Training Manual

Training Program on Brackishwater Farming

16-22, December
2015

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ICAR

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Topics & Authors

1. Efforts for fisheries enhancement

A. P. Dineshbabu

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

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

Production Enhancement: Mariculture, hatchery technology, sea ranching.

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

Mariculture:

Among these three measures product enhancement methods, mariculture provide direct results of production enhancement in quantifiable terms and rest are the indirect means to enhance the production. Mariculture is identified as a prime industry to tap the enormous sources of and very good potential for India. According to Food and Agriculture Organization (FAO), the projected global aquaculture production in 1995 was 19.29 million tonnes and it is expected to increase to 26.90 million tonnes by 2000 AD. Currently in India, there is a growing interest in aquaculture in order to meet the protein demand of the fast growing population. Marine finfish culture has been an established practice is now undergoing rapid development. Information on the relative abundance of cultivable fin fish seed together with physico-chemical conditions of the environment is a essential prerequisite for aquaculture. At present, in marine finfish culture practices only a part of seed requirement is met from the hatchery and most of the culture practices in India are supported by the supply of seed collected from the natural environment. The technology for the mass production of marine finfish seed by induced breeding are being carried out in various Institutions which started providing very promising results which will lead to adoption of finfish culture in India in large scale. India have developed technologies for mass scale seed production of seabass, cobia, pompano, prawns, crabs, Ornamental marine fishes etc. India is having a long coast line of 8129 Km with many estuaries, creeks, coastal lagoons, mudflat and swamps .

Mariculture development in India:

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

(i) Pond Culture

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

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

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

(ii) Pen Culture

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

(iii) Cage culture

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

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

Marine cages:

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

(iii) Molluscan farming:

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

Present status of mariculture in Karnataka

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

CMFRI has developed adaptable technologies in bivalve culture in Karnataka. Green mussel (*Perna viridis*) and edible oyster (*Crassostrea madrasensis*) farming practice holds good potential in coastal and estuarine areas of Karnataka. Breakthrough in extraction of GME will increase the demand for bulk quantities and for meeting the demands of the market

Standardization of clam farming protocols are being carried out for advising on ideal relaying densities in suitable substratum this may boost the sustainable production of bivalves along Karnataka coast.

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

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

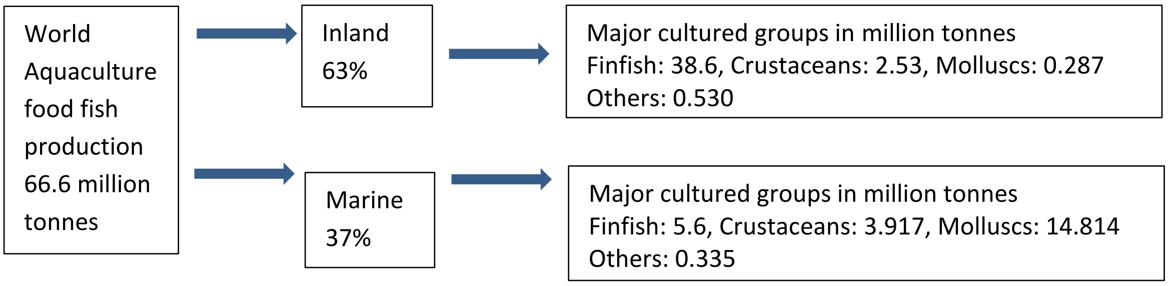
2. An overview of coastal aquaculture and mariculture in India

Prathibha Rohit

Fisheries, both capture and culture plays a significant and multifaceted role in the overall development of any nation, in terms of providing livelihood opportunities, food security. Globally the fisheries sector is not just a vital source of protein rich food contributing to the food security as well as to the overall health of the consumers but also provides employment and supports livelihoods of millions. In addition fish and fishery products continue to be the most traded food commodity earning a huge revenue for the country. The role of fisheries becomes all the more important for developing countries, including India for poverty alleviation, food security, income generation and overall long term sustainable development and prosperity of the coastal population. Recognizing the important role played, keen interest has been evinced world over in developing this sector. The global fish production has grown steadily over the years form 140.7 million tonnes in 2007 to 158.0 million tonnes in 2012. Similarly, the world per capita fish consumption too has increased from 17.6 kg to 19.2 kg in 2012. The fish production from the capture sector too has registered an increase during the past years but the rate of increase has been marginal the production being 91.3 million tonnes in 2012, marginal increase of 0.5% only as compared to 90.8 million tonnes in 2007 and less by 2.5% as compared to a production of 93.7 million tonnes during 2012. Aquaculture on the other hand has registered a steady and impressive increase in production during the past few years. The aquaculture production increased form 49.9 million tonnes in 2007 to 66.6 million tonnes in 2012. This remarkable increase in production through aquaculture led to it being recognized as an important and highly productive agricultural activity resulting in the concept now accepted as "blue revolution". Aquaculture refers to all forms of active culturing of aquatic animals and plants, occurring in marine, brackish or fresh waters. Mariculture on the other hand refers to rearing of the aquatic organisms under controlled or semi-controlled conditions in coastal and offshore waters. The mariculture environment thus includes sea, backwaters, estuaries and coastal lagoons. Marine organisms include both migratory species to estuaries/backwaters and non-migratory species confined only to the sea. Mariculture activities can be carried out both in coastal nearshore area and in the open seas. Most of these species are capable of tolerating variations in the environment.

The world aquaculture production during 2012 valued at US$ 144.4 billion comprised of 66.6 million tonnes of food fishes values ta US $ 137.7 billion and 23.8 million tonnes of algae values at US$ 6.4 billion. Further an additional 22,400 tonnes of non-food products (pearls, shells etc.,) valued at 222.4 million also contributed to the aquaculture production.

The total cultured food fish production estimated at 96.6 million tonnes (70.5 million tonnes food fishes and 26.1 Million tonnes of algae) during 2013 has registered an increase of 5.8% as compared to 2012. The global cultured food food fish production has more than doubled during 2013 as compared to a production of 32.4 million tonnes during 2000. Interestingly, countries in the Asian continent are the major contributors to the global aquaculture production accounting for more than 88% with China's production comprising 59% of the total production. The aquaculture production is more from the fresh water systems with the marine system forming only 37% of the total production in 2012. A study by FAO has indicated that India, Bangladesh, Egypt, Myanmar and Brazil rely mainly on Inland production and mariculture production of finfish remains largely untapped. While in Norway, aquaculture is exclusively on finfish mariculture particularly on marine cage culture of Atlantic salmon, in countries like the Republic of Korea, Japan and Chile aquaculture production is equally contributed by fresh water and marine culture systems.



Fishes (salmon, trout's and groupers) crustaceans (shrimps), molluscs (bivalves-mussels and oysters) are the major groups farmed/ cultured in marine/brackish water environments.

Indian Scenario

Fishing, an age old practice in India has grown in leaps and bounds during the last few decades and with an average annual growth rate of over 4.5 percent is now second in global fish production, only next to China. The fish production has registered an eleven fold increase from 0.75 million tonnes in the fifties to 9.6 million tonnes during 2012-13. Over 14.5 million people are dependent on fisheries activities for their livelihood and in addition to supplementing to the food security of the countrymen, earns foreign exchange to the tune of US$ 3.51 billion (2012–13) from export of fish and fisheries products. As observed on a global basis, the rate of increase in total fish production has been more through aquaculture and more so through freshwater aquaculture. Aquaculture in India has evolved as a viable commercial farming practice from the level of traditionally backyard activity over last three decades with considerable diversification in terms of species and systems, and has been showing an impressive annual growth rate of 6-7 percent. Presently, India ranks second in the world in total fish production with an annual fish production of about 9.06 million metric tonnes.

Aquaculture in India has a long history, with references to fish culture in Kautilya's Arthashastra as early as 321–300 B.C. and King Someswara's Manasoltara during 1127 A.D. The traditional practice of fish culture in small ponds in eastern India is known to have existed for hundreds of years. With success in controlled breeding of carp in bundhs (tanks or impoundments where riverine conditions are simulated) significant advances were made in the State of West Bengal in the early nineteenth century. Fish culture received notable attention in the state of Tamil Nadu (formerly Madras) as early as 1911, and subsequently, states such as Bengal, Punjab, Uttar Pradesh, Baroda, Mysore and Hyderabad initiated fish culture through the establishment of Fisheries Departments and support to fishers and farmers for expansion of the sector.

India's aquaculture production basically can be classified into freshwater, brackish water and marine production. Carp culture forms the backbone to freshwater aquaculture practice in India. The technological breakthrough in induced breeding of carps through hypophysation in 1957 revolutionized freshwater aquaculture of the country and elevated the existing homestead type of farming activities to a more stable and scientific form of fish farming. Over the years, research on species diversification has resulted in culture of murrel, catfish and freshwater shrimps and clams in suitable freshwater bodies.

Brackish water aquaculture in India has a long history of traditional practice in bheries of West Bengal and pokkali fields of Kerala. In the traditional system of culture, tidal water is impounded in the inter-tidal mudflats by raising bunds. There is no manuring and feeding. Thus, with no additional input, except that of trapping the naturally bred juvenile fish and shrimp seed, these systems have been sustaining production levels between 500–750 kg/ha/year with shrimp contributing 20–25 percent of the total production. The importance and role of shrimp farming in India’s economy was realized in the early seventies, and the first experimental brackish water fish farm was established in Kakdweep, West Bengal. This was followed by an All-India Coordinated Research Project on Brackish water Fish Farming in 1975 by the ICAR with centres in West Bengal, Odisha, Andhra Pradesh, Tamilnadu, Kerala and Goa.

Brackish water farming with scientific inputs was initiated in the country during early 80’s. Shrimp seed production studies were initiated in Narakkal, near Kochi, in Kerala. Large-scale development of shrimp farming was initiated after 1988–1989 with the establishment of the commercial shrimp hatcheries Andhra Pradesh Shrimp Seed Production Supply and Research Centre (TASPARC) based in Andhra Pradesh and Orissa Shrimp Seed Production Supply and Research Centre (OSPARC) based in Orissa by the Marine Products Export

Development Authority (MPEDA). These hatcheries provided assistance and paved the way for the establishment of a number of private hatcheries. The semi-intensive farming technology demonstrated by MPEDA achieved a production level of 4–6 tonnes/ha. In addition, a number of development schemes were initiated by the Ministry of Agriculture of the Government of India; including setting up of Brackish water Fish Farmers Development Agencies (BFDA) in the maritime states for the development of shrimp farming.

The technology of hatchery production of shrimp seed involving broodstock development, induced maturation and spawning, larval-rearing and post-larval (nursery) rearing has been standardized. At present about 226 shrimp hatcheries are operational with a total production capacity of 10.5 billion PL20/year. Shrimp is the single commodity that contributes almost the total production of the sector. The production levels of shrimp recorded marked increase from 28,000 tonnes in 1988 89 to 127,170 tonnes in 2001-2002 and to 144 346 tonnes in 2006-2007. Presently the production is hovering around 100 000 tonnes. The black tiger prawn, *Penaeus monodon*, is the most abundantly cultivated prawn species followed by other shrimp species such *as P. indicus*, *P. penicillatus*, *P. merguiensis*, *P.semisulcatus* and *Metapenaeus* sp. Semi-intensive culture practices mainly with black tiger prawn have demonstrated production levels of 4-6 t/ ha in a crop of 4-5 months. The high return coupled with credit facilities from commercial banks and subsidies from MPEDA have helped in the development of shrimp farming in the country to a multi-billion dollar industrial sector. Despite the occurrence of disease in the shrimp culture system since 1994-1995 the industry has learnt to live with certain modifications in pond management.

The country possesses huge brackishwater resources of over 1.2 million hectares suitable for farming and presently (2001-02) only 13% of the potential water area available i.e. 157,400 ha is utilized. More than 90 percent of the shrimp farmers in India are small land holders owning less than 2 hectares. Among the coastal states, Andhra Pradesh is the largest producer of shrimp production in the country.

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

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

The earliest attempt at mariculture in India was made at the Mandapam centre of CMFRI in 1958–1959 with the culture of milkfish (*Chanos chanos*). Over the last three decades, CMFRI has developed various technologies for a number of species including bivalves such as oysters, mussels and clams among sedentary species, as well as for shrimps and finfish. Culture practices for seaweeds too was standardized. Mussel culture was initiated in early 1970s and over the years has resulted in the development of a range of practices for mussel. The production of mussels (green and brown) rose from an insignificant quantity in 1997 to 1,250 tonnes in 2002 from over 250 mussel farms established in the estuaries of Kerala. The near shore coastal waters, creeks and backwaters in all the maritime states are suitable for mariculture adopting different culture practices. The creeks and backwater area have been extensively used for shrimp culture. Some area has also taken up crab fattening. The backwaters too have been used for culture practices and culture of mussels in a large scale is being practiced in Kerala for several years. Mussel culture in the estuarine waters has been taken up in Karnataka, Goa and Maharashtra.

Mussels, oysters and seaweeds have been the main component of mariculture in India with additional culture of mudcrabs and lobsters in small water bodies till 2007. Besides these, ornamental fish culture and seaweed farming, are slowly gaining importance in the aquaculture scenario in the last few years as alternative livelihood supporting sectors as small-scale activities.

Among culture of non-food items, CMFRI initiated a pearl culture programme as early as in 1972 and has successfully developed the technology for pearl production in Indian pearl oysters, success in controlled breeding and spat production of the Japanese pearl oyster (*Pinctada fucata*) in 1981.

The initiation of cage culture in open sea opened up new vistas for mariculture in India. Mariculture of *Lethrinids, Epinephelus* spp., *Mugil cephalus*, *Chanos chanos*, and *Etroplus suratensis* has been tried, either in monoculture or in the integrated systems. Pen and cage culture of finfish has been tried but, not on a commercial semi-intensive or intensive farming scale. However since the establishment of cages in coastal and open waters for finfish production from mariculture has increased several folds. During 2006–2009, the Central Marine Fisheries Research Institute (CMFRI), Kochi, has made commendable progress in marine cage culture. In 2007, a cage of 3 m diameter and 4 m depth was floated in Vizhinjam Bay and stocked with juveniles of *Caranx sexfasciatus.* This was followed by the establishment of sturdy open-sea cages protected by outer predator nets and special shock absorber to withstand and absorb pressure. This open sea cage was moored at a depth of 11 m about 300 m from beach at Visakhapatnam in Andhra Pradesh State and stocked with *Lates calcarifer*.

Cage culture of barramundi has become very popular due it fast growth rate, good market value and due to availability of its seed from hatchery as well as from the wild. Initial trials were made with seabass but now half a dozen species including snappers, cobia, cichlids, mullets and carangids are cultured in cages. Success has been achieved in the broodstock development and spawning of greasy grouper, *Epinephelus tauvina, Lates calcarifer, Trachinotus blochii* and *M.cephalus*.

The potential sites for open sea mariculture have been identified by CMFRI at Palk Bay and Gulf of Mannar in Tamil Nadu, Lawsons Bay near Visakhapatnam in Andhra Pradesh, Balasore in Odisha, Marine bay's in Karwar, Near shore areas in Goa and off Ratnagiri in Maharashtra. The open seas around the Andaman & Nicobar Islands and Lakshadweep too have high potential to take up mariculture activities.

Simultaneously, Cage culture of fin fishes in estuarine waters too has become very popular and has is being taken up as a family avocation in several places. Euryhaline fishes (snappers, barramundi, carangids, cichlids, etc.) seed that are procured form the hatchery and from the wild are reared in indigenous built cages. The activity is more on a homestead basis established close to individual homes, where family members including women and youth are involved in farming activity. These custom built indigenous cages can be placed close to the home of fish farmers living adjacent to the back waters, creeks and open bays; can be easily handled by individual families and a variety of species locally available can be reared. Such estuarine cages have become very popular and several cages have been built and installed in the estuaries of Karnataka and Kerala. The mariculture activity in the estuaries provides year round occupation, alternate livelihood and a source of income for the families engaged in this activity.

3. Brackish water finfish and their culture potential

Rajesh K. M.

Species selection needs to be a well thought –out decision. For any commercial aquaculture there has to be a market for the fish. The fish species should be suited to the local climate extremes and /or should be native to the area. It is essential that established and reliable rearing techniques are known and readily accessible for the intended species or can be obtained by professional consulting and advice. The natural life cycle of the intended fish should be considered so that its basic biological needs can be met e.g. some species can tolerate varying degrees of salinity; some tolerate crowding; some wean onto artificial diets more easily. Here are some criteria which can be followed for selecting species for aquaculture.

Criteria for selection of species for culture

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

Desirable biological characteristics of aquaculture organisms

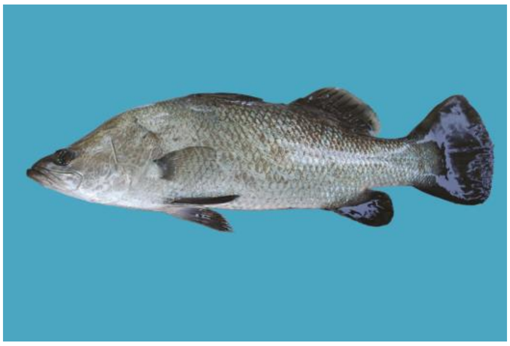
a) Fast growth and higher yields in different types of culture;
b) Efficient conversion of food,
c) Tolerance limits of salinity, temperature and oxygen tension;
d) Ready acceptance of compounded feeds,
e) Good table quality,
f) Disease resistance breeding habits; feeding habits and geographic distribution,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

➢

➢ Brackish water finfish culture is limited to seabass, snappers, groupers and milkfish at present. However, mullets, pearl spots, tilapia, rabbitfish, sea breams and some carangid fishes are reared in some part of the world even though they have very good culture potential.

Seabass

Lates calcarifer, known as seabass in Asia and barramundi in Australia, is a large, euryhaline member of the family Centropomidae that is widely distributed in the Indo-West Pacific region from the Arabian Gulf to China, Taiwan Province of China, Papua New Guinea and northern Australia. Aquaculture of this species commenced in the 1970s in Thailand, and rapidly spread throughout much of Southeast Asia. It is a relatively hardy species that tolerates crowding and has wide physiological tolerances. The high fecundity of female fish provides plenty of material for hatchery production of seed. Hatchery production of seed is relatively simple. It feed well on pelleted diets, and juveniles are easy to wean to pellets. It grows rapidly, reaching a harvestable size (350 g – 3 kg) in six months to two years.



Today barramundi is farmed throughout most of its range, with most production in Southeast Asia, generally from small coastal cage farms. Often these farms will culture a mixture of species, including barramundi, groupers (Family Serranidae, Subfamily Epinephelinae) and snappers (Family Lutjanidae).

Snappers

Snappers belong to the family Lutjanidae. Lutjanidae are next in importance after seabass for brackish water aquaculture. There are 17 genera and 103 species in this family of which 65 species belong to genera *Lutjanus*. Snappers are mainly confined to tropical and subtropical waters. The important species for culture includes the mangrove red snapper (*Lutjanus argentimaculatus*), John's snapper (*L. johni*), yellow streaked snapper (*L. lemniscatus*) and the Crimson snapper (*L. erythropterus*).

The mangrove red snapper is among the high value marine fishes with great potential for export. Snappers are opportunistic carnivores but can be trained to feed on formulated diets as well. Breeding technique is standardised for mangrove red snapper by SEAFDEC Philippines. In India the farmers are still depending on wild caught seeds for the culture of red snappers.

Groupers

Groupers belong to the family Serranidae, which comprise 14 genera and 449 species. There are 16 major grouper species that are cultured; the dominant species vary somewhat regionally. The most consistently abundant species that are captured for culture purposes and also reared in hatcheries are *Epinephelus coioides and E. malabaricus*.

Other important species are *E. bleekeri, E. akaara, E. awoara and E. areolatus. E. amblycephalus, E. fuscoguttatus, E. lanceolatus, E. sexfasciatus, E. trimaculatus, E. quoyanus, E. bruneus, Cromileptes altivelis, Plectropomus leopardus and P. maculatus* are cultured in small amounts.

