*Paphia* sp., *Meritrix* sp.) have been taken up in the country.

Mussel culture

Green mussel, *Perna viridis* and brown mussel, *Perna indica* are the two important mussel species available in the country. The culture technology of these has been standardized. Mussel farming is carried out either in rafts or by long line methods. While long line system is very flexible and can withstand turbulent sea, raft system is more rigid and suited for more calm seas.

Edible oyster culture

The culture of edible oyster in India was initiated as early as the beginning of this century. However, intensive researches on various aspects of the culture were taken up only during seventies. The technique of oyster farming consists of two items, collection of spat and growing the spat to adult stage. The farming practices for *Crassostrea madrasensis* have been standardized. *Saccostrea cucullata* too is gaining commercial importance and farming of this species too has been proposed. Technology has been developed for hatchery production of seed, which has opened up scope for establishment of large-scale commercial farms.

Pearl culture

The success of marine pearl culture in India was achieved in 1973 by the Central Marine Fisheries Institute at its Tuticorin Research Centre. Raft culture techniques are followed for culture of pearl oysters and the important species being *Pinctada fucata*. Culture practices for the black lip oyster *P.margaretifera*, for the production of black pearls, is also being standardised.

Seaweed culture

Seaweed forms an important component of the marine living resources, available largely in shallow seas, wherever, suitable substratum is available. Agar agar and algin are two principal industrial products of seaweeds. Seaweed is also used as food, fodder, fertilizers and in products. The seaweed resources of the country are mainly confined to the coasts of Tamil Nadu and Gujarat. Since 1972, CMFRI is involved in experimental culture of different seaweed species and developed technologies for important agarophytes like *Gracilaria edulis, G.corticata and Gelidiella acerosa.* Both net and rope culture technologies have been standardized. In case of *G. acerosa* both coral stone method and net culture method have been standardized. Culture practices of several other species are on experimental scale.

Finfish culture:

Culture of fishes mostly available in the brackish waters (mullets and pearlspot), using traditional/extensive or semi-extensive method has been practiced since several years. Mixed and poly culture too has been going on in most of the suitable areas. However, scientific semi-intensive monoculture of finfishes in open sea cages, smaller cages in creeks and coastal earthen ponds is a very recent development. The concept and techniques of opensea cage farming for rearing fishes and shellfishes in suitable area along the Indian coast was introduced by CMFRI in 2008. Initial experimental open sea cage farming was initiated at Visakhapatnam and has now extended to all maritime states of the country. Cages of different dimensions and shapes depending on the location, species to be cultivated and depth at the site have been installed in different areas. Seabass, *Lates calcarifer* has been cultured in opensea cages at Balasore in Odisha, Viskhapatnam in Andhra Pradesh, Kovalam in Tamil Nadu, Munambam in Kerala, Karwar and Byndoor in Karnataka. Lobster fattening in cages was done in Maharashtra and Gujarat. Snappers *Lutjanus argentimaculatus,* mullet *Mugil cephalous,* pearlspot *Etroplus suratensis has* also been grown in open sea cages. Open sea cage culture has really taken off in a big way and several groups of fishermen are engaged in this activity.

Smaller cages of rectangular size were installed in shallower saline waters *in* creeks nearshore waters. Such culture activity in smaller cages was initiated in line with the concept of capture based aquaculture a participatory approach for fish culture. It was proposed to collect juvenile fishes caught during fishing in live condition and stock them in such cages. The idea was to use the seeds of potential cultivable fishes available in the wild and grow them to marketable size. Though stocking of such cages still continue to use seed sources form the wild many of them stock hatchery grown fish seeds for culture.

Monoculture of marine fish using scientific method was initiated in 2011. Ponds having facility to draw seawater (>15ppt) are being used to stock seed and grow them to marketable size. Pompano, sand whiting, pearlspot and mullets are being cultured now in such farms.

Governmental support and assistance from public financing institutions with an element of risk coverage in the initial stages are necessary for establishment of commercial mariculture farms. Ownership or leasing right with protection against navigation, traditional fishing and encroachment are other pre-requisites for development of farming, which must be addressed by the Governmental interventions. Taking into account the potentials of production of fish and shellfish from different areas of the fisheries sector, following strategies for enhancing production through coastal aquaculture have been evolved.

Brackishwater area available	1.2 million ha.
Presently under utilization	0.1 million ha.
Present Production	0.9 lakh tonnes
Projected potential production	0.5 million tonnes

Strategies

- Increasing water area under aquaculture practices
- Increasing productivity of existing water bodies
- Diversification of candidate species
- Research support for sustainable, eco-friendly and techno-economically viable hatchery & culture systems
- Fish health management and disease diagnostics
- Fish nutrition and feed formulation
- Fish genetics and selective breeding
- Utilization of inland saline soils for aquaculture

Several State Government departments have envisaged interest in installation of cages in openwaters. Mariculture activities is thus on an expansion trail and this is will ultimately result in increased production from the marine sector.

2. TECHNOLOGIES FOR FISHERIES ENHANCEMENT

A. P. Dineshbabu and Sujitha Thomas, Mangalore Research Centre of CMFRI

By 2050, Global human population is projected to reach more than 9.2 billion, which is within estimates of the maximum carrying capacity of the planet. A fundamental question for science is whether it is possible to increase food production enough to feed a human population of that magnitude and will fisheries be sustainable as human population pressures and accompanying coastal development pressures continue. Capacity of multiplication of fish and fishery resources is considered far higher than from other sources and fisheries is considered to the majour source in meeting the future protein requirement of the human population. Marine fisheries enhancement is possible through three methods, harvest management, production enhancement and habitat management

Harvest Management: We can control fishing catch & effort – seasonal closures, size and catch limitations, area closures, incentives (catch shares), number of angler licenses (limited entry), spatial planning.

Production Enhancement: Mariculture, hatchery technology, sea ranching.

Habitat Management: We can identify, protect and restore essential habitat – EFH, MPAs, spatial planning, habitat preservation and restoration, artificial habitats

Mariculture:

Among these three measures product enhancement methods, mariculture provide direct results of production enhancement in quantifiable terms and rest are the indirect means to enhance the production. Mariculture is identified as a prime industry to tap the enormous sources of and very good potential for India. According to Food and Agriculture Organization (FAO), the projected global aquaculture production in 1995 was 19.29 million tonnes and it is expected to increase to 26.90 million tonnes by 2000 AD. Currently in India, there is a growing interest in aquaculture in order to meet the protein demand of the fast growing population. Marine finfish culture has been an established practice is now undergoing rapid development. Information on the relative abundance of cultivable fin fish seed together with physico-chemical conditions of the environment is a essential prerequisite for aquaculture. At present, in marine finfish culture practices only a part of seed requirement is met from the hatchery and most of the culture practices in India are supported by the supply of seed collected from the natural environment. The technology for the mass production of marine finfish seed by induced breeding are being carried out in various Institutions which started providing very promising results which will lead to adoption of finfish culture in India in large scale. India have developed technologies for mass scale seed production of seabass, cobia, pompano, prawns, crabs, Ornamental marine fishes etc.

India is having a long coast line of 8129 Km with many estuaries, creeks, coastal lagoons, mudflat and swamps .

Mariculture development in India:

India is having a long coast line of 8129 Km with many estuaries, creeks, coastal lagoons, mudflat and swamps. In Many parts of India fish/shrimp culture are being carries out traditionally in natural and constructed ponds. Recently pen culture an cagve culture are also being practiced in various states.

(i) Pond Culture

Shrimps are the major groups being cultured in saline ponds along Indian coast. *Penaeus indicus, P.monodon* were the majour species cultured. Recently *Penaus vannamei*, exotic shrimp species is also introduced to tide over the white spot disease prevalent in *P. monodon* stock.

In pond culture method fin fishes and shrimps are the majour groups cultured. Among finfishes, milk fish and mullets, pearlspot were cultured as monoculture as well as in polyculture with shrimps and other fishes. Monoculture of seabass, is being practiced in saline ponds all along Indian coast. Recently pompano also identified for a candidate species for pond culture in saline ponds.

Crabs *Scylla* spp are being cultured in south west coast of India as culture practice or as a fattening method.

(ii) Pen Culture

Pen culture method is found to be one of the better cuture method for Milkfish and Grey mullets. Recently seabass and pompano also are being cultured by pen culture method

(iii) Cage culture

Cage culture of fish was originated in the Far East and later adopted in several countries.

Estuarine cages were experimented in the country for many groups like Red snapper Rabbit fishes, Groupers, and sandwhiting and seabass. But lack of seed production techniques limited the progress of estuarine cages in seabasss alone. However new development s in seed production in finfishes will be helpful in augmenting fish production from estuarine cages.

Marine cages:

Finfish seed production from hatcheries lead to the popularization of Marine cages are during last decade. Technology for marine cages, location testing of marine cages , Successful demonstration of the culture of different fishes like, seabass, lobsters, cobia, seabreams, snappers and groupers were demonstrated by CMFRI and in production terms it holds great future.

(iii) Molluscan farming:

Mussel farming is one of the most popular mariculture operations in the temperate countries. In India *Perna viridis* is the species extensively used for rope culture in south west coast of India. Mussels have anti-inflammatory, anti-histamine, prophylactic and therapeutic properties. Oysters are one of the most valued seafoods and are farmed extensively. In India, *Crassostrea madrasensis,* commonly known as the Indian backwater oyster is the most preferred species for farming. A number of clam species occur in the coastal regions of India. Experiments conducted to farm these species, indicated the feasibility of clam farming in pen and on bottom methods

Present status of mariculture in Karnataka

Karnataka state has 3 coastal districts and fisheries sector plays an important role in socio-economic development of the state. The State has 300 km coastline and most importantly. It has a pristine unpolluted brackishwater/estuarine area of about 8000 ha. in these three districts. Dakshina Kannada has 5 estuaries with a total area of 1140 ha, Udupi has 8 estuaries of 1885 ha and in Uttar Kannada there are 13 estuaries with about 4200 ha. The bivalve culture has been adopted by fishermen of Karnataka for last 10 years and small scale fish culture cages are also becoming a practice in many parts of Karnataka. Recent success in Open sea cage culture attracted many fishermen to venture into mariculture.

CMFRI has developed adaptable technologies in bivalve culture in Karnataka. Green mussel (*Perna viridis*) and edible oyster (*Crassostrea madrasensis*) farming practice holds good potential in coastal and estuarine areas of Karnataka. Breakthrough in extraction of GME will increase the demand for bulk quantities and for meeting the demands of the market Standardization of clam farming protocols are being carried out for advising on ideal relaying densities in suitable substratum this may boost the sustainable production of bivalves along Karnataka coast.

Crab fattening is a relatively non-intensive form of mariculture technology. 'Soft crabs' collected from creeks and inshore waters can be maintained in prepared ponds for fattening. The advantage of the crab farming activity for small-scale fishers of the coastal areas relies on the fact that it can ideally be carried out in smaller areas (<0.25 ha) as short-duration crops. By virtue of its meat quality and large size, the mud crab, *Scylla tranquebarica* has gained prominence in live crab export trade from India. At present, live water crabs are not exported from Karnataka and it is sold in local markets at comparatively low prices. These natural seed resources can be harnessed optimally and used for farming activity as small-scale grow-out operations in suitable coastal areas of Karnataka. Up-scaling of these techniques have to be tried and the techno-economic viability confirmed and transferred to farmers. Hatchery in East coast of India developed seed production technologies and oit holds good potential for carb culture in Karnataka

By Designing and propagating integrated aquaculture units in estuaries and backwaters to rear fishes will boost the aquaculture production of the state and also empower the fishermen to increase the production and provide alternate livelihood in lean fishing period. In all estuaries and coastal waters, where fishery is prevalent a large quantity of juvenile fishes are caught and being discarded due to its smaller size. Out of the discarded fishes there are large numbers of fast growing fishes, if they are identified well and its culture technologies are propagated this will go long way in boosting fish production. Standardization of small-scale capture based farming units for red snapper and seabass has been developed and practiced in Kundapur district and there is a great demand for seeds for small scale culture in the state. Marine cages for rearing Seabass, redsnapper, seabreams, cobia and pompano has been demonstrated in mariner cages in Karwar and there is a good potential for increase in marine fisheries production through marine cages.

3. OPEN SEA CAGE CULTURE FOR MARINE FINFISH AND SHELL FISHES

K. K. Philipose, S. R. Krupesha Sharma and Jayshree Loka,
Karwar Research Centre of CMFRI

Capture fisheries is undergoing tremendous changes either due to increased fishing pressure or due to decrease in the production of certain groups due to fishery dependent or fishery independent factors. In spite of increasing effort the catch of almost all commercially important fin fishes and shell fishes is on the decline and results in severe resource depletion and unemployment. Fishermen community solely depending on fishing for their livelihood is facing an uncertain future. Decline in marine capture fishery also affects the availability of cheap protein for the masses and also affects the GDP growth of the country. It was in this context cage farming of fin fishes and shell fishes assume importance. Since cage farming is done in open waters where wave action and current takes care of the day to day maintenance of the cage cultured fishes and unlike pond cultured fishes the carbon foot print in cage culture is relatively low and therefore more eco friendly. Cage culture of high value marine fin fishes was initiated in Norway during 1970's and has been developed as a major industry all over the world. Most of the countries where the cage culture has been commercialized are having calm and well protected areas in seas to accommodate cages safely against any unfavorable weather conditions. India, with a vast coast line of 8000 km has an immense potential for the development of mariculture. Central Marine Fisheries Research Institute has initiated cage culture in India for the first time and marine cage was successfully launched at Visakhapatnam, in east coast of India in 2007 (Rao 2009). Later, cage culture was extended to 14 other locations and demonstrated successful culture of Sea bass, *Lates calcarifer,* Cobia *Rachycentron canadum*, Pompano, *Trachinotus blochii.* CMFRI had achieved tremendous success in cage farming at Karwar. At Karwar CMFRI made a production of 2.5 tonnes of Sea bass in 6 meter cages.

