भाकृअनुप
ICAR

कडलमीन™
cadalmin

HANDBOOK ON
OPEN SEA CAGE CULTURE

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)
KARWAR RESEARCH CENTRE
UTTAR KANNADA - 581 301, KARNATAKA

HANDBOOK ON

OPEN SEA CAGE CULTURE

Edited by

K.K. Philipose

Jayasree Loka

S.R.Krupesha Sharma

Divu Damodaran

Central Marine Fisheries Research Institute

Karwar Research Centre

Handbook on

Open Sea Cage Culture

Published on behalf of the Director, CMFRI on the occasion of the training on 'Open sea cage culture' sponsored by National Initiative on Climate Resilient Agriculture (NICRA) and held at the Karwar Research Centre of Central Marine Fisheries Research Institute during 27 to 3 March 2012 and 19 to 24 March 2012

Address

Karwar Research Centre of
Central Marine Fisheries Research Institute
(Indian Council of Agricultural Research)
Karwar -581 301, Uttara Kannada, Karnataka.
Ph: +918382222639 Fax: +918382221371
www.cmfri.org.in

Design, Printed and bound in India by Maya Creative Mind, Calicut, Kerala.

CONTENT

CONTRIBUTORS

1	G. Syda Rao	Director, Central Marine Fisheries Research Institute , Post Box No. 1603, Ernakulam North P.O., Cochin-682 018, Kerala, India
2	E. V. Radhakrishnan	Former Head, Central Marine Fisheries Research Institute, Post Box No. 1603, Ernakulam North P.O., Cochin-682 018, Kerala, India
3	G. Gopakumar	Pricipal Scientist & Scientist -in-Charge, Mandapam Regional Centre of CMFRI, Marine Fisheries Post,Mandapam Camp, Tamil Nadu- 623 520
4	A.P.Dineshbabu	Scientist-in-Charge, Mangalore Research centre of CMFRI, Bolar, Mangalore
5	K.K.Philipose	Scientist-in-Charge, Karwar Research Centre of CMFRI, Karwar -581 301, Karnataka
6	S.R.Krupesha sharma	Scientist, Karwar Research Centre of CMFRI, Karwar -581 301, Karnataka
7	M.K.Sambasivan	Manager, Matsyafed Net Factory, Kochi.
8	P. Vijayagopal	Senior Scientist,Marine Biotechnology Division, CMFRI, Cochin -682018, Kerala.

9	A.K. Abdul Nazar	Senior Scientist, Mandapam Regional Centre of CMFRI,Marine Fisheries Post,Mandapam Camp, Tamil Nadu- 623 520
10	Jayasree Loka	Senior Scientist, Karwar Research Centre of CMFRI, Karwar -581 301, Karnataka
11	Geetha Sasikumar	Scientist, Mangalore Research centre of CMFRI, Bolar, Mangalore
12	D. Divu	Scientist, Karwar Research Centre of CMFRI, Karwar -581 301, Karnataka

PREFACE

The cage aquaculture has grown very rapidly during the past 20 years and is presently undergoing rapid changes in response to pressures from globalization and a growing global demand for aquatic products. Recent studies have predicted that fish consumption in developing and developed countries will increase by 57 percent and 4 percent, respectively. Rapid population growth, increasing affluence and urbanization in developing countries are leading to major changes in supply and demand for animal protein, from both livestock and fish. Within aquaculture production systems, there has been a move towards the clustering of existing cages as well as toward the development and use of more intensive cage-farming systems. In particular, the need for suitable sites has resulted in the cage culture sector accessing and expanding into new untapped open-water culture areas such as coastal brackish and marine offshore waters.

Cage culture of fin fish and shell fish is in the developmental stages in India. Experimental culture of seabass, mullets and spiny lobster was carried out at various centres of Central Marine Fisheries Research Institute with varying degree of success. Although the results obtained at all the places were promising, more works are needed to perfect stocking density, feeding, cage fabrication and cage mooring. The results obtained at Karwar were significantly better because of the favourable environmental conditions and the water quality. Karwar Research Centre of CMFRI has also developed the low cost cage technology thus bringing down the cost of cage fabrication to several-fold low.

There is necessity of transferring the technology through training to fishers and the researchers. In this context the present publication "open sea cage culture" is brought by CMFRI on the occasion of the national training on "open sea cage culture' funded by National Initiative on Climate Resilient Agriculture (NICRA) for the fishermen, fish farmers and officials of the fisheries department. I hope this book will serve as the reference guide to the researchers as well as fish farmers who are interested in mariculture. Any suggestion to improve the handbook is gratefully accepted. We are indebted to Dr. G.Syda Rao, Director, CMFRI for his support and encouragement in conduct of the training programme and preparation of this handbook. We also would like to extend our sincere gratitude to all the contributors who helped in the preparation of this book.

February 2012
Karwar

K.K.Philipose
Scientist –in-Charge &
Course Co-ordinator of
Open sea cage culture

I

CAGE CULTURE: MARICULTURE TECHNOLOGY OF THE MILLENNIUM IN INDIA

G. Syda Rao

Fisheries sector in India has emerged as an important industry during the last six decades. Fish is an important source of cheap protein to the people of India, and also a potential employ ment and income generating sector, besides earning substantial foreign exchange through seafood exports. Fisheries contributed about 5% of India's agricultural GDP and about one per cent of the total GDP during 2008-09. The sector supports livelihood options for about 40 million people in India.

The marine fishery resources of the country include a coastline of 8129 km with numerous creeks and saline water areas, an Exclusive Economic Zone (EEZ) of 2.02 million km^2, which are suitable for capture as well as culture fisheries. The annual harvestable marine fishery resources in the Indian EEZ have been estimated at about 3.93 million tonnes constituting more than 50 % demersal, 43% pelagic and 6% oceanic groups. The Indian fish production is contributed both by marine and inland sectors.

While, the share of marine fish production in the total fish production declined gradually from 71% in 1950-51 to 38.16% in 2008-09, and that of the inland sector increased from 29% to 68.14% during the same period. The marine fish production in India during 2009 was estimated at about 3.16 million tonnes, which is more than 70% of the harvestable potential.

With the marine capture fisheries reaching a stagnation phase with limited scope for further expansion, the alternative is to look for augmenting the fishery resources of the sea. Since the existing capture methods have exploited the resources indiscriminately mainly due to socio-economic pressure, there has been a necessity to exploit the resources in a sustainable way. Under such circumstances, mariculture or cage farming has been identified as one of the methods for augmenting the fish catch from the sea.

Aquaculture has been the world's fastest growing food production system with production steadily increasing at about 10% per year since 1984, compared with 3% for livestock meat and 1,6% for capture fisheries. Of the 300 species being cultured, 22 account for 80% of the production. The majority are filter feeders, herbivores or omnivores, and one species (Atlantic salmon) is carnivorous. In the finfish group Cyprinids dominate the production with 10.3 million meter.

Cage farming

Cage culture has been originated in Southeast Asian countries and now it is a major culture activity all over the world. Mariculture in cages began in Japan in the 1950s but developed largely as a result of the salmon farming industry in northern Europe and North America during the past two decades. Cages account for about 60% of coastal fish culture, and if considering Medite rranean aquaculture, it account above 90% of all seabass and sea bream production. The main advantages of cages when compared to conventional land-based systems include low capital costs and simple management.

Cage farming in India

As an R & D activity, the first open sea cage was launched in Bay of Bengal off Visakhapatnam coast during May 2007. Due to the rough sea conditions, the first version of the cage had lasted only for 45 days in the sea. With further modifications, the second version of marine cage was fabricated involving marine engineering and naval diving experts and was launched in December 2007. With a low stocking density, the trial was successfully completed in April 2008. The recovery percentage was 75% and the weight ranged from 300-1200g. The third version of the cage was also tried and found to be seaworthy at any extreme sea conditions. The first to third versions were 15 m dia HDPE cages. For easy manoeuvring and cost effectiveness in terms of reduced labour, the size of the HDPE cages have been modified to 6 m in the fourth version. In a demonstration trial, these types of cages have been found to be successful in many maritime states along the Indian coast. Latest version of open sea cage is a cost effective GI cage designed for low investment farming operations.

Open sea cage technology developed by CMFRI

Different criteria must be addressed before site selection for cage culture The first is primarily concerned with the physico-chemical conditions like temperature, salinity, oxygen, currents, pollution, algal blooms, water exchange *etc.* that determine whether a species can thrive in an environment. Other criteria that must be considered for site selection are weather conditions, shelter, depth, substrate *etc.* Finally legal aspects, access, proximity to hatcheries or fishing harbor, security, economic, social and market considerations *etc.* are to be taken care.

Size

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 m dia and 15 m dia for grow out fish culture and 2 m dia HDPE cages for seed rearing. Ideal size for grow out cage is 6 m due to its easy manoeuvring and reduced labour. For fingerling 2 m cages can be used.

Cage frames and nets

Culture experiments and demonstrations using different cage materials have been carried out by CMFRI. Business entrepre neurs with high capital investments long lasting and expensive High Density Poly Ethylene (HDPE) frames can be used. Small groups and fishermen can opt for cost effective epoxy coated Galvanized Iron (GI) frames. GI frames have less life span com pared to HDPE frames.

Nets of varying dimensions and materials were tested for cage culture in India. CMFRI has used braided and twisted HDPE nets for grow out purpose. It can last for two or more seasons. 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. Sapphire is also good because of its high breaking strength compared to HDPE and nylon. Cost factor has to be taken care while using sapphire or dyneema materials for net cage. The depth of net ranging from 2 to 4 m for fingerlings and 5 to 6 m for grow out cages are ideal. For open sea cage culture, predator net to prevent attack by predatory organisms is essential.

Potential species and criteria for selection of species for cage culture

The selection of species for cage culture should be based on a number of biological criteria like omnivore or carnivore, hardiness, fast growing, efficient food conversion ability, availability of eggs and juveniles, and disease resistance. Economic marketability and demand are also taken into consideration.

Mariculture is a relative latecomer in the food production industry in the world. Following positive experiences in production of salmonids in floating cages at high densities in European countries, marine finfish farming in cages was successfully initiated in coastal waters of Mediterranean countries as well.

In India, marine fish present problems for the fish culturists since fry supply still remains as a bottle-neck in expanding of industrial mariculture. Marine fish eggs and small size larvae at first feeding make it too complicated a matter to rear them throughout their life cycles. Culture of marine fish has taken up only due to the promotion of cage culture of sea bass by CMFRI and to the improvement of the hatchery techniques by RGCA (MPEDA) which has enabled the fry production under a controlled price. Asian seabass *L. calcarifer* has been proven as a fine species for cage culture due to the availability of hatchery produced seed, market demand and fast growth. Another species which has great potential is cobia *Rachycentron canadum*, for which hatchery technology has been initiated by CMFRI. Once the technology is commercialized, cobia will snatch the scene of mariculture in India due to its fast growth and excellent market value.

Among crustaceans, lobster rearing in open sea cages has been proved highly lucrative. CMFRI has demonstrated lobster rearing in cages at Vizhinjam, Kanyakumari, Mandapam and Veraval. Within a short span of 3 months fishermen were able to raise more than four times revenue by lobster rearing. Otherwise, juveniles of lobsters are sold for meagre amount in the local market. This practice also leads to reduction in loss of natural stock due to juvenile capture which is not uncommon in Indian waters.

Stocking

Although stocking densities should be determined by species requirements and operational considerations, the influence of stocking densities on growth and production has been determined empirically. The stocking density depends also 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. For producing 5 tonnes of 500-600 g seabass from a 6 m dia. HDPE cage, 30-50 individuals (100 g) per cubic meter can be stocked.

Feeds and feed management

Fresh or frozen trash fish, moist pellet (MP) and floating dry pellets are the common feed for growing fish in cages. Feeding in cages is quite easy compared to that in ponds. The ration can be divided into equal portions and supplied at regular intervals. Feeding can be done either by broadcasting or using feeding trays.

Harvest

Harvest of fish or lobster in cages is made very easy compared to that in ponds. Cages can be towed to a convenient place and harvest can be carried out. Also based on demand, partial or full harvest can be done.

Cage management

Cage culture management must result in optimizing production at minimum cost. The management should be so efficient that the cultured fish should grow at the expected rate with respect to feeding rate and stocking density, minimize losses due to disease and predators, monitor environmental parameters and maintain efficiency of the technical facilities (Chua, 1982). Physical maintenance of cage structures is also of vital importance. The raft and net-cages must be routinely inspected. Necessary repairs and adjustments to anchor ropes and net-cages should be carried out without any delay. Monthly exchange of net should also be considered, as this ensures a good water exchange in the net, thereby washing away feces, uneaten food and to a certain extent reduce the impact of fouling.

Fouling of cage net

Fouling of cage nets and other structures has been observed at many instances of cage farming. Nets get covered with bio-foulers. Fouling by molluscs, especially edible oysters and barnacles have to be checked before its growth advancement. Algal mats and other periphytons can be removed by introduction of omnivorous grazers in cages. A fouled net will be heavier, thereby increasing drag, and this result in loss of nets and fish.

To avoid/ reduce fouling, net should be changed as and when required, which may vary from 2 to 4 weeks depending on the intensity of fouling. During oyster fouling, net exchange has to be done immediately after the seasonal spat fall.

Herbivorous fish such as rabbit fish (*Siganus* spp.), pearl spots (*Etroplus* spp.) and scat (*Scatophagus* sp.) can be used to control biofoulers (Beveridge, 1987), but their application on a large scale needs to be assessed.

Disease monitoring

Monitoring of fish stock health is essential and early indi cations can often be observed from changes in behavior, especially during feeding.

TechnicaL issues in developing open sea cage farms in Indian waters

- Lack of sea farming policy is a major issue which has to be taken care by the concerned states in the country before taking up commercial cage farming.
- Modification of the cage design to withstand strong sea currents/ tidal flow and retain their effective volume; developing cages that are better suited to the sea conditions in different regions and to different species.
- Developing stronger cage-nets that can withstand varying sea conditions and fouling.
- Producing associated facilities and equipment, including that for safety and security of the structure and stock, feeding,

grading, net-cleaning, monitoring, harvesting *etc*.

- Developing cost-effective and nutritionally complete formulated feed to replace the trash fish that is used at present. Formulated feed has been used in aquaculture for more than 30 years, but is not widely used in marine cage culture.

Capture based aquaculture

Capture based aquaculture (CBA) is a good concept for species for which hatchery technology has not been developed. Southern blue fin tuna (*Thunnus* spp) is cultured in Australia using wild-caught juveniles, which has great demand in global market. In India also many species can be cultured in a similar way. The juveniles of high valued species caught in different gears if brought alive can be effectively used for CBA in cages. Juveniles of koth, ghol, pomfret, pompano, snappers *etc.* can be used for CBA. The only precaution to be taken is that CBA should not target to any single species, which might lead to vulnerability to endangering/ extinction in future. CBA enhances marine fish production and reduce the wastage of resource as low value by catch and regular supply of high quality seafood items.

Constraints that may occur in open sea cage culture

- Biological, mainly disease problems, and biodiversity concerns due to the introduction of new species in the region.
- Market constrains, such as fluctuation of prices based on supply, quality control problems, demand for aquaculture products, *etc*.
- Zoo-technical constraints, such as seasonality of production
- Environmental concerns, linked to the location of farms and the impact of their effluents on the surrounding environment (in commercial ventures only)
- Scarcity of potential sites for new aquaculture projects, and competition with other coastal users (urbanization, tourism, navigation, wildlife park projects, harbours, maritime traffic, *etc*.) and

- Scarce administrative organization with regards to the integra tion of aquaculture activities in coastal areas.

Economic analysis

The success of the adoption of any innovation or new technology lies in its economic performance. The rate of return per rupee invested is the economic indicator that guides the investor to choose a particular enterprise or practice. Besides, the analysis of the economic performance serves as an indicator for the investor to allocate his resources in the enterprises. This becomes very much essential, since the resources are scarce and the investor is interested to invest his scarce capital resource in that enterprise that gives the maximum return for his investment.

The economic performance of the cage culture experiment had been worked out by calculating the annual fixed costs, variable costs and the annual total costs from the cost side. From the returns point of view, the harvest from the cage, the gross revenue from the sales of the product had been worked out. Using the cost and returns figures, the economic indicators are estimated to test the economic viability and financial feasibility of any enterprise. This would serve as guidelines to the institutional agencies that are extending the financial support to the enterprise.

Case studies

Demonstration of open sea cage culture for finfish and shellfish was carried out by CMFRI in Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh and Orissa. Lobster culture was successful at Kanyakumari, Vizhinjam and Mandapam. Asian seabass culture was highly encouraging at Karwar, Balasore and Chennai. Mullets, seabass and pearl spot were also successfully harvested from backwater cages at Cochin. Based on the success CMFRI has developed an open sea cage farm at Karwar bay. The detailed economic analysis of the experimental cage culture demonstrated in Visakhapatnam (Andhra Pradesh) and Balasore (Orissa) is given in Tables 1-5 to indicate how the economic analysis of the enterprise is done.

Visakhapatnam

Table 1- Initial investment of the cage culture farm of 1061 m^3

Sl. No.	Items	Investment (in Rs.)	% to total	Economic life(in yrs)
1	HDPE Cage frame	4,00,000	27.12	10
2	HDPE nets	3,00,000	20.34	10
3	Galvanized Iron Chains	80,000	5.42	10
4	Mooring equipments	60,000	4.07	10
5	Stone Anchors	1,50,000	10.17	50
6	Floats	1,50,000	10.17	10
7	Shock absorbers	25,000	1.69	10
8	Ballast	35,000	2.37	10
9	Ropes-HDPE	35,000	2.37	10
10	One time launching charges	2,40,000	16.27	
	Total Initial Investment	14,75,000	100.00	

Table 2. Details of annual fixed cost

Sl.No.	Details	Amount (in Rs.)
1	Depreciation	1,16,000
2	Insurance premium (5% of investment)	73,750
3	Interest on fixed capital	1,77,000
4	Administrative expenses (2%)	29,500
	Total fixed cost	**3,96,250**

Table 3. Details of annual variable cost of cage culture (crop duration: 7 months)

Sl. No.	Details	Cost	% to total
1	Feeding	2,24,000	14.02
2	Seedling	1,50,000	9.39
3	Feed cost	9,00,000	56.32
4	Net cleaning	75,000	4.69
5	Underwater inspection	50,000	3.13
6	Net mending and Maintenance	25,000	1.56
7	Post crop overhauling	20,000	1.25
8	Security	1,00,000	6.26
9	Interest on working capital @6% for one crop duration	54,040	3.38
	Total	**15,98,040**	100.00

Table 4. Economic indicators of the cage culture of *Lates calcarifer*

Sl. No.	Details	Amount (in Rs.)
1	Annual fixed cost	3,96,250
2	Annual Variable cost	15,98,040
3	Annual total cost	19,94,290
4	Gross revenue (after harvesting from 5th to 7th month)	37,50,000
5	Net operating income	21,51,960
6	Net income (profit)	17.55,710
7	Capital Productivity (Operating Ratio)	0.43
8	Annual Rate of return to capital	119%

Balasore

At Balasore, the initial investment for a 6m diameter cage worked out to Rs.3,00,000. The fixed costs for the culture period of six months was calculated at Rs.54,000. The variable costs of the culture operation worked out to Rs.2,31,750. Thus the total cost of production to the participants worked out to Rs.2,85,750 (Table 5).

Table 5. Economic analysis of the experimental cage culture demonstration at Balasore

Sl. No.	Details of cost and returns	Amount (in Rs.)
1	Initial investment for a 6m diameter cage	3,00,000
2	Fixed cost (For crop duration of six months)	
	a) Depreciation	30,000
	b) Insurance (2% on investment)	3,000
	c) Interest on Fixed capital (12%)	18,000
	d) Administrative expenses	3,000
3	Total Fixed cost (A)	54,000
4	Operating costs	
	a) Cost of seedlings	5,0000
	b) Cost of feeding and other labour chages	1,75,000
	c) Interest on working capital (6%)	6,750
	Total Operating cost (B)	2,31,750
6	Total cost of production (Six months)	2,85,750
7	Yield of sea bass (in kg)	3,032
8	Gross revenue from 3032 kg	5,75,760
9	Net income (8)-(5)	2,90,010
10	Net operating income (Income over operating cost)	3,44,010
11	Cost of production (Rs./kg) (6)/(7)	94.24
12	Price realized (Rs./kg) (8)/(7)	189.89
13	Capital Productivity (Operating ratio) (5)/(8)	0.50

The culture of sea bass yielded 3.03 tonnes at the end of six months, thus earning a gross revenue of Rs.5,75,760 to the participants. The culture has earned a net operating income of

Rs.3,44,010 at the end of six months and a net profit of Rs.2,90,010 at the end of the same period. The cost of production per kg of sea bass worked out to Rs.94.24 against the value realization of Rs.189.89 per kg. The capital productivity measured through operating ratio was worked out to 0.50. These economic parameters indicate that this open sea cage farming of sea bass is economically viable.

Factors to be considered before the establishment of open sea cage farms

- Identification of scientifically suited, resource specific and location specific sites for the establishment of open sea cage farms.
- Appropriate leasing policies conferring the rights/ or legally valid authorization to the fishermen groups, SHGs or fishermen cooperatives to undertake open sea cage farming.
- Introduction of a socio-economically conducive mechanism under participatory mode to share the cost and economic benefits so that social conflicts are avoided.
- Ensuring adequate and regular supply of seed of the selected species from hatcheries, providing technical support and arranging for suitable financial assistance with the help of organizations like the State Fisheries Departments and development organizations like National Fisheries Development Board (NFDB).

Conclusion

Responding to the challenge of filling the gap between growing demand and capture fisheries supply, mariculture production has to satisfy the optimistic expectations. Significant progress is being made by CMFRI in this area through cage culture as evidenced by both the scientific achievement and the production trends. The economic analysis of the cage culture has also been worked out with higher net operating income and net income in a crop period of seven to nine months. It is to be noted that once the practice is further expanded to many areas and farms, the cost will decline due to the economies of scale of operation. Open sea cage farming is a viable alternative and economically and financially feasible mariculture operation for the stake holders to make use of. Open sea cage culture develop ment must be sustained in future by research and development in genetics, nutrition, health management, production economy, product handling *et*c. Technological advances aiming to reduce capital and operating costs are particularly needed as to counteract the tendency for prices to fall as mariculture production increases. Future project assessments should involve not only technological and socio-economic considerations, but also its environmental efficiency. Co-operation between government, investors and financial institutions is a prerequisite into achieving a new era of mariculture development in India. The State Fisheries Departments and the organizations like NFDB can promote the concept of cage culture on a large scale with their institutional and financial support, availing the technical expertise of CMFRI.

■

II

REGULATORY FRAME WORK FOR MARICULTURE DEVELOPMENT AND MANAGEMENT

E. V. Radhakrishnan and A.P. Dineshbabu

Introduction

Mariculture is becoming a promising area of aquaculture all over the world and is one of the most important and rapidly growing components of Asian aquaculture contributing substantially to the increased demand for high value seafood items in the global market. India has a long tradition of aquaculture from time immemorial and is a leader in the world after China, contributing to about 5.2% of the total production in 2003 (FAO, 2005). Globally, coastal aquaculture is one of the fastest growing food sector industries. The production from coastal ecosystem through farming, which was less than 0.5 million t. in 1950, increased to 10 million t. in 1990 and to 36 million t. by 2007 (FAO, 2009). A sub continent, with seas all around on three sides, India has a long coastline of about 8129 km. The country's continental shelf is estimated as 0.5 million square km, within its Exclusive Economic Zone (EEZ) that extends to 2.2 million square km. The southern edge of the Indian peninsula extends in to the Indian Ocean, with the Bay of Bengal in its eastern part and the Arabian Sea in the west.

