Course Manual

Winter School on Technological Advances in Mariculture for Production Enhancement and Sustainability

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INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR), NEW DELHI

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ICAR- CENTRAL MARINE FISHERIES RESEARCH INSTITUTE (CMFRI), KOCHI

Course Manual

Winter School
on
Technological Advances in Mariculture for Production Enhancement and Sustainability

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S P O N S O R E D B Y

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O R G A N I S E D B Y

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Winter School on Technological Advances in Mariculture for Production Enhancement and Sustainability

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FOREWORD

Today aquatic products provide nearly 3 billion people with at least 15% of their animal protein intake and fish constitute the dominant source of animal protein in many low income and food deficient countries. The world's growing population consumes more and more fish and stagnating catches from our oceans cannot keep up with the demand. The rapid development of aquaculture has to some extent enabled us to meet this growing demand and currently the aquaculture sector provides half of all fish destined for human consumption. However, the gap between demand and supply is increasing and so the pressure on aquaculture to meet this shortfall has led to development of the sector rising up political agendas worldwide. Global mariculture has increased rapidly in the past four decades, with main production coming from Asia, Europe, and South America. A significant part of the global aquaculture expansion is anticipated to take place in the oceans and coastal areas. Many coasts today, especially in tropical developing countries like India, experience increased pressure from human activities. Expansion of aquaculture in these areas can bring socio-economic benefits to the coastal communities. Aquaculture activity can also provide livelihood alternatives and employment opportunities. However, the interactions with the environment from some aquaculture systems may, directly or indirectly impact negatively on existing livelihoods and people's wellbeing as has been reported. Potential environmental impacts from aquaculture expansion are in general determined by the characteristics of culture systems (species, intensity, technology, etc.) and site characteristics. Sustainability is but a broad concept, even so it needs to be reduced to specific actions to be useful as an objective for ongoing development of aquaculture.

The Winter School on "**Technological Advances in Mariculture for Production Enhancement and Sustainability**" is very ideal for the current scenario in Indian mariculture. Though mariculture development in India is in the early stages, ICAR-Central Marine Fisheries Research Institute (CMFRI) has immensely contributed to every bit of it. The Manual released on this occasion covers all aspects of mariculture prepared by experts in their respective fields. I congratulate the Course Director and Head in Charge Mariculture Division, Dr. Imelda Joseph and Dr. Boby Ignatius, Principal Scientist and all other staff members of Mariculture Division and CMFRI for their efforts in bringing out the Manual in time and to arrange the programme in a befitting manner.

A. Gopalakrishnan
Director, ICAR- CMFRI

PREFACE

Mariculture encompasses the cultivation of many varieties of plants and animal species in a wide range of habitats.The scale of mariculture can range from small-scale, familyrun operations to large-scale, industrial projects.Guidelines that direct mariculture development procedures and related environmental and financial aspects are essential for promoting development of mariculture while ensuring sustainability. Key management tools to be further developed as part of the guidelines and integrated into the approval process are: environmental impact assessment (EIA) requirements, monitoring, licensing, siting criteria, and environmental quality standards. Integration and use of these tools in mariculture development should be specified in the guidelines and supported by policy. Sustainable development of small-scale mariculture can be facilitated by increased coordination between national and local authorities, and increased support to local governments by central government. These actions will help to ensure that mariculture activities are appropriate and sustainable. Development can be promoted by strengthening the ability of R & D institutions to act in a concerted fashion guided by governmental policy, as clear regulations and procedures are yet to be formulated. Integration of policy, development of mariculture guidelines and a mariculture development plan are strategies that can help resolve the most fundamental issues that now constrain sustainable mariculture development in India.Though India is not a leading producer in true mariculture we are second in aquaculture production next to China. To date, the Indian experience with mariculture is limited to shrimp, lobsters, mollusc (oysters and mussels), seaweed and finfish (cobia, pompano, sea bass, mullets etc.).The biological feasibility of culturing these species has been demonstrated locally and internationally. In other Asian countries with similar climate and natural endowments, revenues from mariculture production make significant contributions to national economies. Because mariculture development has been slow in India, there is an opportunity to develop sustainable forms of mariculture by learning from experiences in other parts of the world. Even though there is vast scope, recently only India has taken up mariculture technologies to the stake holder level. Due to the success achieved in mariculture, it has been identified as a potential source of production enhancement for high valued species like lobster, seabass, cobia and pompano for which the capture fishery is negligible.

CMFRI is the premier marine fisheries research institute in India and has the infrastructure and man power for human resource development at any level of stake holders. CMFRI have conducted series of trainings and Winter/ Summer Schools and has played lead role in capacity building in Mariculture in the country. The Course Manual being released on this occasion contains the lecture notes by the resource persons from CMFRI and other organisations. I thank Dr. A. Gopalakrishnan, Director CMFRI for the facilitating in the successful conduct of the Winter School. Dr. Boby Ignatius, Principal Scientist was with me all through the process and I specially thank him. Other scientists of Mariculture Division at Cochin, Technical staff, Young Professionals, supporting staff and contractual staff also supported us in organising the Winter School. I thank all the resource persons who have contributed material for the Course Manual in time. All Heads of Divisions at CMFRI also supported us in this endeavour.

I am confident that the Course Manual released on this occasion would be of use for the participants to enhance their knowledge and competence in the area of mariculture and will be of use in their future research in that line.

Imelda Joseph
Course Director

January, 2016

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Overview of Mariculture

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Aquaculture, the farming and husbandry of aquatic animals is the promising area for increasing aquatic food production in future years. It is the fastest growing food production sector with an annual average growth of >6% in the last two decades. It increased from <1 million tonne in 1950 to 70.2 million tonnes in 2013. An update of aquaculture production (FAO) revealed that the total world aquaculture production continued to grow in 2013, reaching 97.2 million tonnes (live weight) with an estimated value of USD157 billion. A total of 575 aquatic species and species groups grown in freshwater, seawater and brackish water have been registered in the FAO Global Aquaculture Production Statistics Database. The production of farmed food fish (finfish, crustaceans, molluscs and other aquatic animals) was 70.2 million tonnes in 2013, up by 5.6 percent from 66.5 million tonnes in 2012. The production of 27 million tonnes of farmed aquatic plants was a 13.4 percent jump on the 23.8 million tonnes of 2012. The contribution of aquaculture to the world total fish production reached 43.1 percent, up from 42.1 percent in 2012. It was only 30.6 percent a decade ago in 2003. Meanwhile, world production of aquatic plants, mostly seaweeds, is still overwhelmingly dominated by aquaculture (95.5 percent in 2013). On a global scale, the production of major non-fed species contributed 30.7 percent to world food fish aquaculture production in 2013, including 13.9 million tonnes of bivalves and 7.7 million tonnes of filter-feeding carps.

Mariculture is a specialized branch of aquaculture involving the cultivation of marine organisms for food and other products in an enclosed section of the sea (cages/pens), or in tanks, ponds or raceways which are filled with saline water. Generally the mariculture production data focuses on commercial data, which is the output of marine and brackish farming activities for profit whose final harvest is used for human consumption.It is a promising sector by which the additional marine fish requirement can be met in the future years. It is also the fastest growing sub-sector of aquaculture. At global level, mariculture produces many high value finfish, crustaceans, and molluscs *viz.* oysters, mussels, clams, cockles and scallops. In 2013 mariculture has contributed around 25.5 million tonnes of foodfish globally which formed about 36.3 % of the foodfish aquaculture production . (World food fish aquaculture production was 70.2 million tonnes in 2013). Molluscs dominated the global mariculture production (59.7%) followed by finfish (22.7%), crustaceans (16.2%) and others (1.4%). In addition about 26.9 million tonnes of macro algae and seaweeds were also produced by mariculture. The total mariculture production including the sea weeds was 52.4 million tonnes in 2013 which constituted 53.9% of the total aquaculture production during the year (The total global aquaculture production including the aquatic plants was 97.2 million tonnes in 2013).

Indian scenario

The dwindling catch rates in capture fisheries and rampant unemployment in the coastal region focus towards the development of mariculture and coastal aquaculture as a remunerative alternate occupation. The Central Marine Fisheries Research Institute (CMFRI) is the pioneering institution in the country which has initiated mariculture research and has been developing appropriate mariculture technologies and Central Institute for Brackishwater Aquaculture (CIBA) is the lead institution for R & D on brackishwater aquaculture in India. In India till date saline water aquaculture activities are confined only to coastal brackish water aquaculture, chiefly shrimp farming. Although about 1.2 million hectares are suitable for land based saline aquaculture in India, currently only 13% is utilized. Farmed shrimp contributes the major share in the total shrimp export. In 2013-14 the estimated farmed shrimp production was about 3,25000 tonnes.The farming of shrimp is largely dependent on small holdings of less than 2 hectares, as these farms account for over 90% of the total area utilized for shrimp culture. Coastal aquaculture is mainly concentrated in the states of Andhra Pradesh, Tamil Nadu, Orissa and West Bengal.

The other coastal aquaculture activities are green mussel farming which is confined to Malabar Coast in Kerala producing more than 15,000 tonnes and seaweed farming along the coast of Tamil Nadu producing about 17000 tonnes (wet weight) annually. Many mariculture technologies are very simple, eco-friendly and use only locally available infrastructure facilities for construction of farm, feed and seed and hence the entire farming can be practiced by traditional fishermen. Another advantage is that most of our brackish and coastal areas are free from pollution and suited for aquaculture. In recent years, the demand for mussels, clams, edible oysters, crabs, lobsters, sea weeds and marine finfishes is continuously increasing and brings premium price in the national and international markets. The long coastline of 8129 km along with the adjacent landward coastal agro climatic zone and the sea-ward inshore waters with large number of calm bays and lagoons offer good scope to develop mariculture in the country. In addition, a fast growing trade of marine ornamental fishes and other tropical marines has also emerged in the recent years which open up the possibility of culture and trade of these organisms.

Existing major mariculture species and farming technologies

Shrimp seed production and culture

Brackish water shrimp farming started in a big way in India in the early 90s especially in the coastal districts of Andhra Pradesh and Tamil Nadu. So far, shrimp remains as the single largest and maximum value earner among the seafood exported from the country. Shrimp farming in India, till 2008, was synonymous with the monoculture of tiger shrimp, *Penaeus monodon*. Since 1995, culture of *P. monodon* is affected by White Spot Syndrome Virus (WSSV) and the development of shrimp farming has become stagnant. Most of the Southeast Asian countries like Thailand, Vietnam and Indonesia shifted to culture of exotic white leg shrimp, *Litopenaeus vannamei*. The successful development of Specific Pathogen Free (SPF) and Specific Pathogen Resistant (SPR) broodstock of L. *vannamei* also favoured the large scale expansion of its farming. However, in India, pilot-scale introduction of *L. vannamei* was initiated in 2003 and after risk analyses large-scale introduction was permitted in the year 2009. Currently, farming of the white shrimp *Litopenaeus vannamei* has gained momentum in India and is contributing to the bulk of farmed shrimp production. Of late *L. vannamei* farming is being threatened by outbreak of new diseases namely Early Mortality Syndrome (EMS), Acute Pancreatic and Haematopoietic Necrosis Syndrome (APHNS) and many viral diseases.

Shrimps being a highly valued export commodity, its farming are considered a lucrative industry. Depending on the area of the pond, inputs like seed, feed and management measures like predator control, water exchange through tidal effects or pumping, etc., farming systems have been classified into four groups: extensive, modified extensive, semi-intensive and intensive. The farming community has now become more responsive to the concepts of environment-friendliness and sustainable aquaculture. Disease problems are being overcome through adoption of closed system of farming (recirculation system, zero water exchange) in grow outs, application of probiotics, secondary aquaculture of selected fishes like mullets, milkfish, molluscs and seaweeds in reservoirs and drain canals, adoption of indigenous, good quality seed, feed and reduction in stocking density. The recent advances in shrimp farming are directed towards, disease prevention, environment safety and food safety. Bioremediation has assumed a greater importance with the intensification of farming. A number of culture systems have been evolved which incorporates sustainability as the main criteria.

The very fact that diseases are common to many of the shrimp species, the aqua farmers are now desperately looking for an additional species for farming. Hence, species diversification with viable finfish can be one of the best options for a long term solution for sustaining the aquaculture sector. The major constraints for initiating and developing marine finfish farming in the country are the lack of seed production technologies for suitable high value species and the non-availability of commercially viable farming techniques. Now, with the development of indigenous technology for seed production and farming of cobia and silver pompano by CMFRI, and sea bass by CIBA/RGCA there is great scope for the aqua farmers to diversify their aquaculture practices.

Marine Finfish

In recent years at a global level a rapid growth in marine finfish culture is noted which has shown an average annual growth rate of 9.3% from 1990 onwards. The major finfish groups which are maricultured include salmonids, amberjacks, sea breams, sea basses, croakers, groupers, drums, mullets, turbot, other flatfishes, snappers, cobia, pompano, cods, puffers and tunas. The expansion of sea cage farming on a global basis can be attributed as a shot in the arm for the increased farming of marine finfish. Cage culture has made possible the large-scale production of commercial finfish in many parts of the world and can be considered as the most efficient and economical way of rising fish. The most vital prerequisite for the development of sea cage farming is the technology for breeding and seed production and the reliable supply of good quality hatchery produced seeds of suitable high value marine finfishes. In India, much research attention was not given for developing seed production methods for high value finfishes suited for sea farming. Till recently we had commercial level seed production technology of only one marine finfish – the Asian sea bass (*Lates calcarifer*). Here also private entrepreneurship for seed production has not yet been developed. Unless an intensified research on the development of commercial level seed production technologies is taken up, sea farming cannot emerge as a significant seafood production sector in the country. In the recent past, the Central Marine Fisheries Research Institute (CMFRI) has been intensifying its research activities on the breeding and seed production of high value marine finfish and success was achieved in the breeding and seed production of cobia (*Rachycentron canadum*) and silver pompano (*Trachinotus blochii*) for the first time in the country at Mandapam Regional Centre of CMFRI.

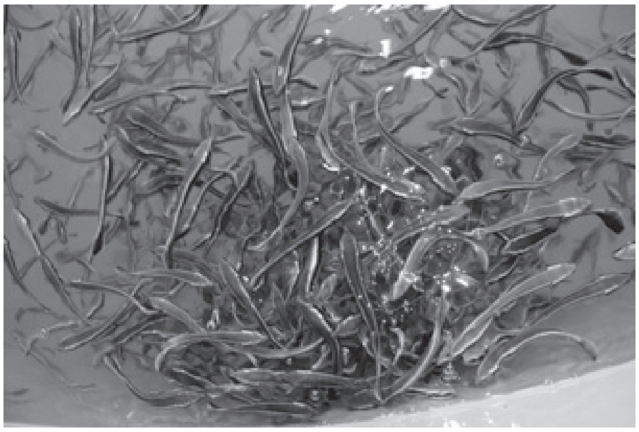
Asian seabass

Comprehensive technology for controlled breeding of seabass was developed in 1997 and sincethen the technology has been further refined andvalidated. The technology includes captive broodstock development, acceleration ofmaturation, providing optimum conditions like water quality management, health management and feed management, induction of spawning through hormonal administration and facilitating natural spawning in the Recirculating Aquaculture System (RAS). Larvae are reared feeding with live feeds like rotifers up to 9th day followed by *Artemia* nauplii up to 20 days and afterwards weaned to formulated diet or shrimp/fish meat. The fry arefurther reared in nurseries. Several pond farming and cage farming demonstrations were successfully carried out.

Cobia

Fast growth rate, adaptability for captive breeding, low cost of production, good meat quality and high market demand are some of the attributes that makes cobia an excellent species for aquaculture. In recent years the seed production and farming of cobia is rapidly gaining momentum in many Asian countries. Envisaging the prospects of cobia farming in India, CMFRI has developed for the first time in the country the broodstock development, breeding and seed production of cobia and several successful seed production trials were conducted and the technology is now standardised at its Mandapam Regional Centre.

The farming protocols for the hatchery produced cobia fingerlings in sea cages with different feeding strategies were developed, tested and validated. Based on the trials, an economically viable farming model has been evolved. Several front line demonstrations and participatory farming were successfully carried out.



Silver pompano

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 silver pompano is caught only sporadically in the commercial fishery and hence its availability is rather scarce. It is a much sought after species and hence the demand can only be met through aquaculture.The farming can be successfully carried out in ponds, tanks and floating sea cages. 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.

CMFRI has successfully developed and standardised the broodstock development, induction of spawning, larviculture and fingerling production of silver pompano for the first time in India. The first farming demonstration from the hatchery produced seed was carried out in a coastal aquaculture pond at Antharvedi Village, East Godavari District, Andhra Pradesh. The growth performance, survival and productive capacity of silver pompano, *Trachinotus blochii*, were evaluated in a brackishwater pond. Based on the experience gained from the above demonstration, farming protocols were evolved. Several pond and cage farming front line demonstrations and participatory farming were successfully carried out.

Ornamental Fish Culture

On a global basis a lucrative marine ornamental fish trade has emerged in recent years which area low volume high value industry. There are a wide variety of ornamental fishes in the coral reef ecosystems along the Indian coast, which if judiciously used, can earn a sizeable foreign exchange. However, a long term sustainable trade of marine ornamental fishes could be developed only through hatchery produced fish. The Central Marine Fisheries Research Institute has pioneered in the development of techniques for breeding, seed production and culture of more than a dozen species of marine ornamental fishes which are in heavy demand in the national and international trade. They include *Amphiprion percula, A.ocellaris, A. perideraion, A. ephippium, Dascyllus aruanus,* *Pomacentrus caeruleus* and *Chrysiptera cyanea.* Hatchery production and culture of marine tropical ornamental fish is very lucrative due to the high price per unit of ornamental fish. The clown fishes and damselfishes of the family Pomacentridae offer immediate scope for hatchery production due to the availability of seed production methodologies.

Recirculating Aquaculture System (RAS)

Closed-system aquaculture presents a new and expanding commercial opportunity. Recirculating aquaculture systems (RAS) are tank-based systems in which fish can be grown at high density under controlled environmental conditions. They are closed-loop facilities that retain and treat the water within the system. In a RAS, water flows from a fish tank through a treatment process and is then returned to the tank, hence the term recirculating aquaculture systems. Recirculation systems use land based units to pump water in a closed loop through fish rearing tanks and consist of a series of sub-systems for water treatment which include equipments for solids removal, biological filtration, heating or cooling, dissolved gas control, water sterilization and photo-thermal control. Sustainable production of bio-secure cobia seed all through the year employing photo-thermal conditioning is possible only by recirculating systems.

At Mandapam Regional Centre two recirculation aquaculture systems are installed for controlled broodstock development and breeding. The first successful off-season spawning of cobia through thermal regulation has been achieved in the RAS. Breeding experiment was conducted in the RAS through thermal regulation by installing titanium water heaters. During this season the temperature in source seawater was 25.1 to 26.0°C and it was raised in the RAS to 29.7 to 30.3 °C, by titanium heaters. The cobia brooders were healthy and broodstock development was continued in the RAS by regulating the temperature. Intra-ovarian cannulation biopsy revealed the maturation of ova in the altered temperature. The female cobia was weighing 9.29 kg and males were 9.89 kg & 10.34 kg. Successful hormonal induction with hCG was carried out and spawning was achieved. The fertilized eggs were collected and stocked in the incubation tanks for hatching. It is felt that the present success is a major breakthrough which can pave way for the successful spawning and seed production of cobia all through the year. The same infrastructure can be utilized for seed production of other species also.

Sea cage farming

The sea cage farming has been expanding in recent years on a global basis and it is viewed by many stakeholders in the industry as the aquaculture system of the millennium. Cage culture has made possible the large-scale production of commercial finfish in many parts of the world and can be considered as the most efficient and economical way of rising fish. The rapid growth of the industry in most countries can be attributed to (i) availability of suitable sites for cage culture (ii) well established breeding techniques that yield a sufficient quantity of various marine and freshwater fish juveniles (iii) availability of supporting industries such and feed, net manufactures, fish processors etc. (iv) strong research and development initiatives from institutions, governments and universities and (v) the private sector ensuring refinement and improvement of techniques/ culture systems, thereby further developing the industry. Total reported cage aquaculture production from 62 countries and provinces/regions from where data is available amounted to 2412167 tonnes (excluding China) On the basis of the reported information, the major cage culture producers in 2005 included - Norway (652306 tonnes), Chile (588 060 tonnes), Japan (272 821 tonnes), United Kingdom (135 253 tonnes), Vietnam (126 000 tonnes), Greece (76 577 tonnes), Turkey (78 924 tonnes), and the Philippines (66 249 tonnes). Currently on a global basis commercial cage culture has been restricted to the culture of high value, compound feed fed finfish species, including salmon, Japanese amberjack, red sea bream, yellow croaker, European sea bass, gilthead sea bream, cobia and groupers. Cage culture systems employed by farmers vary from traditional family owned cage farms (Asian countries) to modern commercial large scale salmon and trout cage farms in Northern Europe and Americas.

Marine cage farming is relatively new in Asia and was developed initially in Japan for species such as yellowtail (*Seriola quinqueradiata*) and red sea bream *Pagrus major.* Over the last twenty years the cage farming practice has spread almost throughout Asia. The major cage farming countries are China, Indonesia, Taiwan Province of China and Vietnam. A large number of finfish species are farmed in cages in Asia *viz*. groupers, snappers, carangids, seabass and cobia. In most countries individual operations are not large, and often a clustering of farming activities, which is due to limited site availability in coastal waters, is seen.

When compared to many countries in the Asia-Pacific Region, India is still in its infancy in sea cage farming. For the first time in India as part of R & D a marine cage of 15 m diameter with HDPE frame was successfully launched in 2007 and operated at Visakhapatnam, in the east coast of India by the Central Marine Fisheries Research Institute. Since then, a lot of innovations on designing and fabrication of cages and mooring systems were made which led to the development of better designs of cages of 6m diameter with improved mooring systems that can withstand rough sea conditions. Subsequently demonstrations of cage farming were undertaken along different parts of the Indian coast under a participatory mode with the local coastal fishermen. Successful sea cage farming demonstrations were conducted at Kanyakumari, Vizhinjam, Kochi, Mangalore, Karwar, Veraval, Mandapam, Chennai and Balasore. Cobia, Sea bass and spiny lobsters were the major groups employed for farming. These demonstrations have created an awareness regarding the prospects of sea cage farming in India. Many entrepreneurs, fishermen and farmers are coming forward to take up this venture.

The commercial cage farming of cobia undertaken by Cobia Fisherman Welfare Association, a self help group from Rameswaram under the technical support of Mandapam Regional Centre of CMFRI is a step forward in the popularization of sea cage farming in India. Ten cages of 6m diameter and 3.5m depth were fabricated and floated by them. All the investments in the fabrication of the cages, the cost of seeds, feeds and managing the sea cage farm were borne by the association. A total of 6400 fingerlings of hatchery produced cobia were supplied from Mandapam Regional Centre. The farming was initiated during the middle of November 2013. The harvest of cobia was conducted on 8th May 2014. The length of fish harvest ranged from 48 to 62 cm and weight from 1.0 to 2.3 kg. The farm gate price was Rs. 270 / kg. A total of 10 tonnes of fish was harvested during the fishing ban period and yielded a good farm gate price. This has created wide spread interest among fishermen communities for taking up sea cage farming in the area. Several successful participatory cage farming demonstrations taken up at different parts of Indian coast is paving the way for the spreading of cage farming and in the immediate future it can contribute to additional sea food production.

Mussel Farming

In the wild, mussels are mostly found in the littoral and sublittoral zone in clusters on various substrates. The two mussel species found along Indian seas are *Perna virdis* and *Perna indica*. *Perna viridis* is distributed along the north and south of east coast and the south west coast of India. The brown mussel *Perna indica* species is found along the south west coast. The Institute has developed technologies for culture of bivalves *viz.*raft method (in bays, inshore waters), rack method (in brackishwater, estuaries) or long line method (open sea). These methods are commonly adopted for mussel farming (*Perna indica* and *P. viridis*). Mussel seeds of 15-25 mm size collected from intertidal and sub tidal beds are attached to coir/nylon ropes of 1-6 m length and enveloped by mosquito or cotton netting. Seeds get attached to rope within a few days while the netting disintegrates. The seeded ropes are hung from rafts, racks or longlines. A harvestable size of 70-80 mm is reached in 5-7 months and production of 12-14 kg mussel (shell on) per metre of rope can be obtained. Innovations such as automatic seeding machines and depuration protocols were also evolved. The farming of mussels is currently being practised commercially at brackishwater areas of Malabar Coast, Kerala.

When mussel farming is taken up on a larger scale, depending on the wild seed may not be practicable because it may affect the wild mussel fisheries. Hence low value high volume seed production technologies are needed for hatchery production of mussel seeds for farming. CMFRI has already succeeded in the low cost production of mussel seeds in hatchery and standardisation of the protocols for large-scale productionis needed.

Edible Oyster Farming

CMFRI has developed methods for edible oyster (*Crassostrea madrasensis*) culture and has produced a complete package of technology, which is presently being widely adopted by small scale farmers in shallow estuaries, bays and backwaters. In the adopted rack and ren method, a series of vertical poles are driven into the bottom in rows, on top of which horizontal bars are placed. Spat collection is done mainly from the wild on suitable cultch materials. Spat collectors consist of clean oyster shells (5-6 Nos.) suspended on a 3 mm nylon rope at spaced intervals of 15-20 cm and suspended from racks, close to natural oyster beds. Spat collection and further rearing is carried out at the same farm site and harvestable size of 80 mm is reached in 8-10 months. Harvesting is done manually with a production rate of 8-10 tonnes/ha. Oyster shells are also in demand by local cement and lime industry. Hatchery production techniquefor edible oyster seeds is also developed by CMFRI.

Molluscan shellfish (mussels, oysters and clams) are much sought after and widely consumed throughout the world as gourmet food. But in India this nutritious seafood have not found much acceptance. Currently farmed mussel and oyster production in India is between 10,000 and 15,000 tonnes. In order to create awareness on the general public on molluscan shellfish as a highly nutritious food, ShellCon 2014 was organised by CMFRI in which shellfish food festival and programmes for the popularisation of the consumption of molluscan shellfish were conducted.

Mabe Pearl Production

CMFRI successfully developed and standardised a simple technique for value added marine pearls, called mabe pearls. A mabe pearl is a dome shaped or image pearl produced by placing a miniature image against the side of the oyster shell interior. The result is an exquisite pearly nacre coated image. The main advantage is the very short gestation period (2 months) and the superior quality of the nacre of Indian pearl oyster *Pinctada fucata*. There are two ways to make pearl oyster spat available for pearl oyster farming, (1) hatchery production of seed and (2) wild collection of seed by setting up artificial spat collectors in the sea at subsurface during oyster spawning season. The hatchery technology developed by CMFRI is helpful in overcoming the problem of insufficient supply of oysters for cultured pearl production.

Seaweed Culture

Around 60 species of commercially important seaweeds with a standing crop of one lakh tonne occur along the Indian coast. Seaweed products like agar, algin, carrageenan and liquid fertilizer are in demand in global markets and some economically viable seaweed cultivation technologies have been developed in India. CMFRI has developed technology to culture seaweeds by either vegetative propagation using fragments of seaweeds collected from natural beds or spores (tetraspores/carpospores). It has the potential to develop in our large productive coastal belts. The rate of production of *Gelidiella acerosa* from culture amounts to 5 tonnes dry weight per hectare, while *Gracilaria edulis* and *Hypnea* production is about 15 tonnes dry weight per hectare. Recently the culture of the carageenan yielding sea weed *Kappaphycus alvarezii* has become very popular due to its fast growth and less susceptibility to grazing by fishes and is being cultivated extensively along the Ramanathapuram, Pudukkottai, Tanjore, Tuticorin and Kanyakumari districts of Tamil Nadu producing about 17000 t wet weight annually.

Integrated Multitrophic Aquaculture (IMTA)

On a global basis, the mariculture practices are dominated by intensive monocultures which have led to sustainability problems, environmental degradation and consequent disease problems. In this context, the idea of bio-mitigation of the environment along with increased biomass production integrating commercially important species of different trophic levels is emerging as an innovation in aquaculture. Integrated Multi trophic aquaculture (IMTA) is the practice which combines in appropriate proportions the cultivation of fed aquaculture species (E.g. fin fish / shrimp) with organic extractive aquaculture species (e.g. shell / herbivorous fish) and inorganic extractive aquaculture species (e.g. seaweed) to create balanced systems for environmental stability (bio-mitigation) economic stability (product diversification and risk reduction) and social acceptability (better management practices). IMTA is well recognized as a mitigation approach against the excess nutrients / organic matter generated by intensive aquaculture activities especially in marine waters, since it incorporates species from different trophic levels in the same system. In addition, it is also relevant in the implementation of ecosystem approach to aquaculture (EAA) propagated by FAO. IMTA can also increase the production capacity of a particular site. It is well understood that the increasing use of coastal waters world wide coupled with rapid growth and expansion of mariculture demand for more sustainable practices and hence the concept of IMTA has much relevance and scope.

Way Forward

Seed availability is the major constraint for the initiation of commercial level farming of marine finfishes and shellfishes. The huge demand for cobia and pompano seeds received at CMFRI from fish farmers and entrepreneurs is indicative of the need of the sector. Hence there is an urgent need to establish marine finfish hatcheries by fisheries development agencies /private sector to ensure the seed availability. In addition, it is required to intensify research programmes for the development of seed production techniques for at least one dozen species of high value marine fishes. In this context, CMFRI has already taken up broodstock development and seed production of orange spotted Grouper *Epinephelus coioides*, Indian Pompano *Trachinotus mookalee* and Malabar Red Snapper *Lutjanus argentimaculatus*. Initial success has already been obtained in the broodstock development and seed production of *E. coioides* and *T. mookalee* at the Vishakapatnam Research Centre of CMFRI. Broodstock development of *L. argentimaculatus* is being pursued. If seed production technologies of more species are available, the farmers will be able to select the species as per the need of the locality.

The commercial level farming of lucrative shellfish species like the sand lobster, *Thenus unimaculatus* and the blue swimmer crab *Portunus pelagicus* can also be practiced if hatchery produced seeds are available. CMFRI is able to succeed in the seed production of both the species and now research is being focused on the standardization of these techniques for consistent production. Similarly seed production techniques are already developed by the Institute for edible oyster, pearl oyster and green mussel. The methods can be scaled to commercial level production as per the requirement of the sector.

The development of farming systems especially the sea cage farming deserves prime attention. To promote sea cage farming in the country, identification of suitable sites with proper depth, water quality and water current are required. Site selection survey and identification of at least a dozen sites suitable for cage farming by the entrepreneurs and farmers deserves urgent attention. Availability of logistic support for cage farming should be given careful consideration if a profitable business is to be established. Cage farming has to be promoted away from the human settlements, discharge points of industrial and municipal waste, so as to maintain ideal water quality for sea farming. Further, policy for leasing the suitable sites, bank finance, and governmental support through subsidy assistance are the needs of the hour.

The bivalve farming which is already being practiced at a few locations can be further expanded. The carrying capacity assessment, low value availability of hatchery produced seed and the feasibility of open sea farming of bivalves require attention by the R&D sector. Similarly the expansion of sea weed farming offers immense scope. A concerted effort by the developmental agencies for popularization of sea weed farming is warranted.

On a global basis, the mariculture practices are dominated by intensive monocultures which have led to sustainability problems, environmental degradation and consequent disease problems. In this regard, the biomitigation impact of IMTA is away forward in sustainable aquaculture. In addition, it is also relevant in the implementation of ecosystem approach to aquaculture (EAA) propagated by FAO. The development of IMTA in marine and coastal environments, has not been demonstrated as a viable enterprise in India and hence there is an urgent need to impart front line demonstrations on this potential sector of mariculture to different stake holders.

The development of commercial level seed production technologies for a few species of high market value finfish and shellfish, establishment of hatcheries by fisheries development agencies, identification of appropriate cage/coastal farming sites, development of economically viable farming protocols, formulation of suitable grow-out feeds, health management protocols, development of mariculture policies and appropriate marketing strategies can go a long way to promote mariculture as a substantial contributor of sea food production in India.

Recent Advances in Coastal Aquaculture

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Introduction

The world fish production is around 152 million tonnes supporting the nutritional security of the growing population of the world. Out of the total fish production, aquaculture contributes around 42%. The capture fisheries, though intensive efforts are made for exploitation in many cases is static or declining. In some areas through continuous unregulated over exploitation it has often exceeded the maximum sustainable yield (MSY) and aquaculture has to necessarily support the fish production. Aquaculture is considered as one of the potential growth sectors showing annual growth rate between 8 and 10%. and is dominated by Asian countries. The importance of coastal aquaculture in the context of augmenting fish production, improving rural economy and productive utilisation of water resources is well-established. The development of coastal aquaculture received attention since certain fish stocks in the marine capture fishery indicated optimum level of exploitation, and their catch returns, despite increased efforts, showed declining trend. Following this, national Institutes concerned with research and development of marine and brackishwater fisheries, initiated investigations on coastal aquaculture such suitable organisms.

Resources

The potential coastal water area available in India includes about 8.9 million ha of inshore waters for open-sea farming, and 1.7 million ha of estuaries, backwaters, brackishwater lakes and swamps. A variety of high valued fishes, crustaceans, molluscs, seaweeds and other marine organisms, possessing high reproductive capacity, short larval development, fast rate of growth, and physiological features to adjust to wide changes in the environment are available in our coastal waters. For mariculture, adequate seed resources of the cultivable species are also available, if all local prioritized species are taken into account. There are also a large number of unemployed and under employed fishermen who could advantageously take up coastal aquaculture.

Recent advances

The marine fish production and the bulk of the brackishwater fish catch of our country are realised through the capture fisheries, the main emphasis of research and developmental activities has so for been in this field. Except for a few isolated studies and experimental and pilot-scale projects taken up by the Fisheries Departments of certain maritime states, there have been no detailed investigations or concerted efforts to develop coastal aquaculture. However, following the recognition of the potentials in the field, its Importance and the high priority assigned to its development, several intensive research programmes have been taken up during the last five decades. Most of these investigations are centred on the culture of prawns, lobsters, crabs, mussels, pearl oyster and pearls, edible oysters, clams, fin fishes and seaweeds because of their commercial importance.

Crustaceans

Researches on the culture of prawns were mainly carried out at the Central Marine Fisheries Research Institute, the Central Inland Fisheries Research Institute, the National Institute of Oceanography, the Central Institute of Fisheries Education, the Konkan Krishi Vidyapeeth, certain Universities and by the All India Coordinated Research Project on "Brackishwater prawn and fish culture". The investigations were mainly directed towards developing an indigenous technology of large-scale culture of prawns on scientific lines. The techniques of breeding and rearing of larvae of the commercial penaeid prawns, namely, *Penaeus monodon, F. indlcus, P. semisuicatus, P. merguiensis, Metapenaeus dobsoni, M. monoceros, M. affinis M. brevicornis* and *Parapenaeopsis stylifera* under controlled conditions have been developed. In India, shrimp farming developed at an annual growth rate of nearly 15% during 1990 to 1995. Since 2009, after the introduction of SPF *L. vannamei* in the country, the shrimp production levels have increased from 1 lakh tonnes to 4.34 lakh tonnes in 2014 -15 with *L. vannamei* contributing nearly 83%.

Although isolated experiments on the breeding of the spiny lobsters (*Panulirus* spp.) and rearing of phyllosoma larvae were conducted earlier in our country, directed research on lobster culture, particularly on *Panulirus homarus* was taken up at the Field Laboratory of the Central Marine Fisheries Research Institute at Kovalam, near Chennai and later at Kochi. Techniques of collection of pueruli that migrate into the coastal waters, by special collectors were developed. The young ones of lobsters thus collected were reared in the laboratory. The results of these experiments have indicated that the young lobsters of 35 mm carapace length grow to a size of 57-58 mm carapace length in about 15 months and reach marketable size in 18 months. At present farming of lobsters is only fattening in cages and the species are *Panulirus homarus* and *P. polyphagus*.

Among the edible crabs occurring in our country, the most suitable species for culture is the mud crab, *Scylla serrata,* and *S. tranquebarica.* These are fast growing and can withstand wide ranges of salinity from almost freshwater to that of sea the species involve collection of seed crabs from the wild and growing them either individually in cages or baskets. Seed production is carried out by MPEDA and ICAR-CIBA.

Molluscs

Culture of brown mussel *Perna indica* and the green mussel *P. viridls* have been initiated since 1971 by CMFRI. Mussels can be cultured by raft culture method using ropes in 10-20 m depth zone, or on poles in shallow areas. The current production is around 20,000 tonnes in the country. One of the remarkable contributions made to promote mariculture in our country, is the successful development of an expertise on the techniques of production of pearls under controlled conditions. Researches leading to this achievement were started in 1972 at CMFRI. Culture of edible oysters, particularly *C. madrasensis*, was initiated at Tuticorin and techniques of collection of spat from the wild on different kinds of material such as lime coated tiles, oyster shells and empty coconut shells and growing them by rack and long line culture methods, on poles as well as in trays were standardized.

Finfish

Most of the species which can be commercially farmed are suitable for farming in marine and freshwater also. Some of the candidate species identified suitable for commercial aquaculture are seabass (*Lates calcarifer*), groupers (*Epinephelus* sp.), cobia (*Rachycentron canadum*), Pearl spot (*Etroplus suratensis*), milk mish (*Chanos chanos*) and grey mullet (*Mugil cephalus*). For the development and expansion of aquaculture, the most important pre-requisites are the seed and feed. Seed production technologies have been developed for some species like seabass, cobia, pampano and pearl spot and for other species like groupers, snappers, grey mullet and milk fish, efforts are made by different R & D Institutions in India to develop and standardize seed production technology. Technology for controlled breeding of seabass was developed in by CIBA in 1997 and since then the technology has been further refined and commercialized by RGCA. The technology includes captive broodstock development, induced maturation, water quality, health and feed management, induction of spawning through hormonal administration and spawning in the Recirculating Aquaculture System (RAS). In the farming front, Sea bass is considered as the best species for cage farming due to its fast growth, market demand and price. For pond culture also seabass is found good.

Groupers are another species which attain maturity after 2 years and are around 2-3 kg in size. They are protogynous, where many are females in the early period and reverse to male when they are larger in size. In hatchery operations, for obtaining male sometimes require intervention through exogenous hormone administration. Successful breeding of orange spotted grouper *Epinephelus coioides* has been achieved by CMFRI. Considering its high potentiality for farming along with other fishes and shell fishes with low cost inputs, the good market demand in some parts of India like Kerala, West Bengal Grey Mullet *Mugil cephalus* is farmed in cages as well as in coastal ponds. However, breeding of grey mullet under controlled conditions, though being attempted for some years, is yet to be taken off. Milk fish *Chanos chanos* breeding and seed production has become a house hold activity in countries like Philippines, Indonesia and Taiwan. However in Indian context, breeding of milk fish under captivity is yet to make a beginning. Captive broodstock of milk fish developed after feeding them with formulated feed @ 2-3% body weight after 5 years of holding under captive conditions have shown male maturation and the female fishes have not attained gonadal maturity preliminary success in seed production in India. It is a suitable species for cage and pen farming, and for Polyculture in coastal ponds.Pearl spot *Etroplus suratensis* is also a candidate species suitable for cage farming as well as coastal pond farming in Indian waters. CMFRI has developed seed production technology for the species by cost- effective methods.

Technology for seed production Silver pompano *Trachynotus blochii* and Indian pompano *Trachinotus mookalee* has also been developed by CMFRI. Pompano is a suitable species for coastal pond farming.

Benefits of Coastal aquaculture

Generally, the socio-economic benefits arising from aquaculture expansion include the provision of food, contributing to improved nutrition and health, the generation of income and employment, the diversification of primary production, and, increasingly important for developing countries, foreign exchange earnings through export of high-value products (UNDP/Norway/FAO, 1987; Schmidt, 1982). Aquaculture is also being promoted for its potential to compensate for the low growth rate of capture fisheries. Stocking and release of hatchery-reared organisms into inland and coastal waters support culture-based fisheries (Larkin, 1991). Sustainable development of aquaculture can contribute to the prevention and control of aquatic pollution since it relies essentially on good-quality water resources. Culture of molluscs and seaweeds may in certain cases counteract processes of nutrient and organic enrichment in eutrophic waters, which is popularized as integrated multi-trophic Aquaculture (IMTA) Conversely, productivity of oligotrophic waters may be enhanced due to the nutrient and organic wastes released from aquaculture farms.

Marine Fish Hatchery

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Introduction

Availability of required quantities of high quality juveniles at the right time and at reasonable cost is the prime requirement for successful commercial fish farming. Any failure to obtain the right seed in quantity and quality at the right time, the production plans will not be attained. Thus, it has long been internationally recognized that a good source of juveniles is the most important prerequisite for fish farming. Most of the worlds fish aquaculture still depend on the fry almost comes exclusively from wild. Seed supply from the wild is often unpredictable and seasonal. Controlled hatchery production of seeds of economically important finfish ensures a steady supply of quality seeds for aquaculture operations.

For a successful hatchery production of marine fin fishes, number of factors have to be considered. In the following sections advances in fish hatchery management particularly in the areas of brood management, induced spawning and larval rearing will be reviewed.

BROODSTOCK

An adequate supply of broodfish is essential for successful induced-breeding operations or artificial propagation, especially of the most important cultured species. There are two sources of finfish broodstock: wild-caught adults and those reared in ponds or cages. Most marine fish (groupers, seabass, snappers etc.) broodstock are obtained as wild adults. The disadvantages of using wild stock are uncertainty of capturing them, the relatively large expenditure needed for their capture and transport, and the limited opportunities of obtaining good quality eggs.

In certain cases, it is also difficult to obtain adults from the wild. Thus developing breeders in ponds/cages is another option. Fishes domesticated for few years attains sexual maturity in captive conditions. It is advantageous to use pond or cage-reared broodstock as they are already used to culture conditions and are thus easier to develop into broodfish. In general, fish selected for broodstock should be fast-growing, lively fish, among the largest and strongest members of their age group and free from parasites and diseases.

Age at maturity

The age at maturity varies for different species of fishes. Knowledge about the age at which the species matures is useful in the selection of right sized brooders for breeding purpose. Rabbitfish begins sexual maturation and spawning in one year of captivity. As Protandrous hermaphrodites, the seabass are mature males in the third year of captivity and became females on the following year. On the other hand, groupers, being protogynous hermaphrodites, are mature females after four years of its growth. It takes longer for them to be transformed to mature males. Both milkfish and snappers take 5 years to attain sexual maturity.

Determination of sex and maturity of spawners

Two common aspects in the artificial propagation of finfish are the determination of sex and the maturity of spawners. Often, it is difficult to determine the sex of spawners through examining the external morphology of the fish. In some species, a gravid female exhibits a fuller profile than the ripe male; its abdomen is distended. Ripe males are easy to distinguish during the spawning season since milt oozes out from the urogenital pore as its abdomen is pressed. If the degree of maturity is right, the milt will be white and creamy; poor milt is watery and curdled. Milt which is not ripe will demand strong pressure and will be mixed with blood.

Assessment of gonadal maturation of broodstock is still a major difficulty in the artificial propagation of finfish. The commonly-used method to assess sexual development is through gonadal biopsy. Gametes are removed from either an anaesthetized or unanaesthetized fish by using a polyethylene cannula. The inner diameter of the cannula to be used varies with the size of eggs to be sampled. The cannula is inserted 4–15 cm into the ovary or testis and gametes are drawn into the cannula by aspiration as the cannula is slowly withdrawn. The distance to which the cannula is inserted varies with the length of the ovary or testis. Samples from the middle portion, especially of the ovary, are generally considered to be the most representative.

The eggs collected are removed from the cannula by blowing them into a Petridish. They are preserved in 1% formalin in 0.9% NaCl. The average egg diameter is determined from a batch of 50–10 by using a micrometer and their developmental stage is assessed under the microscope. Gonadal maturation is then expressed in terms of average egg diameter and the developmental stage of the eggs.

The milt collected is removed from the cannula by blowing it onto a clean dry Petridish. A small portion of this is mixed with a drop of seawater or brackishwater, depending upon the species, and examined immediately under the microscope. Sperm motility and vitality are then assessed.

Transporting spawners

There are several ways of transporting spawners: from the most simple receptacle, such as plastic bags, to the most sophisticated like special transport vehicles. Containers vary with the size, species and number of fish to be transported and the location of the collecting grounds. A combination of pre-transport starvation, rapid anaesthetization at capture, cool transport water and anesthetization at transport were also used for long distance transport.

Factors affecting gonad development

Nutrition

Poor nutrition can result in poor or no reproductive performance and that lack of vitamin supplement could affect sperm quality. Mere reliance on natural food may lead to poor or variable reproductive performance. Fish broodstock diets are now formulated to include high levels of n-3 fatty acids which include enhanced levels of both decosahexaenoic acid and eicosapentaenoic acid. Eggs considered to be of better quality have higher content of these fatty acids. Furthermore, successful embryonic development in fish has been shown to be dependant on the balance of aminoacids present in the egg. Results of other studies indicate that reduced feed levels may adversely affect fecundity and composition of ova. Deficiency of Vitamin C in the diet results in eggs that show considerably higher mortalities than eggs. However broodstock fed on 'natural diet/s' often produce eggs of better quality than those on formulated commercial diets. Thus it appears that different fish species may have different dietary requirements and that diets of broodstock should be tailor made to ensure good egg quality.

Environment

Photoperiod

One of the factors considered being of great importance to the inducement of sexual maturation and spawning is photoperiod. Photoperiod manipulation is now being employed to alter the normal reproduction of a few cultured species, for example, mullet, rabbitfish, rainbow trout, tilapia, carp and catfish. The greatest advantage of altering the spawning time of the cultured species is the availability of fry for stocking in ponds, pens and cages throughout the year.

Temperature

Water temperature is another important factor which influences the maturation and spawning of fish. In some species of fish functional maturity is directly controlled by temperature; in others, the time of spawning is regulated by the day-length cycle such that it occurs when the temperature is optimum for survival and the food supply is adequate.

Salinity

Some species of fish, e.g., salmon, migrate from the marine to the freshwater environment in order to spawn, while other species, such as eels, migrate from freshwater to the marine environment to complete their reproductive cycle. This confirms that salinity is somehow related to maturation and spawning.

Other environmental factors

In addition to photoperiod, temperature and salinity, there are other less obvious factors which may affect the maturation and spawning of broodstock. There is, however, paucity of information regarding the effects of these less obvious factors, which include rainfall, stress, sex ratios, stocking density, isolation from human disturbance, dissolved oxygen, social behaviour of fish, heavy metals, pesticides, and irradiation. Furthermore, the design of holding systems for broodstock such as ponds, tanks and cages is largely unknown.

SPAWNING AND FERTILIZATION

Selection of spawners

The selection of spawners from the broodstock should be done months before the beginning of natural spawning to allow ample time for the fish to be conditioned to environmental and diet controls. Spawners are normally selected based on the following criteria:

- fish should be active
- fins and scales should be complete
- fish should be free from disease and parasites

- fish should be free from injury or wounds
- males and females of similar size are preferred

Spawning

Presently, two major techniques are employed in the mass production of fish seeds: artificial fertilization and induced spawning.

1. Artificial Fertilization

Spawners are caught in natural spawning grounds near the mouth of the river or in saltwater lakes. Normally, the fishermen will net the fish during spring tide 2–3 days before the new moon or full moon, up to 5–6 days after the new moon or full moon.

The degree of maturity of the collected spawners should be immediately checked. If the female has ripe eggs and the milt of the male is at the running stage, stripping is done in the boat. The fertilized eggs can then be transported to the hatchery for subsequent hatching. In cases where only the male is caught, the milt is collected by stripping into a dry glass container and is then stored in an ice box or refrigerator. The milt can maintain its viability after a week in cold storage (5°–15°C). The preserved milt should be made available for immediate use when a ripe female is caught.

The dry method of fertilization is normally used in this case. The eggs are stripped directly from the female into a dry and clean container where the milt is added. A feather is used in mixing the milt and eggs for about 5 min. Filtered seawater are added to the mixture while stirring and then allowed to stand undisturbed for 5 min.

2. Induced Spawning

All of the cultured species exhibit spontaneous spawning but this is seasonal and at times unpredictable. Thus induced spawning to ensure availability of eggs, to meet fry demand and as a supplement to natural spawning may be undertaken.

Manipulations of various environmental parameters, such as temperature, photoperiod, salinity, tank volume and depth, substrate vegetation, etc. can often improve the reliability of spawning. However, in some species hormonal treatments are the only means of controlling reproduction reliably. Over the years, a variety of hormonal approaches have been used successfully. These methods began with the crude use of ground pituitaries from mature fish containing gonadotropin (GtH. - which were injected into broodstock to induce spawning (Houssay, 1930. Today, various synthetic, highly potent agonists of the gonadotropin-releasing hormone (GnRHa) are available as well as sustained-release delivery systems for their controlled administration. These methods have contributed significantly to the development of more reliable, less species-specific methods for the control of reproduction of captive broodstocks.

A. Hormonal induction of ovulation and spawning

Most research and development efforts on the use of hormones to control finfish reproductive cycles in aquaculture have focused on the induction of Final Oocyte Maturation (FOM), ovulation, spermiation and spawning in fish that do not complete these processes in captivity.

However, hormonal manipulations have important applications in commercial aquaculture, even for fish that do undergo FOM and spermiation spontaneously in captivity. In many fish hatcheries, ovulation is induced with hormones in order to synchronize and optimize egg collection and fry production, thereby minimizing the handling and stress to the fish, and reducing labor requirements

SPH - acetone-dried pituitary gland homogenate

Hypophysation, the use of ground pituitaries and pituitary extracts to induce spawning in fish, started in the late 1930s in Brazil. Collection of pituitaries for hypophysation was done from reproductively mature broodstock, either males or females (Fontenele, 1955). It was found that pituitaries collected during the spawning season were more efficacious in inducing spawning. Use of ground pituitaries, however, is associated with various drawbacks, the most important ones being (a) the great variability in pituitary LH content; (b) the administration of additional hormones present in the pituitary that may adversely affect the physiology of the treated fish, and the potential for transmission of diseases from donor fish to recipient broodstocks.

Human chorionic gonadotropin (hCG)

Unlike LH preparations of piscine origin, hCG is often given in a single dose, which ranges between 100 and 4000 international units (IU) per kg body weight. There is one situation in which hCG be preferred over GnRHa. The advantage of hCG is that it acts directly at the level of the gonad and does not require the existence of LH stores or activation of the pituitary gonadotropes. hCG may be more appropriate because it acts much faster, via direct stimulation of the gonad, in inducing FOM, spermiation and spawning

Use of gonadotropin-releasing hormone (GnRH) and agonists (GnRHa)

Studies in female broodstocks indicated that GnRH and GnRHa were effective in inducing ovarian development, FOM and ovulation in doses ranging from 1 to 15 mg GnRH $^{kg-1}$ or 1 to 100 mg GnRHa kg^{-1}. The use of GnRH peptides for spawning induction therapies has important advantages over the use of GtH preparations. First, GnRH and its agonists are small decapeptides that do not trigger an immune response and can be used again in subsequent spawning seasons with no reduction in their efficacy. Second, by inducing the release of the endogenous LH, the GnRH repairs the endocrine disruption that results in the failure of captive fish to undergo FOM, ovulation and spawning. Also, GnRH acts at a higher level of the hypothalamus–pituitary–gonad axis. Consequently, GnRH can provide a more balanced stimulation of reproductive events and, presumably, a better integration of these events with other physiological functions, by directly or indirectly affecting the release of other hormones necessary for successful FOM, spermiation and spawning. A third advantage of GnRHa, is that it can be synthesized and obtained in pure form, and thus does not carry the risk of transmitting diseases. Finally, because of the structural similarity of the GnRHs among many fish species the use of GnRHs, unlike the use of gonadotropins, is generic and the same GnRHa has been successfully applied to a wide range of fish species.

Sustained-release delivery systems for GnRHa

Almost from the first experiments using pituitary extracts for spawning induction, it was recognized that administration of the hormone in a sustained fashion would improve the efficacy of the procedure. The multiple treatments those are often necessary for a successful response present various problems to the hatchery manager. First, repetitive handling of broodstock requires substantial labor, time and monitoring. Especially in situations where the broodfish are kept outdoors, in ponds or cages, it is difficult, very time consuming, and labor intensive to crowd, capture, anaesthetize and inject the fish with hormones, frequently while hatchery personnel are exposed to the elements of nature. Secondly, repetitive handling is stressful to the fish and can often result in pre-spawning mortalities, or at the very least it can adversely affect the progression of FOM.

Over the last 20 years, a variety of GnRHa-delivery systems have been developed and tested in cultured fishes for the control of FOM, ovulation and spermiation. The first such delivery system was prepared using cholesterol and was tested in Atlantic salmon. Cholesterol implants are prepared as solid, cylindrical pellets (3 mm in diameter) and are implanted intramuscularly using an implanter or a scalpel. This GnRHa-delivery system is easy to fabricate and relatively inexpensive, but the GnRHa release from the pellets seems to be extremely variable probably because each implant is prepared individually. The next type of GnRHa-delivery system was fabricated in the form of microspheres (5–200 mm in diameter), using co-polymers of lactic acid and glycolic acid (LGA). The greatest advantage of biodegradable, microspheric delivery systems is that the same preparation can be used to treat fish varying in size from a few grams to many kg. This can be done because the microspheres are suspended in vehicle and are administered on a volume to weight basis. The last type of GnRHa-delivery system used for spawning induction is prepared in the form of a solid, monolithic implant, using a non-degradable co-polymer of Ethylene and Vinyl Acetate (EVAc. Unlike the biodegradable microspheres and similar to the cholesterol pellets, EVAc delivery systems have a long shelf-life and can maintain their effectiveness for up to 3 years if stored desiccated at 20 °C.

Fishes having eggs with an average diameter equal to or greater than 0.65 mm are induced to spawn by injecting hormones intramuscularly a few centimetres below the dorsal fin. In the first injection the fish is given a combination of 10 mg SPH/kg body weight + 1 000–10 000 IU HCG/kg body weight. In the second injection, the fish is given a combination of 10 mg SPH/kg body weight + 2 000–20 000 IU HCG/kg body weight. Injections are administered intramuscularly a few centimetres below the dorsal fin after which the fish is completely anaesthetized by immersing it in seawater containing 100 ppm 2-phenoxyethanol. The time interval between injections is 24 hours for most marine fish. This interval was selected to ensure that final maturation of eggs is completed before the fish dies or before the eyes of the breeders are completely covered with a white opaque substance.

Milkfish can be induced to spawn when females possess oocytes of 0.67mm in average diameter. The females and the males with milt are injected with either 1000IU of Human Chorionic Gonadotropin (HCG) or 100μg of LHRHa per kg of body weight. Similar spaning agent and dosage was used for snapper, but he minimum oocyte diameter is only 0.42mm as spawned eggs of snapper (0.80mm) was smaller than that of milkfish (1.20mm) the effectiveness of LHRHa, administered by injection or pellet implantation has been demonstrated to induce spawning of seabass. A single injection of 100µg/kg BW induced spawning of seabass with an initial oocyte diameter of 0.40mm and above. A single injection of hCG (2IU/g BW) or implantation of LHRHa can induce spawning of the rabbitifsh.

Usually, only two injections are needed to induce both captive and wild adult fish to spawn as long as the dosage and time-interval mentioned above are followed; however, badly injured fish may need a third injection. In such cases, the dosage of the third injection is that of the second injection. When a third injection is necessary, usually the fertilization and hatching rates are very low.

B. Induced Spawning by Environmental Manipulation

The method involves the simulation of the natural spawning environment in which temperature, artificial rainfall and tidal fluctuation are manipulated.

At the beginning of the new moon or full moon, the water temperature in the spawning tank is manipulated by reducing the water level in the tank to 30cm deep at noon and exposing to the sun for 2–3 hours. This procedure increases water temperature in the spawning tank to 31°–32°C. Filtered seawater is then rapidly added to the tank to stimulate the rising tide. In effect, the water temperature is drastically decreased to 27°–28°C.

The fish spawn immediately the night after manipulation (18.00–20.00 h) or, if no spawning occurs, manipulation is repeated for 2–3 more days until spawning is achieved.

Whether the fish are induced to spawn by hormone treatment or environmental manipulation, they would continue to spawn for 3–5 days after the first spawning provided the environmental factors that stimulate spawning are present, e.g., new or full moon, changes in salinity and temperature, etc.

FERTILIZATION AND INCUBATION

The fish that are induced to spawn by hormone injection will be ready to spawn within 9–12 hours after the final injection. The schedule of injections for subsequent spawning must be synchronized with the natural spawning time of the fish which occurs in late evening between 18.00 and 24.00 h. On the other hand, in the stripping method, it is still necessary to sample the eggs from gonads by cannulation and examine them under the microscope. The fish has spawned only if at least 40% of the eggs are transparent.

Determination of egg and larval quality

Several parameters are used to assess fish egg and larval quality. These include the rates of egg viability, hatching and normal larvae. Chemical composition of eggs are also analysed and of the egg chemical constituents, fatty acids, amino acids, ascorbic acid, yolk protein and DNA and RNA have been reported to have an influence on egg and larval quality.

LARVAL-REARING

The rearing tanks are usually made of plastic, fibreglass or concrete. The shape of the tanks can be retangular or circular. Volume ranges from 1 to 10m^3. The tanks are usually protected from sunshine and heavy rain.

Five hours before hatching, the developing eggs are transferred to larvae-rearing tanks. The tanks are provided with mild aeration. The larvae start to hatch 16–25 h after fertilization depending on temperature and species. The usual stocking density of developing eggs is 100–200 eggs/l.

Factors affecting mass-rearing of marine finfish larvae

- Type of food
- Food density
- Water quality
- Environmental factors

The most important environmental factors affecting larval growth and survival are: (1) light, (2) temperature, and (3) salinity.

(1) Light: The effect of light intensity and photoperiod on the growth and survival of larvae has received little attention in the past. Generally, fish larvae are reared either under continuous light or under day and night conditions.

Light is of primary importance since most marine fish larvae are visual feeders. Nevertheless, the larval eye at first feeding is very simple, with no capabilities of distinguishing between different illuminations. High light intensities of about 1000–2000 lx at the water surface are commonly used in hatcheries. (Naas, K., Huse), I. and Iglesias, J., 1996). Illumination in first feeding tanks for marine fish larvae. *Aquacult. Eng.* 15:4, pp. 291–300 Article | PDF (634 K) | View Record in Scopus | Cited By in Scopus (27). The reflections from surfaces in a tank are very important for the light distribution in the water body. Black tanks are best suited to reproduce natural illumination conditions. White-walled tanks should be avoided since they would be a perfect wall trap due to the phototaxis of the larvae. Green water and dark walled tanks seems to be beneficial, as growth, survival and nutritional condition are usually enhanced.

(2) **Temperature.** Temperature can be either beneficial or detrimental to fish larvae. Temperature regimes outside the tolerance limits of a particular species will cause mortality of larvae while temperature regimes within the range that give good survival may be used to accelerate or even maximize growth of the larvae. High temperatures will shorten the time from hatching to metamorphosis, and consequently, mortality may be reduced.

The effects of temperature on the growth and survival of fish larvae must be determined for each species. Apparently, the eggs and larvae of tropical and subtropical species are generally stenothermal.

(3) **Salinity.** The effect of salinity on the growth and survival of fish larvae is primarily on larval osmoregulation. Survival of larvae of many species may be better at low salinities than higher salinities since low salinities are osmotic to body fluids.

REARING ENVIRONMENT

Good quality seawater at 30–31 ppt is required for larvae rearing. Water temperature is also important and should range from 26° to 28 °C to promote fast growth of larvae.

Larval tanks are prepared one to two days prior to the transfer of newly-hatched larvae. Filtered seawater is added to the tanks and very mild aeration is provided. After stocking, unicellular algae (*Tetraselmis* sp. or *Chlorella* sp.) are added to the tank and maintained at a density of 8–10 × 10 or 3–4 × 10 per ml for *Tetraselmis* sp. and *Chlorella* sp., respectively. These algae serve a dual purpose: as a direct food to the larvae and rotifer and as a water conditioner in the rearing tank.

Green water and clear water

Microalgae affect the microbiology, nutrition, feeding and behaviour of larvae. The addition of microalgae to the tanks during early rearing of the larvae may affect rearing performance. Microalgae addition rapidly affects the biochemical composition of the rotifers in the larval tanks. Larvae from green water tanks showed higher survival and growth, and less gut contents than larvae reared in clear water. In the former, the ingested rotifers had higher energy and protein content, suggesting that these variables are important for achieving high growth and survival in the larvae.

The growth and survival of fish larvae can also be affected by the type of microalgae used. Interactions between algae and bacteria in the larval tanks might be more important than the nutritional value of the algae. Dead or dying algae would increase the bacterial substrate.

Fish larvae can be reared under stagnant or open-system conditions. Generally, partial water changes are provided and microalgae are supplied to the rearing tanks during the initial stages of culture. Low exchange rates of water may affect the retention time of prey in the larval tanks and changes may occur in the biochemical composition of the prey before being consumed by the larvae. Algal addition is advantageous since the prey can continue feeding. Consequently, in clear water systems, there is a progressive decrease with time in prey quality. This loss of prey quality can be partially avoided by reduction of the prey residence time through an adequate adjustment of the prey density and the prey/larvae ratio.

The day following stocking, the bottom of the larvae-rearing tank should be cleaned and every day thereafter. This is done by siphoning off unfertilized eggs, faeces, dead larvae and uneaten food accumulating on the bottom of the tank. About 20% of the tank water is changed daily for the first 25 days of the rearing period, then increased to 40–60% per day for the remaining culture period. Since seabass can also be cultured in freshwater, it is recommended to reduce the salinity of rearing water when the larvae are still in the hatchery, before transfer to a freshwater environment. Beginning from the twentieth day, salinity can be gradually lowered until freshwater condition is reached on the twenty-fifth day.

FEED AND FEEDING

Prey size

Prey size may affect the prey ingestion by early fish larvae. It has been reported that the use of small sized rotifers significantly improves the initial feeding performance of fish larvae at the earlier developmental stages. The effect on feeding of using small sized rotifers is mainly due to an increase in feeding incidence rather than in ingestion rates. Therefore, small rotifer supply would improve the incorporation of the larvae to the exogenous feeding from mouth opening. In spite of this, only large rotifers are commonly used in hatcheries for some species. Small sized nauplii of various copepod species were found to very useful for the larval rearing of marine finfishes especially for the species with small larval mouth openings.

Prey density

Maintenance of appropriate feed density in the larval tanks is most important. Since the marine finfish larvae are visual feeders, availability of the prey in the vicinity increases the chances of feeding and saves energy of larvae used for searching the prey.

LARVAL DIETS

Most species of marine fish that have been cultured are reared on a sequential diet of rotifers, brine shrimp nauplii and dry supplemental diets.

Microalgae are the customary food given to zooplankton that will be fed to larval fish. The type of culture, temperature, nutrients, other conditions and growth phase all can affect the nutritional value of microalgae to zooplankton and to the fish larvae eating them.

Rotifers

The rotifers are considered as an important live feed in hatchery operation due to their planktonic nature, tolerance to a wide range of environmental conditions, high reproduction rate (0.7-1.4 offspring/female/day), small size and slow swimming nature. More over the filter-feeding nature of the rotifers facilitates the inclusion of specific nutrients essential for the larval predators through bioencapsulation into their body tissues. As a result it became a suitable prey for fish larvae that have just resorbed their yolk sac. The availability of large quantities of this live food source has contributed to the successful hatchery production of more than 60 marine finfish species and 18 species of crustaceans worldwide.

Two main species of rotifer have been used are *Brachionus plicatilis* (large size) and *Brachionus rotundiformis* (small size).

Health and nutritional quality of rotifers depends on several culture factors: type of culture, water quality, temperature, foods, rotifer density and age of culture. Rotifers are also cultured in many species of algae. These algae should contain significant amounts of DHA and EPA because one or both of theses are essential fatty acids in the diet of marine fish. The ability of rotifers to synthesize these fatty acids is limited and their diet must include a generous portion of these if the requirements of marine fish larvae eating the rotifers are to be met.

The rotifer diet has little effect on the rotifer size and the use of different strains/species of rotifers is required to provide optimal prey size to the larvae.

Artemia

Among the live diets used in the larviculture of fish and shellfish, nauplii of the brine shrimp *Artemia* constitute the most widely used food item. the unique property of the small branchiopod crustacean *Artemia* to form dormant embryos, so-called 'cysts', may account to a great extent to the designation of a convenient, suitable, or excellent larval food source that it has been credited with. In marine finfish larval rearing, artemia feeding is done when larvae is big enough to capture larger preys. Artemia is usually given after 5-10 days of initial rotifer feeding.

Artemia nauplii are maintained in the larval culture tank at densities of 0.5 to 2 per ml for most species of finfish. To estimate the amount of *Artemia* required one must consider both the volume of the tank and the expected number of *Artemia* the larvae will consume. Based on the stage or the age of the larvae, estimate a daily *Artemia* requirement per ml. The total requirement is calculated by multiplying the predicted requirement per ml by the total volume of the rearing tanks. Each gram of cysts contains approximately 200,000 to 300,000 cysts. *Artemia* generally have at least a 50 percent hatch.

Copepods

Copepods were found to be best alternative and most appropriate for marine fish larvae in which rotifers are an unsuitable first feed. Copepod nauplii are a common natural feed for marine fish larvae species. Small size of copepod nauplii make them suitable for small marie fish larvae at first feeding. Copepods has been used in successful production of marine fish larvae of groupers, snappers, etc. However, the ability to produce copepod nauplii on a large scale has yet to be accomplished as successfully as it has been for rotifers.

Trocophores of bivalves have been found to be a good supplement starter food if given with small rotifers and then replaced with rotifers as soon as the fish are ready. Wild planktons can collected with various nets and traps and can be used for feeding larvae. Nutritional quality is likely to be very high but the appreciable chance of introducing pathogens or pests into the system. Another alternative is extensive culture of zooplankton in ponds and impoundments.

Feed quality

Enormous efforts has been done on improving the quality of both live foods and formulated diets for larval fish by better understanding of the nutrient requirements of larval fish. Enrichment of live foods has been a major area of emphasis. Artemia can be low in several fatty acids and various products and protocols have been investigated to improve artemia nutrient quality. Rotifers, a commonly given first food, are often enriched in an attempt to improve their nutrient quality. There are a number of commercial products are now available for fatty acid enrichment of live foods. The appropriate concentration of a specific fatty acid and how it interacts with other fatty acids is to explored for a better management of feed quality.

Amino acids are another important component of the diet of rapidly developing larvae providing the building blocks for protein synthesis, and are important energy substrates.

Enrichment of live feeds

To reduce uncertainty concerning lipid quality of zooplankton, they can be enriched. Some marine oils are reliable sources of EPA and DHA, and mixtures of purified oils are also used. Because rotifers cultured in baker's yeast alone are deficient in DHA and EPA, they can be enriched upto 48 hrs with yeast enriched with oil and sometimes vitamin or with other materials. Addition of cuttle liver oil to bakers yeast fed to rotifers increased both EPA nad DHA levels. Brine shrimp nauplii can also be enriched with emulsified marine oil or a micronutrient-fortified marine oil emulsion. A variety of commercial enrichment media for rotifers and artemia are available to improve the nutritional quality of these organisms.

Compound larval feeds

The three main types are microencapsulated, microbound and microcoated diets. early marine fish larvae have difficulty in accepting and digesting microcapsules and microparticulates. Early weaning was the orinal goal of supplementing with compounded feed, but co feeding of compounded feeds with live feeds can at least reduce the live food requirement. Microencapulsted eeds provide ad alternative way to administer vaccines and therapeutic agents to larvae. During early stages, larvae have difficulty in recognizing inert particles as feed. Typically, early marine larvae probably depend on to a greater degree on small colloidal proteins in zooplankton because they donot have the enzymes necessary for digesting and absorbing larger protein molecules. Older larvae have greater capabilities to make more kinds of enzymes and to adjust enzyme production according to the type of food.

As greater understanding of the nutrient requirements of larval fish are gained and weaning protocols are improved, formulated diets will become more widely used and used earlier in the life history for many fish.

Feed management

Newly hatched larvae are usually not given food on the first day because they derived their nourishment from the yolk and the eyes and mouth are still non functional. During the initial days the larvae were given enriched rotifers at a density of 5-20 rotifers/ml depnding upon the species and age of the larvae. As the larvae grows bigger, freshly hatched brine shrimp nauplii at a density of 1-10 1induviduals /ml depending upon the species and age of the larvae. As the feeding of brine shrimp progress the rotifer density is slowly decreased and finally stopped. As the larvae grow bigger, compounded feeds were given to larvae at a rate of 1-4g/t.

Water management

Siphoning of the tank bottom to remove dirt, dead larvae, wastes and decaying uneaten food should be done everyday starting from the second day of rearing. Daily water exchange from as high as 70% of the tank volume to as low as 30% is undertaken prior to feeding. The percentage of water exchange is dependant on the age of the larvae.

Fry harvest/packing /transport

At the end of larviculture, fry can be harvested and transported to fish farms. Transport is usually done in cool periods of the day. Fishes are transported in oxygenated bags places inside carton boxes lined with thermocole sheets. The transport densities depend upon the size of the fish, species of the fish, distance to be traveled etc. Reducing the temperature and salinity during transport help to improve the survival.

Conclusion

The hatchery phase is one of the bottlenecks for aquaculture expansion. Broodstock development and induced spawning techniques have improved drastically over years for a number of species by administering gonadotropin releasing hormones via injection or implantation. Advances have been made in broodstock diets, specifically in the use of fatty acids to improve egg quality and quantity to equal that of brooders given natural diets. Advances in the larval rearing systems, better understanding of rearing environment has improved the growth and survival of larvae in captivity. Better understanding of nutritional requirements and by improving the larval feed quality made the hatchery production marine finfishes more successful. Improvements in formulated diets for larval fish have reduced the dependence on live foods at earlier and earlier stages in the life history. Co-feeding during the larval stages helps to reduce the need for live foods and facilitates the transition to formulated diets.

Recent advances in hatchery management have resulted in a much better control of critical life stages of fish. These advances will continue until the science of aquaculture is on a level with that of the other animal sciences.

Ecosystem Approach to Aquaculture

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Traditional eco-friendly farming practices

Aquaculture was practiced in several coastal areas of the world by simple methods such as collecting seed from naturally abundant areas growing them to harvestable size in coastal ponds. Simple supplementary feed using locally available natural resources wereused and the production rates were moderate. The aqua farmers were satisfied since investments were low, mass mortalities of stocked resources were rare and there was moderate profit. These traditional systems in Asia especially in China and Vietnam have been productive for more than 3000 years.These eco-friendly aquaculture practices like paddy cum fish culture have benefitted several millions of rural people in Asia and have been designated as a "Globally Important Agricultural Heritage System".

Development of modern aquaculture

With the increase in human population, the need for farmed fish increased and accordingly farming systems were modified and new systems were developed. Research on inputs required for increasing the productivity of aquaculture such as feed and seed increased and great strides were made in seed production through controlled condition in hatcheries and feed production technologies using varied raw material. Thus the traditional simple aquaculture system began to be replaced by controlled farming methods such as the semi-intensive / intensive type of farming systems where resources are stocked in high densities and farmed under controlled conditions.

Globally, Asia continues to be the leading aquaculture production region with more than 85% of production. Aquaculture provides livelihood to nearly 17–20 million aquaculture farmers in Asia and it is important that the farming systems are sustained. That is, they should continue to flourish and be productive and provide the food and financial security to the farmers. However, unplanned growth and farming without considering the ecological potential of the farming area has lead to several negative impacts both to the farm and also to the natural ecosystem.

Ecological Signals of alarm

There are clear examples of ecological damages when farms are constructedin the same location without taking into consideration the ecological carrying capacity or the potential. One example is that of Sandu Bay, a semi-enclosed bay with an area of 263 sq km whwre yellow croaker, farming was started in 1995. Qingshan region was the main cage farming area in this bay and there were about 1000 fish cages. However, the successful farming operations prompted the farmers to increase the farms each year and by 2005 the number of farms increased to 50 000. The number of farms in the Sandu bay reached 260 000. This large scale expansion lead to frequent outbreaks of low or nil oxygen levels (anoxia), frequent outbreaks of harmful algal blooms (HAB), epidemic fish diseases and mass mortality since then (Zhu and Dong 2013).

Similar problems were also observed in other farming systems and resources like the pearl oyster farms (Fu et al., 2009).

What do we learn from this? Once an ecosystem is damaged and stressed, it cannot be productive. Farmers will have only tales of woe and there will not be any profits. Livelihoods will be affected and can lead to strong social changes including emigration and change of avocation. All these teach us that ecosystem is very important and we have to consider the natural resources and the environmental factors when aquaculture is practiced.

How can aquaculture affect an ecosystem?

In a balanced natural system there is harmony between the food available (plankton, benthos etc.) and the living resources of different trophic levels. These are controlled by several environmental factors like level of nutrients, dissolve oxygen, temperature, salinity, pH, particulate organic matter, total suspended solids and so on. The benthic systems will have specific sediment texture, organic matter, levels of dissolve oxygen, hydrogen sulphide, pH and so on etc. When the ecosystem is utilized for aquaculture, the services of the living and non-living resources will be affected and this mostly depends on the type of aquaculture system like fed (eg. cage farming) or extractive (eg. bivalve farming) and open (eg. cage farming) or closed (eg. shrimp farming).

Globally, several studies have been conducted to evaluate the environment impact of farming on the ecosystem. The results of these studies give us an indication on the factor responsible for negative impact and the damage it can cause. Keeping these in mind, aqua farmers are advised to plan their farming activities in such a way that the ecosystem is not stressed and that the farming is productive.

Enhancement of Ecosystem services by aquaculture

Sometimes aquaculture promotes the ecosystem services of the region where it is farmed. Typical examples are that of bivalve culture. The farmed shellfishes remove nitrogen and other nutrients and make it available to in the food chain. They also act as a breeding place for fishes /shellfishes which favour shades and need hard substrates for attaching the eggs. They act as a fish aggregating device. They also serve to reduce the water turbidity to a certain extent.

Ecosystem Approach to Aquaculture (EAA)

In 2006, the FAO Fisheries and Aquaculture Department recognized the need to develop an ecosystem-based management approach to aquaculture to strengthen the implementation of the FAO Code of Conduct for Responsible Fisheries (FAO, 1995). FAO proposed an ecosystem approach to aquaculture (EAA), defined as A strategy for the integration of aquaculture within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems (FAO, 2010). The strategy is guided by three key principles of which the first principle is related to environment and the ecosystem services and states that Aquaculture development and management should take account of the full range of ecosystem functions and services, and should not threaten the sustained delivery of these to society.

Is EAA significant?

The first principal of EAA states that the ecosystem functions and services should not be affected which means that the services provided by an ecosystem in all aspects such as resource availability and production from other activities dependingon the ecosystem (eg fisheries) should not be affected. Generally, natural ecosystems have high resilient capacities. An ecosystem is said to stable when the living resources are able to grow and reproduction thereby maintain the biodiversity of the systems. They are conditioned to the seasonal variation in environmental parameters. Even when the ecosystem is impacted by natural disasters like cyclone or flood, the ecosystem gets back to the original condition after same time. Contrary, to this, when activities like aquaculture are undertaken in an uncontrolled manner in an ecosystem, it can lead to negative impact, which in long term affect the biodiversity and sustenance. This usually happens when the impacts exceed the threshold and limits of the ecosystem.

One typical example is that of bivalve farming. Bivalves feed on the phytoplankton in the surrounding environment where they live. When bivalves are formed in this ecosystem, there is an additional requirement from the farmed bivalves for the phytoplankton available in the area. If the demand for food by biomass of the stocked bivalves in the farm is within the limit available and replenished by the ecosystem within the limited period there is no problem. In case, the demand of phytoplankton exceeds the supply/ regeneration then the food available to the farmed bivalves and the naturally occurring bivalves will be low. This can lead to low growth rates, affect gonad development and spawning and can affect the production. This will affect not only the bivalve farmers but also the bivalve fishers. This will also lead to a chain of events which can affect the nutrient level and survival of other higher trophic resources. To avoid such instances, we have to consider the carrying capacity.

What is carrying capacity?

Carrying capacity (CC) is an important concept in ecosystem based management. Earlier, while estimating the CC,only the resource which was farmed was taken into consideration and accordingly CC was defined as the maximum standing stock that may be kept within a particular ecosystem to maximise production without negatively affecting growth rate (Carver and Mallet 1990). Later considering the negative impacts aquaculture can have on the ecosystem services CC was redefined and now CC can be defined as "the amount of change that a process or variable may suffer within a particular ecosystem, without driving the structure and function of the ecosystem beyond certain acceptable limits" (Duarte et al. 2003).

In most aquaculture management programmes, the concept put forth by McKindsey *et al.* (2006) is considered. Here four different types of CC are considered i) physical ii)production iii) ecological and iv) social. These can be described as given below.

- **Physical carrying c**apacity is the total area of marine or brackish water farms that can be accommodated in the available physical space.
- **Production carrying capacity** is the stocking density of bivalves at which harvests are maximized.
- **Ecological carrying capacity** is the stocking or farm density which causes unacceptable ecological impacts.
- **Social carrying capacity** is the level of farm development that causes unacceptable social impacts.

Implementation of carrying capacity concepts

For sustainability, identification of critical limits (i.e. performance standards or thresholds) at whichthe levels of aquaculture developments can disrupt an ecosystem, thus requiring management actions should be known. These indicatorsare known as environmental quality standards (EQSs) and are used by planners. The

Association of Southeast Asian Nations has also started the process of standardizing water quality standards within the Southeast Asian region. In many countries, an EIA is essential as part of the licensing process for farms over a threshold size. In some regions if the farmer plans to expand an existing site beyond the approved license size then also EIA is required.

The EIA may be defined as "The process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made" (FAO, 2009). The EIA most often provides the framework for the implementation of environmental carrying capacity criteria, although it can also include social and economic impacts.

In Asia, aquaculture farm size is usually small and the EIA may not be worth monitoring individually. However, when many such farms exists in an estuary, there is a need to evaluate the overall impact on the ecosystem which is called Strategic Environmental Assessment (SEIA). This is to ensure that the sum of the small farms will not exceed the ecological carrying capacity. However, such evaluations are rarely done.

For large farms sharing a common water body, like that of shrimp farming in coastal zones. the combined effects of farms on the receiving water body (e.g. a mangrove estuary) is normally not assessed or monitored. However, the combined farm nutrient loads can exceedthe ecological carrying capacity. In such situations cluster management is advised.

Cluster management in simple terms can be defined as collective planning, decision-making and implementation of crop activities by a group of farmers in a cluster (defined geographical area for example sharing common water source) through a participatory approach in order to address the common risk factors and accomplish a common goal (Ross et al., 2013).