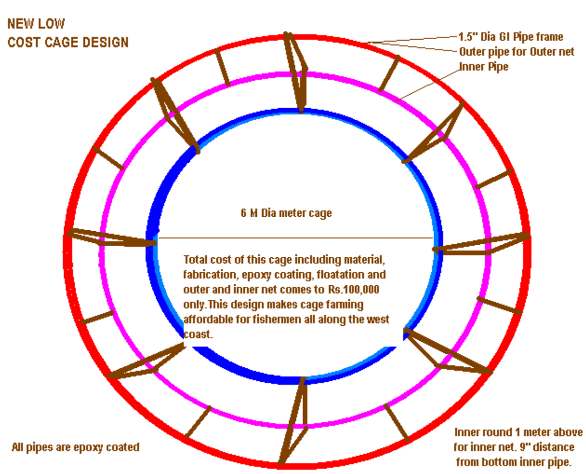
The concept of sea cage farm involving a number of cages and number of species was first tried and successfully perfected at Karwar. The Cage farm of CMFRI now has 20 cages culturing five species of marine fin fishes viz., sea bass, cobia, pompano, snappers and sea breams. In order to meet the rising requirement of fish in the domestic as well as international market there is an urgent need to increase the production of food fishes through marine and coastal cage culture. Although we have achieved remarkable success lot more issues are to be researched in order to develop a healthy and environment friendly cage culture technology. The experimental culture of pompano in coastal water bodies in west Godavari district of Andhra Pradesh had opened a new vista for mariculture development. High saline waters in these areas offer immense opportunities to cultivate not only euryhaline species but also marine food fishes. More studies are required to understand issues like growth, salinity tolerance, stocking density, health issues, carrying capacity etc. Development of sustainable Mariculture in India is the need of the day to promote the propagation of high-value marine fish species like sea bass, cobia, pompano, snappers, shellfishes and seaweeds. This will enhance the competitive advantage of the country's fishery sector globally as well as to increase the overall sustainability and productivity of fish farming communities. Since mariculture has been identified as a thrust area of development recently it is essential to undertake focused research on various issues to establish a sustainable mariculture system in India.

Objectives

1. Development of R&D based fish farms for demonstration
2. Demonstrate viability, profitability and environmental compatibility of cage farming in Indian waters
3. Field testing suitability and compatibility of Indian species for age farming
4. Development of field tested package of practices for entrepreneurs/farmers
5. Training and HRD for local fishers/ entrepreneurs/farmers in various aspects of cage farming
6. R&D on scientific aspects of feeding, growth, survival, disease control, husbandry, harvesting, holding, marketing etc.

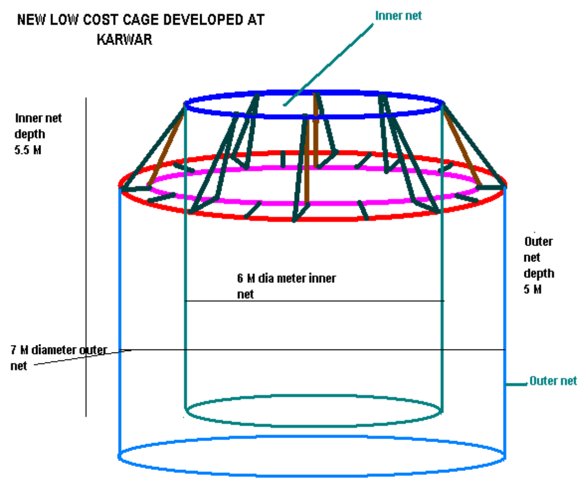
Development of innovative low cost cages for promoting Open Sea Cage Culture along the Indian coast

Central Marine Fisheries Research Institute being the pioneer to the initiate open sea cage culture in Indian waters has been striving hard to promote open sea cage culture at selected locations in all the Maritime states with the involvement of the fisherman community.Cage design and mooring technology has been undergoing refinement through the dedicated and committed efforts of the scientist of CMFRI. Efforts were continuously made to reduce the cost of the cage and mooring systems so as to make it affordable for the fisherman and also to help them to take it up as a lively hood alternative.



Design details of the low cost cage

The present HDPE Cage alone costs about Rs.4,00,000/- Per Cage and together with the mooring systems and net, the cost increase to about Rs.5,50,000/- making it unaffordable to the fisherman. While interacting with the fisherman they expressed their desire to have cage costing less then Rs. 1,00,000/- and lasting at least for 5 years to make it sustainable and economical in the long run. It was with their interest in mind the Karwar Research Centre has looked for alternatives for HDPE cages for promoting Cage Culture in the coastal waters and developed this fifth generation cage.



Technical details of the low cost cage

Design

The low cost cage developed at Karwar is made of good quality 1.5" GI pipe (B class). The diameter of the cage was 6 meter and the height was 120 cm from Base to the railings. All the joints are double welded for ensuring extra strength. Fig (4). After fabrication the structure was provided with single coat epoxy primer and double coat epoxy grey paint to prevent rusting. The total weight of the cage is about 300 kg only.

Low cost cage before epoxy coating

Floatation

Puff or foam field HDPE cage is buoyant enough to float in the water however, metal cage needs additional floatation. Eight fiber barrels of 200 lit. Capacity filed with 30 lb air was used for floating the cage. One of the cap of the barrel is fitted with a valve tube for inflating with air and both the caps are then sealed with M'Seal to prevent air leakage. The cage when floated on inflated barrels provides a stable platform around the cage where fisherman can stand and safely attend work like net cleaning, net exchange etc.

Advantage of the low cost cage

The HDPE cages floats on water surface hence the outer net is always in the water level and predatory fishes enters into the area in between outer and inner net. In the case of low cost cage the outer net is 60cm above water level and provides no chance for predatory fishes to enter in the middle space.

HDPE cage sinks if more than three person climb on the side frame where as the low cost cage can take the weight of as many as 20-25 persons on the platform safely. The cost of 1 HDPE cage including netting, mooring etc, together costs about Rs. 5,50,000, whereas the low cost cage including netting, mooring all together cost only Rs. 1,00,000. The HDPE cage may take a minimum 4 to 5 Crops to recover the input cost whereas low cost cage can recover the investment in a single crop itself. The diameter of the HDPE cage and low cost cage is 6 meters and Depth of the net also is 6 meters. Hence area wise both the cage gives the same performance.

Disadvantages

Unlike HDPE cage wind action is more on metal cage as it is floated on barrels. Hence it will be difficult to float in open sea condition from June to August unless Heavy duty mooring is provided. Except for this the metal cage performance is far superior to HDPE cage. For fabrication of HDPE cage costly parts and specially trained persons are required. Hence fabrication charges are very high. Whereas for GI cage once the design is provided any small scale workshop can make it. HDPE cage once abandoned is an environmental hazard whereas GI cages once abandoned can be recycled.

Low cost cage in the farm

Open sea Cage Culture in India is promoted by the government of India in a big way to increase fish production from coastal waters and to provide livelihood option to the fishermen. In this context CMFRI's initiative to reduce the cost of the cage to make it affordable to the common fishermen, will go a long way in resource and employment generation.

GI cage Provides an excellent working Platform for the farmers

Dismantling type 10 meter cage in the sea

Dismantling type Cages

GI cages reduce the cost of the cage by almost one fifth of the HDPE cage and increase the profitability of the operation. The whole concept of developing the low cost cage was to reduce the input cost and increase the profitability. The earlier GI cages were designed as fused cages where all the joints are welded. In such cages transportation of the cage was a problem and once the cage is welded it cannot be transported from one place to another by road. Another issue was that for the final welding of the cage power was not available at many places and hiring generator works out very costly. Another issue was that the water volume available inside the cage decides the number of fishes that we can grow in that. A six meter dia cage gives 141 M^3 water for rearing so providing more cultivable area in a single cage is very important. Another important observation was that all other expenses like mooring materials; floatation materials etc remain more or less same. Considering all this an attempt was made first to make the cage a dismantling type without affecting its strength.

Initially a 6 meter cage was designed and fabricated as dismantling type and tested it for strength, transportation efficiency and cost difference. When we found the design strong as a next step we designed a 10 meter circular dismantling type GI cage and later a 12 meter circular dismantling type GI cage. The water volume of the 10 meter cage is 392 M^3 and that of the 12 meter cage 565 M^3. This innovation has increased the cage volume by 4 times and the production per cage to 21.6 tonnes (Table-2). Another advantage is that cages can be fabricated in small scale industries units where they get subsidized power and transport it anywhere by road. Similarly after the harvest the cage can be dismantled, serviced and stored in a shed and used again for the next faming when climate is favourable. 6 meter cage can be managed by 6 persons where as for the 12 meter cage 10 persons are required. In short having one 12 meter cage is like having 4 cages of 6 meter diameter. So this path breaking design is going to make cage farming very profitable.

Cage Cost

Sl.No	Material	Cost-6 meter cage	Cost-10 meter cage	Cost-12 meter cage
1	GI Pipe	18900	37400	45900
2	Welding Charges	10000	20000	24500
5	Epoxy Paint	1600	2600	3600
6	Labour charges	1000	1500	2500
7	Floatation	7500	12000	13500
8	HDPE Rope	1000	1500	2000
	Total	**40,000**	**75000**	**92000**

Cost estimates of the GI Cages

Cage Production

Sl.No	Details	Cost-6 meter cage	Cost-10 meter cage	Cost-12 meter cage
1	Cultivable Water Volume (M^3)	141 M^3	392 M^3	565 M^3
2	Stocking Density	5000	15000	20000
3	Sea Bass Production capacity in Kg. (60% survival rate and average weight 1.8 Kg weight after 8 months grow out (October – May)	5400	16200	21600
4	Gross Revenue (Without deducing expenses) assuming that Sea bass fetches an average price of Rs.250/Kg	Rs.13,50,000	Rs.40,50,000	Rs.54,00,000

Production Capacity of GI cages

Cage frame is only a structure to hold the cage net safely throughout the culture operation in the sea. Since the cost of the cage nets mooring etc are same for any type of cages it is advantageous to go for a cost effective structure so that the input cost for the farming greatly decreases and profitability of the cage farming increases.GI cages are being used in Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu effectively. Low cost GI cages are playing a major role in popularizing open sea cage farming among the farmers and fishermen along the Indian coast catalyzing the growth of the blue revolution in the country.

4. WATER QUALITY CRITERIA IN AQUACULTURE

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Water is a prime resource which supports all life forms on earth, its quality and quantity vary from place to place. As habitats of aquaculture, there are three categories of waters, viz. fresh, salt and brackish. All these are characterized by a wide difference in their salinities ranging from nil freshwater to nearly 35 ppt in seawater. This variation in salinity influences the fauna and flora. Brackish water is present in the areas influenced by the tidal regime like the estuaries, deltas of rivers, lagoons and backwaters. Depending on the phase of the tide and volume of fresh water discharged through the river into the sea there will be variation in salinity. The capacity of the residents of an estuary to tolerate a wide range of salinity that prevails there is by virtue of a dynamic physiological process of osmoregulation in which the gills, the kidneys, the skin and the buccal cavity lining play significant roles. Salinity tolerance of a species is one of the important parameters for consideration in aquaculture. The success of a fish farming establishment lies greatly on its water quality management programme. Hence, it requires constant monitoring.

The water quality parameters to be monitored are given below.

Temperature

Each species of fish has an optimum temperature range for growth, as well as upper and lower lethal temperatures. Water temperature is critical in growth, reproduction and sometimes survival. Below the optimum temperature feed consumption and feed conversion decline until a temperature is reached at which growth ceases and feed consumption is limited to a maintenance ration. Below this temperature is a lower lethal temperature at which death occurs. Above the optimum temperature feed consumption increases while feed conversion declines.

pH

This parameter shows the concentration of hydrogen ions (H^+) in the water. The scale for measuring the degree of acidity is called the pH scale, which ranges from 1 to 14. At 25 °C, pH of 7.0 will be considered neutral, i.e. neither acidic nor basic, while values below 7.0 are considered acidic, and above 7.0 are basic. Natural waters range between pH 5.0 and pH 10.0 while seawater is near pH 8.3. The pH is interdependent with other water quality parameters, such as carbon dioxide, alkalinity, and hardness. It can be toxic in itself at a certain level, and also known to influence the toxicity as well of hydrogen sulfide, cyanides, heavy metals, and ammonia (Klontz, 1993). For most freshwater species, a pH range between 6.5 - 9.0 is ideal, but most marine animals typically cannot tolerate as wide range pH as freshwater animals, thus the optimum pH is usually between pH 7.5 and 8.5 (Boyd, 1990).