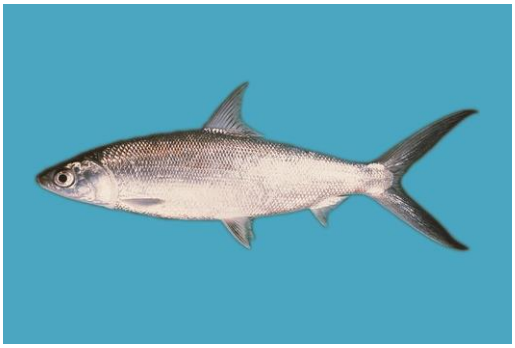
Sea breams

The Seabreams belong to the Family Sparidae. In coastal lagoons and brackish water ponds, sea breams are generally reared with mullet and seabass. Among the various species, the black bream *Acanthopagrus berda*, the yellow bream *A. latus* and the gold lined bream *Rhabdosargus sarba* are important.

These fishes are bottom-living in habit found on rough and muddy sand grounds in coastal waters, estuaries, bays etc., and are cultivable in such localities. They feed on a wide variety of benthic organisms such as molluscs, crustaceans, echinoderms, etc., and grow to 45-65 cm in length with the common sizes between 40-55 cm.

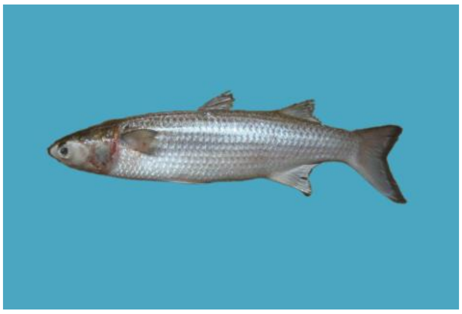
Milkfish

The Milkfish (Chanas Chanas) is one of the most ideal finfishes for farming in coastal areas. lt is commercially important and has many qualities essential for culture. These are: fast growth rate particularly in the first year of its, life, wide range of tolerance to temperature, oxygen and salt contents of the water, feeding mostly on algal growth at the bottom of culture ponds and other salt water bodies and freedom from major diseases and parasites. Although this valuable fish is available in India also, its commercial culture has not yet been practised here. But, experimental culture by various governmental agencies has shown that it can be cultured in coastal ponds and pens, with high levels of production.

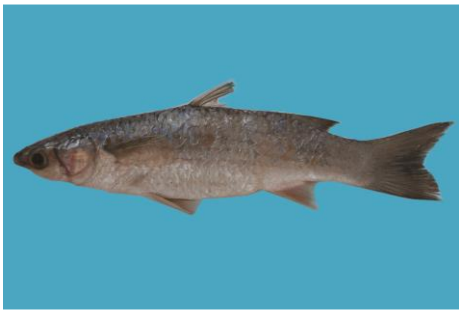


Mullets

These fishes belong to the Family Mugilidae. Mullets are well suited for farming because, like the milkfish, their food consists of the microscopic algae, decaying organic matter etc., at the pond bottom. They need little supplementary feeding and once they are stocked and if the hydrobiological conditions are satisfactory, they are bound to thrive well. They are also tolerant to higher temperature and salinity and hence are ideal for farming in tropical countries. The important species are Mugil *cephalus*, *Liza macrolepis*, and *L. tade.*



Mugil cephalus



Liza sp.,

The seeds of grey mullets (2-3 cm long) are abundant in inshore waters, estuaries, backwaters, etc. In India the fry of one or the other species of mullets are known to be available throughout the year. As per the conservative estimate, about -one million seeds can be easily collected each year in India.

Pearlspot

The Pearlspot, *Etroplus suralensis*, belongs to the family Cichlidae is an important brackish water fish, distributed in India, Srilanka and Pakistan. It is usually available in estuaries, tidal creeks, lagoons, backwaters, swamps etc. and attains a length of more than 30 cm and weight of about 1.5 kg. In India it chiefly occurs in the south-west coast, comprising Kerala and Kamataka, where it is considered as a great delicacy and is much in demand. It is also available in Orissa, Andhra Pradesh and Tamilnadu.

The early fry feed mostly on zooplankton, the advanced fry on aquatic insect larvae and the juveniles as well as adults feed upon filamentous algae and other vegetable matter, including the hair weed Spirogyra, Since *Etroplus* is non predaceous, easily adaptable, quick growing and rapidly breeding, it is another fish ideal for coastal aquaculture

Rabbitfish

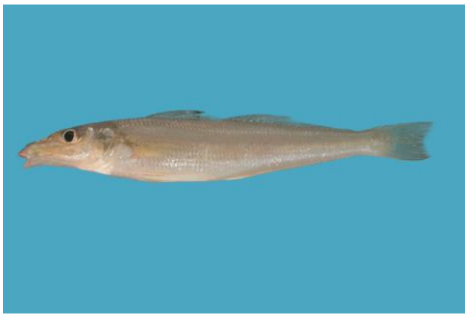
The Rabbit fishes belong to the family Siganidae and are cultured in certain areas at present but have high potentials for commercial culture because of high prices in the markets of countries like Singapore, Malaysia, Indonesia, etc. These do not grow more than about 35 cm in length but are relished in South-East Asia as a symbol of good fortune and are sought after during such auspicious periods as the Chinese New Year.

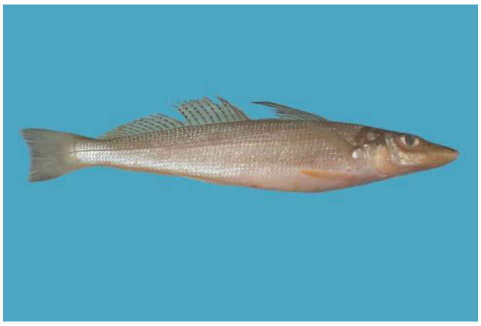
Siganus canaliculatus *S. vermiculatus*

In India, *Siganus javus*, *S. Canliculatus, S. lineatus,* and *S. vermiculatus* are the most important species. They are able to tolerate a wide range of salinity (17-37 ppt) and some species can be acclimatised to a much lower salinity of 5 ppt. They grow well in temperatures between 23 and 36° C. The juveniles and adults are primarily herbivorus, feeding upon different kinds of benthic algae. Under captivity, they become omnivorous, feeding upon a variety of food of both vegetable and animal origin, including feed pellets. The seeds are usually collected from the wild, such as reef flat areas by scoop nets, dip nets, seine nets, etc., at season.

The Sand Whitings

Among the species of Sand Whitings available in Indian waters, *Sillago sihnma,* and *S. vincenti* (Fig. 5.5) inhabiting shallow coastal waters, bays, estuaries, etc. are important ones for culture. They grow to less than 50 cm in length and are good food fishes. The seeds of *S. sihama* are available in good quantities along both the south east and south - west coasts and a few experiments were undertaken at experimental level which gave encouraging results. However, success is yet to be achieved on this aspect and on seed production.





Sillago sihama *Sillago vincenti*

Pompano

The aquaculture of pompano has been successfully established in many Asia-Pacific countries like Taiwan and Indonesia. The farming can be successfully carried out in ponds, tanks and floating sea cages. Among the many high value marine tropical finfish that could be farmed in India, the silver pompano, *Trachinotus blochii* is one of the topmost, mainly due to its fast growth rate, good meat quality and high market demand. The species is pelagic, very active and is 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.

The Central Marine Fisheries Research Institute has initiated aquaculture research on pompano from 2008 and the first successful brood stock development, induced breeding and larval production was achieved in 2011. Following the successful seed production of Silver Pompano, demonstration of farming in brackish water ponds was initiated by the CMFRI to popularize among the farmers about its suitability for aquaculture. These fishes attain an average weight of 450 grams in 8 – 10 months.

Bigeye trevally

Bigeye trevally belongs to the family Carangidae. Carangid fishes viz., Seriola quinqueradiata, caranx mate and Trachinotus sp., are commercially cultured in Japan, Hawaii and USA respectively. Big eye trevally is cultured for the first time in cages in Karnataka by the Research Centre of CMFRI, Mangalore. This is the first instance where the live seeds of bigeye trevally collected from the wild have been grown in cages. After a culture period of about 150-180 days, the bigeye trevally reached an average size of 300–450 g.

4. Site selection criteria for brackishwater fish farming

Sujitha Thomas

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

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

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

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

1.Topographical criteria

1a.**Exposure**

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

1b. **Depth**

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

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

1.c **Bottom condition**

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

2. Physical criteria

2a. **Current movement**

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

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

2b. **Turbidity**

Turbid water which is normally caused by freshwater run-off during rainy season is not suitable for cage culture. Organic and inorganic solids are suspended in the water column as a result of soil erosion. Run-off also brings some heavy metals leached from the catchment area as well as other industrial effluents. It also reduces salinity at the site. Suspended solids in turbid waters with strong current from freshwater run-off will also stir up already sedimented material from the usually soft muddy bottom of estuarine areas causing more solids to deposit on the nets. These sediments act as a substrate for the growth of fouling organisms, which prevent proper water circulation.

In addition, suspended sediments tend to clog fish gills which may lead to mortality from asphyxiation or cause gill epithelial tissues to proliferate and thicken. The presence of suspended solids also relates to some disease such as “fin-rot” caused by Mycobacteria (Herbert and Merkens, 1961; Herbert and Richards, 1963). The visibility of fish to the feeds will also be reduced which may lead to feed loss and impair fish growth.

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

3. Biological criteria

3a. Fouling organisms

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

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

To minimize maintenance cost, net cage farms should be sited in areas unfavourable for the growth of fouling organisms.

3b. **Phytoplankton**

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

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

3c. **Diseases and predators**

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

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

4. <u>Accessibility</u>

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

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

5. <u>Social problem</u>

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

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

6. Legal Aspects

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

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

5. Socio-Economic Issues and Prospects for Brackish water Fish farming

P.S.Swathi Lekshmi

Introduction:

India at present is using only 13 per cent of a total potential brackish water resource of the 1.2 million hectares available for brackish water aquaculture. These underutilised water bodies offer immense scope for farming of finfishes and shell fishes through horizontal and vertical expansion. Brackish water fish farming can contribute tremendously for employment and income generation through the productive use of these unharnessed water bodies. The dominant fishes used for brackish water aquaculture in India are sea bass, grey mullet, tiger shrimp and mud crabs. A number of socio-economic issues confront this sector on one hand apart from providing bright prospects on the other.

Brackish water farming:

- There has been phenomenal growth of the sector, especially in shrimp farming, during last one decade, with area coverage increased from 65,000 hectare(s) in 1990–91 to 152,000 hectare(s) in 2002–03. Andhra Pradesh is the leading state followed by West Bengal, Kerala, Orissa, Karnataka, and Tamil Nadu. The area covered by shrimp farms in the coastal regulatory zone (CRZ) along the entire coastline has remained almost the same from 1997–98 to 2000–01. This was due to the ban imposed by the Supreme Court of India in December, 1996 for construction of new farms in the CRZ. The ban permitted shrimp farming only for new farms following traditional cultural practices (extensive=modified extensive). In order to ensure the implementation of this directive of the court, Aquaculture Authority of India was set up.

- The contribution of the brackish water sector is confined mainly to aquaculture of shrimps as the share of cultures of other fishes and capture fisheries is insignificant. The national shrimp culture output was estimated at 115,320 t during 2002–03. The tiger shrimp (*P. monodon*) constitutes the major share of production, followed by white shrimp (*P. indicus*), and banana shrimp (*P.merguensis*). There was a steady rise in the production of cultured shrimp between 1990–91 (35,500 t) and 1994– 95 (82,850 t); thereafter, it dropped until 1997–98 (66,870 t) before picking up again in 1998–99 (82,630 t). Currently about 91 percent of the shrimp farmers in India own less than 2 ha, 6 percent between 2 to 5 ha and the remaining 3 percent have an area of greater than 5 ha. Out of the total area of 0.152 million ha presently being utilised for shrimp farming in the country, Andhra Pradesh alone provides 47 percent of the area and contributes 50 percent of the total production (FAO,2014). This is mainly due to the adoption of improved culture practices, particularly of disease control practices, as well as horizontal expansion of the industry. The increasing output clearly indicates the potential of the sector for increasing shrimp production and productivity in India.

- **Issues in Brackish water aquaculture:**

Lack of awareness about Brackish water fish farming and too much dependence on capture fisheries:

  - It is a well known fact that in India the coastal fisherfolk have been perpetual hunters of fish and have since time immemorial taken to capture fisheries as the major occupation as well as source of income. Development agencies both governmental as well as non-governmental have been trying hard to instil in them the need for farming of fin fishes as well as shell fishes in the phase of dwindling fish catch from the capture fisheries sector.

- **Interference with routine fishing operations:**
  - The fisher folk are mostly alien to fish farming activities as they feel these will by and large hamper their normal fishing activities. Educating the fisher folk through intensive and extensive extension measures is the need of the hour.
- **Labour availability:**
  - Farming activities such as in shrimp culture is labour intensive and the labourers insist that they remain in employment right from the beginning of farming operations till the very end though in certain stages of farming the labour force need not be employed in full swing.
  - **Water lease policy:**

Water leasing policies has to be made by all the Maritime States in India, and registration of brackish water farms should be made mandatory.

- Problems like multiple pond ownership, non-reorganisation of land based activity, absence of long term leasing policy, non-assurance of seed supply at the proper time and constrained access to credit are other issues faced by this sector.
- Issues that need to be addressed for enhancing aquaculture production on a sustainable basis are:

- Intensification of aquaculture in ponds and tanks.
- Increase of the productivity of ponds and reservoirs.
- Usage of derelict water bodies.
- Construction of new ponds and tanks.
- Introduction of culture based capture fisheries in reservoirs.
- Species diversification and introduction of high value commercial species.
- Development of breeding and farming technologies for new indigenous species that have potential for farming and market demand.
- Assess the potential impact of already introduced alien species and if found environment friendly, develop suitable management practices for their farming as is being done in the case of *Litopenaeus vannamei* and *Pangasius sutchi.*
- Small-scale fish farming through cage culture in back waters and estuaries.
- Establishment and expansion of fish hatcheries for production of quality fish seed.
- Development and availability of low cost fish feed for different species and farming systems.
- Research on aquatic health management and development of disease resistant strains of fish.
- Production improvement through genetics and biotechnology.
- Encourage fish consumption through awareness on the health benefits of fish and its nutritional security.
- Aquaculture needs to be treated at par with agriculture in terms of water, power tariff, tax benefits, subsidy, insurance and credit.

- **Prospects of Brackish water farming in India:**

✓ Increased demand for fish

✓ Emergence of this sector as one of economic importance attracting the attention of public and private sectors.

- ✓ Growing awareness among the public on the issues of sustainability.
- ✓ More and ample scope for production of locally available cost effective feeds by feed mills and companies.
- ✓ Production from capture fisheries has reached a Plateau, giving ample scope and opportunities for the culture fisheries.
- ✓ Increasing per capita availability of fish to 11 Kg/year.
- ✓ Developing policy and legal framework for leasing out of coastal and brackish waters to fish farmers and providing sufficient safeguards for introduction of exotic varieties in to Indian waters.

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6. Spatial planning concept in aquaculture development

A.P.Dineshbabu

Fishery Science and fishery technology contributed immensely in augmenting fish production globally and in most of the countries aquaculture production exceeded the fishery production from the wild. With advancement in the allied technologies, the technological support for aquaculture which were concentrated in fresh water species got extended to mariculture also. Indian mariculture which was restricted to bivalve farming in limited parts of the coast, had entered a new vista of development with cage culture of finfishes and shellfishes all along Indian coast by the beginning of 21st century. Feasibility of cage culture practices was demonstrated all along Indian coast by Central Marine Fisheries Research Institute. These demonstrations attracted developmental agencies and stake holders towards this innovative venture. Getting encouragement from the demonstration of high growth of finfishes in cages, small scale cage culture techniques also got popularity among the fishermen living around saline creeks and estuaries. The growing interest among entrepreneurs and the readiness for the financial and technical support by various developmental agencies has open up optimistic future for mariculture development in India. Cage culture of fin fishes and lobsters in sea and estuaries, rack and raft culture of bivalves, pen culture of finfishes and shellfishes are going to be major activities being expected under mariculture.

Zoning, through GIS technology or other methods, is a first step in implementing policies which promote sustainable development. It is by identifying areas which are environmentally suitable and excluding from development, those which conflict with the elements of sustainable development. Haphazard development of aquaculture inevitably leads to environmental overload, conflict among user groups and serious economic losses to the industry. GIS technology gives the planner and developer the capacity to evaluate the interaction of a wide range of environmental and social factors which affect the potential of a region for aquaculture development. This complex of influences is integrated through a ranking and scoring system. Each factor is scored and mapped accordingly. The product of ranks are scores which identify zones where sustainable aquaculture can be developed. The FAO Code of Good Practice for Aquaculture (Annex 8.3) also reflects concepts of sustainability. If these elements and their core values are accepted as the basis for sustainable development, then aquaculture development planning should incorporate them.

It is now widely recognized that the future of the aquaculture industry will be assured only if it is based on practices which ensure its sustainability. Five elements of sustainable development were given by Muir (1996), citing Jacobs, *et al.* (1987):

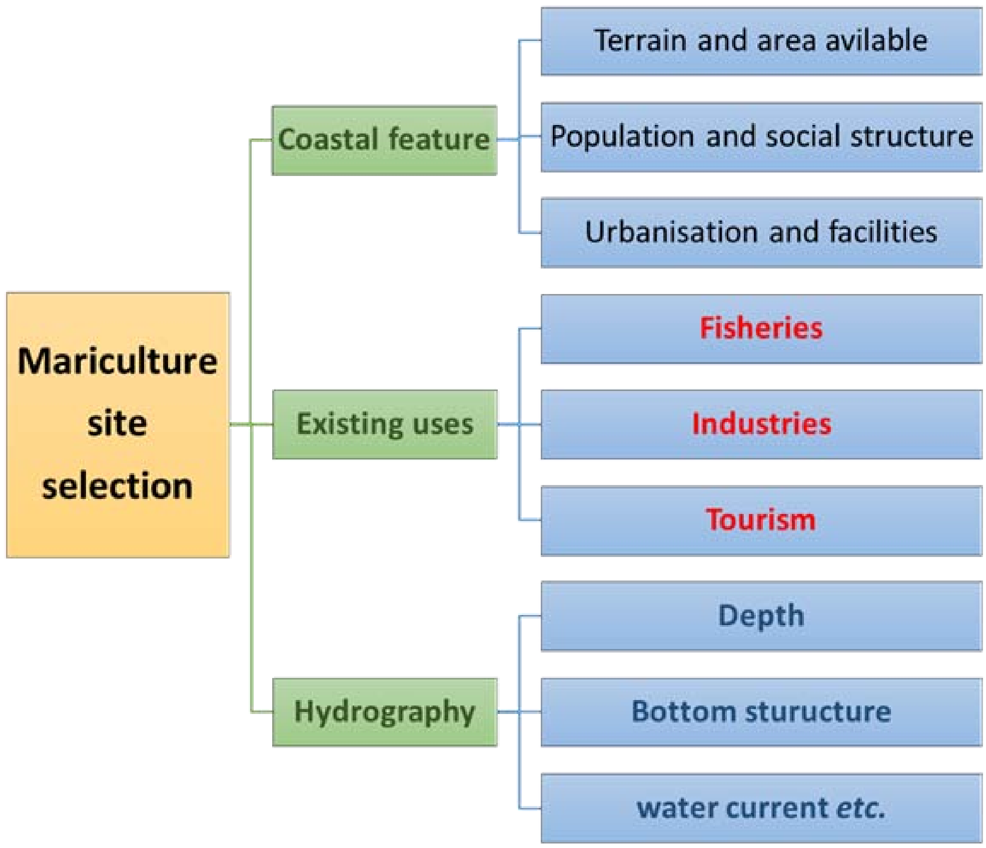
- Integration of conservation and development,
- Satisfaction of basic human needs,
- Achievement of equity and social justice,
- Provision for social self-determination and cultural diversity, and
- Maintenance of ecological integrity.

Spatial planning will help

1. To understand present status of usage of coastal waters: GIS based inventory of fishing, industrial, tourism, transport, shipping, oil exploration related activities along west coast of India will be prepared for the purpose to reduce the user level conflicts.
2. To identify areas available for mariculture activities using Multi-criteria decision analysis.
3. To identify suitable areas for mariculture taking into consideration of physical, chemical, hydrographic, biological social and legal structure from the available water bodies.
4. To identify the suitable technology for selected site, like Open sea mariculture, molluscan culture coastal small scale cages etc.
5. To find out the carrying capacity of selected sites according to the technology suggested.
6. Suggest optimum number of units like cages and rafts in each selected sites to sustain the production from these waters.
7. GIS based modelling of mariculture activities with collected information, to make the development in mariculture eco-friendly and free from conflicts.