Environmental impacts of different farming systems

Usually coastal aquaculture farms are located in estuaries, where tidal flushing is significant and can play a critical role in determining the carrying capacity and lowering the impact on the ecosystem. A well-flushed estuary or bay can make aquaculture more sustainable, or have a larger carrying capacity, than poorly flushed basins.

Mussels, oysters, scallops, pearl oysters and seaweeds are cultured using racks, rafts or longlines. These farming practices are considered as environment friendly due to their nutrient assimilating capacity and there is practically no feed input required. However, the bivalves can cause localized bio-deposition of pseudofaeces. Since these are concentrates of phytoplankton, they can increase the soil productivity. Though mussels or oysters act as a bio-filter, organic pollution from large-scale mussel or oyster culture in form of pseudofaeces cannot be neglected.

A brief summary of the impacts of extractive type of farming such as bivalve farming on the ecosystem are given below.

- Reduction in phytoplankton / seston.
- Increased water clarity leading growth of sea grasses.
- Increased abundance of cyanobacteria under bivalve farms.
- Higher organic nitrogen, total nitrogen, chlorophyll, phaeopigments in the surface sediments.

- Increased sedimentation.
- Alteration of sediment texture /sediment geochemistry.
- Altered soil Eh.
- Lower species diversity in sediment communities.
- Reduced macrofaunal biomass.
- Modification of current patterns.
- Higher abundance of benthic predator communities.
- Higher sulphide levels.
- Low oxygen levels.
- Altered sediment phosphate fluxes.
- Deposition of dead bivalve shells.

Finfishes and shrimps have to be provided supplementary feed when they are stocked in cages or in earthen ponds. Most of the farms are located in near shore coastal waters and the impacts are localized. In these systems the excess feed and the wastes from the farm can cause ecological damages. Some of the significant damages /changes due to fed type of farming is given below

- Increased nutrient levels in water due to supplementary feed.
- Changes in phytoplankton community due to varied nutrient levels.
- Increased nutrient levels in sediment.
- Altered soil redox potential.
- Anoxic conditions in the sediment beneath the cage.
- Increased bacterial growth in the sediment.
- Different sediment texture.
- Changes in benthic community structure.
- Altered microbial population.
- Escape of farmed species and change in natural diversity.
- Increased occurrence of disease.
- High BOD levels.

Need for sustainability in ecosystems

Though Asia is the largest aquaculture industry in the world, there are only very few large-scale aquaculture corporations in this region. Most of the production comes from millions of small-scale farms owned by individual farmers. This makes ecosystem management and coordination difficult. Since 1990 there has been rapid growth of aquaculture production supported by technical progress such as technology for manufacture of commercial feeds,seed and aquaculture support systems and this has significantly improved the living standards of most aquaculture farmers. This has also caused the immoderate expansion of farming scale (Dong et al., 1998) and over carrying capacity farming has become a common issue in many coastal and inland systems.

Since most aquaculture farms are situated in the rural and suburban area, which are not economically developed as other regions, local government or policy implementers find it difficult to strictly enforce the laws which curtail farming even if it is for the cause of sustainability. Hence rules related to carrying capacity (eg number of farms per unit area) and water quality management (eg. discharge of effluent water from shrimp ponds) can only be partly enforced.

For different aquaculture systems, the best management practices which support sustained production from the farming system and also support ecosystem services of the adjoining water resources are varied. Farmers and planners are advised to adhere to the EIA procedures and restrict activities which will stress the ecosystem.

Eco labeling and certification in aquaculture

Globally sea food consumers became concerned about the quality of the farmed product during the 1990'swhich is marketed and also about the damage to the ecosystem done through irresponsible farming. This led to the development of concepts such as eco-labeling and organic farming.

Aquaculture certification is a potential market-based tool for mitigating negative environmental impacts and enhancing societal and consumer benefits (FAO, 2012). The Article 9.1.5 of FAO Code of Conduct for Responsible Fisheries (FAO, 1995) prescribes that "States should establish effective procedures specific to aquaculture to undertake appropriate environmental assessment and monitoring with the aim of minimizing adverse ecological changes and related economic and social consequences resulting from water extraction, land use, discharge of effluents, use of drugs and chemicals, and other aquaculture activities".

At present there are at least 30 certification schemes relevant to aquaculture and these includes chemes promoted by retailers, aquaculture industry, governments and NGOs; organic certification schemes; fair trade certification schemes and other schemes. The number of certification and ecolabeling schemes for aquaculture products has significantly increased over the years.

Organic certification addresses the processes involved in production rather than the qualities of the product itself. Organic farming is based on holistic production management systems which promote and enhance agro-ecosystem health, including biodiversity, biological cycles and biological activity. In general, organically farmed fish which is farmed without using antibiotics and pesticides is perceived to be more "natural" and therefore healthier, or even tastier. Because of these new concepts which promote eco-friendly aquaculture, there is a tendency to prevent environment degradation and promote sustainability.

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Bivalve Mariculture in India - Progress in Research and Development

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Introduction

We are all aware that with an average growth rate of 6.9% per annum, aquaculture is the fastest growing food production sector in the world (FAO, 2009) and now accounts for nearly half of the global fish production. Given the projected population growth over the next two decades, it is estimated that at least an additional 40 million tonnes of aquatic food will be required by 2030 to maintain the current per capita consumption. Among the Asian countries, India ranks second in aquaculture and third in capture fisheries production and is one of the leading nations in marine products export. In mariculture, India has been a late starter in developing and commercializing technologies. I recall that in the nineteen eighties, as Director of CMFRI, I gave impetus to research programmes on culture of a number of marine species, such as, mussels, oysters, pearl oysters, sea cucumbers, seaweeds and the like which has now led to a fledging small-scale industry. Until then, mariculture was confined to traditional shrimp culture practices. During the nineteen eighties and nineties several comprehensive technologies, including hatchery techniques for production of seeds were developed for farming in coastal water bodies.

Traditionally, in India, bivalves have always been considered as subsistence food of the poor, save for pockets of high consumption like the Malabar and Goa coasts. In Malabar and Goa culinary preparations with bivalves go a long way back in history. But, taking into account the status of bivalves in international aquaculture production (a third of the total by weight) and trade, focus was placed on developing technologies for its farming and hatchery production of seeds. Through this focused attention, techniques for farming mussels, oysters and pearl oysters were developed by the CMFRI in the nineteen eighties, but they did not achieve commercial status until the mid-nineties. In the case of mussels and oysters due to concerted technology transfer efforts by CMFRI from the nineties, the combined production has crossed 20,000 tonnes making India one of the top-ten countries in Asia in bivalve mariculture production. In marine pearl culture too India has made significant achievements in developing a pearl production technology, besides a protocol for hatchery production of pearl spats. However, several issues hinder its development on a commercial scale. Let us examine in brief the progress in farming for each of these commodities.

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Mussel farming

Although the technology for mussel farming has been demonstrated in several locations within Kerala State and in different maritime States, the diffusion of the technology was predominantly in northern districts of Kerala and now rapidly spreading to other southern districts as well. Several reasons, such as, fast growth of mussels because of favorable hydrological and geoclimatic conditions, availability of seed from nearby coastal areas, and availability of loans and subsidies from banks and development agencies have been identified as contributory factors for this development. Three types of farm ownerships are observed: individual, family, and ownerships by self-help groups (SHGs). The adoption curves are such that there were only a few adopters initially followed by an increasing rate of adoption in the subsequent years because of the demonstration effect. There is a deep-rooted "risk aversion" attitude widely prevalent among technology adopters. Age could not be significantly related to technology adoption, while education and occupation of the respondents significantly influenced the technology adoption process. The biggest outcome of mussel farming in Kerala was the empowerment of women with 87% of the SHG farms owned by women. The successful diffusion of mussel farming is the result of a combination of factors, chiefly, the availability of suitable water bodies; high rate of education; proximity of mussel markets and high degree of mussel consumption in the area; and a unique synergy between technology developers (CMFRI), promoters (State development agencies such as BFFDA and ADAK), and credit advancers (local cooperative banks). This development scenario can surely work as a role model for other states and developing nations where similar hydrological, social, and market environment exists.

The basic method of farming developed and promoted by CMFRI in India is by constructing trestles (called racks in India) and suspending the seeded ropes from the horizontal platform in shallow seas and estuaries, though in certain regions, seed mussels are just sown on the substrate (on-bottom) and farmed.

The annual production of farmed mussels has shown a gradual increase from 1997 and it was steep particularly from 2003. On-bottom farming, which is a custom of simply relaying of seed mussels with low inputs, contributed 19% to the production. In certain estuaries, where the depth is less than 1.5 m, the seeded ropes are not hung vertically; rather, they are tied horizontally parallel to estuary bottom. The value of the mussel produced is estimated at $US 12 million on the basis of farm-gate prices during the period 2009–2010. The total area utilized for trestle farming in 2005–2006 was estimated at 14.14 ha, and onbottom farming was done in 11.17 ha in the state mainly at Kozhikode and Malappuram districts. The average productivity for trestle method was estimated at 564.9 tonnes/ha, while for on-bottom method, it was 171.9 tonnes/ha. However, there were regional differences in productivity, with high values in Kasaragod and Ernakulam and comparatively low values in Kozhikode and Malappuram.

Credit constraints can be a problem for small aquaculture farms in developing countries and it can actually impede adoption. The subsidies provided by the government agencies served to attract villagers to the mussel farming technology, and these first-time adopters continued the farming activity even after cessation of the subsidy after the first year. Obviously, it is the profitability and creditworthiness of mussel farming technology that has driven the adoption process in Kerala. The rate of returns from mussel farming ranged from 190 to 350% and the capital recovery factor ranged from 1.7 to 3.3, depending on the location. As a spin-off, several small business enterprises which supply other inputs for farming have also been established; the economic value of which has been assessed as nearly a million dollars.

Refinements in mussel farming technology have been made by CMFRI to reduce capital costs (mainly on nylon ropes) by using alternate core materials and pre-stitched cotton net tubes. Seeding is one of the most critical activities in mussel farming. The process which is physically demanding (as farmers have to kneel and bend down to do it) is crucial to the success of farming as the uniform attachment of mussel seed around the rope is dependent on how well it is done. Now, to reduce the physical strain and to increase efficiency during this process, a semi-automated mussel seeder has been designed, developed and field tested. Both old and new farmers have adopted this technical advancement. The chief advantages of the seeder are reduction in time taken for seeding resulting in increased efficiency and lower labour costs and reduction in physical strain during the process. The time taken for manual stitching of 1m rope by the conventional method is 8 minutes whereas in the seeder the same can be accomplished in 2 minutes.

Another innovation to easily separate the mussels from the rope during harvest a semi-automated mussel declumping machine has also been developed. The machine had two separate units, a metal drum and a metallic circular fixed shield with a central opening with a diameter of 10mm fixed on a stand and a ramp for placing the harvested rope. One meter mussel rope could be de-clumped in two minutes. The chief advantages were that physical exertion during harvesting could be avoided and that it was more hygienic and efficient.

Oyster farming

Growth in commercial oyster farming in India has not been as phenomenal as that of mussels. Again the state of Kerala, particularly the southern districts, has taken the lead. Although, oysters form an integral part of the biota in intertidal areas all along the Indian coast, oyster fishing is mostly at a subsistence level catering to very restricted local markets, particularly in the states of Kerala, Maharashtra and Goa. The oyster farming technology developed by CMFRI in the nineteen seventies following the rack and ren and rack and tray methods could not be commercialized for more than 20 years due to lack of consumer demand. Again, it is the concerted technology transfer efforts by scientists of CMFRI that has led to a commercial practice. The technology adoption has been slow, mainly because of the difficulty in post harvest handling of oysters and the limited markets. Even among oyster consumers, the preference is for cooked meat, rather than whole and live, making heat shucking a necessity. Heat shucking is tedious in the case of oysters as compared to mussels, as they open their valves only on strong steaming. Besides, oyster processors invariably complain about cuts and bruises on their hands while shucking the oyster meat. So much so, many first-time oyster farmers in Ashtamudi, Kayamkulam and Vembanad Lakes of Kerala have switched to mussel farming. However, this trend is recently being reversed due to better market price and also the realization that oysters are more euryhaline than mussels, and hence more conducive for culture in an estuarine environment.

Women SHGs are in the forefront of oyster farming activities, with nearly 2000 families from central and south Kerala being involved. Production has touched nearly 2500 tonnes, and oyster farming has developed as a small-scale industry. Activities related to seed collection, seeding, heat shucking and marketing has led to economic empowerment of villagers especially women.

The development of hatchery technology for oyster seed production paved the way for the expansion of oyster culture into new cultivable areas where no natural stocks were available or natural spatfall was poor. Initially the set larvae (spat) on cultch were transported from hatchery to culture site. Now scientists of CMFRI have been able to develop a remote setting method by which eyed or pediveliger larvae are transported without water, in moist condition to distant places where they are set on the cultch material. The use of this technique has revolutionized oyster farming along the west coast of USA and is expected to make similar impact here too.

The CMFRI has recently taken up an ambitious R&D programme funded by the World Bank to speed up technology adoption in oyster farming in the states of Kerala, Goa and Maharashtra. Through a value-chain approach, it is planned to develop depuration units, value-added products units and an oyster hatchery along the west coast ensuring supply of spats through the remote setting technique. Of interest is the recent attention in live oyster consumption in high-end restaurants in metropolitan cities linked to the backwater tourism industry. Initial results indicate that the unit price of oysters can go up by as much as 10-times through this value-chain and can function as a means of attracting new farmers and increasing production.

Impact assessment of farming

Bivalve farming is not an entirely eco-friendly practice of aquaculture as previously thought. Several studies abroad and in India have shown that continued farming in one location leads to bio-deposition and change in benthic in-faunal community structure. Indian farmers are advised not to keep farm location in one place for more than 2 years. The ecological disaster which portends widespread farming of bivalves in semi-enclosed water bodies has also been addressed by scientists of CMFRI. The carrying capacities of some of the water bodies for bivalve farming have been determined and this information needs to become an essential input of the regulatory mechanisms. Farm structures and bivalves obstructs the free flow of water currents through the farm site thereby aiding sedimentation and organic enrichment but the short-term farming period during the impacts were not significant. However, short-term oyster/ mussel farming does not alter the sediment characteristics under the farm.

Mussel watch

Bivalves have been used as sentinel organisms for monitoring contaminants in the marine environment and mussel watch data has been used for assuring seafood safety. They are efficient bioaccumulators of heavy metals, polycyclic aromatic hydrocarbons and other organic compounds, and because they are sessile they may reflect local contaminant concentrations more accurately than mobile crustaceans and finfish species. A recent study indicates that coastal waters of Karnataka and Kerala are minimally contaminated with genotoxic and carcinogenic chemicals.

Bivalves- Organic by default

Organic farming is based on holistic production management systems which promote and enhance ecosystem health, including biodiversity, biological cycles and biological activity. Bivalve shellfish aquaculture meets each of these criteria, and in fact, is probably organic by default. Bivalve molluscs are not fed so there are no nutrients being added to the marine environment. They are biofilters which feed on phytoplankton which occurs naturally in the water. This biofiltering activity has the beneficial secondary effect of taking up nutrients and purifying the water column, thereby enhancing ecosystem health. Bivalves also create habitat for other marine creatures. As three-dimensional structures, bivalves are host to flora and fauna which make their homes in shellfish beds. These beds also provide cover and forage for fish during their juvenile out-migration stage, enhancing biodiversity, biological cycles and biological activities through the creation of critical habitat. With a view to meet the demands of the discerning customers, and also to enhance the value of the product (by as much as 30%), organic bivalve farming protocols and guidelines have been developed as part of the NPOP

(National Programme on Organic Protocols) in India. The focus here has been on classification of bivalve growing water bodies following the regulations of the European Union (EU Directive 2006/113/EC). Currently Indian bivalves are not exported to Europe, as the produce does not meet the monitoring protocols set by the EU. Efforts to meet the regulations are being jointly addressed by the MPEDA, CMFRI, CIFT and EIC and it is expected that exports to the EU would be possible in a couple of years.

Pearl Farming

As a technology very close to my heart, considering that we are coaxing the oyster to produce one of the most bewitching of natural gems, I kept this for the last. The allure of the pearl, the most ancient and most precious of gems is timeless and universal for humans. The pearl has a history more ancient, more fascinating and more regal than any other gem and India has a wealth of marine pearl producing oysters: the *Pinctada fucata* distributed in the Gulf of Mannar, Palk Bay and Gulf of Kutch and the blacklip pearl oyster, *P. margaritifera* in the Andaman and Nicobar Islands. The technology for pearl production, based principally on the Japanese methodology of pearl production, was tried and developed successfully in the Indian pearl oysters mainly through the efforts of Dr. K. Alagarswami and his team of scientists from the CMFRI. Later, in the eighties, they went on to standardize the hatchery protocols for this species too.

Once again, this is a technology developed in the nineteen seventies, but unlike mussels and oysters, yet to become a full-fledged commercial practice in the country. I am glad to understand that through funding from the Ministry of Earth Sciences (MoES), the CMFRI is very seriously attempting to transfer the technology through women SHGs in coastal villages in the Gulf of Mannar, Kerala and Lakshadweep. The newly developed technique of mabe pearl production, which is relatively less skill-demanding, and with fast turnover rates (2 months), serves to attract farmers to pearl farming. The MoES is also funding a project on black pearl production in the Andaman and Nicobar Islands being executed by CMFRI. During the last 7 seven years, this project has been able to establish pearl farms and on-farm grow-out techniques; establish a black pearl hatchery and achieve success in production of pearl spat; develop and standardize mabe pearl production technique and develop technique for continuous mabe production without sacrificing oysters and conduct training programmes to shellcraft artisans and women fishers on mabe production. Black pearl production itself has not been achieved yet, but as I understand, a lot of effort is being put to achieve it. Indeed, the scenario in Indian pearl farming appears poised for a big leap forward and I look forward to seeing it during my lifetime.

Clam Farming

A number of clam species, mainly belonging to Veneridae, Arcidae and Corbuculidae family are fished from coastal waters of India, and annual estimates of catches are close to a 100,000 tonnes. Because of the high inter-annual variability of the resource, many fishers have resorted to re-laying of seed clams in water bodies close to their homesteads particularly in Kerala and Karnataka. Out of the total production nearly 10% is obtained through this semi-culture practice. Earlier, the CMFRI had brought out a culture technology package using pen enclosures for the blood clam *Anadara granosa* with a production potential of 40 t/ha/6 months, however, this has not reached commercial application yet. Currently, major attempts are being made to develop on-bottom and off-bottom clam farming techniques for the black clam (*Villorita cyprinoides*) and the short-neck clam (*Paphia malabarica*), which have reasonably good price structure locally and abroad.

On Gender and Bivalves

The development scenario scripted by bivalve farmers in Kerala shows that women were the major players with more than 4,000 women becoming owners of bivalve farms. Support from the government prompted women to form self-help groups. This led to group farming, which helped women overcome social inhibitions and prove their competence. The fact that women increased the farm area and intensity of farming shows that they became efficient aqua-planners and aqua-managers and it also proved that women are better carriers of development. Their prompt repayment of loans increased the faith of the bankers and the schemes of helping groups continued over the years. Women were therefore all-round players, right from planning to utilization of profit.

Application of Biotechnology

In oyster and mussel farming knowledge of the time of spatfall is very important for farmers to decide on the time for setting spat collectors. This is particularly important when the current farming practice is wholly dependent on natural spat as seed. Through a project funded by the DBT, the CMFRI has achieved preliminary success in developing a PCR based protocol for identification of mussel and oyster larvae from a cocktail mix of various holo and mero plankters (as found in a plankton collection). So far, bivalve farming has not been affected by any serious diseases. Very recently scientists from CMFRI were able to detect an OIE listed protozoan pathogen *Perkinsus olseni* in farmed and wild pearl oyster *P. fucata* from the Gulf of Mannar. A PCR kit for its detection was also developed. It is possibile that perkinsosis could be one of the major reasons for the decline of the *P. fucata* beds in the Gulf of Mannar over a period of time.

A recent advancement is the development of a neutraceutical from Indian green mussels, again by scientists of CMFRI, called GME (green mussel extract) which has been found to have definitive anti-arthritic properties mimicking the pain killer drug aspirin. This drug which is now undergoing field trials, is surely a means of value addition to mussels, and bound to improve incomes of mussel farmers.

Prospects for Future Development

It is quite clear from the fast pace of its development in the state of Kerala that bivalve farming can develop as a new sunrise mariculture industry in India. Unlike other aquaculture industries, it is not capital intensive and offers great scope for improving the incomes or the rural fishers as an alternate livelihood. But primarily, what has spurred its growth in Kerala is the considerable demand for the produce among the populace. Other bivalve consuming states like Karnataka, Goa and Maharashtra can also be targeted in the next phase of development. Policy makers and planners need to address the following for sustained development of this spanking industry.

Mussels & oysters

1. Promote bivalve farming, particularly mussels, in all maritime states using Kerala as a developmental model.
2. Since farming depends on seed availability from natural sources, development of methods to collect seeds from the wild is necessary.
3. Determine carrying capacity of backwaters/estuaries for bivalve farming and restrict farming accordingly.
4. Make a prospective (5 years) plan to improve hygiene in farming areas using international guidelines as a criterion.
5. Conduct awareness campaigns for improving bivalve consumption in India

Pearl oysters

1. Demark areas for mariculture and create mariculture zones with adequate legal protection and articulate open-access water body leasing policies.
2. Promote SHGs to take up pearl farming in identified pearl mariculture zones
3. Undertake stock enhancement of blacklip pearl oysters in A&N Islands using the hatchery technology developed recently
4. Priority in research for production of large fucata pearls and black pearls

Processing and marketing

1. Encourage value added products (VAP) for bivalves to increase marketing possibilities (especially live oysters) and to make the farming practice more remunerative.
2. Research focus to be placed on pearl processing for improving value.

Mussel Farming Methods and the Prospects and Problems in India

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Introduction

Mussel farming has a long history that dates back to the thirteenth century. Mussels are farmed in many areas of the world with the most common species cultured being the blue mussel, *Mytilus edulis*. The main producers of mussels are countries such as China, Korea, Spain, Netherlands, Denmark, France and New Zealand. In 2012, 1.829 million tonnes of mussels were produced worldwide valued at 2.053 billion US Dollars (FAO). The Indian mussel production is relatively small and the production is around 10,000 tonnes for the past few years.

In India, mussel culture (*Perna viridis*) is becoming popular in the Malabar area since 1996 following the success achieved by CMFRI in rearing and popularizing green mussel in the backwaters. The simple methods employed for mussel farming was transferred to progressive farmers who took up mussel culture in the backwaters. Soon they found the venture profitable. Demands came from new entrepreneurs for training and mussel farming spread from Kasaragod to Ponnani.

Mussel culture in the backwaters of Kerala was first started in Padanna and Cheruvattur Panchayats in Hosdurg Taluk of Kasaragod district. Later it was taken to Elathur in Calicut district and Vallikunnu and Ponnani in Malappuram district.

Initially this low cost technology of farming was transferred to five groups with 15 to 21 members at Cheruvattur and Valiyaparamba. Financial assistance was provided by the North Malabar Gramin Bank and Cheruvattur Farmers Co-operative Bank. They provided a loan of Rs. 2,60,200/= for the implementation of the project with a subsidy component of 50% subsidy. These groups harvested 67.4 tonnes of mussels during May-June 1997. A portion of the harvested and shucked meat (2000-Kg) was sold to the Integrated Fisheries Project, Cochin at a rate Rs. 45 per Kg. The remaining harvest was sold in the domestic market. The groups could realise Rs. 3,34,555/= from the harvest with a net profit of Rs. 1,04,455/= within a period of 6 months.

Many culture techniques are used for growing mussels worldwide and the most popular are described below:

1. Bouchot or Intertidal Pole Culture

In France, mussel culture is believed to have started in 1235, when an Irish sailor Patrick Walton survived a shipwreck on the Bay of Aiguillon. He found that the wooden poles and nets that he had kept for trapping birds attracted mussel spat settlement. This became the basis for *Bouchot* method which is the oldest and the main method utilised in France on the Atlantic and English Channel coasts. This method, well suited to the large intertidal mud flats facilitated the development of the blue mussel (*Mytilus edulis*) industry in France (Gosling, 2007). The *Bouchot* method extended to other suitable intertidal areas along the Brittany and Normandy coast. The spats are collected on spat collecting ropes made of coir. These spat bouchots are situated offshore and consists of parallel rows of poles with horizontal coir ropes for collecting seeds.When the seed are a few months old, they are removed from the ropes, placed in mesh tubes and transferred to *bouchots* for growth.

Mussel seeds are harvested from August – December depending on the size and density of settlement. The seeds are scraped from the poles using a steel blade attached to a metal wire to hold the scrapped off mussel. In this method, ropes with spat attached are wound around large vertical poles *(Bouchots)* in the intertidal zone. The line of poles mainly oak tree trunks 4-7 M long, 12-25 cm diameter at the wider end and about 7 cm at the opposite end. The lower 3 meter of the pole is inserted in the seabed. Mesh netting is used to cover the mussels to prevent them being detached and lost. A barrier is placed at the bottom of the pole to prevent predators such as crabs from reaching the mussels. *Bouchot* are placed perpendicular to the shoreline and consists of 125 poles running for 50-60m and spaced 15-25m from the next line. This method of culture requires large tidal ranges, in order to supply the densely packed mussels with plankton.

Marketable mussels of 4-5 cm shell length are harvested when they are 12-18 months old. On an average, 25 kg of mussels are harvested from each pole annually. The entire produce is sold domestically. 4000 poles can produce 100 tonnes of mussel per year.

2. Stake culture

In Thailand and Philippines, mussels are grown on bamboo poles (6-8m long) staked at half meter depth and one meter apart or in circle and tied at the top to form a wigwam structure in soft, muddy bottoms. Mussels (*Perna viridis*) settle on the submerged bamboo stakes. Bamboo poles are often observed to monitor growth as to eliminate predators like starfish and crabs. Bamboo stakes are placed in areas where natural spatfall is expected. Mussels are harvested after a growing period of 6–10 months after stocking or when the animals reach 5–6 cm in length. Each pole yields 8-12 kg of mussel. Harvesting is done by hauling up the bamboo poles and loading them into a raft. Divers are employed to pick out the larger mussels and the small ones left for the next harvest season. This selective harvesting results in two or more yields within the 6–8 months of the farming period. Harvested mussels are cleaned and then placed in baskets and shaken vigorously in seawater until they are clean of barnacles and dirt. Bamboo poles that are worn out are removed while the good ones are cleaned for the next culture season. The stake method is an economical and easy way of growing mussels but has also some shortcomings. The bamboos decay easily and it is at times difficult to match staking operations with spatfall. This culture system also facilitates siltation which makes bays and estuaries too shallow for mussel farming. In Philippines a rope strung in a zigzag fashion or rope web method is used. Each unit consists of two bamboo poles 5 meters apart are driven into the substratum. Two polypropylene rope, 2 meter apart are tied to the bamboo poles. 40 m rope of 10-12 mm diameter is used to connect in a zigzag manner. Pegs are inserted at 40 cm intervals (Joseph, 1998).

3. On-bottom culture

This method is widely used in Netherlands, Denmark and Germany. The culture is based on the principle of transferring seeds from areas of great abundance where growth is poor to culture plots in lower density to obtain better growth and fattening of the mussel. The culture plots must have a firm substratum and less of drifting sand and silt particles. In Netherlands, the seeds are dredged from Waddenzee. The seeds are laid in intertidal areas to produce mussels with thick shells and strong adductor muscle. In the sub-tidal areas higher meat yield and thinner shells are produced fit for processing industry. The whole process is highly mechanized from collection of seeds to harvesting and marketing. Waddenzee and Zeeland are the important areas for mussel (*M. edulis*) farming. In Zeeland, the town of Yerseke is the important mussel trading area. Waddenzee in the northern part of Netherland was used as a source of seed. Since 1950, farming plots were also created here. The seeds which are which are fished from the seed beds during the short well defined period are scattered evenly on the beds allotted by the government to mussel farmers. The seeds are gathered by special mussel boats. About 10 tonnes of mussel seed can be gathered in one hour of dredging operation. The seeds gathered are replanted the same day over the plot measuring 500 x 200 meters. 20 to 35 tonnes of seed are used per hectare for relaying depending upon the size of mussel seed. The mussels are distributed evenly by the farmers if the stocking is found crowded. The starfish problem is managed by salt treatment or removal using starfish nets. The filtering activity of the mussels produces silt which gets deposited under the mussel carpet. This hinders the growth of mussels. Chain harrow are used to level the ground. In the Waddenzee the mussel are usually kept in the same area but in Zeeland the half grown mussels are relocated to deeper areas where conditions for fattening and growth are better. Waddenzee mussel being slightly larger are suitable for half shell trade and Zeeland mussels are preferred as raw material for canning factories fetching higher price.The mussels are marketable in the Dutch mussel farming areas when they are 2-3 years old. The production by on bottom culture is about 8 Kg per m^2 of mussel plot or 80 tonnes per hectare. An essential part of the on bottom Dutch mussel farming is the 're-watering' process. Here before marketing the mussels, they are kept in special lots for 10-14 days for the process of eliminating the weak and damaged mussel.

4. Long line culture

This method is becoming very successful in open sea mussel farming. A rope is stretched horizontally near the water surface and maintained 1-2 m from the surface with buoys. Mussels are grown on vertical ropes known as 'droppers' which hang from the horizontal rope for a length of 4 m. Mussel seeds are collected from natural beds and transplanted onto the ropes into a continuous sock-like cotton tube, which is approximately 17.5 cm in width. Small mussels stripped from the collection ropes are inserted. This cotton sock is then wound around the dropper. The mussels grow and attach to the ropes using their byssal threads and the cotton sock slowly disintegrates and falls away. The droppers are placed a minimum of 0.5 m apart and have at least 4 m of free space from the bottom. In deeper waters the gap between the bottom of the line and the sea floor is greater. Anchor ropes extend from each end of the horizontal rope to anchors buried in the mud of the bottom. As the ropes are kept taut, there is no movement around the anchor to disturb the bottom as occurs when boats are anchored. The density at which mussels can be cultured on long lines could be about 300 per meter, but depends on the food availability, which varies from site to site. Mussels grown on long-lines can become smothered by naturally settling juvenile mussels and other fouling organisms. For this reason, most farmers prefer to position their farms away from heavy spat settlement areas to avoid layers of spat attaching to larger mussels.

5. Raft Culture

The basic principle of raft culture is similar to long line culture in that the mussels are suspended on droppers but these are suspended from the raft instead of the long lines. The raft itself is anchored to the seabed removing the need for several anchoring systems. Long line culture however, creates less of a visual impact, and the droppers can be spaced farther apart to maximize the use of the available phytoplankton. Raft culture is more suited to areas of dense phytoplankton and to smaller operations, as there is less scope for mechanical harvesting. This method of culture is used in the Galician Bays in Spain, Saldahna Bay in South Africa but has been abandoned by the New Zealand industry in favour of long lines. This method has its origin in Spain in the Galician Bay. Mussel seeds (*Mytilusgollo provincialis*) settle profusely in the inter-tidal zone in the coastal waters of Galicia. Rias are deep sunken river valleys upto 25 km in length ,2-25 km wide and 40-60m deep. As these rias are protected by islands at their mouth, these sheltered, nutrient rich rias with 3-4 m of tidal range provide ideal environment for suspended mussel culture. The rafts are constructed using a wooden framework of timber and floats of concrete, steel, styrofoam or fiberglass material. The average size of the raft is 23×23 meter which supports 700 ropes. The rafts are anchored along the sides with large concrete moorings. There are over 3000 rafts in the Galician rias. The rafts are spaced at a distance of 80-100m from each other and positioned in groups called parks. These seeds are collected by scrapping the rocks with spade-like steel blades. Seeds can be collected by suspending ropes vertically from the rafts in December and January to catch seeds in February and March. Seeds also settleon the mussel ropes. The length of the mussel ropes varies from 6-9 meters according to the depth of the culture site. Pegs are used at 40 cm intervals to avoid slippage. The average weight of seed per meter of rope is 1.5 to 1.7 kg. About 4600 t of seed per year are needed to maintain the present level of production (Gosling, 2002).

Thinning out of the mussel ropes are done in 3 to 6 months depending upon the growth. The ropes are removed when the weight attain 10 Kg of mussel per meter. The ropes are hoisted and the mussel transferred to new ropes. About 3.5 Kg of half grown mussels are attached per meter of rope. After 8 to 12 months of growth the mussels attain marketable size of 8-10 cm (Korringa, 1976). Growth of mussels on inshore rafts is less than on rafts in the mouth of the Rias, which demonstrates food constraint at inshore sites (Navarro *et al.*, 1991). Temperature plays an important part on the growth as the mussels in the upper part of water column, above the thermocline (2.5m) were significantly larger than those cultivated in deeper waters (7.5 m) (Gosling, 2002). Harvesting is done using mussel boats outfitted with power crane and metal baskets to collect the mussel ropes. As the production is about 10 Kg of mussel per meter of rope, a raft having 600 to 1000 ropes of 6-9 meter may produce 30000 to 90000 Kg of mussel per year.After harvesting, the mussels are kept for depuration for 24-48 hours before they are marketed (Korringa, 1976).

6. Rack culture

This is the simplest of the rope method used for green mussel cultivation in India and Philippines. The main purpose of the pole is to support the structure. In between these poles, ropes are suspended either vertically or kept horizontally where the depth is a limitation. The construction is labour intensive but the simplicity in harvesting and accessibility of local materials for farming purposes makes it very adaptable under local conditions. Mussel culture is fast becoming popular in the Malabar area since 1997 following the success achieved by CMFRI in rearing green mussel by rack culture in the backwaters. The simple methods employed for mussel farming was transferred to progressive farmers who took up mussel culture in the backwaters. Soon they found the venture profitable. Demands came from new entrepreneurs for training and mussel farming spread from Kasaragod to Ponnani. Mussel culture in the backwaters of Kerala was first started in Padanna and Cheruvattur Panchayats in HosdurgTaluk of Kasaragod district. Later it was taken to Elathur in Calicut district and Vallikunnu and Ponnani in Malappuram district. The total production in 2008 was 16,500 tonnes. Some of the constraints are regarding the availability of seed. The seeds required for culture is presently collected from traditional fishing areas and these are often causing conflicts between farmers and mussel fishermen. Hence it is essential that additional spat collectors have to be established along the coast to ensure supply of seeds to the farmers.

The harvesting seasons of cultured mussels is mostly during April – May months and farmers are forced to sell their crop before the onset of monsoon to avoid mass mortality of mussels due to freshwater influx into the backwater system. At present only a few processing plants purchases cultured mussels from the farmers and as a result the local market are flooded with cultured mussels during these months resulting in fall in the prices and thereby affecting the profitability of the operation. Siltation in the backwaters is another problem. This often results in mortality of mussels in the farms. Hence scientific feasibility studies are required to demarcate potential culture sites. Mussel farming is a decade and half old farming practice in India. This is a low investment activity with very good returns. If promoted properly, mussel farming can be used as a tool for women empowerment in the coastal areas and can stimulate a healthy socio-economic development in the area. Better post harvest technologies can develop attractive value added products. Since very good export markets are available for mussels there is further scope of extending the farming practice to suitable areas.

Prospects:

1. Backwater mussel culture opens immense potential for resource and employment generation among coastal communities especially women living below poverty line.
2. Mussel culture is a low investment activity with very good returns. If promoted properly, mussel farming can be used as a tool for women empowerment in the coastal areas and can stimulate a healthy socio-economic development in the area.
3. Better post harvest technologies can develop attractive value added products. Since very good export markets are available for mussels, they can be taken up as a challenging opportunity.

Constraints:

1. Availability of seed:

   The seeds required for culture is presently collected from traditional fishing areas and these are often causing conflicts between farmers and mussel fishermen. Hence it is essential that additional spat collectors has to be established along the coast to ensure supply of seeds to the farmers.
2. Season of harvest:

   The harvesting seasons of cultured mussels is mostly during April – May months and farmers are at times forced to sell their crop before the onset of Monsoon.
3. Storage facility:

   If sufficient cold storage facility is provided, cultured mussels can be depurated, shucked and stored not only for export market but also for local market throughout the year. This will increase the profitability of the culture operation.

4. Post harvest technology:

   Value added products of longer shelf life need to be developed from mussel meat to increase the revenue realization from cultured mussels. Mussel fry, mussel pickle etc. are some of the best examples for value added products. More studies are needed to develop ethnic cuisines with longer shelf life.

5. Siltation of backwaters:

   Some areas in the backwater system have very high siltation levels especially during rainy season. This often results in mortality of mussels in the farms. Hence scientific feasibility studies are required to demarcate potential culture sites.

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Integrated Multi-Trophic Aquaculture Systems (IMTA)

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Introduction

The aquaculture production has grown steadily owing to the dramatic expansion in this sector worldwide. During the past three decades production increased from 6.2 million t in 1983 to 70.2 million t in 2013 (FAO, 2015). Aquaculture surpassed the supplies from the capture fisheries and contributed nearly 51% to the global fish production in 2013. This achievement was possible mainly because of the commercialisation of farm-produced aquatic groups such as the shrimps, salmon, bivalves, tilapia and catfish. This sector also benefitted from the significant production of certain low-value freshwater species through integrated farming, intended for domestic production. This growth in marine aquaculture industry, has introduced many apprehensions about the environmental impacts from aquaculture waste. Intensive finfish farming in cages can release significant quantities of nutrients to the farm site, from uneaten feed, faeces and excretory products. These metabolic wastes from farm effluents, mostly ammonia, may contribute to increased nutrients and localised eutrophication in the farm. One of the major challenges for the sustainable development of aquaculture industry is to minimise environmental degradation concurrently with its expansion. Though majority of aquaculture production originate from extensive and semi-intensive farming systems, the recent increase in intensive farming of marine carnivorous fed-species is associated with environmental concerns. Integrating waste generating (fed) and cleaning (extractive) organisms in mariculture is a practical technology for sustainable mariculture. In a balanced integrated system, aquaculture effluents can be converted into commercial crops while restoring water quality.

Concept of Integrated multi-trophic aquaculture (IMTA)

Integrated aquaculture systems as detailed in Neori *et al*., (2004) Barrington *et al*. (2009) and Angel and Freeman (2009) and case studies in India are briefly given below.

In many monoculture farming systems the fed-aquaculture species and the organic/ inorganic extractive aquaculture species (bivalves, herbivorous fishes and aquatic plants) are independently farmed in different geographical locations, resulting in pronounced shift in the environmental processes. Integrated multi-trophic aquaculture (IMTA) involves cultivating fed species with extractive species that utilize the inorganic and organic wastes from aquaculture for their growth. According to Barrington (2009), IMTA is the practice which combines, in the appropriate proportions, the cultivation of fed aquaculture species (e.g. finfish/shrimp) with organic extractive aquaculture species (e.g. shellfish/herbivorous fish) and inorganic extractive aquaculture species (e.g. seaweed) to create balanced systems for environmental sustainability (biomitigation) economic stability (product diversification and risk reduction) and social acceptability (better management practices).This farming method is different from finfish "polyculture", where the fishes share the same biological and chemical processes which could potentially lead to shift in ecosystem. *Multi-trophic* refers to the combination of species from different trophic levels in the same system. The multi-trophic sub-systems are integrated in IMTA that refers to the more intensive cultivation of the different species in proximity of each other, linked by nutrient and energy transfer through water.

Selection of species

Environmental sustainability is the major consideration in IMTA, therefore the criteria guiding species selection is the imitation of natural ecosystem. Fed organisms, such as carnivorous fish and shrimp are nourished by feed, comprising of pellets or trash fish. Extractive organisms, extract their nourishment from the environment. The two economically important cultured groups that fall into this category are bivalves and seaweed. Combinations of co-cultured species will have to be carefully selected according to a number of conditions and criteria:

- **Complementary roles with other species in the system:** Use species that will complement each other on different trophic levels. For example, species must be able to feed on the other species' waste in order for the newly integrated species to improve the quality of the water and grow efficiently. Not all species can be grown together efficiently.
- **Adaptability in relation to the habitat**: Native species that are well within their normal geographic range and for which technology is available can be used. This will help to prevent the risk of invasive species causing harm to the local environment, and potentially harming other economic activities. Native species have also evolved to be well adapted to the local conditions.
- **Culture technologies and site environmental conditions**: Particulate organic matter and dissolved inorganic nutrients should be both considered, as well as the size range of particles, when selecting a farm site.
- **Ability to provide both efficient and continuous bio-mitigation**: Use species that are capable of growing to a significant biomass. This feature is important if the organisms are to act as a bio-filter that captures many of the excess nutrients and that can be harvested from the water. The other alternative is to have a species with a very high value, in which case lesser volumes can be grown. However, with the latter, the bio-mitigating role is reduced.
- **Market demand for the species and pricing as raw material or for their derived products**: Use species that have an established or perceived market value. Farmers must be able to sell the alternative species in order to increase their economic input. Therefore, they should establish buyers in markets before investing too heavily.
- **Commercialization potential**: Use species, for which regulators and policy makers will facilitate the exploration of new markets, not impose new regulatory impediments to commercialization.
- Contribution to improved environmental performance.
- Compatibility with a variety of social and political issues.

Inorganic extractive sub-system in IMTA

Bio-filtration by aquatic plants, is assimilative, and therefore adds to the assimilative capacity of the environment for nutrients. With solar energy and the excess nutrients (particularly C, N and P), plants photosynthesize new biomass. The operation recreates in the culture system a mini-ecosystem, wherein, if properly balanced, plant autotrophy counters fish and microbial heterotrophy, not only with respect to nutrients but also with respect to oxygen, pH and CO_2. Plant bio-filters can thus, in one step, greatly reduce the overall environmental impact of fish culture and stabilize the culture environment. Furthermore, farming of species that are low in food chain and that extract their nourishment from the water involves relatively low input.

Seaweeds are most suitable for bio-filtration because they probably have the highest productivity of all plants and can be economically cultured. Seaweeds have a large market for human consumption as phycocolloids, feed supplements, agrichemicals, nutraceuticals and pharmaceuticals. Seaweed farming has long been promoted in China in areas of marine cage culture for bio-extraction of nutrients in the seawater. FAO aquaculture statistics record 37 separate seaweed species groups with dominance of *Eucheuma* seaweeds (8.44 million tonnes) *Kappaphycus alvarezii* and *Eucheuma* spp. farmed in tropical and subtropical seawater followed by Japanese kelp (5.94 million tonnes).

The choice of seaweed species for inclusion in an integrated aquaculture system must first depend upon meeting a number of basic criteria such as high growth rate and tissue nitrogen concentration; ease of cultivation and control of life cycle; resistance to epiphytes and disease-causing organisms; and a match between the ecophysiological characteristics and the growth environment. In addition, given the ecological damage that may result from the introduction of non-native organisms, the seaweed should be a local species. Beyond these basic criteria, the choice of seaweed will be influenced by the intended application. If, the focus is placed on the value of the biomass produced, then subsequent decisions will be based on the quality of the tissue and added value secondary compounds. If the principal focus is the process of bioremediation, then nutrient uptake and storage and growth are the primary determinants. The optimal system would include a seaweed species that incorporates both value and bioremediation.

Among seaweeds, the 'thin sheet' morphology has a higher growth rate than the fleshy seaweeds. It is more difficult to generalize on nutrient sequestration. A bio-filter seaweed species must grow very well in high nutrient concentrations, especially ammonium. Seaweed that does not show this capacity has only a limited use. To take up nitrogen at a high rate, fast-growing seaweed should be able to build up a large biomass N content. The common bio-filter seaweeds, when grown in eutrophic waters, accumulate a high total internal N content. When expressed on a percent dry weight basis, maximal values for *Ulva*, *Gracilaria* and *Porphyra* grown in the eutrophic conditions characteristic of fish farm effluent range between 5–7% as N in dry weight (dw) or 30–45% as protein in dw. In addition to the requisites described above, the ideal choice for the seaweed bio-filter also has a market value. This encompasses the sale of seaweed products for a range of markets, including human consumption as food or therapeutants, specialty biochemicals, or simply as feed for the algivore component of the integrated system.

Only a handful of seaweeds have been thoroughly investigated for their aquaculture and/or bioremediation potential. Perhaps the most complete body of research has encompassed the genus Ulva. These flat sheet morphotypes have correspondingly high growth rates as well as high nitrogen contents, making them very good candidates for remediation. Their life cycle and its controls are generally well known, and *Ulva* has been successfully integrated into mid-to large-scale animal mariculture systems. Possibly the only drawback is the limited market for harvested biomass. *Gracilaria* has a history of mariculture study, whereas Kelps (*Laminaria*) and *Porphyra* cultivations are thought to have a potential for generating a viable seaweed mariculture and integrated aquaculture.

Along Indian coast *Kappaphycus alvarezii* were used in IMTA and has emerged as a promising species in open sea integrated aquaculture.

In open mariculture systems, nutrient uptake efficiency by seaweeds has been low in some systems due to the 3-D hydrographic nature of the water flow; this technology therefore requires further R&D and modelling (such as on the potential of several harvests of several crops). Furthermore, studies investigating the open-water integrated mariculture approach have been hampered by the difficulties involved with experimentation and data collection at sea.

Organic extractive species sub-system in IMTA

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.

How filter-feeders interact with the environment, their uptake rate, and other aspects are available in the literature. A native bivalve species must be consider to suit the local ecology, potential markets, and the need to engineer IMTA systems to accommodate them. Literature shows that 95% of particles released from aquaculture systems, fish farms, and closed recirculation systems are ~20 microns diameter (5-200 micron range), and that they will settle. There is evidence that filter-feeders are selective in extracting particles from the water column, rejecting the rest. Thus, it is important to know the particle size of wastes from an IMTA system and to choose from among the wide range of bivalves that will select the required particle size and type.

Marketability of these secondary products is a factor, but it need not be an overriding consideration. You could add a fish range alongside your primary fed fish to act as a first-stage bio-filter and use a marine bivalve as the second stage. An example of an ecosystem-based IMTA model was built as a Peace Corps-style project in Malaysia in the 1990s to remove contaminants from shrimp farm waste water, otherwise normally released into local waters. The project found that 72% of the nitrogen and 61% of the phosphorus could be removed, mostly as harvested shellfish product using a simple, engineered system.

Studies have shown that bivalves are capable of utilising fish farm wastes as an additional food supply. However, few practical studies have been undertaken, with conflicting conclusions regarding the potential for open-water integrated culture to enhance bivalve production and, by implication, to significantly reduce fish farmwastes.

The bivalve mussel, *Perna viridis* and oyster *Crassostrea madrasensis* that are commercially produced along Indian coast, can economically mitigate eutrophication in integrated aquaculture.

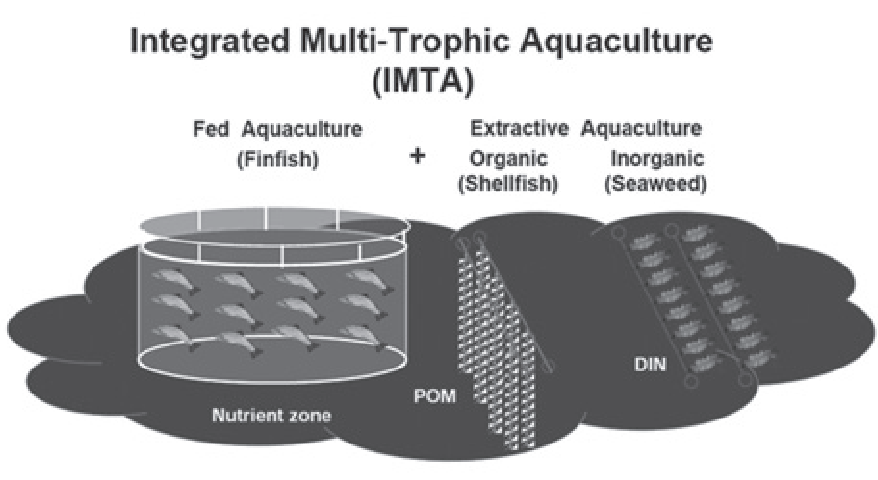
Fed-aquaculture species sub-system in IMTA

Finfish represent the only fed component of most IMTA systems and thus represent the only human provided input of nutrient energy to the system. In their role within an IMTA system, fish provide dissolved and particulate nutrients and oxidation reduction potential reducing compounds to the other component organisms as well as revenue to the industry. The quantity and form of these nutrients is dependent on species, size and feed formulation among other factors.

Feed formulation provides perhaps the most obvious route for fish effluent modification for the extractive components, conversely, other trends in the aquafeeds industry may impact fish effluent quality for an IMTA system. There is a distinction between IMTA systems that are open to the environment (cage based) and semi-closed to the environment (recirculation aquaculture systems). In most open systems the environment is both necessary and sufficient to rear extractive organisms, while in contrast the semi-closed systems require much tighter coupling of the different trophic levels under cultivation. Fish species selection for open and closed systems would likely differ to take advantage of each systems' unique characteristics in order for the industry to be profitable.

IMTA system designs: An effective IMTA operation requires the selection, arrangement and placement of various components or species, so as to capture both particulate and dissolved waste materials generated by fish farms. The selected species and system design should be engineered to optimize the recapture of waste products. As larger organic particles, such as uneaten feed and faeces, settle below the cage system, they are eaten by deposit feeders, like sea cucumbers and sea urchins. At the same time, the fine suspended particles are filtered out of the water column by filter-feeding animals like mussels, oysters and scallops. The seaweeds are placed a little farther away from the site in the direction of water flow so they can remove some of the

Conceptual diagram of an integrated multi-trophic aquaculture (IMTA) operation combining fed aquaculture (finfish) with organic extractive aquaculture (shellfish), taking advantage of the enrichment in particulate organic matter (POM), and inorganic extractive aquaculture (seaweeds), taking advantage of the enrichment in dissolved inorganic nutrients (DIN)



Source: Chopin (2006).

inorganic dissolved nutrients from the water, like nitrogen and phosphorus. IMTA species should be economically viable as aquaculture products, and cultured at densities that optimize the uptake and use of waste material throughout the production cycle.

Case studies

In temperate waters Canada, Chile, China, Ireland, South Africa, the United Kingdom of Great Britain and Northern Ireland (mostly Scotland) and the United States of America are the only countries to have IMTA systems near commercial scale. France, Portugal and Spain have ongoing research projects related to the development of IMTA. The countries of Scandinavia, especially Norway, have made some individual groundwork towards the development of IMTA, despite possessing a large finfish aquaculture network (Barrington *et al*. 2009).

Studies have focussed on the integration of seaweeds with marine fish culturing for the past fifteen years in Canada, Japan, Chile, New Zealand, Scotland and the USA. The integration of mussels and oysters as bio-filters in fish farming has also been studied in a number of countries, including Australia, USA, Canada, France, Chile, and Spain. Recent IMTA research includes a focus on seaweeds, bivalves and crustaceans. Studies conducted in an IMTA systems incorporating *Gracilaria lemaneiformis* and *Chlamys farreri* in North China have shown that a bivalve/seaweed biomass ratio from 1:0.33 to 1:0.80 was preferable for efficient nutrient uptake and for maintaining lower nutrient levels. Results indicate that *G. lemaneiformis* can efficiently absorb the ammonium and phosphorus from scallop excretion.

In China, Seaweeds, *Gracilaria lemaneiformis*, grown over 5 km of culture ropes near fish net pens on rafts increased the density from 11.16 to 2025 g/m in a 3-month growing period. The scaling up of culture area during the following 4 months to 80 km of rope, reported an increase in culture density on ropes to 4250 g/m. An increase in the biomass of *Gracilaria* (in the culture area) to 340 t wet weight was estimated due to its culture in close proximity to fish net pens. Different work along similar principles has taken place elsewhere.

Studies on IMTA have been carried on the East coast of Canada, where Atlantic salmon (*Salmo salar*), kelp (*Saccharina latissima* and *Alaria esculenta*) and blue mussel (*Mytilus edulis*) were reared together at several IMTA sites in the Bay of Fundy. The study has shown that the growth rates of kelp and mussels cultured in proximity to fish farms have been 46 and 50% higher, respectively, than at control sites. Several other studies have also reflected on the faster growth of mussels and oysters grown adjacent to fish cages. This reflects increase in nutrients and food availability from the finfish cages. Taste tests of mussels grown in conventional aquaculture and mussels grown at these IMTA sites showed no discernible difference; meat yield in the IMTA mussels was, however, higher. Findings of the economic models have also shown that increased overall net productivity of a given IMTA site can lead to increased profitability of the farm compared with monoculture.

Studies from land-based systems indicated that seaweeds can remove between 35% and 100% of dissolved nitrogen produced by fed species. The capacity of seaweeds in open-water cultures to remove nutrients from the water column can be estimated based upon the fraction of available nutrients, which are bound by the seaweeds at any given point in time. Experimental data and mass balance calculations indicated that a large area of seaweed cultivation, up to one ha for each ton of fish standing stock, would be required for the full removal of the excess nitrogen associated with a commercial fish farm.

The open-sea IMTA in India is very recent; however, various investigations have been carried out on the beneficial polyculture of the various mariculture species. Combined culture of compatible species of prawns and fishes is of considerable importance in the context of augmenting yield from the field and effective utilisation of the available ecological niches of the pond system. Finfish culture, *Etroplus suratensis*, in cages erected within the bivalve farms (racks) resulted in high survival rates and growth of the finfish in the cages.

Co-cultivation of *Gracilaria* sp. at different stocking densities with *Feneropenaeus indicus* showed nutrient removal from shrimp culture waste by the seaweed. The ratio of 3:1 was found suitable for the co-cultivation. The seaweed (600 g) was able to reduce 25% of ammonia, 22% of nitrate and 14% of phosphate from the shrimp (200 g) waste.

Polyculture of shrimp with molluscs helps in breaking down organic matter efficiently and serves as an important food source for a range of organisms and also either directly or indirectly provides shelter or creates space for associated organism, thus increasing the species diversity of the ecosystem. Studies have shown that an individual mussel can filter between 2-5 l/h and a rope of mussel more than 90000 l/day. The culture of mussels could thus be used in the effective removal of phytoplankton and detritus as well as to reduce the eutrophication caused by aquaculture.

Along the east coast of India, the introduction of IMTA in open sea cage farming yielded 50% higher production of seaweed, *Kappaphycus alvarezii*, when integrated with finfish farming of *Rachycentron canadum*.

Open-sea mariculture of finfishes when integrated with raft culture of green mussels, *P. viridis* resulted in slight, but not significant reduction in nutrients along Karnataka.

The beneficial effect of combining bivalves such as mussels, oyster and clams as bio-filters 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*, 2013, 2015). 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.

Benefits:

- **Effluent bio-mitigation**:Mitigation of effluents through the use of bio-filters which are suited to the ecological niche of the aquaculture site. This can solve a number of the environmental challenges posed by monoculture aquaculture.
- **Increased profits through diversification**: Increased overall economic value of an operation from the commercial by-products that are cultivated and sold. The complexity of any bio-filtration comes at a significant financial cost. To make environmentally friendly aquaculture competitive, it is necessary to raise its revenues. By exploiting the extractive capacities of co-cultured lower trophic level taxa, the farm can obtain added products that can outweigh the added costs involved in constructing and operating an IMTA farm. The waste nutrients are considered in integrated aquaculture not a burden but a resource, for the auxiliary culture of bio-filters.
- **Improving local economy**: Economic growth through employment (both direct and indirect) and product processing and distribution.

- **Form of 'natural' crop insurance**: Product diversification may offer financial protection and decrease economic risks when price fluctuations occur, or if one of the crops is lost to disease or inclement weather.
- **Disease control**: Prevention or reduction of disease among farmed fish can be provided by certain seaweeds due to their antibacterial activity against fish pathogenic bacteria.
- **Increased profits through obtaining premium prices**: Potential for differentiation of the IMTA products through eco-labelling or organic certification programmes.

Challenges:

- **Higher investment**: Integrated farming in open sea requires a higher level of technological and engineering sophistication and up-front investment.
- **Difficulty in coordination**: If practised by means of different operators (e.g. independent fish farmers and mussel farmers) working in concert, it would require close collaboration and coordination of management and production activities.
- **Increase requirement of farming area**: While aquaculture has the potential to release pressure on fish resources and IMTA has specific potential benefits for the enterprises and the environment, fish farming competes with other users for the scarce coastal and marine habitats. Stakeholder conflicts are common and range from concerns about pollution and impacts on wild fish populations to site allocation and local priorities. The challenges for expanding IMTA practice are therefore significant although it can offer a mitigation opportunity to those areas where mariculture has a poor public image and competes for space with other activities.
- **Difficulty in implementation without open water leasing policies**: Few countries have national aquaculture plans or well developed integrated management of coastal zones. This means that decisions on site selection, licensing and regulation are often ad hoc and highly subject to political pressures and local priorities. Moreover, as congestion in the coastal zone increases, many mariculture sites are threatened by urban and industrial pollution and accidental damage.

Prospects:

There is tremendous opportunity to use marine macroalgae as bio-filters, process and produce products of commercial value. Globally, most open-water seaweed monoculture has taken place in Asia, South America, South Africa and East Africa. In 2013, 26.9 million tonnes (wet weight) of aquatic plants from aquaculture was harvested worldwide, while capture production was only 1.3 million tonnes, with China and Indonesia accounting for the major share in production. Instead of monoculture, a fraction of the seaweed aquaculture practice can be integrated with fed-aquaculture as bio-filters. This approach may generate a heightened commercial interest once high value seaweeds species can be cultured as biofilters that produce novel human food products.

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Satellite Remote Sensing Applications in Mariculture Activities

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Introduction

During the last two decades the marine fisheries sector in India has undergone considerable change. The fishing fleet became larger and more energy-intensive, and the catch and trade of marine fishes increased substantially. Concern arising from the increasing fishing effort and the potential for overexploitation in Indian waters, led to scientific assessment of the status of several fish stocks. Consequently, attempts were made to shift from open to regulated access fisheries through Marine Fishing Regulation Acts (MFRAs). However, conflicts in sharing the limited resources intensified within and with other sectors and this, in turn, had high economic, social and environmental costs (Vision 2050, CMFRI). Thus, in recent years, the sector recognized the need for effective management for sustainable fisheries and a healthy marine environment through ecosystem approach and habitat restoration. Success has been achieved in mariculture, raising hopes of producing a plentiful supply of fish in future by farming marine fish.

Mariculture, the farming and husbandry of marine plants and animals in the marine environment, is the fastest growing subsector of aquaculture. Globally, mariculture produces many high value finfish, crustaceans, and molluscs. In India, the potential of mariculture production remains largely untapped. It has been realized that the vast coastal areas of our country are suitable for mariculture of high value finfish, shellfish and sea plants. Presently, standardized hatchery and farming technologies are available only for a limited number of marine finfish and shellfish species. Hence there is a need to enhance mariculture production fora large number of marine species, extend areas of marine farming, and introduce new production systems. Over a period of time, the proportion of production from coastal and marine aquaculture should be aimed at 40% and in terms of value, at 70% (Vision 2050, CMFRI).

Ecosystem Approach to Aquaculture (EAA) and role of satellite remote sensing

For sustainable mariculture in the country, the mariculture practices should aim at optimum production and maintain a 'green environment'. The lessons learnt from the shrimp farming should inspire caution, as intensive shrimp farming resulted in environmental deterioration and consequent disease problems which called for a need for 'Better Management Practices' and species diversification. A green environment necessitates the need to adopt Ecosystem Approach to Aquaculture (EAA) by taking into account the knowledge and uncertainties of biotic, abiotic and human components of the ecosystem including their interactions, within ecological and operational guidelines. Finally, carrying-capacity assessments are essential before any species is farmed either in the sea or land. This is particularly relevant to expansion of sea cage farming in the country. The total number of cages in a given area, stocking density of fish per cage, and feeding intensities should be taken into consideration. For carrying-capacity assessment of cages, dispersal of toxic waste may be looked upon as an important factor. Toxic and metabolic waste dispersal is a function of local residence time (tides, currents, estuarine circulation where relevant) of the waters at the site under consideration. Along the Indian coastal waters, marked asymmetry exists in the tidal ranges between the southern and northern latitudes. Over the west coast of India, the South West (SW) coast shows a tidal range of 10.90 m at Gujarat coast and the North West (NW) shows 1.34 m at Cochin coast. Hence, there is more mixing in the waters of NW coast, resulting in short residence times compared with SW coast. The East coast of India also shows similar variation in tidal ranges from south to north, but less pronounced than on the west coast. So in general, the residence time is longerin southern latitudes and shorter in northern latitudes along the coastal waters of India. However, the effect of tidal currents should also be considered for proper selection of sites of cage aquaculture and scheduling the cage related maintenance activities. Case studies have delineated the role of tidal currents along the west coast of India. Stronger tidal currents occur along the northern shelf compared with the southern shelf.

The changes in the operating environment of the mariculture sector will have to be transformed into opportunities. This, along with technological advances in other sectors such as remote sensing and GIS, provides an environment for holistic development of the marine fishing sector which benefits the fish, the fishermen and the environment. We need a ‘tool’ for effective delivery of EAA in the marine context. Marine Spatial Planning (MSP) is such a ‘tool’: it maps the varied uses of the marine environment and increases the efficiency of EAA. It is a strategic plan for regulating, managing and protecting the marine environment that addresses the multiple, cumulative and potentially conflicting uses of the sea. MSP will serve both as a framework and a process for more integrated decision making. Its goal is a fully comprehensive, integrated, plan-led system of management for the present and future exploitation and development of marine resources and for the use of contested space. The most important task for mariculture in an MSP regime is establishing the broad aim of MSP and elaborating this through a coherent set of more specific objectives with reference to fisheries.

India is a global leader in satellite technology which can be effectively utilized for managing marine fisheries sector. Deploying a dedicated satellite for mariculture/ marine fisheries would provide several opportunities and applications. SRS can also be used for establishment of “e-infrastructure” in the mariculture sector. The concept of “e-infrastructure” deals with establishment of infrastructure (hardware and software) for greater data sharing and connectivity. The same principle can be used for SRS in mariculture in India. The data collected by SRS on synoptic temporal and spatial scales on various ocean properties, along with *in situ* data, can be validated at dedicated data centres in the country. The advisories sent out by data centres can then be used by various management agencies or de-centralized agencies such as Panchayats for effective management of mariculture sites. SRS can be integrated with GIS for MSP. Mapping the various users of marine ecosystems and their real time occurrences will play an important role in EAA in India. Identification of appropriate environments in the ocean from SRS data for potential cage aquaculture sites as well as for inoculation of algal species for algal bioengineering of the oceans is also a possibility. Identification of suitable off-shore mariculture sites where culture will have minimal impacts on ocean health is also possible with SRS data.

Identification of suitable sites, timing and suitable species for open sea cage culture using satellite remote sensing

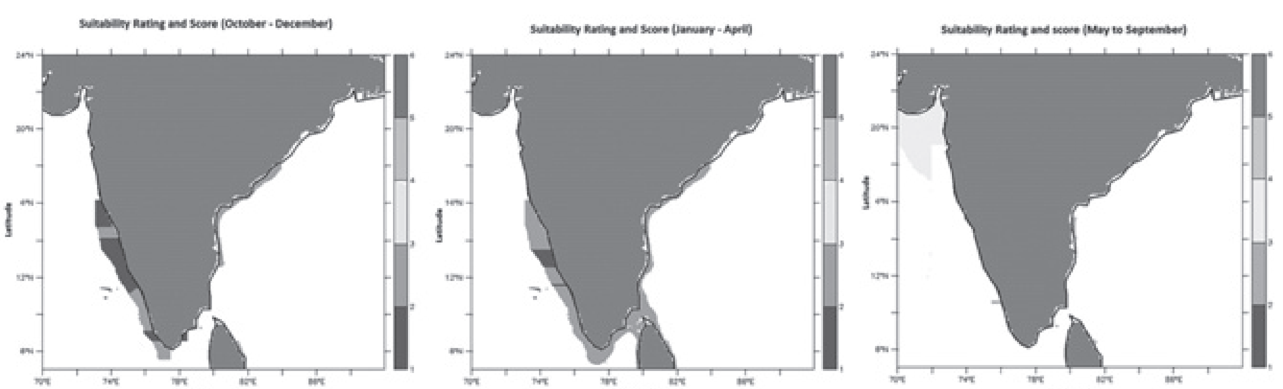
The risks involved in sites of cage installation are to be avoided for successful cage farming. The risks are those arising from severe weather; from toxic phytoplankton; and from accumulation of waste products of metabolism. Protection from severe weather requires analysis of local topography in the context of the prevailing wind and wave fields, as well of the vulnerability to extreme events such as the passage of cyclones. Protection from the toxic phytoplankton requires analysis of the spatial distribution of toxic blooms, such as could be established through remote sensing. In a case study for an all India analysis, we used GIS based multi-criteria analysis (MCA) - a set of evaluation criteria which are quantifiable indicators of the extent to which decision objectives are realised. A suitability score was used as compiled from published literature as Table 1 (Rao et al., 2013).

Table 1: Scoring for site selection based major physical factors

Score	Wind Speed (m/s)	Temperature (°C)	Salinity (PPT)	Depth (m)	Major Tidal Current (cm/s)
1	d” 2.5	27 - 31	25 - 40	0 - “200	5 - 10
2	2.5 - 5	27 - 31	25 - 40	0 - “200	5 - 10
3	5 - 7	27 - 31	25 - 40	0 - “200	5 - 10
4	7 - 9	27 - 31	25 - 40	0 - “200	10 - 15
5	> 9	27 - 31	25 - 40	0 - “200	>15

Optimal / near optimal site MCA was carried out using Ferret- an open source software to identify appropriate locations for cage culture based on a group of factors and constraints. The data source for the study was Wind Speed – Quickscat Scatterometer, Temperature and Salinity – North Indian Ocean Atlas (NIOA) by Chatterjee et al. (2012), Tidal range and Currents –Susant et al. (2013); Subeesh et al. (2013), Bathymetry – etopo2 and Predicted Tide table (http://tides.mobilegeographics.com).

The data available wereanalysed for different seasons and the results are given in the plots below:



Our study indicated that open sea cages are vulnerable to the coastal oceanographic as well as the bio-geo chemical processes and resultant biology. Southwest monsoon period is not suitable for cage farming and species selection and culture period may be based on the available culture time. Therefore, the months from October to April are ideal for cage farming with the defined criteria. A table size pompano (*T. blochii* and *T. mookalee*) can be farmed during this period with good food conversion ratio.

Conclusion

Any planned sectoral development needs appropriate policies, legislations and acts. As the existing policies are inadequate to meet the anticipated challenges in the sector, it is important to develop effective new policies. In the case of mariculture, as it is an emerging sector, there is a need for developing leasing policies and other regulations. The government's role is to manage the fisheries assets on behalf of society and to derive maximum benefits for future generations. The role of research institutions such as the Central Marine Fisheries Research Institute (CMFRI) is to provide scientific support and suggestions to the governments, and to maintain a watching brief thereafter. A sustainable fisheries and mariculture sector is essential for ensuring seafood for all and forever. State-of-the-art practices such as advent in satellite remote sensing (SRS) as well as Geographical Information System (GIS) will be useful for effective planning and can support the mariculture initiatives and their monitoring in the country.

Acknowledgement

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Taxonomy and Biology of Cultivable Species of Shrimps, Crabs and Lobsters

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Aquaculture has beenan age old practice in several countries and is said to have begun in China. World aquaculture production rose from 5.8 million tonnes to 70.5 million tonnes during 2013. In 2012 farmed crustaceans accounted for 9.7% (6.4 million tonnes) of food fish aquaculture production by volume which includes 3.91 million tonnes from mariculture (FAO, 2014). Several species of penaeid shrimps, brachyuran crabs, spiny and scyllarid lobsters are cultivated in several parts of the worldand these organisms also support commercial fishery. Important criteria for the successful cultivation of any organism/species arethorough knowledge of its morphological characters for accurate identification and their biology.

Family-Penaeidae

***Penaeus monodon*– Giant Tiger shrimp**

Rostrum straight, toothed on both ventral (generally 3 teeth) and dorsal sides. Sub-hepatic ridge oblique. Petasma symmetrical and consists of two simple lobes united at the upper edge by hook-lets. Thelycumsub-oval in shape, posterior process triangular. Pale yellow and dark brown bands on the abdomen. Uropods with pale yellow to pink median transverse bands.

***Fenneropenaeus (Penaeus) indicus* – Indian White shrimp**

Rostral teeth on ventral (3 to 6) and dorsal side. Body white or cream in colour. Adrostral crest ending just before epigastric tooth. In males distal segment of third maxilliped as long as the second segment and bear long tufts of hair at the tip. Subhepatic ridge in the branchial region lacking. Fifth pereiopod without exopod.

***Fenneropenaeus (Penaeus) merguiensis* – Banana shrimp**

The rostral crest is elevated and somewhat triangular in shape. Teeth on rostrum present both on ventral (3 to 5) and dorsal side. Adrostral carina not reaching as far as epigastric tooth. Body colour paleyellow or white. In males the distal segment of third maxilliped half as long as the second segment and bears hair at the tip.

***Penaeus semisulcatus* – Greeen Tiger shrimp**

Rostrum curved. Rostrum and abdomen are banded green or grey and white. Mostly the antennae are also banded white and brown. Rostral teeth on ventral (generally 3 teeth) and dorsal side. Adrostral grooves extending just beyond epigastric tooth. Subhepatic ridge is horizontal. Small exopod present on fifth pereiopod (absent in *P. monodon*).

***Melicertus latisulcatus* – Western King shrimp**

Rostrum with dorsal and one ventral teeth. Adrorstral crest extends almost to the posterior margin of carapace. Telson with three pairs of movable lateral spines. Vertical black bar on pleuron. Anterior process of thelycum horn like and strongly bifurcate.

***Marsupenaeus japonicus*– Kuruma shrimp**

Rostrum with dorsal and one ventral teeth. Adrostral crest extends up to near to the posterior margin of the carapace. Carapace with three continuous bands and the band on the last abdominal segment interrupted. Telson with three pairs of movable lateral spines. Thelycum closed infolding laterally forming anteriorly open pocket functioning as seminal receptacle. Distomedian projection of petasma curved forming hood.

***Metapenaeus dobsoni* – Kadal shrimp**

Rostrum extends little beyond the tip of the antennular peducncle. Distomedian projection of petasma with a short filament on ventral surface and another on dorsal surface. Thelycum is long grooved and tongue shaped and ensheathed in a horse-shoe like process formed by lateral plates. Merus of fifth pereiopod in adult males with one or two large triangular teeth.

***Litopenaeus vannamei* – Whiteleg shrimp**

Rostrum with teeth both on ventral and dorsal side, moderately long extending beyond the antennular peduncle in young but shorter in adults. In mature males the petasma is symmetrical, semi open and in mature females the thelycum is open. The species is translucent white. They may have a bluish hue near the margin of the telson and uropods. Legs are white in colour.

Biology of penaeid shrimps

They have two phases in their life cycle – estuarine and marine. The post larvae migrate to the estuaries, where they grow to juveniles/adults and return to the sea. Here they mature and spawn and the cycle is repeated. The eggs, larvae and post larvae have pelagic existence and the juveniles/sub-adults and adults are benthic. Several species like *Penaeus monodon, Fenneropenaeus indicus, Metapenaeus dobsoni, Metapenaeus monoceros, Metapenaeus brevicornis* support important fishery in the estuarine systems in India - Hoogly-Matlah in WB, Mahanadi & Chilka Lake in Orissa, Godavari & Krishna in AP, Vellar & Killai backwaters and Pulicat Lake in TN, Cochin backwaters & Vembanad Lake in Kerala; Narmada-Tapthi and Little Rann of Kutch in Gujarat. Penaeid shrimps are carnivorous, females are usually larger than males and have high fecundity which depends on the species, size of the female and ovary weight. They spawn throughout the year, peak seasons varying between years. Their life span is usually 3+ years. The maturity stages in penaeid shrimps are classified as immature (IM), early maturing (EM), late maturing (LM), mature (M) and spent (SP). Stages of maturity can be ascertained externally through the exoskeleton. *Penaeus monodon* attains maximum length of 300 mm. In the backwaters and estuaries they grow to 120 to 130 mm. From inshore waters they are caught in various types of seine nets and from deeper waters in trawls. It is an important candidate species for culture because of its hardiness, fast growth, large size and high market price. *F. indicus* grow to 230 mm in total length and *F. merguiensis* up to 320 mm. *P. semisulcatus* grows to 250 mm total length. It is the most dominant penaeid shrimp species supporting commercial fishery along Gulf of Mannar and Palk Bay on the southeast coast. The maximum size of *M. dobsoni* recorded is 130 mm. *Litopenaeus vannamei* native of East Pacific coast is an introduced penaeid shrimp in India. It grows to a maximum length of 230 mm.

Family- Portunidae

***Scylla serrata* – Giant mud crab**

Carapace smooth having strong transverse ridges; H shaped gastric ridges deep. Teeth on frontal margin sharp. Nine anterolateral carapace spines of same size projecting obliquely outwards. Carpus of chelipeds with two distinct spines on distal half of outer margin. Colour green to browny black depending on the habitat, outer surface of palm green and often with marbled pattern; last legs marbled both in males and females.

***Scylla olivacea* – Orange mud crab**

Frontal margin usually with rounded teeth. Carpus of cheliped with only one reduced spine. Carapace smooth, more evenly convex with very low transverse ridges. H-shaped gastric groove shallow. The median pair of the frontal lobes more rounded and projecting slightly forwards of the lateral ones.

Biology of mud crabs

S. serrata is usually found in mangrove areas with high salinity, and also in offshore waters where they spawn, can tolerate reduced salinity also whereas *S. olivacea* prefer low saline water. They are found in low intertidal muddy bottom. The megalopa or postlarval stage migrates to the estuaries and backwaters attain maturity and go to the inshore waters for spawning. Immature and mature males have slender triangular abdominal flaps. Immature females have a broad and triangular abdominal flap and mature females a semi-circular flap. They have five zoeal stages and one megalopa stage which metamorphose to the crab instar (seed). They are carnivorous and prefer small molluscs, trash fish and other crustaceans as food.

***Portunus pelagicus*– Blue Swimmer Crab**

Carapace with reticulated markings. Front with four teeth. Inner margin of merus of cheliped with three spines. Nine teeth on anterolateral margin of carapace. Males with blue markings and females with dull green.

***Portunus sanguinolentus*– Three Spotted Crab**

Carapace with three brown or purple spots on the posterior half of the carapace, having white border. Nine teeth on anterolateral margin of carapace.

***Charybdis feriatus*– Crucifix Crab**

Five teeth on each anterolateral margins. Longitudinal stripes of brown and white colour with distinct white cross mark on the median part of the gastric region, hence also called commonly as crucifix crabs. The pleopods or swimming appendages are banded white and brown. They grow to very large size.

Biology

They are marine crabs. *P. pelagicus*is found at a depth of up to 50 m and is caught in trawl and gill nets. They show sexual dimorphism, males being bright blue in colour and females are dull green. The males grow larger and their chelate legs are longer. They have five zoeal stages and metamorphose to the megalopa followed by the juveniles/seed stage. *Charybdis feriatus*are found at a depth of up to 60 m and are caught mostly in bottom trawl. They have six zoeal stages (stage I to stage VI) which metamorphose to the megalopa stage. They have good market in East Asia where it commands substantially higher premium prices than *Portunus* spp. *P. sanguinolentus* are caught at a depth of 30 m. All the three species prefer sandy to sandy muddy substrates.

Family Palinuridae

***Panulirus homarus*–Scalloped spiny lobster**

Anterior margin of carapace with two frontal horns, Antennular plate bearing four equal well separated large spines, Each abdominal segment with a transverse groove, Body greenish in colour with numerous white spots, Transverse bands absent, Antennules banded white and green, Legswith white spots and stripes.

***Panulirus ornatus*- Ornate spiny lobster**

Antennular plate with one pair of principal spines anteriorly and a second pair half the size of first. Abdominal segment smooth without transverse grooves. Each abdominal segment with dark pale spot on the outer margin. Abdomen greenish or brownish grey. Legs with alternate bands of black and white bands.

***Panulirus polyphagus*- Mud spiny lobster**

Broad antennular plate with one pair of principal spines. Abdominal segments without transverse grooves, having white transverse bands. Legs irregularly blotched creamy white.

***Panulirus versicolor*- Painted spiny lobster**

Antennular plate with two unequal and separated spines. Abdominal segments without transverse grooves. Blue black patches and white lines on carapace and abdominal segments. Legs, antennules longitudinally striped. Bases of antennae bright pink.

Biology of spiny lobsters

Panulirus homarus is an important lobster fishery resource in India particularly around Kerala and Tamil Nadu. They are found up to a depth of 90 m and are caught in gill nets, trawls, trammel nets and traps. They use rocky reefs for shelter. *P. ornatus* is found at a depth of 10 to 50 m in sandy and muddy substrates. It is the largest of the *Panulirus* species and can attain a total body length of about 50 cm. The size of lobsters in the fishery ranges from 113 to 233mm TL in males and 128-452 mm TL in females with 41% falling in the size range of 181-190 mm TL, which are juveniles. *Panulirus versicolor* is also a coastal species found up to a depth of 15 m. *Panulirus polyphagus* inhabits coastal waters on muddy and rocky substrates to a depth of 40 m and occasionally seen at 90 m. This species is the most important commercial species contributing to nearly three-fourth of the total lobster catch of the country. Major fisheries are on the northwest coast of India. Size in the fishery range from 75 to 385 mm total length (TL) those between 160 and 230 mm TL forming the mainstay of the fishery in Maharashtra. *P. ornatus* and *P. polyphagus* move to deeper waters for breeding. Phyllosoma larvae are planktonic and are carried away by currents. The last stage before becoming juveniles is the peurulus which swims towards the shore for settlement. Spiny lobsters are susceptible to diseases when held at high stocking density or due to stress or injury. Common diseases are white tail, tail fan necrosis and shell disease.

