Training Manual Series No. 10 / 2016

Training Manual
on

Cage Culture
of
Marine Finfishes

Editors

Sekar Megarajan, Ritesh Ranjan

Biji Xavier & Shubhadeep Ghosh

ICAR- Visakhapatnam Regional Centre of
Central Marine Fisheries Research Institute
Visakhapatnam, Andhra Pradesh, India

About the manual: *Training manual on "Cage Culture of Marine Finfishes" is published by the Central Marine Fisheries Research Institute, Visakhapatnam Regional Centre, Andhra Pradesh under finance assistance from All India Network Project on Mariculture (AINP-M), ICAR. This manual is published as reading material in the training programme on cage culture of marine finfishes held during 7-12th November, 2016 for fishermen, aquafarmers and entrepreneurs involved in mariculture activities. This manual is consisting of different chapters which describe various aspects related to open sea cages.*

Training Coordinator
Dr. Sekar Megarajan

Training Co-coordinators
Dr. Ritesh Ranjan
Dr (Mrs). Biji Xavier
Dr. Biswajit Dash
Dr. Shubhadeep Ghosh

Organised by
Visakhapatnam Regional Centre
ICAR-Central Marine Fisheries Research Institute,
Visakhapatnam -530 003
Andhra Pradesh, India

Financial Assistance
All India Network Project on Mariculture (AINP-M),
Indian Council of Agricultural Research, New Delhi-110 012

Cover page: Designed by
V. Uma Mahesh
M.V. Hanumantha Rao

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7-12 November, 2016

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ICAR-Central Marine Fisheries Research Institute,
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Andhra Pradesh, India

2016

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PREFACE

World human population is increasing day by day and it is envisaged that the population will reach 9.7 billion by the year 2050. In order to meet the increasing food demand, the contribution of fish as food source need to be drastically increased. Presently, fish production is contributed by capture fisheries and aquaculture. However, increasing world demand for fish cannot be fulfilled by capture fisheries, because in the recent years marine capture fisheries has reached a stagnation phase with limited scope for further expansion. In this context, aquaculture plays a major role in increasing the fish production with further scope for expansion. Aquaculture is one of the fastest growing food-producing sectors globally, having the greatest potential to meet the ever growing demand of aquatic food around the world. The contribution of aquaculture to global supplies of fish, crustaceans, molluscs and other aquatic animals for human consumption continues to grow every year, and has reached 73.8 million tonnes in 2014. Aquaculture has been practiced using different strategies in land and open water areas. In the recent years, culture of fishes in cages in open waters is becoming popular as it excludes one of the biggest constraints of fish farming on land. This system of culture utilises natural currents, which provides the fish with oxygen and other appropriate natural conditions while also removing waste and eventually maximise the production. Presently, more than 62 countries are reported to involve in cage culture practises with more than 80 species. Marine cage farming is relatively recent, which was first developed in Japan. It is estimated that more than 90% of marine finfish aquaculture production is from cages.

In India open sea cage culture technology is new and relatively a recent activity. Understanding the importance of cage culture, Central Marine Fisheries

Research Institute initiated cage culture as Research and Development activity to identify appropriate design and suitability of cages suiting to the country's situation in the year 2006-2007. Thereafter, experimental culture of several marine finfishes like seabass, mullet, cobia and pompano was carried out at different location along the east and west coast of India. After successful demonstration, cage culture technology has spread in different maritime states and has showed encouraging results. Understanding the importance of mariculture in food security and income generation, the Government of India has taken several initiatives for providing greater boost to mariculture research and development. The All India Network Project on Maricultue (AINP-M) funded by ICAR, under the Ministry of Agriculture has been initiated by CMFRI in collaboration with different state fisheries colleges. The training programme was conducted as part of the Human Resource Development (HRD) programme under AINP-Mariculture project to develop technical skill among different stakeholders and to disseminate the technology in different locations. This training programme on "Cage Culture of Finfishes" will help fish-farmers to understand the intricacies associated with cage farming in Indian waters. This manual will serve as a stepping stone for the mariculture revolution in the country. We are indebted to Dr. A. Gopalakrishnan, Director, CMFRI for his support and encouragement in conducting the training programme and preparation of this training manual. We would also like to extent our sincere gratitude to the Project Co-ordinator, AINP-M and to all the contributors who have helped for the preparation of this training manual.

Shubhadeep Ghosh

Scientist In-Charge

Visakhapatnam Regional Centre of CMFRI,

Visakhapatnam

Overview of cage culture – Indian perspective

Shubhadeep Ghosh, Loveson Edward L, Uma Mahesh. V and Narasimhulu Sadhu
Regional Centre of ICAR-Central Marine Fisheries Research Institute, Visakhapatnam

Introduction

The decline of fish stocks has been a motivating factor for expanding the role of aquaculture in the fishing industry. Nowadays, the trend demonstrates that while wild harvest volume remains stable (or is in decline in several fisheries), aquaculture production has increased. In this situation, cage farming has an important role in meeting the global demand for fish products. It is one the alternative source to increase the aquaculture production. The development of this type of fish production is a long-term solution to meet the global demand for fisheries products and also provides economic opportunities for displaced and landless fishermen.

Cage culture of marine fish has grown rapidly over the last decade in Asia, Europe and Australia, utilizing inshore or offshore net cages. The cage farming industry, particularly in northern Europe, North America, Chile and Japan, expanded dramatically during the 1980s and 1990s, which attracted the interests of a growing number of large multinational companies seeking to diversify into a new and growing market and with resources to carry out research and development. Similarly the cage culture has spread to South East Asian countries and developed well. Of the estimated one million tonnes of marine fish cultured in Asia, probably 80-90 % is from cage farming. The major advantage in these countries is that they have large, calm and protected bays to accommodate the cages safely against natural bad weather conditions. Compared to that, India is endowed with very few such areas and the sea conditions are hostile at least during certain periods making the safety of structures uncertain. In the simplest term a cage is nothing but an enclosure in the water body whereby the juveniles of aquatic animals are stocked, fed and grown to marketable size. However, in practice it is very complicated in its structural, engineering, social and biological aspects.

Fish farming in cages is a lucrative business for poor coastal communities. In some countries and locations, cage farming provides an important source of fish production and income for farmers, other industry stakeholders and investors. In modern times, cage culture is also seen as an alternate livelihood, for the persons displaced by the construction of reservoirs or acquisition of land for other developmental activities. In such a situation, cage aquaculture has emerged as a promising venture and offers the farmer a chance for optimal utilization of the existing water resources which in most cases have only limited use for other purposes.

History

The earliest record of cage culture practices dates back to the late 1800 in Southeast Asia, particularly in the freshwater lakes and river systems of Kampuchea. Marine fish farming in cages traces its beginning to the 1950s in Japan where fish farming research at the Fisheries Laboratory of the Kinki University led to the commercial culture of yellow tail *Seriola quinqueradiata* and developed into a significant industry as early as 1960. Thailand has developed cage culture techniques for two important marine finfish: the sea bream (*Pagrus major*) and grouper (*Epinephelus* spp.) since 1970. Later, large scale cage farming of groupers were established in Malaysia in 1980. Korea started cage culture in the late 1970s and by the end of 1980, cage culture of the olive flounder

(*Paralichthys olivacens*) and black rockfish (*Sebastes schlegeli*) was established, and developed into a successful aquaculture industry in the 1990s. Cage culture of groupers (*Epinephelus* spp.) in the Philippines has been practiced since 1980s. Mariculture of milkfish in the 1990s led to the further growth and development of the industry. In Europe, cage culture of rainbow trout (*Oncorhynchus mykiss*) in freshwater began in the late 1950s and in Norway, Atlantic salmon (*Salmo salar*) followed in the 1960s. More than 40% of its rainbow trout comes from freshwater cages. Salmonid culture in cages is currently dominated by production from Norway, Scotland and Chile. Cage culture of fish was adopted in USA in 1964. In India, open cage culture started recently by CMFRI and it has demonstrated along the Indian coast in different states for culturing different species such as sea bass, lobster, cobia etc.,

Global Overview

The high tonnage production cage culturing industries has been established in marine environment in some of the temperate countries, and the species include yellowtail (*Seriola quinqueradiata*) and sea bream (*Sparus aurata*) in Japan and salmon/trout in worldwide. Only a small fraction of the world's total aquaculture production comes from cages. However, cage production is nevertheless sizeable, of high monetary value and growing at a very impressive rate. Although no official statistical information exists concerning the total global production of farmed aquatic species within cage culture systems or concerning the overall growth of the sector, there is some information on the number of cage rearing units and production statistics being reported to FAO by some member countries. The total reported cage aquaculture production during 2005 was 3.4 million tonnes. The major cage culture producers in 2005 included China (29%), Norway (19%), Chile (17%), Japan (8%), United Kingdom (4%), Vietnam (4%), Canada (3%), Turkey (2%), Greece (2%), Indonesia (2%), Philippines (2%), Korea (1%), Denmark (1%), Australia (1%), Thailand (1%) and Malaysia (1%). The fish family wise worldwide cage aquaculture production was dominated by salmonidae (66%) followed by sparidae (7%), carangidae (7%), pangasiidae (6%), cichlidae (4%), moronidae (3%), scorpaenidae (1%), cyprinidae (1%) and centropomidae (1%). There are at present 80 species of finfishes currently cultured in cages all over the world. Of these, *Salmo salar* accounted for half (51%) of all cage culture production. The other major contributors were *Oncorhynchus mykiss*, *Seriola quinqueradiata*, *Pangasius* spp. and *Oncorhynchus kisutch* contributing altogether 27% of total cage farmed fish. In addition, *Oreochromis niloticus* contributed 4%, *Sparus aurata* contributed 4%, *Pagrus auratus* contributed 3% and *Dicentrarchus labrax* contributed 2%.

Total European aquaculture production using cage culture technology was estimated at 2.2 million tonnes. Along Northern Europe, the production volume in 2004 was about 0.8 million tonnes of Atlantic salmon and about 80, 000 tonnes of rainbow trout. The European seabass and the gilthead sea bream are currently the most widely caged fish species in the Mediterranean. Production has progressively increased over the last ten years from 34,700 tonnes in 1995 to 137,000 tonnes in 2004, with an average annual growth rate of 17%. In 2004, the cage production of these two species accounted for approximately 85% of the total production. Salmonid production in cages each from North and South of America exceeded more than a few lakh tonnes.

Cage farming in brackish and inshore waters in Asia is relatively recent, started first in Japan. It is estimated that over 95 percent of marine finfish aquaculture is being carried out in cages in these region. Cage farming is most dominant in East and Southeast Asia, but not in South Asian nations. The main species farmed in brackish waters are the barramundi or Asian seabass (*Lates calcarifer*) and the milkfish (*Chanos chanos*). In inshore marine cage farming, apart from traditionally farmed species such as amberjacks (*Seriola* spp.) and snappers (*Lutjanus* spp.), cage farming of groupers (*Epinephelus* spp.) and cobia (*Rachycentron canadum*) is gaining ground in Southeast Asia. Grouper and snappers production from cages in Asia was estimated by FAO in 2004 at around 0.06 and 0.135 million tonnes, respectively.

The Japanese amberjack (*Seriola quinqueradiata*) is the main marine fish species cultured in Asia (mainly in Japan) in cages, comprising 17 percent of total marine finfish production, with just less than 0.16 million tonnes produced in 2003. Most production of cobia currently comes from the cages in China and Taiwan Province of China and totalled around 20,000 tonnes in 2003. Production of barramundi in cages increased during the past ten years, and FAO statistics estimated that 26,000 tonnes were produced in 2004. Milkfish (*Chanos chanos*) production in Asia in cages is significant, with Indonesia and the Philippines contributing the bulk of the 0.515 million tonnes as reported by FAO in 2004.

Growth performance of finfishes in cages

Observation has been made in different place showed that the fishes cultured in the cages are performing equally or even better than the fishes are in the wild. In addition, cage culture system provides scope for the growth enhancement for the fishes cultured through feed manipulation. The growth potential of the Asian seabass in floating sea cage was assessed in different locations all along the Indian coast by CMFRI. The juveniles of 28 g stocked in cage @ 60 no/m^{-3} have grown to 540 g in 112 days period at Vizhinjam Bay, south-west coast of India. Asian seabass fingerlings of 3.5±1.5 g stocked in cage has attained an average weight of 315.5 g in 120 days at Munambam, Cochin. At Karwar, Karnataka with survival rate of 68.8%, after 150 days of rearing, seabass reached 1.02 kg in weight and 412.05 mm in length. Sea bass attained an average of 29.45 cm body length and 996.62 g in body weight after 180 days of culture at Balasore, Odisha. At Rajulalanka, Andhra Pradesh, fingerlings with length and weight of 8.36±0.32 cm and 8.10±0.61 g were stocked in six cages at three different stocking densities, 15 m^{-3}, 30 m^{-3} and 45 m^{-3}, and after 150 days of grow-out, seabass fingerlings reached 36.0±6.0 cm and 690.7±41.3 g at density of 15 m^{-3}, 33.9±0.4 cm and 633.2±17.9 g at density of 30 m^{-3} and 30.2±0.4 cm and then 465.0±21.2 g at density of 45 m^{-3}.

Aquaculture of southern bluefin tuna in Southern Australia is based on fattening fish in offshore cages. Juveniles weighing 5 to 10 kg are caught offshore with purse seines and stocked into a cage. Growth rate of southern bluefin tuna in cages is estimated at 2 to 5% of body weight per day with a grow out period ranges from three to ten months. Cage culture of tilapia (*Oreochromis niloticus*) having mean initial individual body weight of 2.78 g in Brahmaputra river in varying stocking densities (100, 150 and 200 fish/m^3) revealed average daily body weight gains of 0.58±0.07 g, 0.67±0.06 g and 0.35±0.02 g, respectively. The net production rates were 7772±950 g/m^3/135 days, 13608±1261.70 g/m^3/135 days and 9444±600 g/m^3/135 days, respectively.

Spotted rose snapper stocked at body weight sizes of 24.5 ± 3.7 g, 55.4 ± 3.5 g, and 110.2 ± 4.6 g in three replicated marine floating cages of 100 m^3 and reared for 153 days at Mexico recorded growth increment of 0.93 g d^{-1}, 1.21 g d^{-1} and 1.83 g d^{-1}. Mean survival ranged from 67.5 to 74.7%. Mutton Snapper (*Lutjanus analis*) grew from an average weight of 12.25 g to over 300 g in nine months, indicating that the commercial size of 0.5 kg was achieved within a 1-year grow-out period. In nursery and grow-out offshore cages in Taiwan, 100–600 g cobia was cultured for 1–1.5 years and they reached 6–8 kg.