8. Derive GIS based spatial planning for aquaculture development and propose action plan to the government to have a regulatory system for the sustainable mariculture development in India.

Methodology of Multi-criteria decision analysis used for the mariculture site selection taking into consideration of the multi-user scenario in coastal waters is illustrated below.



Aquaculture development can be directed to suitable areas through a permitting process such as the Scoping Committees at the national and State levels. The developer and financial institutions can evaluate the feasibility of projects more readily. Since the open waters are the common property in India, any mariculture development activity should be well planned by taking care of the utilization of the common waters. The areas suitable for mariculture activities should be identified by taking care of general utilization of common waters, with minimum disturbance to the ongoing activities. The activities suitable for each geographic area have to be identified and the carrying capacity of all these selected areas should be identified. The site can be identified for bivalve farming, sea farming of finfishes and shellfishes and also estuarine farming. The estimation of carrying capacity will help in suggesting how many number of rafts, racks, cages can be put in the particular ecosystem/area without disturbing the natural environment. In case of cage culture the species to be selected, number of cages to be installed, the stocking density and the extend of distribution of waste from cages without causing pollution are the major concern to make the production sustainable. Efficient management and strict regulations are required for the sustainable development. There are many instances in agriculture like that in shrimp farming were the lack of proper management has adversely effected the farming.

Geographic Information Systems (GIS), remote sensing and mapping have a role to play in all geographic and spatial aspects of the development and management of marine aquaculture. GIS based spatial planning gives us the projection scenarios of various physical and biological parameters and will help the scientists to come out with suggestions on species suitability for cages, carrying capacity of the water body, stocking density of the cages and the best feeding strategies and feeding schedules incorporating all chemical, biological and physical features. GIS projections are capable to resolve conflicts for space and resources between stake holders and also to understand the social acceptability and the economic implications of mariculture. A legally viable licensing system and water leasing must be developed and put into practice during the initial development stage itself to avoid any future conflicts among the different stakeholders. GIS based spatial planning is a new concept in Indian mariculture, but it is considered as a major tool in aquaculture development around the world. Food and Agriculture Organisation compiled the use of GIS based spatial planning in aquaculture . These are the list of project listed by FAP GIS in 2007. By 2012 it is reported that there are 391 project which were using GIS based marine spatial planning for aquaculture development in the world (FAO (2012).

Spatial planning is a decision support project to support decision making in mariculture development in India sustainable with eco-friendly and human friendly technologies and selection of Site. The development in mariculture at present is disadvantaged by lack of clear policies on the protection of culture structures in common property like Indian seas. The result s from this project will give a illustrative policy decision support to support and regulate sustainable mariculture development in the country. The Ministry of Agriculture in 2014 has stressed the importance of ‘ blue growth’(aquaculture) in sustainable food production and that this sector is confronted with serious inadequacies of planning, and management. In light of this, this project is relevant and essential for proper planning and management of mariculture activity in the country. The projecr result will fill the lacuna od decision support system in supporting and financing the fishermen who are interested to venture into mariculture.

Indian mariculture which was restricted to bivalve farming in limited parts of the coast, had entered in new vista of development with cage culture of finfishes and shellfishes all along Indian coast by the beginning of 21st century. Feasibility of cage culture practices demonstrated all along Indian e coast by Central marine Fisheries Research Institute. These demonstrations attracted developmental agencies and stake holders towards this innovative venture. Getting encouragement from the demonstration of high growth of finfishes in cages, small scale cage culture techniques also got popularity among the fishermen living around saline creeks and estuaries. High market demand for the sea food in domestic and international market as health food also acted as a catalyzing factor in for this resurgence interest in mariculture activities. The growing interest among entrepreneurs and the readiness for the financial and technical support by various developmental agencies has open up optimistic future for mariculture development in India. Cage culture of fin fishes and lobsters in sea and estuaries, rack and raft culture of bivalves, pen culture of finfishes, and shellfishes are going to be major activities being expected under mariculture. Since the open waters are the common property in India, any mariculture development activity should be well planned by taking care of the utilization of the common waters. The areas suitable for mariculture activities should be identified by taking care of general utilization of common waters, with minimum disturbance to the ongoing activities. The activities suitable for each geographic area has to be identified and the carrying capacity of all these selected areas should be identified. Estimating the carrying capacity of the mariculture is very important in suggesting what kind of culture is possible in the specified area. The site can be identified for bivalve farming, sea farming of finfishes and shellfishes and also estuarine farming. The estimation of varying capacity will help in suggesting how many number of rafts, racks, cages can be put in the particular ecosystem/area without disturbing the natural environment. The decision support in sustainable development will lead to fast development of mariculture in the country.

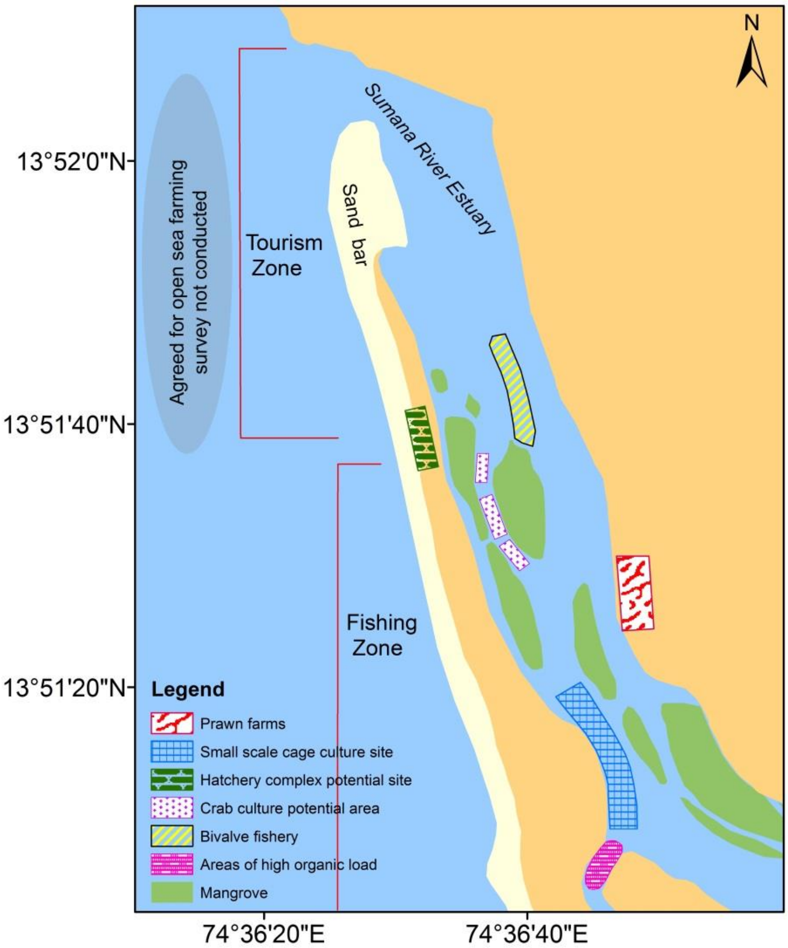


Fig. Spatial planning and aquaculture zoning of of Byndoor estuary, Karnataka.

7. Availability of brackish water fish seeds and collection techniques

Rajesh K. M.

Collection of fish and prawn seed from natural resources is most important for brackish water culture. The seed is available in plenty in creeks, river mouths, low lying areas and ditches near the sea. This seed can be collected from nature with little efforts and less expenses. Adult prawns and fish breed in deep Sea; juveniles enter into creeks and other areas near the sea with high tides during new moon and full moon time. Different types of seed are available in different months. The most common fry collecting devices are dip nets, scoop nets, seines, drag nets and traps. Special fry-congregating devices used are rock walls or lure lines made of fibre ropes strung with plaited strips of coconut and banana leaves. When the fry congregate under the lure, they are collected with dip nets or scoop nets. The best collections are made at creek mouths, at high tides during full and new moon periods. The fry collected fry (10 - 30 mm) are transferred to earthen-ware jars and transported to ponds.

COLLECTION METHODS

Shooting net, hand net, drag net and push nets are used to collect brackish water fish and prawn seed.

- **Shooting net:**

  This net is operated during high tide, when water current is increased. It is fixed when water level is about 2" depth and fixed against the water flow. It is a 'V shaped net made up of fine meshed cloth. It is 320 cm in length, and diameter near the mouth is 510 cm. At the tail it is 25 cm. and the height near the mouth is 60 cm. It has a detachable tail piece. It is fixed with the help of 4 bamboo poles. Two poles are fixed near the mouth, one at tail end and the other at the tail piece. The prawn seed move along with the water flow and get trapped in it. Depending upon the entry of seed, the tail piece is removed and seed is collected. Depending upon the water flow the net is shifted to various places near the shores and collects the seed. Three members are sufficient to operate the net.

- **Hand net:** Single person is sufficient to handle this net. It has an iron ring and a handle. The iron ring is fixed with a 20 or 24 mesh size nylon cloth. The seed is collected with this net in mangrove areas where water level is about 1-2". The seed is attached to the leaves and roots of the plants. By keeping the nets near the leaves or roots the seed can be collected after disturbing them. A single person can collect 250-950 juveniles per hour.

- **Drag net:** It has 13' length and 6.5' width. It is made up of fine meshed mosquito cloth. Three persons are sufficient to operate this net. This net is most useful to catch milkfish seed. Fishermen drag the net in shallow waters to collect fish seed.

- **Push net:** This net is most useful to catch prawn seed and *Mugil cephalus* seed. It is triangular in shape. It is prepared with 3 bamboo poles, one with 6' and the other two are with 4' and 2' length. A fine meshed nylon cloth is fixed to this bamboo frame. One person can operate this net and collect 650-1950 post larvae per hour.

- **Seines:** Seine nets can be used for collection of seed. The collection is usually done during the low tide. The top and bottom of the net has floats and sinkers respectively. The net is operated by two persons. They drag the net encircling an area where seeds congregate and the seeds are collected using hand net.

8.Seed transportation techniques for farming

Sujitha Thomas

Live Transportation of Fish Juveniles and Fingerlings

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

Factors influencing transport

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

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

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

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

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

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

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

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

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

Types of transportation of fishes.

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

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

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

Open Systems of fish transport

The open systems of transport have many technical modification ranging from small transport fish-cans, containers for fish transport within the territory of a fish farm, up to special fish transport trucks and tank wagons. In case of short time (10-30 min) open transport, plastic containers or metal tanks could be used with constant oxygen supply.

Transport longer than half an hour should be in completely filled and closed tanks to prevent splashing and injuries to young fish bumping into each other in the well of the tank. The weight of fish that can be safely transported in a tank depends on the efficiency of the aeration system, duration of the transport, water temperature, fish size and fish species.

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

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

General points to be considered for transportation.

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

9. Nursery rearing of seabass

A.P.Dineshbabu and Sujitha Thomas

Seabass is one of the candidate species in cage culture. Seabass culture in cages involves (i) Collection and transportation of seeds, (ii) Hatchery rearing and grading, (iii) Nursery rearing in earthern ponds (iv) farming in open sea cages. Following are the steps taken for hatchery rearing of seabass done at Mangalore CMFRI

I. Collection and transportation of seeds

The seabass fry (45-55 mm) procured from hatcheries in east coast was transported to the place of rearing. The seeds were packed at a stocking density of 175-250 nos/ bag and transported by road at 25 °C in 19 h. The seeds in oxygen packed bags were transported to the hatchery facility for rearing.

II. Hatchery Rearing

The rearing of seabass was carried out in 15 t indoor cement tanks. The seeds acclimatised to the rearing conditions by floating the bags for 30 ± 15 minutes, and slowly released into the water. The seabass seed of 45 mm size were stocked at the rate of 500 nos/ m^3 and the larger juveniles of 55 mm size are to be stocked at 233 nos/ m^3 in the rearing facility.

Water quality:

The rearing was carried out under controlled conditions. The seawater filtered using a gravel filter layered with gravel, sand and activated charcoal. The filtration system was maintained to ensure adequate nitrification. The filtered water was chlorinated, dechlorinated and stored in overhead tanks. The treated water was filled in the cement larval rearing tanks by gravitational flow. Flow through system was be maintained at a flow rate of 500 l/h. The salinity of the seawater ranged from 26 to 33 ppt. The water temperature during the rearing period varied between 26 to 30 °C

Feeding:

Fishes were fed twice daily at 12 hour interval with imported compounded feed at the rate of 8% body weight. The fishes were weaned to locally compounded pelleted feed. Pelleted feed was supplemented with mince comprising of trash fish, bivalve meat and shrimps depending on its availability. Vitamin premix was added to the mince at the rate of 1%. Left-over feeds were siphoned out after feeding, along with the organic waste.

Grading

Due to differential growth and highly cannibalistic nature of the species, fortnightly grading of uniformed sized seabass was carried out to minimise loss due to cannibalism.

Growth and survival rates

The seabass seed of 45-55 mm at stocking reached 110 mm in 50 days with weight ranging from 20 to 25g by the end of October, 2009. The survival percentage was 94.2%.

III. Nursery Rearing

During October-November, 2009, the advanced fingerlings with an average size of 20 g from the hatchery were stocked in nursery cages floated in the earthern pond in different batches. Earthen ponds with depth ranging from 1 to 1.5 m proximate to the estuarine area at Byndoor, (Uttara Kannada District) was selected. The pond was filled with water (27 to 33 ppt) during the high tide.

Pre-stocking management: Pond preparation was carried out by drying, tilling, sediment removal, fertilization, bottom raking and disinfection, ten days prior to stocking. The earthen pond was dried by draining the water during low-tide by opening the sluice gates as well as by pumping. The pH of the pond was maintained above 7.5 by liming. The ponds were filled with water during high tide after two days. The water depth of 1.5 m was maintained by pumping water from the intake point. The catwalk was constructed in the pond for feeding and monitoring purposes, by erecting *Casuarina* poles vertically into the pond bottom. Bamboo poles were place horizontally connecting the vertical poles as a working platform.

Nursery cage fabrication: The net cages were fabricated using PE net webbing of 15 mm initially. Square cages of 2 x 2 x 1 m were kept afloat by hanging from HDPE frames of 3" diameter. Each square cage was attached with a sealed 1" diameter HDPE frame filled with sand at the bottom as counterweight. The units were allowed to float in the water column of 1.2 to 1.5 m depth for facilitating easy removal of food material and water exchange in the bottom. A bird barrier netting with 2 x 2m square frame was placed on the top of the cage to protect the fishes in cage.

Stocking: The seabass fingerlings were transported from the hatchery during early morning hours by road in oxygenated tanks. They were transferred to the floating cages in the pond at the rate of 700 nos/ cage, with an effective stocking density of 175 nos./ cu. m. The cages were fastened to wooden poles fixed near the catwalk initially to facilitate feeding. Eventually the cages were allowed to float freely inside the pond for continuous flushing of water inside the cage. This also avoided accumulation of waste under the net cage.

Water quality: Water exchange was carried out by opening the sluice gates and draining the pond during the low tide. The sluice shutters were opened to facilitate the exchange of feed laden bottom water. Fresh seawater was pumped daily only during high tide to avoid mixing of pond effluents. The paddlewheel aerators were operated in the pond to increase oxygen level and prevent thermal stratification. The temperature ranged from 28-30°C, salinity 26-28 ppt, pH 7.8-7.96 and Dissolve oxygen 5 - 6.26 mg/l.

Feeding: Feeding began 1 day after stocking at the rate of 7% of the body weight twice daily. The amount fed weekly followed a theoretical regime starting at 7% and declining to 5% for compounded feed mixed with trash fish mince. The net cages were checked daily after feeding and periodically cleaned to allow water circulation inside the cage

Collection from nursery pond: The seabass reared in the nursery were collected in batches by lifting the net cages and transported in oxygenated tanks to the grow-out site during December, 2009, after rearing for 45 to 50 days. Average weight of fish in pond while harvesting was about 80-100 g and survival rate was 80 %.By the above said method cannibalism and natural mortality was reduced to the minimum with increased survival rates

10. Culture of brackishwater fishes in pond

Rajesh K. M.

The brackish waters are areas of confluences of fresh water and sea water and the salinity ranges from 5 to 27 ppt. India is estimated to possess along its coast a total area of 2 million ha suitable for brackishwater fish farming. But the total area under cultivation is only 141,837 ha. and the brackishwater aquaculture was restricted to shrimp farming in farm ponds owing to the high export potential of penaeid shrimps (*Penaeus monodon* and *P. indicus*). The modern brackishwater farming in coastal aquafarms assumes considerable importance in recent times. Later culture of Mullets, seabass, Milk fish, pearlspot and pompano were tried in the states of Kerala, Tamil nadu and Andhra Pradesh.

SEABASS

Cannibalism is one of the most serious problems in seabass culture. High mortality is often encountered when uneven sizes of the fish are stocked. This has been noted to occur mostly where the fish are very young (1–20 cm in length, the first two months of culture). To minimize this problem, culture of seabass should be approached in two phases i.e. the nursery phase and the grow-out phase.

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. Beyond the nursing period, the juveniles can be graded into different size groups and stocked in separate grow-out ponds. Nursing the fry in concrete tanks is not recommended as accumulation of excess feed on the bottom of the tank cannot be avoided. Such accumulation can cause bacterial disease. In addition, constant contact with the tank wall results in wounded fish and subsequent bacterial infection

Nursery pond size ranges from 500 to 2000 m^2 with water depth of 50–80 cm. The pond has separate inlet and outlet gates to facilitate water exchange. Pond bottom should be flat and sloping towards the harvesting or drainage gate. Inlet and outlet gates are provided with a fine screen (1 mm mesh size) to prevent predators and competitors from entering and fry from escaping the pond. Fry ranging from 1–2.5 cm are suitable for stocking in the nursery ponds. Stocking density is between 20–50 individuals per square meter.

Pond preparation: The nursery pond must be drained and dried until the bottom soil cracks to release toxic gases, oxidize mineralized nutrients, eradicate some pests and predators. In cases where the pond cannot be completely drained, derris root (rotinone) may be applied at the rate of 20 kg/ha to eradicate unwanted species. Derris root is prepared by cutting them into small pieces, crushing and soaking in water overnight. Only the solution is applied to the pond. If derris root is not available, a mixture of 50 kg/ha of ammonium sulphate with lime at a ratio of 1:50 will be sufficient to weed out unwanted species. Organic fertilizer (chicken manure) is applied at the rate of 500 kg/ha. Then water depth is gradually increased for the propagation of natural food. Two to three weeks prior to stocking, newly-hatched *Artemia nauplii* are inoculated into the pond (1 kg of dry cyst/ha). Artemia will utilize the natural food as feed for growth and will reach adult stage within 10–14 days. The fry are immediately stocked at the rate of 20–50 individual per square meter.Another approach to the improved technique is to stock Artemia nauplii in the separate pond and grow them into adult. Adults could be harvested daily to feed the fry.

Nursery pond management: Although seabass can be cultured in either freshwater or saltwater, fry must be acclimatized to the salinity and temperature prevailing in the pond on stocking to prevent loss. Transfer the fry to a tank, gradually add nursery pond water. This can be completed within one day or more depending on the salinity difference. If the temperature and salinity in transport bag does not differ by more than 5°C and 5 ppt with the pond water, acclimation can be done by floating the bag in the pond for some time to even out temperature difference. Pond water is then added gradually until both salinity become equal and the fry can be released.

Seabass fry are stocked in the nursery pond at a density of 20–50 fry/m^2. Stocking is usually done in the early morning or early evening when the temperature is cooler. Water replenishment is needed to prevent deterioration of pond water quality due to the decomposition of uneaten feed or excess growth of natural food. Normally, 30% of pond water is changed daily.

Supplementary feed is given daily. The feed used for nursing seabass is chopped and grounded (4–6 mm^3) trash fish, normally at the rate of 100% of biomass given twice daily in the first week (at 0900–1700 hours), gradually reduced to 60% for the second week and 40% in the third week. This has been found to be most effective feeding strategy for ponds without artemia inoculation. The nursing period lasts about 30–45 days until fingerling stage (size 5–10 cm). At this stage, they are ready for transfer to grow-out ponds.

Pond culture: There are two culture systems employed in pond culture of seabass:

Monoculture: This culture system entirely dependent on supplementary feeding. The use of supplementary feed reduces profit to the minimal, especially where the supply of fresh fish is limited and high priced.