Giant Tiger shrimp

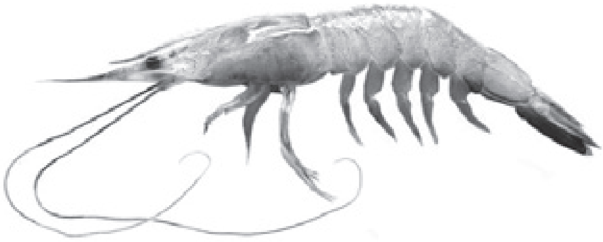
Indian White shrimp

Banana shrimp

Greeen Tiger shrimp

Western King shrimp

Kuruma shrimp



Kadal shrimp

Whiteleg shrimp

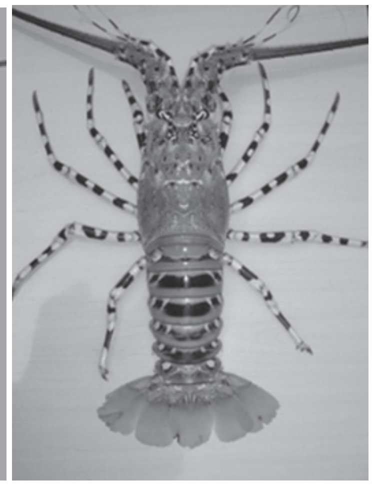
Orange mud crab

Blue Swimmer Crab

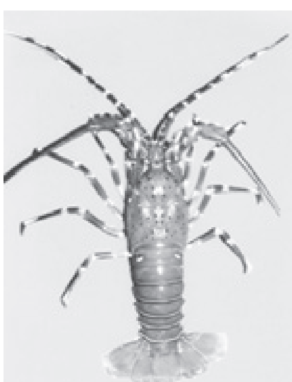
Three Spotted Crab

Crucifix Crab

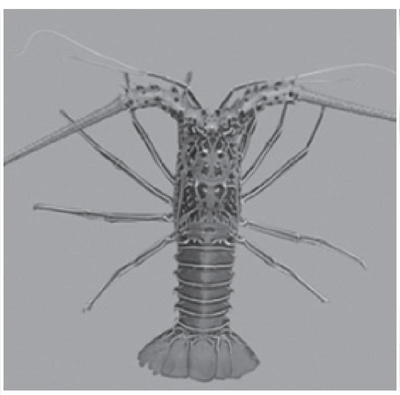
Scalloped spiny lobster



Ornate spiny lobster

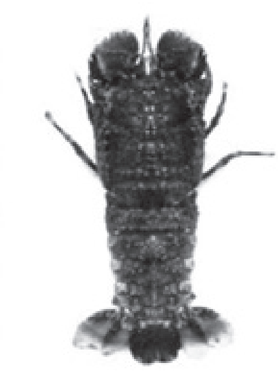


Mud spiny lobster



Painted spiny lobster

Slipper lobster/sand lobster



Hunchback locust lobster

Family Scyllaridae

***Thenus unimaculatus*– Slipper lobster/sand lobster**

Body dorsoventrallyflattended, pale brown in colour.Three spines on the antero lateral border of carapace and a notch in middle of each segment. Fifth abdominal segment with a spine on the dorsal side. Tubercles present on the body.Variable purple to black pigmentation (blotch or large or narrow streak) on the inner surface of merus of second and sometimes third legs.

Biology

It forms a fishery in trawlers along the Saurashtra coast, Kollam and Chennai. They burrow in sand and generally feed on molluscs. The phyllosoma stages (I-IV) are completed in 7, 5, 7 and 7 days respectively and the nisto stage in 4 days.The lobsters are usually caught at a depth of 50 m. They form bycatch in trawls and are also caught in gillnets.

***Petractus rugosus* (H. Milne Edwards, 1837) – Hunchback locust lobster**

Rostral teeth reduced to tubercle. Median teeth on carapace before the cervical groove blunt and inconspicuous. Gastric tooth most conspicuous. Surface of carapace uneven and tubercles are high. The dorsal surface of the body is grayish or purplish brown with darker spots. The first abdominal somite shows dorsally often a dark blue colour. The abdomen shows a distinct median longitudinal carina on somites 2 to 5, that of somite 3 is the highest; in each somite there is a wide transverse groove.

Biology

They are found at depths of 20 to 60 m. They attain a total length of 2.5 to 6cm. They have ornamental potential and presently forma component inthe low value bycatch in trawl.

Pelagic Finfish Resources of India

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India is endowed with a long coastline of 8129 km. Being tropical country, the marine ecosystem bordering Indian sub-continent contain large number of species adapted to wide range of habitats, from mangrove swamps, estuaries, saline lagoons, sea grass meadows, sandy/ muddy/rocky coasts, coral reefs, oceanic islands to deep oceanic realms. Theses resources are supporting the marine fishery of the country. The water spread of continental shelf is 0.5 million sq. km and of EEZ is 2.02 million sq. km. The annual catchable marine fishery potential of the EEZ is 4.5 million tonnes..

Pelagic finfish resources:

Finfish resources are classified broadly as pelagic and demersal based on their distribution in the water column. Small to large fishes which occupy mainly the surface and subsurface layers of the water column are pelagic resources. Most of them are characterised by their shoaling behaviour. While fishes which are either bottom dwelling or inhabiting mainly along the lower layers of water column are termed as demersal resources.

Oil sardine:

The resource is represented by a single species, *Sardinella longiceps and* distributed widely along the Indo-Pacific region. They form the mainstay of pelagic fishery of India. They occur all along the Indian coast. Till recently their abundance was largely restricted to the coastal waters between Quilon and Ratnagiri with 90% of the fishery from this area alone. However, in recent years, they are emerging as a major resource along the east coast up to Orissa waters towards north.

Lesser sardines:

Nearly 13 species constituted the resource and fishery. They occur along the entire Indian coast but their abundance and fishery confined largely to the inshore waters of Kerala, Tamilnadu and Andhrapradesh. It include 10 species under the genus *Sardinella,* two species under *Dussumieria* and *Esculosa thoracat*. Dominant species are *Sardinella gibbosa, S. albell, S. fimbriata, S. dayii* and *S. sirm.* Species show discontinuous distribution.

Wolf herrings (Dorabs):

They are non-shoaling fishes, abundant along both east and west coast with large abundance along the southeast coast. Two species namely, *Chirocentrus dorab and C. nudus* supported the resource and fishery. Large abundance in shallow waters between 10 –30 m depth. They migrate to deeper waters for spawning. They usually form fishery along with other resources.

Anchovies:

Resources and fishery are supported by species belonging to the genera *Stolephores, Thryssa, Thryssina, Coilia* and *Setipinna.* White bait belonging to the genus *Stolephores* constitite nearly 70% of the catch. They are abundant in coastal waters of 5-20 m depth. They concentrated in area between Ratnagiri and Gulf of Mannar. Abundance of other anchovies are relatively large along the coastal waters of Andhra, Tamilnadu, Kerala, Karnataka and Mharashtra.

Other Clupeids:

Widely distributed along the east and west coast, with large abundance along the east coast. Several species belonging to different genera, *Pellona, Hilsa ilisha, Elops, Megalops, Anadontosoma etc.* support the fishery.

Mackerel:

Resource is represented by three species in Indian waters. However more than 95% of the stock and fishery was supported by one species, *Rastrelliger kanagurta* alone. *R. brachisoma* and *R. faugni* form sporadic fishery respectively in Andaman, Madras waters. Mackerel is abundant in coastal waters within 25 m depth. Nearly 80-90% of the total mackerel catch is from west coast. However in recent years, their abundance and fishery is on the increase along east coast.

Tunas and Billfishes:

These are typical oceanic fast swimming and highly migratory pelagic fishes and most of them have cosmopolitan distribution. Resource is represented by several species belonging to the genus *Auxis, Euthynnus, Thunnus, Katsuonus, Sarda* and *Gymnosarda.* These are typical shoaling fishes and aggregate in large numbers around any floating objects in open sea. Bill fishes form by-catch in tuna fishery. They are represented by *Istiophores, Makyra* and *Xiphia* Spp.

Seerfishes:

These are well relished fishes with very high market demand. Five species namely *Scomberomores commerson, S. guttatus, S. lineolatus, S. koreanus* and *Acanthocybium solandri* supported the resource and fishery. They are abundant in the neretic and oceanic waters of both coasts. But undertake long term inshore migration and form fishery in shallow waters. *S. guttatus* is available in less saline turbid waters of coastal belt.

Carangids:

Carangids are a diverse group of fishes having different body shapes. They are widely distributed along the entire coastal waters of India, Their major abundance confined to shallow waters up to 60 m depth. More than 35 species constituted the resource, with many species showing discontinuous distribution. However, commercial fishery was supported by few species. Horse mackerel and scads dominated the fishery.

Ribbonfishes:

They are abundant along east and west coast with large abundance along the peninsular region. Resource was supported by six species dominated by *Trichiurus lepturus.* Their maximum abundance was reported in deeper waters between 25-75 m depth. They being carnivores, used to follow shoals of small pelagics and Acetes and were fished in large quantities by shrimp trawls.

Bombay duck:

Second largest single species resource and fishery of India supported by *Harpodon neherius*. Resource distribution was discontinuous confined to northern sector of east and west coast. Major share of the resource and almost 98% of the fishery is confined to North West coast *ie*. Gujarat and Maharashtra coast and the rest from coast of Orissa, Andhra Pradesh and Tamilnadu. They are fished mainly by fixed Dolnetat 15-50 m depth zone. Sizeable quantities were also landed by trawls.

Flying Fishes:

They inhabit off shore waters of 30-40 km away from the shore. Several species belonging to *Parexocoetus, Cypselurus* and *Exocoetus* supported the fishery. Good fishery occur along the Coramandal and Gulf of Mannar coast of Tamilnadu and small quantities from Andhra coast.

Belonids and Hemirhamphids:

Good resource of garfishes and half- beaks were available in the Gulf of Mannar nad Palk Bay and support a potential local fishery. Approximate annual exploitable stock of the resource by some workers is 25,000 tonnes. Average production was 179,000 t during 2000-01 and constitutes nearly 7.1% of the marine fish production.

Barracudas

The barracudas are pelagic predatory fishes, distributed in tropical and subtropical oceans and enjoys important position in the marine food web as apex predators. Twenty nine valid species represented the family globally and only ten species have been reported from Indian waters. The barracudas (Sphyraenidae: Perciformes) are marine pelagic predatory fishes, distributed in tropical and subtropical oceans (Williams, 1959; Blaber, 1982) and enjoys important position in the marine food web as apex predators (de Sylva, 1963; 1973; Friedlander and de Martini, 2002). Thirty species represented the family globally and only ten species have been reported from Indian waters viz., *Sphyraena acutipinnis*, *S. barracuda*, *S. jello*, *S. putnamae, S. qenie, S. forsteri, S. obtusata, S. flavicauda*, *S. chrysotaenia, S. helleri* and *S. arabiansi* .

Mahi- mahi

These are carnivores fishes with abundance and distribution mainly towards oceanic waters. Excellent table fishes with fast growth rate. Two species represents the resource and and have good potential for domestication. Major abundance is along the North West coast.

Kingfishes

These are carnivores fishes and were represented by single species. Major abundance is along the North West coast and is excellent table fish with fast growth rate. And so have good potential for domestication.

Mullets

They in Indian waters were represented by several species. Euryhaline fishes with wide distribution in brckish and marine waters. A potential group of fishes cultured in fresh, brackish and marine environment.

Taxonomy and Biology of Cultivable High Valued Marine Demersal Finfishes

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In a world where the global population is expected to grow by another 2 billion to reach 9.6 billion people by 2050 and where more than 800 million continue to suffer from chronic hunger we must meet the huge challenge of feeding our planet while safeguarding its natural resources for future generations. (SOFIA, 2014). Global fish production has grown steadily in the last five decades, with food fish supply increasing at an average annual rate of 3.2 percent, outpacing world population growth at 1.6 percent.

Cage culture systems employed by farmers are currently as diverse as the number of species currently being raised, varying from traditional family-owned and operated cage farming operations (typical of most Asian countries) to modern commercial large-scale salmon and trout cage farming operations in northern Europe and the America. Commercial cage culture has beenmainly restricted to the culture of higher-value (in marketing terms) compound-feed-fed finfish species, including salmon (Atlantic salmon, cohosalmon and Chinook salmon), most major marineand freshwater carnivorous fish species (including Japanese amberjack, red seabream, yellow croaker, European seabass, gilthead seabream, cobia, Rainbow trout, Mandarin fish, snakehead)and an ever increasing proportion of omnivorous freshwater fish species (including Chinese carps, tilapia, *Colossoma*, and catfish). However in southeast Asian countries, marine species being cultured are groupers and snappers.

Groupers

a. Species cultured

A diversity of grouper species are cultured, but only a few are produced in hatcheries to any significant extent. *Cromileptes altivelis*, *Epinephelus fuscoguttatus*, *E. coioides*, *E. malabaricus*, *E. akaara*, *E. lanceolatus*, *E. tukula*, *E. areolatus*, *E. tauvina*and *E. polyphekadion* are reported (Rimmer, Williams and Phillips, 2000; Rimmer, Mc Bride and Williams, 2004) from hatcheries around the region and are expected to form the mainstay of grouper production in the future. Orangespotted grouper (*E. coioides*), greasy grouper (*E. tauvina*), Malabar grouper (*E. malabaricus*) and duskytail grouper (*E. bleekeri*) are cultured in cages in Myannmar using using fry and juveniles caught from the wild. Most grouper grow out is conducted in cages located in marine estuaries or sheltered coastal areas. Groupers are generally sold alive at a size range of 0.5–1.2 kg per fish, with the average weight for table-size fish being 850 g, requiring ready access to markets. In Thailand, six species of groupers (*Epinephelus coioides*, *E. malabaricus*, *E. areolatus*, *E. lanceolatus*, *E. fuscoguttatus* and *Plectropomus maculatus* are cultured. In Malaysia, interest in grouper culture has led to atleast six species being introduced. Commonly cultured species include brown-marbled grouper (*Epinephelus fuscoguttatus*), orange-spotted grouper (*E. coioides*)and Malabar grouper (*E. malabaricus*). Other minorspecies include fourfinger threadfin (*Eleutheronema tetradactylum*).

Taxonomy: Groupers, rockcods, hinds, and seabasses belong to serranid Subfamily Epinephelinae which comprises of about 159 species in 15 genera. Grouper species are identified by their colour pattern, morphological characters including configuration and size of the fins, the shape and relative size of the head and various parts of the head and body; and the number of fin rays, scales and gill rakers body shape.

Species in Indian waters:

***Epinephelus merra* Bloch, 1793 - Honeycomb grouper**

D XI, 17; A III, 8; P 17; V I, 5.

Body robust, slightly compressed, elongated; mouth superior, large, maxilla exposed, slightly protractile; small, slender teeth on jaws, vomer and palatine; some small canines on front; eyes prominent; dorsal profile of the head sloped; pre-operculum serrated; one flat spine on operculum; small ctenoid scales; pectoral fin like an hand fan; caudal fin rounded.

Body grey above and lighter below; brown to black spots all over the body, hexagonal anteriorly, rounded posterior; fins rays of dorsal and caudal fin yellowish; pectoral and pelvic fins dark brown to black Brown body.

***Epinephelus polyphekadion* (Bleeker 1849)**

Camouflage grouper

D XI, 15; A III, 8; P 16; V I, 5; LL 47 to 52; Gr (8-10) + (15-17).

Dorsal profile of head evenly convex; maxilla reaches rear edge of eye; pre operculum rounded, the serrae at corner slightly enlarged; two undeveloped spines in operculum; inter spinous membranes moderately incised; caudal fin rounded; body scales ctenoid.

Body pale brownish covered with numerous small dark brown spots; some irregular dark blotches superimposed with the spots scattered in head and body; a prominent black blotch on caudal peduncle; dark spots extend all over head, including lower jaw, lips and inside of mouth; numerous small white spots on fins and a few on head and body.

***Epinephelus malabaricus* (Schneider, 1801)**

Malabar grouper

D XI, 14-16; A III, 8; P 18-20; V I, 5; Ll 98-114.

Body depth contained 3.0 to 3.6 times in standard length. Preopercle finely serrate, with a shallow notch, the serrae enlarged at the angle; rear nostrils not more than twice the size of anterior nostrils; lower gillrakers 13 to 16; midlateral part of lower jaw with 2 rows of teeth. midlateral body scales distinctly ctenoid with minute auxiliary scales.

Head and body generally pale greyish brown covered with small orange, golden brown, or dark brown spots. Five more or less distinct, slightly oblique, irregular, broad, dark bars on body; these bars are darker dorsally and the last 3 are usually bifurcate ventrally; the first 4 bars usually continued onto the dorsal fin, the last bar covers most of the caudal peduncle; usually 3 dark blotches on interopercle, the first 2 sometimes merging to one blotch; small, irregularly shaped and spaced, white spots visible on head and body of some fish; soft dorsal, caudal, anal and pectoral fins brownish-black with small dark spots on basal half of fins

***Epinephelusl anceolatus* (Bloch 1790) - Giant grouper**

D XI, 14; A III, 8; P 16; V I, 5; LL 46-51; Gr (9-11)+(17-19).

Body robust in adult and slightly deep in juveniles; dorsal profile of the head slightly convex; eyes small; mouth moderately big, terminal to superior; maxilla reaching rear edge of eye; pre-operculum finely serrated in edges; inter fin membrane of spines notched; soft rays of dorsal and anal fin, pectoral and caudal fins rounded.

Body greyish yellow above, grayish white below and sides with numerous uneven black blotches all over the body; head darker; fins yellowish with black blotches; juveniles with 3 irregular black bars in body, large adults dark brown to grey.

This species is protected under Indian Wild Life Protection Act (1971)

***Cephalophalis miniata* (Forsskål, 1775)**

Coral hind

D XI, 14; AIII, 8; P 17; V I, 5; LL 47-56; Gr 7-9+14-16.

Body moderately deep; dorsal profile of the head straight, with convex above eye; maxilla big, crossing the rear edge of eye; eyes small; pre-operculum rounded; soft rays of dorsal and anal fin, pectoral and caudal fins rounded.

Body orange to reddish brown, with small blue spots all over the body including fins; Margin of soft rays of dorsal and anal and caudal fins bluish.

Biology: Groupers are protogynous hermaphrodites. The gonad lies ventral and slightly posterior to the swim bladder. The ovary is in the form of a bilobed sac that unites posteriorly to form a common oviduct In a mature female, numerous oocytes are arrayed in lamellae surrounding a central lumen,with spermatogenic tissue in small dormant cryptson the periphery of the lamellae. After spawning asa female for one or more years, the grouper changes sex and thereafter functions as a male. Atsexual transition, the oocytes degenerate, the spermatogonia proliferate, and the ovary is transformed into a functional testis. Evidence of the ovarian origin of the testes are the remnants of oocytes andthe ovarian lumen, which can be seen in cross-sections of the testes. This protogynous mode of reproduction is complicated in certain species bythe 'occurrence of some large females that do not change sex and some small males that are mature atthe same size as the smallest females. (Heemstra and Randall, 1993)

Most fishes are gonochorists (Wootton 1991; Helfman *et al.* 1997), which means they are either born as males or females and reproduce only as one sex throughout life. But many species, including many serranids, exhibit several sexual patterns such as hermaphroditism (Sadovy de Mitcheson and Liu 2008). Hermaphroditism includes simultaneous and sequential hermaphroditism and the latter is further divided into protogyny and protandry (Sadovy and Shapiro 1987). *Epinephelus malabaricus* change sex between 97 and 113 cm TL with the length at 50% sexual maturity of female *Epinephelus malabaricus* reported to be 79 cm (7.5 kg) (Lydia and Ian 2013). *E. tauvina*, is a protogynous hermaphrodite and sexual transition is found to occur in individuals 55-75 cm in length, and is related to spawning activity. Fecundity estimates for *E. tauvina*, of length 35.142.3 cm ranged from 850 186 to 2 904 921.

In the case of *E. tauvina*, lunar cycle has been shown to affect the reproductive cycle. The fish matures at 52 cm total length ie 4- 5 years old whereas *E. chlorostigma* attains sexual maturity at 28 cm TL.

Giant grouper (*E. lanceolatus*) is popular with farmers for its hardiness and rapid growth and is reported to grow to around 3 kg in its first year.

The Serranidae exhibit both synchronous and protogynous hermaphroditism (Lavenda, 1949; Reinboth, 1962,1970; Smith, 1965; Yamamoto, 1969; Atz, 1964;Bortone, 1977; Bouain, 1981) as well as the gonochoristic pattern. Van Oordt(1933) made the first observations on hermaphroditism in *Epinephelus* from the Java Sea. and since that time there have been several reports on sex transformation in this genus (Smith, 1965; Reinboth, 1968; Moe, 1969; Tan & Tan, 1974; Brusle & Brusle, 1975a,b; Chen *et al.,* 1977, 1980)

Snappers

The snapper is a demersal fish occurring on the continental shelf down to a depth of about 200 m, but most abundant in depths of less than 70 m. It lives on all kinds of bottom-sand, mud, rocks-There are several species of seabream cultured in Asia, mainly in more temperate parts of the region.These include squirefish (*Chrysophrys auratus*), goldlined seabream *Rhabdosargussarba*), blackporgy (*Acanthopagrus schelgeliischlegelii*) and redseabream (*Pagrus major*). In Thailand, *Lutjanus argentimaculatus* is the major species cultured. In Malaysia, Snappers (Lutjanidae) are next in importance; these include the yellow streakedsnapper (*Lutjanus lemniscatus*), the mangrove red snapper (*L. argentimaculatus*), John's snapper (*L. johnii*) and the crimson snapper (*L. erythropterus*).

Adult red snappers were primarily piscivorous, although in certain seasons, they fed heavily on tunicates. Juvenile red snappers fed primarily on crustaceans, but periodically took fish

Biology: They are solitary and wary fish, rarely found in groups or schools except during spawning aggregations (Domeier et al., 1996). Snapper is a serial spawner and releases many batches of eggs over a period of several months Water temperature is the most important factor influencing the timing of the breeding period. Eggs are spherical, with a diameter of 0.85- 0.97 mm and a single oil droplet 0,1H,25 mm in diameter. The yolk is non-segmented, Snapper eggs are planktonic and after fertilisation float freely in the sea until hatching, which takes from 36 to 54 hours, depending on temperature.The snapper's capacity to spawn many times during a season enables it to produce a very large number of eggs and is one of the reasons for its great success as a culture species.

Snapper is a predatory fish and its food is extremely varied. Its ability to feed on almost any animal food available enables it to penetrate different habitats and is another reason for its great success as a species.

Snappers in Indian waters

Mangrove snapper - Lutjanus argentimaculatus

Halibut

The name flounder is used for several only distantly related species, though all are in the suborder Pleuronectoidei (families Achiropsettidae, Bothidae, Pleuronectidae, Paralichthyidae and Samaridae). Some of the better known species that are important in fisheries are:

- Western Atlantic
- Gulf flounder - *Paralichthys albigutta*
- Southern flounder - *Paralichthys lethostigma*
- Summer flounder (also known as *fluke*) - *Paralichthys dentatus*
- Winter flounder - *Pseudopleuronectes americanus*
- European waters
- European flounder - *Platichthys flesus*
- Northwestern Pacific
- Olive flounder - *Paralichthys olivaceus*

Species in Indian waters:

***Psettodes erumei* or the Indian halibut**: *P. erumei* is highly predacious benthic fish which lives on muddy and sandy bottomsof the continental shelf down to about 100 meters depthand is predominantly piscivorous in habit. Body is oval and flat, but thicker than in most other flatfishes. Mouth large with strong teeth; maxillary extends well beyond hind edge of lower eye; both eyes are on left or right side; upper eye lying immediately below dorsal edge. Gillrakers are not developed. Dorsal fin origin is well posterior to eyes; anterior fin rays isspinous. Lateral line is almost straight. Body colour is usually brownish grey, sometimes with 4 broad, dark crossbars. Dorsal, analand caudal fin tips black. Blind side is white to partially coloured. Diet is mainly fish with Molluscs and arthropods supplemented to some extent. *Paralichthys olivaceus* the Bastardhalibut is cultured in onshore tank farms.

Temperate species

Psetta maxima is a benthic marine species, living on sandy and muddy bottoms, from shallow waters to 100 m. *Psetta maxima* is a gonochoric species with separate sexes. Younger individuals tend to live in shallower areas cryptic, imitating the colour of the substrate. Juveniles are carnivorous feeding on molluscs and crustaceans, and adults feed mainly on fish and cephalopods. Spawning (sequenced, every 2-4 days) usually takes place between February and April inclusive in the Mediterranean, and between May and July inclusive in the Atlantic. Eggs have a single fat drop. Larvae are initially symmetric, but by the end of metamorphosis (day 40-50, 25 mm) the right eye has moved to the left, giving rise to asymmetry.

***Solea* spp.**

Body oval in shape. Blind side of head covered with numerous small hair-like fringes; upper eye is separated from dorsal profile of head by a distance distinctly greater than its diameter; anterior nostril of blind side surrounded by a small ridge but not enlarged, distance from this nostril to head profile contained 1.5 to 1.8 times in distance from nostril to mouth cleft; anterior nostril on eyed side with tube directed backwards, not reaching anterior margin of eye. Dorsal fin has 72 to 95 rays, with origin on dorsal profile of head before the eyes. Anal fin with 53 to 80 rays. Pectoral fins equally well developed on both sides, with 7 to 10 rays, the fin on eyed side asymmetrical in shape. Base of caudal fin united by a membrane to last ray of dorsal and anal fins, but caudal peduncle still distinct. Lateral line with 116 to 163 tubed scales, its supratemporal prolongation with a smooth curve on head. Eyed side greyish brown to reddish brown in colour; blind side white. Pectoral fin of eyed side with a black blotch restricted to distal end of fin; hind part of caudal darker than rest of fin.

Tropical species

Soleasenegalensis has numerous small hair-like fringes; upper eye is separated from the dorsal profile of the head by a distance distinctly greater than the diameter of the eye; anterior nostril of blind-side is surrounded by a small ridge but not enlarged, distance from anterior nostril to head profile is 1.5–1.9 times the distance from nostril to mouth cleft; anterior nostril on eyed-side with tube directed backwards, not reaching anterior margin of eye. Dorsal fin, with 73–86 rays, originates on dorsal profile of head anterior to the eyes. Anal fin has 61–74 rays. Pectoral fins are equally well developed on both sides, with 7–10 rays, the fin on eyed-side is asymmetrical in shape. The base of the caudal fin is united by a membrane to the last rays of dorsal and anal fins, but caudal peduncle is still distinct. Lateral line with 116–165 pored scales, with its supra-temporal prolongation describing a smooth curve on head. Colouration of eyed-side varies from greyish-brown to reddish-brown, with large and diffuse dark spots; blind-side is white. Pectoral fin of eyed-side has a black blotch on the distal end; hind part of tail darker than rest of fin. Average adult size is 30–40 cm, but can reach up to 70 cm size (standard length).

S. senegalensis is better adapted than *S. solea* to the warmer waters of temperate climates, and therefore is more suitable for production along the southern coast of Spain and Portugal. During the 1980s, it was cultured extensively in earthen ponds, which often were former salt production ponds. Since then, numerous research projects in Portugal and Spain have studied methods to improve production.

Soleasolea

A demersal marine species living on sandy or muddy bottoms, ranging from near shore to 200 m of depth. Adults feed mainly on polychaete worms, molluscs and small crustaceans. Females reportedly reach sexual maturity around four years old and total length of 27–30 cm. Spawning periods differ depending on geographical location: in the Mediterranean spawning takes place between January and April, with two peaks in February; in the Bay of Biscay spawning occurs between December and May; and in the North Sea spawning happens between April and June. The optimal temperature for spawning ranges from 8 to 12 °C.

Rabbitfish

Rabbit fishes belong to the genus *Siganus* of the family Siganidae. *Siganus* species are all remarkably similar to each other in most of the features. All species possess thirteen dorsal fin spines, and seven anal fin spines. The genus *Siganus* is also unique among marine fish having two pectoral spines on each side which are separated by three soft rays. Along with these twenty-four spines, one procumbent spine is found in front of the first dorsal spine which is part of the proximal pterygiophore. It is completely embedded or sometime protrudes from a small groove and collectively makes up the main defense of fish. The spines are poisonous. The teeth are also remarkably similar to each other. The number of teeth and the overall shape are "identical." with a single row on top and the bottom jaw. They are very compressed and incisiform in shape. The teeth also overlap and are individually spadelike and pointed.

Species in Indian waters:

***Siganus canaliculatus* (Park, 1797)**

Distinctive Characters: Body compressed, fairly slender, with a headwith a concave slope above eye. Snout is blunt, anterior nostril is with a long flap in juveniles (shortening with age, absent in old fish);tip of flap reaching less than halfway to posterior nostril in specimens larger than 12 cm standard length. A forward-directed spine is present in front of dorsal fin; last dorsal spine the shortest, contained 0.5 to 0.6 times of the longest dorsal spine; last anal spine contained 1.2 to 1.5 times of the longest anal spine (usually the third). Caudal fin is almost emarginate in specimens under 10 cm SL, forked in larger fish. Scales minute with naked cheeks or with few to many very fine scales; 21 to 27 scale rows between lateral line and bases of leading dorsal spines. Colour in live fish is highly variable from greenish grey on dorsal side to silver on ventral side; numerous pearly blue match-head size spots covering nape and sides, arranged more or less in horizontal rows. Caudal fin grey or with pale and dark grey bars; pectoral fins hyaline; dorsal, anal and pelvic spines and rays have same colour as adjacent areas of sides; fin membranes greyish in colour; after death fins usually with pale and dark grey, dorsal fin rays banded.

Biology: Common rabbit fish reported from India are *Siganus javus, S. canaliculatus, S.lineatus , S.stellatus, S. vermiculatus*.

S. canliculatus is generally found and its sizes vary from 20-25 cm, with a maximum of 45 cm TL. They are found in coral reef areas, mangrove swamps and shallow lagoons (Saoud *et al.*, 2008) and are able to tolerate a wide range of salinity (17-37 ppt), low dissolved oxygen upto 2 ppm and pH upto 9 and high stocking densities andgrow well in temperatures between 23 and 30°C. All these characters make this species suitable for culture.

Siganus canaliculatus are reported to grow to a length of 8 cm in about 3 months, 10 cm in about 4½ months and 14 cm in 7–8 months. The juveniles and adults are primarily herbivorous, feeding on different Kinds of benthic algae. Under captivity, they become omnivorous, feeding on a variety of food of both vegetable and animal origin, including feed pellets in the culture system. Juveniles form schools in algal and seagrass beds, feeding mainly on filamentous algae. Rabbitfish have also been reported to eat amphipods, copepods, sponges, foraminifera, crustaceans and brittle stars which suggest that these species may in fact be opportunistic omnivores. Adults are also schooling and move into shallow water with the rising tide to feed on benthic plants. The seeds are usually collected from the wild by scoop nets, dip nets, seine nets, etc. during season. The larvae can be fed with a mixture of phytoplankton, rotifers, copepods and the larvae of Artemia in culture (Bensam. 1993).Two-fold increase in the length and ten fold increase in weight over 5 weeks have been reported in the fry fed with algae and fish feed pellets.

Siganids are lunar-spawners. April and May are the peak months of spawning in tropical waters. The arrival of juveniles starts from the fringing reefs, to the patch reefs and associated seaweed beds and finally onto the seagrass (mostly Enhalusacoroides) beds. The main spawning season of *Siganus canaliculatus* in Singapore and Philippine waters has been reported to be from January to April (Lam, 1974; Manacop, 1937). In Palau, *S. canaliculatus* spawns during March to May [31] (Hasse et al. 1977). Occurrence of juveniles of *S. canaliculatus* was reported during February through May in the Gulf of Mannar (Mohan, 1985). The spawning season of the species also extends from November to February. In HongKong, *S. canaliculatus* has a definite spawning period from March to June (Tseng and Chan 1982). Mating occurs in synchronization with the lunar cycle for some of the rabbitfish. *Siganus canaliculatus* spawns four to seven days after the new moon in both Guam. Study on reproductive biology of *S .canaliculatus* in the Southern Arabian Gulf (Grandcourt *et al* 2007) and research on schooling of rabbitfish within mariculture facilities indicates that the eggs are adhesive, though not demersal, hatching within three days. After four weeks of a pelagic life, the larvae settle and begin feeding on filamentous algae.

The defined spawning period of *S. canaliculatus* supports the contention that seasonal reproductive cycles are common among tropical fishes (Robertson, 1990). Spawning of this species has been reported to occur between January and April in Philippines. In Singapore Sadovy (1998) has reported similar spawning. Furthermore, there was a small peak in the gonadosomatic index in November, suggesting that a second but less well-defined spawning season exists. A second, although less pronounced, spawning period has also been reported for this species in Singapore, Philippines and Palau. Studies on Induced spawning of *S. canaliculatus* has been carried out by Patrick G. Bryan 1974. The reproductive cycle of *S. canaliculatus* in the southern India, therefore appears to be the same as it is observed in other locations of the Indo-Pacific. Female influenced sex ratios are a characteristic (though not diagnostic) feature of protogynous species Sadovy, 1996).

Asia-Pacific region is characterised by a high species diversity that reflects the biodiversity of the region. But development of breeding technology for these species is highly demanding both on a monetary basis as well as on the research front. Cage culture has great development potential. Hence, research has to look into more and more species for which information on biology is available, more and more species which has faster growth rate and better feed conversion ratios. This will certainly go a long way in improving the food security planning in the country.

Current trends and Prospects of Seaweed Farming in India

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Introduction

The Seaweeds are macrophytic algae, a primitive type of plants lacking true roots, stems and leaves. The word seaweed gives the wrong impression that it is a useless plant. Seaweeds are wonder plants of the sea and highly useful plants. Seaweeds grow in the shallow waters. Root system and conducting tissues like land plants are absent in seaweeds. Most of them have hold-fast for attachment and some drift loose in the sea. Four groups of seaweeds are recognized according to their pigments that absorb light of particular wave lengths and give them their colours of green, blue, brown and red. Most seaweed belongs to one of three divisions - the Chlorophyta (green algae), the Phaeophyta (brown algae) and the Rhodophyta (red algae). There are about 900 species of green seaweed, 4000 red species and 1500 brown species found in nature. The greatest variety of red seaweeds is found in subtropical and tropical waters, while brown seaweeds are more common in cooler, temperate waters. Economic importance Some 221 species of seaweed are utilized commercially. Of these, about 145 species are used for food and 110 species for phycocolloid production.

Natural seaweed stocks have become inadequate to meet the industrial requirements and hence cultivation of these important resources has become necessary. Asia stands as the world leader in seaweed cultivation and more than 80% is contributed by China, Korea and Japan. India has not taken up seaweed cultivation interestingly in the past though it is bestowed with a coastline of more than 17,000 km, embracing 821 species of seaweeds. Only recently, seaweed cultivation is picking up in certain coastal districts of the Tamil Nadu state. Central Salt Marine Chemical Research Institute and Central Marine Fisheries Research Institute have developed culture techniques for some of the commercially important seaweed species in India. As a result of this effort, a lot of Self Help Groups, Village Youth Groups and NGOs have come forward to promote seaweed cultivation as an alternate livelihood option for the coastal poor. Considering the great demand for these resources in the international market and availability of adequate manpower and interest in the country, seaweed cultivation has a very good prospect and it can be developed as a successful cottage or co-operative sector industry.

Uses of seaweeds

Seaweeds new renewable source of food, energy, chemicals and medicines. Provides valuable source of raw material for industries like health food, medicines, pharmaceuticals, textiles, fertilizers, animal feed etc.

Seaweeds used for production of Agar, Alginates & Carrageenan. Chemicals from brown seaweeds such as alginic acid, mannitol, laminarin, fucoidin and iodine have been extracted successfully on a commercial basis. As the alginates can absorb many times their own weight of water, have a wide range of viscosity, can readily form gels and are non-toxic, they have countless uses in the manufacture of pharmaceuticals, cosmetic creams, paper and cardboard, and processed foods. Agar-agar, agarose and carrageenan are commercially valuable substances extracted from red seaweeds and find extensive use in many industries. The greatest use of agar is in association with food preparation and in the pharmaceutical industry as a laxative or as an outer cover of capsules. With the advent of modern molecular biology and genetic engineering, agar gums producing an 'agarose' factor are used extensively in electrophoresis in most laboratories around the world. Carrageenans are generally employed for their physical functions in gelation (include for example, foods such as ice cream), viscous behavior and stabilization.

Seaweedshave been a staple food in Japan and China for a very long time. The green seaweeds *Enteromorpha, Ulva, Caulerpa* and *Codium* are utilized exclusively as source of food. These are often eaten as fresh salads or cooked as vegetables along with rice. *Porphyra* (Nori), *Laminaria* (Kombu) and *Undaria* (Wakame) are used for making fish and meat dishes as well as soups and accompaniments.

Seaweeds were rich in minerals, vitamins, trace elements and bioactive substances, seaweeds are called medical food of the 21st century. *Digenea* sp. (Rhodophyta) produces an effective vermifuge (kainic acid). *Laminaria* sp. and *Sargassum* species have been used in China for the treatment of cancer. Anti-viral compounds from *Undaria* sp. have been found to inhibit the Herpes simplex virus, which are now sold in capsule form. Research is now being carried out into using *Undaria* sp. extract to treat breast cancer and HIV. Another red alga *Ptilota* sp. produces a protein (a lectin) that preferentially agglutinates human B-type erythrocytes in vitro. Some calcareous species of *Corallina* sp. have been used in bone-replacement therapy. *Asparagopsis taxiformes* and *Sarconema*sp. are used to control and cure goiter while heparin, a seaweed extract, is used in cardiovascular surgery. Currently there are 42 countries in the world with reports of commercial seaweed activity. China holds first rank in seaweed production, with *Laminaria* sp. accounting for most of its production, followed by North Korea, South Korea, Japan, Philippines, Chile, Norway, Indonesia, USA and India. These top ten countries contribute about 95% of the world's commercial seaweed volume. About 90% seaweed production comes from culture based practices.

Seaweed resources in India

Seaweeds grow abundantly along the Tamil Nadu and Gujarat coasts and around Lakshadweep and Andaman and Nicobar islands. There are also rich seaweed beds around Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam and Pulicat inTamil Nadu and Chilka in Orissa. Out of approximately 700 species of marine algae found in both inter-tidal and deep water regions of the Indian coast, nearly 60 species are commercially important. Agar yielding red seaweeds such as *Gelidiella acerosa* and *Gracilaria* sp. are collected throughout the year while algin yielding brown algae such as *Sargassum* and *Turbinaria* are collected seasonally from August to January on Southern coast. The surveys carried out by Central Salt and Marine and Chemical Research Institute (CSMCRI), Central Marine Fisheries Research Institute (CMFRI) and other research organizations have revealed vast seaweed resources along the coastal belts of South India. On the West Coast, especially in the state of Gujarat, abundant seaweed resources are present on the intertidal and sub tidal regions. These resources have great potential for the development of seaweed-based industries in India. Seaweed industry in India The seaweed industry in India is mainly a cottage industry and is based only on the natural stock of agar-yielding red seaweeds, such as *Gelidiella acerosa* and *Gracilaria edulis*, and algin yielding brown seaweeds species such as *Sargassum* and *Tubineria*.

Why Seaweed Farming

Remedy for non-availability of required quantity of seaweeds for various uses.

Provide occupation for the coastal people.

Provide continues supply of raw material for seaweed based industry.

Provide seaweeds of uniform quality for use in industry.

Conserve natural populations of concerned seaweeds.

Seaweed farming is aecofriendly activity.

Major tool to treat coastal pollution in the sea and reduce CO_2 in global warming.

Methods of Seaweed Farming

1. Single Rope Floating Raft method (Coir Rope & Nylon Rope).

2. Fixed Bottom long line method (Coir Rope & Nylon Rope).

3.Integrated Multi Trophic Aquaculture (IMTA) method.

Seaweed Farming in India

Central Salt and Marine Chemical Reseach Institute (CSMCRI) Marine Algal Research Station (MARS), Mandapam, Tamil Nadu a CSIR Institute developed viable and commercially sustainable methods for cultivating *Gracilaria edulis* and *Gelidiella acerosa* the two seaweed species, widely used in food and pharmaceutical industries and commanded good demand in the market. Method of cultivating Geildiella acersoa in open sea using suspended stones to enhance yield and help the growers get better returns.

Rope with seaweed fragments Anchor cable Synthetic floats Main rope Stone Single Rope Floating Raft culture technique The main culture methods involve either vegetative propagation using fragments from mother plants or by different kinds of spores such as zoospores, monospores, tetraspores and carpospores.

Single Rope Floating Raft (SRFR) method developed by CSMCRI is suitable for culturing seaweeds in wide area and greater depth. A long polypropylene rope of 10 mm diameter is attached to 2 wooden stakes with 2 synthetic fiber anchor cables and kept afloat with synthetic floats. The length of the cable is twice the depth of the sea (3 to 4 m). Each raft is kept afloat by means of 25-30 floats. The cultivation rope (1 m long x 6 m diameter polypropylene) is hung with the floating rope. A stone is attached to the lower end of the cultivation rope to keep it in a vertical position. Generally 10 fragments of *Gracilaria edulis* are inserted on each rope. The distance between two rafts is kept at 2 m. Floating raft technology has been recommended to be used on the Kerala coast for agarophyte cultivation . Certain areas in the Gulf of Kutch have been suggested as suitable for deep-water seaweed cultivation . In addition, CMFRI has developed and perfected techniques for culturing *Gelidiella acerosa, Gracilaria edulis, Hypneamus ciformis* and *Acanthophora spicifera*, and now attempts are being made to find improved techniques for propagation and large scale culture of other economically important seaweeds. Problems and Prospects The major problems in the seaweed industry include overexploitation leading to a scarcity of raw material, poor quality raw material, labor shortages during the paddy harvesting and transplanting season, lack of technology to improve processed product quality, and a lack of information on new and alternative sources of raw materials. Despite the great number of sheltered bays and lagoons suitable for mariculture, no large-scale attempts to grow seaweed have been made in India so far. Efforts are needed to increase production through improving harvesting techniques, removal of competing species, creation of artificial habitats and seeding of cleared areas. As the technology for reliable methods for the cultivation of different commercially important seed stocks and their improvement has either already been developed or presently being in research, it needs to be disseminated effectively to the target community. Extensive surveys need to be conducted to identify suitable sites for large-scale seaweed culture. There is great potential for the agarophyte cultivation because of its low availability from the wild stock due to over-exploitation. Many edible seaweed species are available on the Indian coast; attempts should be made to develop products suitable for the Indian palate and to popularize the same amongst the public. With regard to pharmaceutical substances, heparin analogues (heparinoids) that are inhibitory to thrombin activities have been reported from Chlorophyta of Indian coasts ; this and many other important types of seaweed are available on Indian coast that can be utilized for production of many important pharmaceutical products through extraction of bioactive compounds. Attention should also be given towards developing hybrid species with superior growth and nutritional characteristics, as the same has been proved successful in countries like Japan. Rather opting for high-volume low-value seaweeds, culture of high value seaweeds should be aimed for, as part of integrated coastal and national development programmes10. Seaweed polyculture in association with molluscs and fishes seems to have good prospects to increase harvest and profits. Pond and canal culture of seaweeds (e.g. *Gracilaria*) in shrimp farming areas can help to treat the effluent water. The problem of eutrophication of culture ponds due to overfeeding and excreta released by fish/shrimp can be tackled by culturing seaweeds in such ponds. Out of estimated around US $ 3 billion global phycocolloid and biochemical business, India's share is meager. We can surely grab a bigger part in this lucrative business with sincere efforts towards large-scale cultivation of commercially important species and processing. To facilitate this, more technologically sophisticated extraction plants with easy access to markets and marketing.

The first large scale commercial cultivation of seaweeds in India has been embarked upon by Pepsi Foods Ltd. (PFL) along a 10 km stretch of the Palk Bay side towards Mandapam (Ramanathapuram Dist.) in Tamil Nadu, with technical support from MarineAlgal Research Center, CSMCRI, Mandapam. They have started cultivating *Kappaphycus alvarezii* – exotic species in an area of 100 hectares through a contract farming system in which seaweeds are grown in individual plots of 0.25 ha (40 m x 60 m). Each harvest cycle from planting to harvesting takes 45 days with an annual yield of 100 tons (wet weight) per hectare, which translates into 10 tons of dry seaweed or 2.5-3 tons of carrageenan. The company has plans to expand culture operations to over 5,000 to 10,000 ha in the near future. Furthermore, many agar and algin extracting industries have been established in different places in maritime states of Tamil Nadu, Andhra Pradesh, Kerala, Karnataka and Gujarat the seaweed industry is certainly on its way towards establishing itself well in India. Large-scale Seaweed Mariculture is carried out only in Asia, where there is a high demand for seaweed products and burgeoning populations to create market growth. Cultivation of seaweeds in Asia is a relatively low-technology business in that the whole, attached plants are placed in the sea and there is a high labor content in the operation. The demand from the phycocolloid industry of India is great but the present production from natural habitats is very low and insufficient to cater to the needs of the local industry. This gap between the demand and supply can be bridged through mariculture practices for seaweeds by cultivating the useful species on commercial scale.

Continuous supply, improved yield and quality as well as conservation of natural seaweeds beds are some of the important advantages of seaweed mariculture.

Lakshadweep:

Gracilaria edulis, A Seventeen – fold increase in yield was obtained for Agar yielding species in 76 days in the first harvest at Minicoy Lagoon, Minicoy Island, U. T. of Lakshadweep, India during south west monsoon season by adopting single bottom coir rope method.

Hypnea valentiae, A Twenty five – fold increase in yield was obtained for Carrageen yielding species in 40 days in the second harvest at Minicoy Lagoon, Minicoy Island, U. T. of Lakshadweep during south west monsoon season by adopting single bottom coir rope method.

Acanthophora spicifera, A Thirty six – fold- increase in yield was obtained for Carrageenan yielding species in 42 days in the second harvest at Minicoy Lagoon, Minicoy Island, U. T. of Lakshadweep.

During the southwest monsoon season the lagoon water Cost effective ecofriendly seaweed culture technology developed for economically important seaweeds such as *Gracilaria edulis*, *Acanthophora spicifera*, and *Hypnea valentiae*are suitable species for farming at Minicoy Lagoon at U. T. of Lakshadweep The best method for culture is Single bottom coir rope method and single bottom nylon rope method during the southwest monsoon season at Islands of U.T. of Lakshadweep. This cost effective seaweed farming technology can be practiced by fisherman of Lakshadweep to generate income during lean fishing season of southwest monsoon (May to September) become enriched with nutrients, which help to get good growth of seaweeds.

Kerala:

A record growth of 34.42 fold increase in yield was obtained in 86 days and 30 fold increase in yield in 63 days during post monsoon period was obtained for *Kappaphycus alverizii* by adopting suspended nylon hook method at Thikkodi near Calicut, Kerala.

A maximum of 20.1 fold increase in yield in 80 days and a minimum of 13.2 fold increase in yield in 40 days was obtained for the carrageenan yielding red seaweed *Kappaphycus alverazii* by adopting raft culture method which was carried out as demonstration along with green mussels (*Pernaviridis*) – integrated farming - at Vadakkekad, Padane, Kasaragod District, Kerala.

Gujarat:

Farming of *Hypneamus ciformis* was carried out during post monsoon period using raft culture method at Chorward near Veraval. A fivefold increase in yield was obtained during August to September period in 62 days. During November and December an eight fold increase in yield was obtained in 61 days.

Seaweed culture was integrated with Sea Cage culture. *Kappaphycus alvarezii* was farmed in bags and raft with Sea Cage and the growth was found promising. A maximum of 9 fold increase in weight was obtained by adopting bag culture method in 55 days (January and February) and 11 fold increase in weight by adopting raft method in 64 days (February and March) for *Kappaphycus alvarezii* farming.

***Gracilaria* Farming**

Gracilaria spp. can be cultivated using vegetative fragments. Vegetative fragment culture of *Gracilaria* easy practice and it can be carried out throughout the year. Vegetative fragments of the plants are divided into 5 cm and these are introduced between the twists of the rope at 10 cm intervals. Fixed off bottom long line or floating raft methods can be selected. In the fixed off bottom long line method seaweed inserted ropes were tied to the posts planted in the sandy and muddy bottom of the intertidal regions. The position of the ropes is adjusted to remain at a constant depth in the tidal zone. In the raft method vegetative fragments inserted ropes were tied to the floating raft. First harvest can be made in three months and subsequent harvest in one and months. After harvest it may be dried in beaches itself for a week and kept in bales ready for shipping.

***Kappaphycusalvarezii*Farming**

The farming of the seaweed *Kappaphycus alvarezii* can be a low-cost venture and a profitable one, with the right site. The technology can use family labor in either fixed off-bottom or single raft long-line culture. The more line modules, the more investment and care are needed. After tying seaweed plantlets or “seedlings” to the ropes, and the ropes staked to the sea bed by bamboo or tied to floating rafts staked to the sea bed, seaweed farming needs no more inputs. Weekly visit to the farming site to remove undesirable algae, barnacles, and attached sediments; to re-tie loose or fallen seaweed; to tighten lines; and to check for signs of “ice-ice” disease.

***Kappaphycus* farming - Technology profile**

(1) Get and select good quality seedlings; these are brittle, shiny and young branches with sharp pointed tips, no traces of grazing or whitened thallus (sign of beginning “ice-ice” disease), and 100-150 grams. (2) For fixed off-bottom culture While on land, tie seaweed seedlings 15-20 cm apart to the cultivation rope 10-20 m long with soft plastic string (commonly called “tie-tie”). Carry the ropes to the site at the lowest tide and tie both ends to stakes already placed 1-meter apart on the seabed. For single raft long-line method, tied seedlings as above but anchor ropes to a bamboo raft. A raft unit consists of four bamboos in a square arrangement as support with two ends tied in turn to anchor lines which are staked to the seabed. A longer raft long-line (50-70 m long) can be made floats are regularly spaced in this instance to add buoyancy to the raft.In deeper waters (5-10 m), the hanging long-line may be best; less bamboo support is used but a good concrete block anchor is necessary.(3) Visit the farm two to three times a week. Remove undesirable algae, barnacles, or attached sediments. Re-tie loose or fallen seaweed. Check and tighten loose rope or stake. Check for signs of diseases; totally harvest crops immediately if present. Use new set of seedlings, change farming site / method, and use lower stocking density.(4) Harvest in 45-60 days. Seaweed can be sold wet or dry to processors. Dried seaweed brings more income if it is clean and with moisture content of 35-39%. It is best to keep harvested seaweeds off the ground (remember that the carrageenan is bound for products for human consumption). Use a layer of mat, fish net, or coconut leaves and constantly turn seaweeds to accelerate drying; or dry seaweeds in a platform or hangings lines. Sun-dry for 2-3 days. (5) Tie the seaweed in bales, then store in a clean, cool, dry and well-ventilated place while awaiting buyers.

Why *Kappaphycus alvarezii* farming

- High return on investment
- Demand for seaweeds is high in the local and international markets
- Culture period could be as short as 45 days under optimal conditions
- Environment-friendly method

- Could be a source of supplemental income for small fisherfolk associations and people's cooperatives
- The farming of *Kappaphycus* can be a low-cost venture and a profitable one

Conclusion

In India, Mariculture is a sunrise enterprise. Technologies that have attracted the imagination of coastal stakeholders include mussel farming, seaweed farming and sea cage culture. Mussel *(Perna viridis*) farming technology has diffused along the Malabar coast (southwest India), and seaweed (*Kappaphycus alverezii*) farming prevails along the Coromandel coast (southeast India), after it found a niche in the Gulf of Mannar. Having proven their potential as empowerment platforms for coastal women, the theatres where these technologies were adopted raised a number of issues in the realm of a gendered political ecology. The aim of this paper is not only to diagnose these issues but juxtapose them with some of the epistemological concerns being brought by "gender lens" scholarship, especially in the neo-liberal context of global fisheries. A paradox brought out by the present study is the ambivalence of the State in manifesting itself as a positive "bargaining" force in the intra-household domestic space (by providing State-sponsored platforms through the Self Help Groups) while leaving the "common access resource" space, from which these platforms gain sustenance, less amenable to its democratic ideals.

Seaweed farming based primarily on the culture of *Kappaphycus* species has grown significantly in the Philippines and Indonesia over the last two decades, with growth also taking place at a smaller scale in India and a few other developing countries. Unlike other forms of aquaculture, seaweed farming foregoes the use of feed and fertilizers and has minimum technological and capital requirements. In addition, grow out cycles are short, normally lasting less than two months. Given these unique characteristics, seaweed farming has generated substantial socio-economic benefits to marginalized coastal communities in developing countries, most of which have reduced access to alternative economic activities. In some communities, seaweed farming has emerged as the most relevant livelihood strategy. Given the rising global demand for seaweed-derived products, seaweed farming has the potential to generate further socio-economic benefits to coastal communities in tropical regions.

Aeration, Filtration and Disinfection in Mariculture

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Aeration

Among various water quality parameters for a successful aquaculture practice, Dissolved oxygen content in the water is one of the most important parameters, as the oxygen is a vital for all the organisms living in the water and having an aerobic type of respiration. The purpose of aeration is to increase the concentration of oxygen in the water. In scientific aquaculture practices, this is more critical because, often the rate of consumption of oxygen is much higher than the natural rate of replenishment of oxygen in the water through diffusion from atmosphere and photosynthesis of aquatic plants. Oxygen is one environmental parameter that exerts a tremendous effect on growth and production through its direct effect on feed consumption and metabolism and its indirect effect on environmental conditions. Oxygen affects the solubility and availability of many nutrients. Low levels of dissolved oxygen can cause changes in oxidation state of substances from the oxidized to the reduced form. Lack of dissolved oxygen can be directly harmful to culture organisms or cause a substantial increase in the level of toxic metabolites. It is therefore important to continuously maintain dissolved oxygen at optimum levels of above 3.5 ppm.

Dissolved oxygen is measured either in mg per litre (mgl^{-1}) or parts per million (ppm) with 0 ppm representing total oxygen depletion and 15 ppm representing the maximum or saturation. The solubility of oxygen is influenced by several factors. The solubility of oxygen decreases as the temperature increases; decreases exponentially with increase in salinity; decreases with lower atmospheric pressure and higher humidity and increases with depth. Water temperature is the main limiting factor in aquaculture farms. Oxygen from atmosphere enters the water naturally through air/water interface. This process is enhanced by wind action which creates a mild turbulence at the water surface.

Need for artificial aeration in culture system

- Rise in atmospheric temperature causes an increase in the rate of biological degradation of organic matter and subsequent depletion of oxygen concentration in water.
- Prolonged cloudy conditions causes reduction in the photosynthetic activity by green plants in ponds results in reduction in oxygen concentration.

- Increased stocking rate of animals in semi intensive and intensive farming practices requires greater amount of oxygen for respiration for all aquatic organisms results in depletion of oxygen concentration in water.
- Aeration in ponds helps in mixing and circulation of pond water. Mixing and circulation is more critical in scientific farming which also helps in feed distribution and waste disposal.

Aerators

Aerators are mechanical devices which increases the dissolved oxygen content of the water. Aerators utilizes the energy input to increases the surface area of water available for oxygen transfer andmix water with oxygen to ensure the liquid medium with of oxygen concentration is brought in contact with oxygen or air.

Oxygen Transfer Process

Three steps are involved in the transfer process of oxygen into water

a. Transfer of oxygen in the gas to gas liquid interface

b. Transfer across the gas liquid interface

c. Transfer of oxygen away from the interface into the liquid

Types of aerators

Different types of aerators used in aquaculture are

1. *Gravity aerator*: In gravity aerators, the water falls under gravity and air is mixed into it from the surrounding atmosphere. They can man made or natural.
2. *Surface aerator*: this type of aerators are commonly used on ponds and can also be used in large tanks, cages etc. They are used to break up or agitate the surface of water so that oxygen transfer takes place. There are different designs of surface type aerators available. Paddle wheel aerators and spray type surface aerators are commercial type surface aerators.
3. *Diffuser aerator*: Diffuser aerators inject air or oxygen into a body of water in the form of bubbles. Oxygen is transferred from the bubbles to the water by diffusion across the liquid film.
4. *Turbine aerator*: Turbine aerator consists of a propeller submerged in the water to be aerated. Circulation of water by Rotation of propeller causes greater aeration to occur at the surface. The main disadvantage of using this type of aerator is that propellers can cause damage to the fishes.

Aeration in aquaculture ponds

Steps to maintain optimum levels of Dissolved oxygen would be to support major factors that increase DO and put into check the factors that decrease DO. Photosynthesis plays a major role in oxygen production; respiration of all living organisms in the pond is the major factor involved in oxygen consumption. Oxygen concentration in pond water exhibits a diurnal pattern, with the maximum occurring during the peak of photosynthesis in the afternoon and the minimum occurring at dawn due to night time respiration. The magnitude of DO fluctuation is small and occurs around the level of saturated DO when plankton density is low and increases asplankton density increases. Supplemental aeration is generally provided during night time when DO increases to levels below 4.0 ppm. Photosynthesis of phytoplankton is the major contributor of DO during the day and diffusion accounts for increases when DO is below saturation at night. Diffusion at night can be tremendously facilitated with the use of aerators, which exposes more water surface to equilibrate with atmospheric oxygen. Through reverse diffusion, anaerator operated during the day will tend to remove supersaturated DO. The net effectis a milder diurnal fluctuations of DO similar to the conditions of low phytoplankton density. Such conditions are favorable for semi-intensive culture of prawn and shrimp. Photosynthetic oxygen production is also significantly reduced when large scale depletion of plankton population occurs. Under these conditions, flushing out decaying plankton, providing for additional aerators and a erating for additional hours may be necessary to maintain DO at optimum levels. When plankton density is high, the penetration of sunlight through water gets reduced, thereby reducing photosynthetic oxygen production in the bottom ofthe water column. High plankton density often results from high nutrient loads and other these conditions, large quantities of feed and faecal wastes are found on the pond bottom. This causes an increase in bacterial population and metabolic activity in the bottom sediments leading to high oxygen demand in the bottom sediment. Limited light penetration and increased DO consumption in the bottom may cause significantly lower DO compared to the top layer of the water column. If this causes DO to deplete to lower than critical levels, disastrous effects on the bottom living organisms may happen. Limited light penetration (low secchi disc reading) can also cause differencesin the temperature of the top and bottom layer. Temperature stratification usually occurs during calm and warm afternoons.

Filtration

Removal of particles from a water flow in important in aquaculture. Suspended solids, dissolved solids and organic matter were removed from water by filtration of water through suitable media.

Types of filtration

1. **Mechanical filtration**

In aquaculture, mechanical filtration is used primarily for the separation of solids and liquids. A mechanical filter is a filter that is set into the water flow to collect the particles and larger objects and allow water to pass through. Mechanical filters uses differences in particle size of the solution (or mixture) components to extract one part form the other. The simplest type comprises a static screen, a grating or perforated plate. They are usually simple in operation and relatively easy to maintain.

In sand filters, water is allowed to flow through a layer of sand with particles of varying sizes and depth. The layer is not dense, but contains a number of channels and holes created between the particles that constitute filter medium. When water is passes through the filter medium, particles larger than a certain size will be trapped in the medium.

Various types of mechanical filters are (i) stationary screen (ii) rotary screen (iii) vibratory screen

2. **Gravitational filtration**

Gravitational filtration utilizes the force of gravity to separate particles from fluid. Density difference of the suspended particles and water is used in this type of filtration. A simple example of gravity filtration is sedimentation. Sedimentation is a process of allowing particulate materials having density greater than that of suspending liquid to settle out under gravitational forces. The settling process of the suspended particles can be increased by aggregating the suspended particles by addition of certain chemicals (coagulation) or by adding chemicals to produce insoluble compounds with suspended particles (precipitation).

3. Biological filtration

Concentration of ammonia in culture water is reduced by biological filtration process. Biological filters are devices to culture microorganism that will perform the given task of reducing the ammonia concentration when water with high ammonia level floes through them. In water both Ammonia (NH_3) and ammonium ion (NH_4^+) are present and their sum is known as Total Ammonia Nitrogen (TAN) and their proportions vary with pH. Ammonia (NH_3) is toxic to fish and their presence in water is important in aquaculture practices.

Biological filters (biofilters) are used to maintain water quality in recirculating or closed aquaculture systems. Biofilters are also used to improve water quality before water is discharged from a facility. Biological filers are formed as a component of the main filtration system which ensures water quality in an aquaculture farm. However it is very important in recirculating aquaculture or aquarium system.

In biological filters, bacteria are used to convert ammonia in various steps. (i) Conversion of ammonium to Nitrite (ii) conversion of Nitrite to Nitrate and (iii) Conversion of nitrate to molecular nitrogen. The first two steps, known as nitrification, are performed by specific bacteria which oxidize ammonia. The autotrophic bacteria, *Nitrosomonas* bacteria utilize ammonia as a food source and produce nitrite. This nitrite is further converted to nitrate by *Nitrobacter*. These bacteria grow and colonize on the filter medium of biological filter. Both nitrifying bacteria will grow and colonize the biofilter as long as there is food available. The efficiency of the nitrification process depends on the optimum growth of bacteria on the biofilter medium. One of the main factors affecting bacterial growth is the amount ammonia in the water. Other factors regulate are temperature, oxygen concentration, pH, salinity, organic substances and toxic substances.

Disinfection

Water drawn from coastal waters, estuaries and rivers used for various aquaculture activities often forms an efficient means for the introduction and spread of infectious diseases in the system. So it is very essential to have a pathogen-free water source for success in aquaculture. For aquaculture, the supply water to the farm or hatchery is disinfected by various methods. Disinfection of wastewater before discharging is necessary to avoid the pathogen contamination in the environment. Disinfection can be described as the reduction of microorganisms such as bacteria, viruses, fungi and parasites to a desired concentration. The aim of disinfection of water in fish farming is toreduce the risk of transfer of infectious dieses from water to the fishto an acceptable level.

There are several methods for disinfecting water. Disinfectants can be grouped as chemical and non chemical agents. A four group classification for disinfectants is (i) chemical agents (ii) physical agents (iii) mechanical agents and (iv) radiation. Even though various methods can be used for disinfecting water, the quality of the water to be disinfected is of major importance. Pure inlet water is much simpler to disinfect than the outlet water because latter contains more particles. Turbid water and water with a high content of organic substances such as reuse water are also more difficult to disinfect and therefore not commonly disinfected. For disinfection of water supplies to aquaculture facilities, UV light and ozone are commonly used. When starting disinfection, one must be aware of the production of disinfection bye products which might be harmful for fishes and humans. Disinfection can be performed in different situations in aquaculture. Water equipment, buildings and effluents can all be disinfected.

Ultraviolet Light

UV light is electromagnetic radiation with a wavelength of 1-40nm located at lower end of the visible spectrum and beyond. The ability of UV light to inactive and destroy microorganisms varies with both wavelength and the microorganisms to be inactivated. The most effective wave length for disinfection is 250 – 270nm. UV light damages the genetic materials in the microorganisms which results in their inactivation and death. The efficiency of UV light depends on various factors like lamp intensity, age of the lamp, cleanliness of the lamp surface, distance between the lamp and organisms to be inactivated, duration of UV exposure and purity of water. UV lamps need to be replaced regularly, atleast once in a year. UV light transmission through water depends on the turbidity of water, lower in turbid water.

UV lights can be placed in the water flow which is the usual method or above water flow. The dose required to kill pathogenic microorganisms depends on the organism. Most of the common bacteria requires a lower dose while viruses, which are more difficult to disinfect, needs stronger exposure intensity and duration.

Ozone

Ozone is a very strong oxidizing agent, highly toxic to all forms of life. Ozone, is a colourless gas which is very unstable and will quickly be broken down to O_2. Ozone inactivates the microorganisms by damaging cell membranes and nucleic acids, breaking long chain molecules into simpler forms. Another advantageous effect of using Ozone in aquaculture systems is that by oxidation it reduces the amount of NH_3, NO_2, biological oxygen demand. When using ozone as a disinfectant, it is recommended that particles be removed from water before the ozone is added, otherwise much of ozone will be used to oxidize the particles. When adding ozone to water, special injection system has to be used to ensure good gas water mixing. The ozone needs to given sufficient time to function and oxidize microorganisms. For effective inactivation of pathogens, ozone can be applied in a high dose for a shorter duration and vice versa. Overdosing must be avoided because this may kill the fish. Most pathogens are killed by an ozone dose of 0.1-1.0mg/L and contact time of 1-10 min, but this varies with the organisms.

The water quality parameters like concentration of dissolved organics, particular organics, inorganic ions, pH and temperature will have large impact on the residual ozone concentration after a given time. Because of these variations, it is important to add enough ozone to obtain a satisfactory residual concentration to achieve disinfection.

One of the major problems with ozone disinfection is that it is highly toxic to fishes and humans. Ozone is toxic to fishes even at lower concentrations as it oxidizes gill tissue of fishes. Therefore after disinfection, any residual ozone present in water should be removed or destroyed. An adequate retention time ensures that most of the ozone has reacted and the product is mainly oxygen gas. Being a very strong oxidizing agent, it will oxidize all materials which comes in contact. Ozone will destroy most of the plastic for some extent. Ozone will oxidize metals causing significant corrosion problems.

Chlorine

Chlorine is a very effective disinfectant for water and the most common method used for disinfection of water. It is normally obtained by adding liquid sodium hypochlorite to water, or solid calcium hypochlorite mixed into the water or pure chlorine gas. All these compounds are strong oxidizing agents and have the ability to break down organic molecules.

For effective disinfection using chlorine, specific contact time is required which include time for dissociation in water, time for diffusion through cell wall and time to inactivate selected enzymes. Presence of residual chlorine after disinfection is critical for fishes and overdoing must be avoided. Water containing chlorine is very toxic to fishes. When disinfecting tanks or other equipments with chlorine, it is important that sufficient clean water is used to wash away the chlorine residues produced. There for when using chlorine as a disinfectant, a method for dechlorination must be included.

Importance of Water Quality in Mariculture

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Marine cage aquaculture industry is gaining greater demand worldwide, due to its contribution as an alternate livelihood and also because of its protein and export value, for coastal communities. Water quality is the most important determinant for maintaining sustainable marine cage farming. The most important physico-chemical and biological parameters to be considered in cage aquaculture include water temperature, turbidity, salinity, pH, dissolved oxygen, ammonia, nitrates, nitrites, phosphates and algal blooms. It is also understood that the effects of marine finfish cage aquaculture on water quality are of great concern to the development of an ecologically viable mariculture industry. In India, cage farming of marine finfish is successful with a record production of Asian seabass, *Lates calcarifer* and cobia, *Rachycentron canadum* in 6 m and 10 m dia. steel cages respectively. To achieve a sustainable culture of these species, management of good water quality in the cage farm is of prime importance. This chapter summarizes the most predominant water quality parameters which are to be considered for management of marine cage farming.

Temperature : Water temperature has the maximum effect on fish and can be considered as a primary factor affecting the economic feasibility of a commercial aquaculture venture. Extreme temperatures can induce stress in the animal, and the metabolic activities of fish are affected, which ultimately affects the growth and health of fish. In cage culture, optimum water temperature depends on the type of cultivable species i.e., 26–32 °C for most tropical species and 20–28 °C for most temperate species. Some of the fish species can survive even at varied temperatures but the growth of the fish may be affected due to temperature fluctuations. The sudden change in water temperature will affect fish metabolism, oxygen consumption, ammonia and carbon dioxide production, feeding rate, food conversion, as well as fish growth. The best solution is to select fast growing species and avoid the culture period during the months with unsuitable temperature.

Salinity: Salinity is the most important factor which can influence the ionic balance in the fish and extreme changes in salinity values further affect the growth of fish. In general, the optimum salinity required for cage culture of finfishes ranges between 10-30 ppt. However, the optimum salinity varies with the type of species cultured. Asian seabass can tolerate salinity ranging between 0-33 ppt, whereas, the salinity tolerance of cobia, pompano, snappers and groupers range between 15-35 ppt, 5-35 ppt, 15-33 ppt and 10-33 ppt respectively. Optimum salinity required for culture of Asian seabass, cobia, pompano, snappers and groupers, which are the potential candidate species for cage farming in India, are 15, 25, 15, 25 and 15 ppt respectively. It is suggested to have the culture of these species during the suitable season required for these fishes and also the area suitable and kind of water bodies. It is also suggested to culture Asian seabass in marine as well as brackishwater bodies, as the species can tolerate extreme salinity conditions. The culture of Asian seabass can be practised as in brackishwater areas and in controlled pond conditions as coastal farming. Cobia farming can be done preferably in marine water bodies as the growth rate of cobia is high under high saline conditions in marine water bodies. Pompano, *Trachinotus blochi*, can be cultured both in marine and brackishwater areas in cages and also in ponds as it tolerates all the salinities and the growth rate is more in brackishwater bodies.

Hydrogen ion index (pH): The suitable pH for most marine species is from 7.0 to 8.5. The pH values vary directly or indirectly with other water parameters like salinity and temperature, which also influences the dissolved oxygen and ammonia levels. Extreme values of pH can directly damage gill surfaces, leading to death of fish.

Dissolved oxygen: Dissolved oxygen is one of the prime factor that influences the fish health and growth in marine farms. DO is found to be a very essential element for the maintenance of osmotic activity and also digestion and assimilation of food. DO levels are mainly influenced by other environmental factors, such as temperature and salinity, and the levels decrease with increase in temperature and salinity. Ideal dissolved oxygen levels required for cage culture of marine fish range between 6-9 ppm. However, the oxygen consumption of fish varies, with species, the pelagic fish like snapper and seabass requiring more than demersal species such as grouper. In general, dissolved oxygen should preferably be around 6 ppm or more and never less than 4 ppm for pelagic fish or 3 ppm for demersal species. In the case of cage culture, benthic organisms and sediment wastes may also reduce the oxygen level. Depletion of DO always occurs during night time at neap tide in summer. It is a known factor that the algal community forms a net oxygen consumer and the occurrence of algal blooms more in the areas where nutrient flux is more, and this can lead to the oxygen depletion in water columns. Hence, it is always suggestible to culture the fish in the open waters with sufficient currents that can remove the settled particulate matter and wastes at the bottom.

Turbidity : Turbidity indicates the degree of optical clearness of sea water affected by the existence of dissolved matters, suspended particles and also tides and water currents. The suspended particles should be < 2 mg/L for cage farming of fish in marine waters. Fish wastes and the feed particulates are two major sources of turbidity in cage culture. Increase in turbidity of water results in decrease in light penetration, which in turn affects the phytoplankton production and may further affect photosynthesis of benthic vegetation, and this leads to an increase in microbial loads and in ammonia levels at the cage culture site. During monsoon season, more freshwater runoff will influence the turbidity of the water. Freshwate r runoff due to rains may lead to leaching of heavy metals from industrial effluents and suspension of organic and inorganic solids in the water column. Deposition of solid organic and inorganic materials to the bottom, due to heavy rains, may act as substrate for fouling organisms on the nets, which further prevents proper water circulation. Suspended sediments are also responsible for choking of fish gills, and may lead to mortality due to asphyxiation. Hence, in order to avoid the settlement of suspended particles in the cage, it is preferable to have the culture at sites where high flushing rate conditions are available.

Nutrients: The ammonia-nitrogen levels in the water should be less than 0.1 mg l^{-1}. Ammonia nitrogen levels in water increase by the decomposition of uneaten food and debris at the bottom, and can affect the fish. Normally in the coastal areas, sewage discharge and industrial pollution are the main sources of higher level of ammonia in seawater. The total inorganic nitrogen of water should be < 0.1 mg l^{-1} for a better fish culture operations. The excessive amount of nitrite in water leads to the oxidation of iron in fish haemoglobin, which causes hypoxia in fish. Total inorganic phosphorous plays an important role in growth of algae and other aquatic plants and it should always be < 0.015 mg l^{-1}. Excess of phosphorous levels lead to algal blooms.

Algal blooms: A number of marine algae groups form blooms, including diatoms, Cyanobacteria, prymnesiophytes and dinoflagellates, which interfere with fish gill function. Excessive algal blooms can happen whenever the suitable conditions, such as higher light intensity, higher nutrient level, warm water temperature, stagnant hydrological conditions, prevail. Algal blooms can affect fish by damaging fish gills by clogging and they also compete with fish for dissolved oxygen during night time. Red tides commonly occur in warm water, especially during summer months. Cage site should be selected in those areas where there is no occurrence of blooms and also where the waters are stagnant**.**

Maintaining good water quality of the marine cage culture operations is important to maintain the ecological balance and also for the health of the cage cultured fish. For maintenance of good water quality, it is essential to monitor all the parameters, which influence the growth and health of the fish, at regular intervals throughout the culture period. It is important to develop standard protocols for water quality management for the cultivation of different species. A standard policy should be clearly developed for the water quality criteria to be considered while selecting a site for cage culture operations.

Recommendations for better water quality management practice in cage culture

1. Selection of a suitable site with sufficient depth (6-10 m) is recommended to have better water exchange and to avoid the deposition of suspended wastes at the bottom. It also helps to avoid the contact of cage bottom to the sea floor which eliminates the bacterial interactions and benthic foulers.
2. Cages should be installed at a place where there is a continuous water current for good exchange of bottom fish wastes and suspended materials. The water current velocity should be between 0.05 m S-1 to 1 m S-1 with a tidal amplitude of < 1 m.
3. To avoid the fluctuations in salinity and dissolved oxygen levels, culture of marine finfish in cages should be carried out after monsoon period and also to avoid the current velocity, which further influences deposition of suspended solids at the bottom of the cage.
4. Development of nutrient and water quality threshold values.
5. Development of feeding strategies to improve the FCR and reduce the nutrient influx into the waters.
6. Regular Monitoring of water quality parameters, at weekly intervals, is essential to understand the health status of the cage environment.
7. Regular net exchange, at monthly intervals, also improves the water exchange in the cages and improves the environmental health. The nets which are with biofoulers are to be brought to the shore and should be thoroughly cleaned and can be reused.
8. Measures should be taken while using the farm vessel, and properly operated with minimum spill and leaks, which may cause pollution in the farm site, that may further lead to fish mortalities.
9. Rotation of cages should be implemented to decrease the waste deposition.
10. Fish wasters, dead organisms. debris and other suspended materials must be transported to the shore and properly disposed.

11. Usage of antifouling agents must be avoided and mechanical cleaning of nets and frames is highly suggestible.
12. Integrated Multi Trophic Aquaculture (IMTA) must be practised in combination with other species like mussels and seaweeds, which filter the waste particulates and absorb dissolved nutrients.

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Grow-out Culture of High Value Finfishes in Cost-Effective Cages

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Introduction

Capture fisheries is undergoing tremendous changes either due to increased fishing pressure or due to decrease in the production of certain groups due to fishery dependent or fishery independent factors. In spite of increasing effort the catch of almost all commercially important fin fishes and shell fishes is on the decline and results in severe resource depletion and unemployment. Fishermen community solely depending on fishing for their livelihood is facing an uncertain future. Decline in marine capture fishery also affects the availability of cheap protein for the masses and also affects the GDP growth of the country. It is estimated that the demand for fish will increase by 4% in developed countries and by 57% in developing countries. It is in this context cage farming of fin fishes and shell fishes assume importance as a means to increase fish production. Since cage farming is done in open waters were wave action and current takes care of the day to day maintenance of the cultured fishes. Unlike pond cultured fishes the carbon foot print in cage culture is relatively low and therefore more eco friendly.

Cage Culture

Cage farming was originally developed in Asia especially in China almost 200 years ago. Initially net bags were attached to fixed poles and fishes were reared in these net bags. Later this has developed into a practice that supports the livelihood of the traditional fishermen. In all the Asian countries cage farming is more of a livelihood activity than an industrial activity. The primary reason for this is the large number of fishermen population who are marginalized and poor. Fishermen in many Asian countries are landless people and cage farming is a boon to them. In many Asian countries fishermen families live in the floating cage farm with their children and pets. Where as in the western countries cage farming is an industrial activity or a business activity. Here cages are large managed by advanced equipments for maintenance, feeding, growth monitoring etc. Here cage farming is done by companies and generates huge profits. The main reason for the development of industrial cage farming in the west is lack of manpower to engage in cage farming.

There is a distinct difference between livelihood cage farming and industrial cage farming and one should not get confused between the development models a country like India requires to address the livelihood issues of poor fishermen. India has 14 million fishermen living along both the West and East coast of India. These fishermen are a marginalized group who has limited access to the welfare schemes of the government and solely depends on the declining marine fishery resources in the coastal waters.

In India Central Marine Fisheries Research Institute (CMFRI), initiated research on cage culture in 2007 with the help of the Department of Animal Husbandry Dairying and Fisheries (DADF), Ministry of Agriculture, Government of India and later by National Fisheries Development Board (NFDB), Hyderabad. No country was willing to share cage technology with us and CMFRI scientists has to start from text book pictures and photographs collected while on visit. Initially an experimental HDPE cage of 15 meter diameter was made and deployed at a few selected locations like Visakpatanam, Diu etc. This model failed and again the cage was redesigned with the help of scientists from IIT Kharagpur and another 15 meter HDPE was designed. This model succeeded the rough sea conditions off Visakpatanam. Seabass was cultured in this cage and a successful demonstration was carried out there.

Lot of difficulties was faced in handling this 15 meter cage in the sea. The inner and outer net experienced heavy fouling and there was no mechanism to change the nets manually. This cage provided 1060 m^3 water volume for farming and even at 50 Kg per M^3 it had a production potential of 53 tonne fishes. Considering the management issues of this cage CMFRI designed a smaller version of this cage having 6 meter diameter. This cage has 141 M^3 water volume and a production potential of about 7 tonne fishes. The cost of the HDPE 15 meter cage frame was about Rs.8 lakhs and that of the 6 meter was about Rs.4 lakhs. The cost of a 6 meter cage including one outer net, 3 grow out net and one bird net and the mooring cost, cost 5000 fish seed and cost of feed etc is about Rs.10 lakhs. This is a huge investment for an average fisherman and even with 50% subsidies no fishermen will be willing to take cage farming as a livelihood activity or as a business activity. The risk was too much, which can even wipe out his family.

Under such a circumstance promoting cage farming among fishermen was not a viable proposition. While interacting with the fisherman they expressed their desire to have cage costing less then Rs. 1,00,000/- and lasting at least for 5 years to make it sustainable and economical in the long run. It was with their interest in mind the Karwar Research Centre has looked for alternatives for HDPE cages for promoting Cage Culture in the coastal waters and developed this fifth generation cage. Cage design and mooring technology underwent refinement through the dedicated and committed efforts of the scientists of CMFRI. Efforts were continuously made to reduce the cost of the cage and mooring systems so as to make it affordable for the fisherman and also to help them to take it up as a lively hood alternative.

Design

Considering the effect of climate change on the fisheries resources and to kitigate its effect it was decided that under NICRA an initiative will be made to design a cage to meet the requirement of the fishermen farmers to take up open sea cage farming as a livelihood alternative. The low cost cage developed at Karwar is made of good quality 1.5" GI pipe (B class). The design details of the cage are given in fig-(1) and Fig-(2). The diameter of the cage was 6 meter and the height was 120 cm from Base to the railings. Fig (3). All the joints are double welded for ensuring extra strength. Fig (4). After fabrication the structure was provided with single coat epoxy primer and double coat epoxy grey paint to prevent rusting. The total weight of the cage is about 300 kg only.

Floatation

Puff or foam field HDPE cage is buoyant enough to float in the water however, metal cage needs additional floatation. Eight fiber barrels of 200 lit. Capacity filed with 30 lb air was used for floating the cage. One of the cap of the barrel is fitted with a valve tube for inflating with air and both the caps are then sealed with M'Seal to prevent air leakage. The cage when floated on inflated barrels provides a stable platform around the cage where fisherman can stand and safely attend work like net cleaning, net exchange etc. Fig. (5).