Integrated cage farming

Cage culture systems need to evolve further, either by going further offshore into deeper waters and more extreme operating conditions and by so doing minimizing environmental impacts through greater dilution and possible visual pollution or through integration with lower-trophic-level species such as seaweeds, molluscs and other benthic invertebrates. The rationale behind the co-culture of lower-trophic- level species is that the waste outputs of one or more species groups (such a cage reared finfish) can be utilized as inputs by one or more other species groups, including seaweeds, filter feeding molluscs and /or benthic invertebrates such as sea cucumbers, annelids or echinoderms. However, while there has been some research undertaken using land based systems considerably further research is required on open or offshore mariculture systems. Cage aquaculture will play an important role in the overall process of providing enough (and acceptable) fish for all, particularly because of the opportunities for the integration of species and production systems in near shore areas as well as the possibilities for expansion with sitting of cages far from the coast.

Capture based aquaculture

It is well known that the ready availability of seed in commercial quantities is one of the major limiting factors in the development and expansion of mariculture. The increasing exploitation pressure on the wild stocks of many major marine fisheries has led to overexploitation and consequent decline in their catch and hence the only sunrise sector to augment seafood production is through marine cage farming. Even-though the seed production technologies have been developed for many marine finfish and shellfish species, but still remains a fact that many of these technologies have not been scaled up to commercially viable levels. The hatchery seed production of many high value marine finfishes and shellfishes are complex and expensive due to the high costs involved in the establishment of broodstock and hatchery facilities and also to the complicated larviculture procedures involving culture of proper live feeds, their nutritional enrichment, feeding protocols, grading, water quality maintenance, nursery rearing and disease management. Even-though the production of seeds of the concerned species by development of commercially viable technologies is the ultimate answer for development of sustainable mariculture practices, it still remains a fact that many of these technologies are still in the emerging state and may take many more years for standardization on a cost effective level. Since the marine food production from the capture sector is declining, marine farming has to be developed and expanded urgently and it is not advisable to wait for the standardization of seed production technologies for all the concerned species. In this context, the concept of capture based aquaculture can be considered as a mid way point between fishing and aquaculture and requires to be developed into a sustainable commercial activity for augmenting the seafood production.

Capture Based Aquaculture (CBA) is the practice of collecting seed materials from early life stages to adults from the wild, and its subsequent on-growing in captivity to marketable size, using aquaculture practices. It is well understood that even-though the hatchery technologies have been developed for many high value species, the technologies still remain to be perfected and hence fish farmers have to depend on ‘seed’ available from the wild. Capture based aquaculture has developed due to the market demand for some high value species whose life cycles cannot currently be closed on a commercial scale. CBA is a world-wide aquaculture practice and has specific and peculiar characteristics for culture, depending on areas and species. The species/ groups harvested as wild juveniles at the different countries / regions where CBA is practiced include shrimps, milkfish, eels, yellowtails, tunas and groupers. Even though CBA could be considered as an unsustainable aquaculture practice in the long run due to the successive stock depletion to the wild stock, there are some aspects which highlight the importance and potential of this practice. It is generally considered that further development of marine aquaculture is possible only by the increase in mass production of juveniles in hatcheries. But it remains a fat that much of world's coastal aquaculture can still be expected to come from the supply and availability of capture-based juveniles. Many of the environmental concerns associated with the grow-out of juveniles produced in hatcheries like transfer of diseases and genetic pollution of wild stocks are not encountered in CBA. As 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 in future will increase significantly.

Capture based aquaculture can be considered the midway point between fishing and aquaculture, yet as a commercial activity it constitutes a distinct sector. A very significant proportion (millions of metric tonnes) of the total food fish (finfish, crustaceans and molluscs) aquaculture production reported by FAO is obtained through the on growing of wild caught juveniles (eels, grouper, yellowtail, tunas, milk fish, mullets, most molluscs and some marine shrimp is derived from CBA). Most of the production in CBA is from molluscs. Among finfishes eels, tunas, groupers and yellowtail represent a large proportion of the total volume and an even larger proportion by value. The total value of these four groups exceeded US$ 1.7 billion in 2000. It qualifies to be considered as a separate and distinct entity within the aquaculture sector because it has its own special culture characteristics. CBA is an economic activity that is likely to continue to expand in the short term, both for those species currently under exploitation and possibly with others that may be selected for aquaculture in the near future. In the case of shellfishes like mussels the activity will certainly continue in view of the large scale availability of natural seeds. It is felt that with effective regulations and management practices, the capture based aquaculture offers good scope and potential for the artisanal and industrial sectors in the years to come.

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Cage culture requirements - Site selection and water quality needs

Loveson L Edward, Suresh Kumar, P., Uma Mahesh. V and Jishnudev, M. A
Regional Centre of ICAR-Central Marine Fisheries Research Institute, Visakhapatnam

Introduction

Culture of fish in cage is a popular method of rearing the fish along the coastal areas. Site selection and water quality is one of the most important factors that determine the success and failures of cage culture system. It also determines the cost of production and survival of the system in the long run. Controlling water quality parameters in open water cage culture systems is an impractical; therefore, culture of any species must be established in the sites having adequate water quality and frequent exchange. Before establishing a cage culture site, it is foremost important to conduct a field survey for gaining prior knowledge on the environmental/ hydro-biological parameters of the site so as to ascertain that the water body chosen will support the increased biological demand due to cage culture activities in due course of time.

Topographical criteria

Wind and wave pattern

Cages used in culture activities are susceptible to damage by the strong winds and waves in the water bodies. Therefore, the site selected for the cage culture operation should probably in the site where the velocity of winds and wave action is less. In general, the protected areas in the seas or any other water bodies are the suitable place for the cage culture operation. The information on the prevalence of waves, winds and cyclones could be obtained from meteorological records or literatures. Usually the optimum wind velocity for stationary cage should be < 5 knots and for floating cage < 10 knots. For a stationary cage the area identified should not have a wave height of more than 0.5 m and not more than 1.0 m for floating cage. The selected site should be away from navigational routes, since waves may be created from the wake of passing vessels.

Depth

Areas with limited water depth like shallow bays are not suggested for cage culture since water renewal and settling of wastes may create problems. A depth of 8-10 m during lowest low tide is an ideal condition. A bottom clearance of 3-4 meter is necessary to allow sufficient water exchange. Good water exchange may increase oxygen availability, prevents accumulation of faeces, debris and uneaten feed and thereby prevents the cultured animals from noxious gases such as H_2S generated by decomposition of the deposited wastes. This eventually helps to keep the cultured animals away from stress and prevent the disease. But a stationary cage is allowed 1–2 m minimal clearance to minimize the costs of fixed poles, which are provided to withstand force of strong current if any. On the other hand, the area where the floating cage is positioned should have a maximum depth of less than 10 m, otherwise cost required for initial investment may increase. For a stationary cage the maximum depth should not exceed 8 m since it is difficult to find sufficiently strong supporting posts longer than 8 m for mooring.

Bottom

Sea bottom with a mixture of fine gravel, sand and clay are the ideal site for cage culture. The place with rocky bottom and mud substrates may cause difficulties and require more expensive anchoring system, but have better water exchange rate. Muddy substrates may be suitable for stationary cages as poles can be easily set up. But due to their low water exchange rate they are not suitable for high stocking density. Bottom water exchange is more important to prevent accumulation of wastes and oxygen deficiency. Therefore, the place with flat bottom and adjacent slope may bring in more water exchange and prevents waste accumulation thus forms a suitable area for cage culture.

Physical criteria

Current movement

Favourable tides and current brings fresh oxygenated water and remove waste from the cage. Tidal fluctuations are a primary need for better conditions for high stocking density of fish. But strong currents will generate excessive strain on the fishes as well as on the cage structure leading to damage and less growth of fish. A sound knowledge on tidal fluctuation and current pattern is necessary for positioning of the cage. So a weak but continuous current is most suitable for cage culture operation to bring in the necessary oxygen and to remove accumulated wastes. The ideal current velocity for cage culture operation is 0.5 to 1.0 m/sec. Preferred tidal amplitude of around 1 m is found suitable for marine cage culture.

Turbidity

Turbid water leads to deposition of unwanted wastes and increase organic loads in cage culture site by freshwater run-off from land leading to reduction in salinity. The accumulated waste harbours fouling organisms and microbes /pathogens and thereby prevents proper water circulation and causes health concerns to the fishes. Suspended solids in a suitable site for net cage culture should not exceed 10 mg/l. The turbidity in the water may be due to colloidal clay particles, dissolved organic matter and abundance of plankton. It could be measured with secchi disc visibility readings, and the optimum readings for marine cage culture site should be < 5 m as yearly.

Water temperature

Fishes are cold blooded aquatic organisms. It cannot control its body temperature with changes in the environment. The rise in the water temperature will affect metabolic rate, activity, carbon dioxide production, ammonia and oxygen consumption. This will in turn affect the feeding rate, food conversion, as well as fish growth. The optimum water temperature needed for cage culture of different species differs: 27–31°C for most tropical species and 20–28 °C for most temperate species. In tropical countries the annual temperature range fluctuates between 20–35°C and 2–29 °C in temperate countries. Some fishes can thrive in wide temperature range by compensating its growth. Therefore, it is essential to select the suitable site that may have the suitable temperature for the fish aimed for culture in order to do the culture with good economic benefits.

Chemical criteria

Dissolved oxygen

Dissolved oxygen requirements vary with species, its size and other environmental factors like temperature and salinity. The problem of dissolved oxygen occurs in any culture system which has direct contact with atmosphere and happens mainly during night hours. Benthic organisms and sediment wastes may also reduce the oxygen level in the case of cage culture. Increasing temperature and salinity will decrease the solubility of oxygen in water. Hence depletion of DO always occurs during night times. Grouper and other demersal species consume lesser oxygen when compared to fishes like rabbit fish, snapper and seabass of pelagic origin requires more oxygen. In general, pelagic fishes require dissolved oxygen level of 5 ppm or more and demersal fish species require 3 ppm level.

Salinity

Importance of salinity in cage culture lies over control of osmotic pressure which greatly affects the ionic balance of fish. Rapidly fluctuating conditions of salinity is not suitable for cage culture. Changes in salinity in coastal area are often caused by fresh water runoff from land. In areas where there is no proper mixing, the surface salinity is usually lower than bottom salinity. This prevents vertical transfer of dissolved oxygen and leads to oxygen depletion. The optimum salinity for better growth of different fish species are given below:

Species	**Salinity range (ppt)**	**Optimal Salinity (ppt)**
Seabass(*Lates calcarifer*)	0–33	15
Grouper(*Epinephelus* sp.)	10–33	15
Rabbit fish (*Siganus* sp.)	15–33	25
Snapper (*Lutjanus* sp.)	15–33	25

A normal strength of seawater (salinity) may be optimal for most tropical fishes; they cannot tolerate low salinities such as 10–15 ppt. Thus, the site selected for cage culture should have salinity range between 15–30 ppt for altering the species cultured according to market demands.

Ammonia

In cage culture system, the ammonia level in water is caused by the debris at the bottom and decomposition of uneaten food. Apart from this, sewage disposal and industrial pollution are also the source for ammonia in seawater. Ammonia is the most toxic form of inorganic nitrogen in water which can affect the fish. Ammonia toxicity increases with the increase in pH and temperature. The level of ammonia-nitrogen in the water should be less than 0.1 ppm.

Hydrogen ion index (pH)

Normally, seawater is alkaline with pH values of 7.5– 8.5. Hydrogen ion concentration or pH level at this range makes the water act as buffer to prevent changes caused by other factors. Extreme changes in the pH level of water may affect fishes directly by damaging its gills and leading to death. Estuarine areas where seawater is mixed by freshwater influx during heavy rain are prone for huge variation in pH. Increase in pH values will also affect the fish indirectly by increasing the toxicity of ammonia, heavy metals and several other common pollutants. The optimum range of pH for most marine species is from 7.0 to 8.5.

Nitrate (NO_3-N) and nitrite (NO_2-N)

Nitrite originates as an intermediary product of nitrification of ammoniacal N by aerobic bacteria. Higher amount of nitrite in water becomes toxic to fish due to oxidation of iron in haemoglobin. Marine water has high concentration of calcium and chloride which tend to reduce nitrite toxicity. Nitrate is the end product of nitrification of ammoniacal nitrogen by aerobic autotrophs. Nitrate serves as fertilizer for phytoplankton, so the increase the nitrate level in the water leads to increase the concentration of unwanted phytoplankton bloom.

Land drainage is also another source for the presence of nitrate in the water. Nitrate (NO_3-N) and nitrite (NO_2-N) also contribute to the level of inorganic nitrogen in seawater. The total inorganic nitrogen for marine animal culture is < 0.1 ppm.

Phosphate

Phosphorous is a limiting nutrient needed for the growth of micro algae and aquatic plants. In natural water the total phosphate content may range from 0.01 to more than 200 mg/litre. However, excess concentrations of phosphate can result in algal bloom which causes the sudden depletion in the level of oxygen in seawater. The optimum level of phosphate for a cage culture site should not be higher than 0.015 ppm.

Organic load

Dead phytoplankton, sewage discharge, industrial effluents, uneaten food and fish waste in the cage, becomes the source for organic load in water. This high organic load not only causes bacterial infection in fish but also lowers level of dissolved oxygen in water. The organic load in water can be measured by Chemical Oxygen Demand (COD) which should be less than 1 ppm for a suitable site.

Heavy metals

Industrial effluents and other anthropogenic activities are the main source for most heavy metals which are found in seawater. So the site selected should be free from high level of heavy metals or it may become a source for toxicant to humans who are ingesting the cultured fish. Therefore, it is always better to select an area which is away from industrial activities and sewage discharge site. Heavy metals of importance to human and cage culture and their acceptable / safe limits are given below

Heavy metals	Acceptable limits (ppm)
Manganese (Mn)	< 1.0
Iron (Fe)	< 1.0
Chromium (Cr)	< 1.0
Tin (Sn)	< 1.0
Lead (Pb)	< 0.1
Nickel (Ni)	< 0.1
Zinc (Zn)	< 0.1
Aluminium (Al)	< 0.1
Copper (Cu)	< 0.01
Cadmium (Cd)	< 0.03
Mercury (Hg)	< 0.004

Other pollutants

Domestic sewage contains pollutants, detergents, toxic substances including several organic matters which affect cage fish farming. Several products used in agriculture also makes an entry in to the cage farming systems such as herbicides, insecticides and animal wastes, which might be engulfed by fish and leads to its death. For examination of above toxins, it needs regular sampling and high end equipments in the laboratory. Selecting a site for cage culture away from such contaminations may avoid risk of such happenings in the culture period. The acceptable level of Biological Oxygen Demand (BOD) should not exceed 5 mg/l at 5 days period.