During the last six and half decades, the potential of aquaculture for food production were widely recognized and legal policies drafted in many countries. The development and management of aquaculture is likely to fall within the scope of various pieces of legislation and the expertise of various institutions. Aquaculture activities need to be carefully monitored and controlled because of the numerous interests involved, the diversity of natural resources used the variety of institutions concerned, involvement of a wider range of stakeholders from both public and private sectors. FAO insist that "9.1.1 States should establish, maintain and develop an appropriate legal and administrative framework which facilitates the development of responsible aquaculture" (Code of Conduct for Responsible Fisheries (CCRF), Article 9).

Indian Scenario

Traditionally, brackish water fishes and shrimps are farmed in coastal tide-fed ponds by simple extensive system of farming like the *Pokkali* farms of Kerala, the *Ghazani* and *Khar* of Karnataka and fish farms (*Bheries*) of West Bengal. Semi-intensive farming of shrimps, farming of green mussels and oysters, fattening of lobsters and crabs, finfish farming, seaweed farming, semi-culture of clams have increased the production through aquaculture in coastal ecosystems. The total production (excluding seaweeds) has increased from 3,868 t in 1980 to 1,97,339 t in 2008. This pheno menal increase in production indicates the magnitude of utilization of water resources for coastal aquaculture and mariculture. In spite of these fast paced developments a policy support to govern the mariculture development in a sustainable manner has not been made in the country. Rules and regulations to make shrimp farming sustainable have been put in place by the Coastal Aquaculture Authority of India (CAAI) and specific rules have been framed by some maritime states. The main groups of marine resources which are farmed in India are the crustaceans, finfishes, molluscs, and seaweeds. Molluscs such as clams, oysters, mussels and pearl oysters are mostly sedentary animals hence they are farmed either by on-bottom methods by sowing or from suspended floating structures like the rafts. Recently marine finfish and lobsters farming in marine cages have also been demonstrated successfully in India. List of mariculture practices are details in the table below.

Table 1.Mariculture farming systems prevalent in India

Sl.	Resource	Location	Type of farming	Farming status	Status regarding lease
1	Shrimps*Penaeus monodon, Fenneropenaeusindicus, Metapenaeusdobsoni, M. monoceros*	Intertidal/ subtidal	LandBased (ponds)	Commercial in some Maritime	Lease policiesexists states guided by rulesframed by AAI
2	Oysters*Crassostrea madrasensis*	Intertidal/ Sub tidal Openwaters	Off-bottom (Rack andren)	Commercialin Kerala	Lease policiesexist in somemaritime states
3	Mussels*Perna virdis*	Intertidal/ Sub tidal Openwaters	On bottom, off-bottom(racks, lines, rafts)	Commercial in Kerala	Lease policiesexist in some maritime states
4	Pearl oysters *Pinctada fucata P. margaritefera*	Bay/lagoons/ Oceanic open waters	Off bottom (rafts,cages)	Experimental (Commercializaton-Transitionphase)	None
5	Clams(*Papahia malabarica Villorita cyprinoids*)	Interdical/Sub tidal Open waters	On-bottom	Semi-commercial In Kerala,Karnataka	None
6	Crabs Scylla serrata	Intertidal/ Sub tidal	Cages/lanbased	Commercial fattening	None
7	Lobsters *Panulirus homarus, Thenus orientalis*	Near shore	Land based (Ponds/cages)	Commercial fatte-ning / Experimental	None
8	Finfishes	Open sea Coastal fixedcages	Sea cages Land basedponds,	Experimental/ Commercial Commercial, experimental	None Lease policiesexist in somemaritime states

Leasing policies for coastal aquaculture in India

As per Article 21 of the Indian Constitution the states are empowered to regulate and manage marine fisheries in their territorial waters extending 12 nautical miles off the coastline towards the sea and all maritime states have enacted the Marine Regulations Acts since 1980. The area from 12 nautical miles to 200 km in the EEZ comes under the jurisdiction of the Union Government. The provisions made in the 73rd and 74th amendments to the Constitution of India empower the panchayats to perform functions mentioned in the eleventh schedule of the Constitution in 29 subjects including fisheries. However, due to lack of legal clarity this has not been implemented in any panchayat. The coastal aquaculture leasing policies in India have been drafted mainly for shrimp farming, particularly in Tamilnadu which also has a draft mariculture policy that states in clause 11.2.7 that mariculture activities are not permitted in estuaries, backwaters, lagoons etc. Such a clause indicates lack of proper understanding and needs to be corrected in consultation with research organization. The Government of Gujarat has enacted a land lease policy for aquaculture according to which an individual is admissible for allotment of 5 ha area, co-operative society for 50 ha area while private company is eligible for 100 ha area. Allotment is made by the Revenue Departments authority. It is now essential that leases (short-term or long term) giving the aqua culturist exclusive rights to occupy the site and to the cultured organisms should be developed. Such leases should be guided by a set of rules and principles relevant to public trust responsibilities and should specify the size of farm, duration of farming and other terms of lease. Rents thus collected should be used for development of coastal areas.

Table 2. Principles to be considered to frame policy formariculture lease in open water bodies

	Principle	Policy guided by
1	Common property useconflicts	Use of open water bodies for navigation, fishing should not be hindered by mariculture. Similarly, mariculture activities in open water bodies should not cause disturbances to other users. Further, mariculture when permitted by the state should be afforded complete protection of structure and stock kept in the open water bodies.
2	Carrying capacity	Open water bodies have limited to biological productions and such limits should be defined by the state in consultation with research institutions
3	Environmental protection	The polluter pays principle enacted by the CAAI should be applicable to open water bodies so as to minimize environmental impacts. Pre and post EIA (environmental impact assessment) should also be mandatory.
4	Conservation	Aquatic ecosystems are very sensitive to changes caused by human activities, and hence, all activities should take into consideration conservation of aquatic biodiversity.
5	Zonation	Since mariculture in open water bodies is diverse and region specific, states have to draw-up zonation plans in GIS formats with the help of research institutions. Creation of mariculture parks should be encouraged.

Registration of open water body farms

During the last decade several estuaries and backwaters in Kerala with high saline conditions have been used for bivalve farming. There are no environmental assessments made either prior to farming and after farming. Studies conducted by the Central Marine Fisheries Research Institute (CMFRI), Kochi have indicated that farming bivalve at the same site for more than three years can negatively impact the sediment structure and benthic faunal communities. These aquaculture activities are conducted in open waters where there are other common users, to legally recognize mariculture has become inevitable. Most nations where mariculture has advanced as a commercial activity, government leasing determines the appropriate areas for mariculture activity, allocating the rights to use the resource and evaluation of environmental impacts.

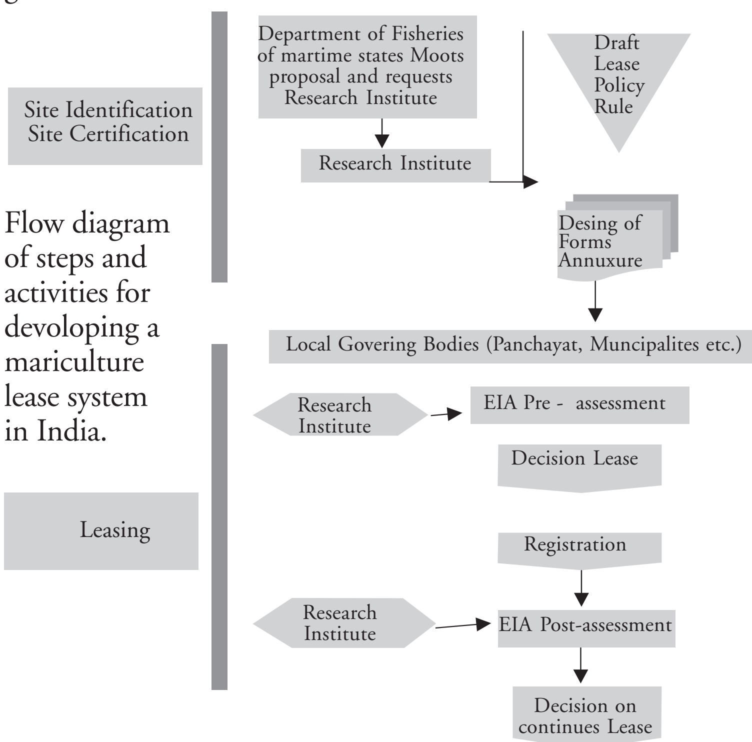
Modalities for implementing a lease: (eg. bivalve farming)

Once the site is approved, the lease conditions can be drafted based on the farm size, the stocking density and other conditions which will promote sustainable bivalve farming. The forms for registration/leasing can be drafted and these forms can be made available through the local governing bodies. Farmers can submit their requests to the state fisheries departments and after evaluation based on the approval by the competent authority can be registered.

1. The application by the farmer should contain a description of the location of the proposed lease by corner coordinates or boundaries with coordinates for one starting point, a map of the lease area and its adjoining waters and shore lands, known riparian owners as they are listed in the panchayat or state property tax records.
2. A list of the species to be cultivated and a description of the proposed source (s) of organisms to be grown at the site should also be included.
3. A description of current commercial, navigational and or recreational activities such as eco-tourism occurring in the proposed lease tract and the immediate vicinity of the proposed lease site should be indicated.

4. The applicant should provide information regarding the financial resources available to operate, accurate and complete cost estimates.
5. The applicant shall submit a resume or other documentation as evidence of technical expertise and capability to implement the proposed project.

The local governing body makes decision on the lease while registration of the farms should be mandatory. Besides being helpful to determine the levels to which carrying capacity ahs been reached for the region, to indicate the origin of the farmed production. After the farms are registered and prior to stocking, the sediment and benthic faunal assemblage study (Pre stocking EIA) should be done. Similar study should be done and corrective measures taken if negative impacts are identified. A Flow diagram of steps and activities for developing a mariculture lease system in India is given below.



Flow diagram of steps and activities for devoloping a mariculture lease system in India.

Policy of Framework

The objective of the policy framework is to encourage responsible open body mariculture in the Indian coastal ecosystems. It should promote a decision making process that is transparent, efficient, coordinated and credible with the entire process taking 3-4 weeks. It should employ a precautionary approach to avoid and minimize environmental impacts and promotes integration into the ecosystem.

It should be consistent with existing Indian laws and Agency responsibilities and be consistent, to the maximum extent possible, with the coastal water environmental and aquaculture policies of adjacent nations; also consistent with India's obligation under International agreements. The policy should be adaptive, and should promote the opportunities for innovation, data collection and continual learning

Certain mariculture practices like the pearl culture and cage farming can be done only in bays and open sea areas which are protected and not affected by cyclones and oceanic disturbances. One of the major impediments in development of mariculture in open access water bodies is the lack of protection of the farm structure. State Governments in consultation with competent research institutions can demarcate selected areas congenial for mariculture as "Mariculture Parks". Those who are interested to invest in mariculture can apply for lease in these mariculture parks and after the approval by the competent authority they will have ownership over the allotted area for the specific time period. There are various Monitoring and Administering Agencies involved in various legislatures and mariculture entrepreneurs has to be need to be given guidelines to abide by the different legislations by different organizations.

Monitoring and Administering Agencies

The monitoring process envisaged in this policy frame work should necessarily vest with a research institute. The admini stering mechanism for the mariculture policy should primarily be vested with the respective state fisheries departments (SFD). The chain of command should begin with the SFDs and end with the local governing bodies. There should be considerable synergy between monitoring and administering agencies for sustainable mariculture development in the country.

Table 3.Institutions responsible for decision–making

Organization	Responsibilities
Ministry of Environmentand Forests	Management of resources in the coastal water
Ministry of EarthSciences	Scientific monitoring of the marine environment,management of resources in the high seas
Ministry of Agriculture	Development of fisheries, aquaculture, fish processing
Ministry of WaterResources	Erosion
Ministry of SurfaceTransport	Ports, shipping etc.
Ministry of Petroleumand Natural Gas	Offshore installation, coastal refineries, pipelines etc.
Ministry of Tourism	Tourism activities in coastal regions
Ministry of mines	Mining activities in coastal regions

Highlights of major policies and programmes

From 1897 onwards various legislations are brought by various agencies and most important legislations are listed below.

Table 4. List of important legislations

Year	Relevant Acts, programmesand policies	Salient features and Amendments
1897	Indian Fisheries Act	Offers protection to fisheries againstexplosives or dynamites
1908	Indian Ports Act	Enactment relating to ports and portcharges
1958	Merchant Shipping Act	Control of pollution from ships and offshoreplatforms
1972	Wildlife Protection Act	Offers protection to marine biota
1974	Water (Prevention and	Control of pollution from Control of Pollution Act) land-basedsources includes tidal waters
1978	Marine fishing RegulationAct	A model act, which provides guidelines to the maritime states to enact laws forprotection to marine fisheries by regulating fishing in the territorial waters.
1980	Forest Conservation Act	Protection to marine biodiversity
1982	Coastal Pollution ControlSeries	Aims at assessing the (COPOCS) programme) pollution status ofcoastal waters.
1986	Environment ProtectionAct	Under this, the Coastal (EPA) Regulation Zone1991 has been notified.

1991	(underEPA,1986)	Coastal Regulation ZoneNotification Regulations on various activities in coastalzone.
1991	Deep Sea Fishing Policy	Allows foreign fishing vessels into Indianwaters beyond 12 nautical miles
1991	Coastal OceanMonitoring and	Assesses the health of Prediction systems coastal waters (COMAPS Project)
1995	UNCLOS	A new international order established foroceans Provides a comprehensive legalframework for integrated treatment ofissues relating to oceans and seas
1996	Coastal Zone Management	Supreme CourtIntervention Plans (CZMPs) that all the Coastal states prepare their CZMPs by1996.
1997	Ocean Observation and Information	Generate reliable 1998 oceanographic datavarious projects of DOD were restructured
1998	Integrated Coastal andMarine	Aims at integrated Area Management management of coastaland (ICMAM Project) marine areas.
2000	The Biodiversity Bill	With an aim to protect and conservebiodiversity and sustainable use

Although enriched with vast natural resources and numerous potential species, the sea farming practices have not picked up in the country, perhaps due to the lack of a policy for usage of open water bodies. The coastal areas of the country are densely populated and their major occupation is related to fishing and ancillary activities. Therefore, demarcation of suitable areas for a relatively new venture such as mariculture may invite multi user conflicts. Therefore, to initiate such projects, it is very important to involve the local community and frame suitable policy for aquaculture. Coastal Aquaculture in the open waters requires statutory support and the Government is yet to take major policy decision in this regard. Therefore, any major effort for commercialization of the technology for mariculture of various species will depend on an effective policy framework. ■

III

SITE AND SPECIES SELECTION CRITERIA FOR CAGE CULTURE

Jayasree Loka, N.G.Vaidya and K.K. Philipose

Cage farming is one of the alternative to inland and brackish water farming to increase fish and shellfish production. Cage culture has been successfully practiced to culture marine finfish for many years. In Australia, Norway, Chile and some of Asian countries, cage culture is being successfully practiced since the 1950's. Due to their large consumption value there is an increasing demand for the culture of many marine finfishes. This further led to an increased demand for marine aquaculture throughout the world. A number of diversity of types and designs of cages are developed of which four types of cages viz., fixed, floating, submersible and submerged are the most common proposed by Beveridge (1996). To establish a cage culture system, a thorough knowledge of site where the cages are to be installed is required which can be met with the data available with Govern ment organizations, local people as well as the extensive field survey to understand the topography, water and sediment quality.

Site Selection

Site selection is the most important factor which determines the commercial viability of mariculture systems. Cage culture can be made possible only when the site for cage culture operation is located, designed and operated to provide optimum water quality and to avoid stress conditions. In addition to water and sediment quality of the site some biological and natural distribution information for the species should also be known before a site is selected for cage culture. The selection of fish for cage culture should be based on biological criteria, such as physiological, behavioural characteristics and level of domestication; marketing criteria and environmental criteria, distribution and habitat of site (Fig. 1).

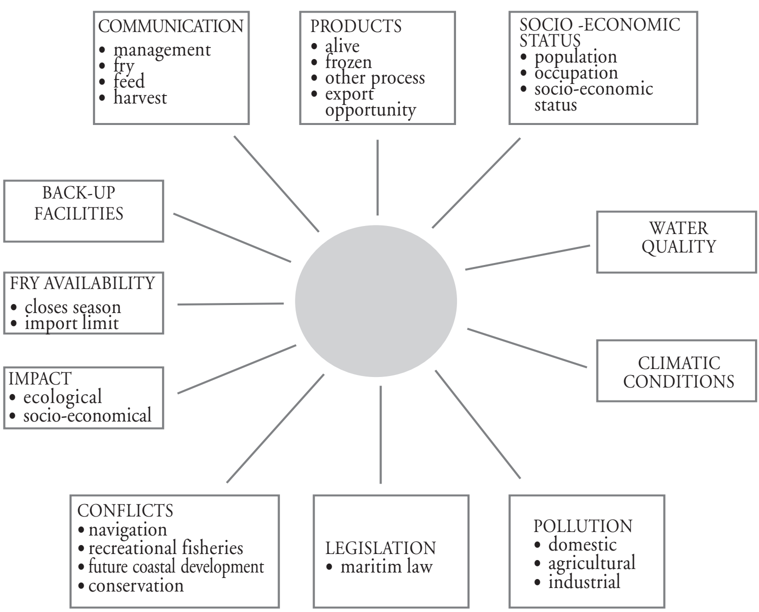


Fig. 1. Criteria for selection of cage site.

Topographical criteria:

The cage site to be selected should be of a suitable depth, have good tidal flow with optimal conditions and ideally be protected from strong winds and rough weather and have sufficient water movements. The size of wind generated waves is determined by (i) wind velocity, (ii) the duration of time that the wind blows, and (iii) the distance of open, unobstructed water across which the wind blows (fetch) (Bascom, 1964). In general, the wind velocity should be less than 5 knots for stationary cage and 10 knots for floating cage. The height of the wave should be less than 0.5 m for stationary cage and 1.0 m for floating cage. Culture sites should be placed at some distance from navigation routes as the waves may be created from the wake of passing vessels.

It is necessary to allow sufficient depth under the cage in order to maximize water exchange, avoid oxygen depletion, accumulation of debris and build up of some noxious gases generated by decomposition of the deposited wastes. In turbid water, silt will tend to accumulate in the cage preventing good water exchange. The minimum and maximum depth of the cage can be calculated as follows:

D2 = M - T + H2

D2 = minimum depth at lowest low water during spring tide

M = measured depth

T = tidal height at the time when M is taken

H2 = minimum tidal height at lowest low water during spring tide

Bottom condition

For an ideal site for cage culture, a firm substrate, with a combination of fine gravel, sand and clay will be highly productive. Depending on the type of substrate present at any given site type of cages also vary. The floating net cages over rocky substrates require more expensive anchoring blocks, but have better water exchange rate. In general, sloping areas from the shore leading to flat bottoms are suitable for cage culture because the waste build-up at the bottom is easily eliminated. Additional site selection criteria should also include accessibility to the cages and the ability to move them out of potential harmful events such as algal blooms and/or low DO events. Continuous, unattended monitoring systems that can send alerts when conditions are close to unacceptable ranges are invaluable in these situations.

Physical criteria

The main physical parameters that need to be considered in cage culture systems include factors such as current movements, turbidity and water temperature.

Turbidity: During heavy monsoons, water becomes turbid due to the freshwater runoff and more turbid waters are not suitable for cage culture. Freshwater runoff due to rains may lead to leaching of heavy metals from industrial effluents and suspension of organic and inorganic solids in the water column. Deposition of solid organic and inorganic materials to the bottom due to heavy rains may act as substrate for fouling organisms on the nets, which further prevent proper water circulation .Suspended sediments also responsible for choking of fish gills which may lead to mortality due to asphyxiation. The presence of suspended solids also relates to some disease such as "fin-rot" caused by Mycobacteria (Herbert and Merkens, 1961; Herbert and Richards, 1963). Suspended solids in a suitable site for net cage culture should not exceed 10 mg/l. But its effects also depend on the exposure time and current speed.

Water temperature: In cage culture, optimum water tempe rature depends on the type of cultivable species i.e., 27–31°C for most tropical species and 20–28 °C for most temperate species. In the Asian region the annual temperature range fluctuates from 20–35°C in tropical countries and from 2–29 °C in temperate countries. Some of the fish species can survive even at varied temperatures the growth of the fish may be affected due to its fluctuations. The change in water temperature will affect fish metabolism and activity, oxygen consumption, ammonia and carbon dioxide production, feeding rate, food conversion, as well as fish growth. The best solution is to select fast growing species (not more than 8 months) and avoid having the culture period running into the months with unsuitable temperature.

Chemical criteria: In cage culture, chemical parameters of marine waters play an important role in the assessment of water quality of cage systems. The natural tolerance of each species should also be studied for assessment of suitable site. Most important chemical factors to be considered in cage culture are Salinity, Dissolved Oxygen, pH, Ammonia, Nitrates and Nitrites.

Dissolved oxygen: Oxygen consumption for each species of fish varies, with pelagic fish like snapper and seabass requiring more than demersal species such as grouper. In general, dissolved oxygen should preferably be around 5 ppm or more and never less than 4 ppm for pelagic fish or 3 ppm for demersal species In the case of cage culture, benthic organisms and sedimented wastes may also reduce the oxygen level. Solubility of oxygen in water declines with increasing temperature and salinity. Hence depletion of DO always occurs during night time at neap tide in summer.

Salinity : For most tropical species, the optimal salinity is normal strength seawater; they cannot tolerate low salinities such as 10–15 ppt. Suitable site for cage culture should thus be with salinities between 15–30 ppt so that cultured species can be changed according to market demands. Seabass (*Lates calcarifer*) can tolerate a wide range of salinities from 0 to 33 ppt and an optimum of 15 ppt is required for culture of seabass. For culturing snappers the optimum salinity required is 25 ppt.

Hydrogen ion index (pH): The suitable pH for most marine species is from 7.0 to 8.5. Extreme values of pH can directly damage gill surfaces, leading to death (McDonald, 1983).

Ammonia: The level of ammonia-nitrogen in the water should be less than 0.5 ppm. The suitable time for measurement of ammonia level should be during neap tide when water current is slow. The ammonia level in water caused by the decomposition of uneaten food and debris at the bottom, can affect the fish. Normally in coastal area, sewage discharge and industrial pollution are the main sources of higher level of ammonia in seawater.

Nitrate (NO_3-N) and nitrite (NO_2-N): For a suitable cage culture area, nitrite level should not exceed 4 mg/litre while nitrate level should be below 200 mg/litre. The excessive amount of nitrite in water becomes toxic to fish due to oxidation of iron in haemoglobin from ferrous to ferric state (Tiensongrusmee, 1986). It will cause hypoxia in fish because haemoglobin molecule cannot bind with oxygen.

Biological criteria

Phytoplankton: Although a few tropical marine species of Cyanobacteria are toxic (eg. Lyngba and Oscillatoria, Moore, 1982), their blooms are uncommon. A number of marine algae groups form blooms, including diatoms, Cyanobacteria, prymnesiophytes and dinoflagellates. *Chaetoceros convolutus* has a number of prominent spines which interfere with gill function and loss of blood from injury (Kennedy, 1978). Excessive blooms of phytoplankton can happen whenever the suitable condition prevails such as high light intensity, high nutrient level (organic load), warm water temperature, stagnant hydrological conditions. These conditions should be avoided when selecting cage farming. Algal blooms can affect fish, not only by damaging fish gills by clogging, but also by competing for dissolved oxygen at night. Red tides commonly occur in warm water, especially during summer months.

Fouling organisms: Fouling is generally more rapid in areas with low current velocities, high temperature, high turbidity (enriched water) and high salinity. More than 34 species of algae (cyanophytes, rhodophytes, chlorophytes) coelenterates, polyzoans, annelids, arthropods, molluscs and simple chordates have been observed clinging to netcages after immersion for only two months (Cheah and Chua 1979). Colonization of fouling organism is primarily caused by silt particles deposited at the net which serve as substrate for fouling organisms. Silt particles can be more than 50% of total fouling weight (Chou, 1988).

