Annexure B

A MANUAL ON OPEN SEA CAGE CULTURE

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INTRODUCTION

Sea cage culture involves growing fishes in the sea while being enclosed in an encage which allows free flow of water. It is a production system comprising of a floating frame of varying dimensions and shape, net materials and mooring system, to hold and culture a large number of fishes.

- Cage farming can be undertaken in open seas, sheltered bays or lagoons having suitable water quality and with prior permission from concerned government authorities. Thus, the vast unutilized are as in the sea can be brought under marine culture practices.
- Production per unit (m^3) in cage culture is 50times more than shore based systems.
- Recurring expenditure associated with development and maintenance of infrastructure are lower in cage farming compared to shore based farming practices.
- Stock monitoring is simple in cage farming, facilitating regular observation of behavior, feeding and growth that are critical in avoiding problems related to stress and disease outbreak.
- Harvesting is easy and can be planned as per the demand, offering better quality product at higher price.

1. Site Selection

Choosing a site in cage farming is crucial because it impacts the economic viability of farming. Site selected should provide optimum water quality to avoid stress conditions and achieve maximum growth of farmed fish, and ensure proper and secure installation of cages, logistic and other support for supply of inputs, harvesting and marketing of fish. Sea cage site has a direct bearing on operational cost, fish mortality, production and overall profitability of farming operation.

***Exclusion of areas for cage farming*:** Sites which are active fishing zones and close to harbors/fish landing centers and navigation channels, defense areas, marine protected areas, coral reefs, mangroves, areas under coastal management plan, points of industrial effluent discharge, sewage pollution, heavy fresh water discharge by rivers, presence of underwater pipelines, telecom cables, explosives dumping and areas of historic ship wreck are to be avoided during site selection.

4.1 Environmental Parameters

Physical Factors

Depth: Culture site should have a minimum depth of 6 m at the lowest low tide. A clearance of minimum 2 m should be available between the cage net bottom and seabed. This will maximize water exchange, reduce oxygen depletion and encourage flushing-out of metabolic and feed wastes that accumulate under the cage. Depth of farming site determines mooring design and length of mooring chains, affects routine net and mooring line inspection, etc.

Current: Seawater current speed of 0.5 – 1.0 m per sec is considered ideal. Current speed above this will exert very large force on cages and mooring systems and cause mortality of farmed fishes. Current speed influences water exchange, feed dispersion, net shape and volume, solid waste dispersal and effective monitoring.

Shelter: Sheltered are as preferred as it will protect cage sin extreme weather conditions. However, in such areas after long-term farming operations, when food waste and fecal matter will settle, there is a tendency for large quantities of waste to accumulate and pollute the sea bed at the cage site. Thus, for undertaking long-term farming operations, semi-exposed and exposed areas are preferable.

Wind and Waves: Wind affects the wave height and when waves are high it will

affect the accessibility to cages and it becomes difficult to do routine activities like feeding fish, monitoring cages, etc.

Seabed: The nature of seabed determines the mooring system and type of anchors to be used. Thick mud, clay, sand and pebbles will provide good holding for anchors. Seabed having rocks, stones, corals will require a deadweight (gravity) anchorage with Gabions (mesh boxes filled with rocks or concrete blocks).

Water Quality Criteria

Cage site should have good water quality to meet the biological requirement of the farmed species. These criteria include optimum temperature, salinity, and pH and dissolved oxygen. The water should be free from excessive suspended solids, frequent algal bloom sand disease causing organisms.

Table1. Water quality criteria for sea cage farming off in fish

Sr. No.	Water Quality Parameter	Optimum Range
1	Dissolved Oxygen	5–8mg/L
2	Water Temperature	28–33^{0}C
3	pH	7.9–8.3
4	Salinity	25–34ppt
5	Transparency	>40cm

2. Materials and Design of Sea Cage

A sea cage essentially comprises of cage frame and net cages. For sea cage fabrication the materials used should be sturdy enough to withstand rough sea conditions and weather. Cage frames are fabricated either with High Density Poly Ethylene (HDPE) or Galvanized Iron (GI) material to withstand rough conditions in the Indian seas. HDPE pipe PE100 or GI pipe (1.5") B/C Class are preferred for cage frames. When GI pipe is used, all joints are double welded and the GI cage frame is epoxy coated and floated on air-filled HDPE barrels (200 liter, 8-10 nos.). Sea cages are preferably circular-shaped as they can withstand sea conditions better than rectangular or square shapes.