Biological criteria

Fouling organisms

Fouling organism comes along with the silt particles which gets colonized at the cage net and frames as substrate. Out of the fouling materials, more than 50% will be of silt origin. Fouling leads to clogging of net mesh, which restricts the water flow, lowers the dissolved oxygen and prevents waste removal from the cage. Fouling rate depends on the surrounding environment and materials used for cage and net fabrication. Marine waters are more prone for fouling than in brackish water as per the earlier reports on cage and pen culture. Frequent cleaning and washing is required in areas of high fouling growth, to facilitate water exchange and to reduce the additional weight on cage frame. This makes net changing troublesome, tedious and time consuming. To optimize the running cost, cages should be located in places unfavourable for the growth of fouling organisms.

Phytoplankton

Favourable conditions including physical and chemical parameters may promote sudden burst of algal growth leading to its bloom. A site which is prone for sudden bloom may be avoided while selecting for cage farming. Algal blooms create problems to fish, directly by clogging its gills, and indirectly by depleting dissolved oxygen at night. Toxin producing blooms not only kill the fish but also pose high danger for human consumption. Algal blooms might also occur if the source water contains fish farm wastes and effluents from fertilizer plants. Thus, care should be taken and proper enquiries should be made along the nearby areas for such occurrences before selecting a site for cage farming

Accessibility

The cage culture site should have access to both water based and land based mode of transportation. Hassle free transportation leads to availability of culture needs (seed, feed, fuel) and other supplies which are necessary. A floating raft with cabin for labourers close to the cages would increase their productivity. It would enormously optimize production costs if other supplies which are necessary are nearer to cage culture sites.

Social problem

Security is a big concern while selecting a suitable site for cage culture. Since cage culture units are located in natural water bodies, laws and regulations are necessary to safe guard the cage reared animals from theft. There is a risk of probable pollution and conflicts which may occur with common users of the sea such as harbours and other marine related industries. This always leads to conflicts and finally leads to poaching problem. One should be cautious to prevent poaching, and wise to select a site away from villages and common users to prevent such future problems.

Legal aspects

Most nations have a rules and regulations for leasing open water bodies for fisheries and aquaculture use. Government has the full rights over the land below the low tide level. Several nations instruct farmers to take prior permission or license before starting a cage culture venture with restrictions over area, species, size and type of culture practised. To avoid future conflicts with end users, prior identification of suitable sites for cage culture may be carried by the licensing authority. Lease, license and regulation rules and procedures have to be formulated in advance to avoid any obstacle and lengthy processing involved in obtaining permission. Cage culture operations should strictly follow the norms required by the government to avoid future problems and to sustain cage aquaculture as a profitable venture.

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Engineering aspects of cage design, mooring and net design for open sea cage farming in India

Biswajith Das, Ritesh Ranjan, Shubhadeep Ghosh, Narasimhulu Sadhu and Vamsi Balla

Regional Centre of ICAR-Central Marine Fisheries Research Institute, Visakhapatnam

Introduction

Cage is an aquaculture production structure comprising of a rigid floating frame, flexible net materials and mooring system (synthetic mooring rope, buoy and anchor) with a round or square shape floating net pen to hold and culture large number of fishes and other aquatic resources which can be installed in reservoir, river, lake or sea. The design and operating variables in engineering aspects of an open sea cage is of great concern in mariculture operations as they are installed in exposed sites in the off shore areas. The design of the cage and its accessories is specially made in agreement to the individual farmer's requirements. A well engineered cage design will provide the opportunity to reduce the cost of the cages. HDPE material is found to be suitable to make cage frame for open sea cages. The HDPE float frames installed in open unprotected water can withstand wave conditions. Round cage (volume depends on diameter) with floatation system made of butt-welded HDPE pipes, designed for the culture of fishes such as milkfish, mullet, cobia or pompano, sea bass and lobsters, and this very well used in many countries. However, the sea is perhaps the most difficult environment for engineering operations. The sea generates great storm forces on any floating or sea bed mounted structure and the storm events occur randomly. The constant 24 hour per day bending compression and tension within structural member are optimum conditions for fatigue. Similarly constant motion in a corrosive fluid is ideal for mechanical wear and corrosion. Repairs and salvages are more difficult and in some cases access may be denied to some structures during a storm. Because of all these reasons the design of an aquaculture cage system is very complex in nature and of-course the most difficult task. Hence, it is essential to select a proper site, ideal construction materials and proper designing, suitable mooring and good management in bringing out cage culture production more viable, economical and profitable. The cage frame and nets used for cages has to withstand all types of weather conditions in the entire year. Next to frame, net is another important component in the cage and damage of the net is an important source of fish loss in cage culture systems. Thus, many considerations are to be taken into account while making a net for a specific purpose including forces applying on the net, kind net of materials, make of rope frame and the way in which the nets are tied. The main forces on any net structure are from winds, waves and currents and the interactions of the cage structure and its mooring systems with the resulting movements. Thus, cage systems in open sea are influenced by several prevailing conditions in the sea that may affect the safety of the system and cultivated fish species, if the system is not properly designed or engineered. Hence, cage design plays major role, because the designed cage need to withstand strong sea currents/ tidal flow and retain their effective volume; developing cages that should better suited to the sea conditions in different regions and to different species. In addition, it is also essential to implement well engineered design to lower the cost and increase the performance of the cage system. In this respect, the following factors are needed to be considered

Size of the cage

It is a fact that costs per unit volume decrease with increasing cage size, within the limits of the materials and construction methods used. However, very large cages may limit stocking, grading and harvesting options, and maintenance aspects like net changing and disease treatment also become increasingly difficult as size of cages increase. CMFRI has developed open sea cages of 6, 12 & 15 m dia for grow out fish culture and 2 m dia HDPE cages for seed rearing. However, the suggested ideal size for grow out cage is 6 m due to its easy manoeuvring and reduced labor. Presently, in India 6 m dia circular cages being popularly used in both west and east coasts.

Cage frame design

The design parameters for the cage frame are based on several earlier experiments of cage farming in India, as well as on guidelines from published studies. The size and shape of the cage were firstly defined by applying the criteria of Huguenin (1997) and Beveridge (1996), and the structure and floating system is defined on the basis of experience of Indian farms. The weight and flotation of the cage is calculated by applying formulas and data defined by Prado (1990). The current, wind and wave forces applied in the cage were calculated using the criteria of Milne (1972), Fridman (1986), Carson (1988) and Aarsnes *et al*. (1990). The cage frame may be of any shape such as circular, square, rectangular and octagonal shape. However, the circular shape is found to be more suitable as this shape makes the most efficient use of materials and thus reduce the costs per unit volume. Also, observations made on the swimming behavior of fish, suggest that circular shapes in a plane area are better in terms of utilization of space. Corners of other shapes (rectangular, square, and octagonal) are not properly utilized by the stocked fishes in the cage.

The cages are commonly made by three different materials, i.e High Density Poly Ethylene (HDPE) and Galvanized Iron (GI) and wooden bamboo poles. The HDPE cages are comparatively costlier than GI cages. However, business entrepreneurs with high capital investments can go for long lasting and expensive (HDPE) frames. Small groups and fishermen can opt for cost effective epoxy coated GI frames in sea and some extent wooden cages in brackish water creek areas. Moreover, the HDPE is best suitable material for the cage frame with respect to its durability and strength. The cage frame prepared using HDPE pipe is given as example and the specification of the material required for the six meter diameter cage frame is given in Table 1. The 6 m dia HDPE cage consisting of 6 m inner dia and 8 m outer dia frame material with provisions for connecting inner grow out and outer predator nets, respectively. The cage frame structure is the combination of different structures including, flotation pipes, collars and hand rails. The two floatation pipes (base pipes) generally filled with expanded polystyrene foam material to help for the more flotation of the pipes and also to avoid loss of floatation force in case of the pipe damages. The catwalk goes round the entire cage; the purpose is to supply support to the structure and to make maintenance, feeding, cleaning and other required activities easy. The hand rail is provided for the safety of the workers and to carry out easy way of routine cage management. The collars are another structure made by HDPE pipes used for maintaining the structure, and at the same time helps for flotation. The measurements of handrail and catwalk are according to the convenience of the fishermen. This catwalk can be built of polyethylene panels with stainless steel joints connected between the brackets. Ballast pipe is another structure used in the cage, which helps to keep the nets in proper position and serve as role of sinkers in fishing net. The ballast pipe is either filled with heavy materials or made with the holes for the free flow of the water to increase the weight of the ballast, and some time uses iron ropes inside pipe for increasing the weight. While making cage, the end of the base pipe is joined by welding process used for plastics. The two pipe rings for flotation and brackets will join the handrail. These brackets will give support to the rings and at the same time, it will form part of the catwalk. The brackets will be made of galvanized steel to avoid corrosion and be fitted to the diameter of the pipes. At the same time, these connections hold the brackets in their place to avoid movements in the rings and loss of shape.

Table 1. Specifications of material required for six meter diameter cage frame

Cage Part	Specification	HDPE pipe (outer dia)	HDPE Pipe (inner dia)	Thickness of Pipe	Circumf-erence / Length	Total require-ment
Outer collar	PE100 PN 10 IS 4984	140 mm	126 mm	16 mm	8 m dia	25.12 m
Inner collar	PE100 PN 10 IS 4984	140 mm	126 mm	16 mm	6 m dia	18.84 m
Middle support collar	PE100 PN 10 IS 4984	90 mm	78 mm	12 mm	5.5 m dia	17.27 m
Hand rail	PE100 PN 10 IS 4984	90 mm	78 mm	12 mm	6 m dia	18.84 m
Base Bracket Support	PE100 PN 10 IS 4984	250 mm	228 mm	22 mm	1.2 m	9.6 m
Base bracket vertical Support	PE100 PN 10 IS 4984	90 mm	78 mm	12 mm	0.7 m	5.6 m
Diagonal support	PE100 PN 10 IS 4984	90 m	78 mm	12 mm	1.2 m	9.6 m
Injection moulded machined “T” joints	PE63 PN 10 IS 4984	110 mm	92 mm	18 mm	NA	26 nos.
Injection moulded Long neck collar flange	PE63 PN 10 IS 4984	110 mm	90 mm	20 mm	NA	8 nos
Mooring clamps	Hot dip galvanized iron clamps	NA	NA	12 mm	140 mm OD	3
Nut & bolts	High tensile, tested SS material	NA	NA	25 mm	NA	6
Butt welding supporting base floating collar clamps	2 hot dip galvanized iron clamps	NA	NA	8 mm	NA	4
Butt welding supporting base floating collar clamp nut& bolts	High tensile SS material	NA	NA	16 mm	NA	8
Joint supporting nut & bolts	High tensile SS material	NA	NA	18 mm	NA	52
Longneck Bird net hooks	GI	NA	NA	22 mm	NA	8

Fig.1. View of 6 m diameter HDPE floating cage

Mooring system

The mooring system holds the cage in the suitable position according to the direction and depth decided in the design, and sometimes this helps to maintain the shape of the cage. The mooring joins the cage at the anchor system. A mooring system must be powerful enough to resist the worst possible combination of the forces of currents, wind and waves without moving or breaking up. The materials used in the mooring systems are sea steel lines, chains, reinforced plastic ropes and mechanical connectors. The mooring force capacity depends on both the material and size, and can be adjusted to the requirements. Attachment to the system is by metallic connectors and ties. It offers operational advantages since it allows the cage to drift around the anchor with the current to the point of least resistance, which exerts the least force on the system. This movement allows the cage to have wide area of seabed and by which it could reduce the accumulated waste and pollution problems. Preliminary analysis of the benefits of this system indicates a 2 to 70 fold reduction in deposition of waste on the seabed, depending on mooring geometry and current type.

Mooring system used in most of the Indian cages consisting of 14 mm GI moulded link chain, swivels, C hook, 4 mm U shackles, barrels and cement blocks. C hook or U shackles connect anchor to the GI link chain and swivels is used 5-6 from the anchor, which helps to rotate the cage according to the different force. A cement block of 100-150 kg is used 2-3 m away from cage in mooring system as shock absorber; this system ensures soft movements of the cage with the currents by absorbing possible shocks. The vertical position of the weights depends on the forces acting upon it, thus acting like a shock absorber. In mooring system 2-3 barrels filled with air is used as floating system to identify mooring line. The required depth of the water column for efficient mooring is 12 m and 10 m during high and low tides respectively, with mud-sandy bottom.

Anchor system

The anchor system holds the cage and all other components of cage in a particular site in the seabed and is connected to the cage by the mooring system. There are basically three types of anchors used: pile anchors, dead weight anchors and anchors that get their strength by engaging with the seabed. Pile anchors are buried piles in the seabed, they are effective, especially for systems where a small space is necessary, they are driven into the seabed usually by a pile hammer from a barge on the surface; but, they are expensive to buy and install. Dead weight anchors are usually concrete blocks, and the advantage of the system is that they are fairly consistent in holding power. Hard sand, rock or gravel make no difference to concrete blocks, they can resist at least their own weight in water in soft seabed conditions. This system can hold more than 3-5 times of their own weight under any condition. The third type is mooring anchors; this has to hold into a particular seabed when pulled from one direction only; they are made of steel and should slip easily into the seabed without disturbing the soil. The holding power of the anchor could be increased enormously, if the substrate is compact. All type of anchors is joined to the mooring system usually by chains and metallic connectors. In the east coast of Indian seas, different types of anchors were tried by CMFRI. Presently, dead weight anchor is mostly recommended for its strength and their easy deployment. The concrete blocks (100-150 Kg each) of 10-12 joined together by chains to provide appropriate strength and connected to a buoy by a braided rope. Several concrete blocks instead of one make the building, moving and setting of the system easy and also, this allows to have several points of anchoring. The chain used to connect the anchors to cage is of 1.3 cm is size with 80 grade strength. This specification of the chain is found to be suitable for the prevalent sea condition in the east coast.

Concrete block

Revolving swivel

Mooring chain

Puff filled buoy to hold the mooring chain

Fig.2. Components of mooring system

Net design

The cage bag is a flexible mesh material, which can be prepared by the different synthetic materials, including polyethylene (PE)/ High Density Poly Ethylene (HDPE), polyester (PES) and polypropylene (PP) or polyamide (PA). Among all, the PE material offers economic and technical advantages such as breaking strength, resistance to fouling and resistance to abrasion. The shape of the cage bag is cylindrical with a bottom lid. There are two net bags are used in a cage, i.e., inner and outer net bags. The mesh size of the both net bags are differs and it is majorly depends on the type and size of the fish planned for the culture. The square shaped mesh size is always preferred and to get the proper shape the net panel is attached to head rope with a hanging ratio (E) of 0.71 to produce square meshes, which helps against fouling and provides maximum surface area. Proper mesh size helps for free flows of water, which helps to maintain good water quality and finally it helps to reduce stress, improve feed conversion of the fish in the system. The net material impregnated with a special anti bio-fouling material helps to prevent growth of algae.