Total Alkalinity

Alkalinity is the measure of the capacity of water to neutralize or buffer acids using carbonate, bicarbonate ions, and in rare cases, by hydroxide, thus protecting the organisms from major fluctuations in pH. Without this, free carbon dioxide will form large amounts of a weak acid (carbonic acid) that may decrease the night-time pH level to 4.5. During peak periods of photosynthesis, most of the free carbondioxide will be consumed by the phytoplankton and, as a result, drive the pH levels above 10.0. Recommended alkaline level in freshwater is (5-500 mg/l) and seawater 116mg/l (Lawson, 1995).

Dissolved Oxygen (DO)

In a water body, oxygen is available in a dissolved state. It can enter into the system through direct diffusion and as a by-product of photosynthesis. Oxygen concentration maybe reported in terms of milligram per liter (mg/l) or its equivalent,parts per million (ppm). DO is needed by fish to respire and perform metabolic activities. The amount of oxygen consumption varies, depending on the size, feeding rate, activity level and species. Physical condition such as temperature, altitude and salinity can also affect oxygen level as the temperature and salinity increases, the solubility of oxygen in the water decreases. Thus low levels of dissolved oxygen are often linked to fish kill incidents. On the other hand, optimum levels can result to good growth, thus result to high production yield. A saturation level of at least 5 mg/l is required. The level of dissolved oxygen in the water can be increased through mechanical aeration, liquid oxygen injection, wind and wave action, and presence of aquatic plants and algae. However, it can also cause oxygen depletion when the plant population becomes too dense as DO is removed through respiration and decomposition. Food wastage and feed quality should be monitored as both significantly affect the levels of dissolved oxygen in the system.

Nitrogen is one of the limiting nutrients during photosynthesis. It enters into the aquaculture system through rainfall, in-situ Nitrogen fixation, river run-off and diffusion from sediments, uneaten feeds and fish wastes. Nitrogen is largely controlled by redox reactions mediated by phytoplankton and bacteria. The processes include remineralization, ammonification, nitrification, denitrification and fixation.

Ammonia-Nitrogen (NH_3-N)

Ammonia is the initial product of the decomposition of nitrogenous organic wastes and respiration. Nitrogenous organic wastes come from uneaten feeds and excretion of fishes. Thus, the concentration of ammonia-N is positively correlated to the amount of food wastage and the stocking density. Total Ammonia Nitrogen (TAN) is a parameter that measures the un-ionized (NH_3) and ionized (NH_4^+)

forms of ammonia present in the aquaculture system. High concentrations of ammonia causes an increase in pH and ammonia concentration in the blood of the fish which can damage the gills, the red blood cells, affect osmoregulation, reduce the oxygen-carrying capacity of blood and increase the oxygen demand of tissues (Lawson, 1995). Generally, NH_4+ is harmless and can dissipate into the atmosphere easily, however, NH_3 can be extremely toxic. Its toxicity was found out to be directly correlated with temperature and pH, i.e. NH_3 levels increases as the temperature and pH increases. The level of ammonia should not exceed 1mg/l in marine condition.

Nitrite-Nitrogen (NO_2-N)

Nitrite is a byproduct of oxidized NH_3 or NH_4+, an intermediary in the conversion of NH_3 or NH_4+ into NO_3. This process is completed through nitrification which is done by the highly aerobic, gram-negative, chemoautotrophic bacteria found naturally in the system. The conversion is quick, thus high nitrite concentrations are not commonly found. However, if high levels do occur, it can cause hypoxia, due to deactivation of hemoglobin in fish′ blood, a condition known as the "brown blood disease" (Lawson, 1995).The toxicity of nitrite is dependent on chemical factors such as the reduction of calcium-,chloride-, bromide- and bicarbonate ions, and levels of pH, dissolved oxygen and ammonia. Increasing pH, low dissolved oxygen and high ammonia can increase its toxic effect. High nitrite concentrations plus low chloride levels can result to reduced feeding activities, poor feed conversions, lower resistance to diseases and susceptibility to mortality (Lawson, 1995). The nitrite concentration should less than 0.1 mg l^{-1}.

Nitrate-Nitrogen (NO_3-N)

Nitrate is formed through nitrification process, i.e. oxidation of NO_2 into NO_3 by the action of aerobic bacteria. It is highly soluble in water, stable over a wide range and is least toxic. Nitrate not taken up directly by aquatic plants is denitrified in anaerobic sediments. Denitrification occurs in water bodies subject to enhanced nutrient loading from pollution, in water bodies with long residence times and in wetland ecosystems subject to periodic drying, where oxygen inputs during drying periods stimulate coupled mineralization-nitrification-denitrification within organically rich sediments (Furnas, 1992). However, high levels can affect osmoregulation, oxygen transport, eutrophication and algal bloom (Lawson, 1995).

Phosphorous (P)

Phosphorus (P) is found in the form of inorganic and organic phosphates (PO4) in natural waters. Inorganic phosphates include orthophosphate and polyphosphate while organic forms are those organically-bound phosphates. Phosphorous is a limiting nutrient needed for the growth of all plants- aquatic plants and algae alike. However, excess concentrations especially in rivers and lakes can result to algal blooms. Phosphates are not toxic to people or animals, unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphates. In marine condition below 0.05mg/l phosphorous is ideal for aquaculture.

The sources of phosphorous are wastewater and septic effluents, detergents, fertilizers, soil run-off (as phosphorous bound in the soil will be released), phosphate mining, industrial discharges, and synthetic materials which contain organophosphates, such as insecticides.

Total Solids

Total solids refer to any matter either suspended or dissolved in water. Everything that is retained by a filter is considered a suspended solid, while those that passed through are classified as dissolved solids.

Suspended solid (SS) can come from silt, decaying plant and animals, industrial wastes, sewage, etc. High concentrations have several negative effects, such as decreasing the amount of light that can penetrate the water, lower the production of dissolved oxygen, high absorption of heat from sunlight, low visibility which will affect the fish's ability to hunt for food, clog gills, prevent development of egg and larva. It can also be an indicator of higher concentration of bacteria, nutrients and pollutants in the water.

Dissolved solid (DS) includes those materials dissolved in the water, such as, bicarbonate, sulphate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. These ions are important in sustaining aquatic life. However, high concentrations can result to damage in organism's cell , reduce photosynthetic activity and increase the water temperature. The acceptable TSS value is based on the previous sampling, wherein it should not be increased by more than 10% and 30%, respectively. It is because TSS levels in marine waters are highly variable and depend on many factors, thus, setting an absolute numerical value is not possible.

Heavy Metals

Heavy metals bioaccumulate and results in lower product quality and human health risk. The anthropogenic sources include ore mining and processing, plating industries, smelters, tanneries and textile industries. The concentration of these substances can be determined through chemical analysis of the water, sediments and fish tissue.

Mercury (Hg)

Mercury is toxic to both aquatic life and humans. Inorganic form occurs naturally in rocks and soils. It is being transported to the surface water through erosion and weathering.

However, higher concentrations can be found in areas near the industries and agriculture. The sources are caustic soda, fossil fuel combustion, paint, pulp and paper, batteries, dental amalgam and bactericides.

Lead

(Pb) comes from deposition of exhaust from vehicles in the atmosphere, batteries, waste from lead ore mines, lead smelters and sewage discharge. Its toxicity is dependent on pH level, hardness and alkalinity of the water. The toxic effects on fish are increased at lower pH level, low alkalinity and low solubility in hard water.

Chronic lead toxicity in fish leads to nervous damage which can be determined by the blackening of the fins. Acute toxicity, on the other hand causes gill damage and suffocation (Svobodova *et al.*, 1993).

Cadmium

Cadmium (Cd) is a highly toxic metal and is exceptionally persistent in humans. Low levels of exposure may also result to accumulation in kidneys (WHO, 1989). The most common sources are electroplating, nickel plating, smeltling, engraving, batteries, sewage sludge, fertilizers and zinc mines. In fishes, acute toxic exposure results to damage of the central nervous system. Chronic exposure have adverse effects on the reproductive organs, maturation, hatchability and larval development as well as mortality (Svobodova *et al.*, 1993; Lloyd,1992).

Nickel

Nickel (Ni) is only moderately toxic to fish and has little capacity for bioaccumulation. The dominant form in water is Ni2+. It enters the aquatic environment through the disposal of batteries and effluents from metal plating and ore processing industries. In humans, nickel can be carcinogenic and teratogenic.

Among the four metals, generally, cadium has the most stringent criteria, ranging from less than 0.2-5.0 μg/L, followed by mercury, lead and then lastly by nickel. Under marine condition the level of Hg, Pb, Cd and Ni should be less than 1 μg/L.

Coliform bacteria

Coliform bacteria consist of several genera belonging to Family *Enterobacteriaceae. Fecal* coliform which belongs to this group is found mostly in feces and intestinal tracts of humans and other warm blooded animals. It is not pathogenic per se, however, it is a good indicator of the presence of pathogenic bacteria. High levels of fecal coliform in the water may cause typhoid fever, hepatitis, gastroenteritis and dysentery. Factors which affect the concentration of this bacteria are the presence of wastewater and septic system, animal wastes, run-off, high temperature and nutrient-rich water. Around 30 counts per ml for fresh and marine water is permissible.

Pesticides

Pesticide refers to any chemical used to control unwanted non-pathogenic organisms, including insecticides, herbicides, fungicides, algicides and rotenone (used in killing unwanted fish) (Svobodova, 1993). These chemicals are designed to be toxic and persistent, thus it is also of concern in aquaculture. It can affect the quality of the aquaculture product as well as the health of the fish and humans.

The safe level of some of the pesticides are given below

Pesticide	Safe level (ppb)
Aldrin	0.003
BHC	4.0
Chlordane	0.0043 (freshwater) 0.004 (marine)
DDT	0.001
Heptachlor	0.0038 (freshwater) 0.0036 (marine)
Dieldrin	0.003 0.0019

Source: Boyd (1990)

Aquaculture increasingly plays a more significant role in fisheries sector. Increasing nutrient output from domestic, industrial, agriculture, deforestation and livestock production also adds to the water nutrient load and these have an effect on aquaculture and carrying capacity of the water body. Some water body may have a short residence time, i.e. time for the water to flushed out all the nutrients, while some have long residence time. Thus, the pollution level and its effect to the organisms will not be uniform.

5. CONCEPT OF CBA, REQUIREMENTS AND PRACTICES

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The importance and popularity of culture of food fishes is increasing rapidly in coastal states of India. The support and expanse of marketing network and advancement of preservation technologies solved long standing problems marketing in domestic as well as international market. In view of its high demand in internal and international market, more and more entrepreneurs are getting interested in the farming of food fishes. Innovations in cage culture technology and its success has drawn the attention of policy makers into giving thrust on food fish culture. Those who have invested huge amount in shrimp culture installations along the coastal areas are also showing interest in switching over to food fish farming following these developments and setback in shrimp culture. In estuaries cage culture is the most viable technique to rear fin fishes. The indigenous technology is developed in cage culture of food fishes in India. There are two general types of cages, floating and stationary. A floating cage is made up of a floating unit from which a single or a series of netcages are suspended. Some of them are mobile and can be easily towed away. A stationary cage, on the other hand, is tied to fixed poles at their corners. In Asia, finfish like grouper (*Epinephelus tauvina*), seabass (*Lates calcarifer*), snapper (*Lutjanus* spp.) and siganid (*Siganus* spp.) are cultured in commercial scales in tropical countries such as Singapore, Thailand, Malaysia, Philippines, Indonesia and Hong Kong.

Fishing and aquaculture are in the past have tended to be treated as distinct and isolated sectors. “capture-based aquaculture” is form of overlap between fisheries and aquaculture which is being propagated in many parts of the world successfully. The fishing is put at the service of aquaculture or aquaculture is practiced to avoid the loss of fishery due to juvenile exploitation. Capture-based aquaculture is the practice of collecting “seed” material – from early life stages to adults - from the wild, and its subsequent on-growing in captivity to marketable size, using aquaculture techniques.

Capture-based aquaculture is a global activity but has specific characteristics that depend on geographical location and the species being cultured. The species groups used in capture-based aquaculture include molluscs (e.g. oysters, mussels, scallops), crustaceans (e.g. shrimps, crabs) and finfish (e.g. eels, grey mullets, milkfish, yellowtails, groupers, rabbitfish, tunas). In worldwide CBA is practiced in many species following are some of the species, with the countries where it is practiced.

- Shrimp (*Penaeidae*) in South America and South-East Asia;

- Milkfish (*Chanos chanos*) in the Philippines, Sri Lanka, Pacific Islands and Indonesia;
- Eels (*Anguilla* spp.) in Asia, Europe, Australia and North America, mainly in China, Japan, Taiwan Province of China, The Netherlands, Denmark and Italy;
- Yellowtails (*Seriola* spp.), mainly in Japan, Taiwan Province of China, Viet Nam, Hong Kong, Italy, Spain, Australia and New Zealand;
- Tunas (*Thunnus* spp.) in Australia, Japan, Canada, Spain, Mexico, Croatia, Italy, Malta, Morocco and Turkey; and
- Groupers (*Epinephelus* spp.), which is now widespread in Indonesia, Malaysia, Philippines, Taiwan Province of China, Thailand, Hong Kong, People's Republic of China, and Vietnam, and in other parts of the tropics, for example in southeastern, USA and Caribbean.
- Grouper culture is also on-going in India, Sri Lanka, Saudi Arabia, Republic of Korea and Australia.