5.1 Specifications for 6 m Diameter HDPEC age

The sea cage frame has two collar rings designed with flotation properties and a middle ring as cat walk in between them (Fig.1). In case of HDPE the pipe-ends are joined by using a fusion welding process for plastics. The two collar rings for flotation are filled with poly urethane foam (PUF) or thermocol. The two collar rings, the middle cat walk ring and the hand rail ring are all held in place by means of various support pipes, brackets and T-joints. The pipe used for hand rail is without PUF in side and the brackets made of galvanized steel are corrosion-free and are fitted to the diameter of the pipes. The maximum height of handrail should be approximately 100 cm (shorter than the shortest person). The service systems (catwalk, handrail, etc.) are required for operation and maintenance activities like feeding, cleaning, monitoring, grading, etc. The minimum width for catwalk is approximately 60 cm. The brackets/ base supports, vertical and diagonal supports hold together the collar rings, catwalk ring and the handrail. They also give additional stability and sturdiness to the frame structure.

The ballast pipe is another support system required to maintain the shape and structure of the net bags (Fig.2). Normally 1.5inch (38mm) diameter HDPE ballast pipe with hole sat regular intervals, for the free flow of water, is used. Metal lines are inserted inside the pipe for increasing weights so that the ballast remains sub merged in water.

5.1.1 Technical Specifications

(i) Base Collar

(a) Inner Ring–6 m diameter circle (HDPE, 140mm diameter pipe)

(b) Outer Ring–7 m diameter circle (HDPE, 140mm diameter pipe)

(c) Middle Ring (Catwalk)–6.5 m diameter circle (HDPE, 90 mm diameter pipe)

(d) Base Supports–8 Nos. (HDPE, 250 mm diameter pipe)

(e) Vertical Supports–8 Nos. of 0.8 m length (HDPE, 90 mm diameter pipe) to connect the base supports to the circular top handrail of same diameter with 8 Nos. of suitable T-joints. The T-joints should be fixed with fusion welding as well as with SS bolts and nuts. 16 hooks (2 inch SS) must be fixed to hand railing to tie the bird net.

(f) Diagonal Supports–8 Nos. (HDPE, 90 mm diameter pipe), to connect the cat walk ring to the circular top handrail with T-joints fixed with fusion welding as well as with SS bolts and nuts.

[(d), (e) and (f) can be replaced with any suitable brackets (metal /HDPE /equivalent)]

All pipes should be made of HDPE, filled with PUF (poly styrene or equivalent), 10 kg pressure, PE-100, PN-10, and ISI Standard is 4984.

(ii) Handrail

6 m diameter circle (HDPE, 90 mm diameter pipe), fitted about 1 m above the Inner Collar Ring and connected by vertical as well as diagonal supports with the Base Collar Rings (Fig.1 and 2).