Fig.3. commonly used inner and outer nets in cages

While preparing net bags, eight crisscross ropes are provided in net bag to strengthen the net bag. The inner net bag is fitted to the upper side handrail and lower inner collar by the help of rope, which holds net in cylindrical shape. The outer net bag is fixed to the outer collar of cage. The bottom of the inner net bag is provided with ballast pipe for maintaining the shape of cage. A bird net is fixed to the top of the cage frame (hand rail) to avoid the menace of birds.

Table.2. Specifications of nets for a cage of 6 m dia. and 6 m depth used for fish culture

Name of the net	Material Specification	Twine size	Mesh size	Depth of the Net	Net bag diameter
Outer net	HDPE braided	4 mm	90 mm	6.25 m	6.75 m
Inner net	HDPE Sapphire	2 mm	20 mm	6.70 m	6.0 m
Juvenile net (Seed net)	HDPE Sapphire	1.5 mm	12 mm	3.0 m	6.0 m
Bird protection net	HDPE	1 mm	90 mm	NA	6.0 m

Nets of varying dimensions made by different materials were tested for cage culture in India. After the through research, CMFRI has suggested to use braided and twisted HDPE nets for grow out purpose. It can last for more than two years. Nylon net can be used economically, but since it is light weight, to hold the shape intact more weight has to be loaded in the ballast pipe. The commonly used depth for the net ranging from 2 to 4 m for fingerlings and 5 to 6 m for grow out cages. For open sea cage culture, predator net is compulsorily recommended to prevent the attack by predatory organisms.

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Selection of candidate species for cage culture in India

Biji Xavier, Sekar Megarajan, Vamsi Balla and Ponnaganti Shiva

Regional Centre of ICAR-Central Marine Fisheries Research Institute, Visakhapatnam

Introduction

In recent years, cage culture has emerged as one of the most viable method of sea farming. This aquaculture farming system offers the farmer a chance to utilize existing water resources, which is not used for other purposes. At present, situations like increase in consumption of fish, decline in wild stock and poor return from other culture systems paved strong interest for the fish production through cage culture among the fish farmers. Selection of fish species is playing major role in cage culture operation. Therefore, while selecting the species the biological as well as economical criteria should be taken into consideration, which includes available source of fish seed either from wild or hatcheries, seasonal abundance of the fish seeds in wild, acceptance to artificial feeds, consumer acceptance to the fish, economic value of the fish in local and international market, regional preference, compatibility of the species to culture in various system, resistance to disease and stress, ability to breed and produce the seed in confined environments. By considering the above criteria, a variety of commercially important marine fish species are highly found suitable for cage farming. The important candidate species from different parts of the world includes cobia (*Rachycentron canadum*), seabass (*Lates calcarifer*), snappers (*Lutjanus sp.*), pompanos (*Trachinotus sp.*) and groupers (*Epinephelus sp.*), etc. Commercial level seed production technology for majority of these fishes has been developed in many of the South East Asian countries. In India, the seed production of cobia, silver pompano, seabass and orange spotted grouper has been achieved successfully by different fisheries research institutions.

Availability of seed

Availability of adequate quantities of seed stock is an important criteria for species selection in cage culture operation. It is important because, without a certain and ready supply of seed at stocking time, farming becomes unpredictable. Seed is usually fry or fingerling either wild-caught or hatchery produced. In case of wild caught seeds, supply is usually seasonal and unpredictable but they are more robust and hardy as they have already undergone pre-selection by nature. In the case of hatchery produced seeds, supply is more predictable and could be produced on schedule in batch-operation sequence. It is always advisable to select the species for which the hatchery production is in commercial scale, because the farming operations started by rely on wild caught seeds are not withstanding for long period due to scarcity of seeds. Though the seed production technology has been standardized for several species of marine fin fishes around world, in India presently hatchery seed production technology has been well developed only for cobia, pompano, seabass and orange spotted grouper and they form the suitable species for culture. In addition, *Epinephelus* spp, *Lutjanus* spp and *Acanthopagrus* spp are collected from wild and cultured in cages. Although many species are being cultured throughout the world, *Lates calcarifer*, *Epinephelus* spp, *Trachinotus* sp. *Rachycentron* sp. *Lutjanus* spp, *Acanthopagrus* spp. *and Panulirus* spp are found to be more suitable species for cage culture in India with respect to seed availability.

Seasonal abundance of fish seed

Seasonal abundance for different species of fish seed need to be considered for cage culture operation where the practice is depends on the wild seed resources. This information is essential to plan the cage culture operation in well advance. In India, recently concentrated effort has been put to collect the information regarding the availability of seed from wild by CMFRI and other fisheries colleges across the Indian coast under the All India Network Project on Mariculture. This will certainly help to get the clear picture on the seasonal availability of fish seeds in different parts. In Andhra Pradesh availability of wild seabass fish seed observed in the month of April to December.

Stocking density

Stocking density depends on the carrying capacity of the cages and the feeding habits of the cultured species. Optimal stocking density varies with species and size of fish. Uniform sized fish should be stocked in the cage to obtain growth of the fishes, which will help to avoid cannibalism among the stocked fishes. Stocking at lower densities will help to get bigger in shorter time than the stocking fishes at higher densities. However, stocking fish at densities lower than recommended numbers may result in aggressive behaviour. The best time for stocking is when the water temperature is cool. This will reduce the handling stress, stress related disease and mortality.

Fast growth and time to reach marketable size

Most of the aquaculture production system in confined environment is constrained largely by the growth efficiency of the species cultured. Thus, the growth rate of the fish is an important criteria for the selection of a particular species. The fish species with medium to fast growth rate is considered as suitable for the culture, essentially the fish with fast growth rate will help to get maximum economic benefit to the farmers. In general, the selected fish should reach at least the table size within 6-8 months of culture period, eg: sea bass, grouper, snapper, cobia etc. The optimum market size for the fish is around 500-800 g. However, fishes like cobia and seabass grows more than 1 kg/year after stocking in grow out system. In addition, factors like feeding, water quality and stocking density, etc plays important role in enhancing the growth rate of the fish in a culture system and manipulating these parameters may have positive impact on the growth.

Acceptance to artificial feed / external feed

Acceptance to artificial feed by a fish plays major role in selecting the species for cage culture activities since there are no significant sources of food except for small fish which stray in and out of the net. So, the selected fish must be able to accept external source of food especially if the species is carnivorous. The external source of feed may be of natural source, usually chopped trash fish or sometimes artificial feed (floating/sinking/slow sinking pellet). The response of the fish towards feeding differs according to the species, so the feeding should be depends on the feeding behaviour of the fish. It is observed very well that the fishes like grouper, sea bass, snapper and pompanos respond very well to the artificial feeds that are given in the cage. Therefore, these kinds of fishes are most suitable for cage culture activities since they utilize the feed efficiently and avoid feed wastage.

Consumer acceptance and price of the species in the market

It is very important character to select the for any culture operation, the fish should get good consumer acceptance with high market value to cope up with relatively high cost of production in net cage farming and also to get high profit to the farmer/cultivator. Species having high market value in live fish trade would be more appropriate for cage culture, e.g grouper and other reef fishes. The biggest advantage of cages is that the fish can be easily harvested in live condition and marketed as per market demand. Some of the important potential high value finfishes and shellfishes available in India are: groupers, snappers, seabreams, cobia, sea bass and lobsters.

Regional preference of the species

It is understood very well from the long observation is that some of the fish species are popular in specific region of the country because of their availability, taste. Thus, they are mostly preferred in that region and fetching high price in the market. The selected species for cage culture should have either international acceptance or regional preference. In India, fishes like, Indian sand whiting *(Sillago sihama*), pearl spot (*Etroplus surentensis*) and hilsa (*Tenualosa ilisha*) are considered as delicacy and poplar fish in states like Karnataka, Kerala and west Bengal, respectively. These fishes can be given preference along with the fishes of international importance for the culture in cages.

Compatibility of the species

Integrated multi-trophic aquaculture (IMTA) is an ecosystems approach in mariculture that has been proven to solve sea pollution problems associated with fish culture mainly in temperate waters. In this system, the organisms occupying different tropic level maintained in the same culture system and it is different from poly culture. This type of culture mainly practised in many of the countries for the farming of different species, where the wastes of one species recycled as feed for another species. While selecting species for this kind of culture, the main target cultured organisms such carnivorous fish is nourished by feed such as artificial pellets or trash fishes. The co-cultured organism that is the extractive organism is extracts their nourishment from environment i.e. the waste of fed fish (cultured fish). The two economically important cultured groups that fall into this category are bivalves (oysters and mussels) and seaweed. Combinations of co-cultured species will have to be carefully selected by understanding the compatibility the organisms. In India, green mussel has been cultured with carnivorous fishes like seabass and cobia and this system of culture has shown as successful method of culture.

Resistance to stress and disease

Species selected should be hardy and tolerant to the stress conditions like confined environment, crowded conditions and rigorous handling during net changes in cages. Stocking density in net cages is comparatively higher than the pond culture. Therefore, in net cages the fishes are subjected to greater physical contact and stress during feeding as there is often a rush for the food by the entire fish population in the net cage. If the fishes in the cage are not able to manage to the stressful condition in the cage, then it may leads to secondary bacterial infection, eventually stock in the cage may collapse. Thus, the selected species should with stand the above condition. In India, fish species such as seabass, cobia, groupers, and snappers have found to be potential species for culture and they with stand to the stressful condition prevalent in cages.

Ability to reproduce and spawn in captivity

Availability of sufficient number of fish seed is the major factor for the sustainable production of fish through cage culture technology. A fish species for which the seed production and nursery rearing technology has been standardised in confined environment may be suitable species for the culture, since continuous seed may be available for the uninterrupted culture. Breeding, seed production and nursery rearing techniques in confined system has been developed for more than 20 number of marine fin fishes species in different countries across the world. In India, seed production techniques for fishes like cobia, seabass, silver pompano and orange spotted grouper has been standardised and they may be suitable species for culture in cages.

Candidate species for cage culture in Asian countries

Brackish water and marine farming is dominated by few species. Marine fish farming is entirely from cage farming and the leading fish species in cage culture are follows:

Species prescription	Advantages	Constraints
Chanos chanos (milkfish) • Major producer: Philippines, Indonesia, Taiwan province of China. • Production: 872 184 tonnes in 2012	• Omnivorous/herbivorous. • Fast growth in both pond and sea cages (commercial size in 6 months) • Fry available from the wild • Tolerates high fluctuations in salinity. • Suitable for polyculture.	• Hatchery successes are yet to be standardized in most of the countries and mostly rely on wild fry. • Moderate-to low-value fish. • Only suitable for domestic markets
Lates calcarifer (barramundi) • Major producer: Indonesia, Malaysia and Taiwan Province of China. • Production: 185 073 tonnes in 2012	• Hatchery seed production standardized. • Fast growth (plate size in 4 months, 1 kg in 8 months). • Suitable for both pond and cage culture. • Very high tolerance of salinity and water variations (freshwater to marine culture). • Ideal species for culture high demand for fresh fish in local consumption.	• High protein diet is required. • High cannibalism.
Rachycentron canadum (cobia) • Major producer: China and Taiwan province of China. • Production: 41 399 tonnes (2012)	• Routinely produced in most hatcheries. • Very fast growth (6–7 kg in year). • Suitable for high-density cage culture and easy to culture and manage.	• High protein needs but quite good FCR (<2). • Needs relatively large production units, less than 30°C & high-quality water. • Sensitive to diseases,

	• Suitable for mass production of white fillets (fresh/frozen). • The survival rate in grow out is high, and it is not difficult to obtain 90% average survival.	especially in lower quality water. • Not very high value on fresh domestic market or whole fish export market.
Jacks *Seriola quinqueradiat, S. rivoliana & S. lalandi* (amberjack) • Major producer: Republic of Korea. • Production -177 909 tonnes (2012) Japan – major producer (160 215 tonnes)	• Fast growth (2 kg in 12 months). • Suitable for intensive hatchery production. • High retail prices. • Suits fresh fish market and sashimi market. • Suitable for both export and local market.	• Brood stock can be hard to find & not well known in most areas. • High protein needs, mostly very high lipid needs (20% or more) and quite high FCR (>2). • Sensitive to parasites. • Subtropical species that might only be for culture in areas.
Siganus spp (rabbit fish)	• Omnivorous/herbivorous. • Medium growth (commercial plate size in 9–12 months). • Suitable for cage culture and tolerant of high stocking densities. • Some species can tolerate variations in water quality (*S. lineatus*). • High prices in some areas. • Suitable for capture based aquaculture (CBA).	• Hatchery production not yet fully developed for all species. • It has venomous spines, which might cause handling problems during culture and harvest. • Value is moderate in some areas. • Known to graze on net cages and thus damage them.
Snappers: (*Lutjanus argentimaculatus*) (mangrove jack) • Major producer: Malaysia , Cambodia, Brunei, Darussalam, Hong Kong SAR, Singapore and the	• Valuable if fish is in red coloration. • Suitable for cage culture. • Tolerant of low salinity. • Tolerant of water-quality variations. • Native to most places with estuarine systems.	• Cultured mangrove jacks are usually grey in colour (lower value). • High protein needs. • Slow growth. • Market value is medium.

Philippines. • Production: 7 283 tonnes (2012)		
Lutjanus sebae (red emperor)	• High-value fish for both fresh export market and local markets. • Suitable for cage culture.	• Routine hatchery production yet to be demonstrated, but has been demonstrated for some species from same genus • High protein needs.
Epinephelus spp (groupers) • Major Producer: China, Taiwan, Indonesia, Malaysia, Thailand, and Philippines. • Production -118039 tonnes (2012)	• Hatchery techniques have been standardized for few species of grouper. • Suitable for both cage and pond culture. • Can be a by-product for shrimp farms. • High prices in live fish market. • High prices on most domestic and international market. • Medium size fish, which makes it easier to handle than other larger species. • Relatively fast growth (plate size in 9-12 months).	• Need high protein diets. • High cannibalism during late larval rearing and early nursery phases. • High competition for export markets with Southeast Asia.
Asian or silver Pompano (*Trachinotus blochii*) •Production - 110,000 tonnes (2011)	Optimum growth, suitable for intensive hatchery production, high retail price and easily acclimatised to different range of salinity and well acceptable for artificial feeds.	• Need high protein diets.
Mugil spp (mullet) • Major Producer: Egypt, Republic of Korea, Italy, Taiwan Province of China and Israel. • Production-13 890 tonnes in 2012	• Fry available from the wild. • Good candidate for food security in densely populated areas, at family scale if juveniles available. • Tolerant of water quality. • Suitable for both pond and cage farming.	• No export value. • Low value in most fresh fish markets. • Hatchery production yet to be standardized in several places.