Advantage of the low cost cage

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

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

Disadvantages

Unlike HDPE cage wind action is more on metal cage as it is floated on barrels. Hence it will be difficult to float in open sea condition from June to August unless Heavy duty mooring is provided. Except for this the metal cage performance is far superior to HDPE cage. For fabrication of HDPE cage costly parts and specially trained persons are required. Hence fabrication charges are very high. Whereas for GI cage once the design is provided any small scale workshop can make it. HDPE cage once abandoned is an environmental hazard whereas GI cages once abandoned can be recycled.

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

Dismantling type Cages

GI cages reduce the cost of the cage by almost one fifth of the HDPE cage and increase the profitability of the operation. The whole concept of developing the low cost cage was to reduce the input cost and increase the profitability. The earlier GI cages were designed as fused cages where all the joints are welded. In such cages transportation of the cage was a problem and once the cage is welded it cannot be transported from one place to another by road. Another issue was that for the final welding of the cage power was not available at many places and hiring generator works out very costly. Another issue was that the water volume available inside the cage decides the number of fishes that we can grow in that a six meter dia cage gives 141 m^3 water for rearing so providing more cultivable area in a single cage is very important. Another important observation was that all other expenses like mooring materials, floatation materials etc remain more or less same. Considering all this an attempt was made first to make the cage a dismantling type without affecting its strength.

Initially a 6 meter cage was designed and fabricated as dismantling type and tested it for strength, transportation efficiency and cost difference. When we found the design strong as a next step we designed a 10 meter circular dismantling type GI cage and later a 12 meter circular dismantling type GI cage. The water volume of the 10 meter cage is 392 m^3 and that of the 12 meter cage 565 m^3. This innovation has increased the cage volume by 4 times and the production per cage to 21.6 tonnes (Table-2). Another advantage is that cages can be fabricated in small scale industries units where they get subsidized power and transport it anywhere by road. Similarly after the harvest the cage can be dismantled, serviced and stored in a shed and used again for the next farming when climate is favourable. 6 meter cage can be managed by 6 persons where as for the 12 meter cage 10 persons are required. In short having one 12 meter cage is like having 4 cages of 6 meter diameter. So this path breaking design is going to make cage farming very profitable.

Cage Cost

Sl.No	Material	Cost-6 meter cage	Cost-10 meter cage	Cost-12 meter cage
1	GI Pipe	18900	37400	45900
2	Welding Charges	10000	20000	24500
5	Epoxy Paint	1600	2600	3600
6	Labour charges	1000	1500	2500
7	Floatation	7500	12000	13500
8	HDPE Rope	1000	1500	2000
Total	**40,000**	**75000**	**92000**	

Table-1.Cost estimates of the GI Cages

Cage Production (Sea bass)

Sl.No	Details	Cost-6 meter cage	Cost-10 meter cage	Cost-12 meter cage
1	Cultivable Water Volume (M^3)	141 m^3	392 m^3	565 m^3
2	Stocking Density	5000	15000	20000
3	**Sea Bass** Production capacity in Kg. (60% survival rate and average weight 1.8 Kg weight after 8 months grow out (October – May)	5400	16200	21600
4	Gross Revenue (Without deducing expenses) assuming that Sea bass fetches an average price of Rs.250/Kg	Rs.13,50,000	Rs.40,50,000	Rs.54,00,000

Table - 2. Production Capacity of GI cages

Cage frame is only a structure to hold the cage net safely throughout the culture operation in the sea. Since the cost of the cage nets mooring etc are same for any type of cages it is advantageous to go for a cost effective structure so that the input cost for the farming greatly decreases and profitability of the cage farming increases.GI cages are being used in Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu effectively. Low cost GI cages are playing a major role in popularizing open sea cage farming among the farmers and fishermen along the Indian coast catalyzing the growth of the blue revolution in the country.

Cage culture in open seas requires a fish variety with the basic characters like, suitability for marketing, commercial importance, consumer accepted fish, easy to culture, adaptability to the cage environment, acceptance to artificial diets, faster growth rate and resistant to common diseases.

A variety of commercially important marine fishes including, Cobia (*Rachycentron canadum*), Seabass (*Lates calcarifer*), Snappers (*Lutjanus* sp.), Carangids (*Trachinotus* sp.) and Groupers (*Epinephelus* sp.) and lobsters are highly suitable for cage farming. Commercial level seed production technology for majority of these fishes has been developed in many of the South East Asian countries.

Cage culture of Cobia (Rachycentron canadum)

Cobia has gained popularity as a good species for mariculture due to its rapid growth and white meat of versatile use. It is considered as one of the most promising candidates for warm-water marine fish aquaculture in the world. Being the only member of the family Rachycentridae, it is found in the warm, temperate to tropical waters of the West and East Atlantic, throughout the Caribbean and in the Indo-Pacific off India, Australia and Japan. To date, research and development of cobia aquaculture has been initiated in over 23 countries and territories, half of them in the Asian-Pacific region. Statistics of FAO (2009) show that the global aquaculture production of cobia has been increasing rapidly from only 9 tonnes in 1997 to nearly 30,000 tonnes in 2007. Since late 1990, cobia aquaculture production has been steadily expanding in Asia, primarily in Taiwan, Vietnam and China, but also in other Southeast and Indo-Pacific Asian countries including the Philippines, Indonesia, Iran and Reunion Island. Although cobia production is expanding rapidly, combined production of Asian countries is still rather lower.

Cobia farming techniques developed by CMFRI

India is late starter in cobia research. Seed production of cobia was achieved for first time in India by the Mandapam Regional Centre of Central Marine Fisheries Research Institute (CMFRI). Later the farming protocols in the High Density Polyethylene (HDPE) cages and Galvanized Iron (GI) cages with different feeding strategies were developed tested and validated at Karwar Research Centre of CMFRI and Mandapam RC of CMFRI. After repeated farming experiments an economically viable farming methods has been evolved.

The basic protocols followed for cage culture of cobia in different phases are narrated as below:-

Nursery rearing

The nursery rearing has to be carried out in specially designed sea cages or indoor tanks. At Karwar FRP tanks of 2.5 M x1.5M x 1.2M size with central drain facility was used for nursery rearing. Each tank was of 4.5 tonne capacity with 4 tonne water storage limits. Fingerlings of 6 cm size, packed in polythene bags of 10 litre capacity stocked with 125 gm to 150 gm of seed was transported from Mandapam Regional centre by road to Karwar. On arrival these seeds were acclimatized to the tank water temperature. Later 1000 seeds were stocked in each tank. The fingerlings were fed @ 5% total biomass of fish with imported weaning feed having 58% protein, 12% fat and 4% fibre. Feeding was done thrice a day followed by 100% water exchange. Grading was done every 10 days using a mechanical grader. Growth was monitored on every 5th day.

Grow-out

Once the seeds reached 15 cm sizes, the seeds were transported to the cage in oxygenated syntex tanks and stocked in cages. The stocking density in the grow out cages has to be maintained at 3.0-5.0 kg/m^3 or 750 nos of juvenile cobia per cage. The juveniles can be fed @ 5% total biomass of fish with chopped low-value fishes (sardine, lesser sardine, rainbow sardine, etc.) twice daily. Net cages have to be changed based on the subjective assessment of fouling of the net in order to have sufficient water exchange. Random sampling has to be carried out at monthly intervals with the sample size of 30 nos. per cage. The entire grow-out culture can be carried out for a period of 6- 7 months.

Performance

The juveniles would reach an average weight of 1.0 kg in 4 months and 2.5 – 3.0 kg in 6- 7 months of grow-out culture in sea cages. The grow-out fishes would reach an average weight of 7.0 kg with a maximum weight of 8.0 kg within the culture period of one year which is almost 100 times the growth of the initial weight.

The unit cost estimate, performance of production and economics of operation gained through the farming trials and participatory demonstration were worked out and given below:-

UNIT COST ECONOMICS FOR CAGE FARMING OF COBIA (IN A 6 METER DIA GI CAGE)

Sl.No	Head of expense	Cost in Rs.
	Capital Expenditure	
	Cage and Net	
1	Cage (6 meter dia) made of ‘C‘ class GI Pipe of 1.5 inch dia)	50,000.00
2	Mooring	15,000.00
3	Nets (2 Inner net and one outer net with ballast pipe)	60,000.00
	Sub Total	**1,25,000.00**

Operational Expenditure*

1	Cost of 750 Numbers of cobia seeds @ Rs 10/seed	7,500.00
2	Transportation	5,000.00
3	Cost of 12.82 tonnes of low value fishes @ Rs.25,000/tonne	3,20,500.00
4	Labour Charges @ Rs.1000/ Person for 7 months for 2 persons	14,000.00
5	Boat Hire & Fuel Charges	10,000.00
6	Harvesting Charges	5,000.00
7	Miscellaneous Expenses	10,000.00
	Sub Total	**3,72,000.00**
	Grand Total of Capital & Operational expenditure	**4,97,000.00**

Item No. 4 & 5 worked out based on the average expenditure/month for a cluster of 10 cages

Sl. No	Production Estimates
1	Survival 95% = 712 fishes
2	Feed Conversion Ratio = 1 : 6
3	Average size of each fish at the time of harvest =3kg
4	Total harvest = 2.136 tonnes/cage
5	Sale price of the produce @ Rs.280/kg = Rs. 5,98,080/-
	Gross Income from the harvest = Rs. 5,98,080/-

Sl. No	Economics
1	Gross income from Harvest = Rs. 5,98,080/-
2	Operational expenditure = Rs. 3,72,000/-
3	Gross income – Operational expenses = Rs. 2,26,080/-
	Net Profit = Rs. 2,26,080/-
4	Partial repayment of the capital expenditure = Rs. 25,000/year(Capital cost Rs. 1,25,000 – Subsidy Rs. 50,000 = Rs. 75,000)Repayment of capital @ Rs. 25,000/year x 3 years
5	Interest on the total project cost @ 11% = Rs. 52,800/-
6	Part of Capital + interest = Rs. 25,000 + 52,800 = Rs. 77,800/-
7	Rs. 2,26,080 – 77,800 = 1,48,280/-
	Net profit (after repayment of interest & part of capital expenditure) = Rs. 1,48,280/-

The results obtained at Karwar shows that from a 6 meter diameter cage fishermen can obtain a net revenue of Rs.2,00,000 from a 6 month crop after meeting all expenses. Since open waters is common to all in order to avoid unnecessary controversies farming involving the fishermen community is promoted and each group having 10 members is encouraged to go for 5 cages. This will give a handsome profit of Rs.10,00,000 in 6 months. This makes cage culture attractive and profitable.

Cage farming of Asian Sea bass (Lates calcarifer)

Seed

Sea bass Seed for the cage culture operations were sourced from RGCA, Sirkali. The seeds were transported by road from Sirkali to Karwar. The size of the seeds varied from 5 cm to 7cm and was nursery reared in CMFRI nursery systems till they reached a size of 15 cm size and 20 to 25 gm in weight. Nursery rearing of sea bass helped to reduce mortality due to cannibalism in cages.

Nursery rearing technology

The average size of the seeds was 6.2 cm and the weight was 2.8 gm. The seeds were directly taken to the nursery for nursery rearing. FRP tanks of 4 tonne capacity with central drain were utilized for nursery rearing. Seeds were stocked in tanks after adjusting the temperature of the covers. Seeds were given a fresh water dip before introducing into the tanks in order to kill any external pathogens.

Feeding

Feeding was done with 0.8 mm pellet feed of 58% protein and 15% fat @ 5% body weight. Later the pellet size was increased to 1.2mm after 10 days and 1.8 mm after 20 days. Feed was given every day at 07.00 hrs, 12.00 hrs and 17.00 hrs. Feed was slowly dispensed taking almost 45 minutes per tank. Since the seeds do not take feed once it reached the tank bottom care was taken to see that all the seeds get feed in the column itself.

Aeration

Intense aeration with one air stone at every square feet of the tank area was given in the nursery tanks in order to meet the high oxygen demand inside the tank.

Hygiene

Hygiene in the nursery area is very important. All the equipments are washed before and after use. Dip pits with sterilized water was provided at the entrance for washing the feet of workers before entering the nursery area.

Siphoning out the waste feed and fecal matter immediately after every feeding

Water Exchange

Water exchange is done with sand filtered and sterilized sea water. Since Screeting feed contains 11% fat, water quality gets deteriorated fast with unfed feed and fecal matter. In order to maintain water quality 70% water together with unfed food and fecal matter was siphoned out immediately after feeding. Water exchange was done at 08.00 hrs, 14.00 hrs and 18.00 hrs every day.

Grading

Grading of the seeds to segregate shooters is meticulously carried out using a mechanical grader. Seeds were graded into four groups after ten day intervals.

Growth monitoring

10 individuals were collected from each group, narcotized with ***Aquis,*** length and weight taken and then in a separate container for 15 minutes. When they regain consciousness they are released into the respective tanks. The growth rate in the first 10 day was 3 cm i.e. 3 mm/ day. However the growth reduced to 2 cm/ day in the next 10 day as the required feed in the desired size was not available. Efforts are being made to source the required feed urgently. Although we have purchased 10100 seeds from RGCA we have lost 70 seeds in transportation due to the breakage of one bag. No mortality had occurred so far in the nursery system

Growth parameters

The following growth parameters were enumerated as per previous methods (Salama and Al-Harbi, 2007).

a. Average Daily Growth Rate (ADGR) was computed using the formula: ADGR (g/day) = W_2-W_1/d, where: W_2 is the mean weight of the fish in the following sampling, W_1 is the mean weight of the fish in the first or previous sampling and 'd' is number of days between samplings.

b. Specific Growth Rate (SGR) which is the growth of fish in percent per day was computed using the formula: SGR = $\ln W_2$-$\ln W_1$/d X 100, where: $\ln W_2$ is the natural logarithm of the mean weight of the fish in the following sampling and $\ln W_1$ is the natural logarithm of the mean weight of the fish in the first or previous sampling.

c. Survival Rate (SR) was computed based on the following formula: SR (%) = N_2/N_1 X 100, where: N_2 is the remaining number of fish and N_1 is the initial number of fish.

d. Biomass was computed by multiplying the mean weight by the number of remaining fish.

e. Biomass Increase (BI) is the difference in the biomass in kilogram between sampling.

f. Feed Conversion Ratio (FCR) was computed using the formula: FCR = TFC/BI, where: TFC is the total amount of feed (Kg) consumed and BI is the biomass increase.

g. Protein Efficiency Ratio was computed using the formula: PER = BI/TPC, where: TPC is the total amount of protein consumed.

Important observations

Nursery rearing is the most critical part of open sea cage culture. Seeds should be fed with high protein diet to get faster growth in the initial days so that stunted growth will not be there in the batch. Feed is the most critical part of the nursery rearing. Feed which remains in the column for longer period or slow sinking feed with a minimum 45% protein is required for sea bass nursery rearing. Water quality management is also very important. Water from the nursery tanks must be removed immediately after feeding at least by 50%.Feeding at regular intervals at pre determined time ensures better feeding. Intense aeration is required in the nursery tanks with air stones at least one per every square feet area for better oxygen levels and better oxidation of the waste materials.

Grow-out

Once the seeds reached 15 cm sizes with 30 gm weight, the seeds were transported to the cage in oxygenated Syntex tanks and stocked in cages. The stocking density in the grow out cages has to be maintained at 21 fishes/m^3 or 3000 nos of juvenile sea bass per cage. During 2010-11 a stocking density of 5000 per cage was tried, however the average growth of the fishes showed a decline. Feeding with the right feed at regular intervals is important to ensure faster growth and also to prevent cannibalism. Seeds were weaned from the pelleted feed used in the hatchery to chopped and minced oil sardine meat slowly. Feeding was done approximately at 5% body weight initially in the first month and then with chopped oil sardines at 10 % body weight subsequently. Feeding was done twice a day i.e at 1000 AM 0300 PM Demand feeding method was followed to avoid wastage of the feed. Net cages have to be changed based on the subjective assessment of fouling of the net in order to have sufficient water exchange. Random sampling has to be carried out at monthly intervals with the sample size of 30 nos. per cage. The entire grow-out culture can be carried out for a period of 6- 7 months.

Growth monitoring

Growth of the fishes was monitored weekly by observing their length and weight. Feed was regulated as per the growth in each cage. Fishes collected from the cage was carefully weighed by placing them in a bolting silk bag and using a field electronic balance. Length was monitored by using a half meter measuring board.

Growth parameters

The following growth parameters were enumerated as per previous methods (Salama and Al-Harbi, 2007).

a. Average Daily Growth Rate (ADGR) was computed using the formula: ADGR (g/day) = W_2-W_1/d, where: W_2 is the mean weight of the fish in the following sampling, W_1 is the mean weight of the fish in the first or previous sampling and 'd' is number of days between samplings.

b. Specific Growth Rate (SGR) which is the growth of fish in percent per day was computed using the formula: SGR = InW_2-InW_1/d X 100, where: InW_2 is the natural logarithm of the mean weight of the fish in the following sampling and InW_1 is the natural logarithm of the mean weight of the fish in the first or previous sampling.

c. Survival Rate (SR) was computed based on the following formula: SR (%) = N_2/N_1 X 100, where: N_2 is the remaining number of fish and N_1 is the initial number of fish.

d. Biomass was computed by multiplying the mean weight by the number of remaining fish.

e. Biomass Increase (BI) is the difference in the biomass in kilogram between sampling.

f. Feed Conversion Ratio (FCR) was computed using the formula: FCR = TFC/BI,

Where: TFC is the total amount of feed (Kg) consumed and BI is the biomass increase.

g. Protein Efficiency Ratio was computed using the formula: PER = BI/TPC, where:

TPC is the total amount of protein consumed to attain a marketable weight of 1.5 Kg.

Economics of cage farming: Economics of cage farming of one GI cage of 6 m diameter with stocking of 2500 juveniles of Asian seabass is given below.

Sl.No	Details of costs and returns	Amount (‘)
1	Initial investment for a 6 m diameter cage (Including nets, Barrels, Ballast and Mooring)	150000
2	Fixed cost (for crop duration of five months) a) Depreciation b) Insurance (2% on investment) c) Interest on fixed capital (12%) d) Administrative expenses	 30000 - 18000 4000
3	Total fixed cost (A)	52000
4	Operating cost (B) a) Cost of seed (2500 nos.) b) Cost of feed c) Labour charges including cost of feeding d) Interest on working capital (6%)	 40000 112500 60000 9120
5	Total operating cost (B)	221620
6	Total cost of production (6 months) (A+B)	273620
7	Yield of sea bass (Kg)	1875
8	Gross revenue from 1875 Kg (60% Survival, average weight-1.250 Kg@ Rs. 250/Kg)	562500
9	Net income (5)-(6)	288880
10	Cost of production (Rs /kg-) (6)/(7)	146
11	Price realized (Rs/Kg) (8)/(7)	300
12	Capital Productivity (Operating ratio;(5)/(8))	0.39

Monitoring the environment

Environmental characters like salinity, temperature, dissolved oxygen and nutrients in the farm site were regularly monitored to understand the best environmental conditions for optimum growth. It was observed that at Karwar best growth is obtained for sea bass from November to April.

The scale of environmental impact would depend on the amount of waste generated by the sea cages, which is decided by the stocking density, quantity and type of feed, feed composition, size of pellets and the hydrographic conditions where cages are located. During the present study, stocking density of sea bass is 3000 nos/cage during 2009-10, whereas, the stocking density was 5000 nos/cage during the period 2010-11. The higher stocking density and fluctuations in the salinity and dissolved oxygen levels might be the reason for the decrease of the average weight of fish after 7 months of culture period during 2010-11. Hence, regular monitoring and management of water quality, feed quality, stocking density and survival rate is the need of the day in marine cage farms in ensuring maximum growth and production of healthy fish.

Net Exchange

Periodic exchange of the inner net of the cage ensures less fouling on the net and better water exchange. Inner net was exchanged every month. Initially net with 14 mm mesh was used followed by 24 mm and 36 mm mesh size. Net exchange technology was simplified to enable the fisherman to do it effortlessly. While exchanging, the new net with ballast pipe is slipped under the old inner net and lifted up. The old inner net is slowly lifted up with the fishes and when the net reaches the surface the middle portion in the bottom of the old net is cut open and the fishes are allowed to move down into the new net.

Harvesting

Harvesting was done as per the market demand normally in the evening. Harvested fishes are brought ashore and packed in crushed ice in plastic boxes. 40 Kg fish was packed in each box. Fish was sent to Goa market and is sold in the next day morning.

The production potential of one cage in a year is about 5 tonne quality fishes thus it is very clear that the technology developed at Karwar is fishermen friendly and can contribute to the economic growth of the country. The coast line of Karnataka, Goa and South Maharashtra extending almost 750 KM in length has a number of protected bays and calm water bodies highly suitable for open sea cage culture. It is estimated that about 2000 cages can be deployed in these areas and a modest production of 25,000 tonne high quality fishes from these cages is possible initially and when fully developed can produce 100,000 tonnes. Once cage culture potential in the coastal waters is fully utilized open sea cage culture involving big industrial houses can be promoted. Big cages of 50 meter diameter or more producing upto 500 tonne fish per cage are possible from these cages and a production of 200,000 tonnes from these cages is possible. The work carried out and demonstrated at Karwar gives confidence to the fishermen and institutions to take up cage culture in a big way.

Further Reading

Philipose, K K., Loka Jayasree, Sharma, S. R.Krupesha and Damodaran, Divu., eds. 2012. Handbook on Open sea Cage Culture. Central Marine Fisheries Research Institute, Karwar.pp.131. www.cmfri.org.in.

FAO: Regional sea farming project. RAS/86/024. Training Manual on Marine Finfish Net cage Culture in Singapore.

Hatchery Technology and Seed Production of Lobsters

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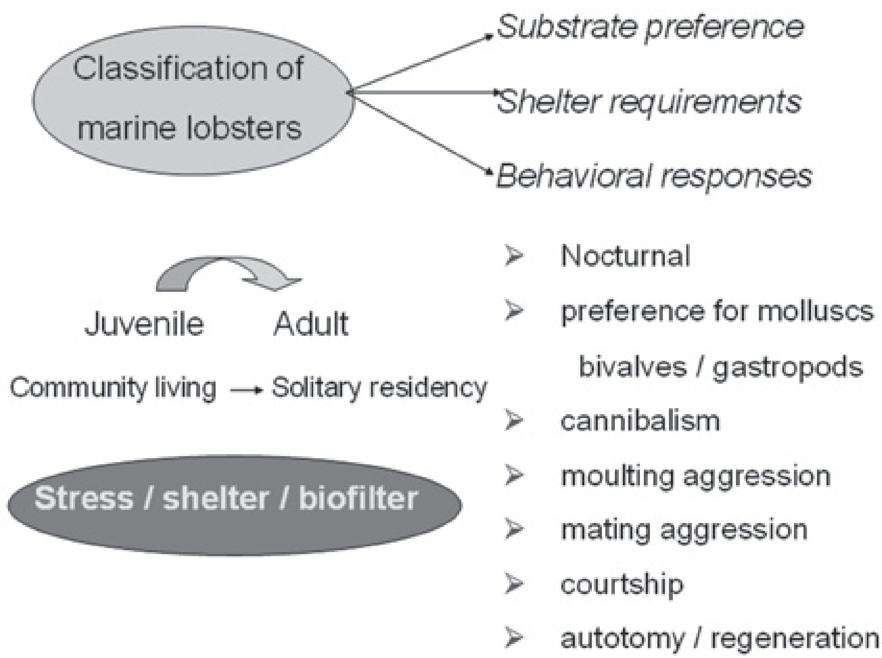
Lobsters are high-value seafood delicacies commanding high demand in international markets, with a high culinary value attached and lobster tails are always in great demand world-wide. Freshwater crayfishes, which are considered a delicacy in many parts of the world, are a favourite aquaculture candidate in North America, Europe and Australia. Crayfish and rock lobster aquaculture practices are initially capital oriented but deliver high production and income turnover in the long run. This industry has already taken off in countries like the U.S.A. and Australia. The lobster fishery in India is supported by two groups of lobsters – the spiny lobsters (*Palinurus homarus*, *P. polyphagus*, *P. ornatus* and *P. versicolor*) and the scyllarid lobster (*Thenus unimaculatus*). Lobster culture in India is still in the infancy stage. With the distinction of being perhaps, the only seafood resource in India's trade economy, which remains relatively low down the ladder in terms of quantity of production but brings in maximum foreign exchange, lobsters have been the subject of study for more than two decades now and C.M.F.R.I. has been spearheading research in the development of culture technologies for different species of lobsters.

The spiny lobster, *Panulirus homarus* has been the chief candidate for lobster aquaculture research in India. While complete larval rearing in captivity is yet to be achieved, other technologies like broodstock development, maturation and breeding in captivity and fattening of juveniles collected from the wild have been standardized. The sand lobster *Thenus unimaculatus* (earlier known as *Thenus orientalis)* which contributes to 8% of the global lobster production, and ranks next to spiny lobsters and tiger shrimp in export value, is one of the most promising candidates for lobster aquaculture in India. Increasing demand for live lobsters in the export market led the farmers and entrepreneurs to collect juvenile lobsters and crabs from the wild and grow to marketable size in ponds and tanks by feeding trash fishes and other discards. Breeding of the spiny lobsters, *Panulirus homarus* and *P. polyphagus* have been achieved in captivity and rearing of early larval stages has been done in different Research Centers of the Institute. Complete larval development of *T. unimaculatus* and *Petrarctus rugosus* was achieved for the first time in India at the Kovalam Field Laboratory of CMFRI in March 2004 (Kizhakudan et al., 2004).

As in any aquaculture system, broodstock development and hatchery management are the primary aspects to be tackled while establishing an aquaculture unit for lobsters. Sub-adult and adult lobsters are usually collected from the wild and acclimatized to captive holding. Different techniques for induced maturation and breeding in captivity involve physical handling and provision of favorable influential factors like artificial and natural diets, shelters and hiding places, pathogen-free rearing medium etc. The life history of lobsters shows a transition from a free-swimming planktonic larval phase to a benthic, crawling adult phase. We need to understand the specific requirements of the species before designing the right type of brood stock and hatchery units. The design of an indoor lobster brood stock and hatchery unit is based on the inherent nature of the animals, as depicted below –



Comparison of traits between sand and spinylobsters

	Thenus	***Panulirus***
Fecundity	10000-30000	100000-600000
Spermatophore	Mucilaginous -2-3 hours life	Stored in gelatinous matrix for repeated spawning
Egg size	bigger	Smaller
Larval stages	4	12
Post larvae	nisto	puerulus
Incubation of eggs	37 days at 27°C	25 days
Feeding	Ctenophores Accept particulate diets well from beginning.	Sagitta and live feeds in the beginning and later accept gel diets and particulates
Aggression	Cluster at feeding, surface swimming and disperse well	Dactyli very sharp, disperse less and crowd at bottom when not disturbed
Cannibalism	No	Yes
Artificial grow out diets	No	Yes
Grow out densities	30-40 lobsters per sq metre	8-10 lobsters per sq metre

BROODSTOCK DEVELOPMENT

Juvenile and adult lobsters are primarily benthic forms preferring to crawl along the bottom of the sea where light penetration is minimal. To simulate natural conditions to the extent possible, broodstock tanks are usually painted black on the insides and kept covered with dark screens. Lighting in the broodstock unit is kept minimal. The time of light exposure for each species has to be fixed based on experimental studies. Habitat preferences are marked among lobsters. Sand lobsters are seen predominantly in sandy substrates and spiny amongst rocks.

Spiny lobsters are comparatively long-lived (5-10 years), while the scyllarid genus (*Thenus*) with slightly lesser (3-5 years) longevity, lead a very stressful life owing to their periodic moulting, nocturnal feeding, sedentary habits and protracted ocean-dependent larval life cycles and complex reproductive behavior. The spiny lobsters are den/crevice loving, living in groups during the juvenile phase and are carnivorous, while the scyllarids are sediment loving, aggregate in habitats and feed on pelecypods and gastropods. Although sex ratio in the wild seems to be almost equal in both the lobsters, males are more aggressive in spiny lobsters and can even harm the female, while in scyllarids the longevity of male lobster is often reduced. The female spiny lobster retains the male sperm attachments for 2-3 repeated spawning in a single intermoult, while repeated mating is essential in scyllarids as the sperm attachments remain only for a few hours.

The spiny lobster females enter into reproductive cycle at the 3rd year cycle while the scyllarids (*Thenus*) enter much earlier (1½ -2 years). After successful mating the females spawn and the eggs, after fertilization, attaches to the pleopodal setae for incubation. The fecundity is much higher in spiny lobsters while very low in *Thenus* and *Petrarctus*, depending on the egg diameter and animal size. However the egg diameter lessens the number of days of incubation more than number of larval stages (spiny); higher the egg diameter, higher the incubation period and lesser the number of larval stages (scyllarids).

Live lobsters in general hold good out of water for at least 12-24 hours, depending on the temperature and the packaging, when in intermoult stages. Lobsters collected and kept at less stressful environment, prechilled and rolled into moist paper rolls or textile kept at 22-25°C can be transported to long distances without water at higher densities. They can be held in higher densities with good aeration and clean water for shorter intervals intermediate to longer shipments.

Broodstock tanks for sand lobsters are provided with a layer of sand at the bottom, in which the lobsters remain buried for a major part of the time. Spiny lobster broodstock tanks require no bottom substratum but need to be provided with structures that provide surfaces or crevices for attachment and sheltering. Water quality and photoperiod were found to play a major role and animals reared in larger tanks with increased water depth show more amenability to captive maturation. Broodstock maintenance and development in sand lobsters are done in a Closed Recirculatory System with fluidized bed filter and minimum light exposure (LD 1:23). Juvenile (<30 mm CL) and sub-adult (30 – 40 mm CL) lobsters collected from the wild and reared in recirculatory systems developed into mature adult lobsters (65 - 70 mm CL) in a period of about 6 – 8 months. Regulation of light exposure and feeding @ 5% of body weight in two divided doses daily give good results.

Like all crustaceans growth in lobsters occurs in stages combined with a molt. Molting is controlled by hormones. Growth is faster in the juveniles and slows down as the adult phase progresses. Beyond maturation, growth, particularly in females tends to be slower. Lobsters, like other crustaceans, prepare well in advance to

Lobster broodstock tanks at CMFRI's Kovalam Field Laboratory (Chennai)

molt and have a short phase of starvation at during and immediately after molting, when they are soft shelled and vulnerable to attack by other lobsters in the brood stock tank. This is particularly seen in the case of spiny lobsters which exhibit tendencies for cannibalism. Therefore, it is necessary to provide shelters and hiding places for these animals in the tank, for seclusion during molting. PVC pipes, asbestos tiles, vertical net screens are some of the commonly used structures for this purpose. Juvenile lobsters coexist in a community living structure while adult lobsters prefer a solitary existence. This also necessitates providing shelters to aid in this transition phase in broodstock development.

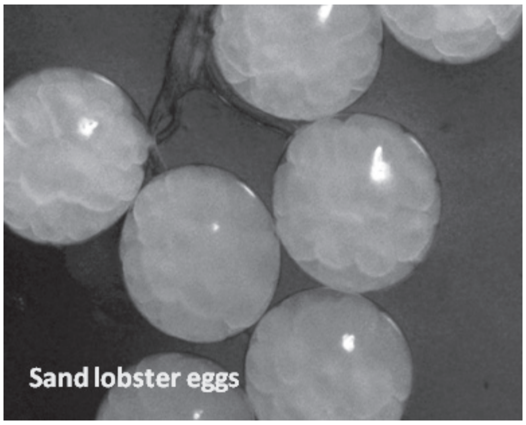
Food is a major factor determining the performance of the animals in captivity. Lobsters show a preference for shellfish, particularly mussels. Sand lobsters show good reception to fresh clam meat. Broodstock diets should be combination of natural diet preferred by the species and artificial diets prepared to meet the protein requirements of the broodstock, with additives to promote growth and maturation.

Collection of lobsters from the wild entails the possibility of the animals harboring pathogenic microbes. Quarantine measures and prophylactic treatments form an integral part of the broodstock management unit. This, combined with a strict regime for seawater treatment and disinfection of tanks between stockings, should be good enough to ensure a healthy environment for the lobsters. One of the major problems seen in lobsters, particularly spiny lobsters, is tail injury caused due to aggressive behavior among themselves. Attacks on soft shelled lobsters also induce injuries which tend to get infected. As mentioned earlier, shelters and crevices are essential to avoid such occurrences.

Broodstock handling and quality assessment

Generally live lobster freshly caught in trap nets are healthy, and are to be checked for any injury on the appendages or body or excessive bleeding. Ectocommensals like goose barnacles, polychaete worms, nemerteans, sponges and ascidians are to be cleaned off and the lobster should be given a dip in 10 ppm formalin to remove planarian larval forms and protistans, particularly ciliates. Lobsters with tail rot and necrotic lesions on the uropod and telson are to be avoided. The water pumping rates through the gill chamber when held by hand suspending the animal by holding on the antenna indicates the animal energy levels. The branchiostegal lines and decalcification indicates the moult status of the animal and the flipping strength of the lobster tails is essentially a tool to identify a healthy lobster.

HATCHERY REARING AND SEED PRODUCTION



The larval phase in most lobsters is usually complicated, extended and highly dependent on external factors. Like other crustaceans, lobsters begin life as a developing embryo inside an egg which is carried by the female along with hundreds or thousands of other eggs, on the pleopods. These egg-bearing females are called "ovigerous". Fertilized eggs are dark yellow or orange in color and turn dark brown at the time of hatching. Unfertilized eggs remain cream or pink in colour and are shed off in 3-5 days. After a rigorous incubation phase (early embryo development inside the eggs) when the eggs are fanned with the help of the pleopods, small, transparent, flattened larvae called "phyllosoma" hatch out. The incubation period varies from 26-30 days in tropical spiny lobsters to 30-37 days in sand lobsters. Hatching takes place in batches only during the early morning hours and is usually completed in 1-3 days. Water quality, tank bottom quality and handling stress, particularly during the incubation period, greatly influence the success rate of hatching.

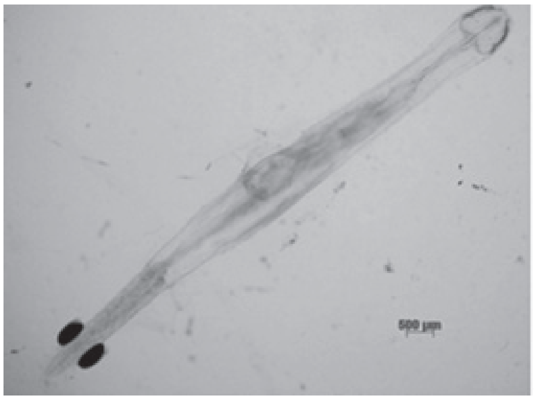
Larvae are usually small when compared to the adult except in clawed lobsters. These larval stages (phyllososma) undergo progressive molts to complete metamorphosis before settling as the post larval stage, called "puerulus" in spiny lobsters and "nisto" in sand lobsters. The hatchery phase is often the crucial stage in lobster aquaculture, since handling of the delicate phyllosoma is very difficult, and renders the hatchery phase labour intensive. The number of larval stages varies greatly among species, ranging from about 12 stages in spiny lobsters to 4 stages in sand lobsters. Compared to the spiny lobsters, the hatchery phase is of shorter duration in sand lobsters. While larval metamorphoses can extend up to 300 days in spiny lobsters, it is usually completed in 25-30 days in sand lobsters.

The rearing system should accommodate only minimum numbers per litre, as most of the species are aggressive and cannibalistic; while 10 phyllosoma per litre in tropical spiny lobsters in the initial stages is fine, as stages progress beyond fourth the density has to be thinned further to 5 and 1-2 per litre towards the final stages. The equivalent stages of most species follow almost the same stocking density limits. Larval rearing tanks are usually of shallow depth with upwelling and flow through designs ensuring very less water agitation and reduced photoperiod intensity. Light source is used to pool the larvae to facilitate collection and shifting.

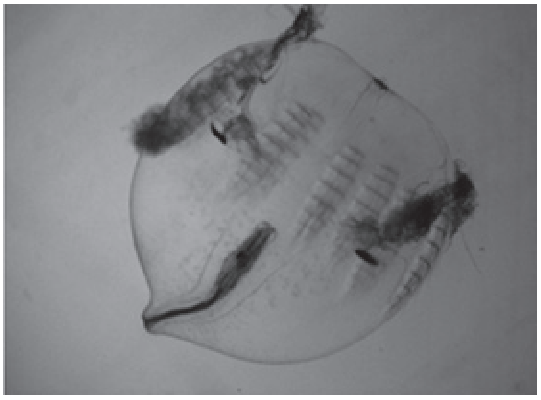
The phyllosoma are mostly phototactic and prefer specific zooplankters as live feed. Spiny lobster larvae ingest arrow worms and other live feeds in the early stages. Sand lobster larvae show a preference for ctenophores. Suitable artificial, preferably gel texture, supplementary diets are also essential in lobster hatchery feeding regimes. These diets should be floating and stable in water. Water quality in phyllosoma rearing is of utmost importance as delay in molting attracts too fouling microbes on the shell which render the larvae immobile and obstruct their feeding activity. Organic load and ammonia load should be minimal in the system and tank surfaces should be devoid of biofilm formation to reduce bacterial invasions. Proper feed and health management can improve larval survival and growth to a great extent.

Improvisations in sand lobster larval rearing

Seawater treatment: The primary source of microbial load in crustacean hatcheries being the incoming



Chaetognath



Ctenophore

seawater, different seawater treatment modes are of utmost importance to rule out the chances of pathogen infection through this source. The seawater treatment course includes heating to 45^0 C, ozone treatment and neutralizing with oxygenation. The seawater thus treated has to be subjected to UV + cartridge filtration and charcoal treatment before being released into the rearing tanks for efficient control on bacterial populations.

System designs & environmental manipulations: Slow upwelling or trickling flow regulated shallow water basins and tanks with mild aerated water influx is ideal for the phyllosomal rearing. High density rearing systems using clear water with water exchange at each feeding is labour intensive and delicate and the larvae is quite sensitive to handling. Modifications in the LRT for management of water flow rate and pattern is essential at each moulted stage as the density and feed size requirements changes. Trials were also carried out to see the viability to culture juveniles without substrates. Rearing systems without soil substrate and provided with net base instead will also gives good results. Shallow tanks with longer holding area and regulated light provide uniform distribution of larvae in the rearing volume, and thus improve feeding efficiency.

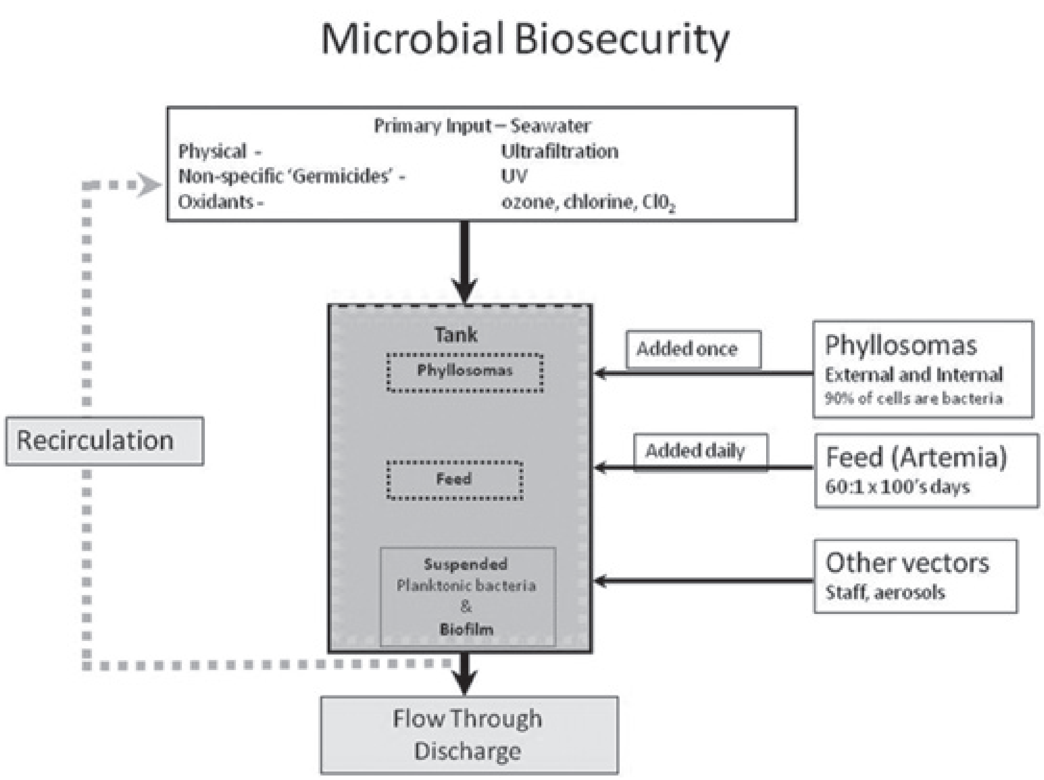
Feed interventions: Spiny and scyllarid lobster larvae are known to prey upon and consume live zooplankton and fleshy objects, and hence the use of pellets and MEDs in lobster larval rearing systems is a drawback. Therefore, soft feeds incorporating necessary nutrients will be ideal. The formulated diets are to be mixed at different concentrations separately and then added with the gelatinized binder, then gelatinized and loaded to a sterile syringe. The pellets are to be extruded through needles and the warm pellets/noodles immersed in various concentrations of cold $CaCl_2$ to solidify the noodle threads and cut to necessary size. The process is based on transformation from a sodium alginate solution to gelled calcium alginate (external gelation). Here the gelation reaction occurs from the surface inwards producing noodles with a shell entrapping the core material (inner sponge-like matrix).The composition of externally gelled micropellets incorporating live feed and other nutritive supplements was formulated and tested successfully for floatation, stability, colour, sizes and suitability to trimming at CMFRI's Kovalam Field Laboratory (Chennai). *Artemia* and algal concentrate were used in artificial diets formulations. The efficiency of the feeds with respect to larval acceptance and deliverance was worked out for sand lobster larvae.

Microbial interventions: Phage therapy has been found to develop autoimmunity in the larval mass against luminescent bacterial invasions. Bacteriophages developed against LB forms in shrimp hatcheries have also been found to show encouraging results in lobster broodstock and larvae.

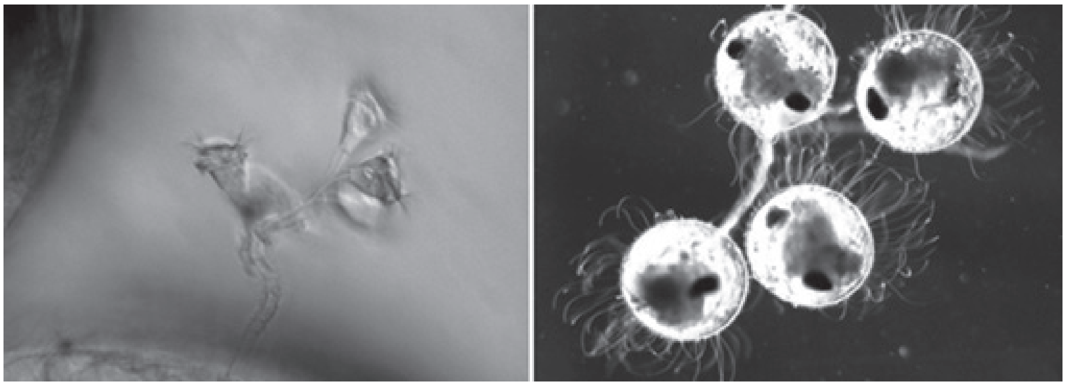
The success of any aquaculture enterprise depends on the efficiency of the rearing system design and its management. Simulation of conditions as close as possible to the lobster's natural environment must be attempted at every stage of its progress from juvenile to adult in the broodstock unit and from egg to juvenile in the hatchery unit. The first hurdle being the steady supply of brooders, the primary aim of the enterprise should be to turn out a good number of adult lobsters developed from wild collected juveniles, and to induce repeated maturation and breeding in captivity. The next hurdle would then be to effect successive larval metamorphosis with high survival rates and post-larval settlement to produce healthy juveniles which would then be ready for generation of a new batch of brooders. Both these aspects can be achieved through a rigid and structured set of management practices as described in this note, but perfected best through practical handling and knowledge gained through experience.

Length of larval period for different species of domesticated lobsters

Species	Larval length
Panulirus homarus	5 months
Panulirus ornatus	6 months
Thenus orientalis	30 days
Thenus unimaculatus	30 days
Petrarctus rugosus	2 months
Scyllarides spp.	8-9 months



Schematic representation of the microbial biosecurity system in lobster hatcher at AIMS, Australia



Vorticella and filamentous bacterial infestation in sand lobster hatchery

Broodstock Development and Breeding of Marine Finfishes

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Introduction

In recent years, mariculture has been growing rapidly on aglobal basis especially with the development and expansion of sea cage farming. On a global basis, a rapid growth in marine finfish culture is noted. It has increased at an annual average growth rate of 9.3% from 1990 to 2010. Salmonids, amberjacks, seabreams, sea basses, croakers, groupers, drums, mullets, turbot, other flatfishes, snappers, cobia, pompano, cods, puffers and tunas are the major groups which are maricultured. One of the major reasons for the growth of sea cage farming is the availability of breeding techniques that can produce sufficient quantity of seeds of different high value marine finfish. Many countries in the Asia-Pacific Region like Australia, China, Japan, Taiwan, Philippines, Indonesia, Thailand, Malaysia and Vietnam have made substantial progress in the development of commercial level seed production technologies of high valuefinfish suitable for sea farming. In India, the broodstock development and seed production of sea bass, cobia and silver pompano were developed and standardized for commercial level production.

The major steps involved in marine finfish broodstock development and breeding are the following:

1. Broodstock collection,
2. Transportation,
3. Quarantine,
4. Broodstock development,
5. PIT tagging,
6. Cannulation,
7. Induction of spawning,
8. Egg collection,
9. Incubation,

Reprinted from the Training Manual for Maldivian Officials

Broodstock Collection and handling

Broodstock development is the vital and time consuming procedure in marine finfish seed production. It is not easy to obtain broodstock fish directly from the wild and hence broodstock development is to be done in captivity. The main selection criteria to identify suitable adult fish as broodstock fishes are as follows:

- Body shape, age and colour,
- Absence of deformities,
- Absence of wounds, haemorrhages, infections and parasites,
- Behaviours like quick response to feed and fast swimming

It is advantageous to collect sub-adults for broodstock development. Larger fishes would have crossed the reproductive age and very small fishes will take longer time to sexually mature. In the case of cobia, fish weighing between 8 to 15 kg could be procured while silver pompano could be procured in weight range of 750 gm to 1.5 kg. Stress should always be minimised during capturing and handling of broodstock. It is best to collect broodstock fishes from trap nets, hook & line, etc., as they cause minimum stress to the fishes. Adequate dissolved Oxygen (DO) should be ensured during transportation.

Quarantine

Upon arrival at the hatchery, broodstock fishes are released into the quarantine tanks for prophylactic treatment. Fish anesthetics like MS 222 (50-100 ppm) and Aqui-S (4 ml / 100 L), can be used for broodstock handling. The prophylactic treatment is given to limit the risk of introducing parasites or bacterial diseases into the hatchery facility. Short time exposure of brooders (maximum 5 minutes) in freshwater will help to remove the external parasites. The prophylactic treatment in hatcheries includes a sequence of medicated baths in formalin, malachite green and Oxytetracycline (OTC). Prophylactic treatment can be repeated three to four times within a week. It is preferable to have a flow-through water circulation in quarantine tanks when treatments are not underway. Smooth inner surface in tanks allow easy and complete cleaning. The following sequence of treatments can be followed:

Day 1: Fresh water bath for 10 minutes and then Oxytetracycline treatment (50 ppm) in seawater for 30 minutes.

Day 2 to Day 7: Treatment with a mix of 200 ppm formalin and 0.2 ppm malachite green for 1-2 minutes, followed by a freshwater dip for 5 minutes. Before returning the fishes to quarantine tanks with filtered seawater, they can be given an Oxytetracycline treatment at 50 ppm for 30 minutes. The fishes should be closely observed during treatments.

During the quarantine, fish should be closely monitored. If the fishes suddenly become immobile or are found with very less opercular movements or are turning upside down, they should be immediately transferred to filtered seawater. The fishes can be fed during the day time when it is not undergoing treatment. Over feeding should be avoided and the fishes can be transferred to maturation tanks after the treatments are over. Apart from quarantine treatment, the broodstock fishes should be given regular prophylactic treatment with freshwater with or without OTC at least once in a month.

Broodstock development

After quarantine, broodstock fishes are moved into Recirculation Aquaculture Systems (RAS) or sea cages for broodstock development. Broodstock development in sea cages was successfully done for cobia at Mandapam Regional Centre of CMFRI. Circular cages of 6m diameter and 3.5 m depth with HDPE frame were employed for the purpose. The major problem in the development and maintenance of the broodstock in sea cages is the risk of contracting diseases and subsequent loss of broodstock. The sudden loss of broodstock will affect the seed production, since loss of broodstock cannot be made good from the wild immediately. Hence, on shore facilities like RAS is advised for development and maintenance of biosecured broodstock.

The vital aspects which affect development of broodstock are the photoperiod, temperature and broodstock nutrition. In a shore based facility, the photo thermal conditioning can be practiced which will accelerate the gonadal maturation. In addition, it is also possible to obtain year round spawning in such a controlled system.

Broodstock nutrition

The viability of the larvae is very much dependent on broodstock nutrition. The nutritional components in the diet, the feed intake rate or the feeding period can all affect spawning, egg and larval quality. In the case of tropical fishes, ovarian development is often asynchronous – oocytes in all stages of development are present at the same time and sometimes independent of season. The ovarian development starts with the formation of primary oocytes. During the primary growth phase, the surrounding granulose and theca cells envelop the oocyte to form the ovarian follicle. In the early stages of secondary growth, cortical alveoli appear and accumulate in the periphery of the oocyte. Even though the oocyte may increase in size several fold during primary and early secondary growth, the most conspicuous size increase occurs during the last part of secondary growth, vitellogenesis. Vitellogenesis is the process of yolk formation and incorporation in the growing oocytes. The yolk protein precursors, vitellogenins, are high molecular weight lipoproteins that are synthesized in the liver and secreted into the blood. The fatty acid composition of the vitellogenins can be affected by long term imbalances in the broodstock diet. It has been well established that feeding broodstock fish with squid, cuttlefish or meals made from cephalopods have beneficial effects. These feed ingredients make the diet more attractive and therefore increase feed intake. Squid and cuttlefish also contain high levels of essential fatty acids.

For quicker maturation, the broodstock fishes are to be fed with highly nutritive diet. Diet rich in vitamins, poly-unsaturated fatty acids (n- 3 PUFA) and other micro-nutrients is essential for obtaining viable eggs and larvae. During gametogenesis, female fish require a food, richer than usual, in proteins and lipids to produce the vitellogenin. As the sole source of food for the developing embryo and the early larval stage until feeding on live preys starts, yolk quality and quantity are key factors for a successful reproduction. Both dry pellets and moist food are also employed during maturation. Dry pellets should include essential nutritional components like polyunsaturated fatty acids (n-3 PUFA), in particular EPA (20:5 μ 3) and DHA (20:6 μ 3), which cannot be produced by fish metabolism. Broodstock fishes are fed *ad libitum* once a day with squids, cuttlefish, crabs, shrimps and chopped oil-sardines depending on the availability.

Tagging

Tagging or physical marking of broodstock fishes through easily detectable methods is very much essential for selection of broodstock for identification, selective breeding and segregation. The most popular method is PIT Tagging. Passive Integrated Transponder (PIT) tag, also known as is a radio frequency device to permanently mark fishes internally. The tag is designed to last the life of the fishes providing a reliable, long term identification method. The PIT tag contains a microprocessor chip and antenna. It has no internal battery, hence the term “passive”, so the microchip remains inactive until read with a reader. The reader sends a low frequency signal to the microchip of the tag providing the power needed to send its unique code back to the reader and therefore fish is positively identified.

The distance from which a tag can be read is the read range. Most read ranges using hand-held readers are 3 to 9 inches depending on the reader. There are currently three basic tag frequencies. The 400-kHz tag was one of the first developed but it has limited read range. As microchip technology evolved, the 125-kHz and 134.2-kHz tags became available. Compared to the older 400-kHz tags, they have a much better read range and reduced read time. The 134.2-kHz tag was developed to meet international standards for code format. It is very much important that the tag type and reader unit should be compatible. Most readers are capable of detecting both 125-kHz and 134.2-kHz frequencies.

Design engineers’ calculations suggest that PIT tags can last as long as 75 years or more. There is no battery to fail and the glass encapsulation is impervious to almost everything. PIT tags can be removed or recovered from a primary location and reused indefinitely. Reducing stress to the fish is the prime factor in ensuring the success of the tagging and safety of the fish. Therefore, the fish should be anesthetized during the implantation of PIT tags. Species, size and age should be considered when making a decision about anesthetization and restraint. Sterile implants are advised but many field conditions do not allow for sterile implants. Equipment can be disinfected prior to use with alcohol and iodine-based solutions. The tag is encased in glass that protects the electronic components and prevents tissue irritation, thereby very much safe to the fish.

Advantages of PIT tag over other tags

- Highly reliable individual identification
- Permanent identification marker
- Small size and no interference with the behaviour of fish
- No error in recording data
- Rapid data collection

Disadvantages

- Initial cost is high
- Low detection distance

Procedure of tagging

The implant site depends upon the species, size of the fish and the size of the tag. It is preferable to implant the tag on the dorsal musculature of the fish which will be convenient.

Stepwise protocol

- Use sterile needle or implanter to tag the fish. In field condition, disinfect all the components prior to use with alcohol and iodine-based solutions.

- Read the tag before inserting into the fish and record the identification code or number.
- Catch the fish and anaesthetize it with suitable anaesthetic. In sea cages, it is easier to restrain the fish inside the catching net.
- Disinfect the site of implantation with alcohol or iodine-based solution.
- It is a better practice to keep a standard site of implantation so that the reading will be easier and quicker.
- The tag loaded inside the implanter has to be inserted into the muscle tissues. It is advisable to insert the tag parallel to the muscle fibres to avoid much damage to the tissues.
- The tag should be released slowly and steadily from the implanter while removing the implanter from the tissue in such a way that the tag fills the space created by the implanterneedle.
- Once implanter needle is taken out, the site should be disinfected again with alcohol or iodine-based solutions to avoid secondary infection.
- Release the fish as soon as the tagging is over or once it has recovered from anaesthesia.

Cannulation

At the onset of the spawning season, it is necessary to move selected brood stock fishes from maturation tank to spawning tank after assessing the ovarian development through cannulation. Only females with oocytes in the late-vitellogenic stage, with a diameter around 700m in cobia and 500 mm in pompano, are selected.

Ovarian biopsy can be carried out as follows:

- Female brooders have to be transferred to a small tank containing anaesthesia in sufficient quantity.
- Flexible sterile catheters (1.2 mm internal diameter) can be used for cannulation biopsy.
- Introduce the sterile catheter into the oviduct, up to the ovary for a few cm; then suck carefully a small sample of oocytes up into the catheter and place the sample on a glass slide.
- After sampling, release the animal into the spawning tank, where recovery from sedation will take place.
- Put few drops of filtered sea water on the biopsy sample and examine under the microscope and measure the diameter of the oocytes and record the measurements.

Induction of spawning

Spawning can be obtained either naturally or by inducing with hormones. Induced breeding is commonly practiced in most commercial hatcheries. The hormonal treatment is intended to trigger the last phases in egg maturation, i.e. a strong egg hydratation followed by their release. However, if eggs have not reached the late-vitellogenic (or post-vitellogenic) stage, the treatment does not work; hence ovarian biopsy is essential for assessing the ovarian development. The human chorionic gonadotropin (hCG) is used at a dosage of 500 IU per kg of body weight in cobia females and 250 IU per kg body weight for males, whereas, for pompano 350 IU per kg body weight is used for both male and female. This dosage can be administered as a single dose on the dorsal muscles. Use of hCG treatment sometimes gives serious setbacks like not all females respond to it, egg quality may be below acceptable standards with hatching rate lower than 80%, being a large molecule it may provoke immunization reaction, and as a result, fish treated with hCG may not respond when treated repeatedly with this hormone. However, hCG can be successfully replaced by an analogue of the luteinizing hormone-releasing hormone [LH-RHa des-Gly10 (D-Ala6) LH-RH ethylamide, acetate salt]. It is a small molecule with 10 peptides and acts on the pituitary gland to induce the release of gonadotropins which, in turn, act on the gonads. Almost 100% of injected fish spawn eggs whose quality usually matches that of natural spawning.

Spawning

The spawning unit should preferably be kept separated from the main hatchery building to avoid disturbance to the spawners and possible risk of disease contamination. However, for economic reasons, it is usual to keep the brooders inside the hatchery in a specific dedicated area. It is preferable to use circular tanks with at least 1.20 m depth. Shape and depth of tanks count for easy and free movement of brooders. Normally the spawning could be noted within 36 -48 hours after hormonal induction. The spawning in cobia and pompano takes place normally between late night and early morning hours. The number of eggs spawned by cobia ranges from 0.4 to 2.5 million, whereas, the pompano brooders spawn 0.5 to 1.5 lakh eggs.

Egg harvest

The fertilized eggs of cobia and pompano float and are scooped gently using 500 ìm net. To minimise the presence of poor-quality eggs, which usually float deeper in the water, it is advisable to collect only the eggs which float at the water surface. Therefore, aeration can be switched off allowing the unfertilized / dead eggs to settle at the bottom of the tank. The floating layer of eggs thicker than one cm should be avoided. A thicker layer may reduce oxygen supply to the eggs, leading to possible anoxia after a short time. Then in the temporary container, eggs must be thoroughly examined to assess their quality, number and developmental stages. With a pipette eggs should be taken from the floating egg layer in the temporary container, and should be placed on a watch-glass or on a Petri dish for observation under microscope. Few dozens of eggs, which are placed under a microscope or a transmitted-light stereo microscope have to be observed for the egg developmental stages.

As fertilised cobia/ pompano eggs float in the seawater, they can be collected using egg collectors. If well dimensioned and properly placed, these devices harvest only the floating eggs, while the dead or unfertilised ones sink to the bottom. The presence of eggs in the collectors should be checked rather frequently in the case of cobia, as its spawning releases a large amount of eggs in a very short time there is risk of clogging the collectors or of mechanical stress to the eggs.

Check for the following egg characteristics:

- Presence of opaque, whitish eggs which are unfertilised. Similarly, eggs in the sample with transparent, but without evidence of cell divisions
- Regular rounded shape and size (diameter 900-1000 mm in cobia; 800 -900 mm in pompano), regular cell division that can be observed only in the first blastomers; regular shape of yolk (it should occupy the egg volume entirely, without perivitelline space),
- Absence of parasites or associated micro-organisms on the chorion surface.

Incubation of eggs

It is done in incubation tanks of 3-5 tonne capacity. After hatching, only the hatched fish larvae have to be moved to the larval rearing tanks filled with filtered seawater. Prior to this, the aeration should be stopped briefly to enable the debris and exuviae to settle at the bottom which can be removed by siphoning. Aeration needs to be adjusted suitably, not too strong to avoid excessive physical collision among eggs, but not too weak either, to keep the eggs suspended in water column. The main purpose of aeration is to prevent clumping and settling down of eggs. Air bubbles should not be too small as seen while using air diffusers instead of stones, as it results in clumped eggs and damage of the eggs. It is suggested to limit as much the number of air stones as possible. Stocking density can be maintained at a moderate level of 200 to 500 eggs per litre. The development of embryo can be observed at frequent intervals under a stereo / compound bionocular microscope. The hatching of eggs takes place from 18 to 24 hours.

Genetic Selection in Mariculture

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The aim of fish breeding is not to change individual fish, but rather the fish population. Hence, the ***'Mendelian Genetics'*** extended at the level of population is the ***"Population Genetics"***. It is thus most essential to understand the meaning of a population.

Definition of population

In general, a population refers to a group of individuals of a species assembled/living at a place at a time. ***Statistically,*** a population is referred to a group or collection of individual/items having the similar properties. ***Biologically,*** a population refers to a group of organisms/individuals of a species functioning together as a unit at a given place and time. ***Genetically,*** in population genetics, a population is defined as a group of interbreeding individuals. As a result of inter breeding there is gene exchange among the individuals of a population and hence they contribute to the gene pool of the offspring generation. The gene exchange is thus the main and important factor to define population. The population for a population geneticist means the ***"Mendelian Population"*** which is defined as a group of ***interbreeding individuals developed over both space and time*** sharing a common pool of genes, from which meaningful samples can be drawn and within which the characteristics under study follow the Mendelian rules of inheritance.The ***gene pool*** is taken as the sum total of genes in a population. In other words, the gene pool includes collectively all the genetic information distributed among all the individuals of a population.

Size of Population: The number of individuals constituting a population decides the size of the population. Therefore an individual is the unit of population. The number of individuals in a population should be large enough so that the sampling variation is as small as to be negligible. Thus, a population should not be affected by the sampling variation. Such a population which is not affected by the sampling variation is knows as large population and consists the number of individuals in hundreds or even in thousands rather than in tens.

The total number of individuals forming the population is important. The differential reproductive success of different individuals molds the genetic structure of a population in coming time. The counting of the number of individuals in a population is done for three purposes: to assure the existence of population, to determine the gene frequencies, and to estimate the role of chance factor played in the transmission of genes.

Change in genetic structure of a population

The organization of the genes into genotypes is the most essential part of population genetics. The genotypes are not transmitted to the offspring as such but they are broken during meiotic cell division as a requirement of genetic transmission from one generation to the next. Thus genotypes of the parents are broken into gametic pool and each offspring has its newly formed genotype different from its either parent. Therefore, the array of genotypes in a population is re-determined in each generation. For example, the heterozygous parent (*Aa*) may not have any heterozygous offspring. The gametes produced by a heterozygous parent (*Aa*) contain either *A* or *a* allele which may unite with any allele of opposite sex and thus parental heterzygosity is not transmitted directly to the offspring. The relative genotypic frequencies in a population are determined by some biological forces *viz*. breeding behavior, genetic factor (mutation) and environmental factors (migration, selection, sampling process in small population) which act on individuals by affecting their survival and reproduction. Thus the genotype frequencies from one generation to the next are under the control of these forces.

Among the breeding behavior, the simplest and important one is the random breeding or random fertilization which follows no principle (criteria) for breeding of individuals of opposite sex and individual of one sex has equal chance to breed with any individual of the opposite sex. The main feature and consequence of random breeding in a large population is that the relative gene frequencies and genotype frequencies remain constant from generation to generation and thus there is no change in genetic structure of large population under random breeding. This is called as genetic equilibrium. The genetic equilibrium is disturbed if the breeding is non-random and if any of the genetic and environmental force is in action. Any force is capable to change the genetic equilibrium from one generation to the next. There are a number of situation and environmental factors (migration, selection and sampling) to disturb the genetic equilibrium.

Most of the captive populations are not ideal to maintain the genetic equilibrium in view of the man's activities and the role of nature. The ideal population is in which no disturbing force comes in action to upset the genetic equilibrium and the random breeding results in a genotypic distribution consistent with the frequencies of genes. However, the fish breeder is interested to change the existing genetic structure of the population in a desired direction to exploit the existing genetic variability to make the animals more productive and more useful. Therefore, breeders are not interested to maintain the existing genetic structure of the breeding population and they make their efforts to achieve high performance of their animals. This is achieved in a number of ways.

The ***first*** is the selection of the better production animals and to eliminate the low productive and inferior ones. This is called the artificial selection. ***Secondly***, the selected animals are bred following certain criteria rather than allowing random breeding. Thus breeding is non-random (assortative). ***Thirdly***, the breeders keep their captive population in relatively small size. This results in small population size which upsets the genetic equilibrium in two ways. One is that inbreeding is inevitable in small population size which changes the genotype frequencies of next generation. The other effect of small population size is that the possibility of expected genotypic frequencies is low due to lesser number of animals according to the probability because higher number of events makes the expectation more close to reality. Thus smaller number of animals in the herd results in the occurrence of errors in sampling due to chance events. This leads to differentiation of gene frequencies in local populations resulting from sampling. The ***fourth activity*** of fish breeders is the trade breeding under which the animals are sold or transferred to another breeder and thus migration of animals occurs which further increases the possibility of gene flow (migration) from one corner to other corner of the country or the world.

It is thus obvious that most of the conditions for genetic equilibrium are not fulfilled. The fish population size maintained under captive conditions in India is small, the breedings are not random but selective breeding is practiced and the animals are migrated for a number of reasons. Therefore, the genetic equilibrium is not observed in hatchery and farm conditions in all practical situations and the change in genetic structure of populations is likely to occur. The change can be brought to favourable direction and magnitude after having the knowledge and being aware of the genetic effects. Therefore, it is most essential for a breeder to know the process of change in genetic structure of populations under the influence of various forces. There forces capable to change the genetic structure of a population can be classified in several ways as under-

Natural Vs. artificial factors: Both nature and manmade interventions disturb the existing genetic equilibrium and contribute to changes in the genetic structure of the population. The factors which are under the control of nature to upset the genetic equilibrium are the mutation (change in genetic structure of a gene) and the natural selection. The natural selection operates through differential fertility and viability. The manmade activities include artificial selection by way of selective breeding and preferential breeding (non-random breeding), migration of animals through purchase or transfer, and to keep small population size leading to inbreeding and sampling error (random drift).

Factors involved at individual and population level: The first is the change at gene level (mutation) whereby the genetic structure of gene is changed and produces a new gene. The second is the change at population level by gene flow (migration), selection, small population size, and by a change in breeding system from random breeding to preferential breeding (non-random breeding).

The second category of forces brings a change in gene frequencies between generations and consequently result a change in genotype frequencies. These forces include gene mutation, gene flow (migration), selection, small population size and disassortative breeding. The genetic changes brought by the forces of second category are permanent even after switching to random breeding. This is because these forces involve the change in gene frequencies.

Amount and direction of change: On this basis all the forces are divided into two groups. The first group is of the deterministic or systematic forces which are also called as the vectorial process. The second category is the stochastic process or random or dispersive forces. Among the systematic forces are the mutation, migration and selection which tend to change the gene frequencies predictable both in amount and direction. The dispersive process arises in small population. The change brought by dispersive process is predictable only in amount but not in direction.

Data recording and its importance

If the purpose of selection is to improve a production trait, the first step is to measure or record this trait on all animals in the population, and then estimate the average and standard deviation. Selection is then practised by selecting those animals, which have highest breeding values. A fish hatchery or farm is a dynamic and complicated enterprise having the objective of increasing the productivity and profit. In order to achieve the objective of increasing the productivity and changes, activities and requirements for which the fish breeder has to keep the records and get useful information for taking right decisions about selection of genetically superior animals on the basis of their breeding values.

The data or records are essentialin a hatchery or farm for the following purposes:

- To know the pedigree and history of each brooder pertaining to the production, reproduction and health performance.

- This helps to compare the between farm or between hatchery performance of brooders.
- The breeding value for different economic traits can be estimated which help in culling and selection of animals for breeding purposes which in turn bring the genetic improvement of future generations.
- Based on the production performance the feeding requirement can be estimated.
- This also helps in research and development planning.
- To know the health status by keeping records of the daily treatment of animals.

Selection and its Response

Selection is applied to change the fish population for making genetic improvement in performance. The selection is a process of giving preference to certain individuals in a population to reproduce than other individuals which are denied the opportunity to produce next generation. Therefore, selection is the choice of individuals to produce the next generation. In genetic terms, the selection is a process of differential reproduction and survival of genotypes which may be natural or artificial or both.

The selection, without creating any new gene, changes the genetic structure of the population by changing the frequency of genes and genotypes. The frequency of desired genes is increased in the population through selection at the expenses of the frequency of undesirable or less desirable genes. This is the genetic effect of selection. The selection is more efficient for dominant genes at low frequency but it is relatively easy to select for a recessive gene.

The characters are controlled by genes. Therefore, with the increase or change in the frequency of desirable genes, the phenotypic mean of the character of offspring generation is also increased or changed. The change in performance of offspring generation due to artificial selection is known as **response to selection or genetic change or genetic gain**. Now the point of discussion here is that how the performance of the offspring generation of selected parent is changed.

Intensity of selection

The intensity of selection denoted by *"i"* is the mean deviation of the selected animals in units of μ_p of the trait *i.e.* it is the number of μ_p of the trait by which the mean of the selected group is above the population mean before selection. The intensity is expressed as:

$\mu = s/\mu_p$

Factors affecting selectionresponse

The change in performance due to artificial selection known as response to selection depends on the following factors:

1 Additive genetic variability in the trait (μ_A)

2 Intensity of selection (i)

3 Accuracy of selection (r_{ap})

4 Population size

Additive genetic variability in the trait (μ_A)

The selection acts on additive genetic variability. The variation in breeding values (BV) of the individuals within the population is the raw material to act for artificial selection. The selection will not be effective to bring change if there are no genetic differences among animals. Therefore if $V_A = 0$, the $R = 0$. The magnitude of R increases with the increase in differences in B.V. between animals. However, the genetic variability of a trait (B.V.) within a population is determined by the population and the characters and hence it is beyond the control of breeder. It is therefore better to exploit other factors like intensity and accuracy of selection.

Intensity of selection (i)

The intensity of selection depends on the proportion (p) of the population selected. When p is small, the selection is said to be more intense or rigorous. But when p is large (increase in proportion selected) then there is decrease in intensity of selection. The R will be more when p will be small. This is a straight forward way to improve the rate of genetic progress. If all fishes are selected, the S will be zero and no change in offspring mean will occur. The change occurs if some of the best fishes are selected. Therefore, the proportion of fishes selected should be less.

Accuracy of selection (r_{ap})

The selection is effective only when the animals with highest B.V. are selected. The true B.V. of fishes is not known. This requires one or more sources of information to know the estimate of B.V. of fish. The information to estimate the true B.V. of a fish may be collected on the performance of the fish itself and or of its any close relative. The estimate of true B.V. so estimated should be as much accurate as it can be to make the selection more accurate. The accuracy of selection is taken as the correlation between the true B.V. of a fish and the source of information (Selection criteria) which is denoted as r_{ap} where A is the true B.V. and P is the selection criteria. The selection criteria may be a single record of average of repeated records of the fishes itself or on any relative *viz*. dam or average performance of a group of relatives like full sibs, half sibs or offspring groups.

The r_{ap} is equal to square root of heritability (r_{ap}=h). Thus if h^2 estimate is higher, ther$_{ap}$ will also be higher. The h^2 is an indication of the reliability of phenotypic value as a guide to the breeding value (B.V.) because the h^2 shows the correspondence between B.V. and phenotypic value. In other words, the h^2 shows the extent to which the B.V. constitutes the phenotypic value. Thus is directly correlated to h^2 as r_{ap}= h which is a measure of the accuracy of selection. It is, therefore, that for maximum accuracy of selection, the r_{ap} must be as high as possible to make the selection accurate. Thus selection will be more accurate when the h^2 of the trait is high.

The accuracy of selection can be increased by the following methods:

1. *Minimize the environmental variance:* It can be minimized by providing uniform environment, by use of multiple records to estimate h^2, by adjusting the data for environmental effects, by accurate measurement of data, and by analyzing the data based on contemporary group mean.
2. *Combined Selection:* When two or more criteria of selection are used to estimate an individuals' true breeding value (BV) it is called as the combined selection. This means to supplement the individuals' performance belonging records with those of its relatives. This gives more accurate estimate of B.V of the individual. The family selection may be used to support individual selection when h^2 of a trait is low. It is better to select an individual with better record belonging to a superior family compared to an individual with similar

performance belonging to a mediocre or inferior family. The half sib family selection is better than FS family selection.

The reason being that family selection is more effective when the environmental variations common to all the members of a family are as small as possible. This means that environmental similarities among family members should be low. The common environmental variance is less among half sibs than among full sibs. Thus, the environmental correlation among F.S. is more than among H.S. Secondly, the F.S. family selection reduces the genetic variability in the population and also results in a certain amount of inbreeding. The selected parents based on F.S. family averages are more closely related. Thirdly, the effective selection intensity is also reduced for a given testing facility for F.S. family selection.

3. *Selection based on future performance:* The selection should be based on the future performance (most probable producing ability or the expected producing ability) of the animal with more number of records.

Population size

The effect of population size on response to selection can be viewed in terms of inbreeding and genetic drift. The inbreeding is unavoidable in a population of small size. But inbreeding is less when the animals of both sexes are equal which is not possible in fish breeding for the reason that fewer individuals of either sex may be required according to species under selection. This needs to estimate the effective population size (Ne). The Ne is the number of individuals that would give rise to the same rate of inbreeding, if they breed in the manner of an idealized population, in which the rate of inbreeding is ÄF = 1/2N.

Criteria of selection

The performance records of ancestors and collateral relatives of the individual are also used as selection criteria to estimate the breeding value of an individual for the trait under selection.

Selection based on pedigree

The pedigree is a list or record of ancestors in the past few generations of the individual. The ancestors are the parents, grand parents, great grand parents etc. The pedigree having information on the economic characters of the ancestors is useful in selection of an individual. The B.V. of an individual is estimated on the basis of the performance of the ancestors. The selection criteria based on ancestors performance is called as the pedigree selection.

Basis of pedigree selection

An individual receives genes from his ancestors. The percentage of ancestral genes is halved in each generation. This decides the genetic relationship between an individual and his ancestor(s). This relationship is reduced to half in each generation. It is thus important to consider more recent ancestors (parents) rather than distant ancestors (great grand parents) for pedigree selection. This inclusion of more remote ancestors results only in marginal gain in accuracy of selection due to the halving process and sampling nature of inheritance. The pedigree selection adds very little to the accuracy of estimateing the B.V. of an individual if the information on individual are available. The significance of pedigree is decreased when information are available either on the individual or its family members (sibs and offspring).

Guides to pedigree selection

The following factors determine that how much attention is to be given to pedigree selection.

- The degree of genetic relationship of the individual with its ancestor–more closely related ancestors should be given more emphasis.
- Heritability of the character-the pedigree selection is more accurate for traits of high heritability.
- Environmental correlations among the individuals used in the prediction.
- Information available on ancestors.

Practical difficulties to use pedigree selection

- The ancestors' records are always not available.
- The pedigree records are destroyed with passage of time.
- Most of the characters have low heritability.

Merits of pedigree selection

- It is less costly as only compilation of pedigree is required.
- Allows selection at younger age and provides first hand information.
- It is helpful in multistage selection.
- It is useful for sex limited traits and traits expressed in later life or after death of animal.
- It is helpful when two individuals have similar performance but one belongs to a better pedigree.

Demerits of pedigree selection

- There is a disadvantage of using pedigree selection that all animals of similar pedigree are culled out inspite of the fact that an individual may be of good merit and free from recessive allele causing defect.
- Some pedigree gets undue emphasis and favoured irrespective of the true merit of the individual. Better environment is provided to the offspring of favoured pedigree.
- It introduces non random biases because pedigree records are for different environmental conditions.
- Pedigree selection provides no basis of selection among individuals which are descendants of the same ancestor.

Selection based on collateral relatives

The selection criteria to estimate the B.V. of an individual may be the information (Performance records) of its collateral relatives. An individual's collateral relatives are those which are not related with the individual on direct genes donor-recipient basis but receive common genes from their common ancestor(s) e.g. full sibs, half sibs, cousins, etc. The collateral relatives should be more closely related to the individual and these are full sibs and half sibs. The more closely related collaterals to the individual are likely to have more common genes possessed by the individual and can provide more accurate information about the individual. The more closely collaterals can be grouped as full sib families and half sib families. The family mean of these collateral relatives then form the basis to select the superior individual. The procedure to estimate the B.V. of an individual on the basis of family mean is called the family selection or sib selection depending upon the inclusion or exclusion of individual's own record in estimating the family mean. The selection criteria is called as family selection when the individual's own record is included to estimate the family mean but the selection criteria is called as the sib selection when the individual's own recorded is not included in estimating the family mean.

Sib Selection

It is the selection of an individual based on its sibs performance. The sibs may be full sibs or maternal half sibs or paternal half sibs. Thus sib selection is of two types *viz*. Full sib selection and half sib selection. The sib selection is practiced for the following traits for which the measurements on the individual are not available or recorded –

- Slaughter traits.
- Sex limited traits.
- Threshold traits like disease resistance.
- Traits with low heritability in species with high reproductive rate so as many sibs are measured in short time.
- The full sib (F.S) selection is more accurate than half sib (H.S.) selection. However, the H.S. selection is favoured for the following reasons:

■ Half sibs are easily available in more numbers than F.S.

■ The rate of inbreeding is more for F.S. selection than H.S. selection. The inbreeding counter balances the effect of selection.

■ The F.S. correlation is more likely to be increased by c-effects (common environment shared by F.S.). The intra class correlation (t) is rh^2 for H.S. and rh^2+c^2 for F.S. where c^2 is the added contribution of maternal or common environmental effects. This reduces the accuracy of F.S. selection.

Family Selection

The selection criteria are known as family selection when based on the performance of the sibs plus the individual's own record. The family selection like the sib selection is of two types of sibs *viz* Full sib family selection and half sib family selection.The family selection is also taken in another way *viz*. as a unit of selection. Based on the family mean the whole of the family is selected or rejected as a unit of selection.

Common environment (c-effects)

The environmental effects which are different for different families but same for all members of one and the same family are known as common environmental effects denoted as c-effects. The family members share common environment during pre and post natal stage. The c-effects thus create resemblance within family members over and above the resemblance due to having common genes and this contributes to the variance between families. This increases the intra class correlation (t) among family members. The c-effects are more for F.S. than for H.S. To some extent the half sibs also share common environment *viz*. all the offspring of a sire being born almost at the same time and being reared together are likely to be subjected to similar environmental conditions like climatic conditions, feeding regime and management practices etc.

When environmental similarities (c-effects) are present among family members, the intra class correlation among the phenotypic values of family members (t) is increased equal to the amount of c-effects as $(t+c^2)$ where C^2 is the portion of the total variation caused by differences in c-effects among families. This makes the denominator larger and hence the regression is decreased. Thus the c-effects decrease the accuracy of sib and family average.

Advantages of family selection

- The family selection can improve the characters of low heritability in species with high reproductive rates so as to get many sibs in a short time.
- The family selection does not allow the generation interval to increase
- Family selection is a support to individual selection because it is better to select an individual from a superior family.