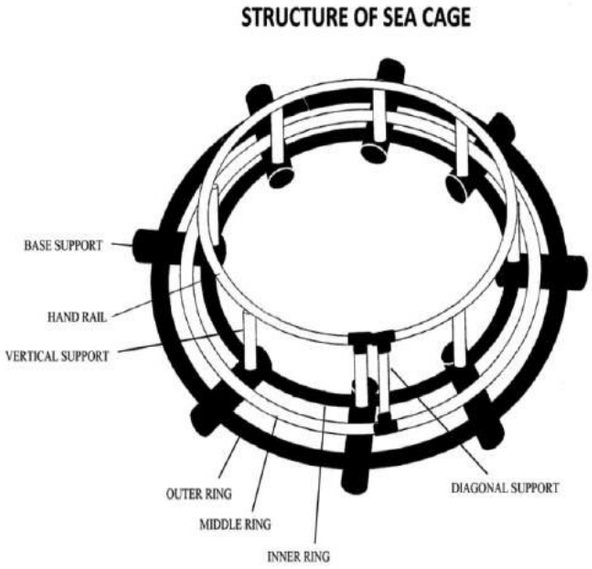


Fig.1.Plan View of HDPE Sea Cage Frame–Collar Rings and Handrail

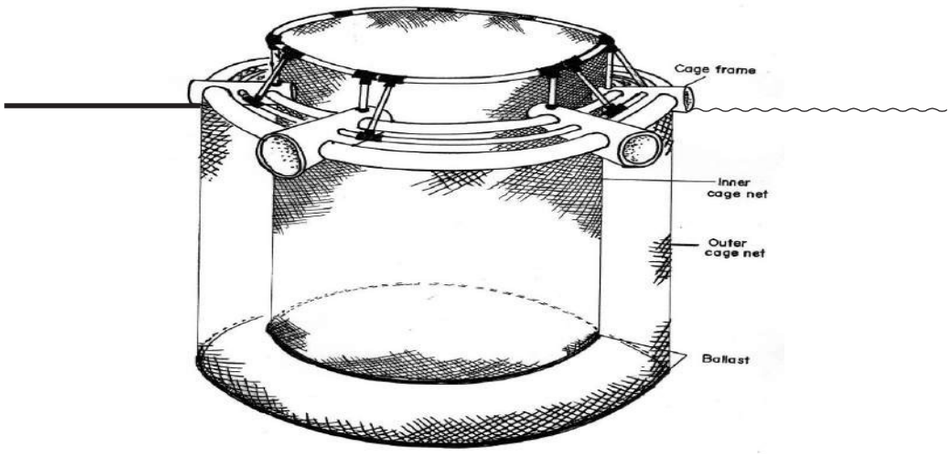


Fig.2. Layout of HDPE Sea Cage – Frame and Net Cages
(Inner & outer)

(iii) Mooring System

Mooring system/assembly holds the cage in desired position and at desired depth using mooring lines, chains and anchors. Individual cages can be moored using single-point mooring system (Fig. 3) and a battery of cages can also be moored by means of grid-mooring system.

Single-point Mooring System components required for 10 cages:

(a) Anchors (embedment type) /GabionBoxes–100kg each, 10 nos.

(b) D-Shackles–for 12.5 tone SWL (Safe Working Load), 3x10=30 nos.

(c) Mooring Chains–38-42 mm thick, length four times the depth at site, 10 nos.

(d) Buoys–200 litre buoyancy, 4x10=40 nos.

(e) Anchor Marker Line– poly-steel rope of 36 mm diameter and 37 m length

(f) Mooring Rope– poly- steel rope of 48 mm diameter, 3-4 strands, and 100 m length. Also splicing, steel thimble and oval ring of 22 mm a tone end, 10 nos.

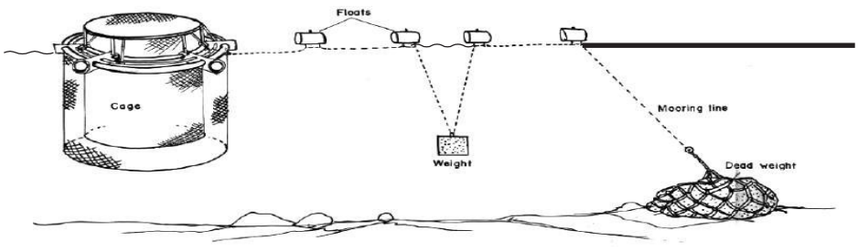
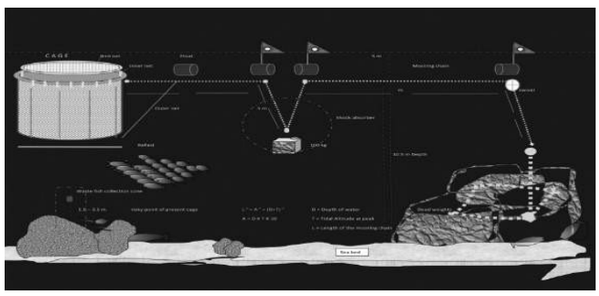


Fig.3.Single point mooring system for Sea Cage: Schematic diagram me

(above) and Artist's view (below)



5.2 Net Cages

Mesh size for the net cages must be selected according to the species of fish farmed and also to ensure good water exchange. Proper water flow enhances water quality, reduces stress, improves feed conversion and allows holding more fishes.