Important cultivable species

Lutjanus argentimaculatus: Mangrove red snapper

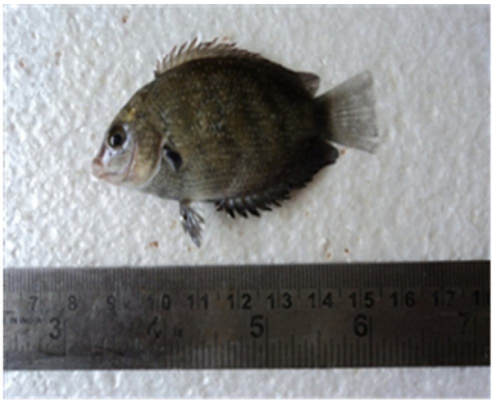
Lutjanus johnii : Golden snapper

Lates calcarifer - Seabass

Chanos chanos - Milk fish

Siganus javus - Streaked spinefoot

Trachinotus mookalee – Indian pompano



Etroplus suratensis : Pearl spot

Epinephelus coioides : Orange spotted grouper

Rachycentron canadum : Cobia

Sillago sihama : Indian sand whiting

Trachinotus blochi : Silver pompano

Mugil cephalus: Grey mullet

Other species

Apart from mentioned species, a wide range of other species are cultured, including threadfins, croakers, drums, gobies, scorpion fishes and others. Many of these species are grown at least on an occasional basis in marine cages. Therefore, above mentioned characters should be critically analysed and give most importance while selecting species for cage culture activities. Some of these characters may have more importance in different places and accordingly those characters need to be given more priority in specific locations to reap the more economic benefit and make the culture system sustainable.

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Different aspects of cage culture management for sustainable fish production

Ritesh Ranjan, Pralaya Ranjan Behera, Biswajit Dash and Chinnibabu. B
Regional Centre of ICAR-Central Marine Fisheries Research Institute, Visakhapatnam

Introduction

A technological intervention has been the major impetus for the rapid development of cage farming of marine fishes across the world. In spite of the various technologies available for the fulfilment of high production and proper installation of the cages, it is necessary to optimise the many factors periodically to avoid the adverse impact of environmental and ecological factors for long maintenance of cages and also to maintain the healthy animals in the cage. In this context, monitoring plays vital role in any type of mariculture activity. Therefore, a well conceived and designed monitoring programme is needed to promote good growth of fishes and to obtain optimal production in a sustainable manner from cages. Cage monitoring is an integral part of the cage culture and it should be continued starting from the installation of the cage to till harvesting the fishes. The following are the major aspects where the cage monitoring is essential and it includes maintenance of cage and its accessories, stocking of the fish, feeding, fish husbandry, health management, water quality and harvesting.

Maintenance of cage and its accessories

The materials are used in constructions of cages have a definite life span and will eventually wear out. Therefore, cage with net and mooring system should be checked periodically during the culture period. Generally algae grow on the cage frame, which makes the frame slippery. It should be scrapped once in a month to keep cage frame clean, so the worker can easily work by standing on the cage. The chain and floats attached to the mooring system should be regularly (once in a month) inspected for any damage such as loosening of shackle and damage of chain. If any damage is noticed, it should be repaired immediately. The mooring system should be compulsorily checked after any extreme weather conditions such as cyclones, storms, depressions, etc. The net attached to the cage frame is always in the water, and it is susceptible to settlement of fouling organisms such as barnacle, algae, etc. Therefore, the nets should be frequently checked for assessing the extent of fouling and if it is observed that the more than 50 % of the net meshes are clogged and then the net must be changed. The inner net of the cage should be changed once in every 3 months or depends on the rate of fouling, and the mesh size used in the inner net should be selected according to the growth of stocked fish. The net must be checked frequently for any damage.

Stocking of the fish

The candidate species for which the seed is readily available is the ideal for cage culture. Seed may be obtained from wild source or can be procured from commercial hatcheries. However, they should be of uniform size for stocking. The seed collected from wild or hatchery should be acclimatized to the water condition in the cage so that mortality will be reduced during stocking. It is better to stock the cage during early morning or evening hours to avoid wide temperature fluctuations. The ideal size of the fish to be stocked in cage is around 10-15 cm. If the size of fish is smaller than recommended size, then it has to be reared in nursery system either in tank or pond or cage itself. When smaller sized fishes are reared in the cage, it is better to stock in hapa of appropriate mesh size. In this case, fishes have to be graded every week to avoid cannibalism depending on the species. A fine knotless mesh hand-net should be used for handling the fish to minimize damage. Feeding of fish on transfer to the cage should commence 3-4 hours after transfer. The stocking density in the cage will vary according to size of the fish. Generally, the recommended stocking density for Asian sea bass (*Lates calcarifer*) of 10-15 cm is 24-30 no/m^3.

Feeding

Feed and feeding regimes need proper management for maintaining better health and growth of the cultured fish. Feeding should be done throughout the culture period at varying levels depending on the growth rate and natural feed availability in the system. Generally, fishes should be fed @ 10 % of body weight during the starting period and slowly it should be brought down to 3-5%. Hand feeding is done in most cases and it is recommended for small-scale farmers. However, mechanical feeders such as demand feeders and automatic feeders are used in large scale farms. Feed rings can be used if floating pellets are used. Feed trays set inside the cages at different positions can also be used for distribution feed evenly. During hand feeding, the feeding of fish can be monitored and can be fed till satiation. While doing so, the stock health status can also be monitored. It is better to give mixed feed for e.g. alternates of pellet feed and trash fish. The mixed feeding scheduled is good for proper growth of fish. When frozen trash fish is given as feed, should be thawed first, chopped and then broadcasted over the surface. The trash fish should be washed properly with fresh water to avoid any external parasite entering into the cage with feed. Overfeeding of the stocked fish should be avoided otherwise it could lead to deterioration of water quality. The fish should be fed at least twice per day once in the morning and then evening. However, at the earlier stage, feeding frequency of more than two times is suggested for better growth.

Fish husbandry

Regular observation of fish stock is essential for any culture system. Therefore, farmers should observe the fish stock without unduly disturbing them which helps to understand the general behaviour of the fish under normal cycle of environmental condition prevalent at the site, i.e., dawn/mid day/dusk/high tide/low tide, feeding/non feeding, etc. If something wrong is observed then fish should be sampled and examined further for changes in physical appearance in different body parts: spine - deformed spine; skin - abnormal colour, presence of lesion, rashes, spots or lumps, excessive mucus; eyes - bulging eyes, cloudy lens; fin and tail - erosion. These clinical signs indicate that the fish stocks are in abnormal condition, which might be due to effects of adverse environmental factors or infected with disease. These problems need to be properly addressed to adopt the further precautionary measures or to give proper treatments to the fishes.

In cage, fish sampling should be done at regular interval of at least once in a month to understand the growth rate of the fish. Periodic information on the growth rate of the fish is required for the calculating the feed requirement of the fish stock. This information will give a fair idea about the stock performance and the feed requirement for further coming days of the culture and then also help to avoid over feeding. Record keeping of the farming practices such as daily mortality, feed consumption, and growth rate should be maintained. It is crucial in understanding the epidemiology of diseases and this allows farmer to identify the critical management point in the production cycle. Observation, collection and storing the data during a culture practices help to take early preventive action in case of disease outbreaks/abnormal situation in the subsequent culture practices.

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Health management

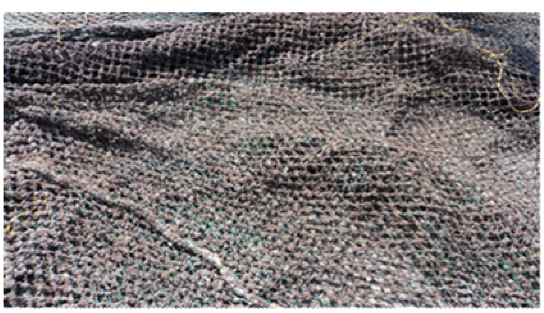
Implementation of the good sanitation practices is essential in any fish culture system. However, it is difficult to implement the practices in cage farming system since there are no barriers between the cage environment and its surroundings (where the pathogen can be found). Even though, it is necessary to reduce the risk of contamination by adopting simple management practices to reduce the pathogen pressure in the environment. The important practices to be followed to reduce the pathogenic loads include, avoid the overfeeding to the stock; wash the trash feed with fresh water; remove the moribund or dead animal immediately, maintain the optimal stocking density in cage, exchange of net at appropriate time. The uneaten food is a potential source of pathogens, so stock must be not overfed. The dead animal is another source of pathogens in the cage, if a moribund or dead fish is noticed it should be removed immediately. Washing trash fish with fresh water will kill almost all the external pathogens from sea origin; hence washing the feed with fresh water is must. The fish stocking density should not be more than the recommended stocking density otherwise it will lead to many complications and finally stock will collapse due to health problem. The net of the cage should be removed at appropriate time, otherwise the water flow in the cage will reduce which may leads to water quality related problems and finally stock will collapse.

Water quality

Maintenance of good water quality parameters in cage farming system is difficult, since the cage culture practiced in open water bodies and no boundary existing between the cage environment and its surroundings. However, the important water quality parameters are to be monitored frequently to avoid losses caused by lethal changes in water quality. It is essential to have long term data on the changes in the water quality parameters at the site; so that changes in the water quality parameters from the site could be observed and predicted and accordingly preventive decision could be taken in advance. Frequent recording of important water quality parameters liken ammonia, nitrite and nitrate, pH, turbidity and temperature will give a clear idea about cage environment and also will help to understand the health status of the animals in the system.

Cage anchored in Sea

Sea bass seed ready for stocking



Fouling on net

Net exchange

Harvesting

Harvesting of fish is done continually or in batches depending on how the production cycle is managed. Before harvesting, the fish may be starved for a day to have empty gut which will help to get long shelf life of the produce. Fish could be harvested in situ or the cages are towed to convenient places where the netting operation may be carried out more smoothly. The process of harvesting is simple where the net is lifted up and fishes are concentrated to a small volume and scooped out.

Cage farming of the fishes in existing open water is a gift to the most of the fish farming communities and this removes one of the biggest constraints of fish farming on land. Cage farms are positioned to utilise natural currents, which provide the fish with oxygen and other appropriate natural conditions while also removing waste. Open sea cage aquaculture is one of the more contentious methods of aquaculture. Environmental groups worldwide condemn the culture practices, but the industry promotes itself as sustainable method of fish culture for the future. In this controversy situation, the culture practise need to be proved as one of the best method for the sustainable production of fish by giving profit to the farmer/entrepreneur through increased production and less investment. This could be achieved through proper management and continuous monitoring the different aspect related to cage culture.

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Capture based aquaculture - Alternate method for sustainable fish production

Sekar Megarajan, Biji Xavier, Vamsi Balla, Chinnibabu. B and Ponnaganti Shiva
Regional Centre of ICAR-Central Marine Fisheries Research Institute, Visakhapatnam

Introduction

Global aquaculture has grown considerably and contributing significant quantities to the world's supply of fish for human consumption and it has shown to be an attractive option for enhancing the fish production in the world. It is the fastest growing, animal based food production sector with 73.8 million tonnes of production in 2014. Food and Agriculture Organization of the United Nations (FAO) define aquaculture as it is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. It is a diverse sector, which employs different strategies for fish production. There are two major strategies are followed in the sector including hatchery based aquaculture (HBA) and capture based aquaculture (CBA). The HBA allows the commercial and viable production for number of organisms through the management of their entire life cycles. In this system, the seeds are produced from the brood stock fish maintained under the controlled environment, and these produced seeds are used for culture. It involves the development of all aspects of fish husbandry, such as the facilities required for the different life-cycles stages of the fish, feed development, fish handling systems, and disease control. This system is possible for those fishes for which the seed production technology has been standardized, e.g. salmonids, seabass, seabream, different species of grouper, pompanos, and cobia etc.

However, the HBA technology cannot be followed for the species that may not be presently spawned in captivity and also for the species, whose complete life cycle has only been completed at the research and development level. Therefore, enough numbers of seed may not available for commercial farming operations due to controlled breeding techniques have not been perfected. In this contest, farmers have to depend on seeds available from the wild for aquaculture operation and this method is called as capture based aquaculture (CBA). CBA referred as the practice of collecting seed (larvae and juveniles or even large individuals) from the wild, and subsequently growing them in captivity to marketable size, using aquaculture techniques (FAO).

Capture based aquaculture industry has developed long back, but recently has received the interest among the researcher and other stakeholders and thereafter term CBA was first appeared in the literature in 2004 by Ottolenghi *et al.*, (2004). This method practices the growing-out or fattening of wild-caught seeds, using a range of marine and freshwater vertebrate and invertebrate species. The fish production from CBA is estimated to be at least 20 percent of the total annual aquaculture fish production. Although CBA has been practised for decades, recently it has been clearly distinguished from hatchery-based aquaculture (HBA) and also from capture fisheries. In reality, CBA is a hybrid of HBA and capture fisheries but differs from both as a means of food production and in relation to fishing pressure on wild populations, respectively. Capture-based aquaculture has certain advantages and disadvantages compared to aquaculture which controls the full breeding cycle of farmed species. The system does not depend on reproduction and breeding of farmed species. Thus, species of high market value or those that are readily available naturally can be farmed without the necessity to develop hatcheries or breeding program. Importantly, the CBA method has been developed due to the existence of market demand for some high value species, for which the life cycles cannot currently be closed on a commercial scale.

Species selection for CBA

Species selection is an important criteria for aquaculture practice, the major characters that determine the suitability of a species for aquaculture are its potential marketability, growth rate, easy availability of seeds in the wild and ability to function under culture conditions. While selecting species for CBA, economic considerations should be of more important to an aquaculturist than biological factors. In general, carnivorous species are considered to be a good candidate species for aquaculture operation, because most of the carnivorous species command higher market prices and therefore have greater market potential. The major high value fin fishes including, eels, grey mullets, milkfish, yellowtails, groupers, tunas and other reef fishes, etc. Among the high value fin fish used for CBA, four target species groups, viz. eels, groupers, tunas and yellowtails are of special significance due to their rapid grow-out and high market demand. However, the species selection is also some time depends on the regional specific.