These species are caught and farmed using various techniques and systems, depending on different local cultural, economic and ethnical traditions. In some areas this is typically artisanal, rather than industrial in nature. Economic considerations are the key drivers for capture-based aquaculture. The selection of species for culture reflects their acceptability and demand in local or international markets. Market requirements are determined primarily by people's tastes and customs. As capture-based aquaculture 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 will significantly increase. This development will be capable of causing a number of very important and diverse effects, not all of them beneficial.

Cage based aquaculture is getting adopted rapidly in many parts of the country. When it is being practiced in high intensity some of the scientific factors has to be taken care. Carrying capacity of the water body where cages are is a very important factor. The number of cages should be according to the carrying capacity of the water body and the number of cages exceeds its carrying capacity, it will effect fish growth and survival. There is a strong need for better data on the biology and fisheries of the species. Accumulation of uneaten feed and fish excreta under the cage can become an environmental problem, but this can be avoided by selecting a site with good water exchange to install the cage. capture-based aquaculture provides significant positive returns in areas with depressed and marginal economies, and an alternative livelihood for coastal communities. However, the difficulties of marketing fresh fish and supplying markets that demand live fish (e.g. groupers), and the need to expand markets limit its potential. Skill gaps are evident in the sector, including specific knowledge on economics and management, the suitability of individual (new) species for culture, information on their biology and dietary requirements, and marketing. Capture-based aquaculture is labour intensive in its farming and processing operations, and can contribute to poverty alleviation in developing countries.

Legal and security issues: We will have to envisage some difficulties in future development of capture based aquaculture. Security of the cages is the major issue. For leasing the inland waters and estuaries, the provisions were made in the 73rd and 74th amendments to the Constitution of India empower the panchayats to perform functions mentioned in the eleventh schedule of the Constitution in 29 subjects including fisheries. However, due to lack of legal clarity this has not been implemented in any panchayat. Leases policies should be guided by a set of rules and principles relevant to public trust responsibilities and should specify the size of farm, duration of farming and other terms of lease. Rents thus collected should be used for development of coastal areas.

Food safety issues: The success of cage culture depends on maintaining good water quality around the fish cages and so it is in the farmer's best interests to minimize environmental impacts. Size and intensity of the process should fit to the size of the water body and water exchange rate. It may facilitate to overcome adverse impacts on water and sediment quality. In common with other types of aquaculture, careful choice of aquafeed ingredients and on-growing sites, in addition to good management practices, are necessary to avoid the accumulation of chemical and antibiotic residues, in order to ensure the continued safety of farmed products. Capture-based aquaculture provides other opportunities to reduce the risks associated with food safety.

Site and species selection criteria for cage culture

Cage culture is a popular method of rearing finfish most of Asian countries and it is getting popularised in India also. This new technology utilizes little physical facilities, less space, low initial and is moderately inexpensive to operate. Another advantage is the easy and fast harvesting of live fish which fetch higher price in the market.

There are two general types of cages, floating and stationary. A floating cage is made up of a floating unit from which a single or a series of netcages are suspended. Some of them are mobile and can be easily towed away. A stationary cage, on the other hand, is tied to fixed poles at their corners. In Asia, finfish like grouper (*Epinephelus tauvina*), seabass (*Lates calcarifer*), snapper (*Lutjanus* spp.) and siganid (*Siganus* spp.) are cultured in commercial scales in tropical countries such as Singapore, Thailand, Malaysia, Philippines, Indonesia and Hong Kong. While other finfish like red sea-bream (*Pagrosomus major*), black sea-bream (*Sparus microcephalus*), yellow tail (*Seriola quinqueradiata),* flatfish (*Paralichthys olivaceus*) etc., are cultured in temperate waters, such as in China, DPR Korea, ROKorea and Japan.

Proper site selection for marine netcage culture is of paramount importance as it may considerably affect construction costs, operating costs, growth and survival rate of the fish, and the period of usefulness of the cages. Although floating cages can be usually towed away, sometimes it is not economical to do so.

Site selection criteria also serve as a technical guideline for the production of seafarming resources atlas, rules and regulations, which are necessary for planning seafarming development programme in each country. The guidelines considered in this paper are broad and general, which may have to be modified to suit local conditions and species to be cultured in each area.

1.Topographical criteria

1a.**Exposure**

Cages should be situated in sheltered areas protected from strong wind and wave. Strong winds such as those generated by a typhoon will destroy any structure projecting above the water while waves will bear on any object on and under the water. Normally, storms in tropical countries can be classified into three types: 1) cyclones or typhoons (3–15 m. wave height); 2) tropical storms (1–8 wave height); and 3) depressions (0.75–5 m wave height). Meteorological records in the area will provide an indication of extreme condition of the weather. The information on the long-term frequency, direction and speed of surface wind obtained from meteorological records can be modified for prediction of the height of the wave. Generally, the wind velocity should not exceed 5 knots for stationary cage and 10 knots for floating cage. In relation to the wind speed, the height of the wave in a suitable area should preferably not exceed 0.5 m for stationary cage and 1.0 m for floating cage. Waves are also created from the wake of passing vessels, hence culture site should be at some distance from navigation routes. In case of stationary cages at the mouth of river, creek and canal such as in southern Thailand, the Port Authority has to limit the speed of the vessel instead of removing the cage out of navigation traffic.

1b. **Depth**

The usual depth of a cage is 2–3 m, hence it is necessary to allow sufficient depth under the cage in order to maximize water exchange, avoid oxygen depletion, accumulation of uneaten food, faeces and debris, disease infection, and build up of some noxious gases such as H_2S generated by decomposition of the deposited wastes. In turbid water, silt will tend to accumulate in the cage preventing good water exchange. The clearance for a floating cage should be at least 2–3 m at the lowest low water of spring tide. But a stationary cage is allowed 1–2 m minimal clearance to minimize the costs of fixed poles. Also, because fixed cages are usually placed in the mouth of rivers, creeks and canals where the water flow is stronger than in the open sea. In summary, the selected sites for floating and stationary cages should be at least 5 m and 4 m, respectively at the lowest low water of spring tide.

On the other hand, the maximum depth of the floating cage should preferably be less than 20 m, otherwise investment and maintenance costs will be higher as longer anchoring ropes and heavier anchor blocks are required. The maximum depth of a stationary cage should also not exceed 8 m since it is difficult to find sufficiently strong supporting posts longer than 8 m.

1.c **Bottom condition**

A firm substrate, with a combination of fine gravel, sand and clay presents an ideal site for cage culture. The design of the cage is directly influenced by the type of substrate present at any given site. For example, floating netcages over rocky substrates require more expensive anchoring blocks, but have better water exchange rate. On the other hand, stationary cages easily set up in a muddy substrate with the use of cheaper poles are not suitable for high stocking density due to their low water exchange rate. In general, sloping areas from the shore leading to flat bottoms are suitable for cage culture because the waste build-up at the bottom is easily eliminated.

2. Physical criteria

2a. **Current movement**

Tidal currents bring fresh oxygenated water to and remove waste from the cage. A large tidal range generally indicates better conditions for high stocking density of fish. On the other hand, strong currents will generate excessive strain on the raft anchoring system or fixed poles, distortion of the nets and cage structures, slow growth of fish caused by too much expense of energy in swimming against the current, and food losses. If the fish is unable to swim against the current, the stress will occur, from their being impacted on one side of the net. It would be therefore necessary to reduce the stocking density of fish. The direction of current is also a major criteria for positioning a raft. To minimize the strain on the anchoring system resulting from strong currents, the rectangular raft should be in a direction parallel to the current. This is opposite to the weak current areas where a cage needs to be positioned against the current for a better water flow.

The most appropriate time for measuring the maximal current velocity is at 1–2 hrs after the peak of high water during spring tide. Current velocity is generally stronger at falling tide than at rising tide except that there are other factors involve such as storms, etc. The maximal current should be ideally less than 50 cm/sec and should not exceeding 100 cm/sec. If the maximum current is less than 10 cm/sec, it will cause poor water exchange, especially during neap tide, for intensive culture of fish.

2b. **Turbidity**

Turbid water which is normally caused by freshwater run-off during rainy season is not suitable for cage culture. Organic and inorganic solids are suspended in the water column as a result of soil erosion. Run-off also brings some heavy metals leached from the catchment area as well as other industrial effluents. It also reduces salinity at the site. Suspended solids in turbid waters with strong current from freshwater run-off will also stir up already sedimented material from the usually soft muddy bottom of estuarine areas causing more solids to deposit on the nets. These sediments act as a substrate for the growth of fouling organisms, which prevent proper water circulation. In addition, suspended sediments tend to clog fish gills which may lead to mortality from asphyxiation or cause gill epithelial tissues to proliferate and thicken. The presence of suspended solids also relates to some disease such as "fin-rot" caused by Mycobacteria (Herbert and Merkens, 1961; Herbert and Richards, 1963). The visibility of fish to the feeds will also be reduced which may lead to feed loss and impair fish growth.

Suspended solids in a suitable site for netcage culture should not exceed 10 mg/l. But its effects also depends on the exposure time and current speed. In estuarine site during flood periods, the turbidity can be higher than 100 mg/l but the exposure time is only at low tide and the current is also rapid enough to prevent the sedimentation of solid matters.

3. <u>Biological criteria</u>

3a. **Fouling organisms**

There are about 200 species of marine fouling organisms in the world (Lovegrove 1979). More than 34 species of algae (cyanophytes, rhodophytes, chlorophytes) coelenterates, polyzoans, annelids, arthropods, molluscs and simple chordates have been observed clinging to netcages after immersion for only two months (Cheah and Chua 1979). Colonization of fouling organism is primarily caused by silt particles deposited at the net which serve as substrate for fouling organisms. Silt particles can be more than 50% of total fouling weight. Clogging of the net by fouling organism restricts the water flow thus lowering the dissolved oxygen and waste removal in the netcage. It also increases surface area of the net which causes deformation of the cage in strong current and also increases the stress on both cage structure and anchoring system.

Rate of fouling varies with the environmental conditions and materials used. Fouling is generally more rapid in areas with low current velocities, high temperature, high turbidity (enriched water) and high salinity. It was found that the rate of fouling of galvanized mesh and netting panels was much less than that of synthetic fibre netting panels. In an area of high fouling growth, netcages would have to be cleaned and washed more often to facilitate water exchange. The additional weight of fouling will make net changing difficult and time consuming.

To minimize maintenance cost, netcage farms should be sited in areas unfavorable for the growth of fouling organisms.

3b. **Phytoplankton**

Excessive blooms of phytoplankton can happen whenever the suitable condition prevails such as high light intensity, high nutrient level (organic load), warm water temperature, stagnant hydrological conditions. These conditions should be avoided when selecting cage farming. Algal blooms can affect fish, not only by damaging fish gills by clogging, but also by competing for dissolved oxygen at night. Some species of phytoplankton can produce toxins which can kill fish or accumulate in fish up to the level that becomes toxic to human. A number of marine algae groups form blooms, including diatoms, Cyanobacteria, prymnesiophytes and dinoflagellates. In estuarine area, blooms of some freshwater species which can produce toxin, will become dominant due to the influx from river.

The most important group of toxin-producing algae is dinoflagellates (the cause of red tides). Red tides commonly occur in warm water, especially during summer months. Fish farm wastes and effluents from fertilizer plants can also generate red tide blooms due to nutrient loading. Before selecting the site for cage culture, it is necessary to inquire with the local people or concerned authorities about the occurrence of red tides in the past in that area.

3c. **Diseases and predators**

Most pathogenic or potentially pathogenic organisms spread to the cage farm with the polluted water from sewage (domestic, industrial and agricultural) and the nearby cages. For example, ‘red-boil disease’ in estuarine grouper (*Ephinephelus salmoides*) is produced by the bacterium, *Vibrio parahaemolyticus*, and is contracted following skin damage caused by handling (Wong et al., 1979). This organism is commonly found in excessive amount in sewage-polluted water. Ectoparasitic marine isopod, *Nerocilia,* which attacks the rabbit fish (*Siganus* spp.) is also more prevalent in organically enriched marine water (Chua, 1979). E. coli number in water is used as an indicator to determine the degree of pollution as well as the possibilities of disease infection in fish. A good site for cage culture should have an *E. coli* count of not more than 3,000 cell/ml.

The setting up of a large number of cage culture units in the same area, will cause the outbreak of diseases, especially when they spread from long-established cages. Wild fish as well as some intermediate hosts of parasites can also carry some disease and transmit them to the caged fish. Fish predators include sea birds, puffer fish and some small fish which compete in feeding. Some of these predators can also carry diseases. Hence the above problems should be considered for site selection.

4. <u>Accessibility</u>

The culture site should be near a shore preferably with a jetty for boat connection with farms and near a good road for land transportation. Good accessibility facilitates distribution of farm products, (especially live fish), transport of feed, fingerlings, fuel, farm equipment, supplies and other necessities. The owner can visit the farm site more often to ensure proper management if it is easily accessible. There are many evidences that the production in the farm is poor because the owner leaves only one or two labourers staying at the farm in an isolated area. Fresh water is needed for daily living and washing of farm equipment. The suitable site should have above facilities close by.