Accessibility: The culture site should be near a shore preferably with a jetty for boat connection with farms and near a good road for land transportation. Good accessibility facilitates distribution of farm products, (especially live fish), transport of feed, fingerlings, fuel, farm equipment, supplies and other necessities. The owner can visit the farm site more often to ensure proper management if it is easily accessible.

Selection of species for cage culture

Species selected for farming in floating netcages must have a good demand and high market value should be hardy, should be able to accept external source of food under confined conditions. Food from external source may be a. natural eg. trash fish or b. artificial eg dry formulation. Criteria to be followed to select the species for cage farming are

High-valued species

a. It is preferable to culture species with high market value so as to off-set the relatively high cost of production of net cage farming.

b. As the fish can be easily harvested live, the farmer can sell the produce in prime, live condition. In doing this, he obtains a better price for the fish than would be possible if they were sold chilled or frozen as is the usual case in pond culture.

c. Other than Banana shrimp and seabass mentioned, other high valued species include finfish like the groupers, viz *Epinephelus spp.*, snappers (*Lutjanus spp*), Seabreams (*Acanthopagrus latus*), Cobia, Pampano, crab (*Scylla serrata*) and lobster (*Panulirus spp.*).

Hardy and tolerant species

a. Species selected should also be hardy and tolerant to confined, crowded conditions and to the rigours of handling during net cage changes.

b. Stocking in net cages is often more than 10 times that of pond culture eg.5/m2 compared with 40/m2 for grouper culture in ponds and net cages respectively.

c. Flan in net cages are also subjected to greater physical contact and stress during feeding as there is often a rush for the food by the main bulk of the population in the net cage. Both estuarine grouper and seabass are found to thrive well under such crowded conditions and do not respond so well to feeding when they are small numbers.

Ability to accept external source of food

a. As there are usually no other significant sources of food within the net cage except for small fish which stray in and out, selected fish must be able to accept external source of food especially if species is carnivorous. The selected feed, usually chopped trash fish, would drop through the netcage if it is not eaten by the time it reaches the net bottom.

b. The loss of feed is greater when dry feed is used. Feeding trays can be suspended in the net cage to catch the pellets as they fall and this is used in net cage culture of shrimp. Net cages can be deepened to allow greater pelleted feed retention time within the netcage, or a slow-sinking dry pelleted feed would also maximise this retention time.

c. Some fish like the grouper, seabass and golden snapper respond to feed discharged from autofeeders. In fact, the fish will swim around the feeder in anticipation of the feed drop.

d. Spiny lobsters and Rabbit fish (*Siganus canaliculatus*) are able to graze on the algas growing on the sides of the netcage and derive part of their food from this source. They can also serve as biofculing controls in netcages. Rabbit fish will also respond to feed given to them.

e. Seed availability: Seed, which is usually fry or fingerling, can be wild-caught or hatchery-bred. In the former, supply is usually seasonal and unpredictable but are however more robust and hardy as they would already have undergone pre-selection by nature. In the case of hatchery-bred seeds, supply is more predictable, and, depending on whether the parent stocks were wild-caught or farm raised could be produced on schedule in batch-operation sequence. The need to ensure that seed stock is available is important because without a certain and ready supply of seed at stocking time, farming becomes unpredictable.

Although many species are being cultured throughout the world,*Lates calcarifer, Epinephelus spp, Trachinotus sp. Rachycentron sp. Lutjanus spp., and Acanthopagrus spp.* are found to be more suitable species for cage farming in India and are being cultured successfully at Karwar by CMFRI (Fig. 2).

Acanthocephalus Iatus

Lutjanus argentimaculatus

Raccchycentron canadum

Trachinotus blochii

Lates calcarifer

Source :

FAO: UNDP/FAO Regional seafarming development and demonstration project in Asia NACA-SF/WP/89/13. Site selection criteria for marine finfish net cage culture.

FAO: Regional sea farming project. RAS/86/024. Training Manual on Marine Finfish Netcage Culture in Singapore. Species selection, culture and economics.

IV

DEVELOPMENT OF INNOVATIVE LOW COST CAGES FOR PROMOTING OPEN SEA CAGE CULTURE ALONG THE INDIAN COAST

K.K. Philipose and S.R. Krupesha Sharma

Introduction

The progressive decline in marine fish landing all along Indian cost poses serious question about availability of fishery resources as a source of cheap protein to the common man. It also raises serious concernes about the arising unemployment in the coastal belt of the country. Alternate technologies are the urgent need of the hour to produce more resources from the costal water and also to generate employment opportunities for the fishermen.

Open sea cage culture is one answer to address this problem partially. India has a cost line of 7517 km where open sea cage culture can be initiated at selected places where these systems will not clash with the fishing operation of the traditional and mechanized sector.

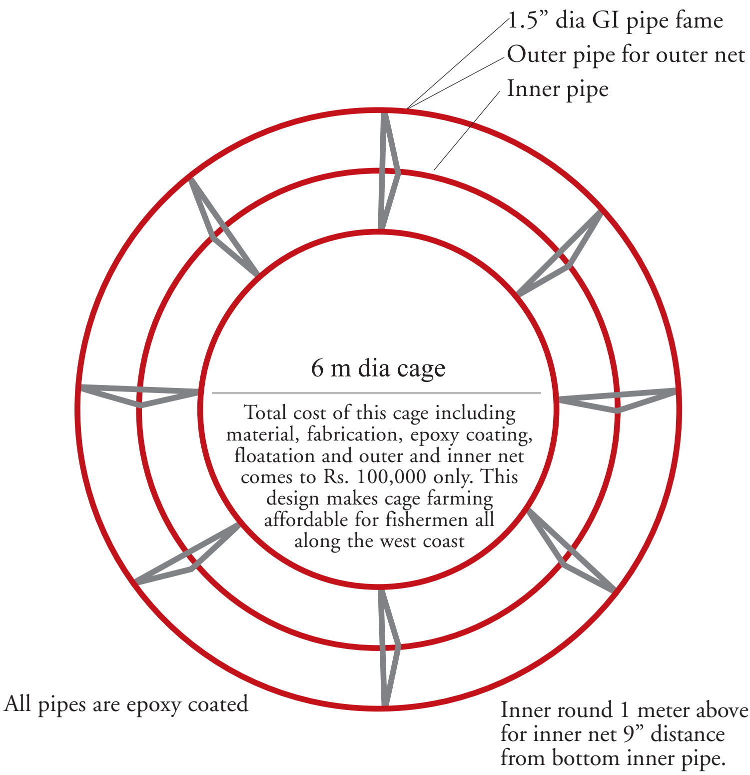


Fig.1. Design details of the low cost cage

Central Marine Fisheries Research Institute being the pioneer to initiate open sea cage culture in Indian waters has been striving hard to promote open sea cage culture at selected locations in all the maritime states with the involvement of the fisherman community. Cage design and mooring technology has been undergoing refinement through the dedicated and committed efforts of the scientist of CMFRI. Efforts were continuously made to reduce the cost of the cage and mooring systems so as to make it affordable for the fisherman and also to help them to take it up as a lively hood alternative. The present HDPE cage costs about Rs.4,00,000/- per cage and together with the mooring systems and net, the cost increases to about Rs.5,50,000/- making it unaffordable to the fisherman. While interacting with the fisherman they expressed their desire to have cage costing less then Rs. 1,00,000/- and lasting at least 5 years to make it sustainable and economical in the long run. It was with their interest in mind the Karwar Research Centre has looked for alternatives for HDPE cages for promoting cage culture in the coastal waters and developed fifth generation cage.

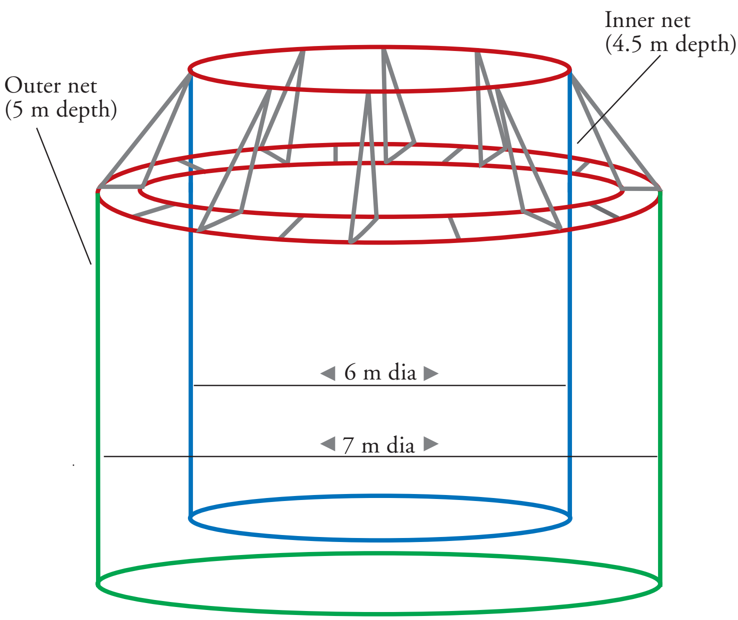


Fig.2. Technical details of the low cost cage

Design

The low cost cage developed at Karwar is made of good quality 1.5" GI pipe (B class). The design details of the cage are given in fig-(1) and Fig-(2). The diameter of the cage is 6 m and the height is 120 cm from base to the railings. Fig (3). All the joints are double welded for ensuring extra strength. After fabrication the structure was provided with single coat epoxy primer and double coat epoxy grey paint to prevent rusting. The total weight of the cage is about 700 kg.

Fig.3. Low cost cage before epoxy coating

Floatation

Puff or foam field HDPE cage is buoyant enough to float in the water. However, metal cage needs additional floatation (Fig.4). Ten fiber barrels of 200 l capacity filled with 30 lb air are used for floating the cage. The cage when floated on inflated barrels provides a stable platform around the cage where fisherman can stand and safely carry out works like net clearing, net replacement etc.

Advantage of the low cost cage

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

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

Disadvantages

Unlike HDPE cage wind action is more on metal cage as it is floated on barrels. Hence, it will be difficult to float in open sea condition from June to August unless heavy duty mooring is provided. Except for this the metal cage performance is far superior to HDPE cages.

Fig.4. Metal cage developed at Karwar

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

V

DIFFERENT TYPES OF NETTING MATERIALS & THEIR PROPERTIES

M.K. Sambasivan

With the invention of Poly Amide fibres (Nylon) in 1935 by W.H.Carothers(USA) there happened tremendous improvement in the quality of fishing gear materials. There after a series of petrochemical based synthetic fibres were developed which is widely in use in the fishing net industry. The following are the major classes of synthetic fibres.

(i) Poly Amide (Nylon)	:	PA. (W.H.Carothers, USA, 1935)
(ii) Polyester	:	PES (J.R.Whinfield & J.T.Dickson, UK,1940-41)
(iii) Polyethylene	:	PE (Ziegler,Germany-1950)
(iv) Polypropylene	:	PP (Natta,Italy-1954)
(v) Polyvinyl chloride	:	PVC (F. Klatte & H.Hubert, Germany-1934)
(vi) Polyvinyl alcohol	:	PVA (W.O.Hermann & W.Haehnel,Germany-1931)

The most important and widely used synthetic fibres are Nylon (PA) and Polyethylene.

Nylon : Very high breaking strength, high melting point(215 c) and high extensibility are the important qualities of Nylon which makes suitable for the fabrication of fishing gear.

There are nylon monofilament and nylon multifilament twines.

Table 1. Different types of Nylon monofilament & multifilament twines

Nylon multi filament twines			Nylon monofilament twines	
1	2 PLY	210/1X2	1	0.10mm
2	3 PLY	210/1X3	2	0.12mm
3	4 PLY	210/2X2	3	0.16mm
4	6 PLY	210/2X3	4	0.20mm
5	9 PLY	210/3X3	5	0.23mm
6	12 PLY	210/4X3	6	0.28mm
7	15 PLY	210/5X3	7	0.32mm
8	18 PLY	210/6X3	8	0.40mm
9	24 PLY	210/8X3	9	0.50mm
10	27 PLY	210/9X3		
11	30 PLY	210/10X3		
12	36 PLY	210/12X3		
13	45 PLY	210/15X3		
14	54 PLY	210/18X3		
15	72 PLY	210/24X3		

Nylon fishnets

(I) Nylon Multifilament Fishnets – Knotless & Knotted
(II) Nylon Monofilament Fishnets

Nylon Multifilament fishnets are commonly used for the fabrication of various types of gill nets, ring seine, Purse seine, Cast net, Chinese nets, Drift nets etc.

Common specifications of nylon multifilament twine for fishing ranges from 210/1x2 to 210/12x3.

The mesh size commonly required is from 8mm onwards to 450mm for different fishing gear. It is more effective for fishing than polyester because of the better sinking speed and extensibility.

Nylon monofilament is better for long lining and various types of gill netting. The twine range for fishing purpose is from 0.10 to 0.50 and for long line fishing 1.5mm to 3mm. The mesh size is normally starts from 16mm to 450mm.

Thinner monofilament nets are more effective for fishing but less durable and not repairable.

High Density Poly Ethylene (HDPE):HDPE is a linear polymer which is prepared from ethylene by a catalytic process. More closely packed structure without branches and higher density, higher chemical resistance make HDPE more suitable for fishnets.

Other properties of HDPE:

i. It can withstand high temp. up to 110c.
ii. 1HDPE is highly resistant to dilute and concentrated acids, alcohol and bases.
iii. Very good chemical resistance and high rigidity make it a good choice for cage nets.
iv. Very low moisture absorption and high tensile strength are other characteristics of HDPE.

HDPE twine is of two types; Braided and twisted. HDPE fishnet is usually used for the fabrication of trawl nets.

Important qualities of fishing net:

(i) Raw material quality as per BIS.
(ii) Perfect knot formation and knot tightness.
(iii) Accurate mesh size, mesh depth.

Synthetic twines manufactured from HDPE are totally resistant to sea water, acids, alkalies and chemicals. They do not absorb water and cannot rot very easily. These are the main reasons why HDPE fishnets are preferred for the fabrication of net cages.

Table 2. Different size of HDPE twines

Sl. No	Code	Apprx.Dia.	Apprx. Runnage (Mtrs/Kg)	Apprx. Br.strength (in Kgs)
1	280D/1/3	0.25mm	11100	3
2	280/2x3	0.50mm	5490	6
3	280/3x3	0.75mm	3080	9
4	280/5x3	1.00mm	1890	15
5	280/6x3	1.25mm	1612	18
6	300D/8x3	1.50mm	1200	24
7	300/12x3	2.00mm	802	36
8	300/21x3	2.50mm	432	63
9	300/28x3	3.00mm	342	84

HDPE is more suitable for the fabrication of net cages

The following qualities of HDPE make it more suitable for the fabrication of cages.

(i) Breaking strength of HDPE in water will be 110% as that of dry condition but that of nylon is 85-90% only.
(ii) Shrinkage in water is 5-8% only where as for nylon it is 10-12%.
(iii) HDPE will not absorb moisture but nylon absorbs.
(iv) Weight in water will be same but weight of nylon in water will be 12% more.
(v) HDPE is easy for handling and cleaning.
(vi) Because of rigid nature the mesh opening will be perfect which enables free exchange of water.

Nets suitable for open sea cage culture

Mesh size of any fish net used for fabricating the cages must be selected according to the species and also to ensure good water exchange. Proper aeration can also enhance water quality, reduce stress, improve feed conversion and allow to hold more fishes.

Because of the turbulent nature of the sea and presence of cannibalistic animals a suitable predator prevention net is essential for open sea cage culture. Considering the strength, durability and cost factor usually braided UV treated HDPE of 3mm thickness and 80mm mesh size is recommended and found very effective. The diameter of the cage can be decided as per requirement from 6 m to 8 m and a depth 5-7m for easy handling. The cages are mounted to floating circular frames with ropes and rings.

For the fabrication of inner cage twisted HDPE of 0.75mm to 1.5 mm depending on the size of cultivable species can be selected with a mesh size ranging 16mm to 28mm. Usually for sea bass 1.25 mm/26 mm to 1.5 mm/30 mm mesh size is recommended. The inner cage has to be periodically cleaned for better durability.

In order to prevent predator birds proper protective nets are also must be provided. HDPE twisted & UV treated 1.25mm 60 mm to 80 mm mesh size will be ideal for preventing the birds of prey.

Net cages for Inland water bodies

In the inland water bodies there are predators like crabs, certain type of eels which can destroy the nets and penetrate into the cage. In such water bodies Braided HDPE net having 2 mm to 2.5 mm thickness can be used as outer net to prevent the predators. Otherwise 1.5 mm twisted HDPE net can also be used.

The specification of inner cage can be decided depending on the species, from HDPE 0.5 mm/10 mm mesh size to 1.0 mm/22 mm which will be cost effective and durable. Predator birds are also common hence proper prevention net also must be used.

VI

MARINE FISH NUTRITION, FEED FORMULATION, FEED PRODUCTION AND FEEDING

P. Vijayagopal

With the initiation of cage culture of food fish in India by Central Marine Fisheries Research Institute (CMFRI) the major recurring inputs into these food production systems to be addressed are seed and feed. As the availability both of these inputs have to be maximized, we shall discuss here the pros and cons of nutrition mainly under the heads, principles of nutrition, feed ingredients, feed formulation, feed production and feed management.

Nutrients and their roles

Any material used for feeding contains the following five principles.1.Protein,2. Carbohydrate,2.Fat,4.Minerals and 5.Vitamins.

Proteins are building blocks in the feed and they are made up of amino acids. There are 20 amino acids among which 10 are called essential amino acids and the remaining 10 are called non-essential amino acids. Essential amino acids are those which cannot be synthesized by the animal at a rate required for the normal growth of any organism and so they have to come through food. Non-essential amino acids are the amino acids which can be synthesized by the animal in case they are not available through the food. Therefore, proteins are essential for growth of the animal and a deficiency can lead to what can be called as sub-normal growth. Other than the growth promoting role of protein they are required for the normal immune function of the animals preventing them from disease attack. Most of the enzymes present in animals are proteins, there are protein hormones, and there are structural proteins like keratins. In short protein have multiple functions in the animal body among which growth can be considered to be the most important.

Carbohydrates (starch and sugars) are energy yielding components in food. Even though fishes do not have an absolute requirement of carbohydrates, they are used in fish feeds for imparting several functional properties to pelletized feed like buoyancy, that is, sinking, slow sinking and floating properties to the pellet.

Fat are also energy yielding components if food. The quantum of energy available from fat is 2.5 times more than the energy available from carbohydrates. Fats are made up of fatty acids, among which, a few are considered essential (essential fatty acids). These fatty acids have to be supplied through feed.

The aforementioned three components of feed are called macronutrients because they make up the major chunk of the feed. Minerals and vitamins are called micro nutrients because they are required only in small quantities in the feed.

Minerals generally looked at in feeds are Calcium (Ca), Phophorus (P) which are called macro minerals because of their relatively high levels of inclusion. Other minerals, Copper (Cu), Cobalt (Co), Iron (Fe), Sulphur (S), Iodine (I), Magnesium (Mg), Manganese (Mn), Zinc (Zn) etc., are called microminerals. Most of these minerals have diverse functions in the body and deficiencies in the diet and water can lead to deficiency diseases. Similarly, an excess can lead to toxicity also which can be lethal.

Vitamins are micronutrients which can be classified as fat soluble and water soluble. Fat soluble vitamins are the ones which are soluble in fat. As fat is stored in the body these vitamins dissolved in fat is also stored. The fat soluble vitamins are A, D, E and K. Waters soluble vitamins being soluble in water cannot be stored in body and hence any excess is voided through urine. As mentioned in the case of minerals, vitamin deficiencies in the feed can lead to deficiency diseases and excesses can also cause certain metabolic disorders.

Having described the macronutrients and micro nutrients in feed, we shall have a look at their requirements in marine carnivorous fish which is summarized in the Table below

Table 1.Nutrient requirements of marine carnivorous fishes (in percent)

Size of fish	Moisture	Crude protein (CP)	Crude fat or Ether Extract (EE)	Crude Fiber (CF)
Fingerling (1 inch – 20 g)	<12	>42	>5	<4
Juvenile (20-50 g)	<12	>40	>5	<4
Grower (50-300 g)	<12	>38	>5	<4
Marketable size (> 300 g)	<12	>35	>5	<4

Carnivorous fish feed on live prey in nature and in practice also feeding the cultured fish with low value trash fish is practiced. This practice is not only unsustainable but also uneconomical. Trash fish feeding pollutes. It is fairly estimated to be 38% as compared to 10% for pelleted feeds. This may be an underestimate because there are some reports which say 45000 t trash fish is required to produce 300 t of high value fish in marine cages. In this situation, the amount of food needed to produce

1 kg fish equals 15 kg (i.e., apparent food conversion ratio or AFCR). However, under well managed experimental conditions it is reported to be as good as 3.5: 1 in the case of cage cultured groupers. In practice, it varies from 6:1 to 17:1. When converting this into dry matter basis (excluding the eater content in trash fish) true food conversion ratio (TFCR) – 1 kg trash fish is capable of producing 1 kg fish. The fact which cannot be ignored is that trash fish cannot be procured on a dry matter basis. Moreover, under typical farming conditions it is observed that TFCR's vary from 2:1 to 4:1 for marine carnivorous fish.

Feed ingredients

Feed ingredients used for making feeds can be classified as protein rich ingredients which are mainly fish and meat products of animal origin and oilcakes of plant origin. Energy rich ingredients are mainly cereals and cereal by products. Other than these there are non-conventional feed resources (NCFR) which are used in feed manufacture.

Table 1.Proximate composition of selected feed ingredients of plant origin in India (%)

	Moisture %	Crude protein %	Crude fat %	Crude fibre %	Ash %	NFE % Nitrogen (free extract)
rice bran	10.0	8.0-12.0	8.0-10.0	12.0-20.0	15.0-19.0	35.0-40.0
rice polish	10.0	10.0-14.0	10.0-16.0	8.0-10.0	5.0-6.0	40.0-45.0
wheat bran	8.0	12.0-14.0	2.0-3.0	10.0-12.0	4.0-6.0	50.0-55.0
groundnut cake	10.0	40.0-42.0	6.0-8.0	10.0-12.0	3.0-4.0	25.0-28.0
sunflower cake	9.0	30.0-32.0	4.0-6.0	15.0-20.0	5.0-7.0	35.0-40.0
mustard cake	9.0	30.0-35.0	7.0-9.0	10.0-15.0	7.0-9.0	30.0-35.0
sesame cake	9.0	32.0-36.0	7.0-10.0	10.0-14.0	8.0-10.0	20.0-25.0
rapeseed cake	10.0	30.0-35.0	2.0-3.0	12.0-14.0	5.0-7.0	30.0-34.0
salseed cake	9.0	8.0-10.0	2.0-3.0	3.0-5.0	8.0-10.0	65.0-70.0
cotton seed cake	8.0	35.0-40.0	3.0-5.0	11.0-13.0	6.0-8.0	25.0-28.0
rubber seed cake	9.0	30.0-35.0	10.0-15.0	7.0-8.0	8.0-10.0	32.0-36.0
copra cake	12.0	20.0-24.0	6.0-8.0	12.0-14.0	5.0-6.0	40.0-43.0
soybean cake	9.0	45.0-50.0	1.0-2.0	8.0-10.0	7.0-8.0	30.0-35.0
palm kernel cake	9.0	12.0-14.0	5.0-7.0	25.0-28.0	3.0-4.0	42.0-46.0
tamarind seed cake	9.0	13.0-15.0	6.0-8.0	13.0-15.0	3.0-4.0	60.0-65.0
black gram husk	9.0	24.0-26.0	10.0-15.0	8.0-10.0	40-6.0	30.0-34.0
green gram husk	9.0	24.0-26.0	3.0-5.0	5.0-7.0	5.0-6.0.	30.0-35.0
mulberry leaf	10.0	24.0-27.0	2.0-4.0	10.0-12.0	6.0-8.0	45.0-48.0
ipomoea leaf	12.0	16.0-20.0	2.0-4.0	9.0-10.0	8.0-10.0	45.0-48.0
ipil-ipil (leucaena)	8.0	18.0-21.0	4.0-6.0	5.0-7.0	8.0-9.0	48.0-52.0
Tapioca leaf meal	12.65	34.37	5.93	15.73 5.05	26.27	

Modified from P. K. Mukhopadhyay and Gopa Mitra 2007 Plant derived feedstuff for freshwater aquaculture in India .AQUA Culture AsiaPacific Magazine 19-21 pp.

