सत्यमेव जयते

NFDB

Guidelines for Sea Cage Farming in India

Towards Blue Revolution

Department of Animal Husbandry, Dairying & Fisheries
Ministry of Agriculture & Farmers Welfare, Government of India
Krishi Bhavan, New Delhi - 110 001
January 2018

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FOREWORD

India is endowed with vast marine fisheries resources such as 8,118 km long Coast Line, 193,834 km^2 of Territorial Sea, about 4 million Marine Fishermen living in 3432 Marine Fishing Villages in 66 Coastal Districts of 9 Maritime States and 2 Union Territories, besides 2 Island Territories of Andaman & Nicobar and Lakshadweep. Infrastructure available includes 6 Major Fishing Harbours, 40 Minor Fishing Harbours and 1537 Marine Fish Landing Centres.

The current marine fish production in India is about 4 million tonnes of which 2 lakh tones comprise of high-value fish that are in great demand for human consumption. The projected marine fish production by 2050 is expected to be a maximum of 6 million tonnes. Responsible fishing methods and closed fishing seasons are being observed along the East and West Coasts of India for sustaining the dwindling marine fishery resources.

In view of the vast marine resources available in the country, Sea Cage Farming has emerged as a viable option to increase production of high value marine fish and shellfish. Sea Cage Farming provides immense opportunities for enhancing marine fish production while simultaneously reducing fishing pressure on natural stocks and providing livelihood to coastal communities.

After intensive research into broodstock development, hatchery technology, seed rearing, etc., the ICAR-Central Marine Fisheries Research Institute, Cochin, Kerala, with NFDB funding has successfully undertaken trials and demonstrated feasibility and economic viability of Sea Cage Farming of marine fishes such as Cobia, Silver Pompano, Seabass, Groupers and Spiny Lobsters at various locations along both the coasts of India.

Subsequently, commercial Sea Cage Farming was successfully tested and demonstrated by the Marine Fishermen Association Members along the Gujarat, Maharashtra, Goa and Tamil Nadu Coasts with NFDB funding and technical assistance from CMFRI. In view of the success achieved in trials and available potential for expansion, the Govt. of India has come up with a Scheme to promote Sea Cage Farming (Open Sea Cage Culture) under the CSS Blue Revolution "***Neeli Kranti Mission***".

As part of Blue Revolution it was felt necessary to develop a policy framework and guidelines for sustainable growth of Sea Cage Farming in the country. To this end, three rounds of National Consultations were held: on 5th August 2016 at NFDB, on 8th and 9th June 2017 at Regional Centre of CMFRI, Mandapam and on 21st September 2017 at NFDB, wherein scientists from CMFRI and NIOT, officials from DADF, officials, stakeholders and industry representatives from Maritime States participated to formulate an action plan for development of broodstock and production of seed of Cobia and Silver Pompano, Sea Cage design and fabrication, etc. Finally a Writeshop was held on 12th October 2017 at NFDB where the 'Guidelines for Sea Cage Farming in India' were deliberated, drafted, revised and now published for the benefit of stakeholders.

I compliment the Director and Scientists of CMFRI for drafting these 'Guidelines on Sea Cage Farming in India' that would go a long way in enhancing marine fisheries production and productivity in a sustainable manner in the country.

I would also like to place on record my sincere appreciation to Dr. K. Ravindranath, Senior Consultant (Tech), NFDB, for the excellent editing.

Hyderabad
25 January 2018

(I. Rani Kumudini)

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1. Background

Mariculture – the farming of marine organisms for food - is the fastest growing sub-sector of aquaculture. The global mariculture production including the seaweeds was 54.0 million tonnes (2014), which constituted 53.4% of the aquaculture production during the same period. In the recent past the marine fish catch in the country is stagnating around 3.5 million tonnes annually indicating that increasing the fish catch in the existing fishing grounds is not sustainable economically and ecologically. Added to this dwindling catch in capture fisheries, rampant unemployment in the coastal region and demand for additional seafood necessitates the development of mariculture as a substantial seafood production sector. It has been projected that in India we need to produce about 18 million tonnes of fishes by 2030 as compared to about 10 million tonnes we produce today. It implies that our aquaculture production has to increase from 4 million tonnes to 12 million tonnes in the next 14 years. Enhancing fish production from inland sector has limited scope and the major portion of the additional demand has to come from mariculture.