Net cages should be as per the dimensions of the cage frame and depth of water at the site. They must be securely fastened to the cage frame. For sea cage farming, 3 types of nets are essential:

(i) Outer Predator Net

Because of the turbulent nature of the sea and presence of carnivorous animals, suitable outer net cage is essential to prevent entry of predators in sea cage culture. Considering the strength, durability and cost factor, usually braided UV treated HDPE netting of 3 mm thickness and 80 mm mesh size is found very effective and recommended. Dimensions of predator net cage–7 m diameter and 5 m depth (entirely submerged) (Fig.2).

(ii) Inner Fish Rearing Net

For fabrication of inner fish rearing/ grow-out net cage, twisted HDPE netting of 0.75- 1.5 mm thickness and 16 - 40 mm mesh size is selected depending on the size of cultivable species. Dimensions of fish rearing net cage – 6 m diameter and 5 m depth (4.0 m submerged and 1.0 m up to the handrail; volume 113 cubic metres) (Fig.2).

(iii) Bird Net

To prevent predatory birds from preying on fish, a protective bird net must be over laid on the cage frame. HDPE twisted and UV treated 1.25 mm twine and 60-80 mm mesh size will be ideal for a bird net.

High Density Polyethylene knotted netting is preferred for net cages. The mesh size of the net cages depends on the size of individual farmed fish. Three sets of net cages of three different mesh sizes are required during the farming operation (18 mm, 25 mm and 40 mm) (Table 2). To maintain the cylindrical shape of the net cages, ballasts of appropriate weight should be used. Concrete blocks tied at suitable intervals can be used. Alternately, HDPE pipe of 1.5 inch (38mm) diameter inserted with MS chain or wire rope of 10 mm thickness can be employed.

5.2.1 Net Specifications

(i) Predator Protection/Outer Net Cage– HDPE braided 3mm; 60mm/ 80mm mesh.

(ii) Fish Rearing /Grow-out /Inner Net Cage–HDPE twisted; 18mm /25mm /40mm /60mm mesh.

(iii) Bird Net– HDPE twisted /Nylon; 60-100 mm mesh.

Predator net cage is uniform for all species, made of braided HDPE (3 mm twine) and usually 80mm mesh; Bird net is also uniform, made of twisted HDPE or Nylon (1 mm twine) and up to 100mmmesh.

Table2. Mesh size of Net Cages used for Rearing /Grow-out of different finfish species

Species	18mmMesh Fish Size(mm/g)	25mmMesh Fish Size(mm/g)	40mmMesh Fish Size(mm/g)	60mmMesh Fish Size(cm/kg)
Cobia	100-200/10-70	200-450/70-1100	460-750/1100-4000	75-100/4-7
Pompano	20-30/2	40-100/35	100-200/500	--
Sea bass	20-100/15	40-200/300	200-400/1500	--
Grouper	20-100/15	40-200/300	300-400/1000	--

3. Species Selection

Cage culture in the sea requires a fish variety that meets criteria such as suitability for marketing, commercial importance, consumer acceptance, easy to culture, adaptability to the cage environment, acceptance of formulated feeds, faster growth rate and resistant to common diseases.

As per the above criteria, Cobia (*Rachycentron canadum*), Silver Pompano (*Trachinotus blochii*), Seabass (*Lates calcarifer*), Snappers (*Lutjanus* sp.), Groupers (*Epinephelus* sp.) and Spiny Lobster (*Panulirus*sp.) are highly suitable for sea cage farming.

4. Seed

Quality of fish seed is of vital importance for the success of grow-out culture in cages. Uniform size seeds appropriate for the mesh size of the fish net cage should be stocked to prevent their escape. This will also help in selecting the correct sized feed for fishes, avoid wastage of feed and reduce cannibalism. Seeds should be healthy, free from diseases and deformities.