The species like groupers are popular food fish farmed in Southeast Asian countries and have the potential to become an important aquaculture species due to their fast growth, efficient feed conversion, high market prices and reduced availability from wild resources. Groupers are good candidates for aquaculture for its gastronomical reasons and they are valued as one of the highest quality sea-foods in many parts of the world. The amberjack or yellowtail is another good candidate species for the diversification of farmed fish products because of its high growth rate and good performance in captivity especially for easy acceptance of food and high survival. Yellowtails have a good market especially in Japan, and this market acceptance has been developed over the last 30 years due to capture-based aquaculture production. One of the most interesting characteristics of the fish is that they can be processed and marketed as range of products, e.g. whole, fillets, steaks, etc. This is one of the few species for which the farm-raised fish is unanimously considered superior in quality than the fish caught from the sea, and fetches a much higher price in the market. Eels are another important species that has gone to commercial aquaculture in many countries for their delicacy meat quality. Traditionally, Western Europe and Japan are the areas where demand is highest. Practice of capture-based tuna farming has been rapidly increasing over the past few years; the major focus is on three populations including *Thunnus thynnus thynnus* in the North Atlantic and the Mediterranean, *Thunnus thynnus orientalis* in the North Pacific, and *Thunnus maccoyii* in Australia. These developments have been driven by the market demand for "*sushi*" and "*sashimi*" products in Japan. Capture-based aquaculture practices involve a thorough understanding of the behaviour, habitat and general environmental requirements of each species, as well as knowledge of its reproductive biology, nutritional requirements, larval and juvenile physiology, culture systems, seed availability and susceptibility to disease under culture conditions. Therefore, the selected species need to be studied for all these parameters before it is cultured.

CBA world scenario

Capture Based Aquaculture (CBA) is a global activity but has specific characteristics that depend on geographical location where the species being cultured. Worldwide, CBA is practiced in different countries with many species; the followings are some of the species with the countries where it is practiced.

Table.1. Capture based aquaculture for different fish species

Species	Region / Countries
Milkfish (*Chanos chanos*)	Philippines, Sri Lanka, Pacific Islands, India and Indonesia.
Eels (*Anguilla* spp.)	Asia, Europe, Australia and North America, mainly in China, Japan, Taiwan Province of China, Netherlands, Denmark and Italy.
Yellowtails (*Seriola* spp.)	Japan, Taiwan Province of China, Viet Nam, Hong Kong, Italy, Spain, Australia and New Zealand.
Tunas (*Thunnus* spp.)	Australia, Japan, Canada, Spain, Mexico, Croatia, Italy, Malta, Morocco and Turkey.
Groupers (*Epinephelus* spp.)	Indonesia, Malaysia, Philippines, Taiwan Province of China, Thailand, Hong Kong, Republic of China, and Viet Nam, and in other parts of the tropics, for example in south-eastern USA and Caribbean. Grouper culture is also on-going in India, Sri Lanka, Saudi Arabia, Republic of Korea and Australia.
Seabass (*Lates calcarifer*)	Indonesia, Malaysia, Philippines, Taiwan Province of China, Thailand, Hong Kong, Republic of China, and India.
Shrimp (*Penaeidae*)	South America and South-East Asia.

These species are caught and farmed using various methods and systems depending on local cultural, economic and traditions. In some areas this sort of culture is typically artisanal, rather than industrial. For example, the collection methods of grouper and seabass seed for CBA systems are local and artisanal in countries like Philippines, Malaysia and India, respectively. However, bluefin tuna culture in Mediterranean is completely industrialized enterprises, which need heavy capital investment, including purse seine boat for catching fish and helicopters to locate fish shoals.

Economic considerations are the key drivers for capture-based aquaculture around the world. The selection of species for culture reflects their acceptability and demand in local or international markets. Compare to other culture methods, the market demand for the species cultured is high in this system and it is likely that the efforts to promote this activity will significantly increase in future. This development will be capable of causing a number of very important and diverse changes on socio economic status particularly in those regions with depressed, marginal low income and characterized by high rates of unemployment.

Advantages of CBA

Higher economic return is the major force for the development of capture based aquaculture technology over the land based aquaculture techniques and capture fisheries. In CBA, mostly the high value fin fishes are produced and therefore the species, size and quality of the produce produced by the farmer is having high demand in international and national markets. The CBA is holding several important revenue enhancing features over the capture fisheries, some of which are similar with land based aquaculture methods and some of the features exclusively for the CBA. In CBA, the producer is holding more control over the production parameters. The important production parameters which help to increase the income in CBA are follows.

1. Increased yield in a cubic meter area, when compared to other culture methods.
2. Improve the quality characteristics of the product through feeding manipulation.
3. Exploit the size related prices for the product by harvesting in appropriate market size.
4. Smooth out supply by doing demand based harvest.
5. Avoid unfavourable natural conditions by ease of harvest in unfavourable conditions.
6. Avoids the unnecessary problems caused by water quality parameters which is prevalent in land based aquaculture methods.

General principles for the development, management and conduct of CBA

Capture based aquaculture depends on both capture fishery and aquaculture activities. It has become an emerging area of fish production and having several socio-economic benefits to the fisher folk compared to original fisheries and aquaculture activities. However, it also has several negative impacts related to environment, ecosystem and social problems. Understanding the problems, the following general principles developed by FAO for the development, management and conduct of CBA in a sustainable manner.

1. Management of the CBA practice is essential and regulatory actions should be undertaken for the area where CBA activity is highly dependent on wild-caught live material.
2. Regional fisheries management organizations (RFMOs) are required in addition to national level organization, and it should ensure that CBA fishery activities are managed and monitored effectively.

3. The ecosystem approach to fisheries and aquaculture needs to be considered and applied. This includes impacts of feeding, seed captured for grow-out, fishing methods and culture operations on the environment and on non-target species, and genetic issues.
4. In CBA activities, due consideration paid to other fishing sectors targeting the same stock to ensures that the sum of fishing does not exceed the natural mortality of the exploited stock.
5. The place where natural-mortality-curve information is unavailable for a new CBA fishery, then no CBA activities should be undertaken for that species, except for controlled collection of live material to produce a natural mortality curve for the species and other relevant biological and socio economic information. Alternatively, exploratory fishing could be conducted at low and controlled levels of fishing intensity, and the CBA fishery should only proceed under a set of guidelines that integrate the adaptive management concept. In all cases, new CBA activities should apply the precautionary principle and consider potential risks.
6. Brood-stock capture should be kept to a minimum and carefully monitored, especially in the case of threatened species. Appropriate handling methods should be applied to seeds or brood-stock to minimize mortalities during transfer or grow-out.
7. Migration routes, spawning sites and important nursery and settlement sites of CBA species should be identified, protected and managed by appropriate spatial, temporal and technical means.
8. Holistic management is required for additional controls beyond fishery management measures, such as controls on the aquaculture component of the operation. These might include licensing of hatcheries or culture operations, requirements for reporting and monitoring, regulations on quantities and size of wild seed or brood-stock used.

9. Monitoring and reporting of CBA fisheries should include information on the transfer of seed into aquaculture operations (i.e. including mortalities from capture and during transfer) and, where possible, data from the aquaculture operation, such as mortality levels during the culture period.
10. Place in which the wild capture live material or brood-stock fishery is not under management and overexploitation of the wild stock and adult fishery is likely, so the fishery should be halted or restricted until sustainability can be demonstrated. The material or brood-stock fisheries should not come from illegal, unreported and unregulated (IUU) fishing.
11. When management measures are proposed, the social and economic impacts of the management should be identified, along with mitigation measures and appropriate agencies such as non-governmental organizations, international non-governmental organizations, RFMOs, etc. All stakeholders, inclusive of fishers from all fishing sectors, fishery managers and aquaculture operators, should communicate to ensure that the linkage between the sum of capture pressure and supply and demand for seed is appropriately measured and controlled, and to ensure consultation across fishing sectors and interests.
12. Countries which performing CBA activities should collect separate statistics on CBA with data clearly disaggregated between wild fisheries capture for CBA and aquaculture production.

CBA - Indian scenario

India has the vast area of suitable coastal waters, lagoons and bays which can be utilized for mariculture through capture based aquaculture (CBA). India is bestowed with vast potential area for mariculture activities, but production is restricted to around 1 lakh tonnes annually and it is mainly contributed by marine shrimps. The mariculture activity through capture based aquaculture in India was mainly confined to shrimp, mussel and edible oyster farming. Till recent years CBA for marine fin fishes were not practiced or initiated due to unavailability of confined culture system and difficulties in rearing of marine fin fishes in tank/pond. But, in the last few years, initiative has been taken up by Central Marine Fisheries Research Institutes (CMFRI) for development and popularizing of marine cage culture for mariculture activities. Thus, CBA has become reality in India with help of cage culture and now CBA could be possible for high value marine fin fishes. A large number of juveniles of high value finfish and shellfish are caught as by-catch in many of the non selective bag type gears that are commercially operated in India. The catches of fish juveniles are either discarded or sold in the market at very low price. If these juveniles can be brought in live condition, these can be used for capture based aquaculture practice by which the resource can be conserved and utilized for increasing production.

In India CBA started with shrimp/prawn culture in several decades back in traditional water bodies like pokkali paddy field. The culture was practiced by trapping the young-ones of prawns brought in by the tide and growing out in the field till they attain market size. Thereafter, move on mussel and oyster farming was initiated by CMFRI. The mussel farming is mainly consisting of green and brown mussels and oyster farming is mainly of giant oyster. Culture of these species is mainly practised in the west coast of India especially in Kerala. For culture, the wild seed are collected and grown until attaining the market size using raft and rack culture methods. The technology of raft and rack culture was developed by CMFRI and it has been demonstrated and disseminated successfully among the villagers for taking forward. Lobster culture is recent initiative by CMFRI, where the coastal spiny lobsters *Panulirus homarus, P. polyphagus, P. ornatus, P. penicillatus and P. longiceps* are the good candidate species for farming. Spiny lobster farming/fattening was demonstrated by Veraval regional centre of CMFRI by rising under sized or juvenile lobsters of wild origin in suitable enclosure to marketable size through appropriate feed and water quality management. Marine finfish culture through CBA has got popularized and becoming an emerging area after advent of cage culture in India. The most common cultivable candidate species of marine fin fishes include seabass, rabbit fish, pearl spot, groupers, snappers, sea bream, mullet, etc. Culture of some of these fishes has been demonstrated in cages in different places using wild collected seeds by CMFRI. Added to several other factors, identifying the available seed resources of the marine finfishes plays major role in the development the culture method in India. Therefore, recently, CMFRI has taken initiative to prepare the seed calendar of marine finfishes all over the India, pertaining to information on species availability, location and seasonality under the All India Network Project (AINP) on Mariculture. Certainly, it would bring correct picture on the available seed resources in India and may help for the CBA culture programme.

To popularise the capture based aquaculture activities for marine finfish in India, initial attempts were made by CMFRI in different maritime states like Karnataka (Karwar & Mangalore), Kerala (Cochin), Tamil Nadu (Chennai), Andhra Pradesh (Visakhapatnam) and Odisha (Balasore). In the beginning different marine finfish species collected from the wild including seabass, mullet, pearl spot, etc in cages. From the several studies, the culture of Asian seabass was highly encouraging at the Karwar, Balasore, and Chennai. In Cochin, cage culture of fishes like mullet, seabass and pearl spot performed in open sea and back water showed promising result. Recently, as a part of the CBA programme, CMFRI attempted culture of the carangid species, *Alepes djedaba* (shrimp scad) along with the mangrove snapper, *Lutjanus argentimaculatus* in 13 cages at Uppunda village, Byndoor, Karnataka. The demand for the species is good and it sold for Rs. 250-300/kg in that region. The results of the demonstration showed that the shrimp scad, *Alepes djedaba* is also one of the promising carangid species for capture based aquaculture.

Success story on capture based aquaculture of Asian seabass at Nagayalanka

Visakhapatnam Regional Centre of CMFRI (VRC of CMFRI) has been striving hard to disseminate the cage culture technology since 2007 in different districts of Andhra Pradesh state. Cage farming of seabass was demonstrated in back waters of Krishna river at Nagayalanka, Krishna District in collaboration with Mr. T. Ragu Sekhar. A total numbers of 13 cages were used, of which 11 were wooden cages (square shaped; 4 x 4 x 2 m size) and 2 were HDPE cages (circular with 6 m dia). The cages were installed with help of barrels for floatation and anchor (iron and stones) for mooring. All the cages were stocked with 6 inch sized sea bass in the month of August to November, 2015 and were fed with trash fishes. The seabass seed source was from wild and were collected from sea shore and back water areas in Krishna districts. Total of 500 numbers of fish seeds were stocked in each cage. Fishes has grown to 0.5 kg to 1 kg in 5-8 months of culture period. The grown fishes were harvested on 15.5.2016 and Hon. Shri. Mandali Buddha Prasad, Deputy Speaker, Govt. of Andhra Pradesh flagged off the fish harvest. A total of 3 ton of sea bass was harvested from cages and sold in live at the rate of Rs. 340 per kg, instead of Rs. 270/kg for dead fish, in local market. While addressing the gathering, Mr. Mandali Buddha Prasad, Deputy Speaker, promised to take the initiative for helping the fisher folk to involve in the cultivation of high-valued fish species through the floating cage technology. Mr. Ragu Sekhar, farmer, Nagayalanka mentioned that selling live fish has helped him to earn Rs 70/kg extra. He also mentioned that demand/need based fish harvest, will fetch higher returns. This demonstration programme was carried out as part of All India Network Project on Mariculture through Visakhapatnam Regional Centre of CMFRI.

Cage farming site at Nagayalanka

Seabass harvested from cage

Hon. Shri. Mandali Buddha Prasad, Deputy Speaker, Govt. of Andhra Pradesh with the harvest

The chief guest addressing the audience

Fig.1. Capture based aquaculture of Asian Seabass at Nagayalanka

Conclusion

Capture based aquaculture is becoming an emerging area, increasingly contribute to world aquaculture production and having many advantages. But still it is considered as an unsustainable aquaculture practice, due to the increasing pressure on fish stocks that could cause successive stock depletion; low recruitment; stock collapse; reductions in genetic biodiversity; and subsequent impact on the ecological dynamics and processes in the wider aquatic environment. Recently, several initiatives have taken place to make it as sustainable practice with help of recent advances in the knowledge of breeding technology and larval biology. In addition, several management practices have developed to mitigate the effects of CBA on the environment, which include used of proper modelling and assessment methods, proper selection, and control of stocking densities, good feeding regimes, good health management and accurate environmental impact assessments. If these management measures are acknowledged and adopted, CBA will become a sustainable practice and may bring several changes in fisher folk community by providing alternative source of income generation for the traditional fisherman during the lean fishing season, particularly in fishing ban season in India.

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Economics and policies for open sea cage culture in Andhra Pradesh

S. S. Raju, Muktha Menon and Phalguni Pattnaik

Regional Centre of ICAR-Central Marine Fisheries Research Institute, Visakhapatnam

Introduction

The fisheries sector plays a significant role in providing employment, reducing poverty and promoting health. Fish is an extremely nutritious, a vital source of protein and essential nutrients. The sector provides employment opportunities to nearly 14.5 lakh people directly and indirectly in Andhra Pradesh. In recent years, sea farming is gaining popularity and a couple of finfish, shellfish species and some sea weeds are now being farmed. Ornamental fish farming also has a promising future and is likely to contribute to the overall growth of fisheries sector in the coming years. Good governance and good culture practices can enable fisheries to thrive sustainably. Therefore, the Government of Andhra Pradesh is unveiling the policy to create a suitable eco-system for the rapid growth of fisheries and aquaculture for the coming years.