Disadvantages or limitation of family selection

The family selection to be effective requires large family size and more number of families to avoid inbreeding as well as to increase the intensity of selection. In view of this it can be inferred that –

- Family selection is costly of space particularly when the breeding space and testing facilities are limited. The limited facilities reduce the intensity of selection.
- The family selection as a unit of selection results in inbreeding and thus limits the genetic diversity. This is because only few families represent the next generation.
- The F.S. family selection can only be applied in species with high reproductive rates to get large family size.

Within family selection

It is the selection criteria when individuals are selected on the basis of their performance expressed as deviation from their mean. The individuals that exceed their family mean by the greatest amount are selected. Thus it is opposite to family selection because family mean is given no weight. This selection criteria is preferred when c-effects are important *i.e.* when a large component of environmental variance is common to all members of a family. A large component of environmental variance common to members of a family arises when the different families differ in the environment to which they are exposed. Thus the families differ largely due to differences in environment and hence whole family get good or poor environment. The selection within family eliminates the environmental differences among families.

Thus within family selection economizes the breeding space and minimizes the rate of inbreeding. In within family selection, each family contributes equally to the parents of next generation, when single pair breedings are made and two individuals from each family are selected as replacement of the parents.The within family selection is better than individual selection when the sib correlation (t) is very high and caused largely by environmental effects. Within family selection operates on a large amount of additive variance within families.

Selection and Breeding for Disease resistance:

There are three possible methods to identify and select the individuals for differences in resistance/ susceptibility to a certain disease/parasite. These are as under:

- Occurrence of the disease under normal environmental conditions,
- Inoculation of animals with pathogen causing the disease and
- Use of indicators of resistance.

The first method to identify the resistant animals on the basis of the incidence of the disease is not effective in the sense that under the changed environmental conditions the resistant become susceptible. The second method of inoculation is not likely to be applied because of the objections to deliberate infection with pathogenic organisms. The third one requires very great efforts and research to find a better indicator of genetic resistance; which do not require deliberate exposure to pathogens.

The efficiency of individual selection and family selection on the basis of the incidence of the disease with two visible classes is discussed. The effectiveness of selection depends on the selection differential which, in turn, depends mainly on the proportion selected. But in case if threshold characters (all or none characters), the selection differential depends on the incidence rather than on the proportion selected. Selecting all the resistant individuals or only a portion of them will give their mean as the mean of the resistant group. Thus, selecting a smaller proportion than the incidence, does not give an added advantage. It is, thus, evident that maximum selection differential is achieved when the proportion selected is equal to the proportion of resistant individuals. The individual selection is less effective when the difference between the two (incidence of resistance and proportion selected) is more. Further, the individual selection is less effective when the proportion of resistant individual is very low, but the family selection is more effective. An individual's phenotype as resistant or susceptible is not precisely known whereas the family is more precisely known for the proportion of affected members of the family. However, the precision depends on the family size and on the incidence of a disease in the family.

Conclusion

Although aquaculture is a biological production system has a long history, systematic and efficient breeding programs to improve economically important traits in the farmed species have rarely been utilized until recently, except for salmonid species. This means that the majority of aquaculture production is based on genetically unimproved stocks. In farm animals the situation is vastly different, practically no terrestrial farm production is based on genetically unimproved and undomesticated populations. This difference between aquaculture and livestock production is in spite of the fact that the basic elements of breeding theory are the same for fish and shellfish as for farm animals. One possible reason for the difference is the complexity of reproductive biology in aquatic species, and special consideration needs to be taken in the design of breeding plans for these species.

In aquaculture, selection programs are not commonly used by the industry and for many species production still rely completely on catching wild broodstock and/or fry. There is no obvious reason for the lack of efficient breeding programs in aquaculture. The economic important traits in fish and shellfish appear to be little different from those in farm animals and plants. Selection response is usually higher in fish and shellfish than in farm animals. One reason for the scarcity of breeding programs in aquaculture species is that the reproductive cycle is often complex, and so is frequently not fully understood, and is therefore not able to be completed or controlled in captivity. This is the case particularly for marine species. A further factor contributing to the scarcity of breeding programs in aquaculture species may be the deterioration of the stock simply because of a rapid build-up of inbreeding as a result of using few broodstock each generation (and without identification to prevent re-use). This is a problem in all species with high fecundity. Because there has been little interest in developing breeding programs in aquaculture, the information about phenotypic and genetic parameters of economically important traits are quite limited for most of the species farmed. Before a breeding program can be established, breeding goal must be defined; estimates of genetic variance, heritability, phenotypic and genetic correlations among traits must be available. There is therefore a great need to run breeding experiments in order to get reliable estimates of genetic parameters for economically important traits in the most important farmed species.

The applications of molecular techniques in aquaculture are promising, but still some what uncertain. While high costs seem to be the only hindrance for widespread application of DNA markers for identification purposes and marker assisted selection, the situation regarding commercial use of genetically modified fish is more complex. Although the potential importance of gene transfer technology is large, a major concern relates to the possible impact, which release or accidental escapes of gene-modified individuals may have on natural ecosystems. Other technologies are also rapidly emerging which are either being used or are likely to be used in the future in the aquaculture species. For example micro-array technology has the potential to contribute very large amounts of information on the genes and pathways of genes, which affect the economic traits in aquaculture species.

Sustainable farming methods for community development in fishing villages

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The availability of fish from the sea is declining in recent years mainly due to overexploitation of fish stocks. In order to address the issue of declining capture fisheries, the major management strategy being followed worldwide is the adoption of fishing holidays. Though trawl ban is diligently followed in our country for 45 days in east and west coast annually, it is felt that the same alone may not be sufficient to ensure the long-term sustainability of stocks. Another option is to ban trawling in a phased manner. The demand for fish is increasing year after year as it is an important source of protein and it is an essential nutrient to poor section of the society. Hence in future years the additional marine fish requirement has to be met by farming- Mariculture. Some of the sustainable farming methods which were already adopted by fishermen groups in the coastal areas of Tamil Nadu are mentioned below:

1. Cobia farming in sea cages
2. Silver pompano farming in coastal ponds
3. Marine ornamental fish culture
4. Seaweed farming
5. Pen farming of milkfish
6. Lobster fattening/farming in pen/cages
7. Integrated Multi Trophic Aquaculture (IMTA)
8. Mud crab fattening in cages
9. Blue swimmer crab farming in pen/cages

The important details like stocking density, culture period, harvest quantity, cost and benefits are mentioned under each farming methods.

1. Cobia farming in sea cages

Cage dimension (GI pipe)	6m dia and 4 m depth
Stocking density	750 nos per cage
Culture period	6 months

Fixed cost	Rs. 1.25 lakhs
Operational cost	Rs. 3.25 lakhs
Harvestable size (six months)	2.5 kg (average)
Harvest quantity per cage	1.8 tonnes
Gross income (@ Rs.320 per kg)	Rs. 5.76 lakhs
Profit	Rs. 1.26 lakhs (1st crop), Rs. 2.51 lakhs (2nd crop)
Prospects	High export quality
Need	Establishment of hatcheries to cater the local seed requirements

2. **Silver pompano farming in coastal ponds**

Coastal pond	One hectare
Stocking density	10,000 nos per ha
Culture period	8 months
Total cost	Rs. 7,91,400/-
Harvestable size (8 months)	450 g (average)
Harvest quantity per pond	4,050 tonnes
Gross income(@ Rs.300 per kg)	Rs. 12,15,000/-
Profit	Rs. 4,23,600/-
Prospects	Good export quality, huge demand in local markets
Need	Establishment of hatcheries to cater the local seed requirements

3. Marine ornamental fish culture

Area (Shed with cement tanks)	144 sq.m.
No. of tanks	51 RCC tanks (3 ft dia and 2 ft depth) with 350 litres capacity
Total number of pairs (clownfishes)	10
Saleable size and duration	One inch & 45 to 60 days
Fixed cost	Rs. 6.5 lakhs
Operational cost	Rs. 2.5 lakhs
Sale of clownfish fingerlings @75 per fingerlings (240 juveniles × 10 pairs × 12 months = 28,800)	Rs. 21.60 lakhs
Profit	Rs. 12.60 lakhs (1st year), Rs. 19.10 lakhs (2nd year)
Prospects	Low volume and high trade, huge demand in international markets

- Establishment of marine ornamental fish broodbank and producing plenty of half inch juveniles by an Institute.
- Many Self Help Groups can be encouraged to start the ornamental unit for whom the half inch juveniles will be supplied.
- They grow them up to one inch size and marketing will be arranged to sell them.

4. Seaweed farming in bamboo rafts

Bamboo raft (12 × 12 ft.)	45 rafts
Seed material	60 kg per raft
Culture period (one cycle)	45 days
Total cost	Rs. 63,000/-
Harvest quantity for 45 rafts (after retaining 2700 kg as seed for next cycle)	9000 kg
Seaweed Dry Weight @ 10: 1 ratio	900 kg
Selling price (@ Rs. 37 per kg of dry wt.)	33,300
Gross income for 4 cycles in 7-8 months	1,33,200
Profit	70,200/-
Prospects	Carrageenan and Liquefied Seaweed Fertilizers (LSF) can be produced in huge quantities to meet our countries demand
Need	Farming of native seaweed species has to be promoted

5. Pen farming of milk fish *Chanos chanos*

Pen (fish nets & casuarina poles)	120 × 120 m
Stocking density & size	25,000 milk fish seeds with average weight of 4.6 g
Culture period	10 months
Total cost	Rs. 2.5 lakhs
Harvestable size (10 months)	300 g (average)
Harvest quantity per pen	2562 kg
Gross income	Rs. 3,58,680/-
Profit	Rs. 1,08,680/-
Prospects	Good demand in local markets, price is more during the months of April and May (Trawl ban)
Need	To encourage many SHGs to take up pen farming wherever possible

6. **Lobster fattening/farming in pen/cages**

Pen (fish nets & casuarina poles)	16 x 16 feet
Stocking density & size	2 nos per sq.ft.& 70 g per wild collected seed
Culture period	7 months
Total cost	Rs. 45,000/-
Harvestable size (7 months)	200 g (average)
Harvest quantity per pen	100 kg
Gross income (@ Rs.2,000/- per kg)	Rs. 2.0 lakhs
Profit	Rs. 1.55 lakhs
Prospects	Candidate species for live trade, huge demand during the months of December, January and February
Need	To develop the hatchery technology for producing lobster seeds
To reach 500 g size it takes 18 months and costs Rs.2,700/- per kg.One kg size of lobster costs Rs.3,500/-	

7. **Integrated Multi Trophic Aquaculture (IMTA)**

One of the anticipated issues while expanding the sea cage farming is environmental degradation and consequent disease problems. In this context the idea of bio-mitigation along with the increased biomass production can be achieved by integrating different groups of commercially important species which are having varied feeding habits. This concept is known as Integrated Multi-Trophic Aquaculture (IMTA) which is getting importance at global level. In this context a trial on IMTA was conducted by Mandapam Regional Centre of CMFRI with participation of seaweed farmers from Munaikadu village near Mandapam. The centre has given 3 numbers of low cost G.I. cages of size 4.5 m× 4.5 m× 3.5 m and stocked with cobia fingerlings at the rate of 100 numbers per cage. The seed material (720 kg) for the seaweed was also supplied for integrating with the cages. A total of 652 kg of cobia was harvested. The length ranged from 59 to 83 cm and weight ranged from 1.8 to 4.2 kg (average weight: 3.25 kg). The farm gate price of cobia realized was Rs. 210 per kg. The total seaweed harvested was 2,700 kg wet weight. The seaweed harvested was used as the seeding material for the next crop. It was observed that the seaweed rafts integrated with cobia cages had a better average yield of 225 kg per raft in contrast to 150 kg per raft of others which were not integrated. It is felt that this practice is effective both in terms of increasing the production and also for alleviating the organic load to the environment due to fish farming. It is an initial step towards the development of a full-fledged integrated marine fish farm at Munaikadu village which will be first of its kind in the country where seaweed, mussel/oyster, lobsters, high value marine food fishes and ornamental fishes can be farmed together.

8. **Mud crab fattening in cages**

Cage dimension	3×2×1 m
Stocking density & size	4-5 nos per m^3 (750 g per mud crab)
Period for fattening	15 - 20 days
Fixed cost	Rs. 5,000/- per cage
Operational cost	Rs. 10,000/- per cage
Harvestable size	800 g
Harvest per cage	20 kg
Gross income (@ Rs.1,200/- per kg)	Rs. 24,000/-
Profit	Rs. 9,000/- per cage
Prospects	Candidate species for live trade, huge demand during the months of September to December
Need	To standardize the hatchery technology for producing seeds

Recirculating aquaculture systems

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Introduction

Closed-system aquaculture presents a new and expanding commercial opportunity. Recirculating aquaculture systems (RAS) are tank-based systems in which fish can be grown at high density under controlled environmental conditions. They are closed-loop facilities that retain and treat the water within the system. In a RAS, water flows from a fish tank through a treatment process and is then returned to the tank, hence the term recirculating aquaculture systems. RAS can be designed to be very environmentally sustainable, using 90-99 percent less water than other aquaculture systems. RAS can reduce the discharge of waste, the need for antibiotics or chemicals used to combat disease, and fish and parasite escapes. RAS have been under development for over 30 years, refining techniques and methods to increase production, profit and environmental sustainability. There is a large cost involved in setting up and running a recirculation system and we need to consider a number of factors in designing the system that will fit our needs. This type of aquaculture production system is more commonly used in freshwater environments and can also be used in marine environments. Since failure of any component can cause catastrophic losses within a short period of time, the system must be reliable and constantly monitored. An important component of RAS is the control system which must measure and control all the critical system parameters. Recent developments in control technology and microcomputers may revolutionize the operation and control of RAS. A properly-controlled RAS will also be energy efficient since production can be optimized with respect to the various inputs. In addition, water levels, disruption of electric power, fire, smoke and intrusion of vandals should also be monitored.

Biosecurity

Hatcheries with RAS facility are often fully closed and entirely controlled, making them mostly biosecure - diseases and parasites cannot often get in. Biosecurity means RAS can continusously operate without any chemicals, drugs or antibiotics. Water supply is a regular route of pathogen entry, so RAS water is often first disinfected or the water is obtained from a source that does not contain fish or invertebrates that could be pathogen carriers.

Water quality and waste management

The most important parameters to be monitored and controlled in an aquaculture system are related to

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water quality, since they directly affect animal health, feed utilization, growth rates and carrying capacities. The critical water quality parameters that are taken care in RAS are dissolved oxygen, temperature, pH, alkalinity, suspended solids, ammonia, nitrite and carbon dioxide (CO_2). These parameters are interrelated in a complex series of physical, biological and chemical reactions. Monitoring and making adjustments in the system to keep the levels of these parameters within acceptable ranges is very important to maintain the viability of the total system. The components that address these parameters can vary from system to system.

A successful water reuse system should consist of tanks, filters, pumps and instrumentation.

Fish tanks

The round or octagonal or square design with rounded corners and the arrangement of in and outlets of water treatment units support the circular water flow. Additional circular water flow and aeration can be enhanced by aqua jets. The circular flow promotes the behavior of fish. Circular tanks are good culture vessels because they provide virtually complete mixing and a uniform culture environment. When properly designed, circular tanks are essentially self-cleaning. This minimizes the labor costs associated with tank cleaning. Typically, water is introduced into a circular tank at the side and is directed tangential to the tank wall. The incoming water imparts its momentum to the mass of water in the tank, generating a circular flow pattern. The water in the tank spins around the center drain, following an inward spiral to the center of the tank. Centrifugal forces and the inward, spiraling flow patterns transport solid wastes to the center drain area where they are removed easily. Once the mass of water in the tank is set into motion, very little energy is required to maintain its velocity. The momentum of the water circling the center drain helps sustain the circular flow. The primary disadvantage of circular tanks is that they do not use space efficiently. A circular tank of a given diameter will have about 21% less bottom culture area than a square tank whose sides are the same length as the diameter of the circular tank. This means that if circular tanks are used there will be 21% loss of potential production in a given amount of space.

Aeration systems

The most efficient aeration devices move water into contact with the air. The commonly used air stones produce larger air bubbles which rise quickly to the surface and hence the dissolution of oxygen is low. So,the usage of air diffusers are preferred in RAS. These diffusers produce small air bubbles within the tank that rise through the water column. The smaller the bubbles and the deeper the tank, more oxygen is transferred.

Carbon Dioxide (CO_2) Control and Removal

CO_2 is produced through the respiration of fish and microorganisms and will accumulate within recirculating systems if not removed at a rate equal to its production. Elevated CO_2concentrations are not greatly toxic to fish when dissolved oxygen is at saturated levels. For most aquacultured fish, free carbon dioxide concentrations should be maintained at less than 20 mg / L in the tank for good fish growth. CO_2 is usually removed through some form of gas exchange process either by exposing the water to air in a “waterfall” type of environment, or mixing air into the water to remove excess CO_2.

Stocking number and density

In evaluating RAS production capabilities, the unit most often used is maximum tank or system stocking density (kg/m^3 or lbs./gallon). However, in terms of production potential, this unit of measure is meaningless.

Fish can be held at very high stocking densities while feeding only enough to maintain their basic needs. Underfed fish consume less oxygen and produce less waste. Therefore, the stocking rate of a system (fish/m^3) and ultimate maximum fish density (kg / m^3) achieved within a tank should be defined by the maximum feed rate (kg feed / hr or day) that the system can accommodate without wasting feed and still maintain good water quality. This maximum feed rate capacity will be a function of the water treatment system's design, type of fish being grown, and type of feed.

Solid removal in recirculation systems

One of the key problems in RAS is related to the load of suspended solids and in particular to very fine particles. The presence and accumulation of particulate wastes in RAS (faeces, uneaten feed, and bacteria flocs) will negatively impact the water quality by affecting the performance efficiency of the water treatment units. High suspended solids load has many disadvantages:

- Particulate matter consumes oxygen during biological degradation which will decrease the availability of oxygen for fish in culture
- The breakdown of organic wastes will increase the Total Ammonia Nitrogen (TAN) concentration in the water affecting nitrification. Small quantities of unionized ammonia can be toxic for epithelial tissues and disturb the elimination of protein metabolites across gills.
- Solids support the growth of heterotrophic bacteria which can outgrow and compete with nitrifiers. The nitrification process is strongly inhibited by heterotrophic processes when high amounts of organic carbon are present.
- Particles can potentially clog biofilters and reduce their efficiency
- Excessive solid loads can cause plugging within aeration columns, screens, and spray nozzles orifices, which could ultimately result in system failure.
- Suspended solids offer an ideal temporary substrate for facultative pathogens while they try to find a final host. It is also suspected that suspended solids may be involved in bacterial gill disease (BGD) outbreak.

Some type of filters used for the solid wastes are drum filters, bead filters, screen filters and rapid sand filters.

Biofiltration

In closed aquaculture systems the accumulation of nitrogen compounds, as ammonia and nitrite, has a deleterious impact on water quality and fish growth. The biological filtration (BOD removal and nitrification) is a fundamental water treatment process in every recycling method for the cultivation of aquatic animals. It mainly digest dissolved organic material (heterotrophic bacteria) and oxidizes ammonium-ions via nitrite to nitrate (two-step nitrification) by bacteria like *Nitrosomonas sp.,* and *Nitrobacter sp*. A solid medium is used as substrate for the attachment of the micro flora. Conventional biofilters employ sand or coral gravel as filter media. Modern filters make use of various plastic structures as grids, corrugated sheets, balls, honeycomb-shaped or wide-open blocks. The main goal is to provide a big active surface area for the micro flora settlement. During the last few years moving bed biofilters have received growing attention. These allow to have more specific surface area at the same volume, they need low maintenance due to self-cleaning (no back wash needed). Moving bed reactors are interesting cross between upflow plastic bead filters and fluidized bed reactors. These filters use a plastic media kept in a continous state of movement. The beads are usually buoyant or slightly heavier than water. The specific surface/volume ratio is about 800-1000m^2/m^3. The plastic beads are mixed by hydraulic means driven by air.

Even if nitrate is usually mentioned as the least toxic form in comparison to ammonia and nitrite, high concentrations can reduce immune response and influence osmoregulation in fish. Optimal bacterial growth is the crucial step, otherwise toxic compounds like nitrite, nitrogen or hydrogen sulfide can be formed. The quantity required for denitrification can be calculated on basis of the influent nitrate, nitrite and dissolved oxygen concentrations. The oxidation-reduction potential (ORP) is measured to monitor the denitrification. Sequential removal and reduction of oxygen, nitrate and nitrite result in sequential decrease of ORP in the media.

Foam fractionation

Many of the fine suspended solids and dissolved organic solids that build up within intensive recirculation systems cannot be removed with traditional mechanisms. Foam fractionation is used to remove and control the build-up of these solids. This process, in which air introduced into the bottom of closed column of water creates foam at the surface of the column, removes dissolved organic compounds by physically adsorbing on the rising bubbles. Fine particulate solids are trapped within the foam at the top of the column, which can be collected and removed. The main factors affected by the operational design of the foam fractionator are bubble size and contact time between the air bubbles and dissolved organic compounds. Foam fractionation is a suitable process in sea water as well as fresh water and the efficiency is increasing with increasing salinities. That is related to the increasing surface tension allowing smaller air bubbles in sea water and there with a higher filter area. Foam fractionation is working very efficiently from salinity of 12ppm and more.

Disinfection of culture water

Installation of suitable UV sterilizers or ozonisers in the water flow would remove unwanted bacteria, algae and pathogens. The capacity and the flow rate of the UV sterilizer/ ozoniser should be calculated based the on quantity of water to be treated and effectiveness of treatment.

Hatchery protocols for seed production of cobia and pompano

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Introduction

Many Southeast Asian countries, European nations and Western countries like USA have developed commercial marine finfish hatchery technologies for many commercially important species namely groupers, salmon, tilapia, sea bass, sea bream, snappers, mullets, Chanos, etc. They have developed capacity to produce large and dependable quality of fish seeds which is the key for establishing reliable and sustainable marine finfish aquaculture sector. In India, technology for production of marine finfish seeds is in primitive stage except for sea bass. The Mandapam Regional Centre of the Central Marine Fisheries Research Institute (CMFRI) has developed hatchery technology for cobia, *Rachycentron canadum* during March 2010 for the first time in the country. Again the Centre has developed hatchery seed production technology for the silver pompano, *Trachinotus blochii* for the first time in the country. Both the technologies are standardised and hence the CMFRI has entered into agreements with interested entrepreneurs and farmers for dissemination of technologies for development of cobia and silver pompano aquaculture sector in our country.

The cost-effective hatchery technologies developed by the Mandapam Regional Centre of the CMFRI comprise

1. Induced spawning protocols
2. Appropriate live feeds for larval rearing,
3. Commercial-scale protocols for larval rearing,
4. Nursery and grow-out culture protocols

The larval rearing procedures of cobia and pompano are described below

Egg harvest

The fertilized eggs of cobia and pompano float and are scooped gently using 500 μm net. To minimise collection of poor-quality eggs, which usually float deeper in the water, it is advisable to collect only the eggs

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which float at the water surface. Therefore, aeration can be switched off allowing the unfertilized / dead eggs to settle at the bottom of the tank. The floating layer of eggs thicker than one cm should be avoided. A thicker layer may reduce oxygen supply to the eggs, leading to possible anoxia after a short time. The eggs should be sampled and examined for their quality, number and developmental stages. The embryonic development inside the eggs could be studied using a microscope.

Check for the following egg characteristics:

- Presence of opaque, whitish eggs which are unfertilised. Similarly, eggs in the sample with transparent, but without evidence of cell divisions
- Regular round shape and size (diameter 900-1000 μm in cobia; 800-900 μm in pompano), regular cell division that can be observed only in the first blastomers; regular shape of yolk (it should occupy the egg volume entirely, without perivitelline space),
- Absence of parasites or associated micro-organisms on the chorion surface.

Incubation of eggs

Incubation of eggs is done in incubation tanks of 3-5 tonne capacity. After hatching, only the hatched fish larvae have to be moved to the larval rearing tanks filled with filtered seawater. Prior to this, the aeration should be stopped briefly to enable the debris and exuviae to settle at the bottom which can be removed by siphoning. Aeration needs to be adjusted suitably, not too strong to avoid excessive physical collision among eggs, but should be sufficient only to keep the eggs suspended in water column. The main purpose of aeration is to prevent clumping and settling down of eggs. Air bubbles should not be too small, as seen while using air diffusers instead of stones, as it results in clumped eggs and damage of the eggs. Stocking density can be maintained at a moderate level of 200 to 500 eggs per litre. The hatching of eggs takes place from 18 to 24 hours. As the fecundity is normally high in cobia, we may require more incubation tanks, whereas pompano requires only one tank/ female.

The embryonic developmental stages of cobia and pompano normally look alike except for the duration of development and size of the larvae. The photos of embryonic development and newly hatched larvae are provided below;

Larviculture

The marine fish larvae are generally classified into altricial and precocial type. The altricial type of larvae is having very less yolk reserves at hatching and hence, the larvae are in an undeveloped stage when the yolk sac is completely resorbed. The development of digestive system is also very primitive in these types of larvae. Many of the marine fin fishes which are suitable for aquaculture are having the altricial type of larvae which poses challenges in their larviculture. When the yolk reserves are fully exhausted, the larval size and mouth gape are very small and the perceptive powers for searching and taking external feed is also very less. The period when the yolk reserves are fully exhausted and larvae need to resort to exogenous feeding is a critical period in the larviculture of most marine fin fishes. Unless proper live feeds of required size is provided in sufficient densities in larviculture media and its nutritional requirements especially in terms of PUFA are met, large scale mortality is bound to happen at this stage and hence it is evident that the larviculture of marine finfish having altricial larvae is really challenging and proper management of live feed is the most vital pre-requisite for the success in terms of survival and growth of the larvae.

In addition, since most of the larvae are visual feeders providing the required light also affect the larval survival. During the critical period, the density of the live feed and its nutritional qualities determines the percentage of the survival of the larvae. The density of the larvae of the concerned species should also be regulated in the larviculture tanks for getting good survival. The marine fish larvae exhibit highly differential growth even from very early stages (in the case of cobia, starting from the first week) and hence grading from an early stage is also very much needed for increasing the survival. In addition, variety of other factors such as tank colour, size of the tank, water temperature, water quality, etc., affect the larval survival and growth. From the foregoing, it is clear that the larviculture of marine finfish is highly complicated, unless each and every factor is taken care of, the survival and growth of the larvae will be very meagre.

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

- shape and dimensions
- deformities, erosions and abnormalities
- appearance of internal organs
- pigmentation
- absence of external parasites

The larvae hatched in the incubation tanks or larval rearing tanks need to be distributed in larviculture tanks to have minimal stocking density of 5 to 10 larvae/ litre for cobia and 10-20 larvae per litre for pompano. Care should be taken to avoid any mechanical stress or damage. Soon after hatching, the mouth is closed and the digestive tract is not fully developed. During this period the larvae survive on its reserves in the yolk sac.

Larviculture of cobia

Newly hatched larvae of cobia normally measures 3.4 mm size. Larval mouth opens at 3-5 days post hatch (dph). Metamorphosis starts from 18-21 dph. Newly hatched cobia larvae generally start feeding at 3 dph and they can be fed with the enriched rotifer (*Brachionus rotundiformis*) at the rate of 10-12 nos / ml, two times a day till 10 dph. From 8 dph, the larvae can be fed with enriched *Artemia* nauplii at the rate of 2-3 nos / ml, 2 times a day. During the rotifer and *Artemia* feeding stage, green water technique can be used in the larviculture system with the microalgae *Nannoc loropsis occulata* at the cell density of 1×10^{7} cells / ml. The weaning to artificial larval diets has to be started from 15- 18 dph. While weaning, formulated feed should be given 30 minutes prior to feeding with live feed. Size of the artificial feed has to be smaller than the mouth size of the fish. Continuous water exchange is required during weaning stage. Between 25-40 dph, the larvae are highly cannibalistic and hence size-grading has to be undertaken at every three days interval. During this stage, the fry could be weaned totally to artificial diets. Larval rearing can be practised both intensively in tanks and extensively in ponds. The major factors affecting the growth and survival of larvae are nutrition, environmental conditions and handling stress. Since there is high demand for essential fatty acids (EFAs), enrichment protocols are needed for live-feeds. The water exchange can be practically nil till 7dph and it can be gradually increased from 10-100 % from 8 to 12 dph. But, tank bottom siphoning should be carried out from day 1. The environmental conditions required during the larviculture period are DO_2: > 5mg / l, NH_3: < 0.1mg / l, pH: 7.8 – 8.4, Salinity: 25-35 ppt, water temperature : 27-33° C.

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

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

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

Nursery and grow-out rearing of cobia

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

Larvae and fingerlings are shown in the given plates (*dph = day post hatch*).

Larviculture of Pompano

The newly hatched larvae were stocked at a density of 15000 larvae in FRP tanks of 2 m^3 capacity filled with 1.5 m^3 filtered seawater. The tanks were provided with mild aeration and green water at a cell density of 1 $x10^7$/ml. The mouth of the larvae opens on 3dph and the mouth size was around 230 μ.

The larvae were fed from 3dph to 14 dph with enriched rotifers at a density of 6-8 nos. per ml in the larviculture tanks. Wherever possible, wild collected copepods could also be added as supplements. Co-feeding of rotifers with enriched *Artemia* nauplii has to be done during 12-14 dph, and thereafter upto 19 dph with enriched *Artemia* nauplii alone by maintaining a density of 3-5 nos. per ml in the larviculture tanks. Weaning to larval inert feeds has to be started from 15 dph and co-feeding with *Artemia* needs to be continued until 19 dph. From 20 dph feeding can be entirely on larval inert feeds. The metamorphosis of the larvae starts from 18 dph and all the larvae metamorphose into juveniles by 25 dph. Though cannibalism is not witnessed, grading has to be done during 20-25 dph to separate the shooters. Critical stage of mortality would occur during 3-5 dph and subsequent mortalities are negligible. The water exchange can be practically nil till 7dph and it can be gradually increased from 10-100 % from 8 to 14 dph.

Nursery Rearing of Pompano

Nursery rearing could be initiated from 25 to 30 dph. At this stage, artificial feed of 800 μ size could be provided. Thereafter, fingerlings were fed with progressively higher size range of floating extruded larval feeds. Daily water exchange of 100% is advisable. Water quality parameters like salinity, temperature, pH, Oxygen level and ammonia are closely monitored during the entire larviculture period. After 55dph, the fingerlings with size range from 1 to 1.5 inch size can be supplied to farmers for stocking in the happas / tanks for further nursery rearing and grow-out farming thereafter. The pompano fingerlings can be reared at salinities as low as 5 ppt. At lower salinities *i.e*. from 10 to 15 ppt, they grow faster than in pure seawater.

Seed Production and Culture of Marine Ornamental Fishes

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Introduction

The marine ornamental fish trade has been expanding in recent years and has grown into a multimillion dollar enterprise. The ornamental animals are the highest valued products that are mostly harvested from coral reef environments. The global marine ornamental trade is estimated at US$ 200-330 million. The trade is operated throughout the tropics. Philippines, Indonesia, Solomon Islands, Sri Lanka, Australia, Fiji, Maldives and Palau supplied more than 98% of the total number of marine ornamental fish exported in recent years. It is a multi-stakeholder industry ranging from specimen collectors, culturists, wholesalers, transhippers, retailers, and hobbyists to researchers, government resource managers and conservators and hence involves a series of issues to be addressed and policies to be formulated for developing and expanding a sustainable trade. It is well understood that a long term sustainable trade of marine ornamental fishes can be developed only through the development and commercialization of hatchery production technologies for the species which are in high demand in the trade.

Global scenario

In recent years it has been reported that nearly 1500 species of marine ornamental fishes are traded globally and most of these are associated with coral reefs. Nearly 98% of the marine ornamental fishes marketed are wild collected from coral reefs of tropical countries. Among the most commercially traded families of reef fishes, family Pomacentridae dominate, accounting for nearly 43% of all fish traded. The family contains about 235 species worldwide. They are followed by species belonging to Pomacanthidae (8%), Acanthuridae (8%), Labridae (6%), Gobiidae (5%), Chaetodontidae (4%), Callionymidae (3%), Microdesmidae (2%), Serranidae (2%) and Blennidae (2%). In recent years the blue green damselfish (*Chromis viridis*), the clown anemone fish (*Amphiprion ocellaris*), the whitetail Dascyllus (*Dascyllus aruanus*), the sapphire devil (*Chrysiptera cyanea*) and the three spot damsel (*Dascyllus trimaculatus*) are among the most commonly traded species.

Hatchery production technologies

Indiscriminate exploitation of ornamental fishes from the coral reef areas has been threatening the long term sustainability of the trade. Hence hatchery production of selected marine ornamental fishes is the only option for the development of a long term sustainable trade. The Central Marine Fisheries Research Institute (CMFRI) has been focusing on this vital aspect for the past few years. The Institute was able to develop hatchery production methods of the following species of ornamental fishes which are in high demand in the international trade.

1. *Amphiprion percula* - Orange clown
2. *A. ocellaris* - False clown
3. *A. sebae* - Sebae clown
4. *A. nigripes* - Maldive's clownfish
5. *A. ephippium* - Red saddleback clownfish
6. *A. perideraion* - Pink skunk
7. *A. clarkii* - Clark's anemonefish
8. *Premnas biaculeatus* - Maroon clown (spine cheek anemonefish)
9. *Pomacentrus cearuleus* - Blue damsel
10. *P. pavo* - Peacock damsel
11. *Dascyllus trimaculatus* - Three spot damsel
12. *Dascyllus aruanus* - Humbug damsel
13. *Chromis viridis* - Bluegreen damsel
14. *Neopomacentrus nemurus* - Yellowtail damsel
15. *N. cyanomos* - Filamentous tail damsel
16. *Chrysiptera cyanea* - Sapphiredevil damsel

Clownfishes

Success was obtained in the seed production of eight species of clownfishes which are in good demand in the international trade of marine ornamental fishes.

Amphiprion ocellaris

The spawning time was during early morning hours and the frequency of spawning ranged from 12 to 15 days. The clutch size per spawning ranged from 300 to 1000 eggs. Hatching was on the evening of 8th day of incubation and the newly hatched larvae measured from 3.2 to 4.0 mm in length. The larviculture protocols were developed and during the 15th to 17th day of hatching the larvae metamorphosed into juveniles.

Amphiprion percula

The spawning was during day time (0600 -1530 hrs) and the spawning interval ranged from 14 to 18 days. The clutch size per spawning ranged from 112-557 eggs. The hatching was on the evening of the 8th day of incubation and the length of the newly hatched larvae ranged from 1.91 to 2.02 mm. The larviculture protocols were developed and during the 19th -20th day of hatching, the larvae metamorphosed into juveniles.

Premnas biaculeatus

The broodstock was developed in 500 litre FRP tanks fitted with biological filtration and by providing special broodstock feeds. The spawning was during day time. The number of eggs per spawning ranged from 150 to 1000 numbers and the spawning interval was 15 to 20 days. Hatching occurred on the evening of the 6th day of incubation. The newly hatched larvae measured from 350 to 410 μ. Greenwater technique was employed for larval rearing and feeding protocols with enriched rotifers and newly hatched *Artemia* nauplii were developed. At 15 to 17th day of post hatch, the size of the juveniles ranged from 12.0 to 16 mm.

Recently success was also obtained in the breeding and seed production of five more species of clownfishes *viz. Amphiprion nigripes, A. perideraion, A. frenatus, A. ephippium and A. clarkii.* The breeding and seed production techniques are similar to the species mentioned above.

Damsel fishes

Broodstock development and larval rearing were achieved for six species of damsel fishes *viz.* the three spot damsel (*Dascyllus trimaculatus*), striped damsel (*Dascyllus aruanus*), the blue damsel (*Pomacentrus caeruleus*), the bluegreen damsel (*Chromis viridis)* , the yellowtail damsel (*Neopomacentrus nemurus)* and the sapphire devil damsel (*Chrysiptera cyanea*).

Dascyllus trimaculatus

The mature fish ranged in total length from 9-10 cm. The clutch size in a single spawning ranged from 12000 – 15000 eggs. The average periodicity of spawning was two weeks. The average length of newly hatched larva was 2.5mm. The green water technique with sufficient nauplii of copepods was the key factor for the success of early larval rearing. The larvae started metamorphosing from 35th day of hatching and all larvae metamorphosed by the 40th day. The just metamorphosed young one measured from 12-13mm in length. The second generation matured and spawned in the hatchery at eleven months of age.

Dascyllus aruanus

The brooders ranged in length from 7-8 cm. The clutch size in a single spawning ranged from 8000 – 10,000. The average periodicity of spawning was two weeks. The average length of newly hatched larva was 2.4 mm. The larvae started metamorphosing from 25th day of hatching and all the larvae metamorphosed by 31st day.

Pomacentrus caeruleus

The breeders ranged in length from 7-9 cm. The clutch size in a single spawning ranged from 5000-6000 eggs. The average periodicity of spawning ranged from 3 to 12 days. The average length of the newly hatched larvae was 1.2 mm but the mouth gape was comparatively larger (around 200μ). Greenwater technique and feeding with sufficient nauplii of suitable copepods for the first ten days and thereafter with freshly hatched *Artemia* nauplii was the methodology followed. The larvae started metamorphosing from the 17th day and by 21st day all of them metamorphosed. The average length of just metamorphosed juvenile was 21 mm.

Chromis viridis

The broodstock development of the green damsel *Chromis viridis* was carried out in 2 tonne FRP tanks fitted with biological filter and by feeding with special broodstock feeds. The fishes became broodstock at a total length range of 8 -9 cm. The average frequency of spawning was 5 per month with an interval of about 5 days. The egg was oval shaped and the average length was 502 μ. The total numbers of eggs per spawning ranged from 1300 -1500 eggs. Hatching occurred on the evening of the fourth day of incubation. Larvae were altricial type with no mouth opening at the time of hatching. The average length of newly hatched larva was 2.25 mm. The larvae were transferred to 5 tonne capacity round FRP tanks in which cultures of the harpacticoid copepod *Euterpina acutifrons* and the calanoid copepod *Pseudodiaptomus serricaudatus* were maintained in green water produced by adding *Nannochloropsis* culture. Mouth opening was formed on the second day of hatching and the gape measured around 190 μ. The larvae started feeding on copepod nauplii from the 3rd day onwards. From the 32nd day of larval rearing freshly hatched Artemia nauplii was also supplemented. Metamorphosis started from 30th day and completed by 49th day.

Neopomacentrus nemurus

The broodstock of the yellowtail damsel *Neopomacentrus nemurus* was developed in 2 tonne capacity FRP tanks. The average interval of spawning ranged from 4 -5 days. The length of freshly laid egg was 870 *μ*. The eggs hatched on the evening of the fourth day of incubation. The freshly hatched larva measured 1.8mm with a mouth gape of about 100*μ*. The larvae were transferred to 5 tonne capacity FRP tanks in which mixed culture of copepods were maintained in green water produced by adding cultures of *Nannochloropsis*. The larvae started feeding on nauplii of copepods from the third day of hatching. From the 12th day onwards the larvae were also fed *ad libitum* with freshly hatched *Artemia* nauplii. From the 16th to 21st day of hatching the larvae metamorphosed into juveniles. The length of the just metamorphosed juvenile ranged from 10 -13 mm.

Chrysiptera cyanea

Broodstock development was done in two tonne capacity FRP tanks with biological filter and by feeding *ad libitum* with natural feeds. The size of broodstock fish ranged from 5 to 6.5 cm. The number of eggs per spawning ranged from 2000 - 2500. The interval between successive spawnings ranged from 5 to 20 days. The eggs were either attached to the sides of the broodstock tank or on the substratum provided in the broodstock tank. The eggs were oval - shaped and measured around 1.3 mm in length and 0.6 mm in width. Parental care by the male was noted. Hatching occurred on the night of the third day of incubation. The larvae were altricial type but with mouth opening at the time of hatching. The length of newly hatched larvae averaged to 2.5mm and the mouth gape around 150 μ. Larviculture was done in five tonne capacity FRP tanks by employing greenwater produced by the microalgae *Nannochloropsis occulata*. Different larviculture systems were experimented by varying the cell counts of greenwater and the live feeds. The cell counts of green water employed for the experiments were 1×10^4 ml^{-1}, 1×10^5 ml^{-1} and 1×10^6 ml^{-1}. Four sets of experiments were conducted by feeding with different live feeds – one set with enriched rotifer (*Brachionus rotundiformis*) alone, the second set by employing mixed culture of two copepods species viz. *Euterpina acutifrons* and *Pseudodiaptomus serricaudatus*, the third set by employing copepods and rotifers together as live feed and the fourth set with copepods as starter feed for the first six days followed by enriched rotifers from 7 -15 dph. The larval survival was recorded on 15th day of post-hatch. Feeding experiments with *B. rotundiformis* alone and those with *B. rotundiformis* and copepods together as live feeds were not successful. Co-culturing of the two selected species of copepods in the optimum range of cell count of greenwater gave the best survival. In this set, survival rate of larvae on 15 day post-hatch (dph) ranged from 5 to 8%. The maximum survival rate was 5-6% in the group fed with copepods as starter feed upto 6 dph followed by enriched rotifers from 7 to15 dph. It was noted that a cell count range of 1×10^5 cells ml^{-1} was the optimum which yielded the maximum larval survival in both these sets of experiments. After 15 dph the larvae were fed with freshly hatched *Artemia* nauplii and no further mortality was noted. Metamorphosis of larvae started from 24th day and all the larvae metamorphosed by 30^{th} day.

The larviculture protocols of the other species are similar to the above.

Grow- out methods

Grow out of ornamental fishes can be effectively practised in *happas* installed in nearshore areas. The growth was found to be much faster. The major advantage is that the colour is much brighter in fishes grown in *happas* due to natural light and good exchange of water. The site for installation of *happas* should have at least 2 m depth of water, good dissolved oxygen content, free from industrial contaminants, low anthropogenic pollution and easy accessibility from land. A protected area is generally preferred.

Construction of floating hapa

Rectangular shaped fixed floating *happa* (2.5 m x 1.5 m x 1.5 m) with PVC frames (dia 1.5 inch) for supporting the net bag structure and to retain the shape are used for the grow out phases of juvenile to marketable size. Here the advantage is that it provides better water exchange and natural environment to the fishes.

Good quality HDPE net having 0.5 mm and 1 mm mesh size could be used to make the net bag. Double layered net bags are stitched in 2.5 x 1.5 x 1.5 m depending upon the design and requirement of the frame. Nylon thread is used for stitching the cages. Nylon rope (6 mm dia) is used for tying the bags and poles. All the joints are reinforced with nylon ribbon (1-1.53). Ribbon loops are provided at regular intervals (0.5 m) both on the upper and lower margins of the *hapa* for tying the sinkers at the four corners with nylon rope. The top of the *hapa* is also covered with net frame. Two opposite corners of the top cover of the *hapa* is made detachable so as to enable regular feeding, growth monitoring and harvesting.

Survival of 90-95% is obtained through proper feeding with different wet feeds like boiled sardine flesh, chopped clam meat, mussel meat and formulated dry feed, two times a day *ad libitum*. Since the *hapa* was installed in the sea, fouling was a regular phenomenon and regular monitoring is advisable. Cleaning the net with coir brush has to be carried out on daily basis. Checking of the outer and inner net was also recommended on daily basis to detect any defects in nets. In addition to this, checking of mooring system twice in a week is advisable. *Hapa* reared marine ornamental juveniles grow faster with increased survival rate and good colouration thereby juvenile fetching better price in the market.

Feeds

For feeding marine ornamental fish CMFRI has scientifically evaluated feeds containing not less than 30 % protein, 9 % fat, 39 % carbohydrates, 7 % ash (minerals) and less than 2 % fiber. These feeds are made up of marine protein, soy protein, wheat flour, oil, vitamins, minerals, color imparting nutrients, immune promoters, an anti-oxidant, antifungal and probionts. They are sold in packets of 50 g capacity. Technology commercialization package is available for production and marketing of this product with CMFRI as knowledge partner.

Prospects of development of a trade through hatchery production

The damaging fishing methods which destroy the fragile corals and over harvesting of the species in demand are the vital problems associated with the trade. It is widely accepted that the ultimate answer to a long term sustainable trade of marine ornamental trade can be achieved only through the development of hatchery production technologies. In this context it is imperative to develop commercially viable seed production techniques of species which are in demand. It is well accepted as an environmentally sound way to increase the supply of marine ornamentals by reducing the pressure on wild population and producing juvenile and market sized fish of wide variety of fish year round. In addition hatchery produced fish are hardier and fair better in captivity and survive longer. The methodologies developed by CMFRI can be scaled up for commercial level production and a hatchery produced marine ornamental fish trade could be developed.

Health Management in Hatchery and Grow-out Mariculture

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Introduction

Mariculture has been steadily growing over the last few decades. To satisfy the increasing demand of local and export markets for fish and to control overexploitation of marine fish species, many countries are expanding mariculture activities. Disease is one of the most limiting factors in mariculture. Intensification of mariculture favours pathogens, which increase disease outbreaks. Diseases are broadly classified into infectious and non-infectious diseases. Infectious diseases are further divided into four groups based on the nature of the pathogen: viral, bacterial, parasitic, or fungal. Non-infectious diseases are divided into neoplastic diseases, genetic and environmentally induced diseases, and nutritional deficiency diseases. Sustainable aquaculture production can only occur when fish are healthy and free from disease. Fish disease management is a combination of preventing the onset of disease and measures to reduce losses from disease when it occurs. Fish cultured in floating cages become particularly susceptible to disease when various environmental parameters such as temperature, salinity, dissolved oxygen and suspended particles fluctuate suddenly or widely, or following rough , although often unavoidable, handling operation. Once conditions suitable for pathological changes develop, progress to disease in the warm water environment is rapid. Early detection of behavioural changes and clinical signs in the cultured animals are critical for proper diagnosis of the disease.

Disease rarely results from simple contact between the fish and a potential pathogen. Environmental problems, such as poor water quality, or other stressors often contribute to the outbreak of disease.

Fish health management

Fish health management is a term used in aquaculture to describe management practices which are designed to prevent fish disease. Once fish get sick it can be difficult to salvage them. Successful fish health management begins with prevention of disease rather than treatment. Prevention of fish disease is accomplished through good water quality management, nutrition, and sanitation. Without this foundation it is impossible to prevent outbreaks of opportunistic diseases. The fish is constantly bathed in potential pathogens, including bacteria, fungi, and parasites. Even use of sterilization technology (i.e., ultraviolet sterilizers, ozonation) does not eliminate all potential pathogens from the environment. Suboptimal water quality, poor nutrition, or immune system

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suppression are generally associated with stressful conditions which allow these potential pathogens to cause disease.

Predisposing factors

- Fish stocks living under stressful conditions are less able to defend against a pathogen and hence will become sick more readily. Fish that are well cared for generally do not become sick even in the presence of a pathogen. The most common error in fish husbandry is overstocking. This leads to problems such as:
- Fish to fish aggression.
- Increased fish and feed wastes.
- Ease of disease spread.
- Increased concentration of pathogens.
- Resultant poor water quality.

High fish density, stress, and ease of transmission increase susceptibility of the fish population to diseases and parasites. In marine aquaculture, diseases present in wild fish can infect cultured fish and spread rapidly.

Types of fish diseases

There are two broad categories of disease that affect fish, infectious and non-infectious diseases. Infectious diseases are caused by pathogenic organisms present in the environment or carried by other fish. In contrast, non-infectious diseases are caused by environmental problems, nutritional deficiencies, or genetic anomalies; they are not contagious and usually cannot be cured by medications.

- **Infectious diseases**. Infectious diseases are broadly categorized as parasitic, bacterial, viral, or fungal diseases.

Common Diseases of Cobia (*Rachycentron canadum*)

S.No	Bacterial disease	Causative organism
1	Pasteurellosis	*Photobacterium damsella* sub sp *pisicida*
2	Streptococcosis	*S. iniae*
3	Vibriosis	*V. anguillarum*
4	Bacterial enteritis	*V. alginolyticus*
5	Mycobacterium infection	MY. Sp 2nd *Aeromonas hydrophila*
6	Viral disease Lymphocystis	Irido virus

Common Diseases of Pompano (*Trachinotus blochii*)

S.No	Disease	Causative agent
1	White spot disease	Ciliate protozoan, *Cryptocaryon irritans*
2	Cardiac myxosporidiosis	Myxosporidian protozoan, *Henneguya* sp.
3	Monogenetic trematode infestation	*Bicotylophora trachinoti*- gills *Benedenia* sp- body
4	Fatty degeneration	Dietary deficiency- protein
5	Parasitic dermatitis (infestation)	Sea lice (*Calligus elongatus*)
6	Amyloodiniosis	*Amyloodinium ocellatum*

Common diseases of marine ornamental fishes

S.No	Disease	Causative agent
1	Red pest	Gram negative bacteria
2	Fin Rot	Gram negative bacteria
3	Fish tuberculosis	*Mycobacterium* sps
4	External Gas Bubble disease	Various causes Commonly caused by excess gas in the system, brought about by super-saturation of gas in high pressure water mains

- **Vibriosis** is a bacterial disease causing significant losses of fish in marine fish farms. Cobia, Grouper, seabream, snapper and pompano species are affected. Vibriosis results in severe skin, muscle, fin, eye and internal organ damage of fish. Diagnosis of the disease requires bacteriological culture of kidney, spleen, skin or eye lesions.
- **Non-infectious diseases**: Non-infectious diseases can be broadly categorized as environmental, nutritional, or genetic.
- A hygienic fish culture environment is essential to the health and productivity of farming operations. The reasons for this include:
- Disease risks are increased in poor and polluted environments.
- Quality of the product depends on clean and healthy environments.

The culture environment incorporates the following components

- Physical farm infrastructure e.g. fish cages, floats, nets, and utensils.
- Water quality e.g. dissolved oxygen and microbial contamination.
- Seabed sediments e.g. solid wastes measured as carbon, nitrogen and phosphorus.
- Introduced chemicals e.g. antibiotics, metals and pesticides.

Husbandry practices:

- Removal of biofouling from net/pens.
- Cleaning of utensils and equipment used to handle fish or feed fish.
- Water quality testing and correction of poor water quality includes the following:
- Measurement of dissolved oxygen and water.
- Maintaining optimal water quality parameters e.g. salinity, temperature, pH, ammonia, nitrite and nitrates.
- Regular assessment of bacterial load of *Vibrio* spp. in water.
- Aeration to maintain optimal dissolved oxygen level.
- Cleaning of the farm seabed and fallowing or rotation of sites.
- Minimising organic pollution from fish wastes and feed wastes.

Preventive measures

- Preventing the introduction of pathogens by proper quarantine procedures.
- Maintenance of good water quality.
- Avoidance or reduction of environmental stressors.
- Adequate nutrition.
- Isolation of cultured animals from feral stocks.
- Regular immunization against major pathogens.

Steps to solve a disease problem

- Determining that a problem exists.
- Identifying the cause of the disease or source of the distress.
- Successfully curing the fish and eliminating the disease or cause of distress.

Hormonal Induction of Spawning in Marine Finfishes

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Introduction

In recent years, especially with the development and expansion of sea cage farming, mariculture is growing rapidly. On a global basis, a rapid growth in marine finfish culture is noted. It has increased at an annual average growth rate of 9.3% from 1990 to 2010. Salmonids, amberjacks, sea breams, sea basses, croakers, groupers, drums, mullets, turbot, other flatfishes, snappers, cobia, pompano, cods, puffers and tunas are the major groups which are maricultured. For most of the cultured species, supply of wild fry from natural sources is insufficient and fluctuates with environmental and climatic conditions. One of the major requirements for the growth of sea cage farming is the availability of breeding techniques that can produce sufficient quantity of seeds of different high value marine finfish. By manipulating environmental and hormonal factors seed can be produced year round rather than relying on wild-collection thereby reducing cost and disease.

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

Gametogenesis and reproductive behaviour

A cascade of events leads to release of mature gametes from ovaries and testes. Marine fishes produce and release sex cells based on maturity of the individuals, their nutrition and overall health, triggered by cues from the environment (temperature, light/dark duration, tides, presence of conspecifics, mates, *etc*.) that in turn influence their hormonal/endocrine systems. Along with endocrine control there is also a steady, intimate, more sudden interplay of the fishes' nervous system.

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Conditioning and triggering of actual spawning involves combining knowledge of modes of reproduction, social factors such as sex ratios, environmental manipulation and possibly direct/exogenous hormonal administration. Either proper environmental stimuli or administration of hormones acting at the level of the hypothalamus, pituitary, or gonads will affect successful release of mature gametes.

Hormonal manipulation

The endocrine system acts like a chemical link between an organism and its environment. Hormones are slow-acting chemical messengers. Along with the faster acting central nervous system they serve to moderate, direct and sustain the physiology of all animals.

Reproduction of fish in captivity can be controlled by environmental manipulations, such as photoperiod, water temperature or spawning substrate. However, the ecobiology of some fishes is not well known, or it is impractical or even impossible to simulate the required environmental parameters (i.e., spawning migration, depth, riverine hydraulics, etc.) for natural reproductive performance. Almost all fishes reared in captivity exhibits some form of reproductive disfunctions. The disfunctions probably result from the combination of captivity induced stress and the lack of the appropriate natural spawning environments. In females there is a failure to undergo final oocyte maturation, ovulation and spawning while in males; there is a reduction of milt quantity and quality. In these instances, use of exogenous hormones is an effective way to induce final oocyte maturation (FOM) and ovulation in females and spermiation in males and produce fertilized eggs. In some fishes, these hormonal manipulations are used only as a management tool to enhance the efficiency of egg production and facilitate hatchery operations, but in others exogenous hormones are the only way to produce fertilized eggs reliably.

Hormonal manipulations of reproductive function in cultured fishes have focused on the use of either exogenous luteinizing hormone (LH) preparations that act directly at the level of the gonad, or synthetic agonists of gonadotropin-releasing hormone (GnRHa) that act at the level of the pituitary to induce release of the endogenous LH stores, which, in turn act at the level of the gonad to induce steroidogenesis and the process of FOM and spermiation. After hormonal induction of maturation, broodstock should spawn spontaneously in their rearing enclosures.

Effectiveness of hypophysation (injection with pituitary hormones) is dependent on the stage of reproductive development of recipients. Injection of hormones in an unripe adult will not generally induce gametogenesis or ripening of eggs. Determination of spawning-readiness is sometimes associated with color or marking changes and distension of the body. There are chemical assays of body fluids which can also be used as guides of readiness, but these are not as commonly employed as much as simple hand-stripping of gametes, their mix and microscopic examination as a guide to broodstock fitness.

Care must be exercised in assaying sexual readiness in spawners. Sometimes generally adopted parameters have proven unreliable. An example of this is females with enlarged abdomens, reddish coloration and protrusion of the cloacal region may be due to engorgement of the intestine, or disease, even during the spawning season. It is often necessary to sacrifice some of the broodstock to assess their reproductive stage.

Two methods of injection are in wide practice (1) Intramuscular, in the flank just below the dorsal fin and behind the gill cover. This method is safer but slower working. (2) Intraperitoneal injections are faster acting but involve a greater chance of injury or death as the injections are made into the body cavity.

Maturation and spawning

At the onset of the spawning season, it is necessary to move selected broodstock fishes from maturation tank to spawning tank after assessing the ovarian development through cannulation. Only females with oocytes in the late-vitellogenic stage, with a diameter around 700 μm in cobia and 500 μm in pompano, are selected.

Ovarian biopsy can be carried out as follows:

- Female brooders have to be transferred to a small tank containing anaesthesia in sufficient quantity.
- Flexible sterile catheters (1.2 mm internal diameter) can be used for cannulation biopsy.
- Introduce the sterile catheter into the oviduct, up to the ovary for a few cm; then suck carefully a small sample of oocytes up into the catheter and place the sample on a glass slide.
- After sampling, release the animal into the spawning tank, where recovery from sedation will take place.
- Put few drops of filtered sea water on the biopsy sample and examine under the microscope and measure the diameter of the oocytes and record the measurements.

Induced spawning

Induced breeding is commonly practiced in most commercial hatcheries. The hormonal treatment is intended to trigger the last phases in egg maturation, i.e. a strong egg hydratation followed by their release. However, if eggs have not reached the late-vitellogenic (or post-vitellogenic) stage, the treatment does not work; hence ovarian biopsy is essential for assessing the ovarian development. The human chorionic gonadotropin (hCG) is used at a dosage of 500 IU per kg of body weight in cobia females and 250 IU per kg body weight for males, whereas, for pompano 350 IU per kg body weight is used for both male and female. This dosage can be administered as a single dose on the dorsal muscles. Use of hCG treatment sometimes gives serious setbacks like not all females respond to it, egg quality may be below acceptable standards with hatching rate lower than 80%, being a large molecule it may provoke immunization reaction , and as a result, fish treated with hCG may not respond when treated repeatedly with this hormone. However, hCG can be successfully replaced by an analogue of the luteinizing hormone-releasing hormone [LH-RHa des-Gly10 (D-Ala6) LH-RH ethylamide, acetate salt]. It is a small molecule with 10 peptides and acts on the pituitary gland to induce the release of gonadotropins which, in turn, act on the gonads. Almost 100% of injected fish spawn eggs whose quality usually matches that of natural spawning.

The cost of LHRHa is very high compared to that of hCG. But, LHRHa is used in very low dosages, usually around 20 μg / kg of body weight.

Capture Based Aquaculture

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Introduction

India is the second largest producer of fish in the world and its share in the national GDP is around 1.4%. With continued human pressure on marine fisheries and ocean resources, aquaculture has become one of the most promising avenues for increasing marine fish production in the future. On a global scale, the decline of fish stocks has been a motivating factor for expanding aquaculture in the fishing industry. It is well known that the ready availability of seed in adequate quantities is a major constraint in the expansion of mariculture. In this context, capture based aquaculture/mariculture can be considered as a viable option for augmenting the production of high value species.

Categories of finfish farming include hatchery-based rearing from egg to adult and capture-based aquaculture (CBA), which involves capturing "seed" material from the wild, then growing it to marketable size in captivity, using aquaculture techniques (FAO, 2004). CBA is an interface between capture fisheries and true aquaculture and provides an alternative income for local coastal communities in developing and several industrialized countries. It has been estimated that CBA accounts for about 20% of the total quantity of food fish production through aquaculture, which is about 7.5 million tonnes per year, mostly molluscs. The production of finfish, especially carnivorous species (including milkfish, groupers, tunas, yellowtails and eels), through CBA, is currently receiving the most attention. CBA has developed due to the market demand for some high value species for which seed production technology is not yet standardized. Many of the environmental concerns associated with the grow-out of juveniles produced in hatcheries like transfer of diseases and 'genetic pollution' of wild stocks are not encountered in CBA. As CBA potentially generates higher profits than other aquaculture systems, the market demand for the products and species cultured is high and it is likely that efforts to promote this activity in future will increase significantly.

Species selection

Potential marketatability, economic value, growth rate, performance under captive conditions *etc.* are the main criteria to be considered for species selection in CBA. Most species farmed under CBA are carnivorous due to their higher market demand and value. CBA is practiced for finfish (eels, groupers, blue fin and yellow fin tunas, yellow tail *etc.*), molluscs (oysters, mussels, scallops) and crustaceans (shrimps, crabs) (Pillay, 1995).

Yellow tail

Under the genus *Seriola* (Family: Carangidae), three species are widely used for CBA: the Japanese amberjack

S. quinqueradiata, greater amberjack *S. dumerili*, and gold striped amberjack *S. talandi*. Yellow tails are cultured in Asian countries and in the Mediterranean. Fish aggregating devices (FAD) set along transects extending from shallow coastal waters to offshore (up to 500 m) are used for wild seed collection.

Tuna

In the recent past there has been a rapid increase in the CBA of bluefin tunas, *Thunnus thynnus* (North Atlantic and Mediterranean) and *Thunnus thynnus orientalis* (North pacific) and *Thunnus maccoyi* (Australia). Individual 'rod fishing' with single hook has been adapted for catching juveniles and sub adults. Barbless hooks are used for capturing specimens weighing several kilos. Purse seine fishery is the most important provider of live tuna for CBA. Tuna traps placed in the course of its trophic migration also provide specimens for CBA. The main CBA producers of tuna are Australia, Spain, Croatia, Malta and Mexico. In Japan juveniles of 150-500 g are reared in net cages for 3- 4 years until they reach 30-70 kg when they are harvested and marketed. The major problem encountered in Japan is in obtaining juveniles for culture. In the Mediterranean region, bluefin tuna fattening is a major industry, where live catches taken from wild are reared in offshore HDPE floating cages (30- 50 m diameter) and kept for variable periods ranging from a few months to years depending on the farming location and fish size. In Morocco, 120 x 40 x 30 m HDPE floating net cages moored in open sea at a depth of 55 m are used for tuna farming. In Australia, 50 m diameter floating cages, partially anchored are employed for tuna farming, for its convenient shifting from one location to another. Irrespective of its high production cost, tuna farming is highly profitable due to the heavy demand for 'sushi' and 'sashimi' products in Japan. The fish raised by CBA are not only gaining weight, but also adds on the fat content which makes it more valuable.

Groupers

Epinephilus coides, E. tauvina and *E. malabaricus* are the most abundant species caught for CBA. Grouper seed are caught by artisanal methods from coastal areas, particularly around seagrass beds, mangroves and shallow brackishwater areas. Large fixed nets, traps and shelters, hook and line, artificial reefs *etc.* are employed for catching the seed (1-4 cm). Groupers are cultured in South East Asian countries including Indonesia, Malaysia, Philippines, Taiwan Province of China and Viet Nam. Groupers can grow into 600 g in 12 months and marketable size is attained in 8 months (>500 g). Wooden cages are employed for grouper farming. The market is dominated by trade through Hong Kong. The future development in CBA of groupers is likely to be influenced by factors like (i) development of markets outside the specialist live markets, (ii) cost effective production methods so that 'non live' markets can be accessed at a profit, (iii) development of formulated feeds to avoid using trash fish, (iv) better management practices for disease control and (v) development of new culture systems to move beyond the existing congested/ polluted sites.

Eels

The eel catch comprise of the European eel *Anguilla anguilla*, Japanese eel *A. japonica,* American eel *A. rostrata* and shortfin eel *A. australis*. Global eel culture is totally dependent on the availability of glass eels and elvers. Japanese and European glass eels supply the international eel market. Juvenile eels are captured by hand nets, traps, trawlers using wing net, dip net *etc.* Eel farming employs a variety of reliable well established systems from relatively low density flow- through pond culture, semi intensive pond and tank culture to super high density closed recirculation tank culture. Intensive eel farms rely on artificial feed in the form of moist paste for glass eels and steam pressed or extruded pellets for later developmental stages. Advantage of eel culture is that they can be stocked at very high densities.

The Indian scenario

Irrespective of its vast potential, the marine/ brackishwater culture production in India is only about 3-4 lakh tonnes annually, which is almost entirely from shrimp production. Even though many Asian countries are leading in mariculture, India is yet to make an impact in this sector. Constraints are many in this line. However, it is time that India should focus on these issues and make a change in the present scenario of mariculture production. Commercial level seed production techniques are to be standardized for many species except Asian seabass. In many non selective gears, and shore seines juveniles of high value fish are caught which are either discarded or sold for nominal prices. If suitable measures are followed, these juveniles could be used for CBA for resource conservation as well as for increased seafood production.

Research & Development on CBA in India

Shrimp

During the first half of the 20th century, prawn filtration in traditional paddy fields in Kerala involved only trapping young ones brought in by high tide and holding it for few days and harvest by filtration during the lowest low tide. Menon (1954) was the pioneer in prawn farming in India and he has reported a production of 400 lbs/ acre/ crop of *Penaeus indicus* in 2-3 months and Muthu (1978) has modified the culture system by stocking with fast growing species and adoption of scientific farming for achieving higher productivity. Central Marine Fisheries Research Institute (CMFRI) has given elaborate guidelines for utilizing a variety of wet lands, in addition to the traditional prawn filtration areas, such as backwater and estuarine areas, brackishwater canals in coconut groves and derelict water bodies along the coastlines. The two candidate species recommended for shrimp farming in India were *P. indicus* and *P. monodon* (Alagarsami, 1981). The availability of shrimp seed, shrimp seed collection, identification and transport *etc.* were recorded by many researchers of CMFRI over the years. Now except for the few traditional farms, the shrimp culture industry is entirely dependent on hatchery raised seeds from India as well as imported from other countries.

Lobster

Spiny lobsters *Panulirus homarus, P. polyphagus, P. ornatus, P. Pencillatus*, *P. longiceps* and sand lobster *Thenus orientalis* are the lobster species available in India for farming or fattening. Farming/ fattening of sand lobster *T. orientalis* has been demonstrated by CMFRI and the technology has not been perfected to commercial level. Radhakrishnan (1995) has detailed on the spiny lobster farming in India. CBA of lobster has potential in India because of its high value and demand from export market. *P. polyphagus* fattening in cages has been successfully carried out in Gujarat and Mumbai.

Crab

Mud crab *Scylla serrata* and *S. tranquebarica* are suitable species for farming in India. Even though seed production technology has been developed for these species, adequate quantity of seed is not available for extended farming practices. Fattening of wild collected crab is practiced in several states in India. About 300-400 g size individual crab kept in small brackishwater cages for two to three weeks by feeding trash fish are exported live to South East Asian Countries.

Mussel and Oyster

Perna indica and *P. viridis* are the two species of mussels suitable for farming in India. CMFRI, National Institute of Oceanography, Goa, Konkan Krishi Vidyapeeth, Ratnagiri and Central Island Agricultural Research Institute (CIARI), Port Blair, have implemented research programmes on mussel farming. From early 1970s itself, CMFRI has developed grow-out structures suitable for open sea farming, seeding method and farm management measures. The first commercial mussel farm in the country was set up at Padanna, Kasaragode, Kerala in the year 2000 (Appukuttan *et al*., 2001). Mussel culture in India is entirely based on CBA and the total production of farmed mussel is around 20,000 tonnes.

One of the first reports of CBA of oyster in India is that of Hornell (1910) who has attempted collection of oyster spat by placing lime- coated tiles in Pulicat Lake. Awaiti and Rai (1931) have reported oyster fattening at Kelwa, Navapur and Utsali in Maharashtra. However, the concerted efforts to develop farming methods were started at CMFRI in 1970s. Methods for spat collection and grow out culture methods (rack and tray, stake, rack and ren methods) were developed then onwards.

Clam

The farming techniques and production rates of the blood clam *Anadara granosa, Meretrix meretrix, M. casta* and *Villorita cyprinoides* have been developed by CMFRI from 1980s. *Paphia malabarica* and *V. cyprinoides* are widely distributed in the major estuaries of west coast and in several regions semi- culture systems are developed wherein under sized clam caught in the fishery are stocked for further growth and for harvest after 2- 3 months.

Marine finfish

The major marine finfish species which are cultivable include Asian seabass (*Lates calcarifer),* rabbit fish (*Siganus* sp.), groupers (*Epinephelus* spp.), pompano (*Trachinotus* spp.), snappers (*Lutjanus* spp.), seabreams (*Lethrinus* sp., *Sparus* sp.), cobia (*Rachycentron canadum*), pomfrets and seer fishes. Currently mariculture of finfishes is almost entirely supported by the seed collected from wild. It has been reported that on a small stretch of 100 km of N. Andhra coast, shore seines land about 15 lakh juvenile seerfish in April, which can easily be conserved in live condition for CBA. Similarly good juvenile fishery for pomfrets exists along Orissa, Maharashtra and Gujarat which can be taken advantage for CBA till their seed production techniques are developed and standardized. Similar opportunities exist for many more marine fish seed along our inshore area and Andaman and Lakshadweep area through most seasons along the coasts. Survey on distribution and availability of fish seed resources has been carried out from estuaries, backwaters and coastal waters in India by CMFRI. CMFRI has carried out experimental pen and cage culture of different species of fishes like rabbit fish (*Siganus canaliculatus, S. javus*), groupers (*E. tauvina* and *E. hexagonatus*), and the sand whiting (*Sillago sihama*).

Impacts of CBA

Wild source of seed will be unsustainable in the short term and inadequate in the long term because the catch per unit of effort of seed whether juveniles or adults- appears to be in decline. Overfishing of the target resources frequently occurs during normal fishing activities, but is exacerbated by the demand created by CBA. The collection of seed for CBA can also lead to mortalities in non-target species and the destruction and disturbance of habitats; it also generates discards, contributing further to the depletion of other resources. In addition, the transfer of seed to CBA farms is characterized by high mortality rates (and thus wastage of resources).

The culture of fish in cages can cause potential threat to the surrounding environment. Such impacts include distortion of local ecosystem, eutrophication, pollution, transmission of parasites and pathogens and aesthetic deterioration in coastal areas. The effects of CBA on environment can be significantly reduced by careful site selection, controlled stocking, good feeding regimes, good health management and accurate environment impact assessments.

CBA represents an alternative livelihood for coastal communities and have significant, positive economic returns in those economically backward areas. CBA can have significant economic multiplier effects, due to labour intensiveness associated with operating and infrastructure requirements, exporting of fresh, chilled and frozen products *etc.* Related activities can also generate significant number of jobs. It can also contribute to poverty alleviation in developing nations and enhance the standard of living of the poor.

Considerations for sustainable CBA

The application of responsible production methods should be the main consideration in CBA. In many cases, CBA represents the first step towards true aquaculture. However, this evolution will not affect the characteristics of certain forms of CBA as currently practiced, such as the stocking of large bluefin tuna. Furthermore, the CBA of new species will emerge. It is therefore essential that governments explore and develop legal and institutional instruments that recognize CBA as a distinct sector. CBA also needs to be integrated into resource use and development planning. International agreements for specific actions in the CBA sector need to be drafted and signed by all the countries that share common resources. The management of CBA, particularly where the practice is currently unsustainable, needs to be improved. If governments are actively promoting CBA, it is likely that it will lead to the rearing of new aquaculture species, reducing the pressure on existing wild stocks.

Future Perspectives of CBA

CBA is to continue to expand in the short term, both with finfish species currently under exploitation likely and probably with others that will be selected for rearing in the future. In the case of non-finfish species, such as a variety of bivalves (e.g. mussels), CBA is certain to continue indefinitely in view of the very large number of seed released. However, the CBA of selected species of finfish is more uncertain; where it becomes a direct competitor of capture fisheries it is therefore critically important that economically viable means be found to rear the species concerned throughout their full life cycle. When that goal is achieved, not only will the future aquaculture production of those species be assured, but the feasibility of restocking programmes may be explored to enhance their capture fisheries. It is felt that with effective regulations and management practices, the CBA offers good scope and potential for the artisanal and industrial sectors in the years to come.

Genome-based technologies in Mariculture

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Fish genetic resources for food mostly come from the capture due to low domestication level in fisheries sector. Aquaculture can play a pivotal role in providing nutritional and livelihood security for the growing global populations. The aquaculture technologies so far developed are primarily based on husbandry and management practices. They have their own limitations and beyond which they may not be economical. At this juncture, recent technological advancements in the field of genetics and biotechnology have provided immense scope for the growth in aquaculture to meet the challenges ahead. The history of fish genetics has been reviewed by Gjedrem (2005). The different approaches available in the field of genetics in fishes are selective breeding, hybridization, genome manipulations, hormonal sex reversal and transgenics.

Selective breeding

Selection is aimed at modifying the genetic structure of a breed in order to obtain animals with superior performances for the traits of interest. Selection may be done to increase yield, survival rates and resistance to biotic and abiotic stress and also for improving product quality. Selective breeding that exists in nature is called 'natural selection'. In this process, the most strong and fittest individual that can withstand variation or the changing situations in their environment alone will survive. Such individuals which can perform well or the best can also be developed through artificial selection also. Artificial selection is a classical approach and the methods have been profitably utilized in aquaculture too.

There are different methods of selection, *viz*., mass selection, family selection, within family selection, combined selection etc. In the case of fishes, most commonly followed methods are either family selection or mass selection. Most of the time, combined selection is also followed. While mass selection can be used for only a single trait, family selection/combined selection helps in selecting for different traits such as growth, disease resistance, meat quality or reduced fat content etc. In any selective breeding programme the individuals that perform more than the population average for the target traits are captive bred and progeny is again selected for generations for the breeding purpose. In the whole selection programme, caution is taken to avoid breeding of closely related individual which depress the possible genes due to inbreeding. In aquaculture, genetic selection and hybridization have been used for growth, carcass composition and quality. Some of the successful examples of selective breeding programmes in aquaculture are Atlantic salmon in Norway, Jayanti Rohu in India and Nile tilapia in Asia. A pioneering effort in selection programme in developing tropical countries has improved the tilapia breeds in the Philippines. The International Centre for Living Aquatic Resources Management (ICLARM – presently the World Fish Centre) and the Collaborating Philippine and Norwegian

Institutes have achieved about 60% gain in growth of Nile tilapia on farm trials under a project known as Genetic Improvement of Farmed Tilapias (GIFT). The GIFT project was established in 1988 and worked on the status of Asian and African tilapia stocks and towards the development of self-sustaining national fish breeding programmes. It concentrates on Nile tilapia, a species that is of interest to over 60 countries. Its short generation interval, from six to ten months in a breeding programme, makes it an excellent model for the development of applied genetic improvement methods for fish. The other important aquaculture genetic improvement programmes that are in progress include *Penaeus monodon, Marsupenaeus japonicus, Fenneropenaeus chinensis* and *Litopenaeus vannamei* for traits such fast growth rate and disease resistance; and for smaller naupliar size (SNS) in *Artemia franciscana* and Indian strains of *Artemia.* Artemia cysts are the most extensively used live food for most diversified groups of aquatic animals. Although its size at different stages especially the naupliar length restricts its use as a food for some groups of fish, this problem can be overcome using selective breeding techniques. In an experiment at the Central Marine Fisheries Research Institute (CMFRI), Kochi, Kerala, bidirectional mass selection was employed to reduce the naupliar length of *Artemia franciscana*. Six generations of selection for smaller naupliar size (SNS) resulted in a phenotypic response of -45.32 mm and -37.52 mm decreases in naupliar size in males and females respectively compared to the control (Shirdhankar *et al*., 2004). It is apparent that there is much scope for the application of quantitative genetics to improve the performance of several cultured finfish and shellfish species of Indian waters.

In a selective breeding programme, we select the best performing individuals/family from the population so that they can produce the best progeny. Again from the progeny, we select the individuals for breeding. Thus, generation after generation selective breeding of stock goes on. Additive genetic variation increases in the selected breed and thus the stock is improved for the particular trait. In the selection programme, care is taken about the genetic relationships of the individuals because closely related individuals when bred show inbreeding depression. In selective breeding programmes, as aquatic animals are too small to tag by physical methods, families must be reared for long periods in separate cages, tanks or ponds until they can be tagged at the family or individual level. This approach is space and labour intensive and generally takes place on dedicated breeding facilities rather than on production farms. DNA fingerprinting has been proposed as tool for reconstructing the pedigree of communally reared aquaculture populations. Recent investigations of VNTR (Variable Number of Tandem Repeat) loci using multi-locus and single-locus DNA fingerprinting of several fish populations have yielded promising results showing high level of polymorphism and resolution at the level of individual sub-population and population. Use of molecular markers in aquaculture studies are mentioned below.

Molecular markers

The potential of molecular marker assisted selection and the domestication programmes are often explored, benefitting from the development of new genome resources and analytical tools. Molecular markers can be used in a variety of aquaculture studies, at the individual or population level, and the choice of the markers to be used depends on both the aim of the research and on the marker characteristics. Molecular markers often used in population genetic studies too. The main purpose of *population genetic* studies is to provide tools for preserving the existing genetic variability, which is fundamental for the survival of the species, because it allows individuals to face changes in the environmental conditions. Genetic homogeneity in the stocks of the pearl oysters (*Pinctada fucata*) and grey mullet (*Mugil cephalus*) from east and west coasts of India were reported by CMFRI using allozyme markers. Similarly, using mitochondrial markers, allozymes, RAPD and morphometrics data, populations of Indian mackerel (*Rastrelliger kanagurta*) and oil sardine (*Sardinella longiceps*) from east and west coasts of India were reported belong to the same unit stock. However, there has been growing evidence from genetic markers that even the widespread marine species are geographically structured, and that there can be sharp genetic disjunctions sometimes where there are no obvious barriers to dispersal. Such evidence has been observed in the stocks of shrimp *Penaeus monodon*, *P. indicus,* skipjack tuna *Katsuwonus pelamis* and the endangered marine white fish, *Lactarius lactarius* from east and west coasts of India with allozyme and RAPD markers and TRUSS network analysis (Lakra and Gopalakrishnan, 2009).

Any selection programme leads to a reduction of the genetic diversity, which should be limited as much as possible in order to avoid the negative effects, known as inbreeding depression. From this point of view, molecular information can be used to maximize the genetic diversity when assembling a founder population in order to ensure maximum long-term genetic response from the breeding programmes. The routine population genetic studies using neutral/type II molecular markers, though useful in devising conservation strategies, reveals little about the adaptive side of the evolutionary coin. For example, the correlation between divergence of neutral markers and quantitative traits among populations of commercially important fishes can, at best, be characterized as weak. As important fitness traits in the wild are often also economically important production traits (e.g. growth, maturation, disease resistance and temperature and salinity tolerance), there will be a number of potential mutual benefits for population genomics and the aquaculture industry by gaining insights into the distribution of adaptive genomic variation in natural fish populations of the cultivable species. The link of population genomics with aquaculture will be capable of providing large-scale facilities for conducting controlled experiments, allowing the establishment of the 'missing' links between DNA polymorphisms, trait architecture and environmental driver of evolution. Accordingly, there is large interest in demonstrating adaptive population divergence at the molecular level, as well as in identifying the genetic architecture of local adaptive traits conferring fitness advantages to resident individuals of species that are in aquaculture. Knowledge of local adaptation is also critical in order to define management units and setting priorities for conservation.

Linkage mapping in aquaculture

A linkage map is an ordered listing of genetic markers located along the length of the chromo-somes in the genome. Construction of a linkage map requires four major components: polymorphic markers, genotyping platforms, reference families and software for analysis of linkage among markers. Linkage maps have been used for quantitative trait locus analysis and Marker Assisted Selection (MAS). Microsatellite DNA markers and Single nucleotide polymorphisms (SNPs) have become markers of choice for development of linkage maps.

Linkage mapping of aquaculture species for MAS was initiated later as compared with agricultural livestock. In past 25 years linkage maps of over 40 aquaculture species has been constructed (Yue, 2014), such as fresh-water pearl mussel, tilapia, catfish, Asian seabass, Japanese flounder, European sea bass, Gilthead Sea bream, salmon, rainbow trout, Channel cat fish, Rohu, common carp, Arctic char, tiger prawn, Kuruma prawn, oysters, Scallops and abalones. In India, a genetic programme to develop linkage map of *Labeo rohita* is completed with 68 microsatellite markers consist of 25 linkage groups and 3193 SNPs.