Polyculture: This type of culture approach shows great promise in reducing if not totally eliminating the farmers' dependence on trash fish as food source. The method is achieved by simply incorporating a species of forage fish with the main species in the pond. The choice of forage fish will depend on its ability to reproduce continuously in quantity sufficient to sustain the growth of seabass throughout the culture period. The forage fish must be such a species that could make use of natural food produced in the pond and does not compete with the main species in terms of feeding habit such as *Oreochromis mossambicus, Oreochromis niloticus,* etc.

Pond design and construction: Seabass ponds are generally rectangular in shape with size ranging from 0.2 to 2 hectares and depth of 1.2 to 1.5 meters. Each pond has separate inlet and outlet gate to facilitate water exchange.

Pond preparation: Preparation of grow-out ponds is similar to the procedure followed in nursery pond system. In monoculture, the fish are stocked immediately after neutralizing the pond soil with lime. Ponds are filled immediately after pond preparation.

In polyculture, after the pond soil is neutralized, organic fertilizer (chicken manure) is applied at the rate of 1 ton per hectare. Then water depth is gradually increased for propagation of natural food. When abundance of natural food is observed, selected tilapia broodstocks are released to the pond at the rate of 5,000–10,000 per hectare. Sex ratio of male to female is 1:3. The tilapia is reared in pond for 1 to 2 months or until tilapia fry appear in sufficient number. Seabass juveniles are then stocked.

Seabass juveniles (8–10 cm in size) from nursery are stocked in the grow-out pond at the rate of 10,000–20,000 per hectare in monoculture and 3,000–5,000 per hectare in polyculture system. Prior to stocking, juveniles are acclimatized to pond culture and salinity conditions. Stocking the fish in uniform sizes will be most ideal and should be done at cooler times of the day.

Feeds and feeding: Supplementary feed is not required in the polyculture system, but in monoculture, daily feeding is a normal practice. It must be remembered that seabass never eat the feed when it sinks to the pond bottom. Therefore, feeding should be slow. When the fish are filled to satiation, they disappear thus feeding should be stopped. The same procedure

should be followed at every feeding time. The first few days after stocking, feeding should be 5 to 6 times a day to teach them to accept dead feed. Once the fish is accustomed to it which takes about 5–7 days, feeding frequency is reduced to twice daily.
Growth and harvest: Normally seabass grows to 1.5 to 2.0 kg when big sized juveniles stocked in the pond. Harvesting can be done in batches or at once by draining the water.

MULLETS

Mugil cephalus, a very popular member of the grey mullet has been accepted as a good food fish around the world. It is a highly suitable species for both mono and poly-culture with shrimps, prawns and other herbivorous fishes. For its distribution and well availability in all the tropical and sub-tropical waters around the globe, rapid growth, herbivorous feeding habit and high fecund, this species is considered to be the good cultivable fish for brackish water aquafarming.

Seed procurement: Plenty of *M. cephalus* seed (15 to 60 mm) is available both in east and west Coasts during September to February, along with *Liza tade and Liza parsia*. The fry of *M. cephalus* is easily identifiable by the help of dark blue spot at the base of the pectoral fin. Fry can be collected by simple type of cloth dragnet and scoop net from low lying coastal areas during the low tide.

Nursery rearing: After acclimatization, fry are stocked in earthen nurseries at high densities (up to 125/m^2), where they depend mainly on natural food. 2.5 to 5.0 tonnes/ha of animal manure are added to the soil before filling with water; then chicken manure and chemical fertilizers (usually phosphate and nitrates) are added in suitable amounts (25-50 kg/ha) on a weekly basis to keep secchi disc readings of 20–30 cm. Rice or wheat bran is sometimes used as an additional source of food. Fry are kept in the nursery ponds for 4–6 months until they are about 10 g. The fingerlings are then caught, either by draining or by netting.

Grow out ponds: Mullets are usually grown in polyculture in semi-intensive ponds and netted enclosures in shallow coastal waters. Mullet can be polycultured successfully with many other fish, including common carp, grass carp, silver carp, Nile tilapia and milkfish, and can be reared in freshwater, brackishwater and marine water.

Prior to stocking, aquaculture ponds are prepared by drying, ploughing and manuring with 2.5–5.0 tonnes/ha of cow dung. Ponds are then filled to a depth of 25–30 cm and kept at that level for 7–10 days to build up a suitable level of natural feed. The water level is then increased to 1.5–1.75 m and fingerlings are stocked. Productivity (measured by secchi disc) is kept at the required level by adding chicken manure and/or chemical fertilizers. Optimal dissolved oxygen is maintained by the use of various types of aerators, especially after sunset. Extruded feed is supplied to semi-intensive ponds to cover the feeding requirements other fishes reared in the pond. The growing season is normally about 7–8 months.

If mullet are mono-cultured, manuring may be sufficient to reach the required feed level. In many cases, mullet has been found to feed directly on chicken manure and good levels of production have been recorded. Growth is checked by sampling, and if growth rates are not as expected, rice and/or wheat bran is added daily in amounts of 0.5–1 percent of biomass to supplement the natural feed in ponds.

Acclimatized to the appropriate salinity, and stocked as 10–15 g individuals at 6 000 – 8000/ha, a harvest of 4.5–6.0/tonnes/ha/crop can be obtained. In semi-intensive polyculture with tilapia and carp, mullet fingerlings are stocked at 2500–4000/ha together with 2000–2500/ha of common carp juveniles and 60,000–70000/ha 10–15 g Nile tilapia fingerlings. Total harvests are typically 20–30 tonnes/ha/crop, of which 2–3 tonnes are mullet.

After an on growing season of 7–8 months in either culture systems flathead grey mullet reach 0.75–1 kg; if kept for two ongrowing seasons, they reach 1.5–1.75 kg each. Rearing for a second year depends on the market requirements; in some countries mullets are marketed at a size of 1.5 kg and larger.

Harvesting: Daily harvesting, according to market demand, can be carried out using gillnets of suitable mesh size. Nets are stretched in a zigzag line across ponds at sunset and collected at the early morning.Fish usually move with the flow of water to a concrete catch pond at the pond outlet. A seine net can be used to collect those that do not reach the catch pond.

MILKFISH

Chanos chanos, popularly known as milkfish or the white mullet is the only species of the family Chanidae. It is a well-known marine fish throughout the Indo-Pacific region. The milkfish is a fast growing euryhaline food fish suitable for culture in brackishwater ponds. Milkfish is an important food fish in Indonesia, the Philippines and Taiwan. In fact, these countries are the major milkfish producing countries followed by a few other Asian countries including India. Some small scale culture is attempted in peninsular India and Sri Lanka, but the total production is very small. In India, milkfish culture is taken mostly in the states of

West Bengal, Kerala, Tamilnadu and Andhra Pradesh by trapping fry during high tides from the smooth and shallow waters of the Bay of Bengal. The traditional culture practices yield production more than 500 kg/ ha/year. In semi-intensive farming, the production ranges between 2000 and 4000 kg/ha/year. The most common system used for the culture of milkfish is the brackishwater coastal pond. The ponds may include nurseries and rearing ponds.

Fry Collection: Milkfish spawn in the sea near the coast and the small larvae (12-15 mm in length) occur periodically along the sandy coasts and in the estuaries. The collection and rearing of fry from these areas for sale to farmers has become an industry of importance, employing a large number of people in Indonesia, the Philippines, Taiwan and even in some places of India. In India, fry are available in abundance from March-June and in small quantities from September - November. Almost all the tidal creeks, estuaries and backwaters along Tamilnadu, Andhra, Orissa, Kerala and Karnataka coasts provide collection grounds for *Chanos* fry. The most common fry collecting devices are dip nets, scoop nets, seines, drag nets and traps.

Rearing of fry: For fry rearing, separate nursery ponds are being maintained in some farms. They normally represent about 3-5% of the farm area. The nursery ponds are shallow and ranging in size from 1000 to 4000 m^2.

Pond Preparation: The preparation of the ponds starts about two months before the fry are introduced. The ponds are drained completely during low tides. The bottom is levelled, raked with a wooden rake or ploughed to bring the subsurface soil nutrients to the surface and to eradicate weeds. Besides eradicating pests and predators, drying also helps in the mineralization of organic matter in the soil. The water gates of the pond are protected with fine-meshed screens to prevent the entry of fish or other organisms from outside. The ponds are then treated with poultry manure at the rate of 2 tons/ha. Water is let in just to cover the pond bottom. After 2 or 3 days, 150 kg/ha of 16:20:0 NPK fertilizer, or half that quantity of 18:46:0 NPK fertilizer per ha are added. In order to speed up the breakdown of chicken manure, urea may be added at the rate of 25 kg/ha. The benthic algae (lablab) build up gradually. The water level in the pond is then gradually increased to 25-30 cm in a period of 1 month, by increasing the level by 3-5 cm each time. The maintenance of this benthic complex requires proper water management and grazing levels. Further applications of NPK fertilizers are made, if necessary, at intervals of 1 to 2 weeks to maintain the growth of lablab.

Fry Stocking and Acclimatization: The density of fry in the nurseries is generally 30 - 50/m^2. Fry can be stocked directly in the nursery ponds if the salinity of the water in which they are transported is approximately the same as the salinity of the pond water. If there is a difference of over 5 ppt, fry should be acclimatized before transfer.

Nursery Pond Management: Nursery pond management involves the maintenance of suitable conditions for the growth of fry and its natural food (lablab). In order to avoid salinity increases during the summer months, some exchange of water may be needed. If the growth of natural food is not adequate for the stock, artificial feeds like rice bran is provided. In 2 months, the fry grow to a weight of 1-3 g and are then stocked in rearing/production ponds.

Grow-out: Procedures for preparing rearing ponds are generally the same as for nursery ponds. The ponds are drained and the bottom dried. Initial fertilization is done with a combination of organic and inorganic fertilizers. After the ponds are stocked, fertilization with urea and NPK fertilizer is continued at about half the initial dose at fortnight intervals taking care to exchange the water regularly.

Fish stocking: In traditional milkfish ponds stocking is carried out with milkfish only but during the course of culture other species especially grey mullets, shrimps (mainly *Penaeus* and *Metapenaeus* spp.) gain access converting it into a polyculture system.

The usual practice is to stock a single size group of fingerlings (10-15 cm)at the rate of about 2000/ha, and completely harvest when they have grown to marketable size. The main disadvantage of this system is that there is wastage of food when the fish are small, as they cannot utilize all the food produced, and when they have grown the food produced in the pond may be insufficient because of the increased food requirements of the larger biomass. In order to avoid shortage of food at critical times in rearing ponds, a procedure known as the "progression method" is practised by many farmers in the Philippines. Rearing is carried out in two stages. The fingerlings grow for a certain period in one pond and are then transferred to another pond where they grow to the market size. The food resources in both the ponds are not exhausted and several crops can be raised through proper management. This method has been further improved to a so-called 'modular-method', which involves a 3-stage rearing. Three contiguous ponds form a series, progressively increasing in size at a ratio of 1:2:4. The first pond is stocked at a density of 15000/ha. After about 6-7 weeks the stock is transferred to the second pond, and after about 4-5 weeks to the third pond, until they reach market size.

Intensive farming consists of stocking different size groups and repeated selective harvesting, and this is sometimes referred to as the "multi-size stocking method". Initial stocking may be with 3 size groups; e.g., 3000 fingerlings of average length 5 cm, 2000 of 15 cm length and 2000 of 18 cm length. Subsequent stocking may be with smaller fingerlings (5 cm length) at about 1-2 months intervals, at the rate of 2000 - 3000/ha each time. Repeated selective harvesting is performed 3 to 5 times to remove the market sized fish.

Feeding and Pond Management: As milkfish farming is largely based on the production of natural food, artificial feeding is provided only when the natural food is not adequate. Locally available feedstuffs like rice bran, groundnut cake and soybean meal are used for supplementary feeding. On an average each fish grows to about 300-500g and yield 7000 – 8000 kg/ha.

PEARLSPOT

Pearl spot / *Karimeen* (*Etroplus suratensis*) is a brackish water cichlid fish commonly found in peninsular India and Srilanka. In India though it is found in the southern states, the fish is cherished and used as a delicious food only in Kerala. Karimeen is a highly preferred fish in Kerala and the market price is around Rs. 450/- per kg, extensive farming of this fish is not being done mainly due to the non-availability of sufficient seed. Though growth is slow, at a high stocking density table-size fish can be harvested in 9-12 months culture period.

Seeds are available throughout the year along the south-east and south-west coast of India. A simple method of seed collection is adopted taking advantage of the tendency of the fish to congregate in large numbers for feeding on epiphytic growth. In this method twigs or branches are kept submerged in the water a week ahead of day of collection. Juveniles congregating for feeding are trapped using an encircling net or trap.

Pond Preparation: Before letting in water, the ponds are drained and lime is applied at the rate of 300 kg/ha. In undrainable ponds, piscicide (Mohua oil cake @ 200-250 ppm) may be used to eliminate the weed fishes. Water is let in through screens to avoid the entry of undesirable fishes. The pond is filled up to the appropriate level (1.2 m) and cow dung applied at the rate of 1500-2000 kg/ha for promoting plankton production. The pearlspot is suitable for culture in fresh and brackishwaters. The culture of pearlspot is more economical under polyculture system especially with milkfish and mullets than under monoculture. The fish can attain a marketable size of 120-150 g over a period of 8-10 months. Though growth rate is relatively slow, high stocking density with low input management can yield optimum production. Pearlspot farming could be adapted to any scale integrating with other occupations like poultry farming. The poultry droppings form good manure for natural food production in the culture ponds. Harvesting is usually undertaken by draining the water from the ponds and operating a seine net, cast net or a drag net for capturing the fish.

POMPANO

Among the many high value marine tropical fish that could be farmed in India, the silver pompano, *Trachinotus blochii* is one of the topmost, mainly due to its fast growth rate, good meat quality and high market demand. The species is pelagic, very active and is 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. The shape, colouration and meat quality of this fish is comparable with silver pomfret.

Pond preparation: The pond has to be dried properly until the cracks appear on the surface. Ploughing has to be done to tilt the soil below 30 cm. The average water pH of 7.5-8.5 would be ideal for pompano farming. The level of lime application during pond preparation depends on the pH of the soil. Hence, the dosage has to be calculated accordingly. Water filling has to be initiated by covering the inlet pipe by using 2 layers of fine nets (100 micron) to avoid introducing other fishes and predators. A week before stocking, the pond must be fertilized with either organic or inorganic fertilizers to stimulate the plankton bloom. Pompano can tolerate vide range of salinities from 5- 40 ppt. However, ideal salinity for farming would be between 15 – 25 ppt and the pond has to be filled with a minimum water level of 100 cm prior to stocking of fish seeds. During the entire culture period 1.5 meter water depth has to be maintained.

Nursery Rearing and Seed Stocking: Hatchery produced pompano fingerlings of 1 inch size can be stocked in hapas/ pens of 2 meter length, 2.0 meter width and 1.5 meter depth. In each hapa about 200 fingerlings can be stocked. Initially the fishes have to be reared in hapas for 60 days or until they attain 10 – 15 grams size and thereafter it can be released into the pond. The mesh size of the hapa could be initially at 4 mm size and it can be changed with 8mm mesh size hapas after 30 days. After attaining 30 grams size ideally 5,000 Nos. can be stocked in a one acre pond.

Nutritional requirement & feeding: Pompano is a fast moving marine fish and it requires highly nutritive feed to meet the energy requirements. During nursery rearing Pompano can be weaned to any type of feeds viz., extruded floating pellet, sinking pellet feed and chopped trash fishes. Feeding has to be done 3 times a day. The feed size should be lesser than the mouth size of the fish and hence, suitable sized feed has to be selected for feeding the fishes. A mix of two sizes of feed pellet can be used if there is any size variation of the fishes found during the regular sampling. If sinking pellet feed is used, at least 4 – 8 feed trays (80 cm x 80 cm) per pond could be placed. Regular sampling of fishes once in 15 days has to be carried out to determine growth rate.

Harvesting: Each fish grows to about 350-450 g. in about 7-8 months. Harvesting of pompano could be carried out by using drag net as in the case of fresh water fishes.

TILAPIA

Tilapia has been considered as the Food Fish of the 21st century and is popularly known as aquatic chicken. The world aquaculture production of tilapia is 4.0 million tonnes with an estimated value of around $ 3 billion. FAO reports indicate that the Global Tilapia production is expected to reach 7.3million tons by 2030. In countries like China, Egypt, Phillippines, Brazil, Thailand and Bangladesh Tilapia contributed substantially to the Food Security Programmes. Therefore, it was felt at the national level that Tilapia would be one of the candidate species which could be cultured to address the food security in general and cheap protein requirement of the growing population in particular.

The main advantage of rearing in ponds is that fish can be grown very cheaply through fertilization. Many different types of ponds are used for tilapia culture. The most widespread, but most unproductive are low input ponds with uncontrolled breeding and irregular harvesting; yields are typically 500-2000 kg/ha/yr of uneven sized fish. If monosex fish are stocked and regular manuring and supplementary feeding is practiced yields can be up to 8000 kg/ha/yr of even sized fish. Polyculture of tilapia with other native fishes in freshwater ponds is also widely integrated with agriculture and animal farming.

For brackish water pond culture of tilapia, the preparation of the pond and methods of culture are similar to those for milkfish. The Nile tilapia (*Oreochromis niloticus*) can only tolerate brackish water of up to 25 parts per thousand (ppt) while the Mosambique tilapia (*O. mossambicus*) can tolerate salinities of up to 40 ppt. The hybrid of the two species can withstand salinities by up to pure seawater (32 ppt). Stocking of tilapia fingerlings can range from 1 to 2 /m^2 for extensive culture and 4-5 /m^2 for intensive culture with water depth of 0.3-1 m. Use of pond fertilization, supplemental feeding, or commercial feeds can be applied depending on the cultural management. The culture period can last for 3-5 months and yields of harvestable-sized tilapia (100-200 g) can be 1-5 mt/ha per crop in intensive farming. With artificial feeding and culture periods of 3-5 months, yields of 30-50 kg/m^2 of harvestable-sized tilapia can be obtained.

11.Brackish water bivalve farming in Karnataka

Geetha Sasikumar

Introduction: Oysters, mussels and clams are commercially important bivalves distributed along the inshore and coastal waters of Karnataka. Bivalves are ideal species for farming as they are efficient converters of organic particulate matter (particularly phytoplankton) in the water column, to high quality protein. Thus, farming practices for bivalves, in the lower trophic levels are simple, less capital intensive and environment-friendly with no input cost on feed and feeding. The commercially important bivalves farmed along the coast are *Perna viridis* (green mussel) and *Crassostrea madrasensis* (Indian backwater oyster). Commercial mussel and oyster farming is established in Kerala (Malabar area), and recently in southern Karnataka.

Mussel Farming

Mussels are found attached to the hard substratum in the littoral to shallow sub-littoral zones of the coastal areas by secreting long fine silky threads called byssus threads. Bivalve farming is a relatively less intensive form of aquaculture that depends upon natural stocks for seeding.

Site selection: An appropriate culture site for mussel farming must have the following characteristics: 1) Moderate water currents (0.17-0.25m/s at flood tide and 0.25-0.35m/s at ebb tide) to provide adequate food supply; 2) 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; 3) Salinity above 20psu, but the ideal salinity for rearing is 27-35psu; 4) Sedentary bivalve fauna are exposed to very high probability of contamination therefore the site must be free from industrial waste, sewage, turbidity, harmful algal blooms and other pollutants; 5) Seawater with rich plankton is considered ideal for mussel culture; 6) Proximity of farming site to adequate spat or seed source is an important criteria for site selection; 7) Sites must avoid navigational channels and avoid interference with public right of access to fishery and allied activities.

Type of farming: Mussels are farmed in open sea or estuaries. **Open sea farming** is practiced in areas free from strong wave action, less turbulent and with high productivity, having 5-15m water depth. 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. 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 in areas having suitable substratum.

Farming method:

- **On-bottom method:** In areas where water depth is less than 1.5 m, mussels can be farmed by sowing directly on the bottom substratum/ or seabed.
- ***Bouchot* culture:** This method involves farming mussels in intertidal mud flats on poles combining spat collection with on growing.
- **Suspended farming methods:** For suspended farming method, the water depth can be a limiting factor as a minimum water column is essential throughout the culture period
  - ✓ **Rack method:** Racks are suitable in 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.
  - ✓ **Raft method:** Rafts are moored in open sea areas that are 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 metallic or 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 in unprotected open sea conditions and are particularly adopted in areas having high tidal amplitude. Synthetic rope of 16-20mm is used for the main-line, supported with floats at every 5m. Seeded ropes are suspended from the main line 1.5-2m apart. Long-lines with floats are anchored in position using concrete blocks and nylon ropes or metal chain at both the ends.