Table2.Proximate composition of selected feed ingredients of plantorigin in India (%)

Ingredient	Moisture	Crude protein	Crude fat	Crude fibre	Ash	Nitrogen free extract
Rice polish	12.6	14.5	17.3	7.5	n.a.	n.a.
Rice polish	10.0	12.2	16.0	9.0	6.0	46.8
Rice polish	8.4	11.4	15.3	11.0	12.9	41.0
Rice, broken	10.0	12.0	4.2	5.3	3.1	65.4
Rice bran	10.1	12.6	11.3	19.3	10.2	36.5
Rice bran	7.8	7.8	6.1	14.4	20.5	43.4
Rice bran	8.4	2.9	5.0	18.0	27.3	38.4
Rice bran	8.7	9.4	4.7	13.5	31.4	32.3
Defatted rice bran	7.2	12.1	1.3	15.2	23.8	40.4
Wheat bran	12.3	15.8	4.3	8.7	n.a.	n.a.
Wheat bran	10.0	13.5	2.6	12.2	3.0	58.7
Wheat bran	13.0	8.2	6.6	33.5	4.2	34.5
Wheat bran	9.3	12.6	7.5	11.9	4.2	54.5
Wheat, broken	9.0	11.5	1.9	4.0	0.2	73.4
Wheat flour	12.6	14.5	3.7	2.7	2.3	64.2
Groundnut cake	7.8	28.6	13.8	7.5	13.4	28.9
Groundnut cake	6.0	37.7	11.5	13.2	7.3	24.3
Groundnut cake	10.0	42.0	7.3	13.0	2.5	25.2
Groundnut cake	8.3	46.6	7.7	6.5	7.7	23.2
Groundnut cake	7.1	35.8	8.5	8.2	10.5	29.9
Groundnut extr.	7.0	48.0	2.0	11.2	2.7	29.1
Sunflower extr.	8.0	31.0	2.1	18.4	1.5	39.0
Sunflower extr.	10.2	30.1	2.9	24.7	6.5	25.6
Palm kernel cake	8.9	12.2	4.9	25.6	2.6	45.8
Soybean meal	11.8	46.3	1.3	5.0	n.a.	n.a.

Soybean meal	3.0	58.6	1.4	0.4	5.3	31.3
Soybean meal	10.0	46.0	0.9	7.3	0.6	35.2
Soy sauce waste	12.0	13.5	8.2	5.8	5.3	55.2
Rapeseed cake	11.0	35.9	0.9	13.2	6.9	32.1
Salseed cake	8.6	8.2	2.9	1.7	10.2	68.4
Sesame cake	8.3	41.9	9.2	6.2	14.8	19.6
Sesame cake	10.0	29.0	12.9	18.3	10.0	19.8
Sesame cake	10.0	42.7	6.9	5.7	12.9	21.8
Mustard cake	8.5	30.8	9.3	6.2	10.3	34.9
Mustard cake	9.2	23.6	9.6	6.3	10.4	40.9
Cotton seed cake	7.0	37.0	6.7	13.0	1.0	35.3
Cotton seed cake	8.2	42.7	1.0	12.6	8.2	27.3
Gingely cake	9.0	34.0	7.8	7.9	3.1	38.2
Gingely extr.	7.0	40.0	2.0	9.7	2.9	38.4
Niger extr.	7.0	35.0	2.0	19.0	3.5	33.5
Copra cake	12.0	22.0	6.5	12.2	5.2	42.1
Copra cake	8.4	20.3	11.4	16.2	6.2	37.5
Copra cake	n.a.	22.0	6.0	12.0	2.1	n.a.
Tobacco seed extr.	7.7	30.6	0.3	-	13.7	47.7
Maize meal	13.5	9.5	4.0	4.0	1.5	67.5
Maize	10.4	4.6	7.8	3.5	1.0	72.7
Sorghum	10.0	9.0	2.8	3.0	0.1	75.1
Spirulina	8.7	50.5	1.0	2.1	11.0	26.7
Tapioca flour	11.5	3.1	2.3	2.0	2.3	78.8
Tapioca flour	8.0	1.8	1.3	1.8	0.2	86.9
Coffee pulp	12.3	14.0	1.2	20.8	8.2	43.5
Colocasia meal	5.8	24.6	4.5	8.2	9.9	47.0
Eichornia meal	3.3	19.5	2.3	18.3	9.3	47.3
Pistia meal	4.9	19.5	1.3	11.7	25.6	37.0
Leucaena meal	11.8	33.1	4.7	9.0	7.2	34.2
Mulberry leaf, dry	8.9	27.7	2.4	11.5	8.1	41.4
Salvinia meal	2.6	16.2	1.1	18.5	22.0	39.6

Table3. Proximate composition of selected feed ingredients of animal origin in India (%)

ngredient	Moisture	Crude protein	Crude fat	Crude fibre	Ash	Nitrogen free extract
Fish meal	8.6	64.4	7.5	0.3	19.2	-
Fish meal	9.5	53.6	5.4	3.1	20.9	7.5
Fish meal	9.2	56.1	2.5	17.8	2.5	11.9
Fish meal	14.0	47.8	10.3	2.6	18.3	7.0
Fish meal	10.0	72.0	10.0	0.5	n.a.	n.a.
Fish meal	9.0	50.0	7.0	1.0	4.0	29.0
Fish meal	10.0	45.0	8.0	1.2	6.0	29.8
Shrimp waste	10.0	28.0	2.7	12.5	n.a.	n.a.
Shrimp waste	9.0	22.5	3.6	35.3	18.6	11.0
Shrimp waste	3.6	34.2	6.7	12.2	27.9	15.4
Shrimp waste	15.6	28.3	1.1	7.1	31.6	16.3
Squilla meal	14.1	46.0	2.6	13.5	18.0	5.8
Squid meal	8.0	75.0	6.5	4.0	n.a.	n.a.
Clam meal	7.0	52.0	11.6	5.5	n.a.	n.a.
Clam meal	8.1	50.7	8.9	3.9	6.4	22.0
Silkworm pupae	7.1	43.9	25.7	4.2	15.8	3.3
Defatted sw. Pupae	8.1	68.0	2.6	1.3	7.2	12.8
Blood meal	10.0	65.3	0.5	n.a.	n.a.	n.a.
Blood meal	12.9	76.6	1.1	1.0	3.8	4.6
Meat meal	8.0	50.0	4.4	6.8	5.0	25.8
Meat meal	10.0	71.2	13.3	0.7	n.a.	n.a.
Liver meal	7.0	65.0	3.4	1.2	2.4	21.0
Earthworm meal	5.0	51.7	3.4	12.8	12.5	14.6

Table 4.Proximate composition of feed ingredients (analyzed values% on Dry matter basis)

	DM	Moisture	CP	EE	CF	NFE	Ash	AIA	Cost INR kg-1
Malabar Sole – Kozhikode	97.02	2.98	47.35	3.21	45.57	0.729	3.14	2.37	80
White bait - Kozhikode	94.66	5.34	61.74	3.39	23.97	0.13	10.77	1.63	100
Shrimp waste – Kozhikode	94.85	5.15	45.00	3.45	40.26	7.02	4.27	16.92	
Black clam - Kochi	94.92	5.08	67.60	7.52	9.12	0.30	15.46	2.95	100
Wheat flour - Kochi	89.93	10.07	11.15	1.29	0.59	1.84	85.13	0.08	20
Soy flour - Kochi	91.64	8.36	52.09	0.51	7.85	6.95	32.6	0.02	60
Shrimp meal - Kochi	96.39	3.61	68.98	3.42	17.59	3.08	6.93	1.67	120
Squid - Kochi	94.56	5.44	84.75	5.62	4.53	0.31	4.79	00.05	160

Apart from these ingredients, mineral mixtures, vitamin mixtures and other additives such as oil, phospholipids, carotenoids are also added according to the needs. Non-nutrient additives such as synthetic binders, anti-oxidants and anti-fungals are also added.

Feed formulation

With a fair knowledge of nutrients and the feed ingredients, the next aspect to be understood is the need for blending of feed ingredients to have a nutritionally complete and balanced feed mix. As is the case in human nutrition, when feed material is blended the food that is consumed will be balanced in terms of nutrients and complete in terms of nutrition. For eg. Plant proteins are deficient in sulphur containing amino acids like cysteine and methionine. Animal proteins are rich in both these amino acids. Similarly, plantz proteins are rich in calcium and poor in phosphorus and cereals are poor in calcium and rich in phosphorus. Likewise many examples can be seen in nature. In essence, mixing of feed ingredients takes care of these imbalances and when done with a scientific basis a nutritionally complete feed can be made which will be effective in producing the desired results in terms of fish production.

In feed formulation, when we mix two ingredients in equal proportion, the resulting mixture will have only 50% of the nutrients contained in each. Suppose, a mixture of groundnut oilcake (GNOC) containing 45% protein is mixed with rice bran (RB) containing only 10% protein in equal quantities the mixture will contain only 22.5 + 5 = 27.5% protein. If we vary the percent composition to 60% GNOC and 40% RB then the mixture will contain 27 + 4 = 31% protein. Let us not forget that this is applicable to all other nutrients present in these two ingredients. From this simple scenario, we will be able to visualize complex scenarios which will contain more ingredients and more no of constraints. Such scenarios can have only mathematical solutions which can be solved in a simple Excel spreadsheet which will be demonstrated. More complex problems are solved using linear programming with dedicated software. Solver is one such linear programming software available in MS Office in Excel.

Feed production technologies

In aquatic nutrition the feeds should have the physical properties suitable for the fish to consume the feed with minimum loss of nutrients in water. The evolution of the technologies starts from a dry mash to a wet ball to a pellet. Now, the pellets are produced which sink, slow-sink or float depending upon the feeding habit of the fish farmed. For marine carnivores a floating pellet of a slow sinking pellet is found to be appropriate. Sinking pellets, mainly used in shrimp culture are produced using steam pelletizers where steam is used to cook and gelatinize the starch to obtain binding. For production of floating and slow-sinking pellets the technology used is extrusion which is the state-of-the-art in aqua feed production. In this process the starch and protein are gelled using different time temperature combinations forcing the feed mixture to pass through two screws which are co-rotating (twin-screw extrusion). Moreover, puffing of the starch which traps air imparts the floating property to the product.

Feeding

Feeding rates, feeding frequency and time of feeding are all important factors to be considered in feeding of the fish. As a general rule of the thumb most of the vertebrates including fish consume 2.5 to 3.0% of the body weight in dry matter. Feeding rates and frequencies are related to fish growth. Small larval fish and fry need to be fed a high protein diet frequently and usually in excess. When fishes grow bigger, feeding rates and frequencies should be lowered. Feeding fish is a labour intensive activity and feeding frequency has to be programmed in such a way that it is economically viable. Generally growth and feed conversion increases with increase in feeding frequency. Apart from this many other factors affect feeding rates in fish. Feeding of the fish is also influenced by the time of the day, season, water temperature, dissolved oxygen levels and other water quality variables. Even though, several feeding charts are available it is better to construct one of your own with information on Days after stocking, Fish weight, Protein in feed, Meal/day, Feed consumed as % of body weight, Average daily gain(ADG) and Feed conversion ratio (FCR).

VII

BROODSTOCK DEVELOPMENT, BREEDING & LARVAL REARING OF COBIA AND POMPANO

G. Gopakumar and A.K. Abdul Nazar

In recent years, finfish mariculture has been growing rapidly on a global basis especially with the development and expansion of sea cage farming. One of the major reasons for the growth of sea cage farming is the availability of breeding techniques that can produce sufficient quantity of seeds of different high value marine finfish. Many countries in the Asia-Pacific Region like Australia, China, Japan, Taiwan, Philippines, Indonesia, Thailand, Malaysia and Vietnam have made substantial progress in the development of commercial level seed production technologies of many high value finfish suitable for sea farming. But even in these countries, seed stock supply is one of the vital issues for further expansion of mariculture.

In India, much research attention was not given for developing seed production methods for high value finfishes suited for sea farming. At present we have commercial seed production of only one marine finfish – sea bass (*Lates calcarifer*). Here also private entrepreneurship has not yet been developed. Unless an intensified research on the development of commercial level seed production technologies is taken up, sea farming cannot emerge as a significant seafood production sector in the country. In the recent past, the Central Marine Fisheries Research Institute (CMFRI) has been intensifying its research activities on the breeding and seed production of high value marine finfish and success was achieved in the breeding and seed production of cobia and silver pompano for the first time in the country at Mandapam Regional Centre of CMFRI.

Cobia (*Rachycentron canadum*) and silver pompano (*Trachinotus blochii*) are two marine finfish species with very high potential for aquaculture in India. Fast growth rate, adaptability for captive breeding, low cost of production, good meat quality and high market demand especially for *sashimi* industry are some of the attributes that make cobia an excellent species for aquaculture. In recent years the seed production and farming of cobia is rapidly gaining momentum in many Asian countries. Similarly, pompano is having fast growth rate, good meat quality and high market demand. Envisaging the prospects of cobia and pompano farming in India, broodstock development was initiated at the Mandapam Regional Centre of Central Marine Fisheries Research Institute in sea cages during 2008 and the first successful induced breeding and seed production was achieved for cobia in March – April 2010 and for pompano during July 2011.

Broodstock development Broodstock Collection and handling

Broodstock fish are generally collected from the wild and are conditioned and matured in captivity. The main selection criteria to identify suitable adult fish as broodstock fishes are size, age (for those collected from grow-out farms) and appearance. The following are the details of the selection criteria:-

- body shape, age and colour,
- absence of deformities,

- absence of wounds, haemorrhages, infections and parasites
- behaviour like quick response to feed and fast swimming
- It is advantageous to collect sub-adults for broodstock develo pment. Larger fishes would have crossed the reproductive age and very small fishes will take longer time to sexually mature.

Cobia weighing between 8 to 15 kg can be collected for broodstock development. Whereas,the pompano brooders could be procured in weight range of 750 gm to 1.5 kg.

Stress should always be minimised during capturing and handling of broodstock. It is best to collect broodstock fishes caught using trap nets, hook & line, etc., which cause minimum stress to the fishes.

Quarantine treatment

Upon arrival at the hatchery, broodstock fishes are released into the quarantine tanks for prophylactic treatment. Fish Anaesthetics like MS 222 (50-100 ppm), Aqui-S (4 ml / 100 L), 2-phenoxyethanol (200-300 ppm) and quinaldine dissolved in acetone (3-5 ppm) can be used for broodstock handling. The prophylactic treatment is given to limit the risk of introducing parasites or bacterial diseases into the hatchery facility. Short time exposure of brooders (5 – 15 minutes) in freshwater will help to remove the external parasites. The prophylactic treatment in hatcheries includes a sequence of medicated baths in formalin, malachite green and Oxytetracycline. Prophylactic treatment can be repeated three to four times within a week.

Broodstock holding and maturation

After quarantine, broodstock fishes are moved into 100 tonne capacity RCC tanks for maturation and long-term holding in the hatchery. During gonadal maturation, water salinity needs to be 31-35 ppt. Water quality parameters like salinity, temperature, dissolved oxygen, pH, ammonia, and fish stock condition viz., general behaviour, feeding activity, disease symptoms, prophylactic treatments, etc. are monitored regularly. Normally sex ratio of 1 female: 2 males are maintained for cobia while it is 1: 3 for pompano.

Fig.1.Cobia broodstock fishes

Fig.2. Pompano brooder

Broodstock development in cages

For larger fishes like cobia, broodstock development in FRP tanks/ RCC tanks is possible only with recirculating aquaculture system due to its high metabolic rate. Alternatively, broodstock development can more effectively be practised in circular (6 meter diameter and 4.5 meter net cage length) or square (5 m X 5m) sea cages.

Broodstock Feeding

For quicker maturation, the broodstock fishes are to be fed with highly nutritive diet. Diet rich in vitamins, poly-unsaturated fatty acids (n- 3 PUFA) and other micro-nutrients is essential for obtaining viable eggs and larvae. The brood fishes can be fed *ad libitum* once a day with chopped oil-sardines, crabs, shrimps and squids stuffed with vitamin, micro- and macro- nutrient premixes.

Fig.3. Broodstock cages at Mandapam

Tagging of Fish

Tagging or physical marking of broodstock fishes through easily detectable methods is very much essential for selection of broodstock for identification, selective breeding and segregation. The most popular method is Passive Integrated Transponder (PIT) tagging. PIT tagging also known as 'microchips' is a radio frequency device to permanently mark fishes internally. The tag is designed to last the life of the fishes providing a reliable, long term identification method.

Maturation and spawning

The natural process of sexual maturation of the broodstock fishes can be accelerated by altering the photo-thermal period and it is also possible to obtain viable larvae almost throughout the year. At the onset of the spawning season, it is necessary to move selected broodstock fishes from maturation tank to spawning tank after assessing the ovarian development through cannulation using flexible sterile catheters (1.2 mm internal diameter, Fig.4). Only females with oocytes in the late-vitellogenic stage, with a diameter round 700 μ in cobia and 500 μ in pompano, are selected.

Fig.4. Cannulation of Cobia

Induced spawning

Spawning can be obtained either by natural or inducing with hormonal treatment. Induced breeding is commonly practiced in most commercial hatcheries. The hormonal treatment is intended to trigger the last phases in egg maturation, i.e. a strong egg hydration followed by their release. However, if eggs have not reached the late-vitellogenic (or post-vitellogenic) stage, the treatment does not work; hence ovarian biopsy is essential for assessing the ovarian development. The human chorionic gonadotropin (HCG) is used at a dosage of 500 IU per kg of body weight in cobia females and 250 IU per kg body weight for males. Whereas, for pompano 350 IU per kg body weight is used for male and female. This dosage can be administered as a single dose on the dorsal muscles. The HCG can be successfully replaced by an analogue of the luteinizing hormone-releasing hormone [LH-RHa des-Gly10 (D-Ala6) LH-RH ethylamide, acetate salt]. It is a small molecule with 10 peptides and acts on the pituitary gland to induce the release of gonadotropins which, in turn, act on the gonads. Almost 100% of injected fish spawn eggs whose quality usually matches that of natural spawning. The LHRHa is used in very low dosages, usually around 20 µg / kg of body weight

Fig.5.Hormonal administration to cobia

Spawning tanks

The spawning unit should preferably be kept separated from the main hatchery building to avoid disturbance to the spawners and possible risk of disease contamination. However, for economic reasons, it is usual to keep the brooders inside the hatchery in a specific dedicated area. Though we use only rectangular tanks based on availability, it is preferable to use circular tanks with at least 1.20 m depth.Shape and depth counts for easy and free movement of brooders.

Normally the spawning could be noted within 36 -48 hours after hormonal induction. The spawning in cobia and pompano takes place normally between late night and early morning hours.The number of eggs spawned by cobia ranges from 0.4 to 2.5 million. Whereas, the pompano brooders spawn 0.5 to 1.5 lakh eggs.

Egg harvest

The fertilized eggs of cobia and pompano float and are scooped gently using 500 µm net. To minimise the presence of poor-quality eggs, which usually float deeper in the water, it is advisable to collect only the eggs found at the water surface. The egg samples must be thoroughly examined to assess their quality, number and development stage using a microscope.

Incubation of eggs

Incubation of eggs can be carried out in incubation tanks of 3-5 tonne capacity. Stocking density can be maintained at a moderate level of 200 to 500 eggs per litre. After hatching, only the hatched fish larvae have to be moved to the larval rearing tanks filled with filtered seawater. Prior to this, the aeration should be stopped briefly to enable the debris and exuviae to settle at the bottom which can be removed by siphoning. The development of embryo can be observed at frequent intervals under a stereo/compound bionocular microscope. The hatching of eggs takes place from 18 to 24 hours.

Larviculture

Newly hatched larvae have to be checked to assess their viability and condition prior to stocking in the larviculture tanks. At least 10 to 20 fish larvae have to be observed under the microscope for the following:

- shape and dimensions
- deformities, erosions and abnormalities

- appearance of internal organs
- pigmentation
- absence of external parasites

The larvae hatched in the incubation tanks or larval rearing tanks need to be distributed in larviculture tanks to have minimal stocking density of 10 to 20 larvae/ litre for cobia and 20-30 larvae per litre for pompano. Care should be taken to avoid any mechanical stress or damage. Soon after hatching, the mouth remains closed and the digestive tract is not fully developed. During this period the larvae survive on its reserves in the yolk sac.

Larviculture of cobia

Newly hatched larvae of cobia normally measures 3.4 mm size. Larval mouth opens at 3-5 days post hatch (dph). Metamorphosis starts from 9-11 dph. Newly hatched cobia larvae generally start feeding at 3 dph and they can be fed with the enriched rotifer (*Brachionus rotundiformis*) at the rate of 10-12 nos / ml, four times a day till 10 dph. From 8 dph, the larvae can be fed with enriched Artemia nauplii at the rate of 1-3 nos / ml, 2-3 times per day. During the rotifer and Artemia feeding stage, green water technique can be used in the larviculture system with the microalgae *Nannocloropsis occulata* at the cell density of $1x10^5$ cells / ml. The weaning to artificial larval diets has to be started from 15- 18 dph. While weaning, formulated feed should be given 30 minutes prior to feeding with live feed. Size of the artificial feed has to be smaller than the mouth size of the fish. Continuous water exchange is required during weaning stage. Between 25-40 dph, the larvae are highly cannibalistic and hence size-grading has to be undertaken at every four days interval. During this stage, the fry could be weaned totally to artificial diets. Larval rearing can be practised both intensively in tanks and extensively in ponds. The major factors affecting the growth and survival of larvae are nutrition, environmental conditions and handling stress. Since there is high demand for essential fatty acids (EFAs), enrichment protocols are needed for live-feeds. The water exchange can be practically nil till 7dph and it can be gradually increased from 10-100 % from 8 to 12 dph. The environmental conditions required during the larviculture period are DO_2: > 5mg / l , NH3: < 0.1mg / l, pH: 7.8 – 8.4, Salinity: 25-35 ppt, water temperature : 27-33° C.

Green water has to be maintained in appropriate densities in the larval tanks. While weaning the fish larvae from rotifers to artemia nauplii, co-feeding with rotifers has to be continued due to the presence of different size groups of larvae. The detail of weaning protocol is as follows.

Table 1.Detail of weaning protocol

Stage of Larvae (dph)	Size of Larvae (cm)	Size of Feed (µ)
18 – 19	2.3 – 2.6	100-200
20 – 23	2.5 – 3.5	300-500
23 – 30	3.5 – 8.0	500-800
31 onwards	> 8.0	800-1200

The juveniles measuring 10 cm length were ready for stocking in happas/ nursery tanks.

Nursery and grow-out rearing of cobia

Nursery phase of cobia can be carried out in happas or sea cages or indoor FRP / cement tanks. During nursery rearing, it is advisable to feed the juveniles with formulated feed of 1200 µ size which can be increased to 1800 µ size from 55 dph onwards. Once the juveniles reach a size of 15 gm, they are ready to stock in sea cages or land based ponds for grow-out farming.