Construction of linkage map using dominant marker (e.g. AFLP & RAPD), small reference family for linkage map construction, low density linkage map and overlapping of linkage map, due to lack of collaboration between the researchers are the various problem encountered in linkage studies.

Aquaculture important traits in QTL (Quantitative Traits Loci) analysis

In aquaculture, recently significant efforts are devoted to the search of markers for most economically important traits such as growth rate, fat content, sexual maturation, sex determination, stress tolerance and disease resistance.

Meat quality

Meat quality traits include fat content, fatty acid profile, colour, texture and dressing yield In most cases, measurements of these traits can only be measured by sacrificing the individuals. QTL for fat percentage and distribution as well as flesh colour were mapped on the genome of salmon for accurate measurement without slaughtering.

Stress tolerance

Salinity and temperature tolerance are two important trait of interest for fishes with purpose to reproduce and grow in areas of higher salinity and lower/higher temperature. QTL for salinity tolerance and temperature tolerance have been identified in some species, such as Rainbow trout, Tilapia, Arctic char and Asian seabass.

Sexual maturation

Sexual maturation is an important trait which influences growth, FCR and fillet quality in several aquaculture species. Therefore, selection for later maturation has been carried out in some species. As phenotypic selection of this trait is difficult and time consuming, MAS in fingering stage is preferred. QTL for sexual maturation have been analysed in rainbow trout, salmon and Arctic charr.

Sex determination

It is controlled by one or more genetic factors, environment and their interactions. Sex determining factors are located on sex chromosomes or on autosomes. In some species, sex is significantly related to growth, such as in tilapia, males grow much quicker than females, while in common carp, females are much bigger than males at the same age. Therefore, sex is regarded as an important trait in aquaculture species. QTL analysis for sex identification has been attempted in tilapia, salmon, rainbow trout and marine mussels.

Disease resistance

Disease resistance is one of the most frequently researched traits in QTL studies as diseases represent one of the major challenges and bottlenecks in aquaculture. QTL for disease resistance have been mapped in several aquaculture species, such as salmon, trout, Japanese flounder and oysters.

Status of QTL mapping in aquaculture species

QTL analyses for important traits have been conducted for over 20 aquaculture species including finfish, mussels and crustaceans. In Tilapia, salmon, rainbow trout, Pacific oyster, Asian seabass, Japanese flounder and Kuruma prawn, QTL for some important traits have been mapped.

Marker-assisted selection

MAS aim to choose the genetically superior individuals using molecular information. MAS is useful for the traits that are difficult to measure and exhibit low heritability. To perform MAS, markers tightly linked to the QTL or major genes directly involved in the phenotypic expression should be found. QTL studies in aquaculture species covered a wide range of traits including growth, meat quality, egg production, disease resistance, stress resistance, reproduction and other traits. All these provide a good starting point to search for QTL within breeding populations. There are already a few example of MAS in commercial breeding programmes in aquaculture species, i.e., Japanese flounder and salmon for resistance to disease. In salmon three markers (SSa0285BSFU, Alu333 and SSa0374BSFU/II), significantly associated with resistance to Infectious Pancreatic Necrosis (IPN), are being applied in the selection for resistance to IPN. The new population of Japanese flounder were developed using MAS with the microsatellite marker, Poli9-8TUF which showed a significant and dominant effect on resistance to the disease.

The application of MAS in breeding programmes means that brooders will be selected according to both genotypes and performance records, rather than on performance record alone. How-ever, to date, little is known about the economic benefits gained from MAS in aquaculture species.

Hybridization

It is well known that hybridization refers to crossbreeding between, either members of different races or strains of the species (intra-specific) or between two species of the same genus (inter-specific) and between species belonging to different genera (inter-generic). Hybridization is usually aimed to combine the positive traits of the parent species in their hybrid offspring. The positive traits may include better growth, resistance to disease/changed environment, meat quality, early or late maturity, better fecundity and so on.

Intra-specific hybridization: Different races or strains of the same species from different geographical regions when crossed have resulted in the production of offspring with heterosis.

Inter - specific and Inter - generic hybridization: It involves hybridization between species or genus. Inter-specific and inter - generic hybridization work among Indian major carps, tilapia, sturgeons *etc.* has shown intermediate traits in some cases and negative traits in others.

In general, hybridization may be useful to combine the positive traits of the parents in the offspring or in producing monosex progeny and also sometimes changing the ploidy status, leading to sterile individuals in certain cases. The resultant traits in the hybrid offspring of any particular cross may probably depend on the compatibility and interaction between the genomes of the two species involved in the cross.

Genome Manipulation (Chromosomal Engineering)

Genome manipulation or chromosomal engineering is another modern approach to produce gynogenetic and androgenetic inbred lines and polyploidy individuals. Gynogenesis and androgenesis are effective tools to produce highly inbred homozygous lines of usually monosex individuals, female and males respectively. These inbred individuals when crossed with normal heterozygous ones may produce offspring with heterosis, particularly for growth.

Gynogenesis:

In gynogenesis the embryo develops solely with maternal genome where in the egg is activated by the sperm without any genetic contribution from the latter. But then the resulting zygotes are haploid. Restoration of diploidy may occur spontaneously in the case of natural gynogenesis or by chemical or a variety of thermal/ pressure shock treatments to the activated eggs in artificial gynogenesis.

Natural gynogenesis: Natural gynogenesis occurs in nature such as coral reefs fishes. In some species of fish of the family Poecilidae and Cyprinidae, gynogenesis is the method of reproduction. Natural gynogenesis has been reported among the members of the family Pleuronectidae too.

Induced gynogenesis: During recent past, gynogenesis has been successfully induced in a number of fishes including Indian major carps and Chinese carps by denaturing the genetic maternal (DNA) of the sperm through irradiation either by UV or gamma rays and activating the eggs with the irradiated milt. Diploidy is restored as mentioned earlier. In some species diploidization of the activated eggs was effective with cold shock treatments while in others heat shocks gave better results. Pressure shocks were reported to yield higher percentage of diploid gynogens in many species. Gynogenesis usually results in the production of all female progeny when the female is homogamous, means female fish that produce eggs having only x/x and not x/y eggs. Most of the females in fishes produce homogamous eggs. Gynogenesis is of two types that can be induced in fishes. One is meiotic gynogenesis and the other is mitotic gynogenesis. These two types of gynogenesis are effective tools to produce inbred lines of fish, in a much shorter time when compared to the conventional means of sib-mating which may take 10-12 generations to achieve complete homozygosity.

i) Meiotic gynogenesis: Meiotic gynogenesis is induced through the retention of second polar body by administering early shock treatments to the activated eggs.

ii) Mitotic gynogenesis: Mitotic gynogenesis is induced by blocking the first cleavage / the first mitotic division (endomitosis) by administering late shock treatments.

Androgenesis:

Androgenesis can also be naturally or induced.

Natural or spontaneous androgenesis: Natural androgenesis though rare, has been found to occur particularly in some hybrid crosses, produced either between distantly related individuals or those with disproportionate or incompatible genomes as in the cross of common carp female and grass carp male. However, the incidence or percentage of occurrence is very rare and low.

Artificial androgenesis: In induction of artificial androgenesis, the genetically inactivated egg is activated by normal sperm of the species. Diploidization of the zygote is achieved through the administration of shock treatments as done in the case of artificial gynogenesis

Polyploidy: An individual is said to be polyploidy if its ploidy consists of additional set(s) of chromosomes over the normal diploid number.

Natural Polyploidy: Natural polyploidy has been observed in some fish species like the common carp, trout etc. mainly due to chromosomal translocation. It may also appear in the cross bred progeny of very distantly related species. Thus, spontaneous triploidy was observed in the progeny of the cross between grass carp and big head carp.

Induced polyploidy: Polyploidy can be induced artificially in the same manner as artificial gynogenesis and androgenesis. In other words, shock treatments of the same nature and intensity and duration applied for inducing gynogenesis and androgenesis, to a given species may be also effective to induce polyploidy. The difference is that to induce polyploidy, shock treatments is administered to normal fertilized zygotes and not to genetically denatured sperm activated zygotes.

However, while triploidy (3n) is induced through the retention of second polar body in the fertilized egg by giving early shock treatments, tetraploidy (4n) is induced by blocking the first cleavage or mitotic division in the fertilized egg by administering late shock treatments. The CMFRI, Cochin were successful in producing triploid edible oyster, *Crassostrea madrasensis* by treating the newly fertilized eggs with 100 μM 6- dimethylaminopurine. This yielded 67% survival and triploid oysters exhibited significantly higher growth rate and meat content (126% higher dry weight, nearly 30% more glycogen, lipids and proteins) compared to diploid individuals. Triploids, particularly aneuploid individuals are generally sterile. Sterility can be made use of in species like common carp and tilapia which bred prolifically even under pond environment, to check unwanted reproduction leading to over-population that will hamper the growth of other fishes in the grow-out culture system for want of food and space. In some species sterile triploids have been reported to grow significantly faster than the normal diploids. Induction of tetraploids resulted in heavy mortality, poor yield and survival. Triploidy has been induced in oysters, e.g. *Crassostrea gigas* primarily to increase their size and flesh quality. CSIRO has induced polyploidy in embryos of Kuruma prawn (*Penaeus japonicus*) via. heat shock to assess the effects of polyploidy under controlled laboratory conditions.

Transgenesis

The first transgenic animal to be produced was mouse (Palmiter *et al.*, 1982). The first recorded instances of production of transgenics in aquatic species were those of Maclean *et al.* (1984) in rainbow trout and Zhu *et al.* (1985) in gold fish. The large number of gametes and the ease of collection, the control over the timing of fertilization, the ease of manipulation because of the large size of the ova and in vitro incubation encouraged the application of gene transfer techniques in a number of fish species. Production of GMOs is a multistage process, which can be summarized as follows:(i) identification of genes of interest; (ii) isolation of these specific genes; (iii) amplifying the gene to produce many copies; (iv) associating the gene with an appropriate promoter and poly- A sequence and insertion into plasmids; (v) multiplying the plasmid in bacteria and recovering the cloned construct for injection; (vi) transference of the construct into the recipient tissue, usually fertilized eggs; (vii) integration of gene into recipient genome; (viii) expression of gene in recipient genome; and (ix) inheritance of gene through further generations. Microinjection, electroporation, retroviral integration, liposomal reverse phase evaporation, sperm mediated transfer and microprojectiles enable transfer of constructs into the large numbers of egg available from aquatic species. Transgenics can take 4-5 generations of breeding to develop a stable transgenic fish line to obtain a single step improvement in growth performance. It appears at this stage that selective breeding can, not only achieve the growth enhancements but also improvement across a number of other commercially important traits that will enhance the overall value of strains in a cumulative manner. Transgenic fishes are associated with lots of controversies arising due to ethical issues and its impact on natural germplasm due to escapes. Therefore, bio-safety concerns need to be adequately addressed during evaluation as well as transgenic fish production. Transgenic research related to modified fish for ornamental trade, pharmaceutical and other industrial products and as biosensors to monitor water pollution levels are more attractive and with less controversies. Transgenic ornamental fish popularly called as "glow fish", harbouring fluorescent genes isolated from jellyfish has recently opened new possibilities for producing new multi-coloured fluorescent fish.

Hormonal sex reversal

Administration of exogenous steroid hormones to control sex in fishes has been in use for aquaculture purposes. The hormonal sex reversal techniques are used for the mass production of either sterile monosex population by interfering with the genetic sex. They are treated at an early stage (spawn or fry) with androgens (male hormone) if all male population is required or with estrogens for all female population. The spawn/fry treated with androgen usually develop testes and those treated with estrogen develop ovaries. Hormone administration is done either by mixing the required quantity in the feed or in dissolving in water medium (dip-treatment or immersion). The early stage of the fish for treatment should correspond with the initial genetic sex or gonadal differentiation. The success or effectiveness of hormonal sex reversal depends particularly on the time of treatment, dose of hormone, duration of treatment and also sometimes the mode of treatment. In addition to producing monosex fish populations, hormone treatments are also carried out to produce sterile fish. The most commonly used hormones for sterility are testosterone and methyl testosterone, at a dose slightly higher than used for masculinization. Hormone treatments have been successfully used to sterilize genetically improved tilapia (through selective breeding) to prevent unauthorized production and sale of the seed of these improved varieties.

Male and female sex hormones: Androgens, both natural and synthetic are used for the production of all male fish population. Among androgens 17a methyl testosterone (MT) is the most widely used hormone. Production of 100 percent male tilapia had been done by administering a dose of 5 mg MT/kg diet during the labile period lasting from 9 to 20 days after hatching. Estradiol 17â and estrone are the two naturally occurring steroids, used to achieve feminization in fishes.

Negative aspects of hormonal sex reversal: Some of the expected and suspected negative aspects of hormonal sex reversal are i) the residues of the administered steroids can be carcinogenic and may interfere with the sex of consumers of the treated fish ii) sexual maturity in the sex reversed female is usually delayed and they may have reduced fecundity iii) it is a costly and time consuming process iv) the process has to be repeated every time whenever monosex/sterile population are required. In conclusion, though it is claimed with experimental proof that the hormone from the body system of the treated fish will be disappearing soon after the treatment is suspended, use of hormonal manipulation has to be carried out with necessary caution.

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Potential Species of Copepods for Marine Finfish Hatchery

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Copepods are the most important group of zooplankton which forms the natural food for many fishes and invertebrates. One of the important problems in the marine fish hatchery is the lack of complete balanced larval feed. Copepods, even the newly hatched nauplii are nutritious, rich in PUFA, DHA and EPA, in most desirable ratios (Watanabe *et al.,*1978; 1983; Sargent1986; Watanabe and Kiron, 1994; Sargent *et al.,* 1997; Stottrup, 2000, 2006), easily digestible (Pederson, 1984; Stottrup, 2000) and rich in antioxidants, astaxanthine, vitamin C, D & E (Van der Meeren, 2003; McKinnon *et al.,* 2003). Copepods if fed during the larval phase, reduces malpigmentation and deformity rates, increases the pigmentation and survival (Bell *et al.,* 1997, Bell, 1998, Stottrup, 2000; Hamre *et al.,* 2005). More than 12000 species copepods are there living in a variety of ecological niches. Most of the early fish larvae are evolutionarily adapted for feeding on copepods than on other animals.

Copepods are successfully cultured in fin fish hatcheries of many countries including India, especially for feeding atresial larvae of certain fishes like groupers. Mostly species belonging to the orders Calanoida, Cyclopoida and Harpacticoida are popular for hatchery production as live feed. Species belonging to the genera, *Acartia, Calanus, Temora, Paracalanus, Pseudodiaptomus, Pseudocalanus, Centropages, Eurytemora, Euterpina, Tigriopus, Tisbe, Oithona* and *Apocyclopus* are widely cultured for hatchery use (Stottrup and McEvoy, 2003; Stottrup, 2006). In a study conducted on the wild-caught fish larvae, it was revealed that calanoidcopepod nauplii were an essential item in the early feedof many fish species. Calanoids of the genera *Acartia* and *Gladioferens* have been proved as important live feed for improving survival of some fish species. Harpacticoid copepods also are a good source of larval and juvenile fish feed in aquaculture. According to Turingan *et al.,* (2005) the prey should be of 80% of the mouth gape of the fish larvae. Many copepod nauplii are less than 100μ in size. Alone or as a supplement, in many cases copepods showed to improved primary growth than rotifers and brine shrimps. The smaller size of copepods enables their feeding by mouth gap-limited fish larvae like that of groupers and snappers (Fukuhara, 1989; Doi *et al.,* 1994). Only a few copepods have been continuously and successfully reared in extensive systems (Stottrup *et al.,* 1986; Stottrup, 2000). Most of the copepod rearing trails are done in small scale lasting for a few weeks or months and used only in experimental basis. Modern technologies including mass production of microalgae, with an input of large quantities of sea water copepod culture can be successfully enhanced and meet the required level like that or rotifers for marine finfish hatchery (Van der Meeren and Naas, 1997; Stottrup, 2006).

Species popularly cultured

Of the planktonic copepods in estuarine and coastal habitat, Calanoids are the most abundant taxa of pelagic realm forming an extreme connecting link between phytoplanktons and the fish in this inshore ecosystem. Due to this significance, Calanoids got keen attention from researchers. Among Calanoids, the popular cultivate is the *Acartia* spp. than *Calanus* spp. and *Temora* spp. Most of the species present in Calanoida are of approximately 1.0 mm total length (Mauchline1998). *Acartia clausi* and *Calanus finmarchicus* are the most widely studied Calanoids. (Mauchline 1998), followed by *Temora longicornis*, *Paracalanus parvis*, *Calanushelgo landicus*, *Pseudocalanus elongates*, *Acartia tonsa*, *Centropages hamatus*, *Centropages typicus* and *Temora stylifera*.

Based on the studies conducted by the Japanese scientists on the improvement of copepod mass culture, 13 species were recommended for mass cultivation. These includes *Acartia clausi* (*A. hudsonica* or *A. omorii*, on the basis of current classification), *A.longiremis*, *Eurytemora pacifica*, *Euterpina acutifrons*, *Microsetella norvegica, Oithona brevicornis* (*O. davisae*, based on current classification), *O. nana*, *O. similis*, *Pseudodiaptomus inopinus*, *P. marinus* and *Tigriopus japonicas* (Omori 1973; Nihon Suisanshigen Hogokyoukai 1979). Among these ,*Tigriopus japonicas* is the only one which is produced on a large scale and used in marine fish farming (Kitajima, 1973; Fukusho *et al.,* 1977, 1978; Nihon Suisanshigen Hogokyoukai, 1979). Based on their studies, rearing of the other species was attributed only to laboratory (Iwasaki and Kamiya, 1977; Iwasaki *et al.,* 1977). Maintenance of cultivation has a lot of difficulties including frequent replacement of water, the high demand for cultured algae as well as the low and unstable population growth.

Harpacticoids of the crustacean class Maxillopoda are easier for culture. These are hardy and can be cultured in high densities than calanoids and cyclopoids. The main disadvantage of harpacticoid copepod is its benthic nature while most of the fish larvae are pelagic in nature. The harpacticoids can be fed using a wide variety of food items including formulated diets. For many marine fish species, they serve as an important food source (Coull, 1990). For some fish species certain harpacticoids serve as prey for their entire life. Species of flatfishes, gobies, salmonids and sciaenids are sometimes considered to be harpacticoid feeders, atleast for a portion of their lives (Coull, 1990; McCall and Fleeger, 1995; Fleeger, 2005). Over 3000 species of Harpacticoids were reported so far (Huys and Boxshall,1991). For the purpose of ecological, physiological and toxicological research, harpacticoid copepods were first isolated from the sediments and cultur Chandler (1986). Later on it was proved that, mass culture of harpacticoids can be easily achieved using wide variety of food items (Battaglia, 1970; Strawbridge *et al.,* 1992; Ingole 1994; Chandler *et al.,* 1997; Lotufo and Fleeger, 1997).

According to Conceicao *et al.,* (2009), the wild zooplankton mostly consisting of copepods are the common food resource for fish larvae in nature.Occurrence of parasitic infections on most of the fish species is the major problem in using wild collected plankton for hatchery. The copepod parasites such as *Lepeophtheirus, Caligus* and *Pseudocaligus* can causes high mortality in fishes if the copepods from the wild collected plankton samples were used for feeding (Chinabut, 1996). Due to risk of parasitic transmission harvesting copepods from natural environmentsis not desirable. In order to avoid this problem Stottrup (2003) was the first to demonstrate the breeding of copepods in a holding tank (as an intermediate host). From tanks, the nauplii can be collected and used as feed for larvae. More than 60 copepod species have been raised in laboratory. For promoting the culture and improving cost-effectiveness of marine copepods in aquaculture industry, the development of appropriate culture techniques is essential. Copepods can be cultured extensively, intensively and semi-intensively. Copepods can be extensively developed in tanks, outdoor ponds, lagoons or enclosed fjords (Coneicao *et al.,* 2009). By using appropriate mesh sizes these cultured copepods can be made available to fish larvae. Planktonic copepods including *Acartia, Centropages* and *Temora* can be cultured in such systems. In extensive systems, culture is done normally on the basis of microalgal booms induced by agricultural fertilizers (Conceicao *et al.,*2009). Inconsistency in the production and domination of undesirable species are the common problem in this method. Rearing copepods in appropriate temperature, sufficient live feed (algae) with frequent exchange of seawater with the use of advanced mesh of varying measurements, continuous and a reliable supply of large scale copepods can be achieved for the use of hatchery without much difficulties.

Nowadays Culture methods for marine copepods are well advanced (Ogle, 1979. Ohno and Okamura 1988, Payne and Rippingale, 2001a,b,c; Santhosh and Anil, 2013). The body of a copepod is elongate, cylindrical, and clearly segmented. Copepods reproduce sexually only. Sexes are separate and can be easily distinguished in most of the cases. Mostly these have six naupliar and copepodite stages each. Two basic types are there, one carry eggsacs and the other scatter their eggs. Mostly these take 10-15days to become adults and live for 25 to 55 days. (Jakob *et al*., 2012; Santhosh and Anil, 2013). In general copepod species that free-spawn their eggs have higher fecundity than species in which females carry their eggs in clusters (Mauchline, 1998). The species that protect their eggs by carrying them in clusters are reported to have lower mortality rates (Kiorboe and Sabatini, 1994). Small pelagic copepod species with short life cycles and fast growth can be cultured with high-yield using semi intensive technologies. In tropical and subtropical countries, with technically qualified labor and facilities, copepods could give good economic results in terms of highly stress-resistant larvae, good survival, growth and biomass productions when compared with enriched *Artemia* or rotifers (Hernandez Molejon and Alvarez-Lajonchere, 2003). Overcrowding (Miralto *et al.,* 1996) and cannibalism (Ohno *et al*., 1990) also have got some influence on fecundity and population growth.

The basic morphology is similar to most of the crustacean type with large cephalosome and a small urosome, large first antennae and small second antennae with typical crustacean mouth parts. There are 4 pairs of two-branched swimming legs and the fifth pair mostly unbranched; each pair fused at the base by a plate which powers the legs to move organized and this is a highly successful evolutionary design. (Dussart and Defaye 2001). The calanoids are mainly herbivorous and the harpacticoids are mainly omnivorous. Most of the cyclopoids are predators. The smaller species tend to be plankton feeders, whereas the larger species tend to be aggressive predators, consuming protozoans, rotifers, and small aquatic animals (Fryer 1957; Hutchinson 1967).

Calanoids

The calanoid copepods are predominantly pelagic, occurring at all depths, with some near-bottom and benthic species. They are mainly feeding on small phytoplankton cells by filtration, rarely predators feeding on a variety of animal prey including copepod eggs. These can be easily distinguished by their long antennules, mostly as long as the body itself or sometimes, even longer, with up to 27 segments and biramous antennae mostly used as accessory locomotor appendages. Usually the antennule of male will be modified (Huys & Boxshall 1991; Dussart & Defaye 2001) and the position of the prosome–urosome articulation is between the fifth and sixth postcephalosome somite (Mauchline 1998; Dussart & Defaye 2001).

Among the calanoid copepods, the genera *Acartia*, *Pseudodiaptomus*, *Sinocalanus*, *Eurytemora*, *Centropages*, *Gladioferens*, *Parvocalanus*, *Bestiolina*, *Temora* and *Labidocera* were popularly proposed for hatchery production. Nauplii of some *Acartia* spp. are as small as 100 μm in length and 50-60 μm in width, making them suitable for first feeding of fish larvae. *Labidocera* sp. found to grow successively larger and produced more eggs in an established laboratory culture. Several Paracalanoid species are larger, thus are more suitable, for feeding to larger fish larvae. Paracalanid copepods are very common in coastal areas, while *Acartia* spp. found almost everywhere (Cheng-sheng Lee, *et al.,* 2005).

Among the families of larval fish that feeds on copepod prey, a vast majority shown clear preference for calanoid copepods and more specifically for small calanoid species (Sampey *et al.,* 2007) are hence considered to be the most promising order of copepod for production and used as live prey items for marine hatcheries (Doi*et al.,* 1997;Stotttrup, 2000). Specifically, pelagic calanoid species from coastal waters with high tolerance to wide ranges of environmental conditions are preferred live prey candidates (Stottrup, 2003; Conceicao*et al.,* 2010). Popular calanoid species reported as ideal live feed are *Acartia grani* (Spain), *A. sinjiensis* (Australia), *A. southwelli* (Taiwan, India), *A. spiniauda* (India), *A. tonsa* (Denmark, Uruguay), *A. parvula* (Germany), *A. centrura* (India), *A. erythreae* (India), *Centropages typicus* (Italy), *Eurytemora affinis* (France, Canada, Mediterranean sea), *Gladioferens imparipes* (Australia), *Pseudiaptomus annandalei* (Taiwan), *P. serricaudatus* (India), *Temoralongicornis* (North Sea, UK), *T. stylifera* (Italy) and *T. turbinata* (India).

Harpacticoids

The harpacticoids, comprises over 50% of copepod species, are primarily marine, free living, benthic organisms rarely represented in pelagic water samples. These are common in sediments occupying spaces between sand particles (interstitial), burrowing into sediment (burrowers), or living on sediment or plant surfaces (epibenthic). They are distinguished by their short and streamlined body, antennules with fewer than 10 segments and biramous antennae. The position of the prosome–urosome articulation is between the fourth and fifth postcephalosome segment (Dussart & Defaye 2001). Usually there is only one egg pouch and males are smaller with a specialized antennule.

Harpacticoid copepods are popular in culture for their higher population density but their benthic nature makes them less available to the fish larvae. However, the nauplii of some harpacticoids exhibit positive photo taxis so that they can be harvested easily and fed separately to fish larvae (Stottrup and Norsker, 1997). Harpacticoids copepod species can be reared to high production rates, are generally not cannibalistic and can be raised on formulated feeds. Two species or more species also can be cultured at high densities. Often harpacticoid come as a contaminant species along with ciliates in the culture of calanoid copepods. The nauplii of *Nitokralacustris* are benthic but the copepodid stages (90 μm in length and 30-40 μm in width) are mostly in column water and are suitable for feeding fish larvae. Nauplii of hapacticoid copepod speciesare difficult to separate from the culture and harvesting from the sediments is also not easy (Cheng-sheng Lee *et al.,* 2005).

Harpacticoid copepods can be cultured easily in high densities than calanoids. Many species are epibenthic in nature with reduced size and can be utilized for feeding fish larvae. Their nutritional value is similar to that of calanoids. Some models are there with semi-automated system for feeding and harvesting of nauplii will minimize the labour using harpacticoid culture (Stottrup, 2006). Usual epibenthic nature of harpacticoids makes them less suitable for the fish larval feed except for some pelagic harpacticoids like *Euterpina acutifrons* which is used in the rearing of pelagic larvae of *Coryphaena hippurus* (Kraul *et al.,* 1992). Popular harpacticoid species in the aquaculture system are *Ameira parvula* (Germany), *Amonordianormani*, *Amphiascoidesatopus* (USA), *Euterpina acutifrons* (Mediterranean sea, India), *Trachidiusdiscipes (*Germany), *Tigriopus japonicus* (India) and *Macrosetell agracilis* (India).

Cyclopoids

The cyclopoids include pelagic, epibenthic, benthic and parasitic species and are more abundant in freshwater environments(Huys & Boxshall 1991). The antennules in cyclopoids are shorter than in calanoids, rarely reaching beyond the cephalothorax and usually have six to 17 segments. Unlike calanoids and harpacticoids, cyclopoids have uniramous antennae which is modified for catching food (Huys & Boxshall 1991; Dussart & Defaye 2001). Like that of harpacticoids, the position of the prosome–urosome articulation is between the fourth and fifth postcephalosome segment (Dussart & Defaye 2001).

Among the cyclopoid copepods, the genera *Oithona* and *Dioithona* are popular in culture. Nauplii of these are mostly less than 100 μm in length and are negatively phototactic, and can be collected in plankton nets. Nauplii of the cyclopoid copepod *Apocyclopsroyi* develop from eggs in 4-5 days and are used for first feeding practices in Taiwan (Cheng-sheng Lee *et al.*, 2005). The swarm forming cyclopoid copepod *Dioithona oculata* culture experiments suggest that this species has good potential for the high density culture (Hernandez Molejon and Alvarez-Lajonchere, 2003). Cyclopoids can be easily cultured and can obtain higher densities than calanoids. They can be fed with a variety of foods but popularly cultured using phytoplankton in intensive systems (Stottrup, 2006). Herna´ndezMolejo´n and Alvarez-Lajonche‘re (2003) reported culture experiments with *Oithona oculata* and with a final population of 13 copepods /ml in 15-day cultures without aeration. Larvae of symbiotic poecilostomatoid copepods, which are swimming but non feeding, reported to be co cultured with mussels (the host of their adult stages) for feeding fish larvae in Taiwan (Cheng-sheng Lee *et al.,* 2005). Ho (2005) reported that a symbiotic (with bivalve mollusk) copepod namely *Pseudomyicola spinosus* belonging to the family Myicolidae, can be used as live feed in marine finfish rearing. The first seven stages in the life cycle of the species are planktonic and can be used as the live feed.

Fisheries agency of Japan has recommended 13 species of copepod for the mass culture as a part of a project entitled “searching for suitable species and mass culture of zooplankton as food for the early stage of fish seed in marine fish farming” for Japan. The species includes *Acartia hudsonica*, *A. longiremis*, *Eurytemora pacifica*, *Euterpina acutifrons*, *Microsetell anorvegica*, *Oithona davisae*, *O. nana*, *O. similis, Pseudodiaptomus inopinus, P. marinus* and *Tigriopus japonicus* (Omori 1973; Nihon Suisanhigen Hogokyoukai 1979) and concluded that among these, *T. japonicus* was the most ideal species to be cultured on a large scale and which can be economically used as larval feed in marine fish farming (Kitajima 1973; Fukusho*et al.,* 1977;Nihon SuisanhigenHogokyoukai, 1979). Popular cyclpoid species in the live feed purpose are *Apocyclops royi* (Taiwan), *A. panamensis* (UK), *Mesocyclops longisetus* (Florida), *Microcyclops albidus* (Florida), *Oithona davisae* (Spain) and *O. rigida* (India).

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Microalgal Culture and Maintenance in Marine Hatcheries

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Introduction

Unicellular marine microalgae are widely used as food in the hatchery production of fish and shellfish. Molluscs like oysters, mussels and clams filter them from the seawater in all stages of life. Rotifers and brine shrimp also ingest algae, and these are then used as food for fish and prawn larvae. In hatchery systems algae are added to the larval rearing tanks to improve 'quality' of water as green water systems. The production of algae is very critical in successful hatchery management.

Marine algae are single-celled plants and like all plants, contain chlorophyll, which traps the energy from light and uses it to convert nutrients and carbon dioxide dissolved in the sea water into organic matter. Microalgae are the primary producers of the sea. Among microalgae, flagellate and diatom species, are primary producers at the base of the marine food chain. They are cultured in hatcheries in suitably treated seawater enriched with nutrients, which include nitrates, phosphates, essential trace elements, vitamins and carbon dioxide. Synthetic seawater may be used but it is expensive except for small laboratory scale cultures. The culture microalgae arise because the natural phytoplankton content of seawater is insufficient to support growth of high densities of larvae and juveniles reared. Particularly in the hatchery, the water treatments will remove almost all of the natural phytoplankton which then needs to be replaced from cultures of preferred, high food value species. In this context, few of the naturally occurring algae of good food value are amenable to artificial culture.

Major classes and genera of cultured algal species

The major classes of cultured algae currently used to feed different groups of commercially important aquatic organisms include species of diatoms, flagellated and green algae, and filamentous blue-green algae, ranging in size from a few micrometers to more than 100 μ. The most frequently used species in commercial mariculture operations are the diatoms *Skeletonema costatum*, *Thalassiosira pseudonana*, *Chaetoceros gracilis*, *C. calcitrans*, the flagellates *Isochrysis galbana*, *Tetraselmis suecica*, *Pavlova lutheri* and *Chlorella* spp. The basic methods of algal culture have changed little over the years. Hatcheries have either opted for indoor, intensive culture with artificial illumination, usually external to the culture vessels, or outdoor, extensive culture in large tanks or ponds utilizing natural light. The intensive techniques are satisfactory in terms of reliability and productivity but are expensive in terms of capital outlay and labour, while the extensive methods tend to be less reliable and, sometimes not very productive.

Isolation of pure algal strains

Sterile cultures of micro-algae used for aquaculture purposes may be obtained from specialized culture collections. A list of culture collections is provided by Vonshak (1986) and Smith *et al.* (1993a). Alternatively, the isolation of endemic strains could be considered because of their ability to grow under the local environmental conditions. Isolation of algal species is not simple because of the small cell size and the association with other epiphytic species. Several laboratory techniques are available for isolating individual cells, such as serial dilution and successive plating on agar media, and separation using capillary pipettes. Bacteria can be eliminated from the phytoplankton culture by washing or plating in the presence of antibiotics. The sterility of the culture can be checked with a test tube containing seawater with 1 $g.l^{-1}$ bactopeptone. After sterilization, a drop of the culture to be tested is added and any residual bacteria will turn the bactopeptone solution turbid. The collection of algal strains should be carefully protected against contamination during handling and poor temperature regulations. To reduce risks, two series of stocks are often retained, one which supplies the starter cultures for the production system and the other which is only subjected to the handling necessary for maintenance. Stock cultures are kept in test tubes at a light intensity of about 1000 lux and a temperature of 16 to 19°C. Constant illumination is suitable for the maintenance of flagellates, but may result in decreased cell size in diatom stock cultures. Stock cultures are maintained for about a month and then transferred to create a new culture line

Agar plating

Agar plating technique can be used to isolate algal strains from raw seawater and for the maintenance of existing strains. The procedure is as follows:

- prepare 0.9% agar medium.
- streak the algal sample onto the agar surface.
- Incubate for 5 - 21 days.
- select the best colonies and transfer them into a test tube.
- incubation on an illuminated glass rack when a colour change is observed in the tube, check the isolated algal strain under microscope.

Serial dilution

Using aseptic technique, dispense 9 ml of media into each of ten test tubes with sterile automatic dispenser or sterile 10 ml pipettes. Label tubes 10-1 to 10-10 indicating dilution factor.

- Add 1 ml of enrichment sample to the first tube (10^{-1}) and mix gently.
- Take 1 ml of this dilution and add to the next tube (10^{-2}), mix gently.
- Repeat this procedure for the remaining tubes ($1O^{-3}$ to 10^{-10}).
- Incubate test-tubes under controlled temperature and light conditions:
- Examine cultures microscopically after 2-4 weeks by withdrawing a small sample from each tube. A unialgal culture may grow in one of the higher dilution tubes e.g. 10^{-6} to 10^{-10}. If tubes contain two or three different species then micromanipulation can be used to obtain unialgal cultures

Physical and chemical conditions

The important parameters regulating algal growth are nutrient quantity and quality, light intensity, pH, turbulence, salinity and temperature. The optimal parameters as well as the tolerated ranges are species specific and a broad generalization is given in Table 1. Also, the various factors may be interdependent and a parameter that is optimal for one set of conditions is not necessarily optimal for another.

Table 1 A generalized set of conditions for culturing micro-algae (modified Anonymous, 1991)

Parameters	Range	Optimum
Temperature (°C)	16-27	18-24
Salinity (g.l-1)	12-40	20-24
Light intensity (lux) (depends on volume and density)	1,000-10,000	2,500- 5,000
Photoperiod (light:dark, hours)	6:8 (min)	24:0 (max)
pH	7-9	8.2-8.7

Maintenance of stock and starter cultures

Stock cultures, otherwise known as master cultures, of the preferred species are the basic foundation of culture. They are normally supplied as monospecific cultures from reputed culture collections. Stock cultures are used as inocula when required. Every effort should be made to minimize the risk of contaminating the stock and starter cultures with competing microorganisms. The sterile procedures described below should be followed to ensure that contamination does not occur. Stock cultures are kept in small, transparent, autoclavable containers. For example, 500 ml borosilicate glass, flat-bottomed boiling or conical flasks fitted with a cotton wool plug at the neck, suitable for containing 250 ml of sterile, autoclaved medium, are ideal. The composition and preparation of Guillard's F/2 medium is given in Table 2.

Table 2: Guillard's F/2 media used for culturing algae in bivalve hatcheries from Guillard (1975)

Nutrient	wt (gl^{-1})
Nitrate $NaNO_3$	75.0
Phosphate $NaH_2PO_4.H_2O$	5.0
Silicate $Na_2SiO_3.9H_2O$	30.0
$FeCl_3.6H_2O$	3.5
Na_2EDTA	4.36
Dissolve in 900 ml distilled H_2O	
Add 1 ml of each of the following trace metal solutions	
Trace metal	**wt (g 100 ml^{-1})**
$CuSO_4.5\ H_2O$	0.98
$ZnSO_4.7\ H_2O$	2.20
$CoCl_2.6\ H_2O$	1.00
$MnCl_2.4\ H_2O$	18.00
$Na_2MoO_4.2\ H_2O$	0.63
Make up the volume to 1 l with distilled H_2O (pH ca. 2.0) Add 1 ml per litre FSW of the above solutions (#1-4).	

Vitamins	wt (mg l^{-1})
Biotin	1.0 mg
B-12	1.0 mg
Thiamine HCl	20.0 mg
Dissolve in 1 l distilled H_20. Store under refrigeration	
Add 1/2 ml of vitamin solution for every 1 l of FSW.	

Stock solutions and salts

The culture media are referred to "working stocks" and "primary stocks". Working stocks are those whose aliquots contribute directly to making the final media. Primary stocks are normally made where several single substance solutions are then combined to form the working stock, eg. $CuSO_4.5H_2O$ and $ZnSO_4.7H_2O$ are two of the primary stocks used to make up the Trace Metal working stock in F/2 medium. It is suggested that all stock or starter cultures be grown with AR grade chemicals it is understandable that in mass culture applications (> 20 - 50 L), particularly for aquaculture, these chemicals may be too expensive when bought in bulk quantities. Stock solutions are made up by accurately weighing the prescribed amount of nutrient and dissolving in a specified volume of distilled water, if possible in a volumetric flask. Some nutrients will readily dissolve; others need heat and stirring to fully dissolve. In contrast vitamin stocks are heat sensitive and should not be subjected to heat treatment and should also be kept in the dark. Failure to fully dissolve the primary stocks of some nutrients such as EDTA can lead to gross precipitation when these stocks are combined to make the media.

Nutrients come with different salts and hydration. For example, while copper and zinc may be two desired active constituents they are readily obtained from suppliers with either SO_4 or Cl_2 salts (i.e. $CuSO_4$ or $CuCl_2$ and $ZnSO_4$ or $ZnCl_2$). Some nutrients also come with different hydrations, i.e. the nH_2O suffix. Substituting one form for another may have no effect on the growth of some microalgae species, but it can lead to poor growth in others and also lead to unwanted and time consuming precipitation problems as the overall ratio of salts in the medium has changed. Therefore deviating from the prescribed recipes is to be avoided and ordering the correct form is recommended.

Procedure for transferring algal cultures from flask to flask

(a) Wipe all inner surfaces of inoculating booth with 85% ethanol.

(b) Place all flasks that will be required in the booth; i.e. all flasks to be transferred from (the transfer flask) and flasks containing sterilized media to be transferred into (new flasks).

(c) Close booth and switch on ultra-violet lamp. Leave for at least 20 minutes. (It is not safe to look directly at ultraviolet light, so a dark cover should be placed over the plexi-glass (transparent acrylic plastic) viewing plate when the light is on.)

(d) Switch off lamp. Ignite small burner.

(e) Remove foil caps from one transfer and one new flask. Flame the neck of each flask by slowly rotating the neck through the flame.

(f) Tilt the neck of the transfer flask toward the new flask. In one motion, remove both stoppers and pour an inoculum into the new flask. Transfer approximately 50 ml for diatom species and 100 ml for flagellates.

Avoid touching the necks of the two flasks. Never touch the portion of the stopper that is inserted into the flask. Once the inoculum is added, replace the stopper in the transfer flask. Slowly flame the neck of the new flask before replacing its stopper.

(g) Replace foil cap over the neck of the new flask. Using a waterproof marker pen, label the new flask with the algal species inoculated and the date of transfer.

(h) Repeat procedure for all flasks within the booth. Once completed, turn off burner and open booth.

(i) Remove all new flasks and place in the algal incubator or a well-lit area in the algae culture facility.

(j) The remaining inoculum in the transfer flasks can be used to inoculate larger cultures such as 4 l flasks or carboys. (from: Bourne, Hodgson and Whyte, 1989)

Starter culture management

Procedures for the maintenance of starter cultures (inocula) are almost identical to those described above. These cultures are specifically grown to provide inocula to start larger volume cultures needed to produce food. A line of starter cultures is originally set-up from the stock culture of the required species. Starter cultures, like the stocks, can be grown in 500 ml boiling flasks in 250 ml of culture medium. Because they are needed to provide inocula it is necessary to grow them quickly. They are grown at 18 to 23 °C with an illumination of 4 750 to 5 250 1ux. Starter cultures are generally aerated with an air/carbon dioxide (CO_2) mixture.

Starter cultures are grown for variable periods of time prior to use. In the case of diatom species, which have short generation times, this period is from 3 to 5 days. For the majority of flagellates it is 7 to 14 days. When ready for use a starter culture is sub-cultured using sterile techniques, as previously described. Twenty to 50 ml, (depending on species and the density of the culture), is transferred to a fresh 250 ml culture – to maintain the starter culture line. The remainder is used as an inoculum for larger cultures (up to 25 l in volume) to be grown for feeding or as an intermediate step in the process of large-scale culture, where they in turn act as the inocula for much larger cultures. Larger volume starter cultures may be needed to inoculate large-volume production cultures. For clarity, cultures of between 2 and 25 l volume will be referred to as intermediate-scale cultures. As an example, a 200 l production culture will initially begin with a 250 ml starter of the required species which is then transferred when it has grown to a larger volume 2 to 4 l starter. When a 200 l culture is about to be started, 200 to 400 ml of the 2 to 4 l starter culture is used to start a new 2 or 4 l starter culture and the remainder to start the 200 l production culture.

With larger volume starters it is advantageous to increase the level of illumination and to aerate the culture with an air/carbon dioxide mixture. It is advisable to dilute the medium to grow diatom species to a salinity of 20 to 25 PSU (practical salinity units, equivalent to parts per thousand) to obtain the best possible growth rates. Most flagellate species are best grown at about 30 PSU.

Intermediate-scale culture

Most laboratories and hatcheries requiring small volumes of algae for food use spherical glass flasks, plastic buckets or glass or clear plastic carboys of up to 25 l volume. These are generally operated as batch culture systems or semi-continuously. Batch culture involves the inoculation of the culture medium with the required species. The culture is then grown rapidly until a further increase in cell density is inhibited by the failure of the light to adequately penetrate the culture, The culture is then completely harvested, the container washed and sterilized and started again with a new culture.The semi-continuous method involves starting the cultures in the same way but instead of completely harvesting them when they have grown; they are partially harvested before the light limiting stage is reached. The harvested volume is then replaced with freshly prepared culture medium and the process repeated 2 or 3 days later. In this way the life of a culture is extended. With some of the hardier species, e.g. *Tetraselmis suecica*, cultures will last for 3 months or more with harvests of 25 to 50% of the culture volume 3 times each week. Batch culture is generally used for delicate species and the rapidly growing diatoms. Semi-continuous culture is mainly used with hardier species of flagellates.

Growth phases of cultures

Harvesting takes place in semi-continuous culture during the exponential phase of growth. Batch harvests are made generally at the peak of exponential growth as the cultures enter the stationary phase. In this case the species cultured is the large, green flagellate, *Tetraselmis*. At inoculation from the starter culture, the starting cell density in the culture is 25 to 50 cells per ml (cells per microlitre). After inoculation these cells grow and divide increasingly rapidly as they acclimatize to the culture conditions. This acclimatization period, which lasts for 2 to 3 days, is called the lag phase. Once adapted to the conditions, the rate of cell division accelerates and increase in the number of cells in the culture is logarithmic. This period lasts for 4 to 6 days and is called the exponential growth phase. Cell division rate then slows as light penetration through the culture and/or nutrients become limiting. The culture then enters the stationary phase, which can last for many days in the case of flagellates or only for a short time for diatoms. Cultures of flagellates remain in this phase by the recycling of nutrients from dead and decaying cells, but in the case of diatoms, which may produce self-inhibiting metabolites, which attract bacterial growth, the culture collapses.

Details of intermediate-scale culture operation

The complexity of the culture operation depends on the requirement for algae and the cost constraints within which the system needs to operate. In the simplest form the culture system may be just a scaled-up version of the starter cultures, using 2 l to 25 l flat-bottomed, glass flasks or carboys. These are part filled with the culture medium – in this case sterile, nutrient-enriched seawater – and then they are inoculated with the required species and aerated with a mixture of 2% CO_2 carried in compressed air. The carbon dioxide is from a bottled gas source with gas pressure and flow regulation. This is to provide the carbon source for photosynthesis and to control pH within the range 7.5 to 8.2. The air/CO_2 mixture is filtered through a 0.2 ìm porosity cartridge or membrane filter to remove the majority of air-borne contaminants and competing microorganisms. The culture medium is prepared from filtered or sterilized seawater.

There are various options for culture water treatment:

a) Either the seawater is filtered to remove bacteria using 0.22 or 0.45 μm membrane cartridge filters, or,

b) It is batch or continuously pasteurized at 65 to 75°C or,

c) It is autoclaved at 1.06 kg per cm2 for 20 minutes (After autoclaving the medium must be allowed to stand for 2 days in a suitable container closed from the atmosphere). Or,

d) It is chemically sterilized with sodium hypochlorite solution at 25 mg per l free-chlorine (by adding 0.5 ml of domestic bleach – 5% sodium hypochlorite – per l of filtered seawater).

e) Before use, the residual free-chlorine is neutralized by adding an excess of sodium thiosulphate solution (50.0 mg per l) prepared in distilled water.

Note: Methods (a) and (c) are most commonly used for small-scale culture preparation; (b) and (d), after prior filtration to 1 or 2 ìm particle size, for large-scale culture.

After the sterilizing treatment, nutrient additions are made. Note that diatoms require the addition of silica (Si) to the basic nutrients. The medium is then ready to dispense aseptically to the culture flasks, which are then ready to be inoculated. To obtain the maximum productivity of most species it may be necessary to dilute the seawater with pure (distilled) freshwater (or from an uncontaminated source) before filtration or autoclaving. Growth and cell division rates of *Chaetoceros calcitrans, Thalassiosira pseudonana* and *Skeletonema costatum* are optimal at a salinity of about 20 to 25 PSU. Productivity of many of the flagellates is optimal at 25 to 30 PSU.

Estimating algal density

Accurate estimates of cell density can be made using a haemocytometer.

Haemocytometers are thick glass slides with two chambers on the upper surface, each measuring 1.0 x 1.0 mm. A special cover slip is placed over these two chambers giving a depth of 0.1 mm making the total volume of each chamber 0.1 mm^3. The base of each chamber is marked with a grid to aid in counting cells within the area. Prior to counting motile algal species, 1 or 2 drops of 4% formalin should be added to a 10 to 20 ml sample of the culture to be counted. With the cover slip in position, one or two drops of the algal sample are introduced by means of a Pasteur pipette to fill both chambers. Cell density is estimated as follows. The central grid of each chamber (outlined in the circle) is sub-divided into 25 squares, each measuring 0.2 x 0.2 mm. The numbers of cells in 10 randomly chosen 0.2 x 0.2 mm squares are counted and the average or mean is calculated. This gives the mean number of algal cells per 0.2mm x 0.2mm x 0.1mm, or 0.004 mm^3.

Example:

a. Counts of algal cells: 40 + 30 + 50 + 60 + 55 + 65 + 70 + 45 + 40 + 70 = 525

   Average = 52.5 cells per 0.004 mm^3

b. Multiply the average by 250 to give the average number of cells per mm^3.

c. Since there are 1000 mm^3 in 1 ml, multiply the value calculated in B by 1 000.

   In this example, the cell density would be 52.5x250 x1000 = 13.1 m (13.1 x 10^6) cells per ml.

Extensive outdoor culture

Commercial hatcheries need to produce large volumes of good quality, high-food-value algae daily to support economic-scale seed production. Outdoor tank culture makes use of natural light. Culture in rectangular or circular tanks with overhead illumination is used in shrimp hatcheries in India. This involves the fertilization of a large volume of seawater with the basic nutrients necessary for production, namely nitrogen, phosphorus and silica in one form or another. It is possible to induce monospecific blooms by prior fine (<2 μ particle retention) filtration of the impounded seawater and the introduction of an inoculum of the required species, as long as it is hardy and vigorous. However, it is difficult to maintain such blooms for long periods because they rapidly become contaminated with other microorganisms.

Principles of large-scale culture management

The objective in culture management is to obtain the greatest possible daily yield of algae so that the culture systems are operated cost effectively. This yield must be sustained for long periods of time to maintain the hatchery output of post larvae. Ineffective management of algal culture greatly influences the potential for production and ultimately the selling price of the seed.

Troubleshooting

Cultures will fail to grow, will become overly contaminated with competing micro-organisms or will crash even in the best-run hatcheries. Below are some pointers to check to determine the source of such failures.

1. Air supply: Is there adequate air entering the cultures? Are the cells sedimenting to the bottom of the culture vessel? This may happen when culturing certain diatoms, in which case the air flow rate should be increased. It should not happen in the case of commonly cultured flagellates. If it does, then the problem lies elsewhere.
2. Temperature: Check min/max thermometer. Were there any increases or decreases in the temperature of the algal culture facility over the past 24 hours? Most of the commonly cultured algal species cannot tolerate temperatures above 26oC for extended periods – or temperatures below 12 ^{o}C. Temperatures in the range 18 to 23 ^{o}C are ideal for indoor.
3. PH: Check CO_2 supply; Is the CO_2 cylinder empty? Check pH of the algal cultures using a pH probe. Is the pH too high (above 8.5)? Is the pH too low (below 7.5)? Adjust the CO2 supply accordingly.
4. Nutrients: Check records for the last time the cultures received nutrients. This is particularly important for semi-continuous cultures.
5. Contamination. Are the walls of the culture container, particularly at the water/air interface, visibly foaming or fouled with what appears to be detritus? If so, the culture is at the end of its useful life and needs to be replaced. If this is a continuing problem in the early stages of the culture cycle with a particular species, then check the starter cultures for signs of contaminating organisms and replace them as necessary.

Exotic fishes in Indian Aquaculture Production and Development: Advantages and Concerns

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Introduction

Aquaculture is one of the fastest growing food producing sectors in the world growing at pace of over 8% (per annum) since 1970. As of 2012, the number of species registered in FAO statistics was 567, including fin-fishes (354 species, with 5 hybrids), molluscs (102), crustaceans (59), amphibians and reptiles (6), aquatic invertebrates (9), and marine and freshwater algae (37)(FAO 2014). India stands second in global fish production and has shown spectacular growth during the past six decades from meager 0.75 million tonnes in 1950-51 to 9.34 million tonnes in 2013 (Basavaraja 2015). Aquaculture in India has evolved as a viable farming practice over last three decades with an annual growth rate of 6-7%, with a production of 4.65 million tones in 2013, placing second highest in the world in cultured fish production, constituting 7.75% of world production (Basavaraja 2015). About 95% of India's aquaculture production has been through inland aquaculture, owing to the large scale culture of carps and other species. Aquaculture plays an important role in socio-economic upliftment, employment generation and improving nutritional security of the country.

Though India is rich and diverse in aquatic genetic resources, the index of biodiversity utilized for aquaculture (BUA) is of the order of 0.13 (~85% from Indian major carps; ~ 5% air-breathing fishes; ~10% rest all species together) (Ayyappan *et al*., 2011), clearly indicating the domestication of resources that can provide sustainable utilization is not proportionate with the level of biodiversity and agro climatic environment. Therefore, diversification of aquaculture with new candidate species to enhance the production, exploring the various aquatic resources and agro climatic environments, is the need of the hour.

Carps form the main stay of the country's aquaculture production and substituting the entire major carp component from the culture system is a remote possibility. In such situation, successful introduction of any new species largely depends on its compatibility with the major carps. Many indigenous species viz *Labeo calbasu, L. fimbriatus, L. gonius, L. bata, Cirrhinus cirrhosa, C. reba, Punitus sarana and P. pulchellus* catfish like *Pangasius pangasius, Horabagrus brachysoma, Ompak pabda, O bimaculatus, Sperata seenghala, S. aoretc* having regional importance, growth potential and consumer acceptability, have been brought to the main stream of culture and tried for their wider domestication all over the country (Jayasankar and Das, 2015). Since availability of mass scale seed production and standard rearing technologies are prerequisite for promoting the culture of any species, efforts are on to standardise their culture technology. But there is an urgent need to cater to the demands of the growing population and with availability of tailormade aquaculture practices and basic information, it is easier for them to adopt the exotic species,hatchery and culture operation and research into exotic species have opened a large number of employment opportunities. Overall, exotic species have served as agents for crop diversification for rural poor

Welcomme (1998) defined 'Exotic animals' as "species occurring outside of its natural range". According to Kottelat & Whitten (1996) An introduced species, (exotic) is any species intentionally or accidentally transported and released by man outside its natural range. The interest and objectives in use of exotics is mostly commercial in nature.

The use of exotic aquatic species to increase food production and income has been an established practice since the middle of the 19th century. The ancient Romans and medieval European monks transported common carp, *Cyprinus carpio*, and redfin perch, *Perca fluviatilis*, around Europe and the Roman Empire and Greeks. Advances in controlling the spawning of salmonids, primarily rainbow trout *Oncorhynchus mykiss* in the mid-1800s led to increased exportation of these fish to other areas (Welcomme 1988). Recent advances in trade and transport have made large-scale movements of many different species over great distances possible. To a large extent, exotic fishes are directly related to the global development of the aquaculture industry and the concomitant demand in many countries for new species for culture.

Reasons for the Introduction of Aquatic Exotic Species globally

Reason	%
Aquaculture	38.7%
Fisheries	8.7%
Angling/Sport	7.9%
Accidental	7%
Ornamental	7.3%
Unknown	15.4%
Other (research, control, bait)	14.5%

(source:www.fao.org/fi/statist/fisoft/dias/mainpage.htm).

Of the 1155 fish introductions for aquaculture globally only 6.8% and 0.7% were considered ecologically and socio-economically adverse respectively, but 45% and 24.5% were beneficial (Bartley & Casal,1998). For example, the introduction of the freshwater sardine *Limnothrissa miodon* to Lake Kariba, Zimbabwe is the best example of success with an introduced fish. Other alien species Mossambique tilapia (*Oreochromis mossambicus*) and Nile tilapia (*O. niloticus*) contribute to inland fishproduction in reservoirs and lakes in Asian countries such as Sri Lanka and Indonesia (De Silva & Funge-Smith 2005). The production of the African cichlid tilapia is much higher in Asia than in most areas of Africa. Introduced salmonids in Chile forms an important aquaculture industry and is responsible for approximately 20% of the world's farmed Salmon. The production of *Litopeneaus vannamei* in Thailand and China represents the country's lion share of total marine shrimp production in (Briggs *et al.* 2004)

Exotic fish in Indian scenario

Blue revolution in the country took off in 1971 with the launching of nation wide demonstration on composite culture of Indian and exotic fishes under the All India Coordinated Research Project (AICRP). This has made huge impact in national aquaculture expansion. The three Indian major carps form the lion's share of the aquaculture produce and the exotic carps viz silver carps, grass carp and common carp, forms the next important group in the country. The Introduction of polyculture techniques with exotic species resulted in maximum use of all available niches. Introductions of exotic fish species are an important part of anthropogenic activities concerning aquatic ecosystems (Garcia-Berthou, 2007). In India, over 300 alien fish species including 291 ornamental species, 31 aquaculture species and 3 larvicidal fishes are recorded. These introductions may be intentional or unintentional (Lakra *et al.* 2008; Singh and Lakra, 2011, Singh, 2014). Many of them are illegally introduced and historical information such as the source, place and period of introduction is unknown.

Historical perspective

During the period1870-1947,exotic fish were introduced in India *viz* Gamefishes: brown trout (*Salmo truttafario*), rainbow trout (*Oncorhynchus mykiss*); Food fishes: *Tinca tinca*, *Cyprinus carpio* (European strain), *Osphronemus gourami*; Larvicidal fishes*: Gambusia affinis*. Trout was the first exotic food fish introduced in 1863 by the British people for angling purposes. Later, two trout species Rainbow trout, *Oncorhynchus mykiss* and brown trout, *Salmo trutta fario,* were brought into India. Atlantic salmon, *S. salar* were brought in the Kashmir in 1960, but failed to establish. These species have been re-established in the states of Uttarakhand, Arunachal Pradesh and in the Nilgiris in Tamil Nadu, Later brook trout, *Salvelinus fontinalis* has also been adopted for aquaculture in the Himachal Pradesh and Jammu and Kashmir

Three varieties of the Prussian (German) strain of common carp, *viz.* the scale carp *(Cyprinus carpio communis),* the mirror carp (*C. carpio specularis)* and the leather carp (*C. carpio nudus)* were introduced from Sri Lanka in 1939.

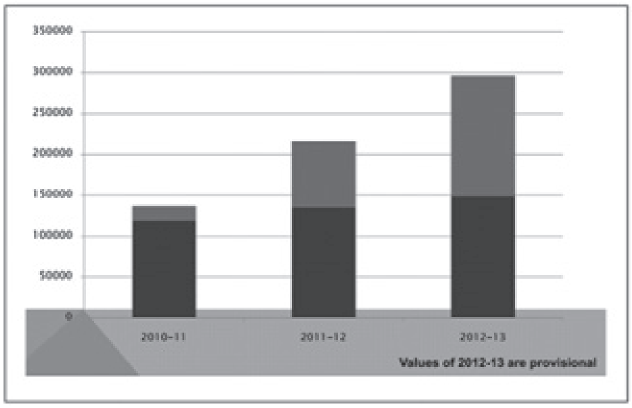
Tilapia, *Oreochromis mossambicus,* was first introduced into pond ecosystems in 1952 and thereafter stocked in several reservoirs of south India for augmenting production (Sugunan 1995).Two species *O. mossambicus* and *O. niloticus* are predominantly available in the country found in almost throughout the country.

During 1950-2000, 14 exotic fish/ shrimp species introduced into India

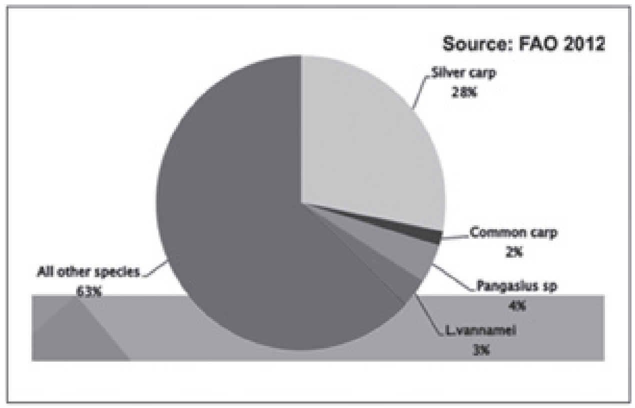
Salmonids	*Salvelinus fontinalis, Onchorhyncus nerka, Salmo salar*
Tilapia	*Oreochromis mossambicus* and *O. niloticus*, red tilapia
Common carp	*Cyprinus carpio* (Chinese strain)*,*
Silver carp:	*Hypophthalmichthys molitrix*
Grass carp	*Ctenopharyngodon idella*
Punti Barb	*Puntius javanicus*
Big head carp	*Aristichthys nobilis*
African Catfish	*Clarias gariepinus*
Red bellied paccu	*Piaractus brachypomus*
Malaysian catfish	*Pangasianodon hypophthalmus*
White prawn	*Litopenaeus vannamei*

Of the 31 alien fish species recorded from aquaculture in India twelve fish species are used commonly under aquaculture in the country (Singh and Lakra, 2011). Culture of some species such as *Pangasianodon hypoththalmus, Oreochromis niloticus, Piaractus brachypomus, Aristichtys nobilis, Onchorhynchus mykiss,* and *Litopenaeus vannamei* have picked up during recent years (Singh, 2014).

Exotic fishes have contributed significantly to the country's aquaculture production from 1990 onwards. The estimated annual average production of alien species fit for human consumption amounts to around 18.2 to 34.5% of the annual average production of marketable fish cultured in India. Over 2 lakh tonnes of Pangas and 1 lakh tonnes of pacu are produced annually. Share of exotic shrimp has increased up to 50% of the total cultured shrimp production. Similarly, the ornamental fish trade in India is also dominated mainly by alien fish species such as gold fish, Angel, Guppy, Swordtail, Oscar, Platy, Cichlids, Tetras, Gourami, Sucker mouths, Pacuetc. which have been introduced from different parts of world, mainly from Asia.



Share of exotic shrimp increased upto 50% in the total cultured shrimp production



Contribution of Exotic fish total aquaculture

Advantages of introduced species:

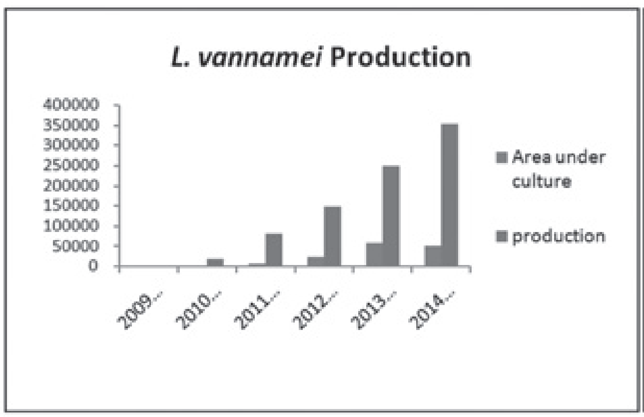
- Availability of tailor made aquaculture practices like easy to breed, ready availability of seed at the door step of the farm and easy to culture
- Relatively higher production over indigenous species (pangas can grow upto 3 kg in an year, where Indian major carps grow upto 1.5 kg);
- compatibility with agro-ecosystems (e.g. can integrated with rice farming or can grow in upland areas);
- Source of alternative income (via sale of table fish or seeds), improves livelihood of people (poor people can buy, due to relatively lower market price, resulting in improved nutrition, improved incomeand employment opportunities)
- Can use for waste recycling/ local resources, weed control e.g. grass carp, and for mosquito control.
- Alien species often command a higher market price than native fishes in international markets but rated low priced for domestic consumption (De Silva *et al.*, 2009)
- In ornamental sector, many fishes are easy to breed and rear, Many species are very attractive and have high market value. Easy to maintain in the tanks and pools.
- Some exotic species can survive very well in adverse conditions for example Tilapia, African catfish *etc*.

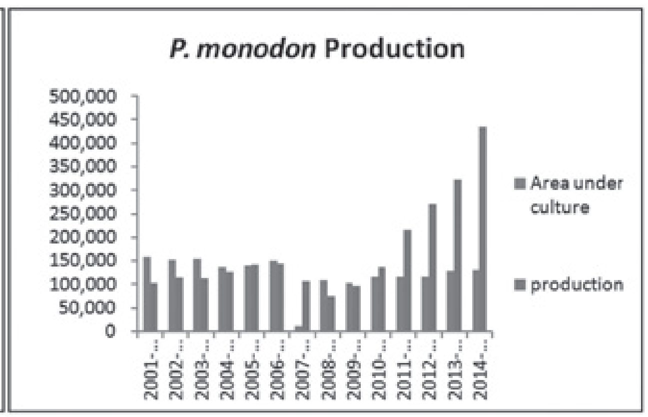
- Species like *Clarias gariepinus* can be fed with any type of feeding material, which is cheaply available to farmers, hence good profit in culture
- Availablity of SPF stocks of species like *Litopenaeus vannamei*

Litopenaeus vannamei

Litopenaeus vannamei is one of the most desired species for aquaculture throughout the world. It has contributed nearly 90% of total shrimp production in world. This species is native to the Eastern Pacific andhas been transplanted to other parts of world by virtue of its monetary value, market demand, fast growth, high survival, disease resistance and ready acceptance of artificial feed. When farming of Black tiger shrimp (*Penaeus monodon*) in India began to decline due to disease outbreaks, aquaculture of *L. vannamei* attracted farmers because of its fast growth, disease resistance, availability of specific pathogen free (SPF) and specific pathogen resistant (SPR) brood stock and ability to tolerate high density and low salinity, lower protein requirements (and therefore production costs), high survival during larval rearing, and some marketing advantages.

At present *L. vannamei* occupies 28% (50240 acres) of total area under shrimp culture with production share of 44.85% (353413 t) (2014-2015) which indicates this species occupies major share in country's aquaculture status. (MPEDA 2015). Introduction of *L. vannamei* in our freshwater system has been a huge success in terms of high yield of 10-15 t/ha and has become popular among the prawn farmers within a short period. The entry of *L. vannnamei* in India has showed a significant milestone in country's shrimp farming as well as seafood export.





Issues of concern for small-scale farmers: It has been observed that only semi-intensive and intensive culture is considered as economical. But shrimp farming sector in India comprises of > 90% of small farmers (less than 2 ha water area) and ETS is mandatory for *L. vannamei* culture irrespective of the size of the farm, putting a significant strain on these small-scale farmers in India who are really 'resource –poor'.

Ways to adopt vannamei culture for small-scale farmers: Cluster based management concept of BMP programs can be good option for adopting *L. vannamei* culture with common reservoir and common ETP and assistance from the Govt. for the modification required infrastructure for ensuring biosecurity. Profitability of low-density extensive cultures which could be adopted by resource poor small farmers must also be investigated.

Future concern: Regional trade with countries facing anti-dumping duties in the US market is growing significantly, excess supply of fresh shrimp from neighboring countries leads to price decrease and low profit margin, further expansion will lead to a further drop in price and increase competition among neighboring countries.

Problems with *L. vannamei* culture

- **Health risk**: Introduction of exotic viruses which might affect the native shrimp species
- **Ecological risk** – escape into natural environment and establishment thereby affecting the biodiversity
- **Environmental risk** – intensive culture leads to high nutrient load in the system.
- **Social risk** – social unrest is bound to result if big investors enter the field and disturb the traditional and improved traditional system of farming that is being practiced by the small farmers.
- **Market risk** – globally increase in supply will result in further reduction in price and we have to compete with established players in the field.

Striped catfish *Pangasianodon hypopthalmus*, *Pangasianodon hypothalamus* is an exotic freshwater catfish that has been introduced into the culture system in West Bengal illegally before the same species was permitted in Indian waters by Govt. of India in 2009 (Jayasankar and Giri, 2013). This species was adopted for culture because various reasons *viz* faster growth rate of achieving 1.5 kg in 6 month; Low cost of production; low sensitivity to dissolved oxygen stress and other factors. Many consumers prefer pangas over the carps in view of the fewer number of bones in the flesh. Most of the farmers have undertaken pangas farming as an alternative in the areas which have suffered losses in shrimp farming and in low productive area. Presently country is able to produce 200,000 mt per annum (Jayasankar and Giri, 2013).There is no denying fact that arrival of pangas in India has signalled a significant milestone, representing the first major component of diversification in the otherwise carp-dominated freshwater aquaculture scenario. With this species country could able to achieve average production yield of 30 t/ ha/yr (Jayasankar and Giri, 2013). The pangas fish is found to be most compatible with IMCs in polyculture also. An estimated 10-15% of farmers stock Pangas in polyculture. The state of west Bengal has been found to be hub of seed production of *P. hypopthalamus* in the country, producing 300 to 500 million fry every year (Jayasankar and Giri, 2013). Seed production is also carried out in other parts of the country such as Andhra Pradesh and Chhattisgarh in a minor scale. Total period of pangas farming extend from 8 to 10 months with an avg monthly growth increment of 150g. A production of 50mt per ha can be achieved under different stocking practices.

- The cost of production of Pangas in India is around Rs. 60-65/kg at present. In 2012-2013 pangas yielded a price of Rs. 72 Rs/kg. Such cost of production downgrades the scope of export of pangas from India to other countries. In other countries such as Vietnam government provide financial assistance for exporting this fish.
- Contrary to the belief regarding the colour of the meat, none of the domestic processors expressed a problem with colour of the meat.
- Value addition in pangas needs improvements. Encouragement for market places, processing industries, enhancing market avenues, and tapping rural markets needs lot of attention.
- Govt. of India extends financial assistance through NFDB funded schemes for Pangas farming in the form of

back-end scheme and financial assistance is extended to the tune of Rs. 50000/ha. Banks have also started providing loan for pangas farming. However such assistance is lacking for increasing marketing potential of pangas in the country.

- Growth potential of striped catfish under current scenario in India reveals that they lack genetic potential for high yields. Proper measures need to be developed to minimise transport stress to the seed. (Jayasankar and Giri, 2013).

Highly volatile and fluctuating market situation in pangas marketing is one of the major problems facing the fish farmers.

Tilapia

Tilapia is a highly versatile fish and one of the most popular aquaculture enterprises worldwide with more than 135 countries producing this fish. It is suitable for low technology farming and is often known as 'Aquatic chicken' chiefly because of its potential to meet the nutritional demands of the booming global population. Tilapia is a favourite in a wide spectrum of producers who primarily target domestic and regional consumers rather than export. Global production of tilapia was around 3.85 million tones in 2011 (Salin, 2015).

The earliest introduction of tilapia *Oreochromis mossambicus* was during 1952, but while it could not develop into a successful aquaculture industry, the fish soon escaped into the natural water bodies, where it contributed towards inland fish production in India. Culture is widespread in all kinds of water bodies including small ponds, cages, public canals and waterways, hence, this species has great potential in the Indian context with regard to the growing demands and efficient use of different water bodies. Recently Ministry of Agriculture, DAHDF, Govt. of India has given clearance to some private farmers to culture *O. niloticus* using formulated guidelines; keeping in view the increased demand for fish (Subrath Ghosh and Datta, 2014)

Red-bellied Pacu

Pacu is an inhabitant of the Rio Orinoco and Amazon River basin in South America. This fish was introduced as cultivable food fish into some Asian countries such as Taiwan, Malaysia, China, Thailand and Bangladesh. In 2001 this fish entered illegally into India, particularly to the fish farming regions of West Bengal and then to Andhra Pradesh via Bangladesh (Lakra and Singh, 2011; Subrath Ghosh and Datta, 2014).

Culture and breeding of this exotic fish was clandestinely started inWest Bengal and lately, it has become popular, particularly the states of Andhra Pradesh, Orissa, Kerala and Maharashtra (Lakra and Singh, 2011). It attains 1.5 -2.5 Kg body weight in a year in pond with proper supplementary feeding. Over one lakh tonnes of cultured pacu is presently produced annually. Polyculture of pacu with major carps, especially rohu is an emerging aquaculture practice in Andhra Pradesh (Nair and Salin, 2007). Farming of Pacu is also reported from Assam and Tripura in both mono and polyculture system along with carps, some farmers in UP have observed better growth and overall economy in polyculture with IMC over monoculture systems (Subrath Ghosh amd Datta, 2014). Overall this fish is not ferocious and aggressive in nature, unlike its close relative piranha that possesses razor sharp teeth (Singh, 2014).

Concern: Even though red bellied pacu has not been introduced legally in India, the eastern and north eastern states of India are major importers of this fish in frozen state from Bangladesh for consumer who cannot afford to buy fishes like major carps. However, till now as there is no clearance, ie legal/ official permission from Government authorities for culture of Pacu in India, authorities will have to judge and decide whether this fish is to be allowed to multiply in the country in context of possible rapid expansion of this species in India aquaculture system (Subrath Ghosh and Datta 2014).

Exotic trouts:

Efforts to develop trout farming in India have borne fruit, especially in Jammu and Kashmir and Himachal Pradesh as result of controlled breeding, hatchery management and production of balanced feed. About 23 trout hatcheries in different hill states produce more than 100 tonnes annually, most of which is produced in raceways.

Barbonymus gonionotus

An exotic medium carp, introduced to India in 1972 to control aquatic weeds. It is commonly called 'silver barb', 'Thai barb', 'Java carp' and 'Tawes'. The fish is an omnivore, but prefers to eat soft weeds like Hydrilla, Najas, Ceratophyllum, etc. The fish can grow 700-800 g/ year in a culture pond. The initial growth rate of the fish is as fast as Indian major carps. Although the fish was introduced in the 1970s, the culture potentiality of this species was only realized during the late 1990s. The fish is now already being cultured in West Bengal, Assam and other north-eastern states. It is a highly preferred fish and fetches the same market price as that of Indian major carps.

African catfish*: *Clarias gariepinus was illegally introduced in India during1990s, since then the culture of this fish has rapidly spread, using animal waste as cheap feed, in many parts of the country illegally. African catfish *is a* very hardy species tolerating a wide range of temperature (12-36 $\pm$ 1°C) as well as salinity (<14 ppt), which facilitate easy culture and marketing in live condition. Culture of this species is legally banned because of its predatory and voracious nature, which threaten indigenous species.

Ornamental fishes

Ornamental fish industry thrives well in India, mainly with the exotic ornamental fishes. The ornamental fishes were introduced from different parts of the world by fish hobbyists, mainly from Asia, but here are no clear records or information available documenting the timing and/or source of these imported species. More than 200 exotic aquarium fish species are now bred in different parts of the country (Ghosh *et al.*, 2003) and provides a promising livelihood alternative for many people. Govt. of India has encouraged many development projects in ornamental fish industry through NFDB and MPEDA in almost all the states of India. Kerala Government also initiated a major programme for exporting the ornamental fishes.

Major concerns

Even though exotic fish culture in India is gaining momentum among farmers, it has also some negative impacts such as prolific breeding, predation or competition by the introduced species affecting indigenous biodiversity, gene pool contamination, negative environmental impacts, loss of indigenous species, potential for disease introduction; low demand (low price); and price drop of indigenous species due to cheaper price of introduced species.

Conclusion

In the past, no heed was paid to the risks of introductions or the latter were not thoroughly premeditated, often because the negative impacts of the alien fish species became apparent only sometime after the alien species were introduced and established in the ecosystem. Over the last two decades, the aquaculture entrepreneurs have been demanding imports of many new fish strains and varieties for improved production and competition in the world market, hence it has proved very difficult to avoid introduction of alien species. Though exotic species have provided socio-economic benefits for a vast number of poor people in the region yet, environmental, socio-economic and biodiversity issues are important considerations for authorities to check and regulate importation of any alien fishes in India. There is an urgent need to develop a well-planned program to assess the impacts. The governments should carefully weigh both the positive and negative impacts for each species before making any national or regional policy. In considering the history of introductions both helpful and harmful one issue that stands out above all is the need for decisions to be well informed and carefully considered. The responsible introduction of an alien species requires that it be carried out in a way that will minimize the risk of harm to indigenous biodiversity. Careful planning of introductions, for example through a risk assessment process, can help to identify and minimize the risk of negative impact as well as to maximize the benefits.

National Bureau of Fish Genetic Resources (NBFGR), Lucknow has undertaken studies on impact of exotic fishes in India. There is a National Committee for Introduction of Exotic Aquatic Species in Indian Waters under the Union Ministry of Agriculture, to check and regulate importation of alien fishes in India. At the national level, quarantine and health certification programmes have been initiated as an integral part of much broader strategies aimed at protecting the natural environment and natural faunas from the deleterious impact of alien fish species and pathogens. A national Plan and Quarantine guidelines have been developed by NBFGR for execution by the aquaculturists and other stake holders culturing alien fishes in India.

Fish species specific guidelines have also been developed particularly for introduction of *O. niloticus, Pangasianodon hypophthalmus* and *Litopenaeus vannamei* and ornamental aquarium fishes. The quarantine facility required for alien fish species introduction has also been designed and can be adopted under public–private partnership mode. The aqua culturists and farmers are advised to comply with the available regulatory mechanisms for all alien fish species along with sanitary and phyto-sanitary standards.

Some exotic species are giving good production in Indian waters and good profit but care need to be taken when unauthorised species are being cultured in India. Proper impact assessment is required before taking up the culture of species. Other wise there is likely chances of escaping the fish into nature and get established, causing threat to indigenous fishes of the country.

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Economic Evaluations in Mariculture

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Introduction

Fisheries sector is an integral part of the Indian economy. It has gained a prominent place in the economic map of the country by its consistent contribution to the GDP and foreging exchange earnings in addition to providing livelihood security to about 14 million people and also a major source of nutritional security. The sector has contributed over Rs. 30,000 crores through sea food export. The estimated value of marine fish landings in India during 2014 was Rs. 31,750 crores at LC level and Rs. 52,360 crores at retail market level. (CMFRI, 2015).

The marine fish landing in the country is stagnating around four million tonnes. The estimated landing in 2014 was 3.59 million tonnes (CMFRI, 2015). The increasing awareness on the nutritive value of fish has increased the demand for fish. When the production (harvest) from marine fisheries reaches a stagnation phase, with limited scope for further expansion, the alternative is to look for augmenting the fishery resources of the sea. Looking into the Sea is an important alternative available in front of us. Among the many alternatives available like sea ranching, artificial reefs, mariculture is one of the potential alternatives, which can be practiced by the fishermen more effectively.

Mariculture systems include in-shore and off-shore and maintain a constant high saline water conditions. In-shore mariculture systems include clams, oysters and other molluscs, which are wild-caught or hatchery-reared seed grown on the sea floor or on suspended nets, ropes, or other structures (Naylor 2001). Off-shore mariculture refers to large intensive fisheries in off-shore fish pens.