Seed source and seeding: Mussel farming mainly depends on the natural spat. The spat-fall in mussel beds commences from September to December along the west coast progressing from the south to the north. Mussel spats are collected by physically scrapping them from the intertidal or subtidal natural beds. Submerged beds are ideal for sourcing mussel seeds. About 500 to 750 g of 15-25 mm seeds are required for seeding 1m of the culture rope. Nylon rope of 16-18mm or 20-22mm 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. Within this period, the seed secrete byssus thread and gets attached to the rope.

Growth: The seeds, which get attached to ropes, show faster growth in the suspended water column. If the seeds are not uniformly attached, crowded portion always show slipping. To avoid slipping, periodical examination of seeded ropes and thinning are essential. The culture ropes should be placed at least 1 m above the sea floor during extreme low tides in order to prevent predators from reaching the bivalves. 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 when the condition index are high, *i.e.*, before the spawning and onset of monsoon. Normally harvest season is from April to May. Mussel ropes are removed manually and washed thoroughly using water jet to remove grit and silt. The mussels removed from the ropes are depurated in tanks to reduce bacterial load. In the depuration tanks about 10-20% of the seawater is continuously replaced. At the end of 12 h the water in the tank is completely drained and mussels are cleaned in running water to remove the accumulated faeces. The tanks are again filled with filtered seawater and the flow is maintained for another 12 h. 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. This method of depuration is effective in reducing the bacterial load of the mussel meat by 90%. Depurated mussels are then sold as live shell-on mussel or as meat. Meat shucking can be done in fresh condition or after boiling or steaming.

Oyster Farming

Oysters are highly esteemed sea food and considered as delicacy in developed countries. In India there is a growing demand for oyster meat in some parts of the country. Serious efforts are now being directed in its development under tropical conditions. Vast stretches of backwaters, estuaries and bays spread over several lakh ha are present along Indian coast harbouring natural population of the oyster suggesting suitability of the habitat for oyster culture. Kerala is the first state to commercialize this technology and many coastal villagers have benefited from this. These farming activities have increased national production of farmed oyster from nil to 3,500 t in 2014. Being filter feeders, the oysters convert primary production in the water into nutritious sea food.

Site selection: Sheltered areas offering protection from strong wave action are preferred. From intertidal region to areas extending up to about 5 m depth can be considered for adopting suitable culture method. In *Crassostrea madrasensis* sexes are separate but occasionally hermaphrodites occur. During spawning, ripe eggs and sperms are discharged into the exterior where fertilization takes place. Oyster seeds are collected from natural oyster beds by placing suitable collectors called cultch in the water column at appropriate period. Therefore, information on spawning period is essential for seed collection. The selected site should have sufficient breeding stock to insure spat fall. In Ashtamudi (Kerala) the spawning period is from November to December whereas, in Mulki (Karnataka) it is February to March and November. The *C. madrasensis* is highly euryhaline and are able to withstand a salinity range of 10-38 psu.

Farming technology:

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

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

larvae to settle. The larval period in *C. madrasensis* is 15-20 days. The ideal time for laying the spat collectors in the water is about 7 -10 days after peak spawning (as determined by gonad examination and abundance of early larval stages in the plankton). Strong currents interfere with larval settlement and may result in poor spat collection.

Farming method:

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

- **On bottom culture**: The oysters are grown either in the intertidal or subtidal area directly on hard substratum. For intertidal culture a minimum of 16 h submergence is suggested to ensure adequate food supply. Oyster seed attached to the collectors are planted on the bottom and allowed to grow for the market. The disadvantages of this method are increased exposure to benthic predation, siltation and low production.

- **Suspended farming method**
  - ✓ **Rack and ren method:** This method is also called ren method. Racks are constructed at 1 to 2.5m, depth as detailed above (see mussel farming). In the farm, the shell strings are suspended from racks.
  - ✓ **Rack and tray method:** The nursery-reared single spat or cultch-free spat from wild, measuring about 25 mm are transferred to trays of size 40 x 40 x 10 cm at a density of 150 to 200 oysters/tray. The tray is knitted with 2 mm synthetic twine of appropriate mesh and is suspended from rack. Once the oysters reach 50 mm length they are segregated and transferred to rectangular tray of size 90 x 60 x 15 cm these trays are placed on the racks. Each tray holds 150 to 200 oysters. The average growth rate of the oyster is 7 mm/month and at the end of 12 months the oysters attain an average length of 85mm. Compared to the string method, this method gives production but the production cost is high.
  - ✓ **Stake method**: A stake is driven into the substratum and on the top end one nail and on the sides two nails are fixed. The nail holds in position a shell with spat attached. The stakes are placed 60 cm apart. In this method, the nursery rearing of spat is carried on the same stake. For about two months the spat on the top end of the stake are covered by a piece of velon screen. Once the oysters attain 25-30 mm the velon screen is removed and in another 10 months they reach the marketable size.

Post-harvest handling and marketing: The oysters are harvested when the meat content (condition index) is high. Along Kerala harvest is ideal during May in Vembanad and Chettuva estuary and during August-October in Ashtamudi Lake. In Karnataka condition is high during September-November and March. Generally high condition index is obtained when the gonad is ripe prior to spawning. Harvesting is done manually and cleaned by jet washing and brushing. They are depurated in filtered sea water before marketing. The oyster meat can be removed from the shell by shucking. A stainless steel knife is used for the purpose. To render shucking easy, oysters are subjected to a wide range of treatments such as exposure to week hydrochloric acid, heat cold, vacuum, microwaves and lasers. Freezing the oysters or immersing them in hot water are the two methods commonly adopted. However in India steaming the oysters for 5 to 8 minutes has been found to be ideal to make the oysters open the valves.

Issues: The key issue in bivalve 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.

Prospects: The availability of large extent of suitable areas along the coast for farming; 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.

12. Integrated farming of finfishes and shellfishes

Geetha Sasikumar

Integrated finfish aquaculture is a system of producing fish in combination with other agricultural/ livestock farming operations centred on the fish farms. In this type of farming, the sub-systems are linked to each other to utilize the byproducts/ waste from one-system and thus ameliorate the environmental impact of monoculture. Combination of finfish-cum-bivalve farming is one of such integrated farming method that beneficially inter-link the fed-aquaculture with non-fed aquaculture, resulting in diversified farm output involving minimum financial and labour costs.

Intensive finfish cultivation in cage/ other farming systems can introduce significant quantities of nutrient wastes from uneaten feed, faeces and excretory products into the local environment. Along with the growth of the marine aquaculture industry, are the concerns regarding the environmental impacts from aquaculture waste. One of the major challenges for the sustainable development of aquaculture industry generally, is to minimise environmental degradation concurrent with its projected expansion. The metabolic wastes from aquaculture, particularly ammonia, are dispersed within the receiving water body and may contribute to localised hyper-nutrification. During seasonal cycles of nutrient availability, additional dissolved nutrient wastes have the potential to stimulate benthic algal production, increase phytoplankton production leading to localised eutrophic conditions, and alter dissolved N/P ratios that promote the growth of toxic algal species.

Environmental sustainability is the major consideration in integrated farming, therefore the criteria guiding species selection is the imitation of natural ecosystem. Combinations of co-cultured species will have to be carefully selected according to a number of conditions and criteria: (1) their complementary roles with other species in the system; (2) their adaptability in relation to the habitat; (3) the culture technologies and site environmental conditions; (4) their ability to provide both efficient and continuous bio-mitigation; (5) the market demand for the species and pricing as raw material or for their derived products; (6) their commercialization potential; and (7) their contribution to improved environmental performance.

In a conceptual open-water integrated culture system, filter-feeding bivalves are cultured adjacent to meshed fish cages, reducing nutrient loadings by filtering and assimilating particulate wastes (fish feed and faeces) as well as any phytoplankton production stimulated by introduced dissolved nutrient wastes. Waste nutrients, rather than being lost to the local environment, as in traditional monoculture, are removed upon harvest of the cultured bivalves. With an enhanced food supply within a fish farm, there is also potential for enhancing bivalve growth and production beyond that normally expected in local waters. Therefore, integrated culture has the potential to increase the efficiency and productivity of a fish farm while reducing waste loadings and environmental impacts.

The beneficial effect of combining bivalves such as mussels, oyster and clams as biofilters in utilizing such nutrient rich aquaculture effluents has been documented in estuaries. In a tropical integrated aquaculture system, the farming of bivalves (*Crassostrea madrasensis*) along with finfish (*Etroplus suratensis*) resulted in controlling eutrophication effectively (Viji *et al*, 2014). The filter feeding oysters improved the clarity of the water in the farming area; thereby reducing eutrophication. The optimal co-cultivation proportion of fish to oysters reported was 1:0.5 in this farming system.

In marine environment, integrated aquaculture has been often considered a mitigation approach against the excess nutrients/organic matter generated by intensive aquaculture activities. In this context, integrated multitrophic aquaculture (IMTA) has emerged recently, where multitrophic refers to the explicit incorporation of species from different trophic positions or nutritional levels in the same system. This method is different from the practice of aquatic polyculture, which could simply be the co-culture of different fish species from the same trophic level. Interestingly this practice has been defined based on pilot studies in marine habitats involving joint aquaculture of fed species, usually fish, together with extractive species such as bivalves and/or macroalgae. IMTA can also allow an increase in production capacity (for harvesting) of a particular site when regular options have established limitations.

Reference

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13.Brackish water cage culture development in Karnataka

A.P. Dineshbabu and Sujitha Thomas

Over the years the estuarine fishery which is one of the subsistence fishery of Indian coast is on a decline due to salinization of estuaries. Salinization is occurring mainly of two reasons, one the anthropological interventions to divert fresh water for irrigation and domestic and industrial use and the second one is the natural cause, due to slow process of climate change inflicted sea level rise which make most of the estuaries of India to remain more and more saline water dominated over the period of time. Grass root level impact of these multiple impacts are being felt by the fishermen who are being deprived of livelihood for last few decades and many of them are looking for alternative vocation for survival in this changing scenario. To address the livelihood issues of the coastal fishermen, fishermen Mangalore Research Centre of Central Marine Fisheries Research Institute, Initiated fin fish culture demonstration in the saline creeks and estuaries using euryhaline species. In southwest cost of India, where the tidal amplitude is less than 2 m, there is a good scope of installation of estuarine cages of reasonable expenditure and manageable operations. The State selected for designing and development of small scale cage culture technology was Karnataka, with a coast line of 300 km coastline and most importantly it has pristine unpolluted brackishwater/estuarine area of about 8000 ha.

Major research aspect in development of small scale cages in estuaries were selection of species, selection of material for cage construction. Care was taken to see that the cage are constructed from the materials which is locally available and affordable to the small scale fishermen and the designing of cages was done taking into consideration of its stability in water current, durability and the ease of management. Research trials also were done for perfecting the nursery rearing protocols to reduce mortality, culture experiments with mixed species culture and monoculture of species, possibility of extending the culture period for more than one year with modification of cages to withstand monsoon rain water flow in estuaries. Economic performance of these cages also was subjected to scientific analysis.

The experiments started with 5 cages in 2009-2010, has taken up widely by fishermen of the State with more than 35 cages being installed and maintained by fishermen themselves at various estuaries of Karnataka by 2014. Production increased from and average production of 350kg in 2010 with a culture period of 8 moths to average 3 tons/cage in 2014 with a culture period of 20 months. Modifications in cage materials and dimensions also helped in increasing production rate from these cages. The total production from small scale cage culture in estuaries In Karnataka increased from 1.8 t in 2010 to 11t in 2014 with an overall income of Rs. 11 million rupees in five years. More than the production and economies, the expertise acquired by the fishermen in fabrication, installation and maintenance of cages could empower them to have an alternate vocation and source of income besides fishing. These empowerment resulted in the improved socio-economic status of the fishers in the region which is visible in the enthusiasm being maintained in installing more and more cages every year. In light of availability of unpolluted brackish water area of 8,000 ha. in coastal Karnataka with 10 major and 16 small brackish water areas, a minimum of 260 cages could be installed without affecting the coastal environment there by augmenting a production of 260 t. of fish every year which generates an income of around Rs. 10 crores(100million).

Designing of low cost cages affordable for small scale fishermen:

The success of cage culture depends on the rigidity and stability of cages and its popularisation depends on its affordability and ease in operation and the production from it. Cage designs for culturing seabass, snapper, pearl spot and carangids which can be reared in the estuaries of Karnataka was designed with these important requirements in consideration. Modifications according to the depths of the water, water currents, tidal influx, bottom structure, easiness of operation, economic viability as well as availability of the quality and dimensions of commercially available fabrication material etc. were experimented. By these studies research team from CMFRI Mangalore could come out with designs of estuarine cages to suit all the estuaries of Karnataka with suggested modification in difference river systems and saline creeks. These models can be adopted almost all creeks along south west coast of India

Capture based Aquaculture System

Genesis of small scale cage culture started in Capture based aquaculture concept to utilise the seed resources of Karnataka for rueing in confinement. The juveniles of Lutjanus argentimaculatus, Etroplus suratensis and Lates calcarifer were collected from the nearby estuaries and it was stocked in the cage together as a mixed species farming. Following are the details of production from two cages of 2.5mX2.5mX2 m cages harvested in 2010 for a rearing period of 8 months.

With the experiments of seed availability and growth in cages, Lutjanus argentimaculates identified as the potential species to conduct capture based aquaculture in Karnataka.

Eventhough the growth was very promising in seabass the local availability of seed was very low when compared to red snapper.

To understand the growth performance of red snapper and seabass in monoculture experiments, culture experiments were carried out with mono-species stocking of Redsnapper and seabass.

Economic evaluation of small scale cage culture in estuaries

Small scale cage culture in Karnataka was initiated in 2008 as capture based aquaculture activity (CBA programme) with fish seeds collected from Karnataka estuaries. Cage model with 2.5 x 2.5 x 2 m was used in initial years and about 5 cages were installed in the estuary. The production from one cage was about 360 kg with a sale price of Rs 350/- total income per cage was Rs 1,26,000/- The success of this method of farming attracted more fishers to this method of culture and it spread along the coast of the estuary. Later the cage culture technology was extended along the coast of Karnataka. Various experiments on material of cage frames, net met aerial and cage dimensions has been carried out in Karnataka estuaries and now the most popular cage dimension adopted by fishermen is 6m.X2m.X2m with GI pipe frames and netlon outer net. Production from small scale cages in Karnataka estuaries are steadily increasing with horizontal extension of the technology in different estuaries and saline water bodies. The production statistics from small scale cage culture in Karnataka is given in the table below.

Production from small scale cages of Karnataka coast in last five years

Year	No. of Cages	Fishes stocked nos./cage	Harvested (t)	Revenue (lakhs)
2009-10	5	500	1.8	6.8
2010-11	7	500	2.5	9.6
2011-12	10	800	5.76	23.0
2012-13	12	800	6.9	27.6
2013-14	14	1100	11.0	44.4
Total			28	111.4

Through the project the fishers were able to develop another source of employment and income besides sea fishing. The fishermen learnt how to rear fishes in the cages for the first time and gained skills in efficient management of fishes in the cages. The additional income has resulted in the improved socio-economic status of the fishers in the region. In light of availability of unpolluted brackish water area of 8,000 ha. in coastal Karnataka with 10 major and 16 small brackish water areas, a minimum of 260 cages could be installed without affecting the coastal environment there by augmenting a production of 260 t. of fish every year which generates an income of around Rs. 10 crores.

Initiatives for popularisation of the technology

CMFRI after the perfection for the technology, conducted awareness programs, harvest melas, field days and exhibitions with involvement of State fisheries officials, bank officials, officials of Krishi Vigyan Kendra and prospective farmers along the coast. This resulted in horizontal spread of this technology to other districts. Trainers training, workshops and hands on trainings were conducted to empower State fisheries officials, faculties and students of Fisheries College to train the farmers in new areas to carry forward the technology throughout the State.

After five years of demonstration we felt that fishermen need financial support for adopting the technology is terms of initial investment and recurring coast. The major investment is cage construction and the procurement if seed. Construction of cage and mooring technology and material is readily available but in the case of seed supply intervention of development agencies is an absolute necessity. At present 35 cages are installed in different estuaries of south Karnataka. If support from developmental agencies are provided for the existing 35 cages and an addition of 15 cages in 2015-2016, annual production expected from 50 cages will be around Rs.150 lakhs (1.5 crores) per year. Net profit from one year successful culture will be more than the investment made on the infrastructure for seed and the cage. By mobilizing the feed from fish cutting plants and fishmeal plants the operational coast can be further reduce the expenses.

PROJECT REPORT FOR PRODUCTION FROM CAGE DIMENTION 6M X 2M X 2M FOR REGULAR CULTURE PERIOD OF 20 MONTHS AND ALSO FOR INTERIM HARVEST IN ONE YEAR.

1	Cage dimension	6m X 2m X 2m
2	Species cultured	Red snapper and seabass
3	Suggested stocking density	1200 nos./per cage
4	Culture period	20 months
4	Survival expected	80% (app.1000 nos.)
6	Average weight expected	3.0 kg.
7	Total production per cage	3,000 kg
8	Average price /kg	Rs. 400/-
9	Total revenue expected	12 lakh

Expenses:

10	Cage construction	Rs.
	GI pie frames (6m) 1.5 inch dia. higher gauge 10 bars	10,000
	Netlon material for outer cover 25 m roll	7,000
	Inner net (12 kg)	5,000
	Ropes	5,000
	Fabrication and mooring cost	8,000
	Floats	5,000
	Total construction coast	40,000
	(Structure last for 5 years)	
11	Seed cost @ 15 Rs./ no for 7cm seed (from Hatcheries from TN)	18,000
	Transportation charges	20,000
	Total expenses for 12000 seeds	38,000
12	Feed cost @ Rs.20/kg low value fish fish/ fish cutting waste 10,000kg	2,00,000
13	Maintenance coast	1,00,000
14	Total expenses	3,78,000
15	Profit expected	8,22,000

Note: In case of estuaries of heavy flow in monsoon and there is no sheltered places for keeping cages safe during monsoon, cages can be harvested in one year.

1	Cage dimension	6m X 2m X 2m
2	Species cultured	Red snapper and seabass
3	Suggested stocking density	1200 nos./per cage
4	Culture period	10 months
4	Survival expected	90% (app.1,100 nos.)
6	Average weight expected	1.2 kg.
7	Total production per cage	1,320 kg
8	Average price /kg	Rs. 350/-
9	Total revenue expected	4,62,000

Expenses:

10	Cage construction	Rs.
	Total construction coast	40,000
	(Structure last for 5 years)	
11	Seed cost @ 15 Rs/ no for 7cm seed (from Hatcheries from TN)	18,000
	Transportation charges	20,000
	Total expenses for 12000 seeds	38,000
12	Feed cost @ Rs.20/kg trash fish/ fish cutting waste 2,000kg	60,000
13	Maintenance coast	20,000

14	Total expenses	196000
15	Profit in one year culture period.	2,66,000

Feed source for future development of small scale cages:

Small scale cage culture of finfishes in coastal waters initiated by Mangalore Research Centre of CMFRI during 2008-09 has resulted in large scale adoption of the technology resulting in increased fish production from Karnataka coast. The fish production from finfish culture in small cages in Uppunda village in Udupi district, Karnataka increased from 1.2 t in 2009-10 to 14 t in 2013-14. The fishermen gained experience and confidence in finfish farming which encouraged them to continue fish culture in cages using seeds collected from the wild as well as hatchery bred fingerlings procured from east coast of India. The success of cage farming in estuarine areas which was launched as a pilot project in Uppunda village of Udupi district was received well by the fishers and it is extended to other estuaries. The fishers in Alvekody, Kundapura and Mulky estuaries have adopted the technology and extensive rearing of fishes is in progress. This technology intervention has augmented fish production and provided alternate livelihood options as well as food and nutritional security to the fishers of the area.