Sea cage farming is viewed as a major option for increasing the seafood production and has been expanding rapidly in recent years at global level. Cage culture has made possible the large-scale production of commercial fin fishes in many parts of the world and can be considered as the most efficient and economic way of raising fish. When compared to many maritime countries, India is still in its infancy in cage culture. Recently, it has been estimated that total number of cages of varying sizes installed in the inshore and brackishwater areas number around 1500 with a total estimated production of around 1500 tonnes. Hence, there is tremendous scope for the further expansion of cage farming in India. The ICAR-Central Marine Fisheries Research Institute (CMFRI) has projected that even if 1% of the inshore waters is used for cage farming, we can deploy 8,20,000 cages with a production potential of 3.2 million tonnes. Thus, there is an urgent need to expand sea cage farming in India.

It is understood that availability of suitable sites for cage culture, well established breeding techniques that yield sufficient quantity of fish fingerlings for farming, availability of supporting industries like feed and net manufactures, strong R&D initiatives, social, economic and financial logistics are prime factors that pave the way for expansion of sea cage farming as a commercial activity. Currently guidelines on the above aspects are lacking in the country and hence a document on the guidelines to be followed is felt desirable for sustainable growth of sea cage farming in the country.

2. Objectives

The objective of the document is to augment fish production in a sustainable manner through sea cage farming to meet the increasing demand for seafood. The following aspects are focused in the guidelines:

- To outline the technical specifications on site selection, materials and design of cage frames, net cages, mooring systems, species selection, seed availability, establishment of hatcheries and feed mills, stocking of cages, feed and feeding, management of stocked fish, harvesting protocols and establishment of post-harvest facilities.
- To suggest measures to combat environmental impact due to cage farming.
- To suggest R&D initiatives required for sustainable expansion of sea cage farming.
- To present guidelines framed under Blue Revolution Scheme of Govt. of India, and address licensing/ ownership issues, etc.

3. Sea Cage Culture

Sea cage culture involves growing fishes in the sea while being enclosed in a net cage 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.

3.1 Advantages of Sea Cage Farming

- 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 areas in the sea can be brought under mariculture practices.
- Production per unit (m^3) in cage culture is 50 times 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.

3.2 Status of Sea Cage Farming in India

Sea cage farming in India was initiated by CMFRI with support from Ministry of Agriculture, Govt. of India and National Fisheries Development Board (NFDB) in 2007 and is gaining momentum as a commercial seafood production system. Several R&D programmes in cage culture, demonstrations and participatory mode of cage farming have led to the emergence of an economically viable farming method which resulted in popularization of the technology. The necessity of seed for farming has led to the development of hatchery technology for high valued finfish like Cobia, Pompano and Grouper. Consequently, seeds of these species also were made available for cage farming along with the already available seeds of Asian Seabass. As a result, cage farming of Cobia, Pompano, Asian Seabass and Grouper became popular among fishermen-groups and entrepreneurs along the Indian coast.

4. 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 harbours/ fish landing centres and navigation channels, defense areas, marine protected areas, coral reefs, mangroves, areas under coastal management plan, points of industrial effluent discharge, sewage pollution, heavy freshwater 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 area is preferred as it will protect cages in 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 seabed 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, pH and dissolved oxygen. The water should be free from excessive suspended solids, frequent algal blooms and disease causing organisms.

Table 1. Water quality criteria for sea cage farming of finfish

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

4.2 Logistics

Distance from shore to cage site should be at the minimum to reduce operational expenses. Road connectivity for transporting cage materials, feed, harvested fish, etc., is required for a successful operation of sea cage farm.

The CMFRI and State Fisheries Departments should take initiative to identify suitable sites for sea cage farming and map them in GIS platform to facilitate proper planning and effective implementation. This will benefit the entrepreneurs to select ideal locations to start sea cage farming ventures.

4.3 Integrated Systems

To promote and expand sea cage farming in India, an integrated approach is vital. In this context creating facilities for manufacture of cage frames, fabrication of cage nets, mooring assembly, establishment of hatcheries, nursery rearing units, feed mills, post-harvest processing units, etc., are to be considered as part of the cage farming system.

5. 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 litre, 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 HDPE Cage

The sea cage frame has two collar rings designed with flotation properties and a middle ring as catwalk 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 polyurethane foam (PUF) or thermocol. The two collar rings, the middle catwalk ring and the handrail ring are all held in place by means of various support pipes, brackets and T-joints. The pipe used for handrail is without PUF inside 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 1.5 inch (38 mm) diameter HDPE ballast pipe with holes at regular intervals, for the free flow of water, is used. Metal lines are inserted inside the pipe for increasing weight so that the ballast remains submerged in water.

5.1.1 Technical Specifications

(i) Base Collar

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

(b) Outer Ring – 7 m diameter circle (HDPE, 140 mm 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 catwalk 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 (polystyrene 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).