Mariculture: The Present status

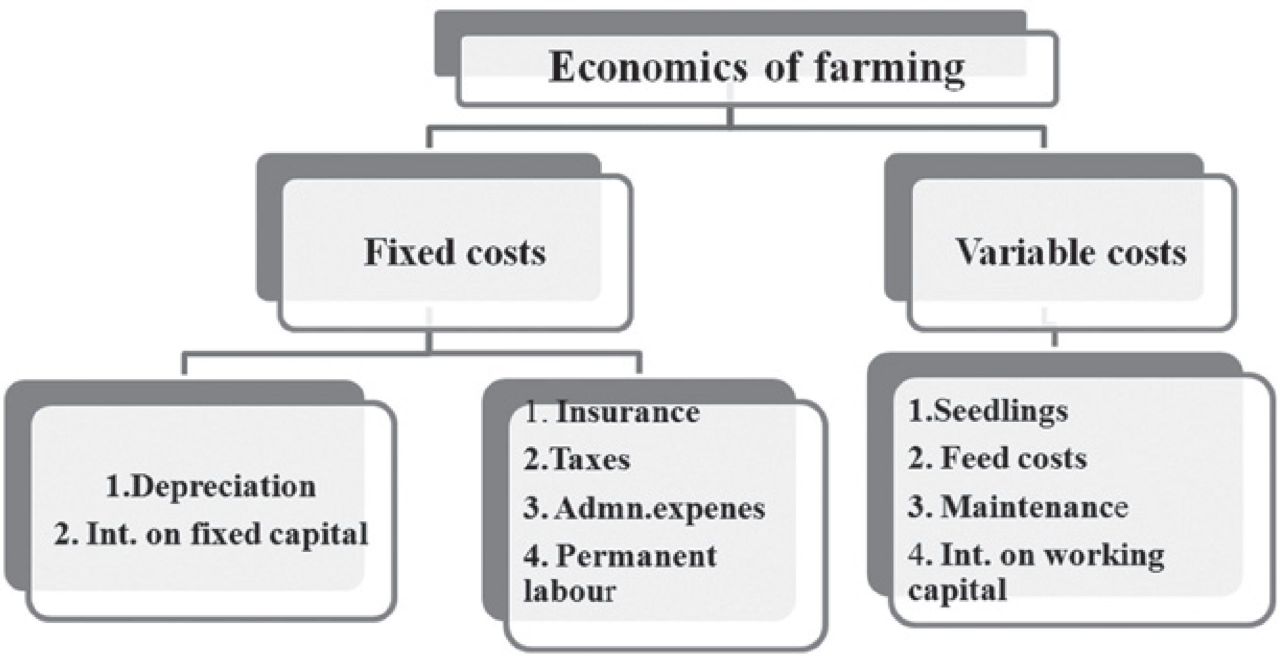
Mariculture has the potential to augment production and incomes through coastal as well as open sea farming. The global aquaculture production increased by a about 25 times in the last 30 years against only seven times increase in capture fisheries production during the corresponding period (Gopakumar et al., 2007). India has vast areas of suitable coastal waters, lagoons and bays which can be utilized for mariculture. Seed production and culture of marine finfishes has been expanding in the recent past in many parts of the world, but in India, it is only an emerging sector. The potential cultivable candidate finfishes are groupers, cobia, rabbitfish, seabass, pompano, snappers and sea bream. Lack of availability of hatchery-produced seed on a commercial scale is the major bottleneck for large-scale marine finfish farming. The availability of seed from wild is often unpredictable, and hence, the development and standardization of seed production techniques for a few commercially important species is receiving research priority.

Why Economic Evaluation

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

Components of ecnomic evaluation

The economic evaluation mainly comprises cost of farming and returns of farming,



Indicators of Economic performance

The economic performance of any mariculture activities can be assessed by working out the following cost and return indicators and financial feasibility of any enterprise. (Narayanakumar, 2009, Sathiadhas & Narayanakumar, 2010).

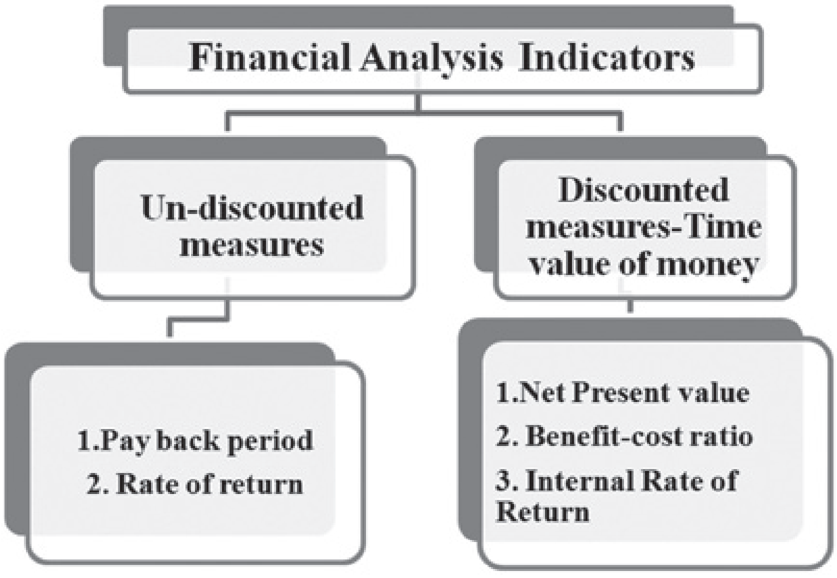
Table 1 Indicators of economic performance of a mariculture enterprise

Sl. No.	Economic Indicators
1	**Initial investment** a) Fixed installations b) Land (if any) c) Major accessories d) Minor Accessorised) Others
2	**Total Investment**
3	**Fixed cost (For crop duration of six months)** a)Depreciation b) Insurance (2% on investment) c) Interest on Fixed capital (12%) d) Administrative expenses
4	**Total Annual Fixed cost (A)**
5	**Operating costs** a) Cost of seedlings b) Cost of feeding and other labour charges c) Interest on working capital (6%)
6	**Total Operating or Variable cost (B)**
7	**Total cost of production [Row(4)+Row(6)]**
8	**Yield of the fish variety (in kg)**
9	**Gross revenue [(8) * Price per kg]**
10	**Net income [(9)-(8)]**
11	**Net operating income [(9)-(6)]**
12	**Cost of production (Rs./kg)[(7)/(8)]**
13	**Price realized (Rs./kg) (9)/(8)**
14	**Capital Productivity (Operating ratio) (6)/(9)**
15	**Rate of return over investment (9)/(2)**

As seen from the table, the different economic indicators of the economic performance of any mariculture enterprise are worked to assess its performance. This will serve as the guidelines to the institutional agencies that are extending the financial support to the enterprise.

Financial performance

The financial performance of an enterprise is analysed by working out various types of indicators as given below.



The financial feasibility analysis is done using the following **capital budgeting techniques** with appropriate assumptions on the duration of the farming, annual days of operation, inflation of costs and returns and related parameters. Three indicators will be estimated namely, **Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Returns (IRR)**

- NPV determines the present net worth of the stream of cash inflows over cash outflows. The cash inflows and outflows are discounted at at particular rate

  $$NPW = \sum B_n (1 + d)^{-n} - \sum C_n (1 + d)^{-n} + V_T (1 + d)^{T} - \sum I_n (1 + d)^{-n} \quad ..\mathbf{(1)}$$

  Where,

  B_n cash inflows in period **n**

  C_n cash outflows in period **n**

  V_T the salvage value realized in the terminal year of the investment

  I_n investment made in the year **n**

- **Benefit Cost Ratio** is the ratio of sum total of annual discounted net cash flows over the economic life of the investment to the investment.

  $$BCR = \frac{\sum B_n (1 + d)^{-n} - \sum C_n (1 + d)^{-n} + V_T (1 + d)^{T}}{\sum I_n (1 + d)^{-n}} \quad \ldots\mathbf{(2)}$$

- **Internal Rate of Return** is that discount rate which makes the NPW equals to zero. It is that discount rate which equates the net cash flows during its economic life with the initial investment.

  $$IRR = \sum B_n (1 + r)^{-n} - \sum C_n (1 + r)^{-n} + V_T (1 + r)^{T} - \sum I_n (1 + r)^{-n} = 0 \ldots\mathbf{(14)}$$

  Where,

  r internal rate of return

  The actual procedure adopted to calculate IRR is by linear interpolation as follows

  $$IRR = \begin{array}{c}\text{Lower}\\ \text{Discount}\\ \text{Rate}\end{array} + \left\{ \left(\begin{array}{c}\text{Difference}\\ \text{between the two}\\ \text{discount rates}\end{array} \right) \left(\frac{\text{NPW at lower discount rate}}{\begin{array}{c}\text{Absolute difference between}\\ \text{The NPW's at the two rates}\end{array}} \right) \right\} \ldots\ldots\mathbf{(3)}$$

Case studies

We can see some of the case studies in mariculture conducted by CMFRI to explain the economic considerations in Maraiculture

1. Cage farming in Balasore, Orissa

Farming in open sea cage farms is an alternative practice with great potential to increase production of high value edible finfish and shellfish. In recent years, open sea cage farming is expanding on a global basis. In India, the sea bass was cultured by CMFRI in cage diameter: 6 m; depth: 6 m off Balasore near Orissa in a demonstration project. The cage was launched near Chaumukh beach in Balasore during January, 2009 and was stocked with

4,357 numbers of locally collected Asian seabass juveniles. After about six months, around 3,200 kg seabass was harvested indicating the potential. The cost of production per kg of sea bass worked out to Rs. 94.24/- against the value realization of Rs.189.89 per kg. The capital productivity measured through operating ratio worked out to 0.80. These economic parameters indicate that this open sea cage farming of sea bass is economically viable (Table 2). (Rao et.al.,CMFRI, 2009).

Table 2 Economic analysis of the experimental cage culture demonstration at Balasore

Sl.No.	Details of cost and returns	Amount (in Rs.)
1	Initial investment for a 6m diameter cage	3,00,000
2	Fixed cost (For crop duration of six months)	
	a) Depreciation b) Insurance (2% on investment) c) Interest on Fixed capital (12%) d) Administrative expenses	30,000 3,000 18,000 3,000
3	Total Fixed cost (A)	54,000
4	Operating costs	
	a) Cost of seedlings	50,000
	b) Cost of feeding and other labour chages	1,75,000
	c) Interest on working capital (6%)	6,750
5	Total Operating cost (B)	2,31,750
6	**Total cost of production (Six months)**	**2,85,750**
7	Yield of sea bass (in kg)	3,032
8	**Gross revenue from 3032 kg**	**5,75,760**
9	**Net income (8)-(5)**	**2,90,010**
10	**Net operating income (Income over operating cost)**	**3,44,010**
11	**Cost of production (Rs./kg) (6)/(7)**	**94.24**
12	**Price realized (Rs./kg) (8)/(7)**	**189.89**
13	**Capital Productivity (Operating ratio) (5)/(8)**	**0.50**

2. Cage farming in Visakhapatnam

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

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

Table 4 Details of Annual Fixed cost

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

Table 5 Details of Annual Variable cost of cage culture (for a crop duration of seven months)

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

Table 6 Economic indicators of the cage culture of *Lates calcarifer, Visakahapatnam*

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

Thus it is seen from the above results that the economic analysis of the experimental cage culture farm has worked out successfully with higher net operating income and net income in a crop period of seven to nine months. It is to be noted that once the practice is further expanded to many areas and farms, the cost will decline due to the economies of scale of operation. Thus it could be concluded that the open sea cage farming is a viable alternative and economically & financially feasible mariculture operation for the stake holders to make use of in the developing countries.

Mariculture: A potential source of employment

The mariculture has proven to an economically viable alternative to augment the biomass production from the seas in situations wherever the fishery resources are harvested beyond the sustainable limit. Looking into the seas, is the key word for increasing the fish production from the sea as well as improving the livelihood of the million people who depend on the sector.

The mariculture activities provide adequate employment opportunities for the fishers to sustain their livelihood. An estimate by Syda Rao and Gopakumar (2010) indicated that the open sea cage farming of a species provide 1,040 man days of work; open sea lobster farming, 496 man days; mussel culture -52,000 man days; oyster farming-30,000 man days and seaweed culture 3.06 lakh man days. Narayanakumar and Krishnan (2013) estimated that with current development projections targeting 5,000 families in the near future , the seaweed sector could generate around 765 thousand man-days of employment in the Ramanathapuram district. It has been estimated that India can produce one million tonnes of dried seaweed and provide employment to 200 thousand families with annual earnings of around Rs. 0.1 million per family. From these estimates, the scope of commercial mariculture can be understood.

Conclusion

Mariculture and research in mariculture is in different stages of development in different countries. The increasing awareness of the consumers on the shell fishes like clams, oysters & mussels and increasing interest for the cultured high valued fin fish can be capitalized by adopting and investing on taking up mariculture practives. This will help the commercial mariculture to develop to greater heights besides contributing to the food security of the country and providing consistent remunerative livelihood to the fishing community.

It is also equally important to see that the fishermen are given rights to farm in the open sea and its legal implications. There should be a strong policy back up for the establishment of such enterprises to enable the fishers to carry on their mariculture activities. A comprehensive policy framework to patronize the mariculture enterprises is the most essential step in promoting mariculture in any country. This supported by a systematic research programme on mariculture will help the country interested in developing mariculture to reach greater heights in the field.

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Assessing and Predicting the Environmental Impact of Mariculture

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Introduction

Mariculture involves the farming and yield of fish, shellfish as well as other aquatic species including seaweeds, where in the medium of growth is seawater. The environment play crucial role in any mariculture activity. Prior to the start of any mariculture programme the environment assessment is absolutely essential for its successful launching, maintenance and harvest. This pre evaluation of environmental suitability is one of the most important factors, determining the type of mariculture fitting to the location. Appraisal of the environment at regular intervals, during the process of mariculture also is equally important for the continued healthy existence of the resources and also for ecological sustainability. The environmental impact assessment(EIA) of any undertaking including mariculture is a process of appraising the probable ecological impacts of the proposed endeavor, taking also into account the interconnected socio-economic, cultural and human-health impacts, both beneficial and adverse.

The knowledge and experience achieved as well as the results of the environmental investigations before, during and after the activity form the basis for the prediction of impacts. The need for exact predictions might not effectivelybe attained during this process, because of uncertainties in the data and if there is a lack of enough baseline data. Rather than making direct predictions, which might not be applicable in a complex natural environment, it is important that the predictions sketch out different scenarios, presenting the underlying assumptions clearly. Further, the impacts should be evaluated and environment management plans (EMP) should be prepared. An EMP is a site-specific plan developed to ensure that all necessary measures are identified and implemented in order to protect the environment and comply with environmental legislation. While this supports the environment, it should also be supportive to the optimum production of the resources.

Once, a mariculture venture is planned, the various steps in the environmental assessment are to be initiated. These steps start with site selection. The site selection determines the water quality to a great extent. Selection of particular site for mariculture is of foremost importance since it greatly influences economic feasibility of the plan.

Site selection and carrying capacity estimation

The site selection criteria are to be followed for initiating a mariculture program. The site selection and water quality criteria for selected mariculture resources (marine fish, shrimp, bivalves and seaweeds) in India were narrated by Prema (2013). Loka *et al*., (2012a) described the site selection criteria specifically for marine cage culture in India. The water quality should be in the preferred range in terms of selected parameters of concern for aquatic life in the marine sector. The importance of water quality for marine cage culture was detailed by Prema (2009). The individual environmental parameters selected as key indicators in the assessment criteria have their own roles singly as well as in combination.

The concept of environmental assessment should be elevated to an ecological approach to aquaculture (EAA) as suggested by the Fisheries and Aquaculture Department of the Food and Agriculture Organization (FAO) of the United Nations(Soto *et al*., 2008). Carrying capacity is an important concept for ecosystem-based management which facilitates defining the upper limits of production and ecological limits, and the social acceptability of the venture without causing any unacceptable changeto both natural ecosystem and social functions and structures (Byron and Costa-Pierce, 2010). Inglis *et al*. (2002) and Mc Kindsey *et al*. (2006) defined four different types of carrying capacities *viz*. physical, production, ecological and social.

- The **physical carrying capacity** is the potential of an area/site to sustain coastal aquaculture in that it has the appropriate physical characteristics (including minimalinfrastructure and access). This is the primary selection criterion for an aquacultureactivity, for site selection and aquaculture zoning.
- The **production carrying capacity** is the maximum yield that can be produced inthe selected water body. This estimates maximum aquaculture production given thesource of food and is typically considered at the farm level but should go beyondthis. It is relevant in choosing the most congenial resource / species for the culture.
- The **ecological carrying capacity c**an be described as 'the population or biomassof a species that a specific habitat can permanently sustain without damaging theecosystem from which it depends.' It is the magnitude of mariculture productionthat can be supported by the environment.
- The **social carrying capacity** can be defined as the amount/type of aquaculture (total production, number and density of farms, species and systems) that a socialsystem can take without incurring in significant negative social changes.

These four types of carrying capacity must be considered in the final decision. The selected area or site should be that where these four overlap. Although these accepted definitions were originally described for bivalve aquaculture, they have also been applied to finfish cage culture (Gacek and Legoviæ, 2010).

The information needed for site selection and estimation of carrying capacity is varied and will usually consist of data describing the physical, biological, economic, social and infrastructural aspects. These data can come from a variety of sources, ranging from primary data from the field or satellite imagery to all forms of secondary data, including paper maps, photographs and textual databases.

An example of some data requirements for carrying capacity estimation in different farming systems.

(The lists of parameters are indicative rather than exhaustive)

Farming system	Physical carrying capacity	Production carrying capacity	Ecological carrying capacity	Social carrying capacity
System 1: Coastal marinecages	Wind, Waves, Currents Depth, Temperature, Salinity, Infrastructure etc.	Temperature Salinity Diet type Feed regime Investment costs Markets etc.	Critical habitats Biodiversity ingeneral impact etc.	Eutrophication indicators EIA data Visual Sea and coastal access rights Access to capital Beneficiaries Workforceetc.
System 2: Ponds (coastal)	Water quantity, Water quality, Slope, Soils Rainfall Evaporation Infrastructure, etc.	Temperature, Diet type, Feed regime, Infrastructure, Investment, costs Markets etc.	Critical habitats, Biodiversity, Eutrophication indicators Visual impact, EIA data in General etc.	Land ownership, Water andriparian rights Access to capital Work force Beneficiaries etc.
System 3: Bivalve culture	Wind Waves Currents Chorophyll and productivity Depth, Temperature Salinity, etc.	Temperature Salinity Chlorophyll, and productivity, Investment, costs Markets etc.	Critical habitats, Biodiversity, Bottom anoxia indicators Visual impact EIA data in General etc.	Sea rights Access to capital Workforce Beneficiaries etc.
System 4: Seaweed culture	Wind Waves Currents Nutrient content, Depth Temperature Salinity, etc	Temperature, Salinity Nutrients, availability, Investment, costs Markets, etc.	Critical habitats Biodiversity Visual impact EIA data in General etc.	Sea rights Access to capital Workforce Beneficiaries etc.

In the case of shrimp farming in India, Central Institute of Brackishwater Aquaculture has carried out research on carrying capacity. The institute has developed decision support software in visual basic to estimate the maximum allowable farming area for a particular creek or drainage canal (Muralidhar *et al*., 2008). This software helps to determine a reliable estimation of impact of shrimp farming and other land use impact in a region under various scenarios of increased development. Further water quality data generated during this research would serves as a baseline data to monitor long term trends of quality of water bodies (Vijayan *et al*., 2014).

Environmental Impact Assessment (EIA)

EIA is commonly focused on high value, intensive farming, and particularly shrimp and marine cage farming Asia. In India, The Guidelines for Sustainable Development and Management of Brackish Water Aquaculture (1995) recommend to carry out a site selection process, which should include proper environmental impact assessment (FAO, 2009). They state that all aquaculture units above 40 ha should be subject to an EIA. State Pollution Control Boards should ensure that such an EIA be carried out by the aquaculture units. Shrimp culture units of 40 ha or more should also incorporate an Environmental Monitoring Plan and an Environmental Management Plan, which covers the following potential impacts: local watercourses, groundwater, drinking water sources, agricultural activity, soil and salinisation, waste watertreatment and green belt development. Smaller farms between 10 ha and 40 ha must also provide information on these items.

The Water (Prevention and Control of Pollution) Act (1974, as amended) provides for the prevention and control of water pollution, for the maintenance or restoration of the wholesomeness of water, and for the establishment of (central and state) Pollution Control Boards. The Act defines "trade effluent" for these purposes as "any liquid, gaseous or solid substance which is discharged from any premises used for carrying on any industrial operation or any treatment or disposal operation other than domestic sewage treatment".

Hence, an aquaculture farmer requires an authorization from the Pollution Control Board to set up a treatment and disposal system that is likely to discharge sewage or trade effluent into waters or onto the land.

The Coastal Aquaculture Authority of India issues Guidelines on the need for Effluent Treatment System (ETS) in shrimp farms. The low dissolved oxygen, higher organic matter; increased sedimentation load of discharged water from farms will affect the assimilation capacity of the environment and will have potential impact in the ecosystem. Such impacts depend on the quantum of waste water outflow. Hence the Marine Products Exports Development Authority (MPEDA) guidelines for sustainable culture advocates the shrimp culture units with an area of above 5 ha to have ETS facility by demarcating at least 10% of the area and have facilities for settlement, treatment and discharge as per the prescribed standards. They further advise to let the bottom sediment to dry between harvest rather than removing sediment accumulations from the pond bottom. The Guidelines also refer to the need for a common ETS for clusters of shrimp farms, where each farm is less than 5 ha in size.

The Indian guidelines on effluent discharge from coastal aquaculture farms are as follows.

Guidelines/standards for wastewater from coastal aquaculture farms in India

Parameters	Final discharge point	
	Coastal marine waters	Creeks/estuaries
pH	6.0–8.5	6.0–8.5
Suspended solids (mg/l)	100	100
Dissolved oxygen (mg/l)	Not less than 3.0	Not less than 3.0
Free ammonia (as NH^3-N) mg/l	1.0	0.5
Biochemical oxygen demand – BOD (mg/l)	50	20
Chemical oxygen demand – COD (mg/l)	100	75
Dissolved phosphate (as P) (mg/l)	<0.4	<0.2
Total nitrogen (as N) (mg/l)	2.0	2.0

An EIA consists of three stages: (i) screening, to define in what context the EIA is needed; (ii) scoping, to define what risks should be assessed and in what terms; and (iii) a written report andconsultation phase to produce an environmental impact statement which should include anenvironmental monitoring strategy to ensure the assessment of risk has been effective (Telfer and Beveridge, 2001).

Environmental assessment is an important part in environmental management of mariculture, and is an integral part of an EIA. For EIA in marine cage culture, a baseline survey prior to the start of the culture as well monitoring surveys during the culture are essential for the environment management. The Central Marine Fisheries Research Institute (CMFRI) has given the protocol for the environmental management of sea cage farms in India (Loka*et al*., 2012b).

Strategic Environmental Assessment (SEA)

Strategic Environmental Assessment (World Bank, 2008) offers a comprehensive approach to identifying likely sectoral impacts, and establishing environmental objectives, quality standards, limits and so on for the industry. It is also a good basis for aquaculture developmentand management plans or integrated coastal zone management (ICZM) plans. The Republic of India had conducted environmental assessment in the shrimp-farming sector (White *et al.,* 2013).

Environmental impacts in mariculture

Observations on water and sediment quality on marine cage culture in India was reported by Prema *et al*., (2010), Philipose *et al*., (2012) and Varghese *et al*., (2015). In the shrimp farming sector in India, EIA had been conducted by Paulraj *et al*., (1997), Muralidhar and Gupta (2007), Jugunu and Kripa (2008). Muralidhar and Gupta (2009) brought out technologies for management of soil and water environment for shrimp culture. The EIA for bivalve mariculture in India was carried out by several studies from CMFRI (Ramalinga and Kripa, 2006, 2007, Kripa, 2011, Prema *et al*., 2012, Viji *et al*., 2014a, 2014b).The impact of environment on sea weed farming in India was well studied by CMFRI (Kaliaperumal, 1989, 1990, Kaliaperumal *et al*., 1990, 1993, 2003, Radhakrishnan, 2001, Seema and Jayasankar, 2005 and Zacharia *et al*., 2015).

De Silva and Soto (2009) narrated the impacts of climate change in mariculture. Due to climate change, sea temperature rise in tropical and subtropical regions would result in increased rate ofgrowth and overall production in aquaculture. The predicted temperature riseitself will bewithin the optimal ranges for most species cultured in such waters (marine, brackishand/or freshwater) and therefore global warming could impact positively on the bulk ofaquaculture production, provided the feed inputs required for compensating the enhanced metabolism are met and that other associated factors, such as disease, do not become more detrimental.

Climate change is predicted to decrease the pH of seawater globally (Hughes *et al.*, 2003; IPCC,2007). Apart from its impact on coral formation, there is the possibility that decreased pH could impede calcareous shell formation, particularly in molluscs, an effect perhaps can be aggravated by increased water temperature and thereby to have an impact onmollusc culture. This has received little attention and warrants urgent research. Currently, mollusc culture accounts for nearly 25 percent of all aquacultureand therefore any negative impacts on shell formation could significantly impact on total aquaculture production. There ispractically no information on the potential impact of increased water temperature on the physiology of the most relevant aquaculture bivalves. But, if coastal plankton productivity is enhanced by higher temperatures and if nutrients areavailable, there may be a positive effect on the farming of filter feeders. However, increased temperatures associated with eutrophication and harmful algal blooms (Peperzak, 2003) could augment the occurrence of toxic tides and subsequently impact production, and also increase the possibilities of human health risks through the consumption of molluscs cultured in such areas. More research is needed toprovide better forecasts of expected net effects. In India, the CMFRI has attempted to study the effects of lower pH in estuarine water on meroplanktonic oyster larval settlement. Experiments were conducted to evaluate the effects of extremes of temperature (20 to 35°C) and pH (6.5 to 8.5) on metamorphosis and survival of oyster larvae. In pH 6.5 there was 100% mortality and complete dissolution of dead shells in 24 h. Survival was highest (81%) in the control temperature of 27°C and less than 50% in 25 and 20 °C (Kripa *et al*., 2015).

The frequency of extreme weather events such as typhoons, hurricanes and unusual floods has increased dramatically over the last five decades due to climate change. Climate change in some regions of the world is likely to bring about severe weather(storms), water quality changes (e.g. from plankton blooms) and possibly increased pollutants and other damaging run off from land based sources caused by flooding, impacting on coastal areas. Such weather conditions will increase the vulnerability ofsea based aquaculture, particularly cage aquaculture, the predominant form of marine aquaculture of finfish and seaweed farming in coastal bays. There is an increased vulnerability of near-shore land based coastal aquaculture, of all forms, to severe weather, erosion and storm surges, leading to structural damage, escapes and loss of livelihoods of aquaculture farmers. Vulnerability assessments have been made by CIBA on shrimp aquaculture and found it as moderately vulnerable to climate change highly vulnerable to extreme events in Nagapattinam District, Tamil Nadu.

Prediction, prevention, adaptationand mitigation of environmental impacts

Adequate site selection and aquaculture zoning can be important adaptation measures to environmental impact. When selecting sites it is very important to determine likely threats through risk assessment analysis. When selecting the best locations forfarms, particularly in coastal and more exposed areas, weather related risksmust be considered. For example, coastal shrimp farms may need levies or otherprotective structures. Fish cages have to be securely fastened to the bottom or a holding structure. Water warming and related low oxygen, potential increase in eutrophication, etc. can be avoided or minimized indeeper sites with better circulation. The likelihood of disease spread can be minimized by increasing the minimum distance between farms for aquaculture clusters or zones. Implementing proper risk communicationis also very important. In this regard, weather information systems play an important role.

For mariculture, prevention systems should be formulated by predictive modeling based on critical and effective monitoring of water bodies and aquatic organisms. A very important adaptation measure at local level is the implementation of effective integrated monitoring systems. Such monitoring systems should provide adequate information on physical and chemical conditions of aquatic environments, early detection of diseases and presence of pest species, including harmful algal blooms.

Frequently, rural farmers may not have the conditions and facilities toimplement such monitoring by themselves. However, some very simple measurements can be implemented such as water temperature and Secchi disk readings etc can also be made at local level which can be used for early detection of algal blooms. Local authorities can assist inimplementing integrated monitoring systems with accompanying risk communication strategies and early warning systems to prepare and warn stakeholders (De Silva and Soto (2009).

Better management practices and systems to mitigate environmental impacts in mariculture in India were identified by Modayil *et al*. (2006). The first attempt in India on experimentation of spatial planning and aquaculture zoning is from CMFRI (Dineshbabu *et al*., 2015). This study provides GIS maps which will help in deciding suitable mariculture activities in specific water bodies using eco friendly methods. Geospatial delineation of potential cage culture sites in Mandapam and Veravel regions of the Indian coast was validated in CMFRI (Mini *et al*., 2015).

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Pre Grow-out Rearing Systems in Farming Operations

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Marine finfish production is a promising industry all over the world and has significantly increased over the years and currently accounts for 394,580 tonnes, valued at nearly US$ 512 million, with China being the largest producer (FAO, 2009). Currently, salmons are the dominant species of temperate waters for cage culture. Tropical marine finfish cage culture is relatively new but is expanding, particularly in Asia. Marine finfifsh species like cobia, grouper, pompano, snappers, seabreams and seabass represent the major potential candidate finfish species for mariculture in Asian countries. In India, the production of marine finfish through aquaculture has started from 2003 onwards and gradually being increased by the introduction of several species of marine finfish having great potential in International market. Cage culture in India has been initiated by Central Marine Fisheries Research Institute, Govt. of India during 2007 by introduction of high value marine finfsihes and could succeed in large scale production of Asian seabass, cobia, grouper, pompano and snappers. In order to scale up the culture activities all over India and commercialization of the cage industry, availability of fish seed and also rearing them upto stockable size in cages is the most essential part before introducing into cages.

SIGNIFICANCE OF PRE GROW-OUT REARING:

Pre grow-out rearing is the most important phase for cage farming of marine finfishes where the fish fry (1-2.5 cm in size) can be reared to juvenile size (8-10 cm). In nurseries, the fry/fingerlings can be stocked at higher densities and reared in order to save the space and time in grow-out phase. In this transitional phase, grading of fish is the most important to avoid cannibalism, acclimatization and weaning to artificial feed and also to adapt to the environmental conditions that could be provided in the grow-out systems. It is a well established fact that the juveniles from the nurseries show better performance of growth and survival than those stocked directly into the grow-out ponds.

TYPES OF PRE GROW-OUT REARING:

The nursery rearing can be carried out either in earthen ponds, happas or cages, indoor cement tanks or fibre tanks.

Pre grow-out rearing in earthen ponds: The most important factor to be considered in nursery rearing of fingerlings to juvenile stage in earthen ponds is size of the pond which can accommodate a optimal stocking density with a good water exchange system. The stocking density and size of fish to be reared are also important factors considered in nursery rearing in order to avoid cannibalism. Pond bottom should be flat and sloping towards the drainage gate. Ponds with a lower dike/area ratio support a higher standing crop at harvest, as supplementary feeding is the major food source toward the end of the nursing phase. Ponds are prepared and fertilized at one week before stocking, to eradicate predators and to enhance the primary production. Artificial pellet feed (6-8% of biomass) should be given twice a day as supplementary feed. The pond should be disinfected by applying quick lime and the quantity of the lime to be used also depends on the type of lime and age of the pond. Inlet and outlet gates are provided with a fine screen (1 mm mesh size) to prevent predators and competitors from entering and prevent the escape of the fry / fingerlings out of the pond. In general, the size of nursery pond ranges from 1000 to 2000 m^2 with a water depth of 80 – 100 cm. Fry ranging from 1.5 – 2.5 cm are suitable for stocking in nursery ponds. The fish after reaching 10-15 cm can be transferred to grow out cages.

Pre grow-out rearing in hapas: Fish Fingerlings can be stocked in nylon cage (2 x 1 x 0.9 m) with 0.1 mesh size; with a stocking rate of 1000 -1500 individuals and rearing can be done for a period of 45 days. The fish has to be fed with artificial pellet feed 2-3 times a day. Grading of fish is done every 7-10 days. The fish after reaching 10-15 cm can be transferred to grow out cages. It is advantageous to conduct nursery rearing of finfish in hapas because it enables closer monitoring and grading resulting in uniform size stocking and better survival compared to open-pond rearing. It is likewise easy to maintain and require very little capital investment.

PRE GROW-OUT REARING IN CAGES:

The fish fingerlings can also be grown to juvenile stage in 3 dia net steel cages. Fish seed procured either from hatchery or wild can be stocked at a density of 2,000 seeds / net cage and monitoring of the fish is easy in net cages. Artificial pellet feed has to be given @ of 6-8% biomass twice a day. The fish can be reared in cages for one to two months. The maintenance cost of the net cages is lesser than the hapas. The fish will grow faster in net cages than hapas as it facilitates more aerations and water movements inside the cages. During the nursery period, size grading should be conducted every 15 days to avoid cannibalism. At the same time, the net cages should be checked for damage to insure that fish do not escape. The fish can be transferred to grow out cages once they reach 10-15 cm.

PRE GROW-OUT REARING IN TANKS:

The best method of nursery rearing of finfish fingerlings to juveniles is by rearing them in cement or FRP tanks in marine hatchery systems. Fish fry or fingerlings which are transported carefully from a hatchery or wild by packing them in plastic bags. During the transportation care has to be taken for maintaining the temperature by using crushed ice and sawdust (1:1) throughout the transport. By this method, the temperature can be maintained between 20-22^{0}C, which avoids the stress and mortality during transportation. After reaching the hatchery, the fish are to be stocked with a density ranging from 2000 to 3000 fingerlings in cement tanks (10' X 6' X 5') or fibre tanks with a capacity ranging from 1 tonne to 5 tonnes based on the stocking density. The density of fish stocked in nursery rearing will be varied from size and species of fish. Continuous aeration is to be ensured throughout the rearing period. The fingerlings are reared in nursery rearing tanks up to 45 days before they are shifted to grow-out ponds or open sea cages.

Feeding regimes: During the nursery phase extruded slow sinking feed is preferred. Crumbled feed should be provided according to the requirements and subsequently the pellet size can be increased. The size of the pellet during the nursery phase is highly correlated with the mouth size of the fry or fingerling. From second day onwards the fish should be fed with commercial fish feed with a pellet size of 0.5 mm diameter at 4 % of the body weight four times a day (6.00 AM, 12.00 PM, 6.00 PM and 12.00 AM) for the first 15 days. Then the pellet size has to be increased to 1 mm for next 15 days while the feeding rate and frequency remains unchanged. For the remaining 15 days, the fishes are fed with a pellet size of 2 mm. 100% water exchange should be done after feeding. It should be ensured that the feed is consumed immediately after feeding with no visible feed pellets settled at the bottom.

Grading and fish samplings:

Size selection or grading is necessary during the whole nursery period to avoid cannabolism and increase the survival of fish. Grading of fish should be done for once in a week with an automatic grader and grouped into different sizes. The mechanical grader available in the market can be used for grading the fries and fingerlings. This exercise will give more survival rate with better growth as the seabass fry are getting the suitable feed according to their mouth size. Also, the cannibalistic characteristics will drastically come down due to timely grading. Growth and health parameters of fish should be analysed at weekly intervals.

Water quality parameters:

Water quality parameters such as temperature, pH, salinity and dissolved oxygen should be monitored daily, while critical parameters such as ammonia (NH_3), nitrate (NO_3) and nitrite (NO_2) are to be measured fortnightly.

PRE GROW-OUT MANAGEMENT

Rearing the fry/fingerlings in confinement is subjected to adverse effects of over-crowding and ecological problems inherent in the culture system. As environmental parameters fluctuate and other factors extend its adaptive response, the fry attempts to maintain or re-establish its normal physiological behaviour. If this process is within the adaptive range the chance of survival of the fish will be high. The behavior and size distribution of the larvae and fry in the tank reflect the management and culture techniques that have been employed for the particular batch.

i. Swimming behavior

If the fry actively swim with head slightly downwards, and aggregate at the level near the bottom of the tank or at the certain level in the water column due to light activating, indicates healthy condition of fish fry/ fingerlings. Healthy fry also prefer staying at a certain distance from the aeration spot, and move actively.

ii. Feeding behavior

The healthy fry/fingerling shows fast swimming behavior around the tank seeking for food and accepts food vigorously. The fry swim slow and remain on the water surface after having enough food.

iii. Size distribution

If the stock is properly managed, the fry/fingerling are uniform in size. Under confinement conditions, the uneven growth of the fry promotes competition among the individuals for food, space and other essentials of survival. The resulting additive effects of stress on the smaller and weaker fry/fingerling, are witnessed by the dark to black color, making them more susceptible to infection or disease.

Uneven growth can cause a significant nursery mortality. The uneven growth could be due to the cannibalistic behavior of the species, dietary and environmental factors involved.

Pigmentation

The healthy fry have bright pigment and lively appearance. Head, body and tail are well developed. The survival rates of fish fingerlings are determined by temperature, salinity, light intensity, stocking density, feed and feeding, water quality, grading and cannibalism.

Grading techniques

Due to cannibalistic nature of the fish, size selection or grading or sorting is of prime importance. The first sorting should start at the second week, because during this period the bigger fish can eat the smaller ones. The easiest way of sorting is to use screen with various mesh sizes/mechanical graders so that the various sizes of fish can be separated easily. Stocking the same size of fish will reduce the rate of cannibalism, thus the survival rate will be increased and the growth rate of the fish could also be faster and more uniform.

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Small Scale Cage Farming and Community Development in Fishing Villages

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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. The impact of this is being felt by the fishermen living along the estuarine coast who are being deprived of livelihood. It is at this juncture the small scale cage farming is introduced along the coastal villages to augment the fish production and also as an alternate livelihood option for coastal fishers. There is scope for culturing euryhaline species in saline creeks and estuaries by installation of small cages along the coast the Indian coast.

Cage based aquaculture is practiced in many part of the world and capture based aquaculture in cages is also popular. Recently Central Marine Fisheries Research Institute (CMFRI) has initiated culturing of marine finfishes in cages and it has proven successful in many maritime states. In this the adoption of sustainable capture based aquaculture initiative by the traditional coastal fishers the state of Karnataka is note worthy. The participatory approach gave exposure to the local fishers on the finfish rearing aspects besides creating awareness on this lucrative farming technique. Encouraged by this success many fishermen group evinced interest in rearing finfish in suitable farming areas near their backyard. Thus the finfish culture in small cages are now propagated along the coast.

The species selected for small scale cage culture are red snapper *Lutjanus argentimaculatus,* seabass *Lates calcarifer,* Bigeye trevally *Cranxsex fasciatus,* pearlspot *Etroplus suratensis*. Factors such as their popularity as a food fish, high market pricehave contributed to substantial interest in these species.

Site selection: Proper site selection for cage 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. The site selection criteria adopted for aquaculture should be followed in the cage culture also.The site selected should have a minimum depth of 2.5 m, it should be free from pollution, with minimum fouling , should have good circulation of water to remove the waste materials falling from the cage etc. It is better to avoid the areas were phytoplankton blooms occur frequently and places where boats are operated. The place selected should have good accessibility.

Fish Seed Source: The estuaries are rich source of seed resources of cultivable fishes. In the estuary fishermen use cast nets and dragnets for fishes. Usually small sized fishes thus caught are not of economical value and is discarded. The concept of cage based aquaculture could be popularized by judiciously utilizing these seed resources. Thus small sized red snappers, bigeyetrevally which is of low market value were used for the cage culture. In addition to that seabass seeds are transported from hatcheries in east coast and stocked in cages and grown to harvestable sizes.

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 is 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 and standardised. 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 in almost all creeks along south west coast of India.

Three models of cages were experimented. The first model was of 2.5 x 2.5 x 2 m size with bamboo poles as frames and netlon material as outer protecting and cover and nylon net in the inside. 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 /m^3 is found to give a survival rate of 90-95% with average weight of 800g by the end of 8 month culture period.

In the second model GI pipe was used for the frame as it was found that this could be used for more than a year when compared to bamboo poles. The dimension of the cage was about 4 x 2 x 2 m and the holding capacity was about 16 t of water. About 50 nos /m^3 was found to give a good survival and growth.

In the third model cage which is now popular in the Karnataka coast is of 6 x 2 x 2 m with GI pipe as frame and netlon net on the outer side and nylon net on the inner side. This has holding capacity of 24 t of water and 50 nos/m^3 was found to be good. About 1000-1200 nos could be stocked in these cages.

For floating of the cages PVC pipes of 4 inch diameter is used. For giving extra floatation plastic cans of about 200-300 litre capacity is also used. The anchoring or mooring of cages in proper position is the key factor contributing to the success of the cage. The depth, substratum and current speed are the important factors to be considered for mooring. Usually nylon ropes are used as mooring ropes and sand bags are used for anchoring the cages. Generally sand bags are given in two points, where the shore is too close and additional mooring is also given to void the cage touching the store.

Growout

The fishes are fed with sardine and low value fishes *ad libitum*. Good growth and survival was attained for seabass and redsnapper in the cages. The fishes are usually grown upto 10 months and harvested before the monsoon season. In some places were heavy flow during monsoon is not there and sheltered bays are present the cages are kept for 20 months . About 1 ton of fishes could be harvested from such cages.

Seabass. The fishes stocked at a size of 10-20 gms would attain a growth of about 1000-1200 gm in 12 months and after 18 months it would attain an average weight of 3.3kg. The survival reported for this species isfrom 85-95 %. Price of the fish range from 300- 500/kg.

Redsnapper: The fishes in the range of 50-100 gms are usually collected and stocked in the cages. These fishes were found to attain weight of 800-1200 g with an average weight of 900g after 9-12 months. The survival recorded was about 95%. In 19 months the fishes attained weight of 1.6 to 2.3 kg with an average weight of 1.8 kg. The price of the fish ranges from 300-400/kg.

The production economics of the small scale cage culture is given below.

1	Cage dimension	6m X 2M X 2M
2	Species cultured	Redsnapper and seabass
3	Suggested stocking density	1200 nos./per cage
4	Culture period	10 months
5	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 cost (Structure last for 5 years)	40,000
11	Seed cost @ 15 Rs/ no for 7cm seed (from Hatcheries from TN)	1,80,000
	Transportation charges	20,000
	Total expenses for 12000 seeds	2, 00,000
12	Feed cost @ Rs.20/kg trash fish/ fish cutting waste 2,000kg	40,000
13	Maintenance coast	20,000
14	Total expenses	3,20,000
15	Profit in one year culture period.	**1.42 lakhs**

Thus the small scale cage culture is lucrative and could be adopted by the fishers living along the coast. One of the major constraint for the spread of this technology is adequate supply of seed and feed. Many artificial feeds are now available in the market and in addition to that a part of fish waste generated from the fish cutting sheds could be utilised for feeding the cage reared fishes. Finfish seed production and judicious exploitation of the seeds from the wild are the areas were interventions are required.

The technology of cage culture was disseminated successfully along the Karnataka coast and it involved technology demonstrations through participatory approaches, focussed group discussions, training by experts, technical assistance in site selection, cage fabrication, management etc., sharing of information and development of linkages between stakeholders, governmental and non-governmental agencies. Over the past six years, the small scale cage farming initiative has paid rich dividends in terms of increase in fish production besides increasing the social and economic benefits to fishers. Technology adoption, increased production through farming, empowerment of fisher folks are visible and tangible outcomes of this venture.

The technology is viable and various modifications and diversification of the species cultured has occurred over the years.. In conclusion, the sustained cage farming initiative and interventions carried out by CMFRI has provided alternate livelihood options and livelihood diversification. This novel technology has brought in new vistas and avenues to explore for fishers and engage in activities which could help them to find an alternate livelihood.

Assessment of Nutritional Quality of Cultured Fishes and Shellfishes

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Introduction

The United Nations Department of Economic and Social Affairs (UN-DESA 2009) statistics says that the world population is expected to reach about 9 billion by 2050. The growing world population can pose different challenges such as how to meet the rapidly changing demand for food from such a larger population, how to meet these demands in a way that doesn't affect the sustainability of environment and finally the most important task - that is to ensure that the world's poorest people are no longer hungry. The increase in food demand can be predominantly met with cereals as carbohydrate source and fish and shellfish as repository of protein, micronutrients, minerals and essential fatty acids. Fishery resources are being widely recognised as an important source of nutrients especially for many low-income populations in rural areas.

Food security is defined as "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FSN Forum 2007). It is estimated that fish provides about 20% of their average per capita intake of animal proteins for about 2 billion people and in many poorer island and coastal states about half of the total animal protein intake (FAO, 2007; FAO 2009). Worldfish reported that about 400 million poor people depend on fish for their food particularly in small island states (FAO 2007; Hortle 2007; Laurenti 2007). Moreover incase of countries with cereal-based diets, fish acts to provide important nutritional supplements to diets (Worldfish, 2010). Apart from being as a food source the fisheries sector is a source of income and livelihood for millions of people with an employment rate of about 44.9 million people worldwide (FAO, 2010). This shows the importance of fish in food security.

Nutritional importance of fishes and shellfishes

Fish is highly nutritious from the health point of view and its nutrient composition varies according to species, age, sex, season, capture and culture methods. The major constituents of fish include proteins, lipids and minerals. Fishes and shellfishes are widely considered as a good source of easily digestible protein with high biological value and arerich in essential aminoacids (AHA 2012). The protein content of fish ranges from about 16-21% and this mainly determines its wholesomeness. The protein content in shellfishes ranges from 8-15% and in oysters it is about 5-14%. Fish proteins generally comprises of three categories: (1) myofibrillar proteins -(actin, myosin, tropormyosin and actomyosin) (2) sarcoplasmic proteins (myoglobin, albumin and enzymes) and (3) connective tissue proteins (collagen and other stroma proteins). The sarcoplasmic, myofibrillar and connective tissue proteins constitute about 20-22%, 65-75% and 3-10% of the total proteins of fish muscle respectively. Shellfish are categorised as a low saturated- fat, high-protein food and hence included as a low-fat diet (Food and Nutrition Board, 2007).

The lipids in fishes generally occur as two major groups: the phospholipids and the triglycerides. The phospholipids are also known as structural lipids as it is essential for the integral structure of cellular membrane. The triglycerides are major depot fats which are used for the storage of energy. The fish lipids are widely considered as an excellent dietary source of long chain highly unsaturated fatty acids of omega-3 type such as EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid). Lot of researches have been carried out worldwide to study the importance of omega-3 fatty acids and their role in human health such as : the potential use of n”3 PUFA in psoriasis (Zulfakar, Edwards, and Heard., 2007), on bowel diseases (Turner, Zlotkin, Shah, & Griffiths, 2008), on treatment and prevention of mental illnesses (Song & Zhao, 2007), on the prevention of several types of cancer (MacLean et al., 2006; Chen et al., 2007), effect on rheumatoid arthritis (Ariza-Ariza,).

Seafood are generally considered as important source of minerals such as sodium, potassium, calcium, phosphorous and magnesium (Bodsha & Sainsbyry, 1978; Farmer, Ashfield, & Samant, 1979; Lal, 1995). The ash content in fish represents the mineral content in fishes and ranges from 0.4-2%. The most predominantly found mineral in fish is potassium. The aquatic organisms generally acquire minerals from their diet and surrounding water and deposit them in their skeletal tissues and organs (Lal, 1989). In case of cultured fishes, the mineral content mostly depends on the commercial feed used.

The minor constituents of fish include carbohydrate, vitamins, and other nitrogen containing extractives. The major carbohydrate present in fish is glycogen. The glycogen content in fishes is about 0.1- 1% and in case of molluscs it is about 1-7%. The glycogen content declines rapidly during stress and struggle. Seafood generally consists two categories of vitamins - water soluble and fat soluble vitamins. The vitamin content in seafoodare generally species-specific and can vary with season. In general, fish meat is considered as a good source of B vitamins and, fatty species rich source of vitamins A and D. Because of the high thiaminase activity in some freshwater species such as carps, they have very low thiamine content. The water-soluble, low molecular weight, nitrogen- containing compounds of non-protein nature in fishes are generally categorised as N-containing extractives (NPN). The NPN-fraction (non-protein nitrogen) constitutes from 9 to 18% of the total nitrogen in teleosts, 20-25% in molluscs and crustaceans and 30-35% in elasmobranchs. The major NPN compounds are: volatile bases such as peptides, urea, ammonia and trimethylamine oxide (TMAO), creatine, free amino-acids, nucleotides and purine bases.

The proximate composition of cultured fishes and shellfishes can vary considerably than its wild counterparts and it also depends on the method of cultivation. So it is very important to analyse the nutrient content of these cultured foods. The nutrient content of fishes is generally analysed using standard protocols such as the AOAC methods, 1990. The proximate composition of seafood such as moisture can be estimated using gravimetric method, protein using Kjeldahls method, fat using Soxhlet method, carbohydrates by furfural colorimetric method and ash by gravimetric method. Apart from this general methods used, other methods are also available. For instance, for the accurate determination of protein, UV absorption method at 280 nm, Bradford or Coomassie brilliant blue protein assay, Biuret or copper based assay, Lowry method or modified Lowry method are available. They all differ in terms of their sensitivity and detection limits. So according to the sample, the method selected can also vary. For the determination of aminoacid composition in foods, High Performance Liquid Chromatography (HPLC) can be used. Usually HPLC with an ion exchange column is used for aminoacid analysis. Similarly, for assessing the freshness of food by quantifying the nucleotide breakdown products and for the determination of fat and water soluble vitamins, HPLC can be used. For the determination of fatty acid composition in seafoods, Gas Chromatography (GC) can be used.

Aquaculture and its importance

The health benefit of fish has been documented worldwide and this inturn has put too much pressure on the demand and supply of fish. The world capture fisheries is not able to keep in pace with this increasing fish demand. There are several reasons attributed to the decline in capture fisheries and one among this is the decline in fish stocks. This has given an impetus to the development of fish or shellfish farming or aquaculture or culture based fisheries. Aquaculture is defined as the farming of aquatic organisms, including finfish and shellfish. It has the potential to become a key contributor in feeding the human population. In the present scenario, aquaculture is widely being recognised as one of the fastest growing food producing sub-sectors with a greater contribution to total world fishery production. Depending on the interventions made in the cultural practices, there are three different kinds of aquaculture systems: extensive, semi-intensive and intensive aquaculture.

The State of World Fisheries and Aquaculture (SOFIA) 2010 (FAO, 2010) reported that aquaculture production of many species showed an increasing trend. Along with capture fisheries, aquaculture supplied the world with about 148 million tonnes of fish in 2010, of which capture fisheries contributed 82 million tonnes, 10 million tonnes from inland capture fisheries, 32 million tonnes from inland aquaculture and 20 million tonnes from marine aquaculture. This report shows the fastest growth of aquaculture than any other food-producing sector and its potential to augment capture fisheries production in response to global demand (Bostock *et al*. 2010). Out of this 148 million tonnes, 128 million tonnes was utilized as food for people. Currently it is estimated that fish produced from aquaculture accounts for over one quarter of the total amount of fish directly consumed by humans.

Taking into consideration the fact that lack of adequate nutrition is a leading contributor to the global burden of diseases, the increasing trend of aquaculture production is a welcome sign (Ezzati *et al*., 2002). The advent in aquaculture systems has made available larger quantities of fish for domestic markets and home consumption (FAO, 1996). For instance, the widespread adoption of aquaculture in a number of countries, such as Bangladesh, China, India, Indonesia, Thailand and Vietnam, have documented the ability of aquaculture systems to improve productivity, contribute to the diversification of farm operations and for generation of additional employment and income.

Nutritional quality of cultured fishes and shellfishes

Aquaculture industry has become one of the fastest growing food producing sectors in the world, contributing to nearly 40% of worlds' fish supply. Though it has many positive sides, many a times we are not sure about the final quality of cultured fishes. Consumers are now a days very much concerned about the quality of food they are consuming. Martin, 1988 defined fish quality as "a combination of such characteristics as wholesomeness, integrity and freshness". Along with freshness, two other factors that determine the quality of fish are organoleptic properties and nutritional value. These two factors inturn depend on the chemical composition of fish which inturn depends on many other factors such as intrinsic characteristics of the fish (eg: species, age, sex etc.), environmental factors (eg: temperature, salinity etc.) and feeding history (composition of diet, feeding ratio etc) (Huss, 1988). Other than this, sometimes the pre-harvesting, harvesting and post harvesting factors can also affect the quality of fishes. Thus fish quality encompasses a wide range of interactions (Caggiano, 2000).

It has been found that the farmed fishes vary greatly with that of the cultured ones. The fatty acid composition among wild and cultured of certain species are being affected by dietary history and seasonality (Grigorakis *et al*., 2002; Ozyurt *et al*., 2005, Senso *et al*., 2007; Alasalvar *et al*., 2002; Ozyurt and Polat, 2006). The calculated atherogenic index (AI) and thrombogenic index (TI) of certain cultured species shows considerably lesser value than decline with that of its wild counterparts (Grigorakis *et al*., 2002; Saglik *et al*., 2003; Senso *et al*., 2007). Even, flavor and other quality aspects of farmed fish vary with that of its wild counterparts and hence less consumer preference towards certain farmed fishes are observed. The sensory tests also rank wild fish as having more pleasant taste and firmer texture than the cultured ones (Grigorakis *et al*., 2004). The highest content of volatile compounds has been attributed as one of the possible reason for the better taste in wild fishes than cultured ones (Grigorakis *et al*., 2004)

Nettleton *et al*., 2000 compared the fat, cholesterol and major fatty acid content of raw and cooked fillets of cultivated and wild channel catfish (*Ictalurus punctatus*), rainbow trout (*Salmo gairdneri*), and coho salmon (*Oncorynchus kisutch*). It was found that the fat content of cultivated catfish and salmon ranged from 2.5-5 times that of wild samples whereas the fat levels in wild and cultivated trout were almost similar. In general, they concluded that the omega-3 fatty acid levels were higher in cultivated than wild samples owing to higher fat content. Researches have shown that the fatty acid compositions of cultured and wild fish are different and the main reason for such differences is the diet (Chen, Chapman, Wei, Portier, & O'Keefe, 1995; Grigorakis, Alexis, Taylor, & Hole, 2002).

Alasalvar*et al*., 2002 studied the proximate composition, fatty acid and trace mineral content in the flesh of cultured and wild sea bass (*Dicentrarchus labrax*). The percentages of total saturated and polyenoic fatty acids as well as the n-3/n-6 ratio were higher in the wild sea bass than the cultured ones. The mineral analysis showed that the Fe and Zn were predominant elements and constituted 78.2 and 81.6% of the total mineral contents in the flesh of cultured and wild sea bass, respectively. They have concluded that total lipid content, fatty acid proportions and trace mineral compositions can be used to differentiate between cultured and wild sea bass. They also reported that these differences can arise due to the constituents of the diet of the fish.

Gonzalez *et al*., 2006 studied the differences in the chemical, physical and sensorial properties of wild and farmed yellow perch by determining its mineral, fatty acid and amino acid contents, proximate composition, texture, color and sensory properties. The study found out that the fat content of farmed yellow perch was significantly higher, whereas the protein content was significantly lower than that of the wild yellow perch. The wild perch fillets exhibited high shear force (total energy/g (J/g)). Mineral analysis showed that farmed yellow perch had higher concentrations of magnesium, phosphorus and potassium whereas the wild yellow perch have higher concentrations of sodium and sulphur. The higher lipid content in farmed fish can be due to a variety of factors including availability and type of food, ingredients of diets such as fish meal and possible periods of starvation encountered by wild fish. Protein and mineral content of fish fillets can be influenced by diet.

Rodrýguez *et al*., 2004 had compared the total lipid, lipid classes and their associated fatty acids in muscle and liver of wild and one-year cultured black seabream (*Spondylio somacantharus*) adults. It was found that the total lipid contents of muscle and liver of the cultured fish were 2.5-fold greater than that of its wild counterparts. This difference in the lipid composition between the wild and cultured black sea bream was because of the diet. Though a good growth pattern and survival rate was observed in the cultured fish, absence of spawning, significant lipid accumulation and the imbalance of essential fatty acids in their muscle and livers were noticed. The study emphasized the need of proper assessment of lipid content in the formulated feeds to ensure proper growth and reproduction in cultured fishes. From these reports, it is very evident that the nutrient composition of cultured fish depends greatly on the diet.

Chemical contaminants in cultured fishes

With the increase in human population, the food demand also keep on increasing and to cope up with these increasing demands, majority of the world's aquaculture systems started intensifying the cultivation methods. These intensification measures include: high stocking density and volume; greater use of inputs, the heavy use of formulated feeds containing antibiotics and other antimicrobials; and the heavy application of pesticides, and disinfectants. The use of such chemicals in aquaculture can cause pollution in the environment. These chemicals can be either from antibiotics, pesticides, herbicides, hormones, anaesthetics, pigments, minerals, and vitamins (Goldberg *et al*., 2001; JSA, 2007).

Apart from pollution, the indiscriminate use of antibiotics, pesticides and other antimicrobials raised a number of potential food safety and human health concerns. Higher concentrations of toxic substances are found in many farmed fishes such as pesticides, polybrominated biphenol ethers (PBDE), and polychlorinated biphenols (PCB) in salmon (Hites *et al*., 2004; Montory and Barra, 2006; Hayward *et al*., 2007), PBDE and dioxin in catfish (Minh *et al*., 2006), dioxin and PCB in turbot (Blanco *et al.*, 2007), PCB in sea bass (Carubelli *et al*., 2007). The consumption of fishes loaded with these chemicals can cause serious health concerns such as cancer than the expected nutritional benefits from them (Hites *et al*., 2004, Foran *et al*., 2005; Hastein *et al*., 2006; Carubelli *et al*., 2007; Dewailly *et al*., 2007). Moreover, this intensification practices result in greater generation of waste products and increased potential for the spread of pathogens. Though researches are being carried out worldwide to evaluate the food safety issues associated with intensive aquaculture there are still gaps existing in the data.

a. Antibiotics

The intensification practices in aquaculture such as high stocking densities can create stressful conditions to the cultured fishes. As a result of this, the risk of getting bacterial infections among cultured fish is high. To resolve this issue, high amounts of antibiotics are administered in fish feed for prophylactic and therapeutic purposes (Alderman and Hastings, 1998; Graslund and Bengtsson, 2001; Holmstrom *et al*., 2003; FAO, 2004a; Cabello, 2006). The most serious outcomes of such indiscriminate practices are the emergence of antibiotic resistant bacteria. Researches have been carried out to study the presence of antibiotic-resistant bacteria and resistance genes from cultured fishes such as the tetracycline resistant gene, beta-lactamase resistance genes (Furushita *et al*., 2003., 2005).

Apart from the antibiotic resistant bacteria another important problem is the antibiotic residues in fish and even in farm ponds. The extensive use of antibiotics in shrimp farming regions of Thailand and the Philippines (Graslund *et al*., 2003; Holmstrom *et al*., 2003) was reported. In 2007, FDA banned the 5 imported fish species from China on the basis that they were contaminated with nitrofuran, malachite green, gentian violet, and/or fluoroquinolone antibiotics (FDA Press Conference, 2007; FDA Import Alert, 2007). It has not been studied in detail whether the exposure of such antibiotic residues can create cause serious health concerns in humans or not.

b. Heavy metals

Metals are present in fish as diet constituents or added additionally for nutritional purposes. The common metals in feed include copper, zinc, iron, manganese, and others. The presence of metals such as mercury and arsenic has been reported from both wild and cultured species (Clarkson *et al*., 2003; Schober *et al*., 2003; Mahaffey *et al*., 2004). The adverse human health effects associated with exposures to heavy metals include neurotoxic and carcinogenic effects. High load of organic arsenic has been reported in farm raised salmon compared to their wild-caught counterparts by Foran *et al*. (2004). Similarly, higher levels of arsenic, lead and zinc was reported from farmed eel than wild-caught eel (Calvi *et al*.,2006). Another study reported higher levels of mercury and methyl mercury in farmed blue fin tuna compared to wild blue fin tuna. The reason for this can be due to the use of large predatory fish such as mackerel as feed for the farmed tuna which have contributed to the higher levels of mercury.

c. Organohalogens

Studies have shown that higher levels of organohalogen compounds such as dioxins, PCBs, PBDEs and other organophosphates (OPs) in muscle tissue of farmed salmon than their wild counterparts (Hites *et al*., 2004a; Hites *et al*., 2004b; Hamilton *et al*., 2005). Similarly, studies have reported higher levels of total PCBs in dry muscle tissue of farm-raised sea bass from Portugal than the wild caught ones (Antunes and Gil., 2004), higher levels of PCBs, PBDEs and OPs (except toxaphene) in farmed salmon than wild-caught salmon (Easton *et al*., 2002). In general, the reasons for these high levels of compounds in farmed fishes can be attributed to the kind of fish feed used and the prophylatic measures adopted to overcome the disease problems (Easton *et al*., 2002; Antunes and Gil, 2004; Carlson and Hites, 2005).

There are several methods available to do the chemical contaminant profiling in seafood. For the determination of heavy metals in seafood, Flame/graphite furnace Atomic Absorption spectrophotometer is being used. For the determination of organochlorine pesticide residues in fish GC-ECD method (QuEChERS method of extraction and clean up) can be followed. For the determination of nitro furan metabolites in shrimp LC-MS/MS is being used. For the determination of polycyclic aromatic hydrocarbons, biogenic amines HPLC can be used.

Conclusion and Recommendations

Owing to the increased demand in fish supply, the global aquaculture production continues to increase at exponential rates by the intensification of production practices. But these intensification practices caused a decline in food quality. Several researches have been carried out to find out the nutritional quality of cultured and wildly caught fishes and shellfishes and they have concluded that the quality of cultured fishes varies considerably with that of the wild ones. Good nutritional quality can be acquired by proper management of diet and also water circulation in culture systems. The wild caught ones rely entirely on the natural food where as in aquaculture practices artificial feed is being given. So, obviously there can be variations in the nutrient compositions of wild caught and cultured fishes. Therefore, utmost care is needed during the development of diets and subsequent analysis has to be carried out to ensure its nutrient composition. Moreover, by giving such feeds the dietary requirements of fish can be met or not, also has to be identified. Because diet represents the major factor influencing the fatty acid composition it can be wisely used as a better tool to modify the fatty acid profile of cultured fishes.

Apart from diet, another factor that affects the cultured fish quality is the use of chemicals such as antibiotics, pesticides, disinfectants. With the indiscriminate use of these compounds, elevated levels of antibiotic residues, antibiotic-resistant bacteria, persistent organic pollutants, heavy metals is observed in cultured fishes compared to that their wild counterparts. Researches have to be carried out not only to fully understand the human health risks associated with cultured fish versus wildcaught fish but also to develop appropriate interventions that could reduce or prevent these risks. The recent U.S. recalls of Chinese seafood indicated the need of ensuring safety of cultured fishes and shellfishes. Immediate actions should be taken to identify alternative methods of aquaculture that focus on the regulated use of antibiotics and agrochemicals. Other than this, an international agreement, under the umbrella of the WHO has to come into place that can regulate the use of antibiotics and agrochemicals.

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Copepod Culture

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Introduction

Copepods represent about 80% of zooplankton in the ocean and are the natural food source for many marine fish larvae. Copepods can adapt to fluctuating environmental conditions and the resting eggs some copepods produced can survive for years. This makes it a suitable group as live feed in aquaculture.

Live prey is necessary for fish larvae for many reasons. The larvae of many marine fish require prey about 50–100 μm wide at first feeding (Detwyler and Houde, 1970; Yufera and Pascual, 1984). Fish larvae with very small eggs and little vittelin cannot survive on the yolk available for many days and such larvae are called the altresial larvae. Such larvae need small feed depending on the smaller mouth size. Also for this type of larvae the stomach is not fully developed and they obtain digestive enzymes from the live feed they prey upon. Another advantage of live feed is that fish larvae prefer moving feed rather than inert feed during early stages of development.

Profile

Most adult copepods have a length between 1 and 5 mm. The body of most copepods is cylindroconical in shape, with a wider anterior part. The trunk consists of two distinct parts, the cephalothorax (the head being fused with the first of the six thoracic segments) and the abdomen, which is narrower than the cephalothorax. The head has a central naupliar eye and uniramous first antennae that are generally very long. Planktonic copepods are mainly suspension feeders on phytoplankton, yeast and/or bacteria; copepods are therefore filter feeders.

Copepods cultured or wild collected have a very good nutritional profile suitable for fish larval rearing. Copepods offer a great variety of sizes, species and qualities (Kinne, 1977; Yufera and Pascual, 1984; Delbare *et al*., 1996), and have high levels of protein, highly unsaturated fatty acids (HUFA), carotenoids and other essential compounds (Kraul *et al*., 1992). In general copepods have high protein content (44-52%) and a good amino acid profile, with the exception of methionine and histidine. The fatty acid composition of copepods varies considerably, since it reflects the fatty acid composition of the diet used during the culture. HUFA are essential for marine fish larvae and Docosahexaenoic acid (DHA; 22:6 (n:3)) has a significant influence on larval stress resistance (Kraul *et al*., 1991, 1993). DHA content is higher in copepods than in recently hatched Artemia nauplii and gives better results in terms of survival, growth and stress resistance (Fujita, 1979). Superior larval stress resistance can be achieved with copepods, even when DHA content is less than enriched Artemia nauplii

(Kraul*et al*., 1992). Other good characteristics of copepods are their swimming movements as a larval visual stimulus, the tank-cleaning performance primarily by benthic harpacticoids, which are grazers (Støttrup *et al*., 1995), their high digestive-enzyme content (Delbare *et al*., 1996) and a possible enhancement of feeding rates with improved growth and survival (Støttrup and Norsker, 1997).The passage of copepods in the alimentary canal of fish larvae is slower than artemia which makes its digestion and absorption more efficient (Pederson, 1984). This is due to the fact that copepods contain more digestive enzymes which are a suitable source of exoenzymes for fish larvae.

Several candidate species of copepods belonging to both the calanoid and the harpacticoid groups have been studied for mass production. Calanoids can be easily recognized by their very long first antennae (16-26 segments), while the harpacticoids have only a short first antennae (<10 segments). Cyclopoid species which has culture potential is *Oithona* sp. Some calanoids that are mass cultured are: *Acartia tonsa, Eurytemora affinis*, *Calanus finmarchicus, C. helgolandicus and Pseudocalanus elongates. Cultured* harpacticoids are: *Tisbe holothuriae, Tigriopus japonicas*, *Tisbenta elongate and Schizopera elatensis*. In general, it may be stated that harpacticoid copepods are less sensitive and more tolerant to extreme changes in environmental conditions (i.e. salinity: 15-70 g.l^{-1}; temperature: 17-30 °C) than calanoids and thus are easier to rear under intensive conditions. Moreover, harpacticoids have a higher productivity than calanoids and can be fed on a wide variety of food items, such as microalgae, bacteria, detritus and even artificial diets. However, as mentioned previously, care should be taken in this respect as the lipid and (n-3) HUFA composition of the copepods is largely dependent on that of the diet fed.

Reproduction

Parthenogensis is not there in copepods. Since both males and females are present, sexual reproduction is present. The fertilized eggs are attached to female's abdomen and the eggs hatch out into naupliar larvae with 3 pairs of legs. They grow and moult several times to become copepodite. Copepodites further grow and moult before becoming adult copepods. Copepods need longer period of time to grow from egg to adult than rotifers and cladocerans. Some species have resting eggs or diapause in egg or copepodite stage, which can be effectively utilized in culture of copepods by storing eggs.

Criteria for selection of copepod for culture

Natural occurrence, type of spawning (free spawner/ egg carrying), daily egg production and fecundity (eggs per female)

Culture Techniques

The culture techniques followed for copepods are as follows:

Culture techniques	Culture volume	Productivity (eggs/ day) (l)
Semi extensive	Large ponds/ lagoons1.200-10.000 m^3	<50
Semi intensive	Tanks:200-300 m^3	<100
Intensive	Flasks or tanks 5-110L	500-6000

Most of the large-scale copepod culture systems are based on outdoor semi-controlled polyculture techniques, although several attempts have been made to culture some species in intensive systems (Støttrup *et al*., 1986; Støttrup and Norsker, 1997).

Collection

Zooplankton samples are to be collected from the estuarine waters using plankton net of 200 micron mesh size on full moon day early morning hours. The samples have to be transported to the laboratory and thoroughly rinsed with filtered water of same salinity. From the samples copepods are identified under microscope using the keys (Kasturirangan, 1963).

Isolation

After collection the zooplankters are screened to isolate size fraction containing adult and later stage copepodites of the desired species. The zooplankton samples are first sieved through a 500 micron mesh to remove the larvae of fish or shrimp. The samples are again sieved through 200 micron mesh to remove smaller zooplankters like rotifers. Copepod nauplii and molluscan larvae. This is repeated 3-4 times by rigorous washing with fresh seawater. After repeated washing, the remaining adult copepods and later stage copepodites are used as stock cultures.

Stock cultures

Stock cultures are maintained in 5-20 litre glass containers with continuous aeration. Periodic water exchange with filtered seawater reduces contamination of the culture. Each time the contents were filtered through 200 micron mesh before water change and the adults that are retained were further reared by feeding on microalgae. The water quality parameters are to be maintained by regular monitoring of pH, salinity, temperature, dissolved oxygen etc. The algal feeds include *Chlorella marina, Isochrysis galbana*, *Chaetoceroscal citrans*. Further scaling up of culture is done by inoculating into bigger containers. Algal stock cultures also have to be maintained for its continuous supply for mass culture. Standard methods are available for algal stock culture.

Production of copepods

Batch culture of copepods is relatively straight forward once proper environmental and nutritional conditions are met. The culture flasks are stocked with adult copepods (10-25 individuals/ml). The stock cultures maintained in 1L conical flasks containing filtered sea water (20-35 ppt) are fed with microalgae in the ratio 1:25 (v/v). The copepods are fed with algae on alternate days. The stock culture is maintained by rinsing with filtered sea water and the eggs, nauplii, and adults separated and put into fresh culture flasks every week. The adult would begin producing eggs/ sperms in 9-12 days; thereafter egg production would initially rise, then reaches the peak and finally falls. Once the hatching success falls below 75%, it is time to terminate the culture batch. For continuous production of nauplii, sequential batch cultures have to be initiated at every 5-7 day intervals. When timed correctly, one tank of a series will be at the maximum productivity at any given time.

Mass culture

For mass culture chlorinated and dechlorinated (using sodium hypochlorate and sodium thiosulphate) sea water is used. The cultures can be maintained in 50L-3000L out–door culture tanks with continuous aeration.Copepods are daily fed with a mixture of micro algal diet (*T. gracilis, C. calcitrans, I. galbana.*) and baker's yeast.

Different Species Used for Coastal Pond Farming in India

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Commonly raised species in freshwater ponds are the carps, tilapia, catfish, snakehead, eel, trout, goldfish, gouramy, trout, pike, tench, salmonids, palaemonids, and the giant freshwater prawn *Macrobrachium*. In brackishwater ponds, common species include Pearl spot, *Etroplussurratensis*, mullet (*Mugil* sp.), milkfish (*Chanos chanos*), and the different penaeid shrimps (*Penaeusmonodon, P. orientalis, P. merguiensis, P. penicillatus, P. semisulcatus, P. japonicus,* and *M. ensis*). The more popular species for culture in marine cages and/or ponds are the Sea bass, Cobia, Pompano, Grouper, Red sea bream, Rabbitfish, and marine shrimps.

Traditional culture of grey mullets *Mugil cephalus* & milk fish *Chanos chanos*

In India two major cultivable fin fishes, namely, mullets and milk fish have been used in the traditional culture practices and also in the scientific culture of fin fishes in ponds and pens. Among mullets, the striped mullet *Mugil cephalus* is a fast growing species and is commonly available on the east and west coasts of India. It is also an important table fish and has a good market in the markets of our country.

Features of *Mugilcephalusas* as a candidate species

- Ability to live in varying genre of water resources.
- Ability to make their living together with a variety of fishes.
- Lively growth rate.
- High survival rate of young ones.
- Delicious taste and flavor.
- Ability to take food from natural sources as well as formulated feeds
- High demands in the markets and the attractive prices in the domestic markets

Seed

Most of the flathead grey mullet fry used in commercial aquaculture are collected from the wild. During the late summer months adults migrate to the sea in large aggregations to spawn. Fecundity is estimated as 0.5–2.0 million eggs per female, depending upon the adult size. Hatching occurs about 48 hours after fertilization, releasing larvae approximately 2.4 mm long. When the larvae are 16–20 mm, they migrate to inshore waters and estuaries, where they can be collected for aquacultural purposes during late June to early September. Shoals of fry are collected by fine seine nets, transported in seawater to hapas or shore. They are then transported by trucks to separate nursery units, or nursery facilities in grow-out farms. They are then transported by trucks to separate nursery units, or nursery facilities in grow-out farms.

Pond preparation

Prior to culture ponds are to be prepared by drying, ploughing and manuring with 2.5 – 5.0 t/ha of cow dung.Ponds are then filled to a depth of 25 – 30 cm and kept for 7 -10 days – for natural feed build up. Increase water level to 1 -1.5 m and finger lings are stocked. Productivity has to be maintained at the required level – Chicken manure / chemical fertilizers.

Salinity	15-35 ppt
pH	6.5 – 9.0
Diss. Oxy	4 -5 mg/1
Nitrate	0.1 - 4.5 mg/1
Nitrite	<0.5 mg/1
Ammonia	Total ammonia <0.1 mg/1
Phosphate	> 60 ppm
Plankton	Good productivity

Nursery rearing

The nursery pond comprises about 1-10 % of the total area. The most suitable place is where it can be easily supplied with fresh unpolluted water at all times and at elevation where it can be readily drained even during ordinary low tides. Water depth should be 15 to 25 cm. A manageable area ranges from 0.01 to 0.25 ha. Feeding areas, corners and side ditches in the pond has to be properly tiled and dried to avoid the formation of black soil. 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.

Grow-out techniques

In many countries mullet fry and fingerlings are stocked in inland lakes and reservoirs as a form of fisheries enhancement (culture-based fisheries). Cultured flathead grey mullet 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, brackish water and marine water.Prior to stocking, aquaculture ponds are prepared by drying, ploughing and manuring with 2.5–5.0 t/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 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 of both carps and tilapia grown in the same ponds.

The growing season is normally about 7–8 months. If mullet are monocultured, 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. When mullet are reared in polyculture, they are usually stocked with tilapia, common carp and silver carp. In this case, feeding and fertilization programmes are usually targeting the other cultured species and the mullet feed on the natural feed, detritus and feed leftovers.

Acclimatized to the appropriate salinity, and stocked as 10–15 g individuals at 6 200 –7 500/ha, a harvest of 4.3–5.6/tonnes/ha/crop can be obtained. In semi-intensive polyculture with tilapia and carp, mullet fingerlings are stocked at 2 500–3 750/ha together with 1 850–2 500/ha of 100 g common carp juveniles and 61 750–74 000/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 in the subtropical region, flathead grey mullet reach 0.75–1 kg; if kept for two on-growing 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. The two seasons are continuous until they reach that size. As usual, the choice of rearing technique depends on market demand and economics.

Feed: In monoculture, mullet feeds on natural food and on the by-products of grain mills and rice polishing plants. In polyculture, manufactured extruded pellets are produced either in feed mills specialized in the production of fish feed or, in many cases, in chicken feed mills that have a line for fish feed production. Feed is formulated according to the dietary requirements of the major cultured species (i.e. tilapia and common carp).

Harvesting: Harvesting of mullet is done usually partial or full according to the demand. 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 morning.In semi-intensive culture, total drain-harvesting is used. 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.

Handling and processing

Fish are collected from the catch ponds by scoop nets and transferred into plastic boxes, washed in running water, and then sorted according to species and sizes. Sorted fish are weighed and packed in plastic boxes with crushed ice or ice flakes.

Harvested mullet is marketed daily and consumed fresh and never kept on ice for more than one day. Older mullet is considered of inferior quality and does not usually gain a good price.

Attributes for aquaculture

- Milkfish is a warm water species. It prefers water temperatures 20–33°C.
- Unlike many other large saltwater fish it is herbivorous and feeds on cyanophyta, diatoms and other similar food items.
- Larvae eat zooplankton. Juveniles and adults eat cyanobacteria, soft algae, small benthic invertebrates, and even pelagic fish eggs and larvae.

- Can be grown in monoculture or in polyculture with other finfishes and crustaceans.
- Wild fry occurs in the tropical and sub-tropical seas.
- Technology for broodstock development and hatchery for large scale seed production is already established in many countries including India (CIBA).
- Technology for nursery and grow-out in ponds, pens and cages in fresh, brackish and marine environment is developed.
- Juveniles can be grown to maturity (broodstock size) in 5–7 years in ponds, tanks and cages under proper management.
- Artificial feeds for intensive farming have been developed.
- Fingerlings (25 g) can also be used as tuna bait.
- Recommended as bio-manipulators to produce green-water for environmentally friendly intensive shrimp farming.
- No known occurrence of disease outbreak in aquaculture.

The demand for milkfish has been growing as population rapidly increases. Scientifically speaking, milkfish is known as *Chanos chanos* and is considered as one of the cheapest source of animal protein in the region. Semi-intensive culture in brackishwater ponds is only one of the major growth areas in milkfish farming. Semi-intensive Milkfish Culture Sites recommended for the milkfish culture are those existing brackish water fishponds which are susceptible to have constant salinity and temperature throughout the year. Soils like sandy clay, loam or silty are best.

Seed

Under natural conditions, larvae and fry migrate inland, seeking tidal pools. They settle in them for 1 month until they become juveniles, then migrate into lagoons, lakes and shallow waters. Larvae for aquaculture can be collected from brackish waters such as shallow sandy areas, mouths of rivers, and lagoons. Intensive milkfish farming depends heavily on hatchery bred fry.

Nursery

Nursery ponds are prepared by sun drying, liming and application of organic and inorganic fertilizer to enhance growth of benthic algae (lab-lab). Supplemental feeding with rice bran and other feedstuff is often done. Fry are stocked in 1–5 hectare nursery ponds, at the rate of 30–40 fry /m^2, for 30–45 days. Densities are reduced as the fish grow. Some are directly stocked in grow-out ponds and the rest go to transition or stunting ponds at 15 fingerlings /m^2 for 6 months to about a year.

Grow-out

A grow-out can be square or rectangular in shape constructed in series design with independent water supply / drain gate / canal system. Sluice gates can be made up wood or concrete. The pond bottom must be leveled flat but inclined towards the gate for convenient water management and easy harvesting stocks. Comparatively, lab-lab excels over other food types in milk fish culture. When it comes to raising milkfish Lab-lab is local term benthic algal communities which consist of yellowish – greenish minute plants and animals that form a mat on the pond bottom. They are sometimes detached and float in clumps or patches. There are different types of grow out systems are practicing in different parts of the world.

***Shallow water culture*:** In the traditional culture method, milkfish are cultured in shallow (40–60 cm) brackish water ponds of 2–50 hectares. Water exchange is tidal. The growth of benthic algae is encouraged through photosynthesis and fertilization. Other natural foods like filamentous algae (lab-lab) may be resorted to, but yield is less compared with lab-lab. Usually stocking; 2,000–3,000 fingerlings (5–10 g)/ ha; 1–2 crop/ year; and yield 1.5–2.0 t/ha/yr.

Deep water culture: Milkfish are cultured in ponds, with a depth 80–110 cm and area 1–10 hectares; usually stocking; 2,000–3,000 (5–10 g)/ha.water exchange is tidal. Production: 1–2 t/ha/yr.

The modular system: Allows 6–8 crops/yr. with yield of 2–4 t/ha/yr. The growing fish are moved through three adjoining ponds of increasing sizes, at the ratio of 1:2:4 or 1:3:9. Ponds are prepared by the lab-lab method of growing natural food. Water exchange is tidal. The program involves pond preparation, stocking, transfer & harvest in regular intervals. To sustain year-round production, an inventory of fingerlings, organic and inorganic fertilizers, and organic pesticides needs to be maintained.Aerated ponds: Increased productivity can be gained through culture in deep ponds (0.1–1.5 m) using paddle wheel aerators, feeding machine and water pump to increase primary productivity. At the minimum stocking density of 8,000–12,000 fingerlings per hectare, production of 4–6 t/ha/yr can be attained. At the highest density of 30,000 fingerlings per hectare, yield is 12–15 t/ha.