Larviculture of Pompano

The newly hatched larvae are stocked at a density of 10000 larvae in FRP tanks of 2 m^3 capacity filled with 1.5 m^3 filtered seawater. The tanks are provided with mild aeration and green water at a cell density of 1 $x10^5$/ml. The mouth of the larvae opens on 3 dph and the mouth size was around 230 µ.

The larvae are fed from 3 dph to 10 dph with enriched rotifers at a density of 5-6 nos. per ml, wherever possible, wild collected copepods could also be added as supplements. Enriched Artemia nauplii are provided at a density of 1-2 nos. per ml from 8-19 dph. Weaning to larval inert feeds was started from 15 dph. From 25 dph onwards, feeding can be entirely on larval inert feeds. The metamorphosis of the larvae starts from 18 dph and all the larvae metamorphose into juveniles by 25 dph. Critical stage of mortality would occur during 3-5 dph and subsequent mortalities are negligible. The water exchange can be practically nil till 7dph and it can be gradually increased from 10-100 % from 8 to 14 dph.

Nursery Rearing of Pompano

Nursery rearing could be initiated from 25 to 30 dph. At this stage, artificial feed of 800 µ size could be provided. Thereafter, fingerlings were fed with progressively higher size range of floating extruded larval feeds. Daily water exchange of 100% is advisable. Water quality parameters like salinity, temperature, pH, oxygen level and ammonia are closely monitored during the entire larviculture period.

After 55dph, the fingerlings with size range from 1 to 1.5 inch size can be supplied to farmers for stocking in the happas/ tanks for further nursery rearing and grow-out farming thereafter.

Live feed culture

Micro-algal culture

Microalgae are the important live feeds required for larviculture of marine fin fishes. Algae like *Chlorella sp., Nannochloropsis sp., Tetraselmis sp., Dunaliella sp*., *Pavolova sp*., and *Isochrysis sp.* can be used as algal diet for growing the rotifers. The size, nutritive value, proliferation rate and digestibility of the algae are the critical factors for selecting the algae for the use in marine hatchery use.

Copepod culture

Copepods have almost become inevitable because they are the only acceptable sized prey for small larvae of many marine fin fish species and the only type of live feed that will support the altritial type of larvae. Copepod nauplii offer a diverse size spectra and nutritious prey that can meet the specialized needs of small fast growing fish larvae. Over the past few years, several articles have been published and many conferences were dedicated to discussions of copepod culture and the important role that copepods can play as live feed for marine finfish larviculture.

Rotifer culture

Rotifers are the smaller size zooplanktons widely used in marine fin fish hatchery operations. The marine fin fish larvae initially feeds on the such smaller size zooplanktons and hence suitable size of rotifers need to be cultured in mass to feed the fish larvae. The important criteria for selecting the rotifer depends on the mouth size of the fish larvae, digestibility, nutritive value of the rotifer and easy for culture and proliferation. Marine and brackish water rotifer species can be artificially propagated in seawater and more popular rotifer species used for marine fin fish hatcheries are *Brachionus plicatilis* and *Brachionus rotundiformis.*

Based on the length of lorica, *Brachionus* is separated into 3 strains: *B. plicatilis* as L type (large) with long of lorica 200 – 360 µm; *B. rotundiformis* as S type (small) with long of lorica 150 – 220 µm; *B. rotundiformis* as SS type (super small) with long of lorica 70 – 160 µm.

Artemia nauplii

Having a larger size than rotifers, the nauplii of brine shrimp *Artemia* are used as the second live food to fed fish larvae. Commercially available *Artemia* cysts are purchased and hatched whenever required. The first *Artemia* larval form is the nauplii, which are smaller in size and richest in yolk, and followed by larger size metanauplii, whose nutritional value has to be boosted by feeding them with special enrichment diets 12 to 24 hours before feeding them to the fish larvae.

Prospects of cobia and pompano farming in India

Trials on sea cage farming carried out at Mandapam showed that the fishes attained an average weight of 2.5 kg in six months and 7.3 kg in twelve months. The species can be grown in salinity as low as 15 ppt and our experiments revealed that the growth and survival at 15 ppt is comparable to that in seawater. Further, a trial of earthen pond culture of cobia which is underway at Anthervedi in Andhara Pradesh shows very encouraging results. All these outcomes point out the possibility of developing a lucrative cobia aquaculture enterprise in the country. Similarly the silver pompano was able to acclimatize and grow well even at a lower salinity of about 10 ppt and hence is suitable for farming in the vast low saline waters of our country besides its potential for sea cage farming. Our farming trials at Anthervedi and Aakkivedu in Andhra Pradesh and at Turicorin and Vedalai in Tamil Nadu show encouraging results. This can be considered as a milestone towards the development of pompano aquaculture in the country.

■

VIII

NURSERY REARING OF ASIAN SEABASS

S.R.Krupesha Sharma,
Praveen Dube and K.K.Philipose

Overview

Seabass, *Lates calcarifer*, is an economically important food fish in many countries. This species is widely distributed in the tropical and subtropical areas of the western Pacific and Indian ocean including Australia, Southeast Asia, the Philippines and countries bordering the Arabian sea. Seabass spend most of their life in a lagoon which connects to the sea. They spend two to three more years in estuarine areas until they mature, then migrate to the sea water around the mouth of a river or lagoon for spawning. Larvae and juveniles live in the sea grass bed in coastal areas for about six months, attaining a size of about 2 to 5 inches. The fish migrate to freshwater when they grow bigger.

Why nursery rearing?

Nursery rearing of seabass fry in ponds and cages to stockable juvenile size is essential before release into the grow-out ponds. The nursery rearing can be carried out either in earthen ponds or indoor cement tanks or hapas. The main purpose of the nursery is to culture the fry from hatchery (1-2.5 cm in size) to juvenile size (8-10 cm). This can solve the problem of space competition in the nursery tanks. Nursery rearing is an important phase in the seed production since this transitional phase can be used for acclimatization and weaning to artificial feed and environmental conditions that could be provided in the growout systems. In nurseries the fry can be stocked in higher densities and reared. This would save the space and time in growout phase. Beyond the nursing period, the juveniles can be graded into different size groups and stocked in separate grow-out ponds. It has been observed that the juveniles from the nurseries perform better in terms of growth and survival than those stocked directly into the grow-out ponds.

Nursery pond size ranges from 1000 to 2000 m^2 with a water depth of 80 – 100 cm. Pond with separate inlet and an outlet gate to facilitate water exchange is recommended. Pond bottom should be flat and sloping towards the drainage gate. Inlet and outlet gates are provided with a fine screen (1 mm mesh size) to cages can be fixed in PVC frames of floating frame, sinker and top lid. Around 2000 – 3000 fry can be stocked and monitoring of the fry is easy in net cages. Also, the maintenance cost of the net cages is lesser than the hapas. The only constraint is that, a floating feed should be used in cages for rearing seabass. The mesh size of the cage is 2 mm, 4 mm, 6 mm and 8 mm. The fry will grow faster in net cages than hapas as it facilitates more aerations and water circulation movements inside the cages.

The best nursing of seabass fry is nursing in tanks. Cement tanks supplied with oxygen and drain pipes are used for nursing of the fry. This paper focuses mainly on raring fry in indoor cement tanks.

From the hatchery the fry are transported to nursery site. In transporting by truck, a mixture of crushed ice and sawdust is needed to control the water temperature in the plastic bags during transport. The mixture is spread uniformly on the floor of the truck before the plastic bags are laid upon it. The proportion of crushed ice and sawdust is 1:1 for long period transport (12–16 hours) and 1:2 for short period (4–5 hours). Transportation should be carried out at night time. By this method, it is possible to control the water temperature between 19–23°C.

Nursery rearing in indoor cement tanks

Rearing system: Immediately on arrival, the fishes are given a fresh water dip and placed in cement tanks of 10' X 6' X 5' containing 7000 l of sea water. 2500 fingerlings can be reared in a tank of this size. Continuous aeration is to be ensured (Fig.1). The juveniles are reared in nursery rearing tanks up to 45 days before they are shifted to grow-out ponds or open sea cages.

Fig.1. Continuous aeration system in nursery rearing tanks

Feeding regimes: During the nursery phase extruded slow sinking feed is preferred. Crumbled feed should be provided according to the requirements and subsequently the pellet size can be increased. The size of the pellet during the nursery phase is highly correlated with the mouth size of the seabass fry.

From second day onwards the fish are fed with commercial fish feed with a pellet size of 0.5 mm diameter at four per cent of the body weight four times a day (6.00 AM, 12.00 PM, 6.00 PM and 12.00 AM) for the first 15 days. Then the pellet size is increased to 1 mm for next 15 days while the feeding rate and frequency remaines unchanged. For the remaining 15 days, the fishes are fed with a pellet size of 2 mm. Eighty per cent of the water is replaced 5 min after feeding with 20 min flow -through thereafter. It should be ensured that the feed is consumed immediately after feeding with no visible feed pellets settled at the bottom.

Water quality parameters:

Water quality parameters such as temperature, pH, salinity and oxygen are monitored daily using portable instruments, while critical parameters such as unionized ammonia (NH_3) and nitrite (NO_2) are measured fortnightly.

Grading and fish samplings:

Owing to the cannibalistic nature of the fish, size selection or grading is necessary during the whole nursery period. Grading of fish is done for once in every week with an automatic grader and grouped into different sizes. After grading, representative samples are collected for studying growth parameters.

The mechanical grader available in the market can be used for grading the fries. This exercise will give more survival rate with better growth as the seabass fry are getting the suitable feed according to their mouth size. Also, the cannibalistic characteristics will drastically come down due to timely grading.

Fig.2. Automatic grader

The fishes are graded every 15 days with an automatic grader (Fig.2) and grouped into different sizes. After grading, representative samples are collected for studying growth parameters like Average Daily Growth Rate (ADGR), Specific Growth Rate (SGR), Survival Rate (SR), Biomass, Biomass Increase (BI), Feed Conversion Ratio (FCR) and Protein Efficiency Ratio.

IX

TRANSPORTATION OF FINGERLINGS AND JUVENILES OF MARINE FINFISH

Jayasree Loka and K.K. Philipose

Open seacage farming has become a viable marine system to grow the marine finfishes in large scale from fingerling stage to marketable size in a commercial way. Major advantage of marine cage culture systems is, unlimited supply of high quality seawater and large carrying capacity for a substantial aquaculture production. In order to stock large scale fingerlings or juveniles collected either from natural waters or hatcheries it is essential to transport them to cage site in live and healthy condition.

There are two basic transport systems for live fish - the closed system and the open system. The closed system is a sealed container in which all the requirements for survival are self-contained. The simplest of these is a sealed plastic bag partly filled with water and oxygen. The open system consists of water-filled containers in which the requirements for survival are supplied continuously from outside sources. The simplest of these is a small tank with an aerator stone.

The basic factors and principles associated with any live fish transport systems are evaluated before the actual ways of fish transport are commented on. The transportation of live fish involves the transfer of large numbers (or biomass) of fish in a small volume of water. During transportation, fish are subjected to handling stress and may die, if survive, growth of fish may be affected. The principles governing packaging, handling and transportation of live fish are essential to minimise stress.

Major stress factors influence transportation

Quality of fish: The quality of fish transported is a decisive criterion. The fish to be transported must be healthy and in good condition. Weakened individuals should be eliminated from the consignment, particularly when the temperature during shipment is high. When the fish are of poor quality, even a great reduction of fish density in the transport container fails to prevent fish losses. If the transport time is much longer, weak fish are killed at a much higher rate than fish in good condition. The fishes should be acclimatized to a lower water temperature before transport to avoid stress factors. To reduce the temperature for cooling the water natural ice should be used and usage of ice of carbonic acid should be avoided. As a guide ratio, 25 kg of ice will cool 1 000 litres of water by 2°C. If the water contains fish during the cooling process, the temperature drop should not be faster than 5°C per hour. Direct contact of fish with ice should be prevented at the same time. The total temperature difference should not be greater than 12–15°C, with respect to the species and age of the fish.

The fish to be transported, except for the larval stages should be left to starve for at least a day. The fish with full digestive tracts need more oxygen, are more susceptible to stress, and produce excrements which take up much of the oxygen of the water. The transport time of the larvae of herbivorous fishes should not last longer than 20 hours and that of many aquarium species should be shorter than 12 hours.

Dissolved oxygen (DO): The presence of dissolved oxygen does not presuppose an absence of stress as other adverse factors can still exist with high DO, eg. high water temperature, pH changes. Fish demand for dissolved oxygen as fish depends on water temperature, fish density (numbers and size), time of last feeding (level of starvation) and transportation time. It is therefore important to keep the transport water cool and fish biomass at an optimum, with due consideration for possible delays in transportation and the need for additional oxygen by the fish. Starving the fish prior to packing would also slow down ammonia accumulation and minimise unnecessary uptake of dissolved oxygen.

Ammonia (NH_3): Ammonia is excreted by fish and is reported to be toxic at low concentrations of 0.6 ppm. Ammonia excretion by fish decreases as its concentration in water increases, resulting in high blood ammonia. High blood ammonia elevates blood pH which affects enzyme-catalysed reactions affecting metabolism. Starvation and lowered temperatures reduce ammonia excretion.

Carbon dioxide: Fish become distressed when carbon dioxide (from respiration) accumulates rapidly in water since the blood is unable to carry oxygen under these conditions. Low levels of carbon dioxide (3–6 ppm) may be beneficial since it prevents the buildup of unionised ammonia. Carbon dioxide is also a mild anaesthetic and may be considered in alleviating stress during transportation.

Handling: Stress during handling and packing may be so severe as to cause chronic and acute mortalities. Poor handling and packing procedure may also cause osmoregulatory and metabolic disfunctions. Therefore it is important to proceed gently and quickly.

Water temperature (heat and cold): Water temperatures greater than 28°C accompanied by declining dissolved oxygen and increasing ammonia, create a hostile environment. This is the likely situation if fish are over-packed or transportation is delayed under tropical conditions. Temperatures that are too low (<18°C) can cause thermal shock, especially in young fish. Stressed fish usually succumb to diseases after 1–2 weeks, if not already dead on arrival.

Methods of alleviating stress

Reducing transport water temperature : This prevents thermal stress and improves oxygen stability. Ice should be used in the correct quantities and this depends on fish species and size and also the transportation period. Alternatively, cooled water (18°C) can also be used by lightly sedating the fish in 18°C water prior to packing, and then using water at the same temperature for transport. Under air freighting conditions, this temperature increases by about 1–4°C after 12–14 hours, and fish are usually alive.

Insulation: The use of insulated containers like styrofoam boxes, newspaper lagging helps to maintain the temperature of transport water, being poor heat conductors. They also reduce vibration.

Anaesthesia: Anaesthesia prevents fish hyperactivity. The oxygen consumption of newly-packed fish elevates for 30–60 minutes and declines as fish acclimate to the new environment. The first 30–60 minutes after packing is therefore important. Some anaesthetics used are MS-222, carbonic acid, benzocaine and phenoxyethanol. However the use of certain chemicals for anaesthetising food fish is not to be recommended.

Transportation of live fish : Fish are transported live as live fish are transported by air, road or overseas source to the local farm site for culture. Transportation can be made by using cheap materials and equipment like plastic bags, rubber bands, compressed oxygen, cardboard or styrofoam boxes. Food fish fingerlings are packed at about 500 per bag at two bags per carton. It can be generally observed that as fish size increases, the numbers packed per bag decreases (Table 1). However, a higher biomass is tolerated by larger fish.

Table 1: Food fish fingerling packing conditions by the 'plastic bag' method and transportation time ranging from 8–12 hours

Packing conditions	Fish mean wt (g)	No./beg	Biomass g/L		Transport water temp. (°C)
Fish species					
Grouper	8–11	100	89–100	7–9	28–29
	11–14	50	102–128	4–5	28–29
	11–17	50	147	4–5	28–29
Seabass	4.5–5	70–100	50–100	11–20	27–28
	>5–10	60–100	93–148	14–35	25–28
	>10–15	50–100	94–180	8–16	27–28
	>15–20	50	133	8	27–28
	>20–30	35–60	200–300	7–10	27–28
	>30–40	35–40	222–267	6–7	27–28
	>40–50	35	292	6	27–28
	>50–70	25	267	4	27–28
	105	20–25	525	5	27–28

Transportation of larger-sized fish (Regional / Local) Transfer of live market size fish from farm to landing point (by boat in tanks).

a. Transportation of live market - size fish from landing point to Landing Centre (in tanks on lorries).

b. Transfer of live fish from farm to farm (by boat, in tanks).

Seabass Fingerling Packing :
Packing in oxygenated plastic bags

Method I

- Measure about 3 times the fish weight of filtered seawater (eg. if fish is 600g, measure about 1.8 litres of seawater) and pour into a plastic bag.
- Transfer the fish gently into the bag.
- Measure the height of water in the bag.
- Insert the delivery tube from the oxygen cylinder well into the water and oxygenate slowly, twisting the plastic bag round the tube to prevent oxygen loss.
- Gradually inflate the bag so that oxygen occupies about 4 times the water volume.
- Secure the bag with rubber bands, leaving the outer bag free. Make sure the bag is firmly inflated and not flaccid.
- Secure the outer bag with more rubber bands.
- Place the packed bag of fish into a styrofoam box lined with newspaper (lagging to prevent rapid temperature change).
- Store the box in an air-conditioned room (19–22°C) for 12 hours to simulate our cargo temperatures and transport.

Method II

- Measure about 3 times the fish weight of filtered seawater (eg. if fish is 600 g, measure about 1.8 litres of seawater) and pour into a plastic bag.
- Transfer the fish gently into the bag.
- Calculate the volume of cooled (18°C) filtered seawater required to cover the fish (weight of seawater = 3 × wt. of fish).
- Pour the water into the plastic bag.

- Calculate the weight of ice required (25g ice/l seawater) and weigh the ice out in a small plastic bag. Secure the bag of ice and place it in the plastic bag of water.
- Transfer the fish gently into the bag.
- Measure the height of water in the bag.
- Insert the delivery tube from the oxygen cylinder well into the water and oxygenate slowly, twisting the plastic bag round the tube to prevent oxygen loss.
- Gradually inflate the bag so that oxygen occupies about 4 times the water volume.
- Secure the bag with rubber bands, leaving the outer bag free. Make sure the bag is firmly inflated and not flaccid.
- Secure the outer bag with more rubber bands. ■

Source:

Berka, R., 1986.The transport of live fish.A review. EIFAC Tech.Pap., (48):52 p.

FAO. Training Manual on Marine Finfish Netcage Culture in Singapore Regional seafarming project RAS/86/024

X

MUSSEL FARMING

Geetha Sasikumar and K.S.Mohamed

Introduction

The mussels are bivalve molluscs typically inhabiting the littoral to shallow sub-littoral zones of the coastal areas. The soft tissue of bivalves is enclosed in a shell consisting of two valves joined at one edge by a flexible ligament called the hinge. Mussels are found attached to the hard surfaces in the littoral and sub-littoral zones by secreting long fine silky threads called byssus threads. Being sedentary, they can tolerate short periods of exposure to extreme temperatures, salinities, desiccation and relatively high levels of turbidity. The two species of mussels with good potential for culture in India are the green mussel, *Perna viridis* and the brown mussel *Perna indica.*

Advantages of mussel farming

Less labour intensive practice

Mussel farming is a relatively less intensive form of aquaculture that depends upon natural stocks for seeding and relies on primary productivity for feeding.

Utilization of water column

Mussel mariculture is carried out in coastal and estuarine waters by suspended farming method in order to utilize the water column. Suspension of the culture substrate enables complete utilization of the water column and facilitates increased production per unit area.

Eco-friendly farming practice

Mussels are filter feeders, feeding exclusively on plankton and suspended organic particles that are available in the surrounding environment. Suspended materials available in the waters are trapped onto the mucous coating of the gills and are ingested. Mussel farming therefore involves the utilization of natural productivity in the farm area, resulting in zero effluent discharge and minimal water quality issues.

Food conversion efficiency

Mussels are efficient in converting plankton and organic matter to high quality animal protein.

Short Duration crop

The mussels are farmed for duration of 5-6 months in the tropical waters during the high-saline phase following the monsoon.

Site-selection

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

Water current

Mussel culture sites should not be in the vicinity of strong currents as strong currents usually generate high turbidity and high siltation rates. However, moderate currents (0.17-0.25m/s at flood tide and 0.25-0.35m/s at ebb tide) are needed to provide adequate food supply as well as to carry away the excessive build-up of pseudofaeces and silt in the culture area.

Water Depth

The depth of water column of a location determines the type of culture method to be adopted. It can range from 1-15 m at average mean low tide. The most important consideration with regard to water depth is avoiding long exposure periods during the extreme low-tides.

Salinity

Mussels grow well above 20psu, but the ideal salinity for rearing is 27-35psu. Open coastal areas are usually fully saline with minor seasonal variations. In estuarine areas, decrease in salinity is usually the major and frequent problem, mainly caused by the influx of freshwater from rivers or land runoff during the rainy season. Therefore sites with a high inflow of fresh water are not suitable for the farming of mussels. The culture season for mussels is December to May, when the estuaries are in the marine phase.

Turbidity

The presence of suspended particles above a certain level disrupts the filtering activity of the bivalve, as the mussels remain closed to avoid tissue damage and also due to gill clogging. In addition, low primary productivity is often the case in sites of high turbidity due to the reduced penetration of sunlight in the water column. As a result poor growth results due to reduced feeding time and limited food availability. It is found that water containing a high suspended load of more than 400 mg/1 have harmful effect on the grow-out of mussels.

Primary productivity and food organisms:

The of food available at a site cannot be easily evaluated by inspection of a few water samples, as there are wide variations in the quality and quantity of micro algae, seasonally as well as annually. Clear seawater with rich plankton production (17-40mg chlorophyll/l,) is considered ideal for mussel culture. The presence of suitable micro algal species is usually not a limiting factor; however, problems do arise when the availability of food is limited.

Source of Seed

Mussel culture requires a proximity to spat or seed source, which may affect site selection criteria. However, if it has to be transported from elsewhere, it should be transported to the farm site within a reasonable time and cost. Transportation itself is not only costly, but usually negatively affects the quality of bivalve seed due to stressful conditions. The mussel (*P.viridis*) seed can remain without water for about 24 h and hence offers easy transportability.

Pollution

The sedentary bivalve fauna are exposed to very high probability of contamination and could act as vectors due to their peculiar feeding habits and bioaccumulation potential. Bivalves are known to accumulate trace metals and pollutants. Waters with heavy industrial contamination such as trace metals and organic compounds are therefore unsuitable for mussel farming. Further, shellfish from contaminated areas are known to accumulate bacteria and viruses that are pathogenic to human beings. Regulations have been established in many parts of the world that provide a system of classification of bivalve shellfish growing/ harvesting areas, broadly based on water test results (National Shellfish Sanitation Program, (NSSP) of USA and Canada; Australian Shellfish Quality Assurance Program, ASQAP of Australia) or tissue test results (Council Directive 91/492/ EEC of Europe) (Table 1&2). These classification systems assign the shellfish harvesting areas as approved, restricted and prohibited based on the faecal coliforms and/or *Escherichia coli* levels. Regulatory agencies may close a fishery when contamination is detected.

Table 1. Limits set by National Shellfish Sanitation Programme for bivalve shellfish harvest (US FDA)

US FDA Classification	Geometric mean[4]	90^{th} Percentile treatment required	Bivalve	Criteria
Approved	MPN <14/100ml	MPN <43/100 ml	None	Acceptable no significant pollution sources
Restricted	MPN <88/100 ml	MPN <260/100 ml	Depuration or relaying	Evidence of marginal pollution
Prohibited	No harvest	allowed		Evidence of gross pollution

Table 2. Limits set by EC Directive (91/492/EEC).