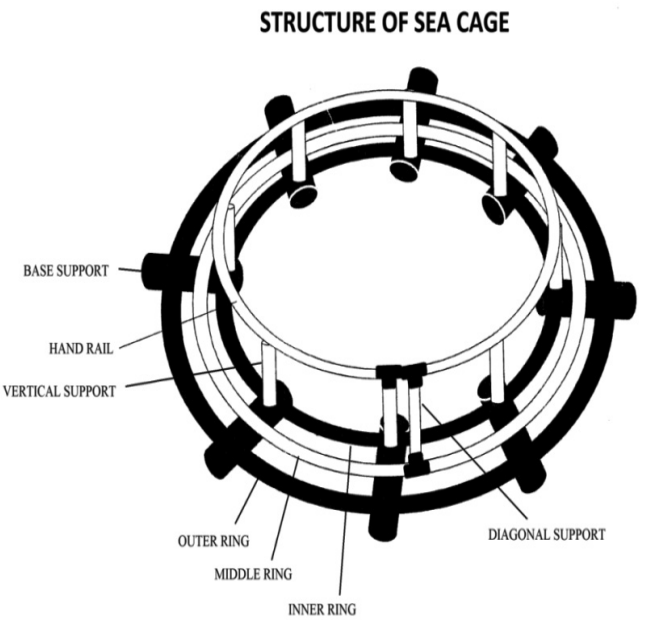


Fig. 1. Plan View of HDPE Sea Cage Frame – Collar Rings and Handrail

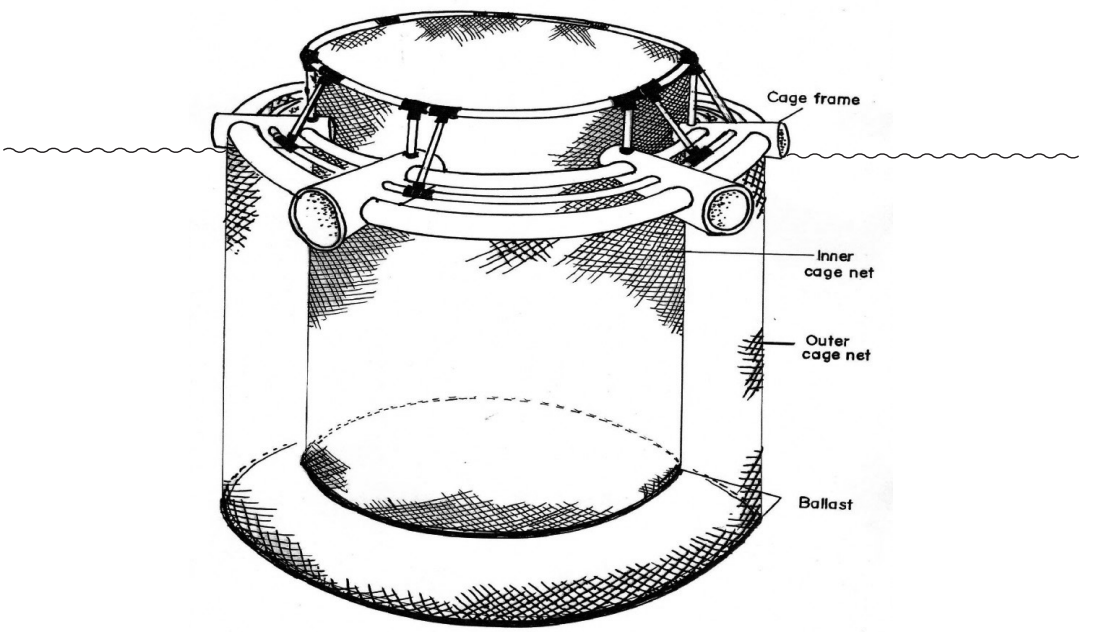


Fig. 2. Layout of HDPE Sea Cage – Frame and Net Cages (inner & outer)

(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) / Gabion Boxes – 100 kg each, 10 nos.