In light of availability of unpolluted brackish water area of 8,000 ha in coastal Karnataka with 10 major and 16 small brackish water areas, a minimum of 260 cages could be installed without affecting the coastal environment there by augmenting a production of about 260 t of fish every year which would generate an income of around Rs 10 crores. The availability and cost of seed and feed were most important impediments which hampers the feasibility and success any aquaculture operation. Many times interventions of Government agencies could solve the problem of availability of the seed of cultivable species. In Karnataka scenario also fishers are optimistically looking forward to such interventions. In India, unavailability of cost effective feed is projected as major problem in fin fish culture , especially for rearing carnivorous fishes. Since the farming practice is being carried out in a low intensity due to non-availability of sufficient fish seeds, so far feed related issues are not reported from cage farmers of Karnataka. But looking at the pace of adoption of the small scale cage farming technology, and anticipation government intervention to ensure sufficient seed supply, Central Marine Fisheries Research Centre of CMFRI anticipates an annual production of 250 to 300 t fishes from small scale cage farming from Karnataka estuaries in immediate future. Anticipating the feed demand for such production in future, Mangalore Research Centre of CMFRI has carried out extensive survey in the State for finding out options for fresh feed availability.

The surveys revealed that lot of fish cutting centres are established for pre-processing of fish along coastal areas to cater to the need of surimi plants and also for frozen fish exports. Along Karnataka around 25 fish cutting centres are established in Mangalore, Malpe, Kundapur and Karwar. These fish cutting centres process pink perch, lizardfish, ribbonfishes, lesser sardines, etc. and the dressed fishes are supplied to the surimi plants and also for direct export as frozen fish. The pre-processing of fish in these centres generates enormous amount of cutting remains and it accounts for approximately 20-30 % of total fish weight, based on the species of fish being processed. This cutting remains (head and tail portion) has more than 10 % meat and was found to be well accepted by snappers and seabass. Feeding of seabass and snappers with fish cutting remains from fish cutting plants is being practiced by some of the fishermen in Udupi district of Karnataka and is found to be an excellent feed source. Most of the fish cutting sheds have the capacity to produce 10-15 tonnes of processed fish daily during peak season of fishing when the availability of raw material in plenty.

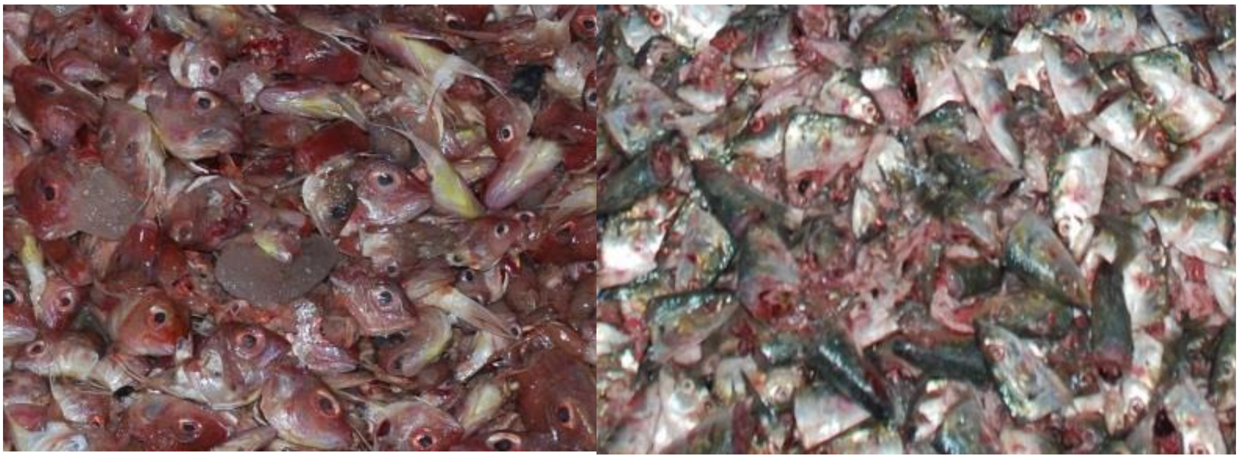


Fig.2. Cutting remains of pinkperch, and oil sardine in one of the fish cutting sheds located at Malpe, Karnataka.

As much as 35,000 to 40,000 tonnes of fishes are being processed by these fish cutting centres of D.K and Udupi in one year which generates about 7,000–8,000 tonnes of cutting remains in a year and now it is being diverted for fish meal preparation. If some portion of these cutting remains is used for feeding the high value fishes cultured in the estuarine small scale cages, it will augment fish production from the Karnataka as well it will improve the socio-economic status of the fishermen/farmers in future.

14. Cage design, fabrication and mooring

Sujitha Thomas and A.P. Dineshbabu

Designing of low cost cages affordable for small scale fishermen:

The success of cage culture depends on the rigidity and stability of cages and its popularisation depends on its affordability and ease in operation and the production from it. Cage designs for culturing seabass, snapper, pearl spot and carangids which can be reared in the estuaries of Karnataka was designed with these important requirements in consideration. Modifications according to the depths of the water, water currents, tidal influx, bottom structure, easiness of operation, economic viability as well as availability of the quality and dimensions of commercially available fabrication material etc. were experimented. By these studies research team from CMFRI Mangalore could come out with designs of estuarine cages to suit all the estuaries of Karnataka with suggested modification in difference river systems and saline creeks. These models can be adopted almost all creeks along south west coast of India

Cage model I.

The experiments in cage design were started in Upunda creek in Kundapur, where the average water depth at lowest low tide low tide was around 2m. The tidal flow was found to be sufficient to make efficient water exchange in the cages. In this creek the first indigenously fabricated cages by CMFRI was introduced.

Cages of 2.5 m x 2.5 m x 2m was fabricated with Bamboo poles as cage frames and netlon material as outer protective net. Nylon net of varying mesh sizes were used as the inner net. PVC pipes were used as floats for suspending the cage in the water. The netlon structure serve as an effective barrier and protect inner net from predators and big fishes. It also hold the shape of the cage in even in heavy water flow without reducing the water holding capacity of the cage. PVC pipes were used as floats for suspending the cage in the water. Additional flotation was given by empty oil cans. Sufficient length for the cages leg (2 to 3 feet) are given so that the cage will rest on this legs in the bottom in the case of lowest low tide. This will avoid the damages to nets by avoiding hitting and abrasion with hard and sharp substances in the bottom. The effective volume available for fish rearing in cages of 2.5 m x 2.5 m x 2m was around 12 tons. A stocking rate of 40 nos /ton is found to give a survival rate of 90-95% with average weight of 800g by the end of 8 month culture period. Average price for Seabass and red snapper ranged from 250 to 400 Rs/kg. At a minimum farm gate price of Rs.

250/kg, the revenue from Cages of 2.5 m x 2.5 m x 2m dimension is expected is around Rs. 80,000. CMFRI proved its economic viability from the demonstration experiments conducted with these cages. Since bamboo poles were used for the frame making, the lifespan for the frame was found to be 1 year. While dragging the cage to shore for the harvest, there was considerable loss of shape and fresh frames has to be fabricated for second crop. If proper periodical cleaning of fouling materials were done, netlon outer net found to last for three years. This cage models were very light in weight which can be carried by two people and also can be transported in a small dugout canoe. But due to low durability of the cage frame, further modification were experimented for longer durability.

Fig. Cage frame with bamboo poles 2.5mX2.5mX2m dimension

Cage model II.

In order to give more durability to cage frame and also to have efficient harvesting with frames intact shape, GI pipes were used for the cage making in the second phase. With stronger frame the cage frame the dimension of the cages also increased in second model. The second model was with 4mX2mX2m. with GI pipe frames. One inch GI pipes were used for the construction of the cage frames. This cage as such is found to last for three seasons. Since the commercially available netlon material is of 2m width, in order to reduce the wastage of material, height and width of the cage was made to 2m., which was sufficient for most of the estuaries as far as height of the cages were concerned. The strength of bamboo framed model was not strong enough for the estuaries with very high water current like Netravathi estuary, in Dakshina Kannada. But the GI framed model is found to be stable throughout the year in the high flowing riverfed estuaries. The PVC pipe in the top of the cages was retained for floatation in some models but later the floatation was done with empty plastic cans available in the market. The PVC pipes used for floatation were found get filled up with water when it is damaged by any reason. The empty plastic cans are comparatively inexpensive and with progression of period of culture there is a provision of increasing the number of cans to provide sufficient floatation.

Fig. Cage frame with GI pipes poles 4mX2 mX2m dimension

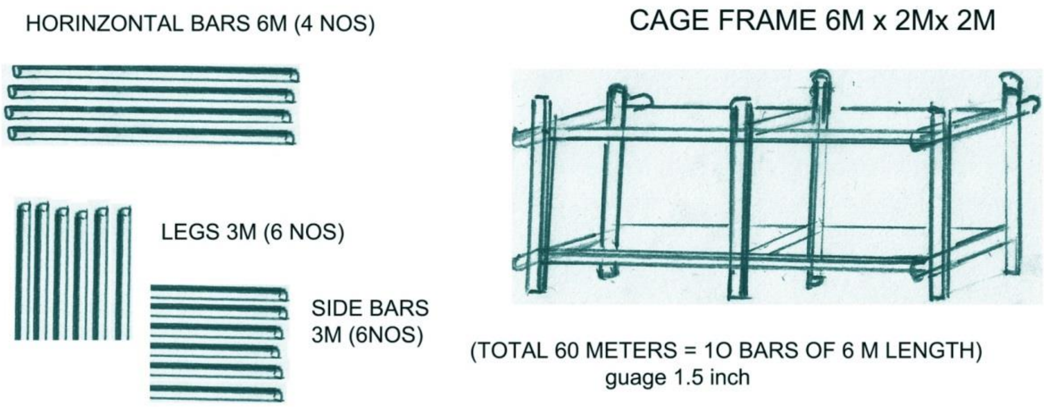
The quantity of water in this model was about 16 t and with a stocking rate of 50/t, 800 seabass or snapper per cage was suggested stocking rate, which were found to attain an average growth of 800g at the end of 8months. With 90% survival total production per cage at the end of 8 months is expected to be 0.5 t. This model is found to be the best model, which was recommended for the estuarine cage culture in Karnataka with its proven stability in heavy tidal influx, durability for three years and easy handling during installation and harvesting.

Cage model III.

Most popular cages designed for the estuaries with heavy current

Cage model II was well accepted all along the areas tested, there found to be little wastage of GI pipes with 4m length model. The GI pipes are sold with a standard size of 18 feet and in order to avoid wastage of material, the length of the cage was extended to 6m, with a dimension of 6mX2mX2m. This has a water holding capacity of approximately 24 tons. Higher density GI pipes and one or two middle support was found to be essential for 6 meter cages to keep the stability and shape.

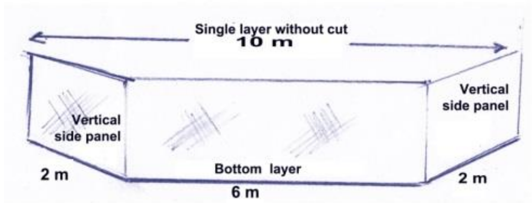
Presently in order to improve the strength of the cage frames in 6m cages 1.5 inch GI pies were used. The installation and harvesting from these cages were found to be is labour intensive in this type of models however in the areas of heavy water flow and wider water spread this types of cages can be used to increase production per cage. When 1 inch gauge GI pipes are used, two ribs were provided for keep the stability pf 6m long cage , If 1.5 inch gauge GI pies are used, one rib in the middle can support to retain cage shape. Welded joints and bolted joints of GI pipes were tried out in different occasions to understand its advantages and disadvantages. It was found the when the frame was made rigid with welding/ permanent bolting the pressure on the cages were very high and GI pipe found to break comparatively faster, when flexible tying of GI pipes with old net pieces were tried out, it found to give total flexibility to cages, with more efficiency in to withstanding heavy currents. Now most of the fishermen are using fishermen knots with old nets to secure the joints in the cage frame.



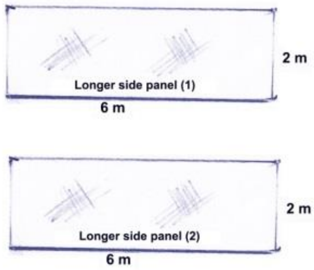

Outer cages:

The netlon is used for the fabrication of outer cage . Netlon structure serve as an effective barrier and protect inner net from predators and big fishes. It also hold the shape of the cage in even in heavy water flow without reducing the water holding capacity of the cage. Generaly a netlon bundle will have 25 meters of 2m width netlon roll. TRhis can be cur into three pieces as given in th figure (..) to make maximum use of the netlon with minimum joints to make 6mX 2mX2 m cage.

Long panel (10m)



Two cut side panels (6m each)



NETLON

Inner cages:

Inner cages are fabricated according the size of the seeds stocked. Hapa may be needed when the fishes reared from juvenile sizes. Inner cage should be tied to the cage frame in the corners with provisions to remove at any point of time. The length of the rope is so adjusted that the loosening and tightening of inner cages can be operated without underwater diving.

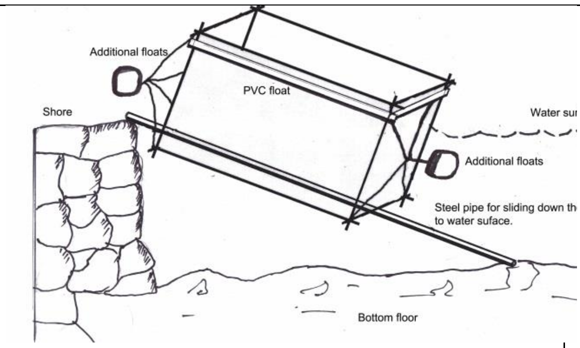
Floatation:

The PVC pipe in the top of the cages was retained for floatation in some models but later the floatation was done with empty plastic cans available in the market. The high gauge PVC pipes used for floatation were found to last for many seasons but comparatively expensive, In some cases water is found to seep into the tube, which may lose its floatation capacity. The empty plastic cans are comparatively inexpensive and but last for three to four months, with progression of period of culture for increasing floatation it is always better to keep for to six plastic drums or cans for emergency.

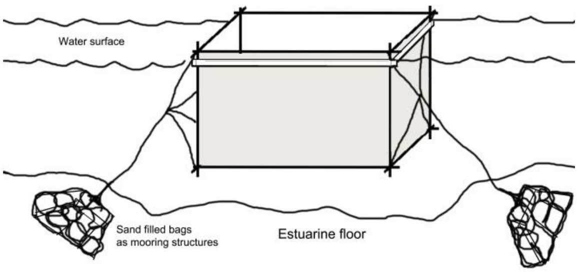
This model will hold 24 tons of water. With a suggested stocking density of 50 nos/cages, 1200 seabass or Snappers can be stocked. With an anticipation of 90% survival and average weight per fish of 800g in a season, the expected production will be around 0.7 tons. Most important feature of GI pipe frames cages are that the cages can be retained in moored position over three seasons which will help the fish to grow to 3 to 5 kg (5.350 kg seabass was harvested in 2015 in 20 months) of in two seasons. In this cases four fold production from these cages (upto 3t) can be anticipated with a higher price for the fishes which can fetch more than Rs. 500/kg in monsoon months.

Cage mooring:

Successful mooring of the cages is the key for the cage culture. The mooring should be according to the depth, substratum and the current speed. Cage can be sided down to estuary with help of iron rode or wooden logs for east transferring to water surface. This will reduce man power requirement and also avoid damage with abrasion and change in shape. Nylone ropes are used for mooring rope and in estuaries sand bags are providing necessary support to keep the cage in position. Generally sand bags are given in two points, where the shore is too close an additional mooring is also given to avoid the cage touching the shore.



Cage shifting to water surface



Cage mooring with sand bags

Construction cost of 6mX 2mX2 m cage.

S.No	Items	Rs.
1	GI pipe frames (6m) 1.5 inch dia. higher gauge 10 bars	10,000
2	Netlon material for outer cover 25 m roll	7,000
3	Inner net (12 kg)	5,000
4	Ropes	5,000
5	Fabrication and mooring cost	8,000
6	Floats	5,000
	Total construction coast	40,000

15. Feeding and maintenance of fish cages

Rajesh K. M.

The sustainability, profitability and well-being of aquaculture systems depend on the feed quality and feeding practices. The adequate supply of nutrients, both in quantity and quality are essential for growth, health and reproduction of fish and other aquatic animals. Hence, feeds used should be nutritionally balanced, highly digestible and economical for the species cultured. In addition to the quality feed, feeding management is also equally important for the sustainability of cage culture. For maximum production and profits, farmers are interested in a high rate of feed consumption. However, the loss of nutrients, if feed is not consumed immediately and uneaten or excess feed represent an economic loss as well as a possible source of environmental pollution. Thus, feed should be fed in such a way as to minimize waste, optimize growth, allow for efficient conversion, minimize stress and maintain fish health.

Types of feed: The feed for fish culture is broadly categorized in three types viz. dry feed, moist feed and semi moist feed. The dry feeds are readily available in market and can also be prepared knowing the requirements of cultured fishes. It is generally available in steam pelleted, partially extruded (slow sinking), expanded & floating types. These feeds can be used according to feeding type of the target fish species. Moist and semi moist feeds are normally prepared using trash fishes, molluscans, crustaceans locally available and some additional supplements like binders etc. For moist & semi moist feeds, availability of trash fishes in local area and its quality (freshness) plays vital role. Some fishes have feeding habit of carnivorous type, in such cases chopped fish meat can be used. The farm made feeds can also be prepared by using the ingredient composition according to the nutritional requirement of the species cultured.

Feeding rates: The feeding rate is calculated according to percentage body weight of the fish on per day basis. During initial stages of fishes (larval, fry, fingerlings) feeding rates are generally higher (5-10%) further it is reduced up to 3-4% per day as the fish grows up to harvest. The feeding rates are dependent on fish size and water temperature also.

Feeding frequency: The frequency is decided after finalizing the feeding rate. Suppose, fish stock is fed at the rate of 5% body weight per day. The quantity of feed to be fed at the rate is equally divided in 2-3 portions which are fed to the cultured stock in morning, afternoon and evening. It helps in preventing overfeeding at a single time resulting in reducing loss of feed.

Since major operational expenditure goes towards feeds, the optimal conversion for feed for growth can be achieved only by efficient feed management.

Following are some guidelines for effective feed management

i) Observation of fishes during feeding - It indicates the overall health of fishes. Active feeding behaviour indicates everything is all right. However, poor feeding response should always be viewed seriously. Observations of fish feeding activity can be made from above cages only if floating feed is used. If sinking feed is used, it will be necessary for a diver to go beneath cages to determine if uneaten feed is accumulating on the bottom.

ii) When temperature reduces suddenly, the feeding level should be reduced.

iii) Stop feeding during stormy or extremely calm weather conditions. These conditions can lead to low dissolved oxygen.

iv) Quality of feed must be ensured before procurement. Feed must be kept in cool, dry place, and utilized within three months of manufacture. For moist feeds and trash fishes, spoiled items should be avoided.

v) Install feeding trays for sinking feed and feeding rings for floating rings to reduce feed wastage.

vi) Prepare feeding schedule to avoid overfeeding. Feeding frequency should not be exceeded beyond 3.

vii) Regularly assess the quantity of fishes stocked in the cage and their weight for calculating the exact feed requirement.

viii) Do not over feed if the fishes are not consuming feed.

ix) Grading of fishes is important at regular intervals.

Fish cage management

In addition to biofouling, the net walls of cages are subjected to siltation and clogging. Biofouling is unavoidable since the net walls usually represent a convenient surface for attachment by organisms such as amphipod, polycheate, barnacles, molluscan spats, etc. These could lead to clogging and reduce exchange of water and may result in unnecessary stress to the cultured fish due to low oxygen and accumulation of wastes. Feeding and growth would likewise be affected.

The cage nets should be cleaned regularly to prevent excessive fouling that may result in net breakage and heavy losses of fish. The smaller the mesh size, the heavier the rate of fouling. The small mesh size nets of less than 2.5 cm must be cleaned every week, whereas the larger size nets in 2-3 weeks intervals.

Regular observation of cages is required. Since fish cages are immersed under water all the time, they are vulnerable to destruction by aquatic animals such as crabs, otter, etc. If damaged, they should be repaired immediately or replaced with a new one. Dead fish should be removed promptly from cages and disposed by sanitary methods

Cages should be placed in areas with good water circulation. Cages should be moved about 300 ft at least once each growing season to protect sediment quality. Measures must be taken to minimize the potential escape of non-native species.

The main precaution against pollution is to locate cages in open water areas where water circulation is good. This will favor transport of wastes away from cages and rapid mixing and dilution of wastes by the water body. The distance between cage bottoms and the bottom of water bodies should be at least 4 to 6 ft to promote water movement beneath cages.