In most of the developed or large scale-intensive cage farms, there are housing facilities on the floating rafts (such as in Singapore) or on the shore close to the cages which always include an office, feed store, laboratory, hatchery and dormitory. Housing facilities on the rafts or close to the cages would increase the possibility of the sewage and toilet waste being released to the water which is not hygienic. It would also minimize production costs if other facilities like power source, telephone, market and food supplies are close to cage culture sites.

5. <u>Social problem</u>

Security is an important consideration anywhere, and probably more so in the region. Since cage culture units are sited in public waters, few countries in the region have laws and regulations to protect the products of cage farmers. Hence the farmers have to keep a careful watch on them to prevent poaching, or select a site far away from the village. These will also increase the production costs in terms of guarding, transportation, and management costs. In some areas such as in Thailand, the owners will site the cages in front of their houses but this also bring in other problems like sewage discharge from village, low water exchanges due to blocking of water currents by boats, jetties and fish traps. In many countries like Philippines, Thailand, etc., a prime consideration in site selection is security.

There are many large scale farms which may have conflicts with villagers. For example, they may have to hire the labour from outside the village. This always brings conflict with villagers and finally lead to poaching problem. If the site cannot be avoided from such villages, it might be a good idea to have a leader of the village be one of the partners. The conflicts may occur from the other common users of the sea, such as waves or oil leak from boats, pollution from industries, waste from other farms and oil spilt from tankers or shipyards.

6. Legal Aspects

Most of the countries in the region have a standard law on lease of public water for any construction and for fisheries. The land below the low water tide level is owned by the government. In some countries in the region cage farmers have to obtain licence to culture fish in cages with restrictions concerning site, species, size structure and type of developments. The government should identify the site for cage culture so as to avoid competing with the other common users of the sea and interference with local navigation regulations. This site identification should also follow the above technical criteria. Size of the farm is also important to avoid or minimize disease outbreak. Lay out plan and strength of cage structures should be approved by the government. Fish species and culture methods should also be regulated with the public interest in mind such as having the proper outputs and avoiding environmental degradation, pollution and other adverse effects

Existing regulations should be carefully studied to avoid any obstacle. Lease and licence (if any) should be applied for early enough due to the lengthy processing involved in obtaining permission in some countries caused by many government departments involved. The operations of cage culture should strictly follow the conditions required by the government such as lighting at night, pollution avoidance, etc.

Fish Species Selection for aquaculture

Species selection needs to be a well thought-out decision. Fishes, with possibly 25,000+ species are in diversity. A study in 2003, conducted for World Aquaculture Society, Salvador 2003, revealed that potentially 60 species had aquaculture potential. For any commercial aquaculture there has to be a market for the fish. The fish species should be suited to the local climate extremes and/or should be native to the area. It is essential that established and reliable rearing techniques are known and readily accessible for the intended species or can be obtained by professional consulting and advice. The natural life cycle of the intended fish should be considered so that its basic biological needs can be met *e.g.* some species can tolerate varying degrees of salinity; some tolerate crowding; some wean onto artificial diets more easily than others do. Here are some criteria which can be followed for selecting species for aquaculture

Criteria for selection of species for culture

- Objectives of culture
- Geographic and climatic considerations
- Culture qualities of the organisms
- Consumer acceptance and marketability
- Cost of production
- Domestic consumption versus export.
- Availability of complete production technology

Desirable biological characteristics of aquaculture organisms

a) Fast growth and higher yields in different types of culture;
b) Efficient conversion of food,
c) Tolerance limits of salinity, temperature and oxygen tension;
d) Ready acceptance of compounded feeds,
e) Good table quality,
f) Disease resistance breeding habits; feeding habits and geographic distribution,
g) Ease of breeding in captivity, early maturation, high fecundity,

Out of 120 families of fishes only two families, sciaenidae and serranidae have good aquaculture potential with 300+ and 500+ species, respectively. There are also special cases such as the cobia, a single member of a fish family, with excellent candidate criteria for production in warm temperate to tropical marine waters. There are some already well established markets available for certain members of the family Carangidae (several species of Yellowtail Jacks, Pompanos and some possible baitfish species) and Sparidae (Breams in EU an US, Snapper in Australia). Grouper culture is well established in Southeast Asia, but has still to catch on in other parts of the world. True snappers, family Lutjanidae, are species rich as well, and routine culture has been established in some species of the genus *Lutjanus* sp., with many more species to be explored. Several species from different genera are in culture for some families of fatfishes (turbot, Atlantic halibut, Japanese flounder), and also the Snooks and two important aquaculture species of the family Latidae in Australlasia. and East-Africa, namely the Asian Seabass or Barramundi and the Nile Perch or Lake Victoria Perch, respectively.

Seabass (*Lates calcarifer*), Grouper (*Epinephelus* sp.), Rabbit fish(*Siganus* sp.) Snapper (*Lutjanus* sp.) are the major fin species found suitable for open sea finfish cage culture in India. Apart from finfishes lobsters are also identified as potential group for rearing in opensea cages.

Cage construction and cage mooring

First generation cages

Cages of 2.5 m x 2.5 m x 2m was fabricated using netlon material as outer net and nylon net as inner net. PVC pipes were used as floats for suspending the cage in the water. The netlon structure serve as a solid frame and protect inner net from predators and big fishes. This will help to maintain the shape of the cage. The net frame was originally fabricated with bamboo poles and PVC pipes were used as floats for suspending the cage in the water. Additional flotation was given by empty oil cans. Sufficient length for the cages leg (2 to 3 feet) are given so that the cage will rest on this legs in the bottom in the case of lowest low tide. This will avoid the damages to nets by avoiding hitting and abrasion with hard and sharp substances in the bottom. For successful installation of long lasting cages, the site selection should be done judiciously. The mooring of the cages is the most important step in successful cage culture.. Mooring should give sufficient anchorage to cage structure throughout the fish rearing period. Filled sand bags packed together in a net material can act as a low coast mooring material. As per the speed of the current the weight of the sand bags are adjusted. The water column at lowest low tide should be more than the height of the cage (more than 3m). The rope attached to the Mooring structure should have enough length to allow the cage float in the water during high tide. To avoid land ward movement of the cage, an additional mooring towards opposite side of the shore should be provided.

Modification of cage fabrication(Second generation cages)

Now with experience the fishermen are finding it feasible to fabricate the cage with frames of GI pipes of 1 inch and the dimension of 4mX 2.5mX 2.5m (with 20 t. of water) with used plastic cans as floats. This cage can last at least for three years only inner net has to be replaced every year.

Live Transportation of Fish Juveniles and Fingerlings

Juveniles and fingerlings procured from the wild and the hatchery has to be transported to the culture site with great care. There are two methods of transportation *viz*., closed system and the open system of transportation. The closed system is a sealed container in which all the requirements for survival are self-contained. The simplest of these is a sealed plastic bag partly filled with water and oxygen. The open system consists of water-filled containers in which the requirements for survival are supplied continuously from outside sources. The simplest of these is a small tank with an aerator stone.

Factors influencing transport

The survival of the fishes during transportation is influenced by number of factor or a combination of factors. The first and foremost of all the factor is the quality of the fish. The fish that is to be transported should be healthy and in good condition. Weakened fishes should be avoided during transportation. Even if the density of the fish is reduced, it is observed that the mortality is high when the weakened fishes are transported.

Reducing the temperature and acclimatizing the fishes to the reduced temperature is another method adopted to reduce the mortality during transportation. Ice could be used for lowering temperature. Direct contact of fish with ice should be prevented and the temperature should not drop drastically. Usually ice packs in plastic bags are kept in between the bags containing fishes to lower the temperature during transportation. A ratio of 25 kg of ice will cool 1,000 litres of water by 2°C. The total temperature difference should not be greater than 12–15°C, with respect to the species and age of the fish (FRG recommendation, 1979).

The fishes except the larval stages has to be starved for a day before the transportation. A fish with gorged stomach would require more oxygen, is susceptible to stress and the excretion would take up much of the oxygen from the water. When fish larvae are transported, their time of survival without food should be taken into consideration. Orloy (1971) has observed that transportation of herbivorous fishes should not last longer than 20 hours.

One single factor which influences the survival during the transportation is the level of dissolved oxygen. Continuous supply of oxygen does not indicate that the fishes are in good condition. The consumption of oxygen by the fish depends on water temperature pH, their tolerance to stress, and concentrations of carbon dioxide and metabolic products such as ammonia. Oxygen consumption in relation to metabolism by the fish is directly related to the body weight and temperature. Heavier fishes transported in warmer water requires more oxygen. In view of fish transport, for each 0.5°C rise in temperature, the fish load should be reduced by about 5.6%; conversely, for each 0.5°C decrease in temperature, the load can be increased by about 5.6% (Piper *et al.*, 1982). The fish at rest would consume minimum oxygen, but during transportation the fishes are disturbed and excited which would result in consumption of more oxygen. Hence during transportation anesthetic agents like Aqueous or Chilaldine or MS 222 or Phenoxy ethanol may be used at lower concentration to keep the fishes on rest. For warm water fish an oxygen level above 5 mg/l during transportation would prevent oxygen from becoming a major stress factor. In closed system of transport, oxygen content in water is not a limiting factor because there is enough pressurized oxygen in a closed bag. In exceptional cases when the density of the fish is high or duration of transport is long which the fish could not stand, oxygen deficit may occur. The dead fishes also compete with the live fishes for oxygen as they increase bacterial multiplication which requires much oxygen, which may further produce toxic metabolites. The slime produced by fish is also another substrate for bacterial growth resulting in decrease of oxygen content. Increase in temperature also intensifies this process.

Water quality is a function of density of the fish and the duration of the transportation. The pH level of the water is an important factor as it is directly related to the CO_2 and toxic ammonia produced. Water pH levels about 7–8 are considered as optimum. With increase in transportation time, the CO_2 level increases which shifts the pH level to acidity which could stress the fishes. Organic buffers which is highly soluble, stable like tris (hydroxyl) methylaminomethane is found to be effective to stabilize the water pH in fresh and salt water. Levels of 1.3–2.6 g/litre are recommended for routine transport of fish (Piper *et al.*, 1982).

Increased carbon dioxide concentrations are detrimental to fish and can be a limiting factor in fish transport. Unless aeration is adequate, the CO_2 level may exceed the oxygen fish consumes. However increased concentration of CO_2 can be tolerated by the fish if the rate of buildup is slow. Tight cover or lids on transportation unit can result in the build up of CO_2 which would stress the fish. Hence adequate ventilation is a necessity for transport units. Aeration of the water will reduce concentrations of dissolved CO_2, if there is adequate ventilation

Chlorine concentration in water is also another factor which is detrimental, although it is also removed from water by aeration. The concentration of 0.5 mg/litre is considered as dangerous, though even lower chlorine levels, e.g., 0.2 mg/litre disturb the fish respiration mechanism considerably (Shevchenko, 1978).

Ammonia (NH_3), which builds up during transportation could be reduced by lowering the water temperature and decreasing the fish activity and by not feeding the fish for day before the transportation.

Consideration should also be given to the factor of space and the density of the fish packed. As to fry, the ratio of the volume of the fish transported and the transport water should not exceed 1:3. Heavier individuals, e.g., parent fish can be transported in a fish: water weight ratio of 1:2 to 1:3, but with smaller organisms this ratio decreases to 1:100 to 1:200 (Pecha, Berka and Kouril, 1983). When fish are transported for acclimation, or when endangered species are transported, the stock density should be lower: in such cases the economic aspects are not of primary importance and 100% survival is required. Nevertheless, the economic side of transport can never be neglected; hence, when the transport costs are high and the value of fish of transported comparatively low, the stock density in the transport units can be increased though losses of fish may be expected to be higher.

Types of transportation of fishes.

The closed systems are represented by polyethylene bags and other sealed transport units. They are used mainly for the transport of the early fry, but also brood fish. The transport of fry in polyethylene bags with oxygen is particularly widespread in the world, being used as a very effective method. It substantially reduces the total volume and weight of transport water, enables public transport to be used for fish-transport purposes, makes it possible to prolong the transport time, and is economically advantageous.

The polythene bags used are of 60- 80 x 40-45 cm dimensions. The upper end is usually open and the bottom has a seam or sometimes the bags are in the form of sleeves and the sleeves are cut into required length and one end is tightened using rubber band or strings. For safety reasons usually the bags are duplicated (one bag inserted into another). When the fingerlings of the fishes are transported, usually papers are inserted in between the bags. This would avoid reflection of the water which could agitate the fishes. During transportation the plastic bags are kept in cases or cardboard boxes protecting it from mechanical damage during transportation. The case keeps the bags in the desired position, enables easier handling and/or providing thermal insulation of the bags.

To cool the temperature, bags of ice could be placed between and under the bags. The desirable amount of ice to be kept is 10-20% of the transport water. This method of packing enables transport by public transport. The water to be used for fry transport in a bag should comply with all requirements. It is best to use water of the same quality as that in which the fish were kept before transport, but there should be no organic pollutants and no dispersed mud of mineral origin. If 50 litres volume bag is used about 20 litres of water is poured and the rest is filled with oxygen , the upper end is twisted to prevent oxygen leak and tied .