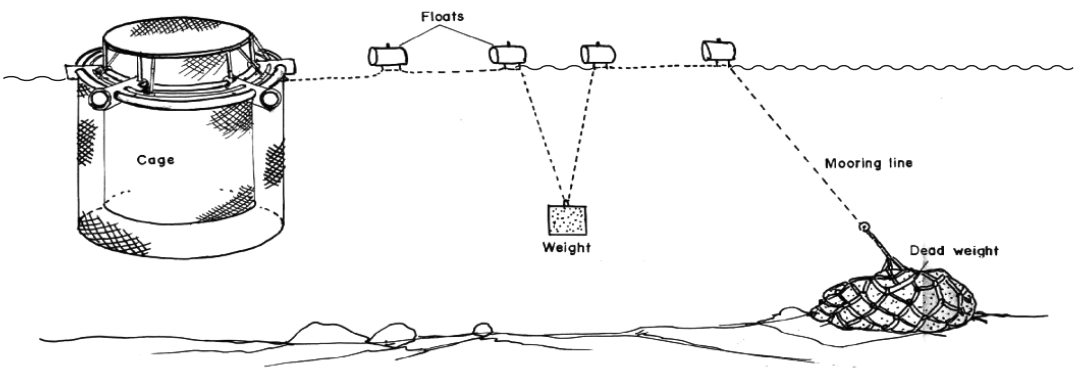
(b) D-Shackles – for 12.5 tonne SWL (Safe Working Load), 3 x 10 = 30 nos.

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

(d) Buoys – 200 litre buoyancy, 4 x 10 = 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 at one end, 10 nos.



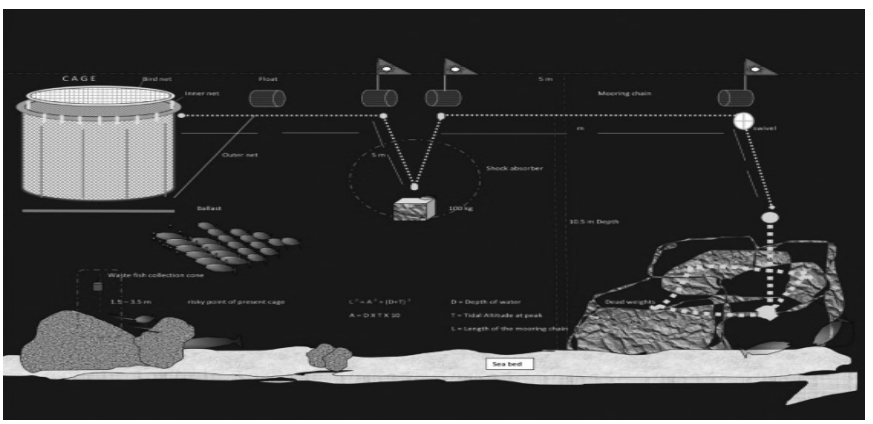


Fig. 3. Single-point mooring system for Sea Cage: Schematic diagramme (above) and Artist's view (below)

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 overlaid 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 (38 mm) 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 3 mm; 60 mm/ 80 mm mesh.

(ii) Fish Rearing/ Grow-out/ Inner Net Cage – HDPE twisted; 18 mm/25 mm/40 mm/60 mm 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 80 mm mesh; Bird net is also uniform, made of twisted HDPE or Nylon (1 mm twine) and up to 100 mm mesh.

Table 2. Mesh size of Net Cages used for Rearing / Grow-out of different finfish species

Species	18 mm Mesh Fish Size (mm/g)	25 mm Mesh Fish Size (mm/g)	40 mm Mesh Fish Size (mm/g)	60 mm Mesh 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	--
Seabass	20-100/ 15	40-200/ 300	200-400/ 1500	--
Grouper	20-100/ 15	40-200/ 300	300-400/ 1000	--

6. 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.

7. 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, Seabass 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 List of Marine Fish Hatcheries

Name of Hatchery	Species
CMFRI, Mandapam, Tamil Nadu	Cobia, Pompano
CMFRI, Visakhapatnam, Andhra Pradesh	Grouper, Pompano
RGCA (MPEDA), Pozhiyoor, Kerala	Seabass, Cobia, Pompano
CIBA, Chennai, Tamil Nadu	Seabass

7.2 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	15 cm/ 35 g	8-10
Pompano	10 cm/ 35 g	30-40
Seabass	10 cm/ 30 g	30-40
Grouper	15 cm/ 40 g	15-20

8. Feeds

Any material used for feeding contains the following five principle constituents: (i) Protein, (ii) Carbohydrate, (iii) Fat, (iv) Minerals and (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 - 20 g)	<12	>42	>5	<4
Juvenile (20 - 50 g)	<12	>40	>5	<4
Grower (50 - 300 g)	<12	>38	>5	<4
Marketable Size (>300 g)	<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 overfeeding 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 cereals and cereal byproducts. 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-fungals 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 of floating 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 feed bags 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 rates and 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 with information 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 Seabass 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 - Seabass

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 – 1000 g	5	3.5
1.0 kg – 2.5 kg	4	5.0
2.5 kg – 5.0 kg	3	8.0

9. Growth Rate

Salinity above 25 ppt is essential for optimal growth of Cobia; whereas Silver Pompano tolerates even 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 Seabass, 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

10. 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 thereby 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 (Table 2).