Too many cages can result in severe organic enrichment and dissolved oxygen depletion throughout the water column. This phenomenon has been responsible for serious mortality of fish both inside and outside of cages.

Wastes may accumulate beneath cages and cause deterioration of sediment quality. This is environmentally undesirable, but it also can have negative impacts on the fish in cages. Sediment quality in areas where cages are located can be protected by periodically moving cages a distance of at least 300 ft to a position where sediment quality has not been recently impacted by cages. Observations on sediment quality could be used to determine when to move cages, but there are no easy ways of evaluating sediment quality. Thus, cages probably should be moved after each crop of fish or at a minimum of 6 to 8 month intervals. Relocating cages will prevent sediment under them from reaching a severe stage of impairment and allow its quality to improve.

Cages should also be located as far as possible away from discharge outfalls form industries, municipal treatment plants, obvious urban storm water runoff collection systems, and other potential pollutant sources in areas with increased potential for accidents or spills.

16. Growth rates of cage reared fishes

Sujitha Thomas and A.P. Dineshbabu

Growth may be defined as an increase in volume and weight over time. In aquaculture the aim is to achieve the maximum growth (or increase in body weight) of each individual fish within a certain time. Knowledge of their nutritional requirement and digestive mechanism is an essential key to obtaining good growth. The growth rate and physiological efficiency of growth is largely determined by temperature, food quality and quantity. Generally growth is faster at lower stocking densities than in higher stocking densities. Specific growth rate (SGR) of the fish can be calculated as follows

$$\text{SGR (\%body wt gained/day)} = \left[\frac{\text{Log}_n \text{ Final fish wt} - \text{Log}_n \text{ Initial fish wt}}{\text{Time Interval}}\right] \times 100$$

The growth of redsnapper and seabass in cages were monitored regularly and the good growth was observed during the culture period. It was also observed that low mortality was found during the second year period.

Monoculture of red snapper in estuarine cages

Monoculture experiments of red snapper of 4mX2mX2m. GI pipes were used as frames for the cage making. Stocking was done continuously during September-December 2011. The quantity of water in this cage was about 16 t and a stocking was at the rate of 50 numbers/t. Approximate stocking density was 800 to 1,000 numbers per cage. The redsnappers attained a weight ranging from 800 to 1,200 g with an average weight of 900g. There was 95% survival and the total harvested weight was 850 kg. With a farm gate price of Rs. 300/kg the income from one cage was about Rs. 2,50,000. Approximately 1500 kg of trash fishes and fish cutting waste were used for the production of 800 kg of redsnappers.

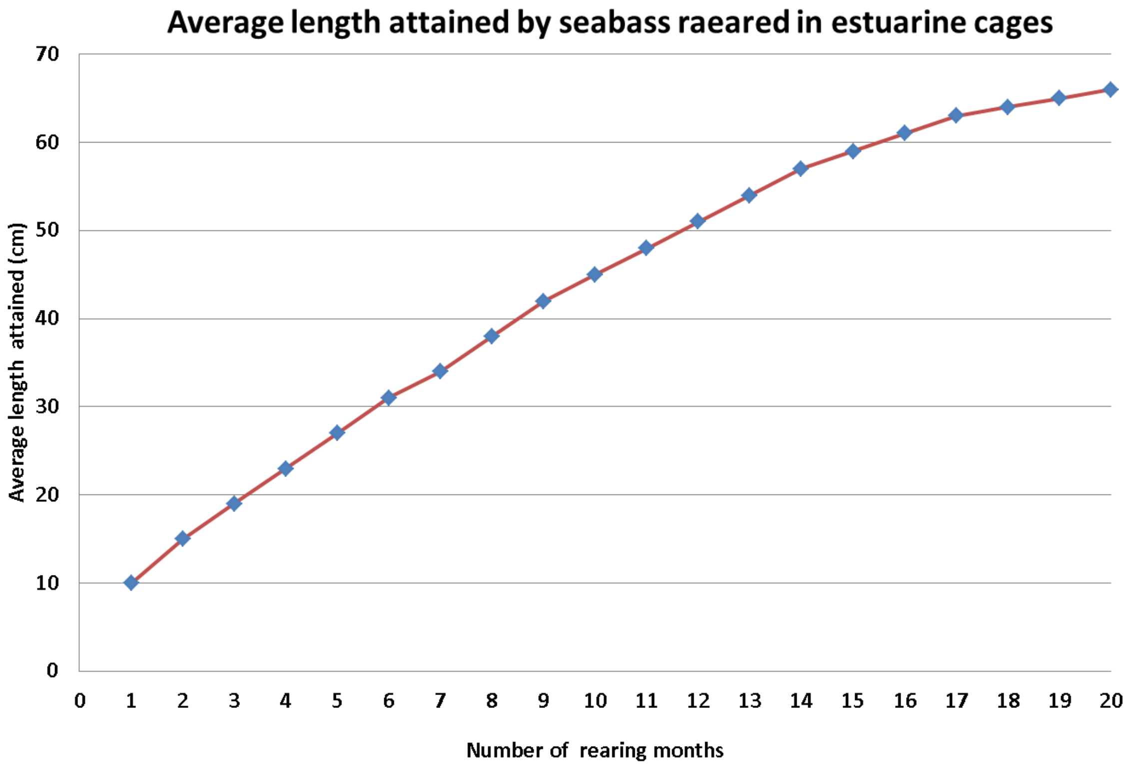
Experiments were carried out to understand the possibility of continuing the culture for more than one season and to understand the capability the fishes to tide over the monsoon condition. Fifty numbers of red snappers with an average weight of 1kg were reared for the second year. The major objective of the experiment was to study its growth rate in two years and also to investigate the possibility of making it into brood stock for breeding experiments in the laboratories of CMFRI. In 19 months (by March, 2014) the fishes were grown to a weight of 1.6 to 2.3 kg with an average weight of 1.8 kg. Mortality was not seen in the second year. The average weight during the start of the experiment in July, 2013 was 50 kg in total (1kg/fish) which was grown to total weight of about 90 kg in nine months.

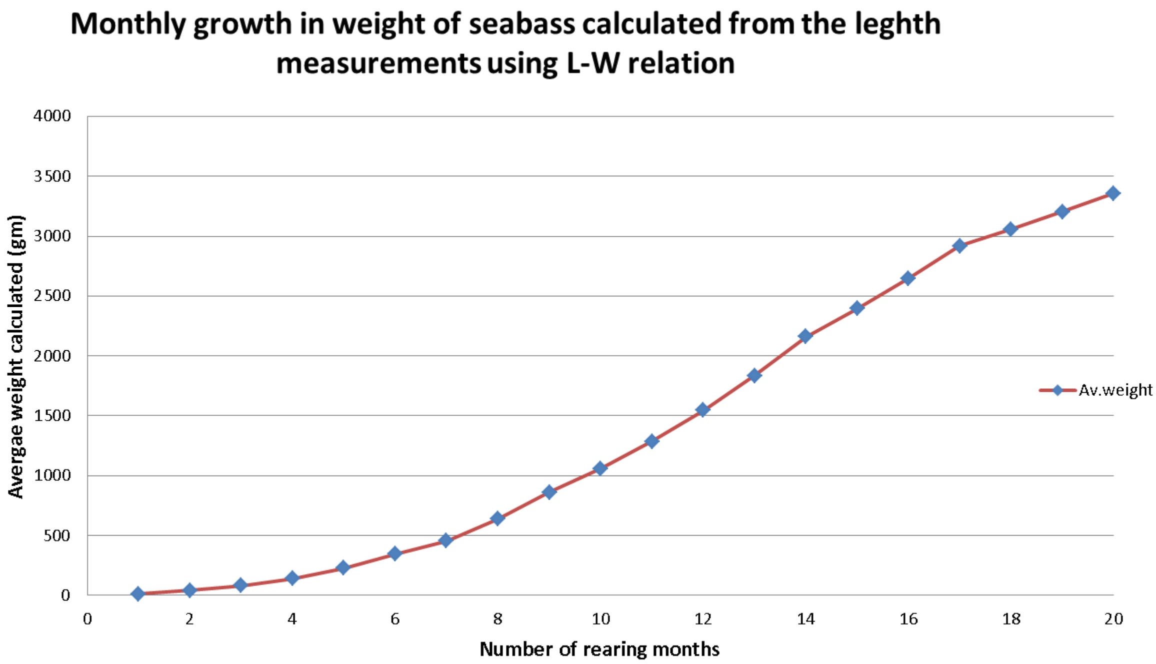
Harvest of Red snappers, 2013

Live fishes collected for brood stock development

Monoculture of seabass in estuarine cages

Sea bass was the most preferred species for the culture in Karnataka due to its high growth rate. The seed source was only from the east coast. In early stages of rearing there found to have a heavy mortality till 10mm size due to cannibalism and water quality. But new nursery protocols of grading of juveniles in haps in the cages reduced the nursery mortality and the survival rate of seabass improved substantially. In 10 months seabass grows to an average size of 50cm with an average weight of 1200g. in 12 months fishes reached 2kg (60cm)and in 18 months the fishes reached an average weight of 3.3kg (75cm). Oil sardine was the most preferred feed and the increase in weight depends on the feeding rate which should be given two times daily .





17. Harvesting and marketing of cage reared fishes

Sujitha Thomas

Being successful at raising fish in cages is not enough. Harvesting, keeping records, marketing, and looking at the economics of the venture are also essentials in successful cage culture. This is particularly true if the goal is to increase farm income.

Harvesting cages is simply a matter of removing the fish from the cage with a dip net. Usually for removing fishes the cages are brought up to the surface by adjusting the floats so that water volume will reduce in the cage . Then the fishes are harvested using dipnets or seine nets. At times the cages are brought to the shore during high tide and when the water recedes the cages are toppled and fishes are harvested. This is one of the major advantages of cages and usually the reason people picked cage culture in the first place. Harvesting can begin whenever the fish reach market size. The market size depends on the species being raised and the market that has been identified. Time for fish to reach market size usually depends on the size of the fingerlings stocked and the overall conditions during the growing season.

All the Fishes do not grow at the same rate. Some fish that reach harvest size early may be removed. Partial harvest is done at times in order to reduce the stocking density.

Before harvesting it is important to sample the fish. Feeding should be stopped for a day prior to harvesting. This gives the fish time to empty their digestive systems and reduces holding and processing problems. At harvest record the number of fish harvested and their weight (length records could also be useful). These records will be necessary to analyse the success of your venture.

Ideally, identify your market before you stock, but always plan your marketing before you harvest. Having no marketing plan will mean frustration and reduce your chances of a profitable venture. Most fish can be sold either live or dressed (processed).

Several possible markets exist for your fish. Which markets are best for you may depend on the number or volume of fish you have to sell, your ability to transport the fish, your ability to process the fish, and your proximity to known markets. Possible markets include:

- live sales direct to consumers,
- direct sales to consumers of processed fish,
- sales to local processing plants,
- and sales to local restaurants

Small producers, with only a few hundred fish to sell will probably find their greatest profit in selling directly to the consumer. Direct sales of live or dressed fish reduce middleman costs and bring all the profit back to the fish farmer.

For seabass and the redsnappers usually the harvesting is planned during the June- July months when trawling is not there. This gave very good price for the harvested fishes.

18. Biofouling in cage aquaculture and management measures

Geetha Sasikumar and B. Santhosh*
***CMFRI, Vizhinjam**

Introduction: The accumulation of unwanted biological matter on surfaces with biofilms created by microorganisms and macro-organisms are referred to as biological fouling or biofouling. The fouling by inorganic or non-biological material also occurs from deposition of suspended particles, corrosion, crystallisation, oil and ice. Marine and industrial biofouling generally include a combination of biofilm, macro-fouling and inorganic fouling, which has economic consequences. In aquaculture, cage nets are exposed to biofouling pressures, hence considered as a major problem and expense factor worldwide.

Biofouling process: The process of biofouling begins when microorganisms make a transition from free-floating to sessile lifestyles, thus initiating the formation of a biofilm prior to colonisation. Within a short interval, these microorganisms adhere to one another and collectively to the surface with an adhesive known as the extracellular polymeric substance (EPS). The submerged surface gets covered with a biofilm, which continues to become more diverse by attracting more microorganisms through chemical "messages". The biofilm covered surface then attracts previously deterred secondary colonisers (macroalgae, protozoans and others) due to the rich nutrients and ease of attachment into the biofilm. Within two to three weeks, the tertiary colonisers or the macrofoulers attach to the surface. Initial settlement of microorganisms on the submerged surface is reversible, but once they secrete the EPS, the bond become irreversible. This permanent attachment allows initial growth, final growth and dispersion.

Biofouling in cages: Multi-filament cage webbings are an ideal substrate for fouling since it has many crevices which can entrap and protect settling organisms. Furthermore, the high level of nutrients generated near cage aquaculture systems through losses of fish feed and faeces, becomes a suitable food material for non-selective filter feeders.

Apart from the microbial load, the typical biofouling communities reported on cage netting can be grouped under algae, molluscs, hydroids, crustaceans, bryozoans and ascidians. On a global scale, the most common fouling organisms are ascidians, bryozoans, barnacles and mussels, with ascidians reported from the northern hemisphere and barnacles having an almost universal distribution.

Intensity and diversity of biological communities that develop on cage nets are distinctive to the specific geographic location and farming environment, for example, in Gulf of Mannar and Palk Bay, barnacles were predominant, forming a very thick mat on the net cages. Barnacle infestation was higher in net cages with smaller mesh sizes. Besides barnacles, the fouling communities also included the rock oysters, pearl oysters, sponges, seaweeds, ascidians and *Modiolus* sp. Along Vizhinjam Bay the biofouling organisms were more diverse. Barnacles (*Balanus* sp.) along with rock oysters, brown mussel, algae (*Ulva* sp.) and sponges were the main epifauna on cages causing maximum damage to the nets. The increase in weight due to biofouling was mainly due to oysters, mussel and sponges. The colonial ascidians, solitary ascidians, hydroids, serpulid worms, nematodes, oligochaetes, polychaetes, harpacticoid copepods, amphipods, brittle stars, pearl oyster, algae, isopods and small crabs also contributed to the biomass. Seasonal variation in biofouling community biomass was recorded in open sea areas. Community biomass along Vizhinjam that was highest during post monsoon season (88g/0.01m^2) reduced to one-fourth (20g/0.01m^2) during monsoon. Similarly in Karwar, the hydroids and barnacles that were documented as the dominant groups in open sea cages, exhibited seasonal and depth variations in distribution.

Compared to open sea, estuarine areas generally harbour dense natural beds of euryhaline bivalve population. Heavy biofouling by marine macro-foulers, dominated by bivalves have been recorded on the webbing of fish cages installed near the bar mouth of the Mulki Estuary, where water movement was dominated by tidal flow. Majority of these biofouling organisms included Indian backwater oyster, C*rassostrea madrasensis* (Indian backwater oyster), *Saccostrea cucullata* (rock oyster) and green mussel *Perna viridis*. Among oysters, C. *madrasensis* accounted for 95% while *S. cucullata* contributed 5% of the biomass. Reduction in salinity may be attributed to the reduced representation of rock oysters as well as marine biofouling organisms, particularly barnacles, in estuarine cages when compared to open sea cages.

Nets can visibly foul within two to three weeks of immersion. In estuarine areas where there are clear diurnal and seasonal variations in salinity, the biomass of euryhaline oysters are reported to be higher than the marine mussels, for example, fouling of biomass of 2.8 kg m^{-2} for mussels at intensities of 110 individuals m^{-2} have been observed on untreated cage netting which had been immersed for 10 months without net exchange in Mulki. While the fouling biomass of C. *madrasensis* was nearly 8.4 kg m^{-2} at intensities of 190 individuals m^{-2} on the same net panel. Biofouling assemblages on nets have been shown to vary significantly with depth with prominent vertical zonation in bivalve distribution on net. In Mulki estuary, oysters were distributed on the upper zone from 0.3-1.7m, while 1.7-2m zone as well as cage bottom had a mixed community of mussels and oysters. The differences between biofouling at the various depths could be due to various factors which affect vertical zonation of fouling organisms. In open sea conditions, the light intensity, recruitment from larval stages, current velocity, nutrient input; and variations in oxygen conditions, among others plays a very important role in determining community composition with depth. While in estuarine conditions, this zonation in distribution can be attributed to the salinity, which changes with the tidal cycles in the estuary. As high saline waters are heavier, the mussels attached to the deeper waters experiences relatively narrow variations in salinity, while the hardy oyster species that can tolerate the broader changes in salinity, flourish even on the surface zone of net-cage.

Bivalve biofouling organisms are associated with rocky and benthic communities. The siting of the finfish farm within a sheltered area, near natural bivalve beds, possibly provides an easy recruitment of spat from the surrounding water onto the nets. In Mulki, two size groups of *P. viridis* were recorded on the cage panels moored in estuarine waters during June. This corresponded to the major spat settlement in November-December (70.2 mm) followed by a minor settlement in March-April (40.4 mm) in the region. Similarly, shell length of *C. madrasensis* varied between 54 and 74 mm. It is therefore possible that the oysters were recruited on the net panels from the immediate environment corresponding to the spat settlement in February-March and November.

Impact: Biofouling greatly reduces the efficiency of cage materials and equipment. Rapid biofouling on fish-cage netting materials influence the structural elements of cages during submergence. This significantly impedes the water flow and thereby reduces the supply of dissolved oxygen to the caged fish as well as removal of waste. Biofouling communities can harbour diseases. In case of bottom-dwelling finfish stocks, contact with hard fouling may result in physical abrasion. A number of benthic marine organisms within the biofouling communities produce secondary metabolites as part of the anti-predation strategies. These chemicals can be toxic to other marine organisms including the culture stocks. Exchanging cage nets to control biofouling can increase stock stress and the associated mortalities.

Indirect effects of biofouling in net cages include remedial cost. Therefore, biofouling in cage farming industry is an expensive problem with highly labour intensive solutions (cleaning, repairing and exchange of nets) and material cost (cage materials, antifouling paints).

Management options:

In cage aquaculture, different methods have been developed to control biofouling, but there are no sustainable and cost effective solutions. The physical methods to control biofouling is the mechanical cleaning of cage webbing by brushing, scraping or regular and frequent jet washing using high power pumps. Air drying the nets and cleaning using high pressure water jets is one of the solutions for controlling biofouling. However, net changing procedures are labour as well as capital intensive. Chemical methods involving the application of biocidal coating on nets are widely employed in cage aquaculture. Such antifouling emulsions, based on cuprous oxide release the active substance in small amounts to deter or kill the biofouling organisms. The major disadvantage of this method is the high cost of antifouling treatments and the undesirable effects of elevated copper levels on the environment.

Most cage farms in developed nations use a combination of strategies to deal with fouling such as 1) antifouling coating combined with washing; 2) antifouling coating combined with drying; and 3) uncoated nets combined with frequent washing. Double net system, where the upper portion of nets is lifted out of the water column to air dry while the other half in left in the water column are also employed in cage aquaculture to control biofouling.

Complete avoidance of biofouling in marine cage farming is not feasible, but location specific, knowledge based tools, developed by diligent monitoring of fouling patterns and intensity, may help farmers avoid major fouling species by implementing removal strategies. Evaluation of biofouling problems at a local or regional level and a concerted action to solve the problem in a practical and cost effective manner is required. For instance, in estuarine areas of Mulki estuary, where biofouling is dominated by bivalves, spat settlement can be controlled cost-effectively by mechanical cleaning by regular and frequent water jets, scraping or brushing during the peak spat settlement time. This synchronisation of husbandry techniques with peaks in settlements can be an effective eco-friendly management practice for controlling biofouling in cages, which is technically simple, less capital oriented and environment friendly as it avoids toxic, copper-based antifoulants.

19. Carrying capacity in brackishwater aquaculture

Sujitha Thomas

Prior to the establishment of a cage culture system or bivalve mariculture structures, an extensive knowledge of the carrying capacity of the water body will be determined . Maximum biomass of a farmed species that can be supported without violating the maximum acceptable impacts to the farmed stock and its environment. Maximum acceptable impacts on the farmed stock and the environment are expressed by standards for water quality in the farm and the surrounding environment (Anders, 2011).

Carrying capacity is defined as the maximum biomass of a farmed species that can be supported without violating the maximum acceptable impacts to the farmed stock and its environment. Maximum acceptable impacts on the farmed stock and the environment are expressed by standards for water quality in the farm and the surrounding environment (Anders, 2011)

In recent years, coastal aquaculture has received wide popularity and further growth is expected in the coming years in India. However, increasing aquaculture production leads to nutrient release into the standing waters leading to eutrophication. In addition, release from domestic, industrial, agriculture, deforestation and livestock production also adds to the water nutrient load and this has an adverse effect on aquaculture and carrying capacity of the water body.