EC Directive (91/492/EEC)	Geometric mean	Criteria
Category A	<230 *E. coli*/100 g flesh or <300 FC /100 g flesh.	Direct human consumption permitted.
Category B	<4,600 *E. coli*/100 g flesh or <6,000 FC /100 g flesh (in 90% of samples).	Purification in an approved plant for 48 hours prior to sale for human consumption.
Category C	<60,000 FC/100 g flesh.	Relaying for a period of at least two months in clean seawater prior to human consumption.

Harmful algal blooms

Another criterion of deciding the suitability of potential culture site is eliminating the threat of Harmful Algal Blooms. Some coastal waters are known for the appearance of sudden blooms of certain phytoplankton capable of producing highly potent toxins that are harmful to marine fauna and any other animal that feed on them. Unfortunately, it is often difficult to predict if any area is prone to be affected by these toxic blooms, however, during the site selection process, an enquiry of the past history of the HAB in the area is necessary. Bivalves affected with red tides are not usually killed, but tend to accumulate toxic substances in their flesh. Depuration studies have shown that those bivalves can be depurated, however the longer depuration time required would make it very uneconomical.

Farming area

Open Sea farming

This is practiced in areas with a depth of 5-20m. The selected area of culture should be free from strong wave action, less turbulent and with high productivity. Long line and raft culture techniques are ideal for open sea farming. Disadvantages of this type of farming are poaching, unpredicted climatic changes and predation.

Estuarine farming

Compared to the open sea, the estuarine ecosystems are less turbulent and shallow (<4m). Stake and rack culture (horizontal and vertical) are ideal for estuarine conditions. Fluctuation in salinity during monsoon season and pollution through domestic and industrial waste are the main constraints in estuarine mussel farming. On-bottom culture by relaying of mussel seed in pen enclosures is also practiced.

Farming technique

On-bottom method

In areas where water depth is less than 1.5 m, mussels can be farmed by sowing directly on the bottom substratum/ or seabed.

This method is generally practiced for thinning overcrowded mussel bed by re-laying spats at lower densities in locations with ideal substratum, that are free from silt and predators. The growing sites are usually prepared to stabilize the bottom before seeding.

Bouchot culture

This method involves farming mussels in intertidal mud flats on poles combining spat collection with ongrowing. Initially poles are set in the intertidal seabed in rows to allow mussel spat to settle and grow. Mussel spats settlement occurs directly on these wooden poles or onto the horizontal coconut fibre ropes strung onto the poles before settlement. When the spat grows slightly bigger they are transferred to tubular nets and transferred to "*bouchot*" placed in shallow waters in the same region. The mussels attain marketable size on the poles.

Suspended farming methods

For suspended farming method, the water depth can be a limiting factor as a minimum water column is essential all throughout the culture period

Rack method: Suitable for estuaries and shallow seas. Bamboo or Casuarina poles are driven into the sea/ estuarine bed at a spacing of 1-2 m and are connected horizontally. Seeded ropes are suspended from the horizontal frames or in shallow areas, they are placed horizontally between the vertical poles. This method is practiced in India and Philippines in shallow waters where the depth is <1m. Due to the effective utilization of the productive upper water column this type of culture gives better yield.

Raft method: This farming method is suitable in deeper open-sea conditions which is not turbulent. It consists of a square or rectangular bamboo or casuarina pole lattice structure from which ropes are hung. The raft is buoyed up by styrofoam / ferroconcrete buoys or metallic/ HDPE barrels of 200 l capacity (metal oil barrel painted with anticorrosive paint). Ideal size of the raft is

5 x 5 m. The rafts are to be positioned at suitable location in the sea using anchors (grapnel, granite, concrete).

Long-line method: Considered ideal to resist storms and wave effect, in unprotected open sea conditions and are particularly adopted in areas having high tidal amplitude. Synthetic rope of 16-20mm diameter is used for the long-line (main line). The main horizontal line is supported with floats/ buoys at every 5m. The seeded ropes are suspended from the main line 1.5-2m apart. The long-lines with floats are anchored in position using concrete blocks and nylon ropes or metal chain at both the ends.

Seed source and seeding

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

Growth

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

Post-harvest handling and marketing

Mussels are harvested once they attain the marketable size and condition index is high, i.e., before the spawning and onset of monsoon. Normally harvest season is from April to June. Mussel ropes are collected manually and brought to the shore for harvest. The ropes are washed thoroughly using water jet to remove grit and slit. The mussels removed from the ropes are maintained in re-circulating seawater for 24h and are washed again in fresh seawater. This method of depuration is effective in reducing the bacterial load of the mussel meat by 90%. Depurated mussels are then sold mainly in the local market as live shell-on mussel. At present farm gate price of green mussel is Rs. 4-5 per Kg in Karnataka. Meat from depurated mussel can be shucked in fresh condition or after boiling or steaming. Further processing of the mussel meat can be done after blanching in 5% salt solution for 5 minutes.

Depuration

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

Expenditure:

Table3.Tentative cost of Mussel Farming – Rack Culture
Rack size 30m x 20m (600 sq. m) (1200 ropes of 1 m)

A. Initial Expenditure		
	I. Farming	Amount
1	Bamboo poles of 4 m length 160 nos @ Rs. 110/-	17,600
2	Bamboo poles of 5 m length 110 nos @ Rs. 125/-	13,750
3	Seeding rope 18 mm (1500 m), 300 kg @ Rs. 125/-	37,500
4	Rope tying the seeded rope; 4 mm, 20 kg	2,650
5	Semi automated seeder II. Post Harvest	5,000
6.	De-clumper	8,500
7	Plastic crates for depuration, (30 nos @Rs.400/-)	12,000

8	Aluminium vessels for heat shucking	10,000
9	FRP tank, 2 ton for chlorination	12,000
10	FRP tank, 1 ton for depuration 2 nos	12,000
11	1HP pump, hose & accessories	10,000
	Total	**141,000**
	B. Recurring Cost	
1	Cotton netting (250mtr @ Rs.15/mtr)	3,750
2	Twine	150
3	Cost of seed (1800 kg @ Rs.6/kg)	10,800
4	Charge for seeding (30 man days @Rs.200/head)	6,000
5	Hire charge of canoe	2,500
6	Charge for harvesting, de clumping and cleaning	10,000
7	Labour for depuration	3,000
8	Plastic wares	4,000
9	Marketing	5,000
10	Miscellaneous	3,800
	Total	49,000
	Expenditure Total (A + B) 1,90,000	**190,000**

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

Suggested reading:

Ashokan P.K. 2005. Site selection for bivalve culture.In Appukuttan K.K. (Ed).Winter school Technical notes on Recent advances in mussel and edible oyster farming and marine pearl production". p92-100.

Velayudhan T.S. 2005.Mussel farming methods & seed collection. In Appukuttan K.K.(Ed). Winter school Technical notes on recent advances in mussel and edible oyster farming and marine pearl production. p122-126.

Mohamed K.S. 2005.Innovations in increase in mussel farming. In Appukuttan K.K. (Ed).Winter school Technical notes on"Recent advances in mussel and edible oyster farming and marine pearl production". p127-123.

Kripa V. 2005.Bivalves and harmful algal blooms.In Appukuttan K.K. (Ed).Winter school Technical notes on "Recent advances in mussel and edible oyster farming and marine pearl production". p183-189

XI

REVIEW OF PROSPECTS FOR LOBSTER FARMING

E.V.Radhakrishnan

Capture fisheries have reached a peak in production, and stock enhancement or aquaculture appears to be the only hope of meeting the ever increasing demand for high value seafood like lobsters. For aquaculture, the pressing need is to solve the dilemma of promoting expansion while at the same time demanding the development of environmentally sound technologies and farming practices (Mace, 1997). Lobsters have excellent market demand and price and especially live lobsters are the most preferred. Customers in affluent countries are ready to pay more for fresh seafood. Lobsters are exported in different forms; live, frozen tails, whole frozen, whole-chilled, whole-cooked and frozen and as lobster meat. The live lobster trade increased from 1.3 % during 1993-94 to 12.7% during 2003-04 period. The foreign exchange revenue from export of lobsters alone amounts to Rs.53 crores during 2003-04. Due to the increasing demand, lobsters of all sizes are caught and marketed and the resource is under extreme fishing pressure. Though Government of India has brought regulation on size of export of four species of lobsters, undersize lobsters are caught in the absence of any regulation for fishing and are still exported illegally. They fetch very low price and therefore result in loss of revenue to the fishermen. These lobsters if fattened can fetch higher price and can be legally exported. Until hatchery technology is commercialized, value addition to the lobsters, is possible through short term fattening. Holding low value lobsters with a view to value adding and harvesting wild puerulii for commercial grow-out appear to be technically as well as economically feasible (Mohan, 2001).

Interest in aquaculture of lobsters has grown worldwide in recent years as the lobster fisheries in many countries are overexploited (Kittaka, 1997, Phillips and Evans, 1997). In addition, high value of live lobster (US $40) has creased intense interest in lobster farming. Among the spiny lobsters, tropical species have more favourable characteristics and are amenable to farming conditions. Tolerance to high stocking in controlled conditions communal living without cannibalism, acceptance of pelleted feed and strong market demand are some of the characteristics, which makes lobsger as a widely accepted aquaculture species. However, for sustainable aquaculture practice, hatchery production of seeds is vital, which is yet to be achieved, though larval phase of a few species have been completed. The biological and technical feasibility of lobster farming is discussed in this paper.

Fattening of low value and undersize lobsters for product enhancement

Ongrowing wild caught seed lobsters are widely practiced in Vietnam, the Philippines and Indonesia. Farming is typically on a subsistence scale (limited by the availability of seed) although the magnitude of production in Vietnam is collectively very large (1000 tonnes annually). In Australia and New Zealand, lobster seed cannot be taken for aquaculture except under strict and limited pilot license conditions. However, there is some in sea and on land holding of legal size lobsters for weight gain and/or more favourable (niche) marketing. In India there being no restriction on fishing, large quantities of juveniles and undersize lobsters are caught and marketed. Though there is good potential for fattening to legal size, there is very little attempt. While some entrepreneurs have shown interest, availability of healthy, quality seed is a major constraint.

On growing involves holding undersized lobsters, which fetch low price or not accepted legally for export, for short period until they attain legal size .These lobsters could be held in tanks, ponds or cages fed with natural or artificial feed. Growth could be further enhanced remarkably through eyestalk ablation and by proper feed and water management. Since live lobsters fetch high market value, these can be marketed to targeted markets in Southeast Asian countries.

Seed availability

Among the shallow water species occurring along the Indian coast, *Panulirus homarus*, *P. ornatus*, *P. polyphagus* and *Thenus orientalis* are the most promising species. These species can be easily distinguished by the colour and morphological features. The hatchery production of *T. orientalis* has already been accomplished. The larval culture of the spiny lobster species occurring in India is yet to be successful though some headway has been made. Therefore farming or fattening of lobsters will have to depend upon either the post larvae (puerulii) or the undersized lobsters caught in artisanal gears. In India, lobsters appear as by catch in trawls operated in Maharashtra, Gujarat and Tamilnadu. The quantum of juveniles caught in trawls is low. Artisanal gears such as trammel nets, gill nets and traps are also used for fishing in inshore areas. Lobsters in gill nets and especially more than 50% of catch in trammel nets are undersized and cannot be legally exported. These are either illegally exported or consumed internally. The secondary holding centres keep the lobsters under highly stressed condition due to paucity of space and seawater facility and therefore the lobsters become weak and highly stressed. They may contact disease even if brought and stocked for ongrowing.

Breeding and hatchery production

Captive breeding of *P.homarus*, *P. polyphagus*, *P. ornatus*. *P. longipes* and *P. versicolor* has been achieved by different laboratories in India. Adult lobsters maintained in broodstock holding system mate and breed when optimum environmental conditions and feed are provided. Repetitive breeding is reported in *P. Homarus*. Juveniles of *P. homarus* and *P. ornatus* were reared to maturity in captivity and successful breeding achieved. Egg bearing lobsters procured directly from fishermen are also suitable for egg hatching and rearing. However berried lobsters procured from secondary holding centres are often infected and not suitable for hatchery operations. Phyllosoma larvae of *P. homarus* have been reared to stage 6 in 60 days. Recently larvae were reared to stage 8 in 42 days on a mixed diet of *Artemia* and plankton. Similarly larvae of *P. ornatus*, *P. polyphagus* and *P. versicolor* have also been reared through early stages. Significant advances have been made in Japan, Australia and New Zealand in culture of phyllosoma larvae of a number of temperate and semi-tropical species of lobsters to settlement. Japanese were the first to succeed in completing the larval phase of five temperate species and one semi-tropical species. Larvae took 132 to 319 days to complete the larval phase in different species. The number of instars was 17 for *Jasus* spp., 9 for *Palinurus elephas* has 25 (estimated) for *Panulirus japonicus.* Survival ranged from o.01 to 10%. Phyllosoma larae of *P. Cygnus* and *J. verraeuxi* were also reared to settlement by the Australians and the New Zealanders. The method developed in northern Japan to culture phyllosoma larvae of five species of cool-temperate spiny lobsters combines the features of upwelling water, co-cultured microalgae and use of mussel gonad as food. The feeding behaviour of phyllosoma larvae shows that they are primarily predators. Recent work has shown that the contamination of culture water by microorganisms such as the fouling protozoans *Vorticella* sp. can greatly reduce phyllosoma survival. Feeding with fish larvae reduced the larval period by half (65 days) in *P. elephas*. However, commercial feasibility of seed production technology is still doubtful for most of the species because of the prolonged larval phase (> 300 days) and poor survival. Until hatchery technology is perfected, lobster farming will have to depend upon naturally available seeds.

Collection and ongrowing of puerulii

Spiny lobsters after completing its long larval life metamor phoses into postlarvae (puerulus),which swims towards the shore and settle in nearshore seagrass/seaweed habitats. They transform into postpuerulus and settle into benthic dwelling juvenile lobster. In the wild, levels of puerulii settlement vary depending on the species and geographic area, which also depends on the spawning stock. Commercial harvest of puerulii and early juveniles from the wild as suggested by the Australians may be possible where there is heavy settlement in the inshore habitat. However, the feasibility of such a proposal is to be examined in other areas, as there is apprehension that this will have serious long-term implications on sustainability of wild resources. Partial harvesting of puerulii from dense settlement areas is suggested as high mortality rates were experienced by juvenile lobsters between settlement and entry into the commercial fishery. This will benefit the wild resource as well as those interested in farming of lobsters. Commercial collection of southern rock lobster puerulii for aquaculture has already commenced in Tasmania. In India, studies conducted off Kovalam near Chennai show that puerulii of three species, *P. homarus*, *P. polyphagus* and *P. ornatus* settle in rocky areas. However, the intensity of settlement is not very high enough to suggest harvesting for ongrowing. There is no information on settlement density of puerulii anywhere along the Indian coast.

Indian lobster fishery is poorly managed as this is a low volume resource and therefore fishing regulations are not strictly enforced. Destructive gears like trammel nets operated in inshore areas bring in large quantity of juveniles and sub adult lobsters which fetch only low price. The undersized lobsters procured from the fishermen were exported until the Ministry of Commerce and Industry, Government of India notified Minimum Legal Size (MLS) for export in 1997. Illegal export of lobsters below the MLS is still in vogue. Since there are no regulation for fishing lobsters in any maritime state, fishermen continue to bring the lobsters entangled in the nets and sell it to exporters. Nearly 50% of the lobsters caught in trammel nets are undersized. In Gujarat, gill nets operated in the reef areas also bring undersized *P. polyphagus*, which are sold, for a very low price. Along the southwest and east coast of Tamilnadu, an estimated 25 tonnes of undersized lobsters are landed annually. By catching these undersized lobsters, the total loss of revenue to the fishermen is to the tune of several crores The MLS for *P. homarus* is 200 g and for *P. polyphagus* 300 g and those below the MLS, which are prohibited from export, can be fattened to the legal size and fetch higher price.

Collection, maintenance and transportation of juveniles

Fishermen either keep the lobsters in wet sand until the traders come and pick it or sell it to local merchants. These traders either keep them in holding tanks with recirculation facility (most of them with inadequate water reuse facility) or keep them in cages kept in rock pools until collected by the exporters. Since only larger lobsters with high price are given more care, the undersized low price lobsters are kept under high stress in very poor quality water. Therefore they are weak and are easily susceptible to diseases. They are unsuitable for fattening purposes. When there are transported to long distances they become further weak and on stocking dies gradually. The green colour of the lobster is lost and their shell becomes reddish in colour, which is indicative of stress. If the undersized lobsters should be useful for fattening, fishermen and traders should follow certain protocols so that they could supply healthy seed to the entrepreneurs. Juveniles are especially susceptible to stress and therefore they should be kept in water soon after they are brought to the shore. It is better to keep them buried in cool moist sand in shade rather than keeping at high densities in poor quality water. Maximum care should be taken so that their appendages are not lost while removing from the net or they are not injured below the abdomen. During holding in unhealthy condition they are infected by deadly pathogens through these injuries and there are instances of high mortality due to infection by pathogenic bacteria.

Fattening in land-based holding systems

Lobsters can be successfully held and fattened in land-based holding systems provided suitable environment is provided. Critical environmental parameters include the concentration of dissolved oxygen, ammonia, nitrite and carbondioxide. Nitrate concentration, pH, salinity and alkalinity levels within the system are also important. In flow through systems, the main limiting factor is dissolved oxygen. The requirement of oxygen will be high during molting and soon after feeding. Both the process normally takes place during night and optimum levels of oxygen shall be maintained during night to avoid oxygen depletion and mortality. Oxygen related stress would adversely affect growth significantly. Unlike shrimps, lobsters are oxygen conformers and may not show any sign of low oxygen conditions, as they are capable of adjusting the metabolism even at very low levels of oxygen. Sufficient water needs to be pumped through or the water needs to be aerated to ensure lobsters are supplied with sufficient oxygen. Sudden salinity fluctuation during rains is a serious situation and in such circumstances salinity, alkalinity and pH should be adjusted in a reservoir, before the water is pumped in. though lobsters can tolerate gradual changes in salinity to a limited range, sudden dilution can lead to stress, susceptibility to disease and mortality. Tolerance limits for various water quality parameters is given in Table. 1.

Indoor tanks

Two main systems are currently being used for fattening lobsters: flow-through and recirculating. In flow through systems, the water that is pumped into a tank is used only once. Water flow is to be decided based on the stocking density and feeding intensity. The incoming water is to be free of sediments and should have water quality parameters required for lobster farming. The water should be regularly monitored to avoid wide fluctuations in environmental parameters. In recirculating systems, the majority of the water is re-used after each pass through the tanks, first being treated to remove waste products before being returned to the tanks. Even though initial set up costs may be higher, there is an increasing interest in the use of recirculating systems. In recirculating systems also the main limiting factor is dissolved oxygen: however, the unionized ammonia concentration becomes increasingly important, and is probably the next important limiting factor. Ammonia should be removed from the system at a rate equal to the rate of production to maintain safe concentration. All recirculating systems remove waste solids, oxidize ammonia and nitrite, remove carbon dioxide, and aerate the water before returning it to the fattening system. Solid wastes can be removed by mechanical filtration, ammonia and nitrite by biological filtration and carbon dioxide by the provision of an air/water interface. The safe level of ammonia for holding lobsters is <2 mgL^{-1}. The flow rate calculations must be adjusted according to the species held, size of the animals, the rate of feeding and the holding temperature. The required estimated flow rate in a tank holding 10000 kg of 500 g fed *J. edwardsii* lobsters at 13% C is 4500 $L\ h^{-1}$. The water management schedule and monitoring frequency of environmental parameters is shown in Table 3.

Tank design

Raceways, rectangular, square or circular tanks can be used. The most preferred are individual raceway tanks. Circular or square tanks made of brick and cement or concrete are also good. Square tanks will save space when compared to circular and are also less expensive as they could be connected serially These tanks will be difficult to clean and feed the lobsters. Raceways are easier to maintain and with proper slope, the wastes can be easily removed through the outlet pipe fixed at the end of the tank. For complete removal of water, the standpipe can be lifted. Square and circular tanks will have a central drainage system or a self-cleaning two way waste removal system by which both suspended and settled wastes can be automatically flushed out of the tank. The wastes can be concentrated towards the centre of the tank by creating a vortex by the incoming water. This tank design is used in flow through systems. For recirculating system the wastewater flowing out of the tank is recirculated after removing the waste products and will be a continuous process. Since lobsters grow fast in subdued light, tank covers have to be provided to avoid bright sunlight.

Stocking density

Undersized lobsters procured from secondary holding centres transported to the fattening facility may be kept under quarantine for 48 hours to relieve the lobsters from stress. The quarantine facility should be away from grow out tanks. Healthy lobsters may be stocked at 1.0-1.25 kg/m^2 after segregating into different size groups. The difference in weight between the lower and upper size should not be more than 20 g. Hideouts provided in the tank will help them to congregate around the shelter during day and prevent them from continuously moving in the tank spending lots of energy. Lobsters feed on variety of natural and artificial feed making them suitable for farming. The natural feed includes mussels, clam, squid, trash fish, and smaller crabs and shrimp meat. Artificial includes shrimp pellets that are suitable for juveniles and subadults. Lobsters feed actively after dusk; feeding during night will reduce feed spoilage and waste.

In Florida, *Panulirus argus* weighing 300-400 g held in captivity molted every 50-60 days and attained an average increase in bodyweight of 40% and is reported to obtain 60% return on investment. Table 2 shows percent postmolt weight increase and intermolt period (days) of spiny lobsters held in recirculating seawater systems at a constant temperature of 29 °C with 12:12 light:dark cycle (Lellis and Russel, 1990). Juveniles of *P. ornatus* stocked at 43/m^2 showed good artificial feed acceptance (>75%), biomass production (4.7 kg/m^2) and good growth rate (SGR 1.56%). It is estimated that a weight increase of 1 kg is possible in less than 18 months. Juveniles of *P. homarus* in South Africa have attained 60 mm CL in 18 months. In India puerulii of *P. homarus* have been reared to 250 g in 18 months at Kovalam Field Laboratory of CMFRI. *P. homarus* weighing 80 g stocked in self cleaning indoor system at Calicut attained 330 g in 12 months with an FCR ranging from 3.5 to 4.0 on feeding with an exclusive diet of green mussel. The minimum exportable weight of 200 g was obtained in 130 days (Radhakrishnan, 2004). Another study in indoor grow out system at Tuticorin showed 172.7 g weight increase in juvenile *P. homarus* in 150 days. In Taiwan, wild caught animals stocked at 2g mean weight reach 330 g in 16 months in small 200 m^2 ponds. A fourty growth study on *P.polyphagus* conducted at Northern Territory University showed lobster juveniles grew substantially to 148.5 g in nine months.

Growth enhancement of juvenile lobsters by eyestalk ablation has been demonstrated in *P. Homarus*, *P. ornatus* and *P. versicolor*. The ablated *P. homarus* gained a weight gain of three to seven times more than the normal. In *P. ornatus*, 100 g lobsters attained 1.5 kg in 8 months. However, food consumption and mortality is higher in ablated lobsters when compared to normal.

Lobster culture in intertidal pits

Fattening of *P. polyphagus* was carried out in intertidal pits along the Bhavnagar coast of Gujarat during early 1990s

(Sarvaiya, 1991). The pits are dug in the limestone intertidal areas and are of varying dimensions. No standardized stocking or feeding regimes were followed. 3000 numbers of lobsters weighing 30-50 g were stocked at a stocking density of 20 lobsters/sq.m in a pit of 21 m x 7 m x 1 m. the pits were covered with nylon nets to prevent lobsters from escaping during high tide. Lobsters were fed with trash fish, small crabs, marine worms and clams @ 10% bodyweight and also on compounded feeds. Juvenile lobsters, which were procured at Rs. 20/kg attained 100-125 g in 90 days, which were sold at Rs.250/kg during 1991. The harvest of live lobsters packed in bamboo baskets are sold to exporters. The highly profitable practice was discontinued due to intensive poaching and non-availability of enough quantity of seed lobsters.