11. Health Management

Disease outbreaks can occur as a 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 a record 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.

12. 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 behaviour while feeding them, to assess health status.
- Integrated Multi-Trophic Aquaculture (IMTA)/ Polyculture of compatible species in cages.

13. Environmental Impact

Cage culture system releases waste to the aquatic environment in the form of uneaten feed, feces and other debris. These may accumulate beneath the cages leading to reduction in dissolved oxygen. The tendency of large quantity of waste to settle on the sea bed is greater at sheltered inshore sites. Continuous farming for several years at the same site in sheltered areas is to be avoided. Change of site after a number of crops should be done. Otherwise, semi-exposed/ exposed sites having good tidal flushing are selected to prevent accumulation of wastes at the bottom of the cage. Adequate spacing between cages and farms is also an essential management practice to reduce the spread of diseases. Indiscriminate use of antibiotics and their release into aquatic environment may result in development of antibiotic resistant bacteria. Cage culture can also introduce diseases, transmit parasites and cause changes in aquatic flora and fauna. Hence, carrying capacity of the environment, as per the nature of the site, has to be given prime importance while undertaking sea cage farming.

14. Harvesting Protocols

Harvesting can be done as per the market demand to ensure maximum returns. Partial harvesting of stock may be practiced, by harvesting the larger fish first, to avoid glut in the market and consequent fall in sale price. Records of harvest should be maintained at the site. It is necessary to have a post-harvest and marketing strategy while undertaking large scale sea cage farming activity.

The production centres should have facilities such as proper craft and gear to harvest fish, facilities for icing, holding and storage of fish, live-fish transport, linkages to post-harvest processing centres and market chains.

15. Human Resource Development

Successful and efficient sea cage farming venture requires technical manpower. At present there are no skilled/trained personnel for sea cage farming in the country. A cadre of sea cage farm managers, technicians, fabricators and service providers is to be developed through capacity building/ skill development programmes; they in turn would provide hands-on training to the farmers and fishers at the sea cage site and also deliver required services.

16. Research and Development

- Mapping of mariculture sites on a GIS platform.
- Assessing carrying capacity of various farming sites for ensuring sustainability.
- Establishing broodbanks to supply newly hatched larvae (1-day post-hatch) to pilot hatcheries that supply fry to nurseries which in turn supply ready-to-stock fingerlings to farmers.
- Production of cost-effective grow-out feeds.
- Evolving integrated sea farming systems with finfish, shellfish, seaweeds and artificial reefs.

- Disease monitoring and health management.
- Identifying additional high-value species suitable for mariculture.
- Initiation of offshore mariculture.

17. Safety Measures

Cage culture in the sea involves working in a risky environment. Hence adequate safety measures should be taken to prevent accidents including loss of life. Life-saving equipment like life-buoys/ jackets, communication devices, and first aid boxes at the cage site should be made mandatory. All persons while working at the sea cage should wear life-jackets.

To avoid poaching or vandalism effective watch and ward arrangement should be made at the sea cage site. Also, to alert fishing craft and seafarers and to indicate the location of sea cages and their moorings, Maritime Signal Flags and Solar Beacon Lights may be positioned on the cages.

18. Economics of Sea Cage Farming

18.1 Economics of Cage Farming of Cobia

- Cage size: 6 m diameter x 4 m depth (volume 113 cubic metres)
- Stocking density: 1000 nos.
- Weight at harvest: 3.0 kg
- FCR: 1:2 (with pellet feed)
- Total harvest: 2400 kg/ cage/ 7 months (80% survival)
- Farm gate price: Rs. 300/ kg
- Production cost: Rs. 192/ kg

Economics of Cobia production per Crop per Cage			
Expenditure (in Rs. lakh)		**Returns & Profit (in Rs. lakh)**	
Capital Costs*	2.50	Gross Returns	7.20
Operational Costs	4.61	Gross Profit	2.59
Total Costs	**7.11**	**Net Profit**	**2.09**

*Capital Costs apportioned in 5 equal installments @ Rs. 0.50 lakh/ crop

18.2 Economics of Cage Farming of Silver Pompano

- Cage size: 6 m diameter x 4 m depth (volume 113 cubic metres)
- Stocking density: 4500 nos.
- Weight at harvest: 0.5 kg
- FCR: 1:2 (with pellet feed)