Open Systems of fish transport

The open systems of transport have many technical modification ranging from small transport fish-cans, containers for fish transport within the territory of a fish farm, up to special fish transport trucks and tank wagons. In case of short time (10-30 min) open transport, plastic containers or metal tanks could be used with constant oxygen supply. Transport longer than half an hour should be in completely filled and closed tanks to prevent splashing and injuries to young fish bumping into each other in the well of the tank. The weight of fish that can be safely transported in a tank depends on the efficiency of the aeration system, duration of the transport, water temperature, fish size and fish species.


Tanks made of fiberglass connected to oxygen cylinder is commonly used for open transport system worldwide. It is light weight and easy to clean and the commonest and simplest design is the round, flat bottom tank with open top.

After transport, or during control on a longer journey, the condition of the fry should be checked before release. The fry are examined for position, i.e., swimming, lying on the bottom, staying in physiological position or turning to one side, for motility, readiness of reaction to light, touch, and/or number (proportion) of dead individuals. The fish are released only when the temperature of the water in the bag reaches the same level as that of the receiving water.

General points to be considered for transportation.

Emphasis should be laid on the requirements to transport the fry after the absorption of food: when the fry are freshly fed the amount to be transported should be reduced by at least 50%. The water in which sac fry are transported should be kept as still as possible (the fry could be damaged in the bags). On the other hand, advanced fry and fingerlings are not affected by increased movement of the transport water. Anesthetics could be used in mild doses to reduce the activity of the fish. The quality of water should be ensured before the transportation. In short the fish transport is a vast area comprising the problems of purely technical design on the one hand, and the chemistry of water, biological reactions of fish and the like, on the other.

Demonstration experiments by Central marine Fisheries Research Institute in Karnataka

Central Marine Fisheries Research Institute is one of the pioneer Research Centres in transferring mariculture technologies in the State of Karnataka. The participatory approach gave exposure to the local fishers on the finfish rearing aspects besides creating awareness on this lucrative farming technique. Encouraged by this success many fishermen group evinced interest in rearing finfish in suitable farming areas near their backyard.

The Karnataka State has 8,000 hectares of unpolluted brackish waters and estuarine areas, which are highly suitable for capture based aquaculture. The local fishermen use dragnets, castnets and gillnets in estuarine and coastal waters, which harvest juveniles of commercially important cultivable finfishes. These juveniles fishes though live at harvest are invariably discarded due to low market demand. The juvenile of commercially important species such as redsnapper, pearlspot, mullets, seabass etc are available in the inshore waters of Karnataka for Capture Based Aquaculture.

The concept of CBA was introduced in this village by collection of *Lutjanus argentimaculatus, Etroplus suratensis* and *Lates calcarifer* fingerlings and stocking in floating cages of 2.5 m x 2.5 m x 2 m, made of Netlon (mesh of 30 mm) lined with nylon net. It was envisaged to use local seeds for culture, in addition to assure good production seeds for *Lates calcarifer* was supplemented by CMFRI. The netlon cages was designed and fabricated by CMFRI with the participation of local fishermen. Five cages were provided to the fishermen for stocking the fingerlings.

The technology envisages the utilization of juveniles which were other wise discarded due to small size, but if thesre is a high demand for the seeds for cage culture, this exploitation may lead to stock reduction in estuaries and also lead to social conflict between capture fisheries and culture fisheries. The development of seed production in hatcheries on an economically viable commercial scale, and the refinement of grow-out technology to ensure that the fattening phase is environmentally acceptable are the critical issues for the future. Failure to address these matters successfully would have severe consequences for both aquaculture and capture fisheries. So attempts are being made to complement the CBA cages with hatchery reared finfishes which may be a viable option in the future.

Cage in estuaries

Husbandry: The red snapper and pearlspot fingerlings were continuously stocked by fishermen and the fishermen community was engaged in the cage setting, cage cleaning, feed sourcing, feed preparation and feeding. Feeding was done with locally available trash fish and also fish waste from fish processing areas/plants.

Production and Harvest: Altogether five cages were installed and three of the cages were partially harvested as and when the fishes were grown to marketable size, to meet day to day needs of the fishermen. Two cages were spared for final harvest to demonstrate total production possible from these cages.
Theses cages were harvested during July, 2011, when the mechanized fishing is banned. The *Lutjanus* sps attained an average weight of 755 ± 415 g ranging from 105 to 1,914 g. The pearlspot ranged from 37-222 g (96 ± 35g). About 255 numbers of seabass of average weight 1819 ± 540 g was harvested. The total production from the cages including seabass, red snapper and pearlspot was around ~400 kg realizing a farm gate price of ~ Rs 75,000 per cage.

The fishermen view this as an alternative source of fish when adverse climatic conditions prevent them from venturing into the sea. This concept could be popularized along the coast of Karnataka and sustainable use of the finfish resources to augment the fish production could be done. Demonstration of this methodology encouraged the fishermen to install cages of similar type in the estuary and at present many cages stocked with fingerlings of *L. argentimaculatus*, *E. suratensis* and *L. calcarifer* are found in the village. Thus this concept of CBA was adopted by the fishermen and the diffusion of the technology in this village has been phenomenal. This concept could be popularized along the coastal Karnataka and sustainable use of the finfish resources to augment the fish production could be done. The popularization and adoption of the concept of CBA by the fishermen would generate alternate livelihood, income and contribute to fish production of the region.

PRODUCTION ECONOMICS

Redsnapper: ***Lutjanus argentimaculatus***

4X2.5X2.5 m cages

- Stocking density : 1000/cage
- Seed cost: : Rs.20,000 per1000
- Rearing period : 10 months
- Weight attained in 10 months : 800 to 1.2 Kg (Average 900gm)
- Survival : 95%
- Total Harvest : 850 Kg
- Fish price/kg : Rs.300
- Income from one cage : 2,55,000.
- Cage construction coast :20,000 (last for three seasons)
- Feed cost: @Rs.5 (1500kg) :Rs. 75,000
  (Fish cutting waste from cutting plants and trashfishes including transportation)

  - Total expenditure (Rs.) : 1,15,000
  - Total income(Rs.) : 2,55,000
  - PROFIT (Rs.) : 1,40,000

  (Considering no labor charges, since it is a family activity)

Sea bass: *Lates calcarifer*
4X2.5X2.5 m cages

- Stocking density : 1000/cage
- Seed cost: : Rs.40,000 per1000
- Rearing period : 10 months
- Weight attained in 10 months : 700 to 1.0 Kg (Average 800gm)
- Survival : 80%
- Total Harvest : 640 Kg
- Fish price/kg : Rs.350
- Income from one cage : 2,24,000.
- Cage construction cost : 20,000 (last for three seasons)
- Feed cost: @Rs.5 (1500kg) :Rs. 75,000
  (Fish cutting waste from cutting plants and trashfishes including transportation)

  - Total expenditure(Rs.) :1,70,000
  - Total income(Rs.) :2,24,000
  - PROFIT(Rs.) :89,000
    (considering no labor charges, since it is a family activity)

Since the seed availability of the Seabass is assured the fishermen prefer Seabass culture over Redsnapper

6. BIVALVE FARMING

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1. MUSSEL FARMING

Introduction

The mussels are bivalve molluscs typically found inhabiting the littoral to shallow sub-littoral zones of the coastal areas by secreting long fine silky threads called byssus threads. They can tolerate short periods of exposure to extreme temperatures, salinities, desiccation and relatively high levels of turbidity. Mussel farming that began in the thirteenth century is practiced in many countries world over. In India, commercially mussel farming is relatively recent and is practiced in the estuarine stretches of the Northern Kerala (Malabar area) and in few locations in southern Karnataka.

Advantages of mussel farming

- Mussel farming is a relatively less intensive form of aquaculture that depends upon natural stocks for seeding and relies on primary productivity for feeding.
- Mussel mariculture is carried out in coastal and estuarine waters by suspended farming method in order to utilize the water column. Suspension of the culture substrate enables complete utilization of the water column and facilitates increased production per unit area.
- Mussels are filter feeders, feeding exclusively on plankton and suspended organic particles that are available in the surrounding environment, resulting in zero effluent discharge and minimal water quality issues.
- Mussels are efficient in converting plankton and organic matter to high quality animal protein.
- Short duration of 5-6 months is sufficient for farming mussels in the tropical waters during the high-saline phase.

Candidate Species

The two species of mussels with good potential for culture in India are the green mussel, *Perna viridis* and the brown mussel *Perna indica.*

Site-selection

The success of mussel mariculture depends largely on the selection of an ideal culture site. Selection of an appropriate culture site shall be based on careful consideration of a number of factors that are critical to the species selected. The range of tolerance of the selected species to various environmental parameters will be the primary consideration in the site selection. Further, the site will have to be suitable to the culture method or system intended to be practiced. The important parameters to be considered while selecting the site for mussel farming are detailed below:

- Water current: Moderate currents (0.17-0.25m/s at flood tide and 0.25-0.35m/s at ebb tide) are needed to provide adequate food supply as well as to carry away the excessive build-up of pseudofaeces and silt in the culture area.
- Water Depth: The depth of water column of a location determines the type of culture method to be adopted. It can range from 1-15 m at average mean low tide.
- Salinity: Mussels grow well above 20psu, but the ideal salinity for rearing is 27-35psu.
- Turbidity: The presence of suspended particles above a certain level disrupts the filtering activity of the bivalve, as the mussels remain closed to avoid tissue damage and also due to gill clogging.
- Primary productivity and food organisms: Seawater with rich plankton is considered ideal for mussel culture.
- Source of Seed: Proximity of farming site to adequate spat or seed source is an important criteria for site selection.
- Pollution: Sedentary bivalve fauna are exposed to very high probability of contamination. Regulations have been established in many parts of the world that provide a system of classification of bivalve shellfish growing/ harvesting areas, broadly based on water test results (National Shellfish Sanitation Program, (NSSP) of USA and Canada; Australian Shellfish Quality Assurance Program, ASQAP of Australia) or tissue test results (Council Directive 91/492/EEC of Europe). These classification systems assign the shellfish harvesting areas as approved, restricted and prohibited based on the faecal coliforms and/or Escherichia coli levels.
- Harmful algal blooms: Some coastal waters are known for the appearance of sudden blooms of certain phytoplankton capable of producing highly potent toxins that are harmful to marine fauna and any other animal that feed on them.

Type of farming

- Open Sea farming is practiced in areas with a depth of 5-20m. The selected area of culture should be free from strong wave action, less turbulent and with high productivity. Long line and raft culture techniques are ideal for open sea farming. Disadvantages of this type of farming are poaching, unpredicted climatic changes and predation.
- Estuarine farming: Compared to the open sea, the estuarine ecosystems are less turbulent and shallow (<4m). Stake and rack culture (horizontal and vertical) are ideal for estuarine conditions. Fluctuation in salinity during monsoon season and pollution

through domestic and industrial waste are the main constraints in estuarine mussel farming. On-bottom culture by relaying of mussel seed in pen enclosures is also practiced.

Farming technique

- On-bottom method: In areas where water depth is less than 1.5 m, mussels can be farmed by sowing directly on the bottom substratum/ or seabed.
- Bouchot culture: This method involves farming mussels in intertidal mud flats on poles combining spat collection with ongrowing.
- Suspended farming methods: For suspended farming method, the water depth can be a limiting factor as a minimum water column is essential throughout the culture period
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1. Rack method: Suitable for estuaries and shallow seas. Bamboo or Casuarina poles are driven into the sea/ estuarine bed at a spacing of 1-2 m and are connected horizontally. Seeded ropes are suspended from the horizontal frames or in shallow areas, they are placed horizontally between the vertical poles. This method is practiced in India and Philippines in shallow waters where the depth is <1m. Due to the effective utilization of the productive upper water column this type of culture gives better yield.

2. Raft method: This farming method is suitable in deeper open-sea conditions which is not turbulent. It consists of a square or rectangular bamboo or casuarina pole lattice structure from which ropes are hung. The raft is buoyed up by styrofoam / ferroconcrete buoys or metallic/ HDPE barrels of 200 liter capacity (metal oil barrel painted with anticorrosive paint). Ideal size of the raft is 5 x 5 m. The rafts are to be positioned at suitable location in the sea using anchors (grapnel, granite, concrete).

3. Long-line method: Considered ideal in unprotected open sea conditions and are particularly adopted in areas having high tidal amplitude. Synthetic rope of 16-20mm is used for the main-line, supported with floats at every 5m. Seeded ropes are suspended from the main line 1.5-2m apart. Long-

lines with floats are anchored in position using concrete blocks and nylon ropes or metal chain at both the ends.

Seed source and seeding

The key issue in mussel farming is the inconsistent or irregular spat settlement in natural beds affecting the seed supply, hatchery sources are not generally depended up on for the mussel spat. Mussel farming mainly depends on the natural spat. The spat-fall in mussel beds commences from September to December along the west coast progressing from the south to the north. Mussel spats are collected by physically scrapping them from the intertidal or subtidal natural beds. Submerged beds are ideal for sourcing mussel seeds. About 500 to 750 g of 15-25 mm seeds are required for seeding 1m of the culture rope. Nylon rope of 12-14mm or 15-20mm coir rope can be used for farming. Seeding is done by placing the culture rope within the pre-stitched tubes of bio-degradable wrapping material and filled with mussel seeds. Generally cotton mosquito nets are used for wrapping the seeds, which degenerates in 2-3 days. By this time the seeds will secrete byssus thread and will get attached to the rope.