The carrying capacity has been categorised into four functional categories (Inglis et al., 2000)

1. Physical carrying capacity – the total area of marine farms that can be accommodated in the available area. It depends on the overlap between the physical requirements of the target species and the physical properties of the area of interest (eg., type of substrate, depth, hydrodynamics, temperature). It also includes some basic chemical variables (eg., salinity, dissolved oxygen etc).
2. Production carrying capacity – the stocking density of the species at which harvests are maximized. In other words it is the optimized level of production of the target species. It greatly depends on the physical carrying capacity and functions of the ecosystem .
3. Ecological carrying capacity – the stocking or farm density which causes unacceptable ecological impacts.It also should take into account other limiting factors such as seed availability or usable area when appropriate.
4. Social carrying capacity – the level of farm development that causes unacceptable social impacts. This is complex than the ecological carrying capacity as it comprise of all the three categories of carrying capacity as well as trade off between all stake holders in order to meet the demands of both the population (traditional fisheries, employment and other uses).

The carrying capacity of a biological species in an environment is the population size of the species that the environment can sustain indefinitely, given food, habitat, water and other necessities available in the environment. Living within the limits of an ecosystem depends on three factors

The amount of resources available in the ecosystem

The size of the population and

The amount of resources each individual is consuming.

Living within the carrying capacity means using those supplies no faster than they replenished . a community that is living off the interest of its community capital is living within the carrying capacity. A community that is degrading or destroying the ecosystem on which it depends is using up its community capital and is living unsustainably. So, in the context of sustainability, carrying capacity is the size of the population that can be supported indefinitely with the available resources and services of supporting natural, social, human and built capital.

In the aquaculture context, environmental carrying capacity is defined as the maximum number of animals or biomass than can be supported by a given ecosystem for a given time. The concept of environmental carrying capacity is not only important for species cultivation but also for other concerns such as water quality and tourism. It is important in the point of view of aquaculturist who wants to optimize the economic value or yield per unit area or regulatory authorities who are interested in minimizing the negative impacts aquaculture can have on the natural environment.

Hierarchical structure to determine carrying capacity of a given area is given below.

Physical carrying capacity — water depth; Currents, temperature etc

↓

Production carrying capacity — Plankton, detritus; Nutrients etc.

↓

Ecological carrying capacity — Community structure; Mass balance model etc

↓

Social carrying capacity — Traditional fisheries; Other stakeholders etc

(Ref: McKindsey *et.al.*, Aquaculture 261(2006) 451-462)

Estimation of carrying capacity

The methodology has been developed from earlier methods. Carrying capacity is computed based on total nitrogen (TN) input, total phosphorus (TP) input, flushing rate and current flow. The assessment is done in consideration of nitrogen and phosphorus as the limiting factors for primary productivity and the consequent biological impact.

Estimation of nutrient effluent loadings. There are several methods for nutrient input calculation and many researchers have used those in many different ways. The equation used to estimate the nutrient load is as suggested by Wallin and Hakanson(1991)

$Nl = P \times (FCR \times Nfeed - Nfish)$

Nl: nutrient loading(g ×m3)
P: fish production (kg ×m3);
FCR: feed conversion rate(-);
Nfeed: percentage of nitrogen in feed (%);
Nfish: percentage of nitrogen in fish (% wet weight)

Calculation of total N and P load often uses total surface area, amount of water discharge during culture with number of discharge and water volume at harvesting discharge in respective months. Nitrogen and phosphorus contents of discharged water during culture and harvest are to be accounted.

Estimation of flushing rate or dilution rate

The crucial part of the mass balance equation (Eq. 1) is the need to obtain a good estimate of the flushing time or dilution rate. Flushing rate can be obtained by using tidal amplitude:

$\rho = Q/V$ (2)

where: ρ: flushing rate (y-1);
Q: total outflow (m3);
V: volumes (m3).

Estimation of Carrying Capacity (CC)

For aquaculture, environmental carrying capacity can be converted into the number of hectares or volume of production cages or feed on a limited resource environment specifically receiving the wastewaters, bays, lagoons break. The carrying capacity (CC) is calculated using the simple equation proposed by Tran and Nguyen (2006):

$CC = EC/PL$ (3)

where CC: Carrying capacity (tons per units);
EC: Environmental capacity (g × m3)
(EC = Thresh hold value for Total Nutrient –
Total Nutrient Loading);

PL: the average total pollutant load per tons of fish production ($g \times m3$).

The carrying capacity represents thus the maximum number of "units" of aquaculture (ha/number of cages) for specific water bodies.

Unconsumed feed has been identified as the most important origin of all pollutants in cage culturing systems. It suggests the importance of increasing the feed utilization and improving the feed composition on the basis of nutrient requirement. For the sustainable development of the aquaculture industry, it is an effective management measure to keep the stocking density and pollution loadings below the environmental carrying capacity. The DFCR-based nutrient loadings analysis indicates, in trash fish feed culturing areas, that it is more critical and has been proved to be a valuable loading calculation method.

Carrying capacity information can give scientific suggestions for the sustainable management of aquaculture environments. It has been proved that numerical models were convenient tools to predict the environmental carrying capacity. The development of models coupled with dynamic and aquaculture ecology is a requirement of further research. Such models can also be useful in monitoring the ecological impacts caused by mariculture activities.

20. Government support required for brackishwater culture development

A.P.Dineshbabu

A SWOT analysis is a structured planning method used to evaluate the strengths, weaknesses, opportunities and threats involved in a project or in an upcoming innovation and development. This is very useful in deciding the prospects of the technology, support needed for the wider adoption of technology and also to know the precautions to be taken to make the developments environmental and human friendly. A SWOT analysis of brackishwater cage culture development in Karnataka was carried out to suggest the possible support and precaution to be taken for sustainable development of the technology in Karnataka waters.

Strength:

Small scale cage culture technology for fin fish culture is developed and demonstrated its feasibility by Central Marine Fisheries Research institute. The technology was developed to improve livelihood vocations of the fishermen living along South west coast of India. There are wide varieties of species which are capable of fast growth in estuarine cages along the coast. Unpolluted estuaries provide physical and environmental support for 8 to10 month culture period, which is essential for reaching the fishes to a marketable size. The large scale adoption of small scale cage culture along Karnataka coast shows the technology is very much feasible and easy to take up by the fishermen. Increasing demand for cage and seeds every year shows that, if government support is provided to overcome some of the weaknesses assessed, the production from estuarine cages can be increased substantially. Production trend from small scale cages of Karnataka in last five years showed substantial increase. The production was 1.8t in 2009-2010, which increased to 11t by 2013-14. In last five years the total production was about 28 t with a revenue of 111 lakh rupees generated. Over the period of time cage dimensions also increased from 2mX2mX2m to 6mX2mX2m and the stocking rate per cages also increased from 500nos/ cages to 1100-1200nos/ cages, which provided higher production and higher stability for the cages to withstand the monsoon currents in the estuaries.

Weakness:

It was found that the seed requirement of the cage culture cannot be met from the natural sources and there need to be sufficient seed supply to help more fishermen. With increased number of cages with increased dimensions and stocking rate the demand for the seeds are so high, which cannot be met with natural collection or by the inconsistent supply from the hatcheries from East coast of India. It is estimated that if 1% of the available brackish water area is utilised 250 to 260 cages can be installed in in Karnataka estuaries without having any environmental problems. The seed requirement for those cages per annum will be around 0.3 million, whereas the present supply is about 15,000, which is hardly less than 5% of the requirement. For further development of cage culture seed supply from available sources is the priority requirement. Lack of vailability of affordable formulated feed is one of the weakness has to be taken care by the government to increase the production from small scale cages.

Opportunities:

Karnataka state has 300 km coastline and most importantly it has pristine unpolluted brackishwater/estuarine area of about 8000 ha. Among the 26 estuaries in Karnataka, Dakshina Kannada has 5 estuaries with a total of 1140 ha area, Udupi has 8 estuaries of 1885 ha and Uttara Kannada has 13 estuaries having an area of 4200 ha. With the preliminary carrying capacity estimation, it is estimated that minimum of 260 cages could be installed in Karnataka estuaries without any environmental worries. The production from these cages per annum can be around 250 t. worth Rs. 100 million. Seed production technologies are developed for fin fishes in hatcheries in the east coast of India. Governmental agencies can take up the responsibility of supply enough seeds by collecting small fishes anb developing nursery rearing of seeds under various schemes of State and Centre governments. Satellite rearing of very small fish seeds to a stockable size in cages can boost the survival of seeds brought for cage culture and the technical know-how for construction and operation of seed rearing facilities are experimented and perfected by Central Marine Fisheries Research Institute.

In case of Karnataka there is an ample opportunity of getting wet feed from fish cutting plants. It is estimated that as much as 35,000 to 40,000 tonnes of fishes are being processed by these fish cutting centres of D.K and Udupi in one year which generates about 7,000–8,000 tonnes of cutting remains in a year and now it is being diverted for fish meal preparation. If some portion of these cutting remains is used for feeding the high value fishes cultured in the estuarine small scale cages, it will augment fish production from the Karnataka as well it will improve the socio-economic status of the fishermen/farmers in future.

Threats:

Lack of policies for leasing the inland waters is a big threat and for future development of the cage culture. Security of the cages till harvest is being done has to be ensured with licences for individuals or societies. Spatial planning carrying capacity estimation also should be the basis of policy development to restrict irrational increase in number of cages to avoid environmental and social issues.

Proposal to the government departments in light of SWOT analysis:

- Developing policies for allocation of inland waters for fishermen and fishery cooperatives is an immediate step needed from government sector to help to proliferate the technology in wider areas. The village Panchayaths are entrusted with allocation of estuaries for fishermen societies and self help group from coastal areas. In some parts of Kerala State the power is being executed by Village Panchayaths for bivalve farming. Efforts are to be made to provide legal authority for cage farming in open waters.

- Major support required from the government agency is to transportation of fish seeds from the existing hatcheries and develop nursery rearing system to rear the seeds transported to a stackable size.

- Government support and subsidies are required for cage construction cost, seed cost and feed cost.

POLICY SUPPORT

<u>Existing legal instruments which have a linkage on estuarine cage farming</u>

Central aquaculture Authority act, 2005

Coastal aquaculture Authority is instituted for regulating the activities connected with the coastal aquaculture in coastal areas.

(c) "coastal aquaculture" means culturing, under controlled conditions in ponds, pens, enclosures or otherwise, in coastal areas, of shrimp, prawn, fish or any other aquatic life in saline or brackish water; but does not include fresh water aquaculture;

(b) no coastal aquaculture shall be carried on in creeks, rivers and backwaters within the

Coastal Regulation Zone declared for the time being under the Environment (Protection) Act, 1986:

Provided that nothing in this sub-section shall apply in the case of a coastal aquaculture farm which is in existence on the appointed day and to the non-commercial and experimental coastal aquaculture farms operated or proposed to be operated by any research institute of the Government or funded by the Government

Provided further that the Authority may, for the purposes of providing exemption under the first proviso, review from time to time the existence and activities of the coastal aquaculture farms and the provisions of this section shall apply on coastal aquaculture farms in view of such review.

Power of Authority to Make Regulations.- (1) The Authority may, by notification in the Official Gazette, make regulations not inconsistent with the provisions of this Act and the rules made there under to carry out the purposes of this Act.

As seen in the coastal aquaculture authority act, many of the clauses are not supporting the cage farming and some of them are totally against any farming in brackish water,

Initiative to help fishermen community from the State governments:

Since fisheries in coastal waters is State subject, State government have power to make act for utilising the water resources in best possible away. Some States have taken a progressive steps in those direction and the most important effort in this

THE KERALA INLAND FISHERIES AND AQUACULTURE ACT 2010 is an important legislation passed by Kerala Assembly with the aim of sustainable development, management, conservation, propagation, protection, exploitation and utilisation of the inland fishery sector in the State. This act aims to promote social fisheries and to regulate and control responsible aquaculture activities. It also ensures protection of livelihood and traditional rights of fishermen, the availability of nutritious fish and food security to the people and management of inland fisheries sector of the state. This act can be effectively implemented with the help of relevant rules and regulations to develop and sustainably exploit the inland aquatic resources of the State. A scientific management strategy taking into consideration the economic and social factors affecting the multiple stake holders of the resource is essential. The implementation of the

THE KERALA INLAND FISHERIES AND AQUACULTURE ACT, 2010

Translation in English of Malyalam version of the act was published under the authority of the Governor.

An Act to codify and amend the laws relating to inland fishery sector and to provide for the sustainable development, management, conservation, propagation, protection, exploitation and utilisation of the inland fishery sector in the State and for promoting social fisheries and to regulate and control responsible aquaculture activities and to ensure protection of livelihood and traditional rights of fishermen and to ensure the availability of nutritious fish and food security to the people and for matters connected therewith or incidental thereto.

CHAPTER I, PRELIMINARY

(b) 'Aquaculture' means growing any aquatic animals or plants by collecting and conserving them naturally or artificially in restricted circumstances in any private or public water body or in any aquatic environment and includes cage culture, pen culture running water fish culture, ornamental fish farming, fish farming in reservoirs;

(x) 'public water body' means any water body or transformable area including estuaries or backwaters or rivers or lakes, ponds or tanks or canals including irrigation canals or reservoirs or check dams or streams vested with the Government or Local Self Government Institutions under section 218 of the Kerala Municipality Act, 1994 or under section 208 (a) of the Kerala Panchayat Raj Act, 1994 or onward by Boards or any other Government – Quasi Government Institutions or organisations;

CHAPTER II
DEVELOPMENT, PROPAGATION, CONSERVATION, MANAGEMENT

(3) Notwithstanding anything contained in any other law for the time being in force, any activity to transform public water bodies from their original state in a manner which would affect fishery activities prejudicially shall be undertaken after consultation with the Fisheries Department in the manner as may be prescribed.

4. Notifying as aquaculture area – (1) The Government may, for the aquaculture related development or for the public interest of aquaculture sector, by notification in the Gazette,

declare any public water body or other suitable area as aquaculture area exclusively for aquaculture related activities;

Provided that the provisions under sub-section (1) shall not be applicable to the areas included in the coastal area as defined in the Coastal Aquaculture Authority Act, 2005 (Central
Act 24 of 2005).

Provided further that for declaring water bodies or areas as aquaculture area under subsection (1), decision shall be taken after consulting with the concerned Local Self Government Institutions.

CHAPTER III
AQUACULTURE

8. Restriction on aquaculture activities –
(c) the minimum size or weight below which no fish or any species of fish as specified shall be caught or stocked or sold;

(f) fish farming without considering the carrying capacity of inland water sources indiscriminately.

CHAPTER IV
REGISTRATION AND GRANT OF LICENCE

(2) No person shall engage in aquaculture or filtration in inland water bodies except with a certificate of registration obtained in accordance with the provisions of this Act and the Rules made thereunder.
12. *Registration of fishing vessel, fixed gear, free net, aquaculture, hatchery, filtration, etc.*
(1) Subject to the provisions of this Act and the Rules made thereunder, any owner of a fishing vessel or fixed gear or free net and any person intending to engage in aquaculture, conduct of hatchery or filtration shall submit an application for registration to the authorised officer of the place under whose jurisdiction the fishing vessel or free net or fixed' gear is to be used or aquaculture, conduct of hatchery or filtration is to be undertaken.

CHAPTER V
PROTECTED FISH SANCTUARIES

28. Declaration as Fish Sanctuary (1) The State Government, on the basis of the recommendation of the Technical Committee appointed in this behalf may, by notification in the Gazette, declare any public water body to be a protected fish sanctuary if they consider that such an area is having fishery related or zoologically or naturally or ecologically sufficient importance in protecting and propagating fish or its environment:
Provided that, if any water body under the possession of Local Self Government Institutions or Government or quasi Government Institutions. Boards or Organisations is situated in the said area, the Government shall, before making the declaration in such area consult the concerned Local Self Government Institutions or Government or quasi Government Institutions, Boards or Organisations.

FINANCIAL SUPPORT

Probable schemes available which can be made suited for estuarine fishermen with intensive effort from fishery officials and researchers: There are many financial schemes available to support coastal aquaculture. Since estuarine cage farming is a new innovation in open waters, most of the eligibility condition defined by funding agencies are as such is not applicable for estuarine cage farming. But many of them can be modified to suit to support estuarine cage farming by interaction with funding agencies.

RKVY Schemes

RKVY have centrally sponsored and Centre and State shared schemes

B. CENTRALLY SPONSORED PLAN SCHEMES

Development of Inland Fisheries & Aquaculture (State share: Central share)

2. Integrated Development of Inland capture resources (Reservoir/Rivers) (25:75)

4. Devt. of Brackish water Aquaculture through FFDA (25:75)

5. Innovative Initiative capacity Building & Training (25:75)

C. STATE PLAN SCHEMES (100% State assistance)

9. Interest Subvention on Long Term Credit Support to fish farmers

12. Promotion of Intensive Aquaculture & Fish seed Hatchery

14. Infrastructure for cage culture

NFDB schemes

Intensive Aquaculture in Ponds and Tanks: Under intensive aquaculture in ponds and tanks the nursery rearing facility of the brackish watee finfish seeds can be taken under following heads. The criteria may not be as such suitable for BW fish farming, but with the intervention of fishery officials the support for seed rearing facility can be availed

E. Establishment of fish seed hatchery,

F. Renovation of fish Seed Farms;

M. Running water fish culture.

4. Coastal Aquaculture

No.	**Name of the Activity/ Scheme**	**Unit Cost**	**Pattern of Assistance**
D	Cage culture of brackish water fin fishes	Capital cost of Rs. 10.00 lakhs / ha. (Subject to the approval of CIBA/ RGCA based on the production levels).	Back ended subsidy of 25% on the capital cost not exceeding Rs. 2.50 lakhs/ha 2. Back ended subsidy of 30% on the capital cost to SCs/STs not exceeding Rs. 3.0 lakhs/ha.
E	Input assistance for cage culture of brackish water fin fish	Rs. 7.00 lakhs / ha.(Subject to the approval of CIBA/ RGCA based on the production levels).	1. Back ended subsidy of 25% on the working capital for first crop with a ceiling of Rs. 1.75 lakhs/ha 2. Back ended subsidy of 30% on the working capital for first crop to SCs/STs with a ceiling of Rs. 2.10 lakhs/ha.
F .	**Need Based Financial Assistance for development and demonstration of innovative/ new technologies**		

5. Mariculture

Sl. No.	**Name of the activity/ Scheme**	**Unit Cost**	**Pattern of assistance**
A	Setting up of open sea cage culture by companies	Rs. 2.00 crores per unit	20% equity participation on investment
B	**Setting up of new**	Rs. 72 lakhs	40% subsidy on the unit cost

	hatcheries for brackishwater fin fish seed production		not Exceeding Rs. 28.80 lakhs/unit
C	Diversification of shrimp hatcheries to Brackishwater fin fish seed production	Rs. 70 lakhs	40% subsidy on the unit cost not exceeding Rs. 28.00 lakhs/unit
D	Assistance for setting up of Open Sea cage culture units	Capital cost of Rs. 6.00 lakhs/cage and working capital of Rs. 4.15 lakhs/ cage of 12 meter dia	90% grant to Central government institutions/state fisheries departments/ Corporations 40 % back ended subsidy on capital and working capital to fishermen groups and entrepreneurs
E	Assistance for setting up of open sea cage culture units by fishermen societies and SHGs	Capital cost of Rs. 1.25 lakhs/cage of 6 meter dia	40 % back ended subsidy on capital cost

Mariculture assistance is at present mainly meant for opensea mariculture. By experiencing the success possibility in small scale cages in estuaries, the fisheries officials can convince NFDB for funding estuarine farming activities.

Participants and faculty

Copy of the certificate

मांगलूर अनुसंधान केन्द्र / MANGALORE RESEARCH CENTRE

CMFRI

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ICAR-CENTRAL MARINE FISHERIES RESEARCH INSTITUTE

ICAR

CERTIFICATE

This is to certify that Mr./Mrs ....

has participated in the training programme on "Brackishwater Farming" held at Mangalore Research Centre of CMFRI from 16 – 22nd December 2015

Mangalore
22 Dec 2015

Scientist-in-Charge