The most vital issue for the expansion of the sea cage farming in India is the shortage of fish seeds. Presently seed of Cobia, Pompano, Sea bass and Groupers are being produced in a few hatcheries in the country. Apart from these species, seeds of fishes like Mullets, Snappers, Milkfish, etc. collected from the wild can also be used for cage farming. To meet the growing demand from farmers, there is an urgent need to produce sufficient quantity of seed either through commercial hatchery production or by importing till we achieve self-sufficiency in seed production.

7.1 Stocking

Stocking appropriate size and number of fish seed in cages is very crucial for the success of cage farming. After allowing the hatchery produced spawn to grow for a period ranging from 30 to 60 days, fish seed can be stocked in cages. Nursery rearing of seed is essential for all species and it can be done as a separate activity, in land based nursery ponds or hapas held in ponds or in floating nursery cages, by individuals or groups at different localities to support sea cage farming with ready to stock fingerlings. Healthy, uniform-sized fingerlings should be procured for stocking in cages.

The fingerling stocking details are given below:

Species	Stocking Size (Length/Weight)	Stocking Density (Nos./m^3)
Cobia	15cm/35 g	8-10
Pompano	10cm/35g	30-40
Sea bass	10cm/30g	30-40
Grouper	15cm/40g	15-20

5. Feeds

Any material used for feeding contains the following five principle constituents: (i) Protein, (ii) Carbohydrate, (iii) Fat, (iv) Mineral sand (v) Vitamins. Proteins are essential for growth of the animal and a deficiency can lead to growth retardation. The nutrient requirements of marine carnivorous fishes (as %) are given below:

Size of Fish	Moisture	Crude Protein	Crude Fat	Crude Fibre
Fry-Fingerling (1- 20g)	<12	>42	>5	<4
Juvenile(20-50g)	<12	>40	>5	<4

Grower(50-300g)	<12	>38	>5	<4
Marketable Size(>300g)	<12	>35	>5	<4

Marine fishes require higher protein (35-40%) feed for their optimal growth. Based on growth of the fish, size of the feed pellet should be adjusted. Normal feeding rate is 10% of the body weight for juvenile fishes which can be reduced to 3% body weight as farming progresses. A feed with an FCR of 1:2 is advisable. Only recommended ration should be given to fishes since over feeding leads to wastage and environment pollution.

8.1 Feed Ingredients

Ingredients used for making feeds can be classified as protein rich ingredients which are mainly fish and meat products of animal origin and oilcakes of plant origin. Energy rich ingredients are mainly cereal sand cereal by products. Other than these there are non-conventional feed resources (NCFR) which are used in feed manufacture. Apart from these ingredients, mineral mixtures, vitamin mixtures and other additives such as oil, phospholipids, carotenoids are also added according to the needs. Non-nutrient additives such as synthetic binders, anti-oxidants and anti-fungal are also added.

8.2 Feed Formulation

With a fair knowledge of nutrients and the feed ingredients, the next aspect to be understood is the need for blending of the ingredients to have a nutritionally complete and balanced feed mix. A nutritionally complete feed can be made by mixing ingredients on a scientific basis which will be effective in producing the desired results in terms of fish production. The feeds should have the physical properties suitable for the fish to consume it with minimum loss of nutrients in water. Feed technology evolved from a dry mash to a wet ball and to a pellet. Now, pellets are produced such that they sink slow-sink or float depending upon the feeding habit of fish. For cage farming floating or slow sinking pellets are found to be appropriate. Production off locating and slow-sinking pellets is done using extruders, which are available in India or can be imported.

8.3 Feed Storage

During storage, feeds undergo deteriorative changes which not only lower their nutritive value but also affect their palatability and appearance. Feeds should be stored in dry ventilated warehouses away from direct sunlight at more or less constant temperature.

All feeds should be used within the prescribed time (preferably within two months of manufacture) and inspected regularly. During long storage there may be changes such as fungal growth, degradation of vitamin potency and fat rancidity. Unnecessary handling may damage feedbags and reduce pellets to powder that is usually not consumed by fish and wasted. Pests like rats, cockroaches, etc., must be strictly controlled in the storage, to avoid contamination. Proper storage of feed is simple, but it is important to keep its quality high.