- Total harvest: 1800 kg/ cage/ 8 months (80% survival)
- Farm gate price: Rs. 300/ kg
- Production cost: Rs. 181/ kg

Economics of Silver Pompano production per Crop per Cage			
Expenditure (in Rs. lakh)		**Returns & Profit (in Rs. lakh)**	
Capital Costs*	2.50	Gross Returns	5.40
Operational Costs	3.26	Gross profit	2.14
Total Costs	**5.76**	**Net profit**	**1.64**

*Capital Costs apportioned in 5 equal installments @ Rs. 0.50 lakh/ crop

19. Implementation and Financial Assistance

Currently there is neither a policy for leasing sites at sea nor regulatory measures for sea cage farming. Leasing policies have to be formulated urgently for development of sea cage farming in the country. Regulatory measures are also needed to prevent the usage of available inshore waters beyond their carrying capacity. It is suggested to evolve a single-window system for the development of sea cage farming entrepreneurship at Panchayat level.

19.1 Centrally Sponsored Scheme on Blue Revolution: Integrated Development and Management of Fisheries (*vide*: Revised Administrative Approval No. 27035-19/2015-Fy (IV), dated 28th September 2017, of the DADF, MoA&FW, Govt. of India)

(i) The total Admissible Government Subsidy (Central + State) will be limited to 40% of the project cost/ unit cost for general category beneficiaries and 60% of the project cost/ unit cost for weaker sections like Scheduled Castes (SCs), Scheduled Tribes (STs), women and their co-operatives.

(ii) Of the admissible subsidy, the Central: State share shall be as follows:

(a) North East & Hilly States : 90% Central share and 10% State share

(b) Union Territories : 100% Central share

(c) Other States : 60% Central share and 40% State share

19.2 Promotion of Mariculture

(A) Open Sea Cage Culture

Unit cost is Rs. 5 lakh per cage having minimum diameter of 6 metres and depth of 4 metres in case of each circular cage and 96 cubic metre volume (6 m x 4 m x 4 m) in case of each rectangular cage.

(i) The applicant shall obtain necessary prior permissions from the concerned State/UT Government and other Competent Authorities for installation of cages in the sea.

(ii) Fishermen Cooperative Societies, SC/ST Cooperative Societies, Women Self Help Groups, Registered Companies of Private Entrepreneurs, etc. shall be eligible for central assistance for 4 batteries of 5 cages each (20 cages) at a particular location.

(iii) The unit cost includes capital, operational and maintenance costs on one time basis.

(iv) The applicants shall be required to submit self contained project proposals together with documentary evidence of necessary permissions and technical knowhow to avail of the assistance.

(v) The proposals shall be routed through the concerned State Govt./UT Administration with clear recommendation.

(B) Seaweed Cultivation

Unit cost is Rs.1,000 per raft (3 m x 3 m size).

(i) The applicant shall obtain necessary prior permissions from the concerned State/UT Government and other Competent Authorities for installation of rafts.

(ii) Fishermen Cooperative Societies, SC/ST Cooperative Societies, Women Self Help Groups, Registered Companies of Private Entrepreneurs, etc. shall be eligible for central assistance for a cluster of up to a maximum of 500 rafts at suitable sites/locations.

(iii) The unit cost includes capital, operational and maintenance costs on one time basis

(iv) The applicants shall be required to submit self contained project proposals together with documentary evidence of necessary permissions and technical knowhow to avail of the assistance.

(v) The proposals shall be routed through the concerned State Govt./UT Administration with clear recommendation.

(C) Bivalve Culture

Unit cost is Rs.15,000 per bamboo rack (5 m x 5 m size).

(i) The applicant shall obtain necessary prior permissions from the concerned State/UT Government and other Competent Authorities for installation of racks.

(ii) Fishermen Cooperative Societies, SC/ST Cooperative Societies, Women Self Help Groups, registered Companies of Private Entrepreneurs etc. shall be eligible for central assistance for a battery of up to a maximum of 40 racks at suitable sites/locations.

(iii) The unit cost includes capital, operational and maintenance costs on one time basis.

(iv) The applicants shall be required to submit self contained project proposals together with documentary evidence of necessary permissions and technical knowhow to avail of the assistance.

(v) The proposals shall be routed through the concerned State Govt./UT Administration with clear recommendation.