Andhra Pradesh stands first in total fish and prawn/shrimp production in India for the year 2015-16 in terms of production and value. The contribution of fisheries sector is 6.01 % in A.P's GSDP, whereas the fisheries contribution is about 0.83 % of GDP of the nation. The overall fish production in India has more than doubled in the past one decade from 8.14 lakh tonnes in 2005-06 to 19.64 lakh tonnes in 2014-15. The fisheries sector has also been one of the major contributors of foreign exchange earnings. The share of Andhra Pradesh in India's sea food exports has increased from about 20 % in 2009-10 to about 40 % in 2013-14.

During 2009-10 the exports from Andhra Pradesh was Rs. 2,100 crores but by 2013-14 exports have increased to Rs. 12,100 crores. During 2014-15, the marine exports have been increased to an estimated value of Rs.16,000 crores.

Nine out of thirteen districts of Andhra Pradesh are coastal districts and the total length of the coast is around 974 kms. The total continental shelf is more than 33,227 Sq.km. The total marine fishermen population in the state is around 6.05 lakh and sea going fishermen are around 1.5 lakh. The total fishing crafts in the state are around 29,195 with around 12,747 motorized crafts, 1771 Mechanized and 14677 traditional crafts. The marine fisheries sector of the state is supported 4 fishing harbours, 353 fish landing centres and 555 marine fishing villages.

Fisheries in Andhra Pradesh – Opportunities and challenges

Opportunities: There are a number of natural as well as infrastructure related aspects that have supported the exponential growth of the sector in the state in the past few years. These can be listed as follows:

1. Market Potential: The State has large marketing potential for fish products in urban areas within the state and in other states of India. In India, 60 % of population is non-vegetarians and hence there is demand of fish consumption. At present the per capita national fish consumption is 11 Kg and in Andhra Pradesh, it is estimated at 7.4 Kg. The world fish consumption is 21 Kg. Hence, there is a huge gap in consumption which can be filled up by Andhra Pradesh by promoting domestic market.

2. Excellent fishing infrastructure: The state has 4 fishing harbours, 1 major port at Visakhapatnam and 14 minor ports in different places offering vast opportunity for exporting fish products.

Challenges: Four different sets of challenges have been identified by Govt of A. P, which if addressed can quicken and improve the rate of growth in Fisheries in the state. These can be categorised as follows:

1. Sustainability

- Excessive fishing capacity causing over-fishing leading to depletion of stock and recruitment in the marine sector.
- Production of good quality seed is a major challenge.

2. Lack of access to modern technology and credit facilities

- The majority of the boats are small fishing boats and such boats lack modern fishing facilities and equipments and information and communication equipment.
- The technology used at various levels of the value chain starting from boats to cold chain is inadequate.
- The fishermen do not have access to institutional financing and new technologies.

3. Inadequate infrastructure and shortfall of skilled personnel

- Post-harvest processing infrastructure in the state is very limited.
- Cold storage and transportation services are also constrained.
- Inadequate infrastructure facilities, information and communication channels.
- Shortage of technical manpower at middle and higher levels.

4. Others:

- Rapid urbanization, degradation of mangroves, oil and gas exploration activities and other anthropogenic activities along and off the coast contributing to pollution, coastal erosion and livelihood destruction.
- Unreliable resource base and statistics.
- Inadequate domestic market development.
- Frequent cyclones leading to loss of man days for sea going fishermen and damage the aquaculture.

Economics for setting up of open sea cage culture

Considering the opportunities for increasing mariculture production in India, cage culture offers the farmers and entrepreneurs with the scope to lay the idle resources of Bay of Bengal and Arabian Sea for a productive use. However, the adoption of any technology depends upon its economic performance. The rate of return per rupee invested is the economic indicator that guides the investor to invest in the particular activity.

The economic performance for setting up of sea cage culture is worked out by calculating the annual fixed cost, variable cost, and return in terms of harvest from cage and revenue generated from these sales. Fixed costs are costs that are independent of the level of production, and have to be paid whether or not production occurs in a particular year. An expenditure on a resource whose quantity is not varied during the production period is a fixed cost. This includes net & material, frames, ballast, floats, anchors, chains and establishment charges. Generally fixed costs are spread out over the expected life of the production input involved. This allows the producer to take into account the long-term view of profitability. The variable cost are cost that are dependent on the level of production and have to be paid for every cycle of culture such as cost paid towards fish seed, feed, labour etc. Returns from cage culture is the money generated from sale of harvest.

The economic analysis indicated that sea cage culture practices will work out successfully with high net income in a crop period of 5 years. It is to be noted that once the practice is further expanded to many years, the cost of production will decline due to economies of scale of operation. Thus, open sea cage farming is a viable alternative for fishermen and an economically feasible mariculture operation for the stakeholders.

Financial assistance for open sea cage culture in India

The National Fisheries Development Board (NFDB), Hyderabad is the primary funding agency for sea cage culture in India. NFDB has a scheme on mariculture aimed at increasing the marine fish production of the country. A principal component of this scheme is open sea cage culture and its popularization among fishermen of India. NFDB will provide financial assistance for setting up of a sea cage for mariculture as well as for model cage culture demonstration to traditional fishermen. The eligibility criteria for assistance for setting up of sea cage culture are:

1. Entrepreneurs/companies with a previous record of undertaking large-scale aquaculture operations and having on-shore facilities for seed rearing.
2. Sea going fishermen groups who will operate the scheme through Fisheries federations/corporations.

3. Availability of necessary clearances for undertaking the cage culture activity in the coastal areas.
4. Commitment of state fisheries federation/corporation, entrepreneur to bear 80% of the cost.

The approximate unit cost of a modern net cage system includes the cost of net material, HDPE frames, ballast, floats, anchors, chains and establishment of on-shore facilities are given in Table 1.

Table 1: Initial investment of the sea cage culture for a cage

Sl. No.	Items	Cost (Rs. Lakh)	Life span (years)
1.	HDPE cage frame	1.91	10
2.	Ballast	0.08	10
3.	Floats	0.19	5
4.	Nets	1.58	3
5.	Chains, swivel, shackles	0.80	3
6.	Stone anchor	0.64	10
7.	One time launching charge	0.80	-
	Total	6.00	

Source: Adapted from Ritesh *et al.*, 2014.

The tentative unit cost economics of cage culture operations are indicated in Table 2. The entrepreneurs / companies willing to set up open sea cage culture in a big way shall be supported by NFDB through equity participation @ 20% of the investment.

Table 2: Tentative Unit Cost and economics for setting up of open sea cage culture in one cage for fisherman household/ SHGs

SI. No	Items	Apprx. Cost and returns / crop (Rs. in lakh)				
CAPITAL INVESTMENT		I	II	III	IV	V
1.	**Fixed assets** Onshore facility ; floating cage	**6.0**				
COST OF PRODUCTION						
2.	Depreciation on fixed assets (@10%)	0.6	0.6	0.6	0.6	0.6
3.	Seed cost	0.5	1.0	1.0	1.1	1.1
4.	Feed cost	1.8	3.6	3.6	3.6	3.6
5.	Harvesting and transporting	0.25	0.50	0.50	0.50	0.50
6.	Miscellaneous expenditure	0.20	0.20	0.20	0.30	0.30
7.	Interest on borrowed money (~@ 8% per annum) (10 lakhs borrowed)	0.8	0.7	0.6	0.5	0.4
8.	Total cost of production	**10.15**	**6.6**	**6.5**	**6.6**	**6.5**
9.	**Annual production (t)**	**3**	**6**	**6**	**6**	**6**
10.	Unit cost of production per tonne (8/9)	3.38	1.11	1.08	1.11	1.08
Financial Analysis						
1.	Sale price	200/kg	220/kg	2240/kg	260/kg	280/kg
2.	Revenue from sales	**6.0**	**13.2**	**14.4**	**15.6**	**16.8**
3.	Profit over cost of production (12-8)	- 4.15	6.6	7.9	9.0	1 0.3
4.	Repayment of loan	0	2.5	2.5	2.5	2.5
5.	Net profit	**- 4.15**	**4.1**	**5.4**	**6.5**	**7.8**

Source: Guidelines for mariculture (modified) 2016, NFDB, Hyderabad.

Proposal for setting up of open sea cage culture should be submitted in Form MC-II (Annexure I) which should be filled by the applicant and counter-signed by the Implementing Agency. Funds will be released in two equal installments by NFDB. The first installment will be released after approval of proposal and after applicant has utilized 50 % of his/her investment in the open sea cage culture. The second installment will be released after the applicant utilizes his/her remaining 50 % investment in the venture and also after receipt of the utilization certificate (U.C) regarding this first installment of NFDB fund from the implementing agency. All subsidy installments will be deposited to the applicant's bank account only. U.C should be submitted in form MC-V (Annexure II) on half-yearly basis i.e., during January and July of each year. The project monitoring committee of NFDB periodically reviews the progress of the activities like physical, financial and production targets.

Another scheme is sponsored by Department of Animal Husbandry, Dairying and Fisheries; Ministry of Agriculture, Government of India. The scheme particulars, pattern of assistance and terms & conditions are given in the Table 3.

Table 3: Details of open cage culture scheme by Government of India

Scheme	**Unit cost (Rs.)**	**Pattern of assistance**	**Terms and Conditions**
Open sea cage culture	5 lakhs/cage (6M diameter x 4M) depth for circular	50% of the unit cost with a ceiling of Rs. 2.50 lakh per cage in coastal states.	1. The applicant shall obtain necessary prior permissions from the state government and other competent authorities for installation of cages in the sea. 2. Fishermen Cooperative

	cages and 6M x 4M X 4M for rectangular cages)		Societies, SC/ST cooperative societies, Women SHGs, 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. 3. The unit cost includes capital, operational and maintenance costs on one time basis. 4. 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.

Source: Dept of A.H, Dairying & Fisheries; Ministry of Agriculture, GOI.

Policy initiatives of mariculture by government of Andhra Pradesh

After evaluating the fishery resources in new Andhra Pradesh state, the following key aspects have been identified for policy, regulatory and other interventions are identified by the Government of Andhra Pradesh. Policy Intervention: There is a need for coherence between the policies within and outside the fisheries sector; suitable amendments shall be made in the existing fisheries acts for long-term, effective and positive governance of this sector. Coordination mechanism for synergy with the agriculture and allied sectors to utilizes the common infrastructure.

Marine fishery

i. The government shall establish fish landing centers with modern infrastructure facilities for hygienic handling of fish in coastal villages.

ii. Mariculture will be promoted aggressively to augment the fish production from coastal waters. Open sea cage culture and sea weed culture shall be undertaken to promote mariculture.

iii. Leasing Policy for promotion of mariculture in the state to be introduced through private sector. Feasible locations of bays, creeks, back waters, mangroves in the coastal region have to be identified.

iv. The government shall take steps to install a large number of artificial reefs/ FADs (Fish Aggregating Devices) for augmenting depleted fish stocks to safe guard small scale fishers.

v. The government shall undertake measures to promote deep sea fishing while protecting the rights of small scale fishers.

vi. The Government shall explore the opportunities for alternate livelihoods for coastal fishers in view of the dwindling of fishing grounds due to establishment of coastal based industries and other activities.

vii. To ensure the safety of fishermen at sea and to catch more fish, sea safety and navigational equipment are proposed to be supplied. INCOIS display boards for Potential Fishery Zone (PFZ) information will be displayed. The shore station facilities shall be effectively utilized for the benefit of fishing communities.

viii. Ban period notified by government will be followed strictly for rejuvenation of fish stocks.

ix. Present fishing harbours and landing centers shall be provided with facilities for hygienic handling of fish as per the International standards.

x. Construction of landing, berthing, bunkering and post-harvest handling facilities shall be considered on a priority basis by the government.

xi. Infrastructure facilities like fish drying platforms, solar drying, dry fish storage sheds, boat building yards, village approach roads shall be implemented at all coastal villages.

xii. Orientation training will held in all 555 coastal fishermen villages, women members of SHGs, 353 fish landing centers on hygienic handling of fish, tuna processing and conservation of fishery wealth in a phased manner.

Fiscal incentives

The following fiscal incentives shall also be given to various stake holders

- Processing units
- Feed manufacturing units / fishery related equipment manufacturing

- Ease of doing business
- Insurance facility
- Research and development
- Infrastructure strengthening
- Domestic market development
- Quality up gradation
- Export promotion
- Welfare
- Human resource development

Others

- Sea cage culture and diversification into high value fish culture shall be prioritized and encouraged by importing technology already developed else ware with buy back agreement from importing country.
- Government shall explore establishment of "Mid Sea Fish Processing/bunkering units" on a pilot basis under PPP mode for high value fin fish like tuna.
- Linkage with MPEDA will be developed for storage/ refrigeration/ Harbor Facilities/ Fiscal Incentives etc.
- Effort will be made to develop fisheries infrastructure for promotion of fish and fish products exports in Bhimavaram and Visakhapatnam which are recognized as the towns of export excellence (marine Sector) in trade policy of Government of India, 2015-2020.
- Government shall issue biometric identification to all fishermen.

- Appropriate steps shall be taken to ensure that quality education and healthcare, housing shall be made available to the families of the fishermen. Fishermen habitations will be provided with safe drinking water, roads etc.
- The extension of subsidies to SCs, STs and women shall be on par with industrial policy vis a vis this policy.
- Information and Communication Technology (ICT) shall be implemented in the department to act as a cost-effective and interactive mechanism for delivering relevant information and knowledge to the stakeholders.

Policy outcomes

The implementation of the A. P. fisheries policy, 2015 is expected to yield the following outcomes:

i. Increased production and productivity thereby increasing the GSDP contribution off fisheries sector.
ii. Prevention of post harvest losses.
iii. Better infrastructure and logistics facilities in the sector ensuring the availability of fish products in all the days.
iv. Increased marine exports and domestic trade thereby increase in foreign exchange earnings.
v. Enhanced capacity building to manage the resources
vi. Better nutritional support through good protein and micronutrients intake can reduce malnutrition among poorer sections.
vii. Gainful employment in fisheries and allied ancillary industries.
viii. Diesel subsidy will benefit many families.
ix. Promote research in frontier areas of mariculture.
x. Better fish farmers welfare.
xi. Empowerment of women fishers.

xii. Enhanced skill of the personnel / fishers

Pattern, mode of implementation of the sponsored development and welfare schemes of Andhra Pradesh marine fishermen are given in the Table 4.

Table.4. Developmental and welfare schemes available for marine fishers in Andhra Pradesh.