8.4 Feeding Schedule

Feeding rates, frequency of feeding and time of feeding are important factors to be considered in cage farming. Feeding rates and frequencies are related to age and size of the fish. Fish larvae and fry need to be fed on a high protein diet more frequently. When fishes grow bigger, feeding rate sand frequencies can be reduced. Feeding fish is a labour- intensive activity and the frequency has to be adjusted in such a way that it is economically viable. Generally, growth and feed conversion increase with increase in feeding frequency. Feed consumption is also influenced by time of day, season, water temperature, dissolved oxygen levels and other water quality parameters. Even though several feeding charts are available, it is better to construct one of your own within formation on: Days of Culture (DOC), Fish Weight, Protein in Feed, Meal/ Day, Feed Consumed as % of body weight, Average Daily Gain (ADG) and Feed Conversion Ratio (FCR). Indicative feeding charts for Cobia, Silver Pompano and Sea bass are as follows:

Feeding Chart–Cobia

Duration (months)	Fish Length(cm)	Fish Weight(g)	Feeding Rate (% biomass)	Pellet Size (mm)
At Stocking	Fingerlings	Up to 20	20	1.5
0	15	40	15	1.8
1	20	71	15	1.8
2	22	94	15	2.5
3	26	125	15	2.5
4	33	468	10	2.5
5	46	1109	10	3.5
6	56	1985	8	5.0

7	73	3316	8	8.0
8	78	4015	5	12.0
9	86	4851	5	15.0
10	91	5622	5	18.0
11	97	6291	3	18.0
12	103	7276	3	18.0

Feeding Chart– Silver Pompano

Fish Weight(g)	Crude Protein (%)	Crude Fat (%)	Feeding Rate (%biomass)	Pellet Size(mm)
<1	50	10	20	0.8-1.0
1–10	46	10	10	1.0-1.5
10–100	45	10	5	1.8
100–250	45	10	4	3.5
250–500	40	10	3	4.5

Feeding Chart-Sea bass

Fish Weight (g)	Feeding Rate (%biomass)	Pellet Size (mm)
Up to 20	15	1.5
25-50	12	1.8
50–100	10	1.8
100–200	9	1.8
200–500	8	2.5
500–700	7	2.5
700–1000g	5	3.5
1.0kg–2.5kg	4	5.0
2.5kg–5.0kg	3	8.0

6. Growth Rate

Salinity above 25ppt is essential for optimal growth of Cobia; whereas Silver Pompano tolerate seven salinity of 10 ppt. Farming duration usually ranges from 7 to 8 months for Cobia and Silver Pompano while it is 6-8 months for Sea bass, to attain optimum marketable size. Indicative growth rates are as follows:

Growth of Cobia in Sea Cage

Duration (Months)	Length (cm)	Weight (g)
At Stocking	17	38
1	21	71
2	22	94
3	26	125
4	33	468
5	46	1109
6	56	1985

Duration (Months)	Length (cm)	Weight (g)
7	74	3316
8	78	4015
9	86	4851
10	91	5622
11	97	6292
12	103	7277

Growth of Silver Pompano in Cage Culture

Days of Culture (DOC)	Length (mm)	Weight (g)
1	31	2
15	50	9
30	73	15
45	85	23
60	103	35
75	138	55
90	158	73
105	169	80
120	182	102
135	186	139
150	204	172
165	224	220
180	227	258
195	248	304
210	273	375
225	288	416
240	297	465

7. Cage Maintenance

Cage Farm management involves optimizing production at minimum cost. Efficient management largely depends on the competence and efficiency of farm operator with regards to feeding rate, stocking density, minimizing loss due to diseases and predators, monitoring environmental parameters and maintaining efficiency in all other technical aspects.