20. Conclusion

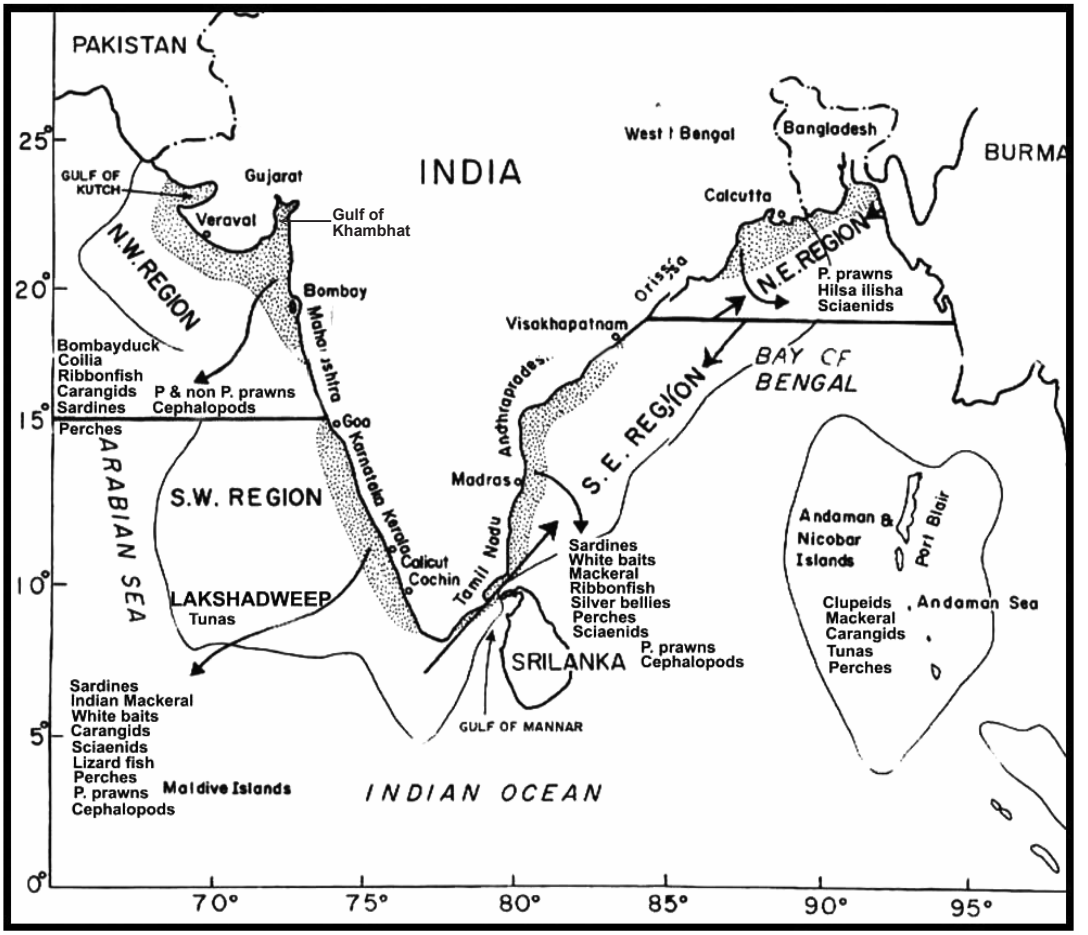
Adherence to the technical guidelines as suggested above and taking measures to combat environmental impact, solving social issues like licensing, ownership, governance, ensuring inclusive development of fishers and farmers, providing incentives and financial assistance and developing necessary backward (inputs) and forward (market) linkages would pave the way for expansion of sustainable sea cage farming and achieve the envisaged marine fish production and productivity in the country.

* * *

Annexure-I

Territorial Sea and Exclusive Economic Zone of India

Fisheries and Aquaculture within the Territorial Sea [12 nautical miles/ 22.2 km from shoreline] are a State Subject, while Fisheries within the EEZ – Exclusive Economic Zone [12 nautical miles to 200 nautical miles/ 370.4 km] are under the purview of Union Govt. The EEZ and Territorial Waters of 9 Maritime States, 2 Union Territories and 2 Island Territories are graphically shown below:



Annexure-II

List of Cage Manufacturers (HDPE & GI)