Lobster culture in cages

In Philippines lobster culture was practiced in floating cages made of nylon material. *P. ornatus* weighing 100-300 g stocked at 8/m^2 attained 800-1.3 kg in 6-15 months. Survival for larger sizes has been more than 90% whereas in smaller juveniles of 30-80 g, survival was less than 50%. Trash fish is the main feed, which is procured at US$ 0.13-0.22 per kg. Selling price of live lobster was US $ 21-31/kg; hence a wet FCR of more than 10 can still be profitable.

In Vietnam, mariculture of lobsters in floating, fixed and submerged cages were practiced in protected bays or lagoons that have a good tidal flow. *P. ornatus* is the main species and *P. homarus*, *P. Versicolor, P. longipes* and *P. stimpsoni* were also cultured. Floating cage is made of nylon net material with a frame and buoy and located at a depth of 10-20 m. Wooden fixed cage is normally 20-40 sq.m and even large cages of 200-400 sq.m are also used. The off-bottom cage is typically about 0.5 m above the seabed. This kind of cage is suitable for sheltered bays. Submerged cage is made of iron framework with a diameter of 15-16 m. The height is 1.0-1.5 m. the cage has a cover and a feeding pipe and is used for nursery rearing. Seed lobsters of about 25-30 mm TL are stocked (100- to 200 per cage) and grown to a size of about 50 g (10-12 cm TL). Lobsters are fed exclusively with either whole finfish or chopped fish or shellfish. Finfish comprised about 70% of the diet and the preferred fish is lizardfish. Feeding trash fish results in water quality problems. The total nitrogen content in the seawater exceeded the standard level for aquaculture of 0.4 mg/L. Increase in cage farming and using fresh trash fish and shellfish has led to disease problems in some areas. Some common diseases are black gill disease, shell necrosis and red body. Treatment protocols followed are treatment with 100 ppm formalin for 3-5 minutes. Red tail disease has been reported in spiny lobsters, which is similar to the *gaffkemia* in *Homarus americanus.* The symptoms are lethargy, reddish colour of underside of the abdomen, spreada eagle posture during late stages, poor food consumption and mortality. The bacteria enter into the body through the injury in the abdomen and multiply in the haemolymph. Isolation of the affected individuals and oral administration of oxytetracycline through feed are protocols for treatment. Antibiotic administration is possible only during the early stages of infection. The disease is highly contagious and spreads through water.

The estimated total annual production of farmed rock lobster was about 1500 metric tones a year with a farm gate value of US$26./75/kg. The average profit margin was 50%. Therefore lobster culture is a profitable industry provided adequate seeds could be collected without disturbing the wild fishery. Suitable artificial diets are to be formulated and feeding regimes established in order to succeed lobster farming in a commercial scale. Disease protection measures should be prioritized. Cage designs should be studied for improved lobster husbandry.

Preliminary experiments in cage culture of lobsters were attempted in India by NIOT, Chennai. Floating and fixed net cages were positioned in protected areas. Fishermen fattened juvenile lobsters caught from the wild stocked in cages. However, the feasibility of large-scale farming is doubtful, as sufficient seeds may not be available for stocking when more number of people are involved. This may also result in high fishing pressure on wild fisheries and negative impact on natural lobster fisheries.

Future prospects

All marine lobsters are highly considered as fine table food and thus are in high demand. Most wild fisheries are overexploited, with many stocks having already collapsed or catch rates closely regulated to sustain the wild fishery. For these reasons, lobsters fetch high prices. The highest price is paid for live product, chilled or frozen products bring much lower prices. Aquaculture offers the only prospects by which lobster supplies can realistically and sustainably be increased. Considerable export potential exists for live product to Southeast Asian markets. Packing and transport conditions for live shipment of lobsters are well developed and would not be a problem. Development of a successful export market would require both continuity of supply and a reasonable volume of production. However, the greatest concern is whether aquaculture production would be sustainable if recruiting seed was taken in large quantities for aquaculture.Attempts in 1970s and in late 1990s to establish large-scale intensive aquaculture of spiny lobsters in the Philippines collap-sed within a few years of establishment when seed supplies became insufficient to support the venture. In India the resource is limited to certain pockets along the coast and lobster landing is drastically declining in all the centres due to indiscriminate fishing. Therefore, before contemplating aquaculture, research is warranted to better determine the stock structures of spiny lobsters and to estimate recruitment patterns and survival rates. Such research would enable responsible fishery management policies to be put in place to ensure sustainability of the wild fishery stocks. Low intensity aquaculture of spiny lobsters for value enhancement and export strictly adhering to the legal procedures could be a profitable industry in some specific locations along the coast.

Table 1: Tolerance limits for various water quality parametersfor the culturable species of lobsters

Parameter	Tolerance limits
Temperature	12 to 31°C (25-30°C)
DO (% saturation)	Minimum 70%Preferably above 80%
Salinity (ppt)	30-38
Ammonia (mg L-1)	< 2
Nitrite (mg L-1)	< 5
Nitrate (mg L-1)	100
PH	7.8 to 8.4
Hardness (ppm)	100-200

Table 2: Postmolt weight increase (%) and intermolt period (days) of spiny lobster (*Panulirus argus*) held in recirculating system at a constant temperature of 29 °C with 12:12 light:dark cycle (Lellis, 1990)

Initial weight (g)	Weight increase (%)	Intermolt time (days)
100-200	52.3	40
201-300	45.9	47
301-400	39.9	53
401-500	35.7	65
501-600	30.1	74
601-700	27.8	83
701-800	23.8	84
801-900	25.0	79
901-1000	21.8	91
>1000	24.4	112

Table 3: Monitoring schedules for different environmental parameters

Parameters	Schedule	Equipment
Temperature	Daily at 1000 hrs and 1600 hrs	Thermometer glass/digital
Salinity	Weekly and before adding new water	Salinity refractometer
pH	Weekly or during water change	pH meter
Oxygen	Weekly: (every 2-3 hrs 0 when new water is added)	Oxygen probe
Ammonia, nitrite, nitrate, alkalinity and hardness	Weekly	Measuring kits

References:

Kitaka, J. 1997. Culture of larval spiny lobsters: a review of work done in northern Japan. *Mar. Freshwater Res.*, 48, 923-930.

Lellis, W. 1991. Spiny lobster: A mariculture candidate for the Caribbean? *World Aquaculture*, 22(1): 60-63.

Lellis, W.A. and J.A. Russel. 1990. Effect of temperature on survival, growth and feed intake of postlarval lobsters, *Panulirus argus*. *Aquaqculture*, 90:1-9.

Mace, P.M. 1997. Developing and sustaining world fisheries resources: the state of the science and management. In 'Developing and sustaining World Fisheries Resources: the State of the Science and Management. *Second World Fisheries Congress, Brisbane 1996*: (Eds. D.A. Hancock, D.C. Smith, A. Grant and J.P. Beumer) pp. 1-20 (CSIRO Publishing; Melbourne).

Philipps, B.F. and L.H. Evans, 1997. Aquaculture and stock enhancement of lobsters: report from a workshop. Mar. freshwater Res. 48(8): 899-902.

Radhakrishnan, E.V. 2004. Prospects for grow out of the spiny lobster, *Panulirus homarus* in indoor farming system. In: program and Abstracts, 7th International Conference and workshop on Lobster Biology and Management, 8-13 February, Hobart, Tasmania.

Radhakrishnan, E.V. and M.Vijayakumaran. 1984. Effect of eyestalk ablation in spiny lobster *Panulirus homarus* (Linnaeus). 1. On moulting and growth. *Indian F. Fish.,* 31(1): 130-147.

Sarvaiya, R.T. 1991. Successful spiny lobster culture in Gujarat. *Fishing Chimes*, 10 (11): 30-31.

XII

FISH GROWTH PARAMETERS AND THEIR MONITORING

D. Divu, K. Srinivasa Rao and K.K.Philipose

Cage aquaculture has grown rapidly during the past decades and is presently undergoing swift changes in response to increasing global demand for aquatic products. Recent studies have predicted that fish consumption in developing and developed countries will increase by 57 percent and 4 percent, respectively. Rapid population growth, increasing affluence and urbanization in developing countries are leading to major changes in supply and demand for animal protein, from both livestock and fish. The need for suitable sites has resulted in the cage aquaculture subsector accessing and expanding into new untapped open-water culture areas such as lakes, reservoirs, rivers and coastal brackish and marine offshore waters.

Growth studies are an essential instrument in the management of fisheries resources since they contribute to estimates of production, stock size, recruitment and mortality of fish populations. The study of growth means basically the determination of the body size as a function of age. Therefore all stock assessment methods work essentially with age composition data. Fish can be aged by examining scales or various bones. Hard body parts grow as the fish grows, adding annual rings similar to the rings in trees. Because the growth in the diameter of the hard body parts is proportional to the growth in length of the fish.

Fish growth and feed utilization

Growth is sensitive to environmental conditions and measurements of growth rate can often be used to provide an index of performance. Slower growth in fishes has been correlated with a variety of life history traits – from higher mortality to reduced food availability and increased age or smaller size at sexual maturity. The health and welfare of a fish can be influenced by a variety of physical factors ranging from water quality to territorial defence, unnatural habitats, stocking densities and available nutrition. Stocking density is well publicized as a factor that can influence fish health and growth rate in so far, as overstocking in a system can negatively affect water quality and food availability. Often, the stocking density alone or in combination with feeding rate is adjusted by fish farmers to obtain a particular size of fish at harvest, thus indicating that fish growth may be a function of available water space.

Specific Growth Rate (SGR)

The specific growth rate can be calculated based on the following method.

$SGR = Log_e W_2 - Log_e W_1 / D \times 100$

where, 'W_2' is the mean weight of the fish during the present sampling, 'W_1' is the mean weight of the fish during the previous sampling and 'D' is the number of days between the two samplings.

Average Daily Growth Rate (ADGR)

This can be calculated using the following formula.

$W_2 - W_1 / D$

where W_2 is the final body weight and W_1 is the initial body weight

Survival rate (SR)

SR = $(N_2 / N_1) \times 100$. The survival rate is always expressed in percentage, where N_2 is the number of survivors during the present sampling and N_1 is the number of survivors during the previous sampling.

Biomass

Biomass can refer to species biomass, which is the mass of one or more species, or to community biomass, which is the mass of all species in the community. The mass can be expressed as the average mass per unit area, or as the total mass in the community. How biomass is measured depends on why it is being measured.

Biomass = Mean weight x Number of fishes

Weight Gain (WG) = Initial body weight - Final body weight of fish

Protein Efficiency Ratio (PER)

PER is the measurement of the body's biological absorption of a protein from a food source to usable protein. PER is a widely used method for evaluating the quality of protein in food.

PER = Gain in body mass (g) / Protein intake (g)

Net Protein Utilization (NPU)

The net protein utilization, or NPU, is the ratio of amino acid converted to proteins to the ratio of amino acids supplied. It is profoundly affected by the level of limiting amino acids within the food stuff. As a value, NPU can range from 1 to 0, with a value of 1, indicating 100% utilization of dietary nitrogen as protein and a value of 0 an indication that none of the nitrogen supplied was converted to protein.

Feed Conversion Ratio (FCR)

FCR is calculated from the number of kilos of feed that are used to produce one kilo of whole fish. The ratio of the gain in the wet body weight of the fish to the amount of feed fed. The true F.C.R includes wasted feed and mortalities. The ratio, usually expressed as a true ratio (i.e. 1 : 1.5) is often quoted as a "rate" (1.5). Two additional terms are used by the farmer, the biological FCR and the economic FCR. Biological FCR is the net amount of feed used to produce one kg of fish, while the economic FCR takes into account all the feed used, meaning that the effects of feed losses and mortalities, for example, are included. Farms reporting a low FCR normally have good management practices in place, with no overfeeding and very low, if any, mortalities. Overfeeding or underfeeding will increase the FCR.

The basic principle in feeding is that the fish should be fed exactly to satiation. If they are fully fed, the fish are not stressed. In an efficient trout or salmon farm, the FCR will be close to 1. This is extremely low when compared with land animals. There are three reasons for this; the biology of the fish, the way the fish live and the high nutrient concentration of fish feed. Fish have a low body maintenance requirement. Fish are poikilothermic (cold-blooded) animals (their body temperature is equal to that of its environment) and thus they do not use feed to maintain body temperature as warm-blooded animals do (e.g. poultry, pigs and cows). For a fish, floating in the water consumes less energy than standing and walking on legs. The fishes are very efficient converters of feed into energy and building blocks (muscles) for growth and their feeds are also more concentrated than those for pigs or cattle, since they do not need ‘filler’ ingredients such as fibres. Fishes use oils and fats as their prime energy source and, therefore, this is more concentrated than the carbohydrates needed by land-living animals. Finally, land animals have a far higher feed capacity than fish and therefore they can grow well on less concentrated feed.

Feed Efficiency

A figure used to represent the efficiency of food use. The inverse of the feed conversion ratio e.g. a feed conversion ratio of 1 : 1.5 becomes a feed efficiency of 0.66 (1 / 1.5).

Feed Rate

The amount of feed given to the fish, over a specified period of time . The most common way of expressing this is as percentage of the animal body weight per day. For example a 1000 gram fish, being fed 20g of feed per day would be on a 2% feed rate [(20 / 1000) x 100)].

Energy Assimilation

The food consumption of fishes can be summarized in the following equation:-

$C = P + R + F + U$

where, C = food consumption in energy terms (Joules); P = energy used for tissue growth (including fat deposition, egg and sperm development); R = energy used for work (including body maintenance, digestion, activity); F and U = energy losses in faeces and urine respectively. The amount of useful energy available to the animal, or assimilation (A) as it is generally termed, can be derived from $A = C - (F + U) = P + R$. Assimilation is often quantified in terms of assimilation efficiency.

Carrying capacity

A major consideration in the site selection process should be the carrying capacity of the site which indicates the maximum level of production that a site might be expected to sustain. Intensive cage fish farming results in the production of wastes which can stimulate productivity and alter the abiotic and biotic characteristics of the water body, whilst less intensive methods can result in over cropping of algae and a fall in productivity. Hence profitability or even viability may be seriously affected. Therefore it is extremely important for all concerned with cage fish farming to have an accurate evaluation of the sustainable levels of production at a particular site before culture. The carrying capacity of a biological species in an environment is the population size of the species that the environment can sustain indefinitely, given the food, habitat, water and other necessities available in the environment. In ecological terms, the carrying capacity of an ecosystem is the size of the population that can be supported indefinitely upon the available resources and services of that ecosystem. Carrying capacity varies based on a number of factors, such as, water flow, volume, exchange rate, temperature, oxygen content, pH, size and species of fish being reared and accumulation of metabolic products. Carrying capacity is based on loading (the weight of fish per unit of water flow) and density (the weight of fish per area of water body) of the fishes in the system.

Condition Factor

An easily measured index of growth is the length-weight relationship, often referred to as condition factor (C). C is the ratio of fish weight to the length cubed. Condition factor, one of the most important feeding and growth criteria. Since 'C' may vary between species, strains, diet and feeding levels, water quality and hatchery management, it should be calculated for each hatchery. 'C' is calculated by weighing a sample of 50-100 fish together. After the average weight and the average length are measured, values are used in the formula $C=W/L^3$. A high condition factor would indicate a well-fed fish, while a low condition factor may indicate a poorly fed fish of the same length.

XIII

ENVIRONMENTAL MONITORING IN SEA CAGE CULTURE

Jayasree Loka, S.M. Sonali, L.S. Korabu and K.K. Philipose

Cage culture is a fast growing industry all over the world and demands good environmental practices to assure sustainability. The sustained development of coastal aquaculture has reached a good understanding with the environment, respecting it and undertaking actions that tend to diminish the possible impacts that may arise from this activity. In order to do so, measures are to be taken in production to avoid degrading the environment, whilst still being appropriate, economically viable and socially acceptable. In this sense, it has been considered necessary to develop some basic environmental strategies to assure the best site for the aquaculture purposes, avoiding possible confrontations with other coastal uses. Basic protocols required to have a sustainable cage culture are to identify the appropriate sites for the installation of open sea fish cages, and to identify the environmental management of such industries. Monitoring is an important part in environmental management of mariculture, and is integral part of an Environmental Impact Assessment (EIA), and should be included in any mariculture regulation programme or coastal zone management plans. A well conceived and designed monitoring programme is needed for measuring environmental change and relating these changes to inputs from fish cages; in effect, investigating impacts from these inputs. However, there are no set ways for monitoring and interpretation of the data obtained. These are dependent on the purposes and aims of the study, the size, characteristics, etc.

In monitoring environmental effects of cage culture, data is collected at various time points and compared with original pre-development data and with contemporary reference data. This will show changes not only with time due to impacts but also allow natural environmental change to be taken into consideration.

Survey techniques vary but generally require a design that collects data before development – a baseline survey – and collection of post-development data – a monitoring survey:

(i) Baseline survey. This provides essential background ecosystem data for subsequent comparison. The survey may be both spatial and temporal, giving pre-development data on the natural environment and its changes throughout the proposed development area. This data can aid in the design of an appropriate monitoring study, i.e. focusing on the areas which are most relevant for investigating change in any particular environment. There are several types of experimental design, incorporating the baseline survey. One of the most commonly used is the BACI or BACUP systems (Underwood, 1991).

(ii) Monitoring study: This provides data on the actual impacts, in relation to the contemporary reference and baseline data. Once interpreted the results may be used directly for management decisions by both fish farmer and environ mental regulator by ensuring adherence to EQSs and acceptable zones of effect (AZEs).

The environmental impact of a sea farm depends to a great extent on the species, the farming method, the stocking rate, feed type and hydrographic conditions. Both organic and non-organic waste from the fish farms can cause nutrient enrichment and even eutrophication where farming sites are in semi-enclosed zones with little exchange of water. Almost 85% of the phosphorus, 80-88% of carbon and 52-95% of nitrogen introduced into the cages can enter the environment through feed waste, fish excreta, faeces production and respiration. In order to interpret the data effectively standard measures, including direct measures, i.e. ionised and un-ionised ammonia, nitrate, nitrite and dissolved reactive phosphorus, and indirect measures of productivity, i.e. dissolved oxygen, chlorophyll 'a' content, turbidity, in addition to temperature and pH, salinity, should be taken.

Long term measurement and monitoring of effects of soluble wastes are difficult due to the high mixing and dilution afforded by the marine environment. This ensures that impacts in all but the most sheltered and enclosed conditions are transient. Particulate wastes tend to settle to the sediments usually distributed in the direction of the main current flow. The wastes usually form a gradient of effect away from the discharge point which causes a variety of changes on the seabed. These changes in sediment composition decrease in dissolved oxygen or sulphur reduction due to increase in microbial production and changes in benthic biota.

A variety of measures are used as indicators - physical and chemi cal changes in sediments can be investigated using: particle size analysis, determination of concentration of organic carbon and nitrogen, redox potential (Pearson and Stanley, 1979), and measurement of sulphide content. Biological changes can be seen by looking at many factors, the presence of the sulphur reducing bacteria *Beggiatoa*, abundance of species which are indicative of nutrient enrichment and investigation of community structure (infauna and associated fauna).

Monitoring methodology

There are several considerations to be taken into account when deciding on monitoring methodology. These include:

(i) frequency of sampling;

(ii) position of sampling stations;

(iii) method of sampling water or sediments; and

(iv) method of analysis of the samples taken to measure the determinants.

These factors will be different with type of culture and method of waste discharge. Again, there is no fixed method of deciding on these factors as this is dependent on the purpose of the monitoring study. Sample strategies usually attempt to maximise data collection per expended effort, which normally entails the use of transects aligned with the direction of principle current flow rather than a less efficient but more statistically rigorous random sample or grid approach. Samples along these transects may be taken using water samplers such as the Van Dorn and sediment samplers like remotely operated grabs, dredges, trawls or corers or diver operated techniques such as photography, video, corers or REMOT systems. Grabs and coring techniques can be used to take quantitative samples which give accurate and easily comparable temporal and spatial data for physical, chemical and biological analysis (Fig.5). Photography and video methods are qualitative or semi-quantitative but are good visual record of change.

Recently, with the advent of advanced computer based electronic methods, surveys can be undertaken using sophisticated ship based technology. Such a method is side scan sonar which has been used, with varying success, to characterise sediment types throughout bays containing fish farms (MacDougall and Black, 1999) and for mapping biotopes in coastal regions. Initial findings show that these techniques need further work but they offer promise for the future where surveys will be able to study large areas of seabed quickly and accurately.

Protocol for the environmental management of aquaculture cage farms:

Data on the following should be provided:

i) Designing of the basic sampling data: on location, occupation, markers, features of the installation works, characteristics of production (species, quantities to be produced, etc.), characteristics of management (feeding, medication, waste treatment, production cycles, etc.).

Sampling : Regarding the sampling design, in each case this should be decided on the basis of previous knowledge existing on the zone. If no previous knowledge is available, the required minimum could be:

(a) Two samplings in extreme seasons: winter and summer.

(b) Five sampling points, whose design should be based on the main dispersal of the waste from the cages. Of these points, at least one should be below the point where the cages are to be installed and another should serve as a reference point for the future in an area unlikely to be affected.

(c) The sampling depths are left to the discretion of specialist carrying out the work, in accordance with the culture system.

(ii) Water column: temperature, salinity, dissolved oxygen, optical properties (turbidity, suspended solids, Secchi disk transparency), nutrients (phosphorus, ammonium and nitrogen), chlorophyll. In this case pollutants such as metals or pesticides could be studied (if so, it would be better to analyse this in filter animals such as mussels or oysters). The data must be used in order to establish the "zero state" so as to compare with that during the environmental monitoring (once the culture is functioning), the real impacts correspond to the predicted ones, in order to act in consequence if this is not the case.

(iii) Sediments: distribution of the soft substrate in the area (linked to bathymetry) with data on granulometry, organic matter and redox potential (Fig.1). In this case pollutants could be studied.

(iv) Bottom communities: with special influence on the presence of communities with a high ecological value (marine phanerograms, coralligen etc.) or with special interest (algae meadow, etc.). Besides identification, data on richness of species, abundance, biomass and diversity should be available.

Fig 1. Sediment grab

(v) Protected areas: establishment of their existence and types of protection.

(vi) Presence of other aquaculture firms: study possible synergies or accumulative effects (maximum stocking rate), from simulation data of the previous Protocol.

(vii) Interference with other uses: concentrate principally on fishing, navigation and tourism

(viii) The impacts should be determined as objectively as possible, and in order to do so, baseline contamination data should be used, as well as legislation data and data from previous environmental studies, etc. The study will be focused on the outstanding impacts.

(ix) Proposal of a monitoring programme: it should include a monitoring proposal

An integral part of monitoring is interpretation of results and relating physical and chemical results to the biological effects. For water samples this is often a compromise due to the transient nature of this environment. Most often water quality monitoring requirements are fulfilled by collection of empirical data which can be directly compared to EQSs. For sediments a similar comparative method may be used but, due to the more stable nature of this habitat, more sophisticated techniques can be employed to investigate both gross and subtle changes, such as those that may be due to discharged chemotherapeutants. These techniques use species abundance data to investigate spatial and temporal changes in sediment dwelling communities and relate these to physico-chemical parameters and waste inputs in order to achieve environmentally sustainable cage culture of marine finfish.

Source:

FAO 2009 Environmental Impact Assessment and Monitoring in Aquaculture.