Growth

The seed, which get attached to ropes, show faster growth in the suspended water column. If the seed is not uniformly attached, crowded portion always show slipping. To avoid slipping, periodical examination of seeded rope and thinning of the same is essential. The culture ropes also should be at least 1 m above the sea floor during extreme low water spring tides in order to prevent predators from reaching the bivalves, to avoid exposure of the molluscs to high water turbidity near the seabed and to avoid losing the bivalves at the end of the rens. The top seeded portion of the culture rope should be prevented from exposure for longer period during low tide. Seeded mussel on the upper portion of the rope shows faster growth due to the abundance of phytoplankton. For better growth the seeded ropes should be spaced at a distance of 25 cm. The mussel grow relatively fast in the suspended farming systems. They attain 80-90 mm in 5-6 months with growth rate of 8-11mm/month.

Post-harvest handling & marketing

Mussels are harvested once they attain the marketable size and condition index is high, i.e., before the spawning and onset of monsoon. Normally harvest season is from April to May. Mussel ropes are removed manually and washed thoroughly using water jet to remove grit and slit. The mussels removed from the ropes are maintained in re-circulating seawater for 24h and are washed again in fresh seawater. This method of depuration is effective in reducing the bacterial load of the mussel meat by 90%. Depurated mussels are then sold mainly in the local market as live shell-on mussel. Meat from depurated mussel can be shucked in fresh condition or after boiling or steaming.

Depuration

Depuration of the harvested mussels is necessary to increase the quality of the mussel meat and to avoid the risk of consuming contaminated mussel meat. Mussels during their process of feeding may accumulate undesirable materials including harmful microorganisms. Before the product reaches the market, it needs to be ensured that the mussels are safe for human consumption. This process of purification is called depuration. The mussels are kept in cleaning tanks under a flow of filtered seawater for the period of 24h. In the depuration tanks about 10-20% of the seawater is continuously replaced. At the end of 12 hours the water in the tank is completely drained and mussels are cleaned by running water to remove the accumulated faeces. The tanks are again filled with filtered seawater and the flow is maintained for another 12 hours. Then the tanks are drained and flushed with a jet of filtered sea water. Further, the mussels are held for about one hour in seawater chlorinated at 3 ppm, and then washed in filtered seawater.

Conclusion

Commercial mussel farming gained rapid strides since 1996 in India. In the recent years it showed spectacular improvements with the farmed mussel production of the country reaching a total of 18,432 t (2009). Though efforts to popularize the technology were undertaken in the States of Kerala, Karnataka, Goa, Maharashtra and Tamil Nadu a quantum leap in the mussel production was observed only in the state of Kerala. The availability of large extent of natural mussels beds along the coast for sourcing the seeds; high price realized for the produce in domestic market; minimal operational expenditure and short term eco-friendly farming techniques are expected to encourage more farmers to come forward to adopt the practice in coastal areas.

2. EDIBLE OYSTER FARMING

Introduction

Oysters are highly esteemed sea food and considered a delicacy in USA, Europe, Japan etc. As early as the first century BC the Romans were the first to develop simple methods of collecting oyster seeds and growing them for food. In India there is a growing demand for oyster meat in some parts of the country. Until recently, oyster farming has been considered as a traditional practice followed only in the temperate countries. The awareness about the vast potentialities for development of oyster farming in tropics is recent. Serious efforts are now being directed in its development under tropical conditions. Vast stretches of backwaters, estuaries and bays spread over several lakh ha are present along Indian coast harbouring natural population of the oyster suggesting suitability of the habitat for oyster culture. Being filter feeders, the oyster converts primary production in the water into nutritious sea food.

Species

The commercially important edible oysters available along the Indian coast are *Crassostrea madrasensis* (Indian backwater oyster), *C. gryphoides* (West coast oyster), *C. rivularis* (Chinese river oyster) and *Saccostrea cucullata* (Rock oyster) of which *C. madrasensis* farmed along the Kerala coast.

Food and Feeding

The edible oyster is a sedentary animal belonging to the Class Bivalvia. Oysters have a soft body, which is protected by two hard shells. Shape of the oyster is extremely variable depending on the environment in which it is grown. The food consists of organic detritus and phytoplankters such as diatoms and nanoplankters. The food particles are entrapped in the mucus of the gills and are passed in the water currents towards the mouth by the rapidly beating gill cilia (fine hairs).

Reproduction

In the genus *Crassostrea* sexes are separate but occasionally hermaphrodites occur. The ovary and testis consist of a series of branching tubules, also called follicles, on either side of the body. During spawning, ripe eggs and sperms are discharged into the exterior where fertilization takes place. During the non-breeding season the gonad is replaced by connective tissue called Leydig tissue which mostly consists of glycogen. In this stage the sex of the oyster cannot be determined. The sex of the oyster may change during the breeding season.

Information on spawning period is essential for seed collection

Species/ Region	**Spawning period**
C. madrasensis	
Kakkinada Bay	January-June
Madras Harbour	Year round spawning
Adayar estuary	October-December and March-April
Tuticorin	July- September and February-April
Mulki estuary	April-June, November
Ashtamudi	November to December
C. gryphoides	
Kelwa backwaters (Bombay)	July and September
Bhatia creek (Ratnagiri)	September and November
S. cucullata	
Ratnagiri	October-January

Condition Index

The condition index of the oysters denotes the quality of the meat and it is useful to determine the best period for harvest. High condition indicates greater proportion of meat in the whole weight of the oyster; those in prime condition are tasty.

Edible Oyster Farming in India

Oyster farming technology developed by Central Marine Fisheries Research Institute is a simple and easily adaptable technique. Kerala is the first state to commercialize this technology and many coastal villagers have benefited from this. These farming activities have increased national production of farmed oyster from nil to 4,700 tonnes in 2013.

Culture Technology Edible oyster culture is a very simple technology, which can be easily practiced. There are a few critical factors (such as seed collection and harvesting period) which are governed by the biology of the species which affect the profit of the farming operations.

- **Seed Collection**: Oyster seeds are collected from estuaries by placing suitable collectors called cultch in the water column at appropriate period. During spawning seasons the spat collectors are suspended from racks. Cultch is the term used for spat/ seed collector. For suspended method of oyster culture cutch made of oyster shells have been found to be ideal. Empty oyster shells are cleaned manually to remove the foulers and then washed to remove silt. A small hole is made on the shell and these are strung on 3mm dia nylon rope with a spacing of 15 to 20 cm between each shell (5 shells per meter rope). Such strings are called ren. The spaced rens can be used as such for grow out system. For seed collection purposes the shells are strung continuously without spacers (10 to 15 shells per meter) and after the attachment of seed they shells can be removed and restrung at the rate of 5 shells per meter which is the ideal density for grow out. If the oysters are to be grown by the tray method then empty shells or lime coated tiles can be placed in the trays for seed collection. Lime coated tiles gave encouraging results and on a single tile, as many as 120 larvae are known to settle.
- One of the main factors that determine the success of the farming operation is the period when the clutches are placed for seed collection. If they are laid in advance of spatfall, they may be covered with silt or settlement of foulers, making them unsuitable for the oyster larvae to settle. The larval period in *C. madrasensis* is 15-20 days. The ideal time for laying the spat collectors in the water is about 7 -10 days after peak spawning (as determined by gonad examination and abundance of early larval stages in the plankton). Strong currents interfere with larval settlement and may result in poor spat collection.

Selection of farm site

For site selection several factors are to be considered

Parameter	Range
• Salinity (ppt)	10 to 38
• Depth (m)	1.5-4.0
• Temperature ^{0}C	23-34
• Dissolved oxygen (mg/l)	3-5 mg/l
• pH	6.5-8.5
• Water current (m/s)	1-5
• Clarity (m)	0.5-1.5

- Availability of seed — within 100 m
- Local market — average to good

Sheltered areas offering protection from strong wave action are preferred. From intertidal region to areas extending upto about 5 m depth can be considered for adopting suitable culture method. Similarly the culture technique is adopted depending upon the type of substratum. On-bottom culture method is substrate-specific while off-bottom method has little to do with the nature of substratum. Large-scale moralities have been reported in salinities below 10 and above 40 ppt when the natural oyster populations of *C. madrasensis* were exposed for prolonged periods. The natural populations occur at a temperature range of 21 to 31^{0}C.

Farming methods

They are broadly grouped as bottom (on bottom) culture and off-bottom culture. Raft, rack, long-line and stake are used in the various off-bottom culture practices. The off-bottom culture methods are advantageous over the bottom culture in the following respects.

- Relatively rapid growth and good meat yield.
- Facilities three-dimensional utilization of the culture area.
- The biological functions of the oyster such as filtration feeding etc. are carried out independent of the tidal flow.
- Silting and predatory problems are negligible.

On bottom culture

The oysters are grown either in the intertidal or subtidal area directly on hard substratum. For intertidal culture a minimum of 16 hours submergence is suggested to ensure adequate food supply. Oyster seed attached to the collectors are planted on the bottom and allowed to grow for the market. The disadvantages of this method are increased exposure to benthic predation, siltation and low production. In U.S.A. the production is estimated at 5 t/ha/year and in France 7.5 t/ha/year. This method is yet to be experimented in India.

Rack and Ren Method

This method is also called ren method. Racks are constructed at 1 to 2.5m, depth. There are several variations in the types of racks. The single beam rack consists of a beam placed and secured to the top of posts driven into the bottom. A series of single beams are placed in a row. The crossbeam rack is constructed by placing cross bar on top of single posts and two long beams are secured on the end of cross beams. In the farm, the shell strings are suspended from racks.

Rack and Tray Method

The nursery-reared single spat (cultch-free) measuring about 25 mm are transferred to trays of size 40 x 40 x 10 cm at a density of 150 to 200 oysters/ tray. The tray is knitted with 2 mm synthetic twine of appropriate mesh and is suspended from rack. Once the oysters reach 50 mm length they are segregated and transferred to rectangular tray of size 90 x 60 x 15 cm these trays are placed on the racks. Each tray holds 150 to 200 oysters. The average growth rate of the oyster is 7 mm/month and at the end of 12 months the oysters attain an average length of 85mm in Tuticorin. The production is estimated at 120 t/ha/year. Compared to the string method, this method gives production but the production cost is high.

Stake culture

A stake is driven into the substratum and on the top end one nail and on the sides two nails are fixed. The nail holds in position a shell with spat attached. The stakes are placed 60 cm apart. In this method, the nursery rearing of spat is carried on the same stake. For about two months the spat on the top end of the stake are covered by a piece of velon screen. Once the oysters attain 25-30 mm the velon screen is removed and in another 10 months they reach the marketable size. The growth rate of the oysters in this method is the same as that of the oysters raised by the string method. The production is estimated at 20 t/ha/year.

Harvest of oysters

The oysters are harvested when the condition is high. At Tuticorin good meat yield is obtained during March-April and August-September and along Kerala harvest is ideal during May in Vembanad and Chettuva estuary and during August-October in Ashtamudi Lake. In Karnatka condition is high during September-November and March. Generally high condition index is obtained when the gonad is ripe prior to spawning. Harvesting is done manually.

Post-harvest Processes

Depuration

Oysters, like other filter-feeding bivalves, accumulate pathogenic organisms in their body. The bacteria of concern are *Vibrio, Salmonella* and *Escherichia* (Coliform type). Members of the Salmonella group cause typhoid fever, while coliforms and vibrios cause gastroenteritis. By depuration the bacterial load is brought down to permissible levels, also faeces, sand particles and silt are removed from the alimentary canal of oysters.

The oysters are placed for 24 h in cleaning tanks under a flow of filtered seawater. About 10-20% of the seawater is continuously replaced. At the end of 12 h the water in the tank is drained and oysters are cleaned by a strong jet of water to remove the accumulated faeces. The tanks are again filled with filtered seawater and the flow is maintained for another 12 hours. Then the tanks are drained and flushed with a jet of filtered sea water. The oysters are held for about one hour in 3 ppm chlorinated seawater, and then washed once again in filtered seawater before marketing.

Transport and storage

Oysters kept under moist and cool conditions survive for several days. However it is desirable that they reach the consumer within three days of harvest. Studies indicate that oysters packed in wet gunny bags are safely transported for 2530 h without mortality and in good condition.

Shucking

The removal of the meat from the oyster is called shucking. A stainless steel knife is used for the purpose. To render shucking easy, oysters are subjected to a wide range of treatments such as exposure to week hydrochloric acid, heat cold, vacuum, microwaves and lasers. Freezing the oysters or immersing them in hot water are the two methods commonly followed. However in India steaming the oysters for 5 to 8 minutes has been found to be ideal to make the oysters open the valves.

7. DEVELOPMENT INITIATIVES IN AQUACULTURE

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Development and growth in fisheries are sustainable only with adequate support for training, extension, skilled human resources and market infrastructure, which lay the foundation for improved productivity and competitiveness. Support services have traditionally focused on capture fisheries but have recently shifted toward aquaculture. Fisheries development depends on the policy and institutional environment comprising laws, administrative directives, institutions, services, infrastructure support and incentives. Here in this chapter, supports available from major different institutes and agencies for taking up aquaculture activities are summarised for the benefit of farmers and entrepreneurs and government officials.