Sl. No.	Name & Address
1	**M/s. Roopak Plastics Pvt. Ltd.** Plot No. 51, AIE Pedagantyada, Visakhapatnam - 530 044, Andhra Pradesh Phone: 0891-2750517
2	**M/s. Poorvi Fabrications** D.No. 50-80-22, Flat No.11, Anjana Residency, Seethammapeta Visakhapatnam - 530016, Andhra Pradesh Phone: 0891-2752926 Mobile: 9849829264 Email: poorvif@yahoo.com Contact Person: Mr. Y.V. Satyanarayana
3	**M/s. TTK Fiber Glass Works** Plot No. 32, F- Block, 3rd Lane, APIIC, Industrial Park Auto Nagar, Visakapatnam – 530 012, Andhra Pradesh Phone: 0891- 2570770 Mobile: 94403 19197 Email: ttkfibreglass@gmail.com Contact Person: Mr. K.V.N. Raju
4	**Mr. Seeni Mohideen** 2/8, Marakayarpatnam – 623 520, Ramanathapuram District, Tamil Nadu Mobile: 8344927487
5	**M/s. Catamaran Cage Fabrications** 5-3592, Raja Nagar, Thangachimadam – 623 529, Ramanathapuram District, Tamil Nadu Mobile: 9600436334 Email: ebipachek90@gmail.com Contact Person: Mr. S. Ebi
6	**M/s. RVR & Co** Residency Plaza, 5th Floor, No. 41/42, Residency Road, Bengaluru – 560 025, Karnataka Mobile: +91 98861 34567 Contact Person: Mr. R V Ramana V. Reddivari
7	**M/s. Das & Kumars** D-63/1D, Mahmoorganj, Varanasi – 221 010, Uttar Pradesh Phone: 0542 – 2220521, 2220414; Mob: 9839098484 Email: daskumars@yahoo.com Contact Person: Pulkit Agarwal
8.	**Mr. Sreekumar Vasudevan** Theruvilparambil House, Pizhala, Kadamakudy, Ernakulam - 682 018, Kerala Mobile: +918943909469

List of Feed Manufacturers

Sl. No.	Name & Address
1	**M/s. Growel Feeds Pvt. Ltd.** Survey. No. 64-67, Chengicharla Village Road Hyderabad.500 039, Andhra Pradesh, India.
2	**M/s. Ananda Feeds** 27-8-21/3, Sivaraopeta, Bhimavaram – 534 202 West Godavari District, Andhra Pradesh
3	**M/s. Rudra Techno Feeds** Nallamadu Village – 534 406, Near Dubacherla Centre, Ungturu Mandal West Godavari District, Andhra Pradesh
4	**M/s. Vishnu Priya Feeds** Town Railway Station Road, Bhimavaram – 534 201 West Godavari District, Andhra Pradesh
5	**M/s. The Waterbase Ltd.,** P.B.No. 4902,(Old No.8), New No. 22, Sadasivam Street, Off Loyds Road Gopalapuram, Chennai – 600 086.
6	**M/s. Uni-President Enterprises Corp.** UPES (India) Foods Pvt. Ltd., 83/A, G.N.T. Road (NH-5) Ponniyamman Medu, Madhavaram, Chennai – 600 110
7	**M/s. C P Aquaculture (India) Private Limited** 47/D4 Gandhi Mandapam Road, Kotturpuram Chennai 600 085, Tamil Nadu, INDIA.
8	**M/s. Uno Feeds** Komarada Village, Bhimavaram Mandal West Godavari District, Andhra Pradesh
9	**M/s. Avanti Feeds Ltd.** Kovur – 534350 West Godavari District, Andhra Pradesh
10	**M/s. Sri Sai Aqua Feeds** Opp. Bharat Petrol Bunk, Near SRKR College Chinnamiram, Bhimavaram – 534 204, West Godavari District, Andhra Pradesh

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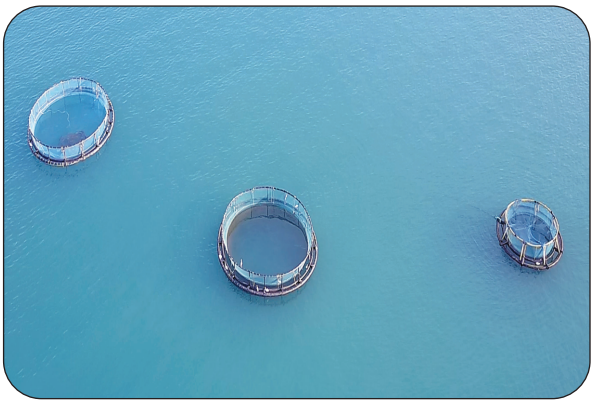
Sea Cage Farming in India



An aerial view of Sea Cages (HDPE Frame)

A battery of Sea Cages (HDPE barrels as floats)

Close-up view of a Sea Cage

Cobia farming in a Sea Cage

Cobia fish harvested from a Sea Cage

Lobsters harvested from a Sea Cage

National Fisheries Development Board

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Send "KISAAN GOV HELP" as SMS to 51969 (Service provider rates apply)