Sl. No	Scheme	Unit cost (Rs.)	Pattern of assistance	Terms and conditions
Developmental schemes				
1.	Motorization of traditional craft	Up to 0.60 lakh/ craft)	50% of the unit cost with a ceiling of 30,000/- per Out-board motor/ In board motor	1. Beneficiary fisher should own the traditional craft & possess a valid registration certificate and valid fishing license. 2. IBM/OBM (2-stroke and 4- stroke) of capacity up to 10 HP is allowed. 3. This assistance shall be provided to beneficiaries only once in 5 years.
2.	Promotion of deep sea fishing (Hook and line)	Rs. 3 lakh for mechanized boats Rs 60,000 for motorized boats	50% of the unit cost	For providing hook and line to fishing at deeper waters.
3.	Assistance to traditional /Artisanal fishermen for procurement of net and net material	Rs. 10,000 – 50,000		Only traditional/ Artisanal fishermen are eligible for the benefit under this component. Beneficiary should possess Biometric ID fishers ID card

4.	Safety of fishermen at sea (Life saving appliances and electronic equipment)	Rs. 30,938 for GPS, Rs. 23,229 for echo sounder, Rs.1,755 for life bouys, Rs 1,480 for life jackets, Rs 25,500 for vhf sets	75% of the unit cost	Beneficiary should possess valid (a) Ownership certificate, (b) Registration certificate (c) Fishing License and (d) Biometric ID fishers ID card.
5.	Supply of insulated ice boxes.	As per actual cost	Rs. 2,000/- for insulated ice box or 90% of the cost, whichever is less.	The choice as to the capacity and company is given to beneficiary. Fish vendors are identified by the district fisheries officers.
6.	Exemption of Sales Tax on HSD oil	Rs.6.03 per liter	The ceiling limit of HSD oil is 3000 liters per month per boat only	This scheme is applicable to mechanized boats only.
Welfare schemes				
1.	Relief to marine fishermen during ban period	Rs.4,000 per crew member	100%	Relief to marine fishermen belongs to mechanized and motorized boats. Crew members should have aadhar card, biometric card and phone number. Govt of A.P observes ban on fishing at sea from 15th April to 14th June.
2.	Revolving fund to Matsya Mitra Groups (MMGs)	Rs.1 lakh per group	100% grant to society / MMG	Fund will be given to fisher women groups (MMGs) fordoing fresh and dry fish business.

				Working capital for fish vending / marketing.
3.	Motorcycle with ice box(RKVY)	As per actual with a ceiling of 0.4 lakh per unit	90% of unit cost	Only for S.C fishery business men.
4.	Establishment of retail fish markets with modern hygienic facilities	Rs. 15 lakhs for municipality area. Rs. 7.5 lakhs for Gram Panchayat area	100% of unit cost	The beneficiaries shall complete the planning, designing of the market facilities and cost estimates etc.
5.	Setting up of retail fish outlet	Rs. 2.5 lakhs	Rs. 2 lakhs	For the purpose of S.C fishermen employment.
6.	Group accident Insurance for active fishermen	Insurance premium@ Rs.20.34/-per fisher per year. (The rate of insurance premium is subject to change on year to year basis)	Premium of Rs. 20.34 to each fisher is shared by the GoI and GoAP equally.	(i) Licensed/ registered fishers shall be eligible for insurance for Rs.2.00 lakhs against death or permanent total disability, Rs.1.00 lakh against disability and Rs.10,000/towards hospitalization expenses. (ii) The insurance cover shall be for a period of 12 months. (iii) All the active fishermen and women either by caste or profession in the age group of 18-70 years are covered under this scheme.
7.	Maintenance of relief boats		39 relief boats	Relief boats with outboard motors located at designated place to be used in natural calamities

				for evacuating of public and relief arrangements.

Source: Office of the Joint Director of Fisheries, Visakhapatnam (A.P)

Suggested readings:

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Annexure-I
FORM-MC-II

Proposal for setting up open sea cage culture

Sl. No	Particulars sought from the applicant	Information furnished by the applicant
(1)	(2)	(3)
1.0	Name and address of the company/ firm (IN BLOCK LETTERS):	
2.0	Addressfor communication: Telephone: Fax: Mobile: E- mail:	
3.0	Details of the area where sea cage culture activity is proposed to be taken	
	State:	
	District:	
	Taluk / Mandal:	
	Near by Revenue Village:	
	Latitude and longitude :	
	Details of lease:	
	Duration of lease:	
	Total farm area (in ha):	
	Details of the proposed construction works of cage farms. (Design details/engineering works to be	
	Number of cage units:	
	Dimensions of each cage:	
	Maximum fish holding capacity in each	
	Details of other structures including floats, anchors, watch towers, light-buoys:	
	Details of mechanized/motorized crafts for transporting men and material to and fro:	

4.0	On-shore facilities for the cage farm: Details of the area where the on-shore facility is proposed to be taken up	
	State:	
	District:	
	Taluk / Mandal:	
	Near by Revenue Village:	
	Survey Number :	
	Whether located in the permitted zone as per the CRZ Act:	
	Ownership (whether free hold or open	
	If on lease, details and duration of lease:	
(1)	(2)	(3)
	Details of the proposed construction works of onshore facility. (Design details/engineering works to be certified	
	Species and source of fry:	
	Details of the holding facility for the seed (fry to fingerling):	
	Number and dimensions of fry rearing	
	Water intake and treatment facility:	
	Source and quality of water:	
	Drainage water treatment facility:	
	Details of feed to be used for fry:	
	Storage facility for feed (for rearing and seed cultured fish):	
	Frozen / Chilled storage facility for harve - sted fish:	
	Details of mechanized/motorized crafts for transporting men and material to and	
	On-shore laboratory for monitoring water quality parameters and disease diagnosis in the cage farm site:	
	Communication facility (wireless/mobile) between on-shore and sea cage facilities:	

5.0	Whether the assistance for the sea cage culture has been sought under any other scheme of the Central/State	
6.0	Whether the Company/Firm is in default of payment to any financial institution/State Government for loan/assistance availed earlier. If yes,	
7.0	Estimates regarding input cost:	
	Species to be cage cultured:	
	Stocking density (please specify the stage of stocking - fry/fingerling) - numbers per cubic meter of cage:	
	Cost of seed (Rs. per thousand):	
	Source of procurement:	
	Transportation cost (Rs. Per thousand):	
	Details of feed to be used, its quantity	
	Source of procurement of feed:	
	Transportation cost of feed from on-shore facility to the cage culture site:	
	Number of culture cycles per year:	
	Salaries/wages:	
	Harvesting cost:	
	Operational cost for the on-shore facility:	
8.0	Experience of the applicant in the cage culture and details of training(s) undergone so far:	
9.0	Details regarding economics of operation:	
10.0	Whether any financial tie up has been made for availing Bank loan, if so please provide the details:	
11.0	Expected date of operation of the farm and tentative schedule of activities:	
12.0	Marketing tie up:	

13.0	Source and number of labour employed for construction as well as day-today culture operations (man days per year):	

Declaration by the authorized signatory of the company / firm

I/We...son/daughter/wife Of...residing At ....hereby declare that the information furnished above is true to the best of my/ our knowledge and belief. I am/ we are fully aware that if it is found that the information furnished by me/ we is false or there is any kind of deviation/ violation of the conditions under which assistance is provided to me by the NFDB, any action as deemed fit for violation of this condition may be taken against me/ us.

Date: Signature of the applicant(s)

Place:

Countersigned by the implementing agency

Date:

Place:

Signature and seal of the authorized representative of the Implementing Agency

Annexure- II
FORM-MC- V

National Fisheries Development Board
Form for Submission of Utilization Certificate

SI. No.	Letter No and date	Amount

Certified that out of Rs. sanctioned during the year in favour of _______________ under the National Fisheries Development Board's Letter No given in the margin and Rs.________________ on account of unspent balance of the previous sanction, a sum of Rs. ______________ has been utilized for the purpose of______________ for which it was sanctioned and that the balance of Rs. _____________ remains unutilized. The same will be adjusted towards the next instalment payable during the period________________.

Physical progress:

Certified that I have satisfied myself that the conditions on which the funds were sanctioned by the National Fisheries Development Board have been duly fulfilled/ are being fulfilled and that I have exercised the following checks to see that the money was actually utilized for the purpose for which it was sanctioned.

Date:
Place:

Signature and seal of the authorized representative of the Implementing Agency

List participants for training program on Cage culture of finfishes

7 - 12 November, 2016

S/ No	Name	Address & mobile No
1.	K. Ganesh	Kruthuvennu, Krishna District, A.P, 521 324. Mobile No: 7382223858
2.	P. Kiran Varma	Kruthuvennu, Krishna District, A.P, 521 324. Mobile No: 9490930555
3.	P. Prajwal	No: 9-16-21/2, C. B. M. Compound, Visakhapatnam, A.P, 530 003. Mobile No: 9848660807
4.	G. Nagamalleswara Rao	Garcepudi, Kruthuvennu Mandal, Krishna District, A.P. Mobile No: 8978259176
5.	Komaragiri Ravi Babu	D.No: 4-45, Boya Bazaar, Patha Tirumuru, Krishna District, A.P, 521 235. Mobile No: 9866804024.
6.	M. Siva Naga Babu	Gudidhibba, Kruthuvennu Mandal, Krishna District, A.P, 521 324. Mobile No: 9949845928.
7.	T. Subba Rao	Gudidhibba, Kruthuvennu Mandal, Krishna District, A.P, 521 324. Mobile No: 9515855984.
8.	Annabathula Ravi Kumar	Prahaladhapuram,Visakhapatnam, A.P. Mobile No: 8688902744.
9.	Dinesh Pandey	D.No: 2-13-9, MVP Colony, Sector-9, Visakhapatnam, A.P. 530 017. Mobile No: 9849861322.
10.	G.V.S. Mallikharjuna Rao	D. No: 49-48-19/2, Santhi puram, N G G O' s colony, Akkayya Palem, Visakhapatnm, A.P- 530 016. Mobile No : 9603710104.

11.	P. Venkateshwara Rao	D. No: 25-9-3/3, Krupam Market, Raja vari street, Visakhapatnam, A.P. Mobile No: 9000990639.
12.	V. Eswara Rao	J. P. Road, Bhimavaram, West Godavri Districts, A.P, 534 202. Mobile No: 9652222227.
13.	K. Prapolla Kumar	V.V Palem, 1-84, Raghuvardha Palem, Khammam Districts, Telangana, 507 318. Mobile No: 9949427099.
14.	D. Narayana Rao	Buthirajupalem, N.A.D. Road, Visakhapatnam, A.P. Mobile No: 9949565577.
15.	M. D. Prasad	D. No:102, 179/1, Visakhapatnam,A.P. Mobile No: 9000810711.
16.	P. Jagadeesh Kumar	D. No: 60-31-172, Janatha Colony, Malkepuram, Visakhapatnam, A.P, 530 011. Mobile No: 7386151500.
17.	P. Srinivasa Raju	D. No: 14-1-23, Pithapuram, East Godavari Districts, A.P. Mobile No: 7396452266.
18.	Pyla Mallikarjunarao	D. No: 60-31-172, Janatha colony, Malkapuram, Visakhapatnam, A.P, 530 011. Mobile No: 9063152368.
19.	Ch. Bangar Raju	Pudimadaka, Atchuthapuram, Visakhapatnam, A.P. Mobile No: 9966887638.
20.	T. Mahesh	Pudimadaka, Atchuthapuram, Visakhapatnam, A.P. Mobile No: 9966486838.

List of resource persons for training program on Cage culture of finfishes

7 - 12 November, 2016

S/ No	Name and Designation	Address
1.	Dr. Subhadeep Ghosh Scientist In-charge	Pelagic Fisheries Division, ICAR-CMFRI, Visakhapatnam Regional Centre, Pandurangapuram, Andhra University Post, A.P- 530 003. subhadeep_1977@yahoo.com
2.	Dr. S.S. Raju Principal Scientist	Fishery Economics & Extension Division, ICAR-CMFRI, Visakhapatnam Regional Centre, Pandurangapuram, Andhra University Post, A.P- 530 003. rajussncap@gmail.com
3.	Dr. Ritesh Ranjan Scientist	Mariculture Division, ICAR-CMFRI, Visakhapatnam Regional Centre, Pandurangapuram, Andhra University Post, A.P- 530 003. rranjanfishco@gmail.com
4.	Dr (Mrs). Biji Xavier Scientist	Mariculture Division, ICAR-CMFRI, Visakhapatnam Regional Centre, Pandurangapuram, Andhra University Post, A.P- 530 003. bijicmfri@gmail.com
5.	Mr. Loveson Edward Scientist	Fishery Environment Division, ICAR-CMFRI, Visakhapatnam Regional Centre, Pandurangapuram, Andhra University Post, A.P- 530 003. loveson_edward@yahoo.co.in
6.	Dr. Sekar Megarajan Scientist	Mariculture Division, ICAR-CMFRI, Visakhapatnam Regional Centre, Pandurangapuram, Andhra University Post, A.P- 530 003. sekarrajaqua@gmail.com

7.	Dr. Biswajit Dash Assistant Chief Technical Officer (ACTO)	Mariculture Division, ICAR-CMFRI, Visakhapatnam Regional Centre, Pandurangapuram, Andhra University Post, A.P- 530 003. dashbiswajit999@rediffmail.com
8.	Mr. Narasimhulu Sadhu Senior Technical Assistant (STA)	Mariculture Division, ICAR-CMFRI, Visakhapatnam Regional Centre, Pandurangapuram, Andhra University Post, A.P- 530 003. sadhunarsing@gmail.com
9.	Mr. Balla Vamsi Technical Assistant (TA)	Mariculture Division, ICAR-CMFRI, Visakhapatnam Regional Centre, Pandurangapuram, Andhra University Post, A.P- 530 003. bvamshimsc@gmail.com
10.	Mr. Chinni Babu. B Technical Assistant (TA)	Mariculture Division, ICAR-CMFRI, Visakhapatnam Regional Centre, Pandurangapuram, Andhra University Post, A.P- 530 003. bathina.biotechnology@gmail.com
11.	P. Shiva Senior Research Fellow (SRF)	Mariculture Division, ICAR-CMFRI, Visakhapatnam Regional Centre, Pandurangapuram, Andhra University Post, A.P- 530 003. shiva.p.775989c@gmail.com

List of cage fabricators and accessories suppliers in Visakhapatnam

1. Manak plastics Pvt Ltd,

   Plot No. 51-A, IP Pedagantyada,

   Visakhapatnam, Andhra Pradesh - 530 044.

2. Y.V. Satyanarayana,

   Poorvi fabricators

   D.NO. 50-80-22, Flat No 11, Anjana Residency,

   Seethammapeta, Visakhapatnam, Andhra Pradesh - 530 016.