The entire structure including cage frame and mooring must be routinely inspected and necessary maintenance and repairs should be carried out. Bio-fouling clogs the mesh of net cages and there by reduces rate of water exchange causing stress due to low oxygen and accumulated wastes leading to mortality of fish. The rate of fouling depends not only on the mesh size of the net cage, but also on temperature and productivity of the water at the cage site. Therefore, timely exchange of fish rearing net cage is to be done, by replacing with a fresh net cage, to ensure good water quality and facilitate faster growth. Also, as fish grow bigger, net cages of appropriate mesh size are to be used (Table2).

8. Health Management

Disease outbreaks can occur as result of intensive farming in cages. Infectious diseases are mainly due to waste accumulation, crowding, handling, variations in water quality parameters and bio-fouling. The most common disease that occurs in cages is Vibriosis caused by *Vibrio* a bacterial species. Cage abrasion can cause fin and skin damage to farmed fish. Occurrence of infections/ diseases can be minimized by selecting good site, optimal stocking density and careful handling of fish stock. Fish farmers should maintain are cord of weather, water quality parameters, feeding rate, length and weight of fish sampled, fish behavioral changes, net cage exchange details, etc. These records provide useful information for analysis of health status.

9. Good Management Practices

Good management practices (GMPs) need to be adopted to satisfy consumer demand and expand the market by offering quality farmed products that meet food safety standards. Adoption of GMPs also helps fish farmers to achieve higher economic returns. Some of the key factors in GMP include:

- Avoiding over-stocking of fish fingerlings.
- Monitoring growth rate at appropriate time intervals.

- Feeding fishes with pellets of good quality and right quantity.
- Regular cleaning and exchange of net cages for effective water exchange.
- Avoiding use of antifouling paints/chemicals.
- Timely removal and proper disposal of dead fishes.
- Periodic monitoring of water temperature, dissolved oxygen, pH, etc.
- Close observation of fish behavior while feeding them, to assess health status.
- Integrated Multi-Trophic Aquaculture (IMTA) /Poly culture of compatible species in cages.

Cage

Economics of Open Sea Cage (1 no.)

A. Capital cost

Sr. no.	Particular	Unit	Rate	Qty.	Amount in Rs.
1.	G.I. cage of 6 mtr. Diameter made of 1.5" Jindal or Tata B Class GI pipe with epoxy coated	Meter	50,000	01	70,000
2.	Outer Net 4 mm braided, 80 mm mesh, Size HDPE 6mt x 7mt circumference	Meter	40,000	01	40,000
3.	Inner Net-I 12 mm mesh size HDPE 6mt x 6mt circumference	Meter	18,750	01	18,750
4	Inner Net- 2nd 24mm mesh size 2mm 8 ply HDPE, 6mt x 6mt circumference	Meter	26,244	01	26,244
5	Inner Net- 3rd 36mm mesh size 2mm ply, 6mt x 6mt circumference	Meter	25000	01	25000
6	Outer Ballast pipe 2" SDP PIPE 21mt/cage	Meter	300	21	6300
7	Inner Ballast pipe 2" SDP PIPE 18mt/cage	Meter	300	18	5400
8	Steel wire rope (40 mt/cage) 32mm rope	Meter	700	40	28000
9	HDPE Rope, 5kg/unit 6mm HDPE	Kg	500	05	2500
10.	HDPE Rope, 5kg/unit 12mm HDPE	Kg	500	05	2500
11.	HDPE Rope, 7kg/unit 26mm HDPE	Kg	500	07	3500
12.	ANCHOR 2/unit 60 kg	No.	8000	02	16000
13.	Barrels 8/cage	No.	900	08	7200
				TOTAL	**251394**

B. Working capital

Sr. no.	Particular	Unit	Quantity	Rate	Amount
1	Cost of seed with transportations	No	3000	45	135000
2	Cost of feed with transportation	kg	3150	110	346500
3	Fuel charges				10000
4	Staff salary		1	8000	80000
5	Office expenses				5000
6	Harvesting				5000
7	Repairs				10000
				TOTAL	**591500**

C. Total Expenditure = Capital cost + Working cost

=251394 + 591500

= Rs. 8, 42, 894/-

D) Revenue:

Production = 2100 kg

= 2100 kg

Total revenue = 2100 * 350/-

= Rs. 7, 35, 000/-