MAFRI Report No. 46. (2002) Gavine,F. M. and Mc Kinnon, L. J. 2002. Environmental Monitoring of Marine Aquaculture in Victorian Coastal Waters: A Review of Appropriate Methods. Technical Report No.46. Marine and Freshwater Resources Institute, Victoria

XIV

DISEASES AND THEIR MANAGEMENT IN CAGE CULTURE

S.R.Krupesha Sharma, N. Sadhu and K.K.Philipose

Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. A cage is a volume enclosed with some type of mesh forming a container for aquatic animals. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Aquaculture is a rapidly growing food producing sector in the world, with an average annual growth rate of 8.9% since 1970, compared to only 1.2% for capture fisheries and 2.8% for terrestrial farmed meat production systems over the same period.

The current trend in aquaculture development is towards increased intensification and commercialization of aquatic production. Like other farming sectors, the likelihood of major disease problems occurring increases as aquaculture activities intensify. Disease is now a primary constraint to the culture of many aquatic species, impeding both economic and social development in many countries. Addressing health questions with both pro-active and reactive programmes has become a primary requirement for sustaining aquaculture production and product trade. It is reported that the principal diseases in cage aquaculture of marine finfish and shellfish in Asia are caused by environmental and management affects, nutritional causes, and viral, bacterial, parasitic, and fungal pathogens.

Diseases caused by viruses

Viral nervous necrosis:

Viral Nervous Necrosis (VNN), also known as viral encephalopathy and retinopathy (VER) causes high mortality with vacuolation of the tissues in the central nervous system of affected fish. The disease occurs mostly in larvae and juveniles but some species such as Asian seabass and grouper are still susceptible at grow-out stages, and the disease with severe mortality has been reported in more than 32 species from 16 families. Electron microscopy revealed that unenveloped round-shaped virus particles, 25–34 nm in diameter, are packed in the cytoplasm of affected retinal and brain cells. The causative agent of VNN was purified from diseased striped jack and identified as a member of the family Nodaviridae, known as striped jack nervous necrosis virus. This disease is included as one of the significant diseases in the OIE Code.

In case of Asian seabass larvae, affected larvae show abnormal swimming behaviour, including spiral swimming, darting or sometimes vertical movement. Affected fish have an inflated swim bladder. Although the pathogenesis of the disease seems to be different among fish species, direct transmission via the epithelium of the skin and the gastrointestinal tract is reported to be important in the infection. The skin of the affected larvae changes from pale to dark. The appetite is affected and fish become lean. The disease occurs as early as at 10 days post-hatching (dph) to 50 dph. In some instances, particularly during stress, fish beyond 50 dph may still be affected. It is also common for the affected fish to have an inflated swim bladder.

The most distinctive lesion in histological sections of the brain and retina from seabass larvae with clinical signs of viral nervous necrosis includes extensive cell vacuolation. In addition, in general, in the central nervous system, the most prominent lesions are observed throughout the spinal cord and medulla oblongata. They include severe massive necrosis of the small nerve cells, spongiform encephalopathy characterized by extensive vacuolar degeneration in the cytoplasm of affected neurons and neuropils. Dark, dense, pyknotic nuclei, neuronal shrinkage and disappearance of Nissle's granule in their cytoplasm is occasionally observed. Focal extensive haemorrhaging in the molecular layer and focal demyelination characterized by degenerated myelin nerve fibres with phagocytic mononuclear foamy cell infiltration were also observed in the area between the Purkinje cell layer and molecular cell layer.

Studies on the development of vaccination methods in groupers are now undertaken.

Iridovirus infections:

Iridoviruses, causative agents of serious systemic diseases have been identified from more than 20 fish species in the recent years. Most fish iridoviruses are members either of the genera *Lymphocystis virus* or of the genera *Ranavirus*. Iridoviruses in genera *Lymphocystis virus* cause the development of cluster of extremely hypertrophied fibroblasts or osteoblasts called lymphocystis cells, while viruses in genera *Ranavirus* may lead to systemic disease in infected animals and are associated with high morbidity and mortality. A typical iridovirus has icosahedral symmetry and measures 130–300 nm in diameter. Characterization of iridoviruses has been hindered by the difficulty in isolating and propagating them in tissue cultures.

The most dramatic change in all affected fish is the presence of basophilic, hypertrophied cells, often in large numbers, in various organs. These cells, with a pale foamy or intensely basophilic granular appearance, were often observed in the splenic parenchyma and capsule, in the renal glomerulus and interstitium, and in the intestinal lamina propria. Hypertrophied cells are also observed in the choroid plexus of the eye, pancreatic interstitium, the connective tissue surrounding ovarian follicles, and in connective tissues throughout the body. They were usually observed in smaller numbers in the liver, heart, gills and brain. Dark staining crescent-shaped cells are frequently observed, forming a "cap" over the hypertrophied cells. Degenerative and necrotic changes are often seen in association with cytomegaly. In some fish, splenic changes consists presence of typical hypertrophied cells accompanied by spongiosis and fibrinoid necrosis of ellipsoids and haemorrhage, with consequent destruction of the entire splenic architecture. Loss of renal glomeruli and interstitium is observed, but the renal tubules are usually unaffected.

Lymphocystis:

Lymphocystis disease (LCD), one of the common infectious diseases affecting marine fish cultures, was discovered in 1874. Distribution has been reported worldwide such as Spain, Korea, Japan and China. The causative agent of LCD is lymphocystis disease virus (LCDV) which is a large virus in the genus Lymphocystis virus of the family Iridoviridae. LCDV is an icosahedral symmetry virus, approximately 200-300 nm in diameter, and contains single linear double stranded DNA. LCD is characterized by the external appearance of nodules, either singly or in groups, on skin, fins, or tail of the affected fish. Although, LCD is not a fatal disease, the external appearance might cause a significant economic loss. The principle mode of transmission of LCD is horizontally by direct contact and external trauma. Other factors such as water contamination and stress condition caused by high stocking density, nutrition deficiencies, low dissolved oxygen, suboptimal water quality, or human manipulation may increase the appearance of LCD symptoms. A recent study reported that *Artemia* sp. might act as a reservoir host of this disease (Cano et al., 2009).

The affected fish reveals multifocal to diffuse white, firm, papilloma-like nodulesscattered on the skin, fins, eyes and mouth.

The diameters of nodules varies in size, approximately 1-2 mm. Microscopically, many clusters of lymphocystis cells are observed in the connective tissues beneath the epidermis on fins, inner layer of operculum, and gills. Histopathologically lymphocystis disease is characterized by cytomegaly of dermal fibroblasts and only rarely is there any systemic involvement. Numerous hypertrophied cells with basophilic intra-cytoplasmic inclusion bodies are seen in connective tissues of the dermis and between the scales. The lymphocystis cells are also detectable in skeletal muscle, gill lamellae and visceral organs including spleen, head and trunk kidney. The lymphocystis-granulomatous also appear in parenchyma of the spleen and kidney.

Lymphocystis can be diagnosed by several immunological assays like indirect immunofluorescence assay, flow Cytometry and immunodot. There are no vaccines against LCDV which makes necessary the development of tools to control epizootics caused by this virus. It is especially important to detect LCDV before the appearance of tumor-like lesions.

Diseases caused by bacteria

Fish diseases of bacterial origin have been one of the most important factors of economic loss since the beginning of marine fish culture. Regarding the infectious diseases caused by bacteria in marine fish, although pathogenic species have been described in the majority of the existing taxonomic groups, only relatively small number are responsible for important economic losses in cultured fish. Clinical signs (external and internal) caused by each pathogen are dependent on the host species, age and stage of the disease.

Vibriosis:

Vibriosis is a disease characterized by haemorrhagic septicaemia and caused by various species of *Vibrio*. It occurs in cultured and wild marine fish in salt or brackish water, particularly in shallow waters during late summer. Within the *Vibrionaceae,* the species causing the most economically serious diseases in marine culture are *Vibrio anguillarum*, *V. alginolyticus*, *V. ordalii*, *V. salmonicida* and *V. vulnificus*.

Vibriosis has become the economically most important disease in marine fish culture, affecting a large number of species. It is also an important disease of many wild fish populations. Fish affected by vibriosis show typical signs of a generalized septicaemia with haemorrhage on the base of fins, ulcers on body surface (Fig.1), swelling and boils, exophthalmia and corneal opacity. Moribund fish are frequently anorexic with pale gills which reflects a severe anaemia. Oedematous lesions, predominantly centered on the hypodermis, are often observed. On the top of the boils, the epidermis is destroyed and the skin is greyish white. Around the boil the skin is haemorrhaged. Internally there are haemorrhage in liver and intestine, and there is fluid in the heart lumen. Histologically the muscle fibres are widely separated.

Vibrio species responsible for vibriosis can be presumptively diagnosed on basis of standard biochemical tests. However, serological confirmation employing serotype-specific polyclonal antisera is necessary. Although commercial diagnostic kits based on slide agglutination or ELISA have been developed for a fast diagnosis of vibriosis, they do not allow the distinction of serotypes and therefore are not useful for epidemiological purposes. Though DNA probe-based detection protocols are available, they are not specific and/or sensitive enough to be used in the diagnosis of vibriosis in the field.

Fig.1. Ulceration in Vibriosis in Asian seabass

Streptococcal infection:

Streptococcal infection of fish is considered as re-emerging disease affecting a variety of wild and cultured fish throughout the world. Five different species are considered to be of significance as fish pathogens: *Lactococcus garvieae*, *L. piscium*, *Streptococcus iniae*, *S. agalactiae*, *S. parauberis* and *Vagococcus salmoninarum*. Therefore, streptococcosis of fish should be regarded as a complex of similar diseases caused by different genera and species capable of inducing a central nervous damage characterised by suppurative exophthalmia and meningoencephalitis. Warm water streptococcosis typically involves *L. garvieae*, *S. iniae*, *S. agalactiae* and *S. parauberis*. It is important to report that the etiological agents of warm water streptococcosis are considered also as potential zoonotic agents capable to cause disease in humans. Among these fish streptococci, *L. garvieae*, *S. iniae* and *S. parauberis* can be regarded as the main etiological agents causing diseases in marine aquaculture. *S. iniae* was isolated from marine fish including European and Asian seabass in Australia. Streptococcus infection can be diagnosed by biochemical tests.

Gaffkemia (Red tail disease):

Gaffkemia is one of the most important and well described infectious diseases of lobsters, primarily as a disease of impounded lobsters. The bacterium and resulting disease were first described in a holding facility in Maine. The causative agent, *Aerococcus viridans (var.) homari* is a free living, gram positive, tetrad-forming coccus (Fig.2), leading to systemic disease in homarid lobsters. The bacterium cannot cross intact lobster integument and does not survive gastric acids; consequently invasion of the host occurs via wounds or punctures of the cuticle. The organism survives well in the benthic environment and in holding facilities, as a free living organism outside the host. Development of the disease is temperature dependent, with death occurring in 180 days at 3 ^{O}C and 2 days at 20 ^{O}C. Stressors which predispose the lobsters to disease include strain of bacterium, handling, temperature changes, and trauma. Homarid lobsters are most susceptible to infection and disease. Clinically, there are no obvious signs in infected lobsters, other than weakness or lethargy and a spread-eagle posture which are apparent in later stages of the disease, and which are not pathognomonic for gaffkemia. Lobsters rapidly become anorexic after infection. The bacteria multiply rapidly in the hepatopancreas and then in the heart. The pathogen multiplies in the hemolymph much later in the infection. Pink discoloration of the ventral abdomen and hemolymph will develop. Death results from metabolic incapacity resulting from dysfunction of the hepatopancreas. Additionally, the clotting mechanism is impaired, and it is associated with marked hemocytopenia. Infected lobsters can become exsanguinated, especially in end-stage disease.

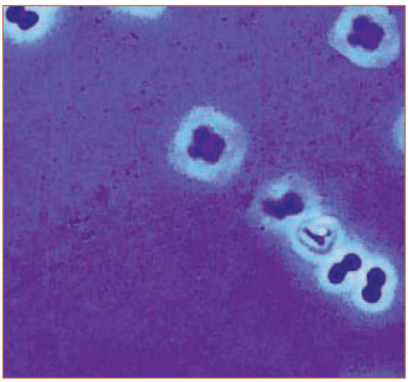


Fig.2. Tetrad forming *Aerococcus viridans*

The disease can be treated with antibiotics after a antibiotic sensitivity test considering other factors. Oxytetracyclin is an antibiotic commonly used in aquaculture. Major challenges associated with use of oxytetracycline in the marine environment include persistence in sediments, bioaccumulation by bivalves or other crustaceans, and development of bacterial resistance. An alternative to chemotherapy is utilization of immunogens derived from virulent strains of *A. viridans*. Low levels of protection were induced with formalin-killed bacteria, and high levels were induced with a vancomycin/live bacteria combination in laboratory experiments.

Diseases caused by parasites

Nematodiasis:

Fish are either intermediate or final host for nematode parasites. About 650 species of nematodes parasitize fish as adults and many others use fish as intermediate hosts. While nematodes are common in wild fish, neither adult nor larval nematodes are usually a problem in most cultured fish because of the absence of other hosts in the life cycle. However, pond raised fish or those fed live and wild caught fish/ arthropods (trash fish) can become infested. Marine fish are usually infected by members of the Ascaridoidoiea (*Contracecum*, *Pseuudoterranova*, *Anisakis*), Camallanoidea (*Camallanus*, *Culullanus*), Dracunculoidea (*Philonema*, *Philometra*), and Spiruroidea (*Metabronema*, *Ascarophis*). Most of the camallanoids, dracunculoids, and spiruroids have two host life cycles where fish are the final host. Adult worms are almost always found in the digestive tract, where some (Capillaria) can cause chronic wasting if present in high numbers. Some adult nematodes inhabit the peritoneal cavity, gonads or swim bladder.

Faecal examination can be used to identify eggs in the digestive tract. Worms are easily identifies as adult or larval nematodes by using wet mounts or tissue sections. The main criteria used to identify species are size, fine structure of the head and tail, position of then excretory pore, and structure of the transitional area between the esophagus and intestine. Anthelmentics can control adult nematodes. Fenbendazole, levamisol and piperazine have been used with some success.

Disease caused by sea lice:

Sea lice is the term used to describe several species of ectoparasitic copepods of the genera *Lepeophtheirus* and *Caligus* that parasitize cultured fish and may cause diseases with damage to the epidermis and in severe cases death through osmoregulatory failure or secondary infections. *Lepeophtheirus salmonis* and *Caligus elongatus* have economic impact on farmed fishes in many parts of the world.; other caligids pathogenic to cultured or wild fish are *C. patulus*,*C. orientalis*, *C. epidemicus*, and *Pseudocaligus apodus*. Formaldehyde, malathion and natural compounds show either poor efficacy or unsuitable therapeutic margins. Pyrethroids are at present the most used therapeutic against sea lice in Norway. Diflubenzuron and teflubenzuron added to feed are also used in significant amounts. Carbaryl and diflubenzuron are efficacious but the compounds make them unsuitable due to undesirable environmental toxicological characteristics. Despite these problems, chemotherapy remains an important component of control strategies. As appropriate sea lice control strategies appear to be prevention of cross-contamination by avoiding overlaps of salmon generations in cultures or biological control by stocking locally obtained wrasse (cleaner-fish of the family Labriadae) into cages when salmon first go into the sea cages. Development of vaccines against sea lice is also a perspective area of control of these parasites.

Cryptocaryon disease

Cryptocaryon disease in the fish, also called the Marine white spot, is caused by the ciliated protozoan parasite. This disease spreads if the quality of water is not good. If the pH level of the water is reduced then, it might lead to the Cryptocaryon outbreak.

One of the signs of Cryptocaryon infection is lethargy in the fish and it might also rub itself against all the objects found in the aquarium. This type of behaviour is obvious if there is Cryptocaryon infection. We can notice white spots (2 mm) on the body and fins. The white spot first appears in the pectoral fins and then spread to the other parts. The gill is one part that has many of these organisms. The white spots spread to the entire body and it might also lead to hemorrhage later. During the advanced stages of this infection the eyes of the fishes would be clouded which might cause blindness and lead to other diseases like fungal infections which adds to the already existing problem.

Since Cryptocaryon is a parasite it will need a host for its development. During the initial stage the Cryptocaryon will be free swimming and it will try to find a host for its development.

Once it finds a host it will penetrate the skin of the host i.e. the fish. The free swimming stage of Cryptocaryon is called tomite and the parasitic stage is called trophont. It feeds on the tissues of the fish and grows. The size of the parasite double every single day and it is visible to the naked eye after two days. After about 4 days a cyst is formed which will give rise to another 100 to 300 tomites. It is only about 5 to 10 percent of the tomites succeeds in finding another host for its development. Every week you can find the population of Cryptocaryon increases ten times. Due to this rapid increase the effect of the infection will also increase dramatically.

Acting at the earlier stage of detection of this parasite will be helpful in eradicating this infection altogether. Dangerous levels of the infections are reached within 12 days of the infection. So it is better to start the treatment at the earlier stage itself to remove those infections.

In the treatment of Cryptocaryon, copper based mediations are useful. The dosage of copper used should be appropriate so that it does not affect the fish. The treatment using copper should be done for several times daily. Even after removal of the parasite the treatment has to be continued for about a week so that you remove all the latent tomonts too. This is to ensure that the fish is not affected again. Fresh water bath will be tolerated by the fish for about half an hour only. However we have to maintain the pH of this water too.

Source:

Alicia E. Toranzo,A.E., Magarinos, B., Romalde, J.L. (2005) A review of the main bacterial fish diseases in mariculture systems. Aquaculture, 246: 37–61.

Muroga, K. (2001) Viral and bacterial diseases of marine fish and shellfish in Japanese hatcheries. Aquaculture, 202: 23–44.

Huguenin, E. (1997) The design, operations and economics of cage culture systems. Aquacultural Engineering 16: 167-203.

Xiao-Wen Wang, X-W., Ao, J.Q., Li, Q.G., Chen, X.H. (2006) Quantitative detection of a marine fish iridovirus isolated from large yellow croaker, *Pseudosciaena crocea*, using a molecular beacon. Journal of Virological Methods 133: 76–81.

Gibson-Kueh, S., P. Netto, P., Ngoh-Lim, G.H., Chang, S.F., Ho,L.L.,Qin, Q.W., Chua, F.H.C,a,. Ng, M.L., Ferguson, H.W. (2003) The Pathology of Systemic Iridoviral Disease in Fish. J. Comp. Path. 129: 111–119.

Cawthorn, R.J. (2011) Diseases of American lobsters (Homarus americanus): A review. J. Invertebr. Pathol 106 (2011) 71–78.

Cano, I., Alonso, M.C, Garcia-Rosado, E., Rodriguez Saint-Jean, S., Castro, D., Borrego, J.J. (2006) Detection of lymphocystis disease virus (LCDV) in asymptomatic cultured gilt-head seabream (*Sparus aurata*, L.) using an immunoblot technique. Veterinary Microbiology 113: 137–141.

Pirarat, N., Pratakpiriya,W., Jongnimitpaiboon, K., Sajjawiriyakul, K., Rodkhum, C., Chansue, N. (2011) Lymphocystis disease in cultured false clown anemonefish (*Amphiprion ocellaris*) *Aquaculture.* doi: 10.1016/j.aquaculture.2011.01.014

XV

CAGE FARMING OF FINFISHES IN ESTUARIES

A.P. Dineshbabu

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

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

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

- Shrimp (*Penaeidae*) in South America and South-East Asia;
- Milkfish (*Chanos chanos*) in the Philippines, Sri Lanka, Pacific Islands and Indonesia;
- Eels (*Anguilla* spp.) in Asia, Europe, Australia and North America, mainly in China, Japan, Taiwan Province of China, The Netherlands, Denmark and Italy;

- Yellowtails (*Seriola* spp.), mainly in Japan, Taiwan Province of China, Viet Nam, Hong Kong, Italy, Spain, Australia and New Zealand;
- Tunas (*Thunnus* spp.) in Australia, Japan, Canada, Spain, Mexico, Croatia, Italy, Malta, Morocco and Turkey
- Groupers (*Epinephelus* spp.), which is now widespread in Indonesia, Malaysia,Philippines, Taiwan Province of China, Thailand, Hong Kong, People's Republic of China, and Viet Nam, and in other parts of the tropics, for example in southeasternUSA and Caribbean. Grouper culture is also on-going in India, Sri Lanka, Saudi Arabia, Republic of Korea and Australia.

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

Cage based aquaculture is getting adopted rapidly in many parts of the country. When it is being practiced in high intensity some of the scientific factors has to be taken care.

The number of cages should be according to the carrying capacity of the water body and the number of cages exceeds its carrying capacity, it will effect fish growth and survival.

There is a strong need for better data on the biology and fisheries of the species. Accumulation of uneaten feed and fish excreta under the cage can become an environmental problem, but this can be avoided by selecting a site with good water exchange to install the cage. Capture-based aquaculture provides significant positive returns in areas with depressed and marginal economies, and an alternative livelihood for coastal communities. However, the difficulties of marketing fresh fish and supplying markets that demand live fish (e.g. groupers), and the need to expand markets limit its potential. Skill gaps are evident in the sector, including specific knowledge on economics and management, the suitability of individual (new) species for culture, information on their biology and dietary requirements, and marketing. Capture-based aquaculture is labour intensive in its farming and processing operations, and can contribute to poverty alleviation in developing countries.

Legal and security issues

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

Food safety issues

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

Demonstration experiments by Central Marine Fisheries Research Institute

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

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

Seed survey for cultivable finfishes

Detailed survey of the estuaries and coastal waters were done from Mangalore Research centre to study the availability of fish seed along the coast. The gears operated during the monsoon season were hand trawls, cast nets and gillnets. It was observed that during the monsoon season lots of juveniles of economically important species are also caught along with the market size fishes. *Etroplus* and *Gerres* juveniles are caught in large quantity in Netravathi and Gangoli estuary. Usually these are discarded and efforts are made to collect these fishes and grow them in the cages as a part of CBA programme. Cages of netlon material was designed with inner nylon net to grow the juveniles discarded in fishery. Specially designed netlon cages fabricated locally with the participation of the fishermen were used for farming. The dimensions of the cages 2.5x2.5 m with a depth of 1.5 m Provisons were made to withstand water level changes during high tide and low tide.

Demonstration experiments in Karnataka

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

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

Husbandry:

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

Production and Harvest:

Altogether five cages were installed and three of the cages were partially harvested as and when the fishes were grown to marketable size, to meet day to day needs of the fishermen. Two cages were spared for final harvest to demonstrate total production possible from these cages.

Theses cages were harvested during July, 2011, when the mechanized fishing is banned. The Lutjanus sps attained an average weight of 755 ± 415 g ranging from 105 to 1,914 g. The pearlspot ranged from 37-222 g (96 ± 35g). About 255 numbers of seabass of average weight 1819 ± 540 g was harvested. The total production from the cages including seabass, red snapper and pearlspot was around ~400 kg realizing a farm gate price of ~ Rs 75,000 per cage.

Table 1.Harvest details (2 cages)

Species	Mean size	Mean weight	Numbers	Harvest wt.(kg)	Amount (Rs)
Red snapper	350 ± 70 mm (190-500 mm)	755 ± 415g (105-1914g)	105	150	27,000
Pearlspot	158 ± 17 mm (115-205 mm)	96 ± 35g (37-222g)	988	150	22,500
Seabass	510 ± 50 mm (310-620 mm)	1819 ± 540g (262-3049g)	255	450	99,000
		Total	1348	750	1,48,500
Production per cage				**375**	**74,250**

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

HANDBOOK ON

OPEN SEA CAGE CULTURE

Cage culture of fin fish and shell fish is in the developmental stages in India. Experimental culture of seabass, mullets and spiny lobster was carried out at various centres of Central Marine Fisheries Research Institute with varying degree of success. Although the results obtained at all the places were promising, more works are needed to perfect stocking density, feeding, cage fabrication and cage mooring. The results obtained at Karwar were significantly better because of the favourable environmental conditions and the water quality.

Central Marine Fisheries Research Institute
(Indian Council of Agricultural Research)
Karwar Research Centre
Uttar Kannada - 581 301, Karnataka