Schemes of NFDB

1. **Coastal Aquaculture**

Name of the Activity/Scheme	**Unit cost**	**Pattern of Assistance**
Construction of ponds for brackish water fin fish culture	Rs. 2.40 lakhs / ha.	25% cost subject to a maximum of Rs. 0.60 lakhs/ha as subsidy.
Additional infrastructure for brackish water finfish culture for modification of existing farms.	Rs. 2.00 lakhs / ha.	25% cost subject to a maximum of Rs. 0.50 lakhs/ha as subsidy.
Input assistance for brackish water fin fish culture.	Rs. 2.00 lakhs / ha. (Subject to the approval of CIBA based on the production levels).	• one time back ended subsidy of 25% to all farmers to a maximum of 0.75 lakhs/ha and • Back ended subsidy of 30% on the capital cost to SCs/STs not exceeding Rs. 3.0 lakhs/ha.
Input assistance for cage culture of brackish water fin fish.	Rs. 7.00 lakhs /ha. (Subject to the approval of CIBA / RGCA based on the production levels).	• Back ended subsidy of 25% on the working capital for first crop with a ceiling of Rs 1.75 lakhs/ha • Back ended subsidy of 30% on the working capital for first crop to SCs/STs with a ceiling of Rs 2.10 lakhs/ha.

2. **Mariculture**

Name of the Activity/Scheme	➢ **Unit cost**	➢ **Pattern of Assistance**
Setting up of open sea cage culture by	Rs. 2.00 crores per unit.	20% equity participation on investment.

companies.		
Setting up of new hatcheries for brackish water fin fish seed production.	Rs. 72 lakhs.	40% subsidy on the unit cost exceeding Rs. 28.80 lakhs / unit.
Diversification by shrimp hatcheries to brackishwater fin fish seed production.	Rs. 70.00 lakhs.	20% subsidy on the unit cost not exceeding Rs. 28.0 lakhs / unit.
Assistance for setting up of open sea cage culture units.	Capital cost of Rs. 6.00 lakhs /cage and working capital of Rs. 4.15 lakhs/cage of 12 meter dia.	40% back ended subsidy on capital and working capital of fishermen groups and entrepreneurs.
Assistance for setting up of open sea cage culture units by fishermen societies and SHGs.	Capital cost of Rs. 1.25 lakhs / cage of 6 meter dia.	40% back ended subsidy on capital cost to fishermen societies and groups.
Training on marine ornamental fish culture.	100% grant.	100% financial assistance to Government institutions as per the guidelines of NFDB.
Assistance to Mussel/Oyster/clam culture / other commercial shellfishes.	Rs. 20,000 / unit of 50 m^2.	50% subsidy on the unit cost.
Seaweed culture.	Rs. 5,000 / unit.	50% subsidy on the unit cost to women SHG's and entrepreneurs.

3. **Construction of new fish/prawn ponds and tanks**

Name of the Activity/Scheme	Unit cost	Pattern of Assistance
Existing species Entrepreneurs / Farmers.	Rs. 3.0 lakhs /ha. for plane areas.	20% subsidy with a ceiling of Rs. 0.60 lakhs/ha. and 25 % subsidy to SC and ST's with a ceiling of Rs. 0.75 lakhs/ha.
	Rs. 4.0 lakhs/ha. in hill states / Districts and NE region.	20% subsidy with a ceiling of Rs. 0.80 lakhs/ha. and 25 % subsidy to SC and ST's with a ceiling of Rs. 1.00 lakhs/ha.

4. **Renovation of existing ponds**

Name of the Activity/Scheme	Unit cost	Pattern of Assistance
Renovation of fish/prawn	Rs. 0.75 lakhs /ha.	20% subsidy for all farmers /

ponds and tanks. Entrepreneurs / Farmers.		entrepreneurs with a ceiling of Rs. 0.15 lakhs/ha. and 25 % subsidy to SC and ST's with a ceiling of Rs. 0.1875 lakhs/ha.
New Species *Pangasius sutchi.*	Rs. 0.75 lakhs/ha.	

5. **Cost of inputs**

Name of the Activity/Scheme	**Unit cost**	**Pattern of Assistance**
For prawn farming entrepreneurs/farmers	Rs. 1.80 lakhs /ha.	20% subsidy with a ceiling of Rs. 0.36 lakhs/ha. for all the farmers.
For fish / prawn farming in paddy fields. Entrepreneurs/farmers	Rs. 0.50 lakhs /ha.	20% subsidy for all Entrepreneurs/ Farmers.
New Species *Pangasius sutchi.*	Rs. 5.0 lakhs /ha.	40% of subsidy of the unit cost for initial period of 2 years and thereafter 20% for all farmers and 255 for SC and ST's.

6. **Establishment of freshwater prawn seed hatchery**

Name of the Activity/Scheme	**Unit cost**	**Pattern of Assistance**
Capacity: 25 million PL / unit /Year State Governments.	Rs. 30.00 lakhs /unit.	90% of the unit cost as one time establishment of hatchery at state Level.
Capacity: 5-8 million PL / unit / year for entrepreneurs / farmers.	Rs. 12.00 lakhs /unit.	20% subsidy with a ceiling of Rs. 2.40 lakhs to entrepreneurs / farmers.

7. **Establishment of fish seed hatchery**

Name of the Activity/Scheme	**Unit cost**	**Pattern of Assistance**
Establishment of fish seed hatcheries with or without nurseries (7-8 million – fry capacity / year.	Rs. 12.00 lakhs /unit for plain areas.	20% back ended bank linked subsidy to entrepreneurs / farmer with a ceiling of Rs. 2.4 lakhs / unit. 90 % of the unit cost as one time grant to the state Fisheries department, Quasi Government organisations and research Institutes.

	Rs. 16.00 lakhs / Unit in hill state / Districts of NE region.	20% back ended bank linked subsidy to entrepreneurs / farmers with a ceiling of Rs. 3.2 lakhs / unit. 90 % of the unit cost as one time grant to the state Fisheries department, Quasi Government organisations and research Institutes.
New species (Cultivable species other than Major carps). Entrepreneurs / farmers.	Unit cost has to be approved by CIFA.	20% back ended subsidy on capital investments.

8. Renovation of fish seed farms

Name of the Activity/Scheme	Unit cost	Pattern of Assistance
Government fish seed rearing farms (aged about 5 years and above).	Rs. 2.00 lakhs /ha rearing area.	90% one time grant for state Fisheries department only.
Renovation / re-modelling / upgradation / reconstruction of hatchery / nurseries in government sectors (aged about 5 years and above) for existing and new species. Capacity: 7-8 million fry / year.	Rs. 4.00 lakhs/hatchery of 7-8 million fry production / year.	90% one time grant for state Fisheries department only.

9. Fish seed rearing units

Name of the Activity/Scheme	Unit cost	Pattern of Assistance
Construction of fish seed rearing units for fry rearing to large fingerlings of 80-100mm size.	Rs. 2.00 lakhs /ha for plain areas area. Rs. 4.00 lakhs / ha. in hill states / Districts of NE region.	20% subsidy for all farmers / entrepreneurs and 25% subsidy to SC and STs. 20% subsidy for all farmers / entrepreneurs and 25% subsidy to SC and STs. 90% one time grant to government / quasi government organizations.

10. Brood stock development

Name of the Activity/Scheme	Unit cost	Pattern of Assistance
Brood stock development programme including ornamental fish. For Government agencies / Government institutions only.	Rs. 25.00 lakhs including a farm transport arrangements for dissemination. Available for the state governments.	Full grants to Government agencies / Government institutions only.

11. Fresh water Ornamental Fisheries

Name of the Activity/Scheme	Unit cost	Pattern of Assistance
Backyard hatchery	Rs. 1.50 lakhs	50% unit cost as subsidy to entrepreneurs, members of women SHGs / Fisherwomen Cooperative Societies.
Medium scale unit	Rs. 4.0 lakhs	50% unit cost as subsidy to beneficiaries.
Integrated ornamental Fishery units	Rs. 15.00 lakhs	90% subsidy to the Government Agencies / Government Institutions and 50% unit cost as subsidy to entrepreneur.
setting up of Aquarium fabrication units SHGs/Enterpreneurs	Rs. 1.00 lakh	50% unit cost as subsidy to members of women SHGs / Fisherwomen Cooperative Societies and 25% unit cost as subsidy to individual persons.

Schemes of MPEDA

S.No.	Name of the scheme	Objective	Quantum of subsidy
1.	Subsidy for new farm development.	For development of new shrimp/scampi farms.	25% of the capital cost, subject to a maximum of Rs.50, 000/- per ha. WSA and restricted to Rs. 2.5 lakh per beneficiary.
2.	Subsidy for small-scale hatcheries.	For setting up of shrimp/scampi hatchery with a minimum production capacity of 10 million seeds per annum.	25% of the capital cost subject to a maximum of Rs. 3.00 lakh for private hatcheries
3.	Subsidy for medium-scale hatcheries	For setting up of shrimp/scampi hatchery with a minimum production capacity of 30 million seeds per annum	50% of the capital cost, subject to a maximum of Rs.20.00 lakh per beneficiary / hatchery limited to 6 hatcheries only
4.	Subsidy for setting up of PCR labs in hatcheries/Pvt. Lab	To establish PCR labs in Hatcheries/Pvt. Lab	50% of capital cost, subject to a maximum of Rs. 5.00 lakh per beneficiary /hatchery 50% of capital cost, subject to a maximum of Rs. 5.00 lakh per beneficiary /hatchery.
5.	Subsidy for effluent treatment system (ETS) in Shrimp Farms	To set up effluent treatment systems attached to shrimp farms	25% of the capital cost, subject to Rs. 1.50 lakh for shrimp farms with a minimum water area of 5.00 ha. and up to Rs.6.00 lakh per beneficiary.

6.	Registration of Aquaculture Societies	For adoption of BMPs and Code of Practices for sustainable shrimp farming for sector wide management of aquaculture farms	50% of the estimated cost subject to a maximum of Rs. 5.00 lakh for setting up of office, ware house/auction hall, common facility etc., Laboratory facilities, Hiring technicians, training farmers / technical personnel and methodology for promoting environmentally sound farming. Being operated in a phased manner.
7.	Providing of financial assistance for farmers for undertaking organic farming of shrimp and scampi	To promote the development of eco-friendly, socially responsible organic farming and to build up a strong economical production center. To implement the organic production of shrimp/scampi seed, feed and to process the organic produce. To develop new export opportunities with special focus on global premium seafood markets.	Extending financial assistance @ Rs. 50,000/- per ha of WSA or 50% of the total cost of certification, feed cost and seed cost (including transportation charges) whichever is less to the farmers for undertaking organic farming in new farms. Ceiling limit for individual farmers in maximum of 6 ha and above or Rs. 3 lakhs whichever is lowest and for padasekharams/ groups/cluster/societies the ceiling is 30 ha and above or Rs. 15 lakhs.
8.	Scheme for providing financial assistance for establishment of Ornamental Fish Breeding Units.	Generate export oriented employment in rural and urban households through mass production ornamental fishes.	50% of the cost of eligible expenditure subject to a maximum of Rs. 75,000 for Grade I unit, Rs. 2 lakh for Grade II unit and Rs 7.5 lakh for Grade III unit.
9.	Scheme for providing financial assistance for establishment of Ornamental Fish Marketing Societies (OFMS).	To provide marketing infrastructure and to reduce intermediaries for ornamental fish breeders.	To provide marketing infrastructure and to reduce intermediaries for ornamental fish breeders.

10.	Developmental assistance for Export of Ornamental/ Aquarium fishes.	To enable Indian Ornamental fishes to penetrate the world market.	10% of f.o.b. value of export effected to the world countries except Singapore and other South East Asian Countries (no ceiling).

Schemes of RASHTRIYA KRISHI VIKASA YOJANE (RKVY)
(Schemes implemented through State Fisheries Department)

1. **MUSSEL CULTURE:**

S.No.	Name of the scheme	Unit cost	Quantum of subsidy
1.	Proposed to establish 50 units for culture of mussels and an allocation of 20.00 lakhs made.	Rs. 20,000 per unit	Each beneficiary will be provided100% subsidy amounting to Rs.40,000. Rs.1.50 lakh provision has been made to train 50 beneficiaries to take up mussel culture.

2. **SEA WEED CULTURE**

S.No.	Name of the scheme	Unit cost	Quantum of subsidy
1.	Proposed to establish 50 units for culture of sea weeds (each unit with 4 rafts). An allocation of Rs.10.00 lakhs is made for this programme.	Rs. 5,000 per unit	Each beneficiary will be provided 100% subsidy amounting to Rs.20,000 Rs. 1.50 lakh provision has been made to provide training to 50 beneficiaries on sea weed culture.

3. **MUD CRAB FARMING**

S.No.	Name of the scheme	Unit cost	Quantum of subsidy
1.	Proposed to provide assistance to take up mud crab farming. The total allocation made is Rs.10.00 lakh.	Rs. 2.50 lakhs / ha.	Each beneficiary will be provided 100% subsidy It is proposed to encourage 4 such ventures (0.4 hectare). Rs.1.0 lakh provision has been made to train 20 beneficiaries under this programme.

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