Pond Preparation and growth of Lab-lab

Drain the pond completely and allow it to dry for about 1-2 weeks until the soil cracks. Do not over dry because prolong drying is not advisable as it makes the soil hard and powdery. Eradicate unwanted species using organic pesticides such as combination of ammonium sulfate fertilizer and agricultural lime. Prepare a mixture of hydrated lime and ammonium sulfate fertilizer (21-0-0) at a ratio of 3:1 at a rate of 100-grams/1000 m^2 and broadcast it in wet waters of pond bottom during sunny days. The mixture releases heat and ammonia, which effectively kills unwanted species in the pond. Fertilize the pond by applying chicken manure at 2 tons per hectare. Fill the water to depth barely covering the pond bottom and broadcast urea (45-0-0) at 15 kg/ha, 2-3 days later to speed up the breakdown of chicken manure. Increase the water depth gradually over a period of half – one month at 3-5 cm from time to time until the stocking depth of 0.8-1.0 meter. An abrupt increase in water depth will cause the lab-lab to detach and float. Install fine-mesh screens at the water gates to prevent re-entry of unwanted species and the possible escape of cultured species. The common practice to get rid of the snails is by collecting them by sweeping or hand picking and burn them. Eradication of Snails Ready the ponds for stocking. Initial size of stocking is being done with average weight of 80-100 grams from reliable source.

Stocking and management

Fingerlings are normally held in hapa nets a few hours before stocking. Stocking should be done during the cooler part of the day. Slowly release the fingerlings to the pond at the density of 50,000 fingerlings/ha per cropping. Count the fingerlings to prevent under or over stocking. When lab-lab starts to get overgrazed, apply inorganic fertilizer (16-20-0) at 50kgs. / ha every 1-2 weeks. Provide formulated diets daily at 5 percent (5%) of the body weight per day. In designated area, broadcast or use feeding tray to condition the fish to eat pellets for about a week. Water management can be either tidal or with the aid of water pump. Tidal management were mainly following the lunar periodicity after stocking, maintain the optimum water condition for both the fish and natural food. When using lab-lab food base, apply fertilizer (16-20-0) at the rate of 50 kg /ha, divide into small doses and apply every 12-15 days. As much as possible coincide the fertilization during the spring tide cycles. Replenish about one-third of the pond water before any fertilizer application. During hot months, increase the frequency application. During rainy months, drain the uppermost freshwater layer in the column to prevent the occurrence of salinity fluctuations. In the middle or towards the end of the culture period, lab-lab may be prematurely depleted because of overgrazing, poor water conditions. Provide supplemental feeds at a rate of about (5%) percent of the average body weight of the fish per day using commercial feeds. Unusual fish behavior may sometimes be experienced when the stocks are exposed to stress. This phenomenon is characterized by the presence of fish at the water surface gasping or swimming in circles. These are indications of stress associated with sufficient dissolve oxygen (DO) concentration. Replenish water at the first opportunity stress associated behavior of the fish. The water may be splashed-on to a piece of wood to increase oxygen concentration in the pond. To attain the highest possible profit, culture period should be about 60 days for cost efficiency. Yield is up to 2.0-2.5 tons/ha./crop which is equivalent to 6.0-7.5 tons/ha/ year for 3 cropping.

Harvest

Milkfish are normally harvested at sizes of 20-40 cm (about 250-500 g). There are three known methods used for harvesting milkfish:

- Partial harvest. Selective harvest of uniformly grown milkfish from grow-out facilities (i.e. cages, pens, ponds, tanks) using seine or gillnets, retaining the undersize fish and harvesting only the commercial sized stocks, with an average body weight of 250 g or larger. Partial harvesting is done by using bigger meshed nets so that small fishes could pass through the net trapping only the bigger and harvestable stocks.
- Total harvest. Complete harvest in one crop period from grow-out facilities (i.e. total draining of ponds by gravity or pump, hauling of the entire net cage structure, seining or the use of gillnets in pens). The harvest size at this stage may vary from 250-500 g.
- Forced harvest. Emergency harvesting, regardless of fish size or grow-out stage, which is carried out during 'fish kills' due to oxygen depletions that are attributed to algal blooms, red tide occurrence, pollution or other environmental causes.

Traditional cultureof Asian Sea bass

Extensive culture of sea bass as a traditional activity is followed in the Indo-pacific region. In low lying coastal ponds, juveniles of assorted sizes collected from estuarine areas are introduced and fed with the forage fishes like tilapia, shrimps and prawns available in these ponds. These ponds receive water from adjoining brackish water or freshwater canals or from monsoon flood. Harvesting is done after 6-8 months of culture. Since sea bass exhibit differential growth, the size of the harvested fishes varies from 0.5 to 5.0 kg. Production up to 2 ton/ha/7-8 months has been obtained.

Pond culture

The two-week nursery reared fingerlings are suitable for pond culture. The production pond can have concrete walls and a soft bottom, ranging in area from 0.1 ha to a few ha, water depth of up to 2 m and salinity of 5-10 ppt is suitable. Seabass culture in ponds can be carried out either by poly-culture method or by feeding with low cost fishes like tilapia/oil sardines or with extruded floating pellets. The pond is at first dried, tilled, leveled and manured with raw cow dung @ 1000 kg/ha. If required, lime is added @ 50-200 kg/ha to maintain soil pH above 7. Urea @ 100kg/ha and super phosphate @ 50 kg/ha can also be added to enhance the algal bloom. Sea water/fresh water is then filled to a depth of 60 – 70 cm in the pond. When the pond water becomes light green in colour indicating sufficient development of algae in the pond, forage fishes are introduced.

In pond culture, stocking with seed of uniform size (5-10 g), @ 3000-5000 nos./ha is desirable. Feeding of fish is carried out following two methods. In the first method, the fish are fed exclusively with chopped trash fish @ 10% of biomass twice daily (08.00 & 17.00 hrs) and reduced to 5% subsequently. In the other, the food is made available in the pond in the form of forage fish like Tilapia *(Tilapia mossambicus)*. Pelletized feed can also be given. In a well-prepared pond, manured/fertilized with raw cow dung @ 1000-1500 kg/ha and urea @ 100-150 kg/ha, Tilapia adults (male and female in the ratio 1:3) are introduced and reared for 1-2 months prior to stocking with seabass. To maintain natural food production for the forage fish, periodic manuring at fortnightly interval is done @ half the initial dose. 20% of pond water is exchanged on alternate days. Harvesting is done by draining the ponds or by using seine nets. Grow-out pond culture of seabass can yield a production of 2-3 tons/ha within a rearing period of 7-8 months.

Harvesting

For sea bass farmed in cages, harvesting is relatively straightforward, with the fish being concentrated into part of the cage (usually by lifting the net material) and removed using a dip net. Harvesting sea bass 'free-ranging' in ponds is more difficult, and requires seine-netting the pond or drain harvesting. After harvesting, the barramundi are placed in ice slurry to kill them humanely and preserve flesh quality. Fresh barramundi is generally transported packed in plastic bags inside styrofoam containers with ice. There is a limited market for live barramundi in Kerala. Fish are usually transported live in tanks by truck.

Pompano culture

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. 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. In the international market, the dockside price of Florida pompano averaged to $ 8 /kg and in India, the current price of silver pompano is about Rs.200/ kg at the fish landing centres and around Rs.250/ kg in the retail markets.

Pond preparation

The pond has to be dried properly until the cracks appear on the surface. The top layer of the soil containing waste accumulated through previous crop of fish or shrimp has to be removed. Ploughing has to be done to tilt the soil below 30 cm. Feeding areas, corners and side ditches in the pond has to be properly tiled and dried to avoid formation of black soil. 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.

Nursery Rearing and Seed Stocking

Hatchery produced pompano fingerlings of 1 inch size can be stocked in happas/ pens of 2 meter length, 2.0 meter width and 1.5 meter depth. In each happa about 200 fingerlings can be stocked. While stocking care should be taken to avoid agitation of the pond bottom and too many persons getting into the pond may increase the suspended solid load in the water, which may cause gill chocking of the fish fingerlings leading to mortality. Initially the fishes have to be reared in happas 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 happa could be initially at 4 mm size and it can be changed with 8mm mesh size happas after 30 days. The stocking density in happa could be maintained as 200 nos/ happa. After attaining 30 grams size ideally 5,000 Nos. can be stocked in a one acre pond.

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., extrudedfloating pellet, sinking pellet feed and chopped trash fishes. Ideally pompano can be weaned to extruded floating pellet feed to avoid feed wastage and spoilage of pond bottom. The CMFRI has conducted pompano farming demonstration by using the extruded floating pellet feed manufactured by M/s. Rudhra Techno Feeds, Bhimavaram, Andhra Pradesh. During the happa rearing phase, feeding has to be done 4 times a day and in pond culture phase it could be 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. The details of feed and feeding schedule of pompano are as follows:-

Water Quality Management

Plankton bloom is essential for early stages of pompano (until 100 grams) culture. If the colour of the pond water is clear a mixture of organic (10-30 kg/ha.) and inorganic fertilizers (1-3 kg/ha) can be applied to obtain algal bloom. Sufficient water level must be maintained in the ponds to reduce risks of the growth of benthic algae. The water depth in the shallowest part of the pond should be at least 100 cm. Water quality can be maintained by exchanging 10% of the water once in a week; 20% per week after 3 months and 30% per week after 6 months. If water colour is too dark, the quantum of water exchange can be proportionately increased. To maintain water pH within an optimum range of 7.5 - 8.5, agri-lime has to be applied regularly. Dissolved oxygen (D.O) level should be maintained above 5 ppm at all times. During the entire culture period the growth pattern of pompano was monitored through regular sampling of fishes at fortnightly intervals. The length and weight measurements taken are presented below:-

Growth Pattern

DOC	Growth (mm)	Weight (g)
1	30.59 ± 0.24	2.00 ± 0.04
30	73.42 ± 0.53	15.08 ± 0.16
60	102.88 ± 1.91	34.60 ± 0.41
90	158.39 ± 2.42	72.54 ± 1.95
120	182.30 ± 2.03	101.82 ± 3.11
150	203.71 ± 3.73	172.39 ± 4.55
180	226.51 ± 2.90	258.31 ± 5.76
210	273.07 ± 3.62	375.32 ± 8.07
240	296.88 ± 6.27	464.65 ± 10.25

Health management

Pompano is a much hardier species and does not get much disease problems. When it is reared 2 in high salinities parasitic infection of copepods may occur. Periodical application of commercially available pond management chemicals like Iodine solution would help to keep the fishes healthier. Feed supplements like LIV-52 syrup can be given by mixing with the feed to improve the immunity levels.

Harvesting: Harvesting of pompano is normally carried out using drag net. To maintain the freshness and quality of harvested fish, washing in clean water and chill killing can be done. Harvested fishes can be stocked in plastic crates by adding layers of ice in equal quantities at the bottom and top of the fish. It is suggested that harvesting of fish can be carried out during the off season period of April to June to get a better price. It is well recognized that for sustainable production in aquaculture, diversification of species is a vital requirement and from the lessons learnt from the shrimp farming scenario in India, it is very much needed to diversify the marine and brackish water aquaculture with high value fin fish species. Generally, high value marine fishes are in good demand in the Indian market and often there is a scarcity of the same. In the domestic market, silver pompano has demand starting from 250 grams size onwards. Hence, it is felt that pompano aquaculture can prove to be much lucrative and can emerge as a major aquaculture enterprise in the coming years.

Aquarium Plants in Kerala, India

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Abstract

The propagation of aquarium plants is recognized as one of the powerful and growing industry in aquarium trade. In India especially Kerala aquarium plant propagation is new to the entrepreneur. A botanical field survey was conducted on the aquatic plants which are naturally growing in the water bodies of Kerala to identify the available economically important and suitable aquarium plants. Conservation and commercial cultivation are necessary for steady supply to the growing aquarium plant industry. The survey revealed that there is a rich diversity and listed 33 species with23 genera of aquarium plants. Out of the 33 species obtained from the survey ,all species were found growing in stagnant water like lake ,pond ,pools etc. were as only 5 species were collected from running water. They are *Aponogeton crispus*, *A. natus Vallisneria spiralis L*, *V. torta Cryptocorynes sp*. However they are also collected from stagnant water. Only 6 species out of the 33 are free floating and other are anchored submerged. The propagation method of the aquarium plants obtained from the survey has been brought out. Three mains type of propagation methods are noted .They are tubers(*Aponogeton*, *Nymphaea)* rooted plants (*Vallisneria, Ludwigia, Cryptocoryne* etc.) and cutting or bunches *(eg. Limnophila*, *Cabomba, Myriophyllum* etc.*)*. Technical know how of modern and scientific practice are necessary to conserve and increase the production of aquarium plant to meet the new demands.

Introduction

Aquatic ecosystem and wetlands are usually looked down upon as waste lands and are being reclaimed for various developmental needs bringing many aquatic species which would be of great potential value in some future time, on the verge of extinction. Kerala is one of the most thickly populated states in India and deserves special attention in this regard. Positive utilization of water plants which are naturally occurring in the water bodies of Kerala has been very meager. Recently there is high demand for both ornamental fishes and aquarium plants. Aquarium plants are used to give the aquarium a natural appearance, oxygenate the water and provide a balance of habitat for fishes. Hobbyists use aquatic plants for aqua scaping. The propagation of aquarium plants is one of the powerful and growing industries in aquarium trade. There are several larger producers of aquarium plants in many parts of the world. In India especially Kerala aquarium plant propagation is new to the entrepreneurs. Aquarium plant industry is dominated by species from the tropics. Currently there is substantial export potential for tropical aquarium plants. In India especially in Kerala, many plants are available in native conditions in water bodies. These wild plants are collected as propagates. This type of wild harvesting is cost-effective than cultivation, but unsustainable. This calls for measures for identification and conservation of such species along with commercial cultivation for steady supply to the growing aquarium plant industry. It is in this context that the aquarium plants which are naturally growing in the water bodies of Kerala weresurveyed. The objective of the study was to identify the economically important and suitable aquarium plants which are naturally growing in water bodies of Kerala and to screen them for adaptability in aquaria.

Materials and Methods

A field survey of aquatic plants which are suitable as aquarium plants in the water bodies of Kerala were conducted. Plants growing in stagnant water like lake ponds, pool etc. and those in running waters like streams, rivers, rivulets, irrigation canals *etc*, were collected and identified by following standard methods (Subrahmanyam, 1961, Ghosh, 2005). Collected plants were classified as free-floating and anchored or submerged. The characteristics of the plants were recorded along with their local names, family, classification, morphology, distrbution, gregariousness, growth form, use and method of propagation.

Results and Discussion

The survey revealed that there is a rich diversity of aquarium plants in Kerala and was listed 33 species.They were: *Aponogeton crispus* Thunberg., *A. natus* (L) Engler, *Azolla pinnata* R. Brown, *Blyxa aubertii* L. C. Richard, *Cabomba piauhyensis, C. aquatica, C. caroliniana, Cryptocoryne* sp., *Hygrophilla difformis* (L), *Blume, Elodea densa (Hydrilla verticillata), Cyperus* sp., *Limnophila, Lemnatrisulca heterophylla, Lemna trisulca, L.sessiflora, Ludwigia arcuata Microsorium* sp., *Myriophyllu maquaticum, M. tuberculatum* Rox burgh, *Nymphaea pubescens* Willdenow, *Ottelia alismoides* (L) Persoon, *Pistia stratiotes* L, *Potamogeton crispus* L, *Riccia fluitans, Salvinia natans, Rotala* sp., *S. auriculata, S. molesta* Mitchell, *Utricularia bifida* L, *Vallisneria spiralis* L, *V. torta, Marsilea minuta, Nymphoides indica* (L) O Kuntze. These 33 species and 25 genera belonged to 19 families of aquarium plants. The family Hydrocharitaceae had the maximum species in Kerala waters.

Out of the 33 species 28 were collected only from stagnant waters and only 5 species from running waters.The five species were: *Aponogeton crispus*, *A. natus*, *Cryptocoryne* sp., *Vallisneria spiralis* and *V. torta*. They were collected from stagnant waters also. Six species were free floating and 25 species were anchored submerged and three weretemporarly anchored. Both free floating and anchored submerged have specific benefits to the fish community and the overall habitat. The roots of free floating aquarium plants are good substrate for some fishes to lay eggs on, and the fry to hide from predators. Of the 33 species obtained from the survey, propagation in 4 species is by tubers, 16 species by rooted plants and 13 by cutting or vegetative propagation. In the cases of aquarium plants which are propagated by tubers, after 7 to 8 months of growth, they shed their mature leaves.Then they need a dormant period before next planting. Tubers in semi-sprouted condition are used for planting. Most of the aquarium plants which are propagated by rooted plants produce runners.

Plants with thick foliage such as *Aponogeton crispus, A. natus, Cryptocoryne* sp. *etc* can be planted in aquaria containing small and shy fishes. They are also good for shade loving fishes. Plants with soft leaves such as *Cabomba piauhyensis, C. aquatica, C. caroliniana, Lemna trisulcaheterophylla, L. trisulca, L. sessiflora, Ceratophyllum demersum* are planted in aquarium containing herbivorous fishes. Most of the aquarium plants studied requires about 10-22 h of photoperiod in order to thrive. *Vallisneria, Cabomba piauhyensis, C. aquatic, Ludwigia arcuata etc* requires strong light whereas *Ceratophyllum demersum* require lesser light. Some plants like *Vallisneria, Aponogeton, Blyxa etc* look best when set in small clumps while others like *Ottelia* look better when planted in isolation. Plants are selected depending on the nature of the fishes kept and the size of the aquarium. Growing aquarium plants is an art which requires scientific and technical knowledge and is challenging and enjoyable.

Sl. No	Botanical Name	Local Name	Family	Propagation	Submerged / free floating
1	*Aponogeton crispus*Thunberg	Ghechu	Aponogetonaceae	Tuber	S (PA)
2	*A. natus* (L) Engler	Paruvakizhangu	Aponogetonaceae	Tuber	S (PA)
3	*Azolla pinnata* R. Brown	Water velvet	Azollacear	Spores	F
4	*Blyxa aubertii* L. C. Richard	Jhanji	Hydrocharitaceae	Seeds	S (PA)
5	*Cabomba piauhyensis*	Fanwort	Canombaceae	Cutting	S (PA)
6	*C. aquatica*	fanwort	Canombaceae	Cutting	S (PA)
7	*C.caroliniana*	fanwort	Canombaceae	Cutting	S (PA)
8	*Ceratophyllum demersum* L	Horn WortKula Payyal	Ceratophyllaceae	Cutting	S (TA)
9	*Cryptocorynes ps.*	-	Araceae	Runners	
10	*Cyperuss ps*	-	Cyperaceae	Seed	S (PA)
11	*Elodea densa (Hydrillaverticillata)*	Hydrilla	Hydrocharitaceae	Cutting	S (TA)
12	*Hygrophilla difformis (L) Blume*	Jhanji	Acanthaceae	Seed	S (PA)
13	*Lemna trisulca*	Duck Weed	Lemnaceae	Seeds	F
14	*Limnophila heterophylla*	Ambulia	Scrophulariaceae	Seeds	S (PA)
15	*L.sessiflora*	Korpur	Scrophulariaceae	Seeds	S (PA)
16	*Ludwigia arcuata*	Needle Leaf	Ongraceae	Rooted Plant	S (PA)
17	*Microsoriums ps.*	-	Pteridophyte	-	S (PA)
18	*Myriophyllum aquaticum*	Parrot Feather	Haloragaceae	Cutting	S (PA)
19	*M. Tuberculatum* Rox burgh	Water Milfoil	Haloragaceae	Cutting	S (PA)
20	*Nymphaea pubescens* Willdenow	Water Lily Red Tiger Lotus	Nymphaeaceae	Tuber	S (PA)
21	*Ottelia alismoides* (L) Persoon	Panikala	Hydrocharitaceae	Seed	S (PA)
22	*Pistia stratiotes* L	Water Letuce	Araceae	Seed or Runner or stolons	F
23	*Potamogeton crispus* L	Curly pond weed	Potamogetonaceae	Cutting	S
24	*Riccia fluitans*	-	Bryophyte	Spore	
25	*Rotala sps*	-	Lythraceae	Cutting	S (PA)
26	*Salvinia natans*	Floating fern	Salviniaceae	Fragmentation	F
27	*S. auriculata*	Butterfly fern	Salviniaceae	Fragmentation	F
28	*S. Molesta* Mitchell	Water fern	Salviniaceae	Fragmentation	F
29	*Utricularia bifida* L	Bladder wort	Lentibulariaceae	Seed	S (TA)
30	*Vallisneria spiralis* L	Eel grass or Tape grass	Hydrocharitaceae	Runner	S (PA)
31	*V. torta*	Corkscrew	Hydrocharitaceae	Runner	S (PA)
32	*Marsilea minuta*	Water clover	Marsileaceae	Vegetative propagules	PA
33	*Nymphoides indica* (L) O Kuntze	Floating heart	Menyanthaceae	Tuber	S (PA)

For successful growing of aquarium plants, it is better to have basic knowledge about their morphology, habitat, growth, multiplication and reproduction in natural conditions. At many instances, plants growing beautifully in natural water bodies miserably fail when grown in aquarium because of the artificial conditions prevailing in tanks.

The survey had listed 33 species belonging to 23 genera of aquarium plants. It has been revealed that there is a rich diversiy of aquarium plants in Kerala. Conservation and commercial cultivation are necessary for steady supply to the growing aquarium plant industry. Technical know how of modern and scientific practice are necessary to conserve and increase the production of aquarium plants to meet the demand.

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Nutrition, Feeds and Feed Technology for Mariculture in India

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Mariculture of finfish on a commercial scale is non-existent in India. CMFRI, RGCA of MPEDA, CIBA are the Institutions promoting finfish mariculture with demonstrated seed production capabilities of Asian seabass (*Lates calcarifer*), cobia (*Rachycentron canadum*) and silver pompano (*Trachynotus blochii*). Seed production is not sufficient enough togo in for commercial scale investment. Requisite private investment has not flown into this segment of aquabusiness and Public Private Partnerships (PPP) are yet to take off. The scenario being this in the case of one (seed) of the two major inputs in this food production system, feeds and feeding, which is the other is the subject of elaboration here.

Quality marine fish like king seer, pomfrets and tuna retails at more than Rs.400/- per kg in domestic markets. In metro cities it Rs.1000/- per kg is not surprising. With this purchasing power in the domestic market, most of the farmed marine fish is sold to such a clientele which is ever increasing in India. Therefore, without any assurance of a sustainable supply of such fish from capture fisheries, there is no doubt that we have to farm quality marine fish. With as deficit in seed supply at present, let us examine nutrition, feeds and feed technology required for this farming system in India.

Farming sites, technologies of cage fabrication and launch, day-to-day management, social issues, policy, economics and health management, harvest and marketing, development of value chains, traceability and certification are all equally important and may or may not be dealt with in this training programme. We will focus here on nutrition, feeds and feed technology.

The species of fish suitable to be farmed in cages in sea are prioritized with a different set of parameters. In general, most marine fish have a prolific fecundity with survival rates in hatchery conditions is some species as low as 10 % and still cost effective because of the return on investment on seed cost, cost of fish of stockable size and farm gate prize of fish.

Broodstock nutrition

Now let us examine what is fed during the hatchery phase. Before that there is another area in fish nutrition know as brood stock nutrition which involves feeding of the fish being reared to spawn in captivity. A multitude of factors are involved here in which nutrition is only one. Sex reversal, temperature, light, water quality, stress, hormones and the list can be populated………

In terms of nutrition, it is not protein and carbohydrate, no doubt, they should be available, it is more of functional nutrients like, fatty acid makeup of the phospholipids, carotenoids and several other unknown factors like the interplay of vitamins minerals and hormones.

So, what should we feed the brood fish? No single ingredient or formulated feed is sufficient. It should be a mix and match of several ingredients with inclusion of functional feeds and nutraceuticals. There are many artisanal practices to nourish aquaculture broostock. Raw seafood, commercial feeds and specialized feed additives or a combination of all the three are applied. It is appalling that scientific brood stock nutrition is not a part of the hatchery management. Science based brood stock nutrition is always rewarding.

Animals should be switched to a broodstock formulation for three to four months for maximum gonadal development. Batch spawners enter a starvation period after gonadal development and rely on bodily stores to supply immense amounts of energy and specific nutrients for final gonad and ovary maturation and ultimately spawning. Therefore, providing the specialized nutrition to allow the build-up of bodily stores greatly influences reproductive success. Continuous spawners which include several marine species should be also fed high quality broodstock diets which greatly influences the egg quality.

Development of a set of data enabling us to make reproductive success predictable should be the broodsotck nutrition management programme. Fecundity, fertilization and hatching rates are good indicators of spawning trend allow planning of broodstock replacemnts, fry production and future needs.

Nutrients identified to have a vital influence on broodstock are, 1-2% of n-3 highly unsaturated fatty acids from marine oils, vitamin E (250 ppm), carotenoids like astaxanthin (100 pm),vitamin C (200 ppm) and amino acids of marine origin (80% of the diet).

Even with limited species-specific information available on broodstock nutrition and limited availability of commercial broodstock feeds, scientific management of broodstock nutrition is important and possible.

Larval nutrition

There is no way we can mimic the micro and macro-environment of the open ocean or fresh water body inside a hatchery. Ensuring all critical inputs to achieve the output of maximum number of young fish is refined day by day through research and development.

The feeds are a multitude of microscopic organisms'phyto and zooplankters among which, phytoplankton, rotifers, artemia and then microfeeds is the norm. Replacing live feeds with formulated feeds, enriching live feed with deficient nutrients have been the approach worldwide. Going into details of all the zootechniques is beyond the scope of this article, certain strong points are presented.

Problems in altricial (born undeveloped requiring care) fish are 1. Marine fish larvae grow more rapidly than juveniles. 2. Natural diets of marine fish larvae are rich in phospholipids rather than triacylgcerol and, 3. The ratio of 22:6(n-3): 20:5 (n-3) in phospholipids naturally consumed is ca. 2:1 whereas this ratio in triacylglycerols in fish oil is less than or equal to 1:1. Thus the marine larval fish feeds based on conventional fish oils with ratios of 22:6 (n-3): 20:5(n3) less than or equal to 1:1 are sub-optimal, either by not providing 22:6(n-3) or by providing an excess of 20:5(n-3). Over emphasis of (n-3) HUFA has resulted in the neglect of arachidonic acid (20:4n-6) as a dietary essential fatty acid for marine fish and the role of mono unsaturated fatty acids as major energy yielding nutrients in fish.

Metabolic interrelationships, conversions and competitions.

18:3 (n-3) ——————→ 20:5 (n-3)
Linolenate EPA

Either non-conversion, or very low conversion due to Ä-5 fatty acid desaturase activity.

20:5 (n-3) ——————→ 22:6 (n-3)
EPA DHA

Conversion at low rates not likely to meet the high demands of larval fish growth fully.

Problems: Visual impairment due to impaired rod function leading to decreased efficiency in capturing prey at low light intensities.

22:5 (n-3) ——————→ 22:6 (n-3) is not by direct Ä-4 desaturation but by a complex pathway where,

20:5 (n-3) is chain elongated to 22:5 (n-3) and then converted to 24:5 (n-3). 24:5 (n-3) is converted to 24:6 (n-3) by Ä-6 desaturase and 24:6 (n-3) is chain shortened through peroxisomal â-oxidation to 22:6 (n-3) or DHA.

Or

18:2 (n-3) ——————→ 18:4 (n-3)
by $\varepsilon\Delta$-6 desaturase

and interestingly, 18:4 (n-3) and 24:5 (n-3) are substrates for the same enzyme.

Thus, 18:3 (n-3) competitively depresses conversion of 20:5 (n-3) ——————→ 22:6 (n-3)

High concentration of 22:6(n-3) exists in the neural tissues. The acyslases and transacylases that esterify fatty acids into phospholipids do not have absolute specificities for particular fatty acids. Therefore, fatty acid compositions of tissues are partly determined by the levels of fatty acids available from the diet. This is true in the case of PUFA where an excess of one dietary PUFA e.g., 20:5n-3, can lead to an elevation of that PUFA in tissue phospholipids at the expense of another PUFA present in much lower concentrations in the diet e.g., 22:6n-3. This effect has been established for phospholipids of fish brain.

Artemia, rotifers and copepods contain substantial amounts of 18:3(n-3) linolenic acid and probably linolenic acid competitively inhibits 20:5(n-3) to 22:6(n-3) conversion, even if the fish has the capacity to carry out this conversion. *Artemia* nauplii supplemented with fish oils preferentially catabolize 22:6(n-3) relative to 22:5 (n-3). Thus final ratio of 22:6 (n-3): 20:5(n-3) is invariably substantially less than the starting feed. Oils with a high ratio of DHA: EPA should be used in live feed enrichment protocols. Relative excess of 20:5(n-3) over 22:6(n-3) can be harmful in larval feeds. 20:5(n-3) competitively inhibits production of eicosanoids from arachidonic acid 20:4(n-6). Arachidonic acid is the major precursor of eicosanoids in fish and higher vertebrates, despite the surfeit of 20:5(n-3) over 20:4(n-6) in fishes. Current emphasis is on a desirable ratio of 20:5(n-3):20:4(n-6) in larval fish feeds.

General understanding is that marine fish lack Ä-5 desaturase activity. Hence they cannot convert 18:2 (n-3) to 20:4(n-6). Therefore, 20:4(n-6) has been an essential function of producing eicosanoids making it an essential fatty acid (EFA) in marine fish, which has to be provided in larval feeds. Supplementation of marine fish larval feeds with (n-3) HUFA fish oils has obscured the potential importance of 20:4 (n-6) in larval nutrition.

The status of knowledge being so, we have replacements for phytoplankton in the shrimp hatchery known as crustacean algal replacement (CAR). In fish hatcheries, green water is the hatching medium till mouth opens and even after the mouth opens, green water continues to be the medium till the larvae feeds upon rotifers or copepodites.

Copepodites have the phospholipid profile with the most appropriate fatty acid ratios. Culture of copepods is difficult and it is well known that if available that is the best live feed once the fish larvae are able to feed on zooplankters. Products like 'Cyclopeeze' is a case in point. Other than that, tuna orbital oil based products, *Schizochytrium* based products like Algamac and many others are available today. CMFRI has also developed a product with fish roe, crude sardine oil and additives which are very cost effective compared to imported products.

Micro feeds

Feeds below 1.5 mm size are called microfeeds. They are used in larval nutrition, nurseries where fish fry a grown to a stockable size, especially for stocking in cages. All particulate feeds, micro embedded diets (MEM) and micro encapsulated diets (MED) come under this category. Twin screw extrusion, followed by marumerization and spheronization are the technologies used for their production. It will not be out of place to mention here that ornamental fish feeds also belong this category.

Indigenous production of these feeds is still in its infancy because capital investment in this segment of aquafeed production is lacking because the market is catered to with imported products. Import and trade of these products increases the cost of seed production. In order to optimize the cost of seed production in our country, at some stage indigenization of this segment is imperative.

Growout feeds

Aquafeed production in India started with shrimp feed. According to American Soybean Association, from 1.25 lakh tonnes in 2005 shrimp feed production is reported to be 7.85 lakh tonnes annually in 2015. During the same period fish feed production from meager 3000 tonnes grew to 5.85 lakh tonnes.

The indications clearly are that fish feed production in India is growing with more and more farmers switching over to floating extruded feeds, especially in the freshwater fish culture.

State-of-the-art extruders have come in and the two types of extruded floating fish feeds are available for the fresh water fish culture sector. Carp feeds containing fishmeal and fish oil, and catfish feeds without fishmeal and fish oil. The feed containing marine ingredients is for carps and the one without them is for catfish.

This is produced by about 14 extruded feed mills and according the American Soybean Association for which there is an overcapacity now. The installed capacity is for 1.5 million tones and the current production is approximately 0.6 million tonnes. There is no commercial scale marine fish feed production because it requires a few add-on technologies.

Marine fish require high protein and fat diets. The requirement is shown below.

Nutrient requirements of marine carnivorous fish (in percent)

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

With fat in these feeds exceeding 10% production of floating feeds require another technology known as post-pellet liquid application (PPLA) which is vacuum coating. The internal fat in feed formulation when exceeds 6% cannot be extruded with the floating property. Therefore, vacuum coating of fat is required to incorporate fat above 6% and still retain the floating property of the feed.

To conclude, it can be said that seed and feed which are the major recurring inputs in aquaculture are sufficiently available for fresh water aquaculture and shrimp culture. For marine fish culture, especially in cages in the sea, seed availability is a constraint. Hatchery and nursery feeds (micro feeds) are imported making the cost of seed production and nursery rearing costly. Indigenous micro feed production capability should be established. For grow out, there is an over capacity already installed for extruded feed production. As the volume of requirement for marine fish feeds grows with add on technologies like vacuum coating, self-sufficiency can be achieved in its production faster than micro feed production for which capital investment is yet to begin.

All feed production figures are from American Soybean Association, India represented by Dr. P. E. Vijay Anand, Deputy Regional Director, Asia subcontinent, USSEC, Mr. R. Umakanth

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Role of Self Help Groups in Technology Transfer and Advancement of Mariculture

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Introduction

It is an unequivocal proposition that, in the advancement of mariculture, and transfer of technologies, the Self Help Groups of fisherfolk play a pivotal role. Rational utilization of common property resources for sustainable development without endangering the environment is possible through community participation. Bivalve mariculture has already been proved as one of the profitable enterprises in the coastal belts as a subsidiary income-deriving source of coastal fisherfolk. The experimental trials conducted by CMFRI have proved the techno-economic feasibility of mussel and oyster farming. (Asokan *et al*, 2001 and Vipinkumar *et al*, 2001).

A Self Help Group (SHG) consists of members linked by a common bond like caste, sub-caste, community, place of origin, activity etc.. The Group Dynamics of these SHG's refer to the interaction of forces between the members. It is the internal nature of the groups as to how they are formed, what their structures and processes are, how they function and affect the individual members and the organization. (Lewin *et al.*1960). In an intensive study of Group Dynamics, Pfeiffer and Jones (1972) identified the Group Dynamics factors as to how the group is organised, the manner in which the group is led, the amount of training in membership and leadership skills, the tasks given to the groups, its prior history of success or failure etc. Like any other sector of agriculture, women participation in aquaculture/mariculture remains largely unnoticed. When the question of adoption of new technology comes the women are rarely considered a target group. But since women constitute 50% of total population, negligence to bring them to the front line action is always a negative approach to the total development process. It is estimated that women carry out almost 70% of agricultural workload, but in aquaculture, their role has not been properly identified. May be it is due to the ignorance of women about the technology, cultural and social barriers, women perception and so on. Women's role in fisheries is very significant and there is gender bias in respect of their works. This discrimination may be noted out from the country's scenario through the economic upliftment of fisherwomen through appropriate policies, programmes and projects.

Mariculture is a developing sector and women participation in this sector needs a meticulous planning for technological empowerment encompassing the social and economic barriers. On-farm trials conducted by DRWA, CIFA, CIBA and CMFRI have brought out, the strong motivation and capability among women for taking up aquaculture (Freshwater, brackish-water and Marine) through SHGs. Empowering women in different aquaculture/ mariculture practices can provide suitable option for sustained economic and nutritional security of the family and thereby an in-depth observation on these dimensions made through the present study has ample scope to explore the paradigm of gender balance and women empowerment. Here an attempt has been made on exploration of a couple of case studies in Kerala and Karnataka on role of Self Help Groups of fisherfolk in transfer of technology and advancement of aquaculture.

Bivalve farming by women SHGs in Kasargod and Kollam districts of Kerala state

Kasargod, the extreme northern district of Kerala is particularly notable for green mussel and oyster farming as it has been successfully accomplished by the women's Self Help Groups (SHGs). These groups were given financial assistance in the scheme namely; SGSY (Swarnajayanthi Gramaswa Rozgar Yojana) by the state government which takes care of economic empowerment of weaker sections (Vipinkumar *et al* 2001). Subsidies, bank loans etc are the part and parcel of the scheme which focus attention on poverty alleviation through organised Self Help Groups. This programme looks into training, credit, marketing, technical knowledge and basic facilities necessary for the upliftment of the poor to bring them above the poverty line within three years in such a way that they should have a monthly earnings of at least Rs 2000 /-. There is tremendous potential for aquaculture diversification in Kasargod coastal belts. Water bodies in these coastal belts have ample scope for the judicious utilisation of bivalve farming, finfish culture, prawn and crab farming. (Asokan *et al* 2001).

Quilon or Kollam, is an old seaport town on the Arabian coast very conspicuous for brown mussel and oyster farming. About thirty per cent of this district is covered by the Ashtamudi lake, thereby making it the gateway to the backwaters of the state. Kollam is an important maritime district of the state with a coast line of 37.3 kms. Fishing has a prominent place in the economy of the district. Neendakara and Sakthikulangara villages thrive in fishing. An estimated number of 22,000 persons are engaged in fishing and allied activities. Cheriazheekkal, Alappad, Pandarathuruthu, Puthenthura, Neendakara, Thangasseri, Eravipuram, Paravoor and Thekkumbhagam are nine among the 26 important fishing villages. There are 24 inland fishing villages also. Considering the unique location and infrastructure available, the Government has initiated steps for establishing a fishing harbour at Neendakara which is expected to augment fish production by 15%. Average fish landing is estimated to be 85,275 tonnes per year. One third of the state's fish catch is from Kollam. There are 38 Fishermen Development Welfare Cooperative Societies in the district. FFDA and VFFDA are promoting fresh water fish culture and prawn farming respectively.

This study was undertaken in two panchayats namely Cheruvathur and Padanna in Kasargod district and Thekkumbhagam and Needakara in Kollam district. The study area, Cheruvathur panchayat has an area of 18.37 km^2 with a population of 24, 504 and about 150 families are engaged in fishing as the main occupation and about 300 families as subsidiary occupation. Similarly, Padanna panchayat has an area of 13.08 km^2 with a population of 17, 961. About 200 families are engaged in fishing as main occupation and about 400 families as part time occupation. The brackish water estuary systems of these panchayats are extremely suitable for bivalve farming. Similarly, in Kaunagappally thaluk situated 27 kms north to Kollam, Thekkumbhagam and Needakara panchayats were selected and of these, Dhalavapuram and Malibagam villages of Thekkumbhagam panchayat and Pannakkal thuruthu and Puthan thuruthu villages of Neendakara panchayaths were selected for data collection. As much as 200 households undertaking bivalve farming were selected and male and female counterparts in each household were separately interviewed, comprising a total of 400 respondents. The data regarding gender participation in different activities, gender needs, decision making and access and control over the resources in respect to bivalve culture were collected through personal interviews of the respondents with the help of a pre tested well structured interview schedule. In addition to this, 10 Self Help Groups of women engaged in bivalve culture at random from 2 districts were selected for drawing explorative case studies to measure the Group Dynamics through personal interviews of the respondents. The Group Dynamics of members of Self Help Groups was measured by developing an index called Group Dynamics Effectiveness Index (GDEI) which was operationally defined for the study as the sum-total of the forces among the member of SHG based on the sub-dimensions, such as participation, influence & styles of influence, decision making procedures, task functions, maintenance functions, group atmosphere, membership, feelings, norms, empathy, interpersonal trust and achievements of SHG (Vipinkumar and Singh, 1998). The Benefit-Cost ratio was analysed in each group and cost dynamics were worked out. The problems and constraints faced by the women were also assessed in each case and listed out. The cost estimates of all the selected Self help Groups were also computed and by taking in to consideration of major expenditure required for bivalve farming is for the materials such as bamboo, nylon rope, coir, cloth, seed, etc. and labour costs essentially cover construction, seeding, harvesting etc. the Net Operating Profit and B:C ratio also were calculated for different SHGs to draw valid inferences.

The study, focused attention on Group Dynamics Effectiveness as a trait of Self Help Groups resulted by the joint influence of individual members of the group generated out of skills and orientations from the past life experiences. It definitely varies from person to person, place to place, time to time, situation to situation and in turn from group to group. This might be the probable reason for the differential degree of GDEI observed among respondents. Six Self Help Groups of women engaged in mussel farming were selected from two panchayaths Cheruvathur and Padanna in Kasargod district and 4 Self Help Groups from Kollam district to draw explorative case studies through personal interviews of the respondents.(Table 1).

Table 1. Details of the SHGs identified in Kasargod and Kollam districts

Name of the district	Name of the panchayat	Village	Samples selected (Self Help Groups)	No. of members
Kasargod	Cheruvathur	Kaithakkad	Mahatma Mussel Unit	13
		Kavunchira	Kairali Mussel Unit	15
		Kaithakkad	Kaithakkad Mussel Unit	13
	Padanna	Thekkekkad	Thekkekkad Mussel Unit	12
		Vadakkekad	Vadakkekkad Mussel Unit	15
		Ori	Ori Mussel Unit :	13
Kollam	Thekkumbhagam	Dhalavapuram	Mahatmaji Kudumbasree Group	19
		Malibhagam	St.Maries Kudumbasree Group	16
	Neendakara	Puthan thuruthu	Ashtajalarani Group	18
		Pannakkal thuruthu	Chavara south Group	15

Profile of Cost Estimates of Bivalve Farming Self Help Groups

The women's groups constituted in the scheme DWCRA started mussel farming as early as 1996-97 and are assisted by loan amount worth Rs 8800 /- per member with a subsidy amount worth Rs 4400/- which looks quiet fascinating. The duration of the loan is 5 years and the rate of interest is 12.5 % per annum. In addition to this, a revolving fund of Rs 5000 /- was also provided without interest. When the SHGs are economically empowered with the provision of loan facilities, the returns from mussel farming help them to repay the loan slowly. The loan was granted through Farmers' Service Cooperative Banks and North Malabar Gramin Banks in Cheruvathur and Padanna panchayaths of Kasargod district. Majority of the SHGs showed considerable progress in repayment of the loans, which can be concluded as an indication of the profitability of mussel farming. The expenditure details of the selected SHGs in the initial year of mussel cultivation are shown in the Table 2. The BC Ratio in all the ten SHGs was computed and found as substantially good which proves the profitability of Mussel farming in the initial trial itself and since during the subsequent years, material costs such as those of bamboo, rope, cloth and labour cost in construction etc. are negligible, this ensures reasonable profit as a major consequence of adoption of mussel farming enterprise bringing about economic empowerment of rural women through organised Self Help Groups.

Experiences and observations already indicated that for a group to be developed as an SHG, it requires a period of at least 36 months and it is a hectic process. It has to pass through various phases such as Formation phase, Stabilisation phase and Self Helping phase. These Self Help Groups promote a cooperative and participative culture among the members, which ensures the empowerment culture of the Self Helping phase. The loan sanctioning, utilisation, accounts maintenance and timely repayment of loans etc. are all perfectly accomplished with proper maintenance of the documented records by the group members. This ascertains the fulfillment of norms and standards of the SHG leading to economic empowerment of the members. The relationship of yield and GDEI of selected SHGs is also presented in Table 2. The yield in Kg per metre length of the rope recorded in all SHGs as Average Yield showed a positive relationship with GDEI score. The correlation coefficient value was ($r = 0.863$). One of the major dimensions of GDEI is achievements of SHG which is an indirect representation of yield and economic gain from the micro-enterprise of the SHGs. Therefore it is quite natural to observe a positive relationship of yield or BC Ratio with GDEI.

Assessment of Gender Perspectives in Bivalve Farming

An assessment of gender perspectives in terms of gender need and gender role in mussel farming in Kasargod and Kollam districts was also done as a part of the study. 200 households from each district were selected and male and female counterparts in each household were separately interviewed in these 2 districts, comprising a total of 400 households. The gender participation in different activities, gender needs, decision making and access and control over the resources in respect to mussel culture were analyzed. Opinion of men and women in above aspect was found to be similar without any significant difference. However, differential gender response was observed between the villages in Kasargod and Kollam districts. Significantly, the accounting/ money transaction is under the control of women and the most important requirement perceived by both men and women is the timely availability of spat. In case of participation and need, both men and women share almost the same opinion (Sahoo *et al*, 2009). Socio-economic, technological and export support requirement was analyzed for gender mainstreaming. Male and female respondents in a household were separately interviewed for getting the response of gender needs in terms of access to resources in mussel/oyster culture, participation in various activities of bivalve farming, gender needs and decision making in various stages. The participation profile in various activities concerned with bivalve farming is presented in Table 3. The gender response in participation in various activities in mussel farming in such as female alone, male < female, male = female, male > female and male alone indicated separately by male and female are presented. It indicates the participation profile in gender perspective in mussel farming for male and female separately. It can be glanced clearly from the perusal of the table that, the male dominating operations of bivalve farming are after care, arranging bamboo poles and ropes, seeding nets, canoeing to the sites, harvesting, hiring canoes to estuary, mussel spat collection, post harvest operation, raft construction, seeding rate and seeding, site selection, transport to shore and tying the seeded ropes to the raft which are labour intensive as per the responses of both male and female. But the female dominating activities are record keeping, shell disposal, marketing of live mussel, shucked mussel, meat shucking etc. In the same way, response to access to resources, the gender needs and the extent of decision making in various activities concerned with bivalve farming of male and female also were assessed separately.

Table 2. Relationship of Yield and GDEI of selected SHGs

SHG	Cost (Rs)	Returns (Rs)	BC Ratio	GDEI score	Correlation Coefficient (r)	Significance (2-tailed)
SHG 1	32,355 /-	40,000 /-	1.236	52.78	0.863**	0.001
SHG 2	50,415 /-	64,000 /-	1.269	54.33		
SHG 3	37,950 /-	48,000 /-	1.265	53.91		
SHG 4	45,550 /-	60,000 /-	1.317	57.32		
SHG 5	55,590 /-	72,000 /-	1.295	55.68		
SHG 6	43,095 /-	58,000 /-	1.346	60.08		
SHG 7	32,000 /-	42,000 /-	1.312	59.14		
SHG 8	31,750 /-	40,500 /-	1.275	57.78		
SHG 9	32,500 /-	42,000 /-	1.292	59.16		
SHG 10	32,850 /-	44,500 /-	1.354	60.17		

Problems and constraints of gender in bivalve mariculture

Mussel and oyster farming faces a number of impediments like water salinity, seed availability, selection of location/site, climatic vagaries, identification of proper beneficiaries and proper monitoring opportunities. The major problems and constraints faced by the women in mussel cultivation in the rank order are unpredictable seed availability, meat shucking problem, marketing of mussel, mortality of seeds during transportation, reduced growth during certain years, social constraints like caste splits, conflicts etc., to a limited extent. Here also, all the group members are of unanimous opinion that the government agencies should come forward with improved marketing facilities as marketing of the mussel was perceived as one of the biggest constraints. Provision of loans with reduced interest rates and freezer facility for storage of harvested mussels can bring about a breakthrough in this sector in the near future. It would be pertinent to have a study on the drudgery in bivalve farming trials as well as effect of coir retting zones on growth and attachment of mussel seeds to the strings, which often found by experiences. Laboratory experiments should be broadened to study the effect of coir retting zones on growth of mussel. Similarly, export potential of mussel can be promoted through value addition experiments on depuration plants in filtered seawater. Organised fishermen's cooperatives can play a vital role in various stages of seeding, harvesting, sorting, grading, packing and marketing with an intention of export potential. Irrespective of the location specific problem oriented resource based alternative programmes for income generation, this study emphasises on the gender need and gender role also ultimately for economic empowerment through bivalve farming as a means of poverty eradication through Self Help Groups.

Table 3: Participation profile in gender perspective in bivalve farming (n = 400)

Activity	Man (Independently)		With Man		With Woman		Women (Independently)	
	Female	Male	Female	Male	Female	Male	Female	Male
Accounting and Record Keeping	6.5	6.03	37	24.12	34.5	46.73	22	23.12
Aftercare	16.5	16.58	74.50	50.25	6	28.14	3	5.03
Arranging Bamboo Poles	43	17.09	51.5	76.38	1	0.5	4.5	6.03
Arranging Ropes	30.65	16.58	65.33	64.82	1.51	14.07	2.51	4.52
Arranging Seeding Nets	25	16.08	65	62.81	8	17.09	2	4.02
Canoeing to the sites	43.72	26.13	53.27	70.35	0.5		2.51	3.52
Disposal of shell	8	2.01	34.5	18.59	35.5	57.79	22	21.61
Harvesting	19	17.09	71.00	49.75	5	25.13	5	8.04
Hiring Canoes to Estuary / Sea	44.72	28.14	52.76	66.83		1.01	2.51	4.02
Marketing of live Mussel	17.5	1.51	23	27.14	37	48.74	22.5	22.61
Marketing of Shucked Mussel	17	1.51	20	26.13	40.5	49.75	22.5	22.61
Meat Shucking	7.5	1.51	28	27.64	42	47.74	22.5	23.12
Mussel Spat Collection	48	27.64	30	49.75		0.5	22	22.11
Post Harvest Operation	19	5.03	38.5	43.72	19.5	28.64	23	22.61
Raft Construction	33.67	22.61	56.78	61.81	4.52	11.56	5.03	4.02
Seeding Rate and Seeding	23.62	17.59	65.83	57.79	7.54	19.6	3.02	5.03
Site Selection	49	34.17	28	35.68	1	8.04	22	22.11
Transport to shore	36.5	16.58	41.5	58.29	3	6.53	19	18.59
Tying the Seeded Ropes to the raft	28.14	15.58	43.22	54.77	23.12	24.62	5.53	5.03
Total	27.2	15.23	46.28	48.77	14.23	22.96	12.28	13.04

2. Case study of mussel farming SHGs in Karwar of Karnataka state

Self Help Groups of fisherfolk were mobilised in Karwar and Bhatkal locations of Karnataka coastal belts. Three SHGs of 15 members each comprising a total of 45 were mobilised in Majali (Open Sea) of Dhandebag and three SHGs of 15 members each comprising a total of 45 were mobilised in Sunkeri of Kali estuary in Karwar coastal belts in Uttar Kannada district of Karnataka state. Training and demonstration on mussel farming was undertaken in these SHGs. Initially, two training and demonstration programmes in these two sites in Karwar were undertaken, one for raft culture in open sea in Majali of Dandebag and one for rack culture in Sunkeri of Kali estuary. The training was imparted to 45 members of three Self Help Groups, each possessing 15 members in 2 sites separately comprising a total of 90 participants. At Majali in open sea, a 5 x 5 metre raft and at Sunkeri of Kali esturay, a 5 x 5 metre rack were constructed for mussel farming. Similarly In Mundalli river of Bhatkal estuary in Karnataka, 4 Self Help Groups of 15 members each exclusively of women fisherfolk mobilised under the NGO, ‘ Snehakunja ‘ comprising a total of 60 participants were trained on mussel farming. They initiated a trial in 5 x 6 metre rack mussel culture by long line method. The sample design for observation including the number of SHGs’ trained , beneficiaries and method of culture is given in Table 4.

Table 4: Mussel culture interventions in Karnataka state

Site	No.Of SHG'sTrained	No.of beneficiaries	Method of culture	Size of the rack / raft
Sunkeri of Kali estuary	3	45	Rack culture	5 x 5 m
Majali of Dhandebag	3	45	Raft culture	5 x 5 m
Bhatkal of Mundalli estuary	4	60	Raft culture	5 x 6 m

Data were gathered from these 10 SHGs through personal interviews of the respondents. For the study, the Group Dynamics of Self Help Groups was again measured by Group Dynamics Effectiveness Index (GDEI). The growth parameters were monitored every week in all the sites and the yield particulars of mussel during harvesting in each SHG was also noted. (Vipinkumar and Asokan, 2005, 2008). The relationship of Yield and GDEI of SHGs, correlation coefficients and t value are presented in table 5.

Table 5 : Relationship of Yield and GDEI of SHGs'

SHG	Yield in Kg / m	GDEI score	Correlation Coefficient (r)	't' value
SHG 1	9.2	53.71		
SHG 2	9.1	52.31		
SHG 3	8.9	51.91		
SHG 4	12.6	57.32		
SHG 5	12.7	56.68	0.958139	9.4656248**
SHG 6	12.5	57.14		
SHG 7	13.6	60.01		
SHG 8	13.1	59.98		
SHG 9	13.8	61.29		
SHG 10	13.2	60.02		

The open sea mussel culture in this particular case met with the impediment of unfortunate sabotage of the seeded mussel by some miscreants. It was rectified by reseeding, but the yield was not that much conspicuous compared to the trials undertaken in estuaries. All the SHG members are of unanimous opinion that the government agencies should come forward with improved marketing facilities, as marketing of the mussel was perceived as one of the biggest constraints. Provision of loans with reduced interest rates and freezer facility for storage of harvested mussels can bring about a breakthrough in this sector in the near future.

3. Case study of Mussel Farming Women's Self Help Groups in Malabar Fisheries Sector

It is a matter of great concern that, despite the economic and socio cultural significance of fishing in Kerala state, the women fisherfolk at large are outside the mainstream of the society in the economically disadvantaged category without accruing the benefits from fishing industry (Kurien, 1994). Malabar areas of Kerala always stand backward and less progressive than the rest of Kerala and about half of the coastline of Kerala state is of Malabar. (MCITRA, 2003) But fisherfolk especially women rarely gain the benefits even when there is tremendous consideration for fish production because fisheries development was most often discriminated from the development of fishing community. This case study in Malabar essentially focused on the major objective of assessing the Group Dynamics of the SHGs of women fisherfolk and identifying the important dimensions contributing to their effectiveness and assessing the influence of personal and socio psychological characteristics on Group Dynamics.

The practical dissemination of bivalve farming technologies in the potential maritime locations in Malabar coasts was undertaken in Kadalundy of Vallikkunnu grampanchayat in Malappuram district of northern Kerala by training 62 women fisherfolk under Community Development Scheme (CDS) of *Kudumbasree* District Mission. These women were mobilised into 11 SHGs comprising 60 members with a provision of a distinct loan amount and 40 % subsidy with a reasonable nominal amount as beneficiary contribution in each SHG. The members possess the joint responsibility through a strong internal amendment with a firm base of interpersonal trust. Assessment of the Group Dynamics Effectiveness of the SHGs was attempted by interviewing the members with standardized protocols developed and the groups with substantial effectiveness score were identified. (Table 6)

Table 6: Selected SHGs and locations

Sl. No	Name of SHG	No. of members	Location	GDEI Score
1.	Nila	5	Vallikkunnu, Hirosnagar	0.65
2.	Puthuma	5	Vallikkunnu, Hirosnagar	0.78
3.	Jalamythri	5	Vallikkunnu, Hirosnagar	0.67
4.	Theeram	5	Vallikkunnu, Hirosnagar	0.77
5.	Olam	5	Vallikkunnu, Hirosnagar	0.78
6.	Soft	5	Vallikkunnu, Hirosnagar	0.68
7.	Chippy	5	Vallikkunnu, Hirosnagar	0.79
8.	Ganga	5	Vallikkunnu, Hirosnagar	0.70
9.	Keerthy	5	Vallikkunnu, Hirosnagar	0.71
10.	Kanakam	5	Vallikkunnu, Hirosnagar	0.69
11.	Muthuchippy	5	Kadalundy Nagaram	0.81
12.	Sagararani	5	Kadalundy Nagaram	0.81

A breakthrough harvest results were noticed in the SHGs due to the high market demand of mussel up to 5 Rs per piece and Rs 250 per kg of meat. The computation of harvest particulars, economic analysis, estimation of socio-psychological characteristics and yield dynamics were undertaken in the SHGs and brought out a BC ratio of 3.5:1 on an average. The influence of personal and socio-psychological characteristics of SHG members on Group Effectiveness also was assessed along with gender perspectives on decision making aspects and gender need analysis in mussel culture. The harvest results of mussel farming by the women SHGs had great expectations on SHG enterprise as a major means of poverty alleviation as each SHG in turn ensures economic sustainability of 5 families. The local availability of green mussel and local self sufficiency of edible mussel products of diversified uses with low cost of production and moderate selling rate make satisfied customers in turn attracting consumers of other states to the enterprise. Ultimately through gender mainstreaming and women empowerment and socio-economic upliftment through the mobilised women SHG, the local economic development of Vallikkunnu gets improved which in turn leads to radical development of fishers of Kerala state in a broader sense. Success cases of SHG mobilization were elucidated and documented which could be used as case models for promoting group action of SHGs on a sustainable basis. The Simple Correlation analysis of the sub-dimensions is presented in Table 7 and it was noticed that Achievement of SHGs was the most important dimension followed by Participation and Group Atmosphere. (Vipinkumar *et al*, 2015)

Table 7: Simple Correlation analysis of sub-dimensions with GDEI

Sl. No	Variable	Quantified value in Per cent
1	Participation	0.947**
2	Influence and Styles of influence	0.938**
3	Decision making procedures	0.919**
4	Task functions	0.907**
5	Maintenance functions	0.913**
6	Group atmosphere	0.945**
7	Membership	0.874**
8	Feelings	0.879**
9	Norms	0.884**
10	Empathy	0.869**
11	Interpersonal trust	0.918**
12	Achievements of SHG	0.949**

** Significant at 1 % level of significance

4. Gender mainstreaming and impact of self help groups in cage farming in Vembanadu lake

Vembanadu lake is conspicuous for the brackish water cage culture undertaken by the mobilized Self Help Groups of fisherfolk. As much as 27 fishermen mobilized under *Vembanadu Kayal Samraskhana Samithy, Srayithodu Unit* as Self Help Groups accomplished the farming of commercially important fishes in 20 cages in Vembanadu lake under the financial assistance of Agency for Development of Aquaculture- Kerala (ADAK) as a part of *Kuttanadu* package. The technical assistance was provided by the experts from CMFRI under the project gender mainstreaming and impact of Self Help Groups in Fisheries Sector. Massive awareness programmes and farmer interaction meets were organized in Vembanadu site and training programmes including cage fabrication and cage installation along with seeding and feeding with video documentation were successfully carried out in the SHGs. The fishes chosen for culture are pearl spot and tilapia, as they are highly adaptable to salinity fluctuations in Vembanadu lake during monsoon season. The gender analysis, performance level of SHG, Empowerment Index and economic feasibility analysis were assessed with socio economic surveys undertaken in the locality with a pre-tested and structured data gathering protocol with standardized scales and indices developed. The male and female counterparts of the families were separately interviewed to assess the gender mainstreaming aspects in terms of equity and equality to access to resources, participation profile, decision making aspects, gender need analysis etc. Though majority of activities are male dominating, the female counterparts of the households also have definite role in decision making, feed preparation, management, harvesting, sales and marketing etc. The social and economic empowerment dimensions and capacity building aspects achieved highest score in Empowerment Index. The economic feasibility analysis gave a BC ratio of tilapia cages as 2.5:1 and pearl spot cages as 3.5: 1 on an average in the first year. The success case study elucidated can be used as a case model and practical manual for promoting group action for mobilising SHGs on a sustainable basis.

5. Seaweed Culture by Self Help Groups in Tamil Nadu

Around 60 species of commercially important seaweeds with a standing crop of1,00,000 tons occur along the Indian coast from which, nearly 880 tonnes dryagarophytes and 3,600 tons dry alginophytes are exploited annually from the wild. Seaweed products like agar, algin, carragenan and liquid fertilizer are in demand in global markets and some economically viable seaweed cultivation technologies have been developed in India by CMFRI and Central Salt and Marine Chemical Research Institute (CSMCRI). CMFRI has developed technology to culture seaweeds by either vegetative propagation using fragments of seaweeds collected from natural beds or spores (tetraspores/ carpospores). It has the potential to develop in large productive coastal belts and also in onshore culture tanks, ponds and raceways. Recently the culture of the carageenan yielding sea weed *Kappaphycus alvarezii* has become very popular and is being cultivated extensively by SHGs along the Mandapam coast. To make the seaweed industry more economically viable, research aimed at improvement of strains of commercially important species by isolating viable protoplasts and somatic hybridization techniques is being carried out. The rate of production of *Gelidiellaa cerosa* from culture amounts to 5 tonnes dry weight per hectare, while *Gracilaria edulis* and *Hypnea* production is about 15 tonnes dry weight per hectare. Pilot scale field cultivation of *Kappaphycus alvarezii* carried out in the near shore area of Palk Bay and Gulf of Mannar showed maximum increase in yield of 4.3 fold after 30-32 days in Palk Bay and 5.7 fold after 22-34 days in Gulf of Mannar. This is a promising venture being undertaken by the women's Self Help Groups in Mandapam. So far as much as 1200 families were engaged in seaweed farming of which 60% of the farmers are women.

Conclusion

The article emphatically disclosed the deep rooted influence of Group Dynamics network among the Self Help groups of fisherfolk in five different narrative cases concerned with mariculture like mussel and oyster farming, cage culture, seaweed culture etc., Irrespective of the location specific problem oriented resource based alternative programmes for income generation, this study emphasises on the economic empowerment of coastal fisherfolk, especially women through mariculture technologies as a means of poverty eradication through Self Help Groups because, poverty can only be alleviated by mobilising the poor to solve their actual problems in the form of organised SHGs. It is a truth that, to bring in social change and economic prosperity, no nation can ignore fifty per cent of its population. Removal of gender imbalances should be established as a priority for ensuring rapid economic development. This would mobilize the remaining fifty percent of the country's human resources and would result in the smooth movement of the economic wheel. National policies should be resolute in tackling this issue and local bodies should ensure the implementation of these policies at the community level. (Shyam *et al*, 2011). It is an essential requisite that, there is immense need to create better opportunities for women in coastal fishing communities to enhance their social and economic role and enable them to participate in development efforts, rehabilitation and conservation of the coastal and aquatic environment. The special features of fisheries and aquaculture make it necessary to link microfinance to appropriate technology development and transfer to women clients. Both capture fisheries and mariculture require upgraded vocational training programmes and technical advice crucial for the success of appropriate micro enterprises. CMFRI has developed a technology for the farming of mussels in the open sea and protected bays. The technology is simple and cost effective and has been widely adopted by the fisherfolk of Kerala and Karnataka though mobilized SHGs. (Pillai, 2000). Several women SHGs in the Malappuram district of Northern Kerala have successfully tailored the venture and proved profitable. Women could significantly contribute to this sector, if trained and oriented in the right direction. Freshwater pearl culture is fast picking up as commercial venture and there are moves to integrate it with the carp culture to generate additional revenue to the farmer. Women could take up pearl culture as a productive income-earning venture on account of the vast unutilized potential. Efforts taken by government and non-governmental agencies to organise fisherfolk into Self Help Groups and involving them in appropriate mariculture technologies has brought out encouraging results. The success cases of Self Help Groups Dynamics highlighted in the article can be used as a case model and practical manual for mobilizing SHGs for effective technology transfer in advanced mariculture or any key areas on a sustainable basis.

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Better Management Practices in Mariculture

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Introduction

The marine finfish in Asia are cultured in ponds, recirculating systems, cages or pen systems. The farming methods mostly involve stocking of fingerlings or juveniles that are caught from the wild or hatchery raised seed. Mariculture is not a well established activity in India, but of recent, picking up However, scope is there for its successful emergence in the immediate future because of the interest of the farmers in diversification of farmed species and the ongoing efforts in cage farming in the country. The high value species suitable for mariculture in India are Asian seabass *Lates calcarifer*, groupers *Epinephelus* sp., snappers *Lutjanus* spp., cobia *Rachycentron canadum*, silver pompano *Trachinotus blochii*, Indian pompano *T. mookalee*, grey mullet *Mugil cephalus*, milkfish *Chanos chanos,* seer fish, pomfrets and a variety of marine ornamental fishes.

The term good practices (GP) have been used in several ways. It can refer to the best-known way to undertake any activity at a given time. GP refers to the practice or practices of only one or a very few producers. It can also be used to define a few, often different, practices that increase efficiency and productivity and/or reduce or mitigate impacts. Better practices are often required by government or others to encourage a minimum acceptable level of performance with regard to a specific activity. In aquaculture, good practices have been developed largely for shrimp and salmon aquaculture, although some efforts are being made to develop that for other aquatic commodities such as tilapias, catfish, molluscs, eels, *etc*, and marine cage culture. GPs should involve positive cooperation rather than more regulations. They are flexible and can be tailored to species, updated to fit new production methods.

GPs suitable for sustainable mariculture with maximum production and minimum issues

1. Site selection

- Based on current flow, wave action and wind speed, open sea sites have to be selected. The site should be free from any fishing and other activities. To select ponds in coastal area specific criteria should be followed.
- Environmentally-sensitive areas that require precaution due to features and characteristics that support protected species and/or unique habitats (*e.g.*, rearing or spawning habitat, migration corridors, protected areas or proposed protected areas, sensitive migratory bird habitat*, etc*.) should be excluded.

2. Design and construction

- Eco friendly structures with minimum impact on environment should be used.

3. Planning

- Plan farming activities in advance of the season among the selected fishermen/ farmer group(s)
- Plan the crop within the capacity of the group in terms of investment, level of commitment possible, and consider local water quality parameters and possible threats in that.
- Follow crop calendar system for farming (in such cases, the fishers will be occupied throughout the year and they will be provided with income during lean fishing season also)
- Implement entire activities in a disciplined and cooperative manner.

4. Seed selection (wild or hatchery reared)/ stocking density

- Select a high value species for which abundant seed availability (wild/ hatchery) is proven after proper survey.
- Quality of the seed and stocking rate (moderate stocking) of the fish in farms need to be standardized for individual species based on growth rate and feeding habits.

5. Water quality management

Effluents of concern from aquaculture systems

- Nutrients (Nitrogen, Phosphorus)
- Settleable solids (especially from harvesting during draining)
- Oxygen demand from organic matter

GP components to reduce effects of effluents

- Reduction of water exchange rates
- Reduction of production levels
- Use of feed trays
- Settling basins of at least 10% pond area
- Forcing farms to reduce discharge (only 2% water exchange rate)
- Stocking calendars to be prepared to follow a uniform pattern of stocking

6. Feeds and feed management

- Mostly high value marine fishes are carnivorous and are fed on trash fish/ bycatch. When trash fish is used as feed, it will not supply adequate nutrients to the growing fish. So for more growth excess feeding is done which results in increased FCR leading to high feeding cost and excess waste discharge to the ambient water (as uneaten feed and faecal matter).
- Select high quality feeds that contain adequate, but not excessive, nitrogen and phosphorous (to avoid eutrophication).

- Store feed in well-ventilated, dry bins, or if bagged, in a well ventilated, dry room. The feed should be used on a first in and first out basis by the expiration date suggested by the manufacturer.
- Apply feed uniformly
- Do not apply more feed than what fish will eat.
- Maintain adequate dissolved oxygen concentrations in ponds to prevent fish stress and enhance the capacity of the pond to assimilate metabolic wastes.

7. Health management

- Establish Fish Health Management Plan, a comprehensive plan for maintaining optimum health of the aquatic stocks in culture, usually consisting of procedures and guidelines for procuring healthy stocks, fish handling and transport, vaccination, feeding and veterinary practice.
- Regular monitoring of the cultured organism for health and growth

8. Disease management

- Make diagnosis for diseases and a recommendation for disease treatment before applying the rapeutic agents. Disease diagnosis and recommendations for treatments should be done by fish health specialists.
- Therapeutic agents to be used only in closed systems. Manage pond water levels to prevent or minimize overflow until therapeutic agents have degraded. Use good water quality management procedures to prevent unnecessary stress to fish.
- Do not allow escape of infected animals to the main water source to prevent spread of disease to other farms

9. Better Harvest and post-harvest Practices

- Improve the quality and sale price of the crop by using better practices for crop harvesting and post-harvest handling of shrimp, fish and seaweed (which retain the freshness of the catch).
- Establish better market access by collaborating with a reliable and good local processor/ trader

10. Record maintenance of daily culture operation should be mandatory

11. Environmental awareness

- Fallowing or site fallowing, to discontinue production at a culture site for a short period, generally up to one season (or year) to sustain the environmental conditions.
- People should be aware of Marine Protected Areas (MPAs), for the conservation and protection of: commercial and non-commercial fishery resources and their habitats; endangered or threatened marine species and their habitats; unique habitats; marine areas of high biodiversity or biological productivity; and any other marine resource or habitat for which special attention is needed should be exempted from aquaculture operations.

Suggested GPs for cage farming

- Cages should be placed in areas with good water circulation.

- It is ideal to change cage locations after each operation to protect the sediment quality.
- It is common for nets, cages, and other gears to become clogged or obstructed with natural foreign matter such as algal and invertebrate species. Deploy anti-fouling techniques to reduce the attraction of fouling organisms and/or to remove them from the affected gear.

GPs for non-native species

- Measures must be taken to minimize the potential escape of non-native species, if they are stocked.
- Active feed monitoring as in closed systems
- Minimize uneaten feed accumulation beneath nets
- Proper disposal of feed bags
- Limit waste discharge during harvest & transport

Possible chances of fish kill in farms/cages and its management

Mortality due to disease or pathogen transmission from wild to farmed fish

- Licensed veterinarian to examine the cultured fish on a regular basis and treat as required.

Mortality due to predation

- Appropriate predator deterrence including predator nets, scaring devices, frequent removal of mortalities, regular inspection of nets.
- Mortality due to abrupt physico-chemical changes
- Select sites of suitable water temperature

Mortality due to hydrogen sulphide

- Do not allow farm waste to accumulate in the benthic environment.

Mortality due to algal blooms

- Consider the potential for algal blooms prior to site selection.
- Cages should not interfere with navigation or other permissible water uses.

Asian seabass (*Lates calcarifer*)

It is a high value carnivorous fish suitable for mariculture in Indian waters. The advantage of the species is that it can grow in very varied conditions and in tolerant to wide temperature ranges. The most advantageous fact is that the hatchery production of seabass seed is standardized and is being done commercially in India.

Contributions towards GP in mariculture by research institutes are:

1. Development of technical guidance documents for brackishwater/estuaries and coastal waters that will serve as "user manuals" for assessing trophic state and developing region-specific nutrient criteria to control over enrichment due to aquaculture practices.
2. Monitoring and evaluation of the effectiveness of nutrient management programs as they are implemented. In shrimp aquaculture, well designed GPs can support producers to:

- increase efficiency and productivity by reducing the risk of shrimp health problems;
- reduce or mitigate the impacts of farming on the environment;
- improve food safety and quality of shrimp farm product; and
- improve the social benefits from shrimp farming and its social acceptability and sustainability

GPs could, in many instances improve the culture activities. Their impacts on resource use efficiency, productivity and more importantly on profitability, environment and social aspects can be similarly striking when compared to worse practices. GPs can be country specific, or developed for a particular location, taking account of local farming systems, social and economic context, markets and environments. GPs are often voluntary practices, but can also be used as basis for local regulations, or even certification programmes.

Positive outcomes of GP in Indian aquaculture

- *Decreased disease incidence:*
- *Increased confidence in contract hatchery system*
- *Reduced cost production:* Through efficient use of feed (FCR of 1:1) and other resources, including reduced use of chemicals, all the farmers will achieve a very good profit for the first time in many years.
- *Production of safe shrimp:* No use of antibiotics. Seed, shrimp and other inputs have been screened for antibiotic residues and they were negative.
- *Motivated farmers in abandoned areas:*

Cluster farm approach helps:

- To reduce the risk of disease outbreaks and improve the production in shrimp farms.
- To organize the farmers under “Self Help Groups”/”Aquaclubs” for sustainable production and to quickly meet the growing market demands.
- To produce better quality shrimps in socially acceptable, environmentally sound and economically viable manner.

Implementing GPsare done by creating:

- Awareness and capacity building of primary producers
- Awareness and capacity building of other stakeholders in the supply chain
- Changing the attitude of key players
- Demonstrating the benefits of GP implementation

Approach followed can be by:

- Facilitation of collective approach (cluster farming)
- On-site programs to create awareness on GPs
- Assisting groups of aquaculturists to develop voluntary guidelines

- Facilitating participatory approach
- Providing regular technical assistance
- Linking to other stakeholders in the supply chain
- Monitoring compliance for adoption

Cluster Farming

Collective planning, decision making and implementation of crop activities by a group of farmers in a cluster through participatory approach in order to accomplish their common goal to reduce risks and maximize returns.

The dissemination of GPs can be done through:

- Farmers meetings
- Regular site visits
- Extension material
- Brochures
- Booklets

Regulations in Coastal Aquaculture in India

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Introduction

Coastal aquaculture entails managed farming or culture of organisms in saline orbrackishwater areas for the purpose of enhancing production, both for domestic andexport markets. Coastal aquaculture in the broader sense includes culturing of crustaceanslike shrimp, prawn & crabs and fin fishes like mullets, milk fish, groupers, sea bream andmolluscs like clams, mussels and oysters. Unsustainable practices by shrimp farmers in the coastal areas have caused both social and environmental harm. In order to ensure protection and preservation of the coastal environment in the country, the Central Government, following direction of the Supreme Court, had set up the Aquaculture Authority in 1997 at Chennai. For more effective management of the coastal areas, the Government of India enacted the Coastal Aquaculture Act, 2005. In its endeavor to fulfill the mandate of its establishment, the Authority is geared up in its activities in accordance with the provisions of the Coastal Aquaculture Authority (CAA) Act, Rules and Guidelines. These guidelines are to ensure orderly and sustainable development of shrimp aquaculture in the country and intended to lead to environmentally responsible andsocially acceptable coastal aquaculture. It also enhances to the positive contributions of the socio-economic benefits, livelihood security and poverty alleviation in the coastal areas.

Powers and Functions of the Authority

- To make regulations for the construction and operation of aquaculture farms within the coastal areas
- Inspect coastal aquaculture farms with a view to ascertaining their environmental impact
- Register coastal aquaculture farms; order demolition of any coastal aquaculture farm which is causing pollution after hearing the occupier of the farm
- Enter on any coastal aquaculture land, pond, pen or enclosure to make any inspection, survey measurement, valuation or inquiry
- To remove or demolish any structure therein
- And to do such other acts or things as may be prescribed
- And perform such other functions as may be prescribed

The CAA also has to

- ensure that the agricultural lands, salt pan lands, mangroves, wet lands, forest lands, land for village common purposes and the land meant for public purposes and national parks and sanctuaries are not converted as aquaculture farms in order to protect the livelihood of coastal community living in coastal areas;

- fix standards for seed, feed, growth supplements and chemicals/ medicines used for the maintenance of the water bodies and the organisms reared and other aquatic life
- direct the owners of the farm to carry out modifications to minimize the impacts on coastal environment;
- order seasonal closure for ensuring sustainability; or in the interest of maintaining environmental sustainability and protection of livelihoods in the interest of coastal environment;
- cancel the registration where any person has obtained registration by furnishing false information or contravened any of the provisions of these rules or of the conditions mentioned in the certificate of registration;
- make suitable recommendations to the Government for amending the guidelines from time to time.

Farm Registration and Renewal

- All persons carrying on aquaculture in the coastal areas shall register their farm with the CAA. Such registration made for a period of five (5) years with facility for further renewal. Aquaculture is not permitted within two hundred meters from the High Tide Line and in creeks, rivers and backwaters within the Coastal Regulation Zone. However, this condition is not applicable to the existing farms set up before the enactment of the Coastal Aquaculture Authority Act, 2005 and to the non-commercial and experimental aquaculture farms operated by any research institute of the Government or by the Government.
- Every application for the registration of a coastal aquaculture farm shall be made to the District Level Committee (DLC) set up by the Authority in **Form I** (obtainable from the office of the DLC or the office of the Authority or be downloaded from the website of the Authority.)
- Every application should also contain/enclose the prescribed fee as stated below.

(1)		(2)
1	Up to 5.0 hectare (ha) water spread area	Rs. 200 per ha (or fraction of a ha), subject to a minimum of Rs. 500/-
2	From 5.1 to 10 ha water spread area	Rs. 1000 plus Rs. 500 per ha (or fraction of a ha) in excess of 5 ha.
3	From 10.1 ha water spread area and above	Rs. 3500 plus Rs. 1000 per ha (or fraction of a ha) in excess of 10 ha.

The fees for registration shall be payable in the form of Demand Draft in favour of the Member Convener of the DLC set up by the Authority.

Manner of considering application for registration

1) On receipt of an application the DLC shall verify the particulars given in the application in respect of all coastal aquaculture farms irrespective of their size; and act accordingly.

    a) In the case of coastal aquaculture farms up to 2.0 ha water spread area, the DLC upon satisfaction of the information furnished therein shall recommend the application directly to the Authority for consideration of registration under intimation to the State Level Committee (SLC).

b) In the case of coastal aquaculture farms above 2.0 ha water spread area, the DLC shall inspect the concerned farm to ensure that the farm meets the norms specified in the guidelines with specific reference to the sitting of coastal aquaculture farms and recommend such applications to the SLC, which upon satisfaction shall further recommend the application to the Authority for consideration of registration.

2) In case any defect is noticed in the application, the attention of the applicant shall be drawn in writing, requesting him/ her to rectify the defect within a specified period and in case of failure on the part of the applicant to rectify the defect within such period, the registration shall be refused.

3) The time-frame for consideration of application for registration shall be as specified in the regulations.

4) For the purpose of this rule, the compositions of DLC and SLC shall be as below:-

Disposal of Applications

As per the Gazette of India Notification No.10 notified on dated 18-14 March 2008 the DLC and SLC shall as far as practicable adhere to the following timeframe with a view to ensure time-bound disposal of applications submitted for setting up or for renewal of coastal aquaculture farms, namely:-

Sl. No	Activity	Time frame
1	Detailed examination of the application, site inspection and dispatching application by the District Level Committee to the State Level Committee or Coastal Aquaculture Authority, as the case may be.	Four weeks from the date of receipt of the application
2	Consideration of the applications by the State Level Committee and dispatching application with recommendations to the Coastal Aquaculture Authority	Two weeks from the date of receipt of the application from the District Level Committee.

Penalty Clause

- Punishment for carrying on coastal aquaculture without Registration
  - If any person carries on coastal aquaculture or traditional coastal aquaculture in contravention of sub-section *(1)* of section 13, he shall be punishable with imprisonment for a term which may extend to three years or with fine which may extend to one lakh rupees, or with both.
- Cognizance of offence.
  - No court shall take cognizance of an offence under section 14 without a written complaint filed by an officer of the Authority authorised in this behalf by it.

The acts or things which are to be done under clause (c) of section 12 of the Act:

- Any person authorised by the Authority shall :-

  1) take samples of water, soil and the farmed animal for the purpose of detection of banned antibiotics, chemicals and other pharmacologically active compounds and to adopt appropriate procedures for collection, analysis, reporting and follow up action

- Subject to the provision of rule 7, remove or demolish any coastal aquaculture farm which is causing pollution and which was not removed or demolished after an order to that effect, passed under clause (d) of sub-section (1) of section 11 of the Act.
- Drain the water from the coastal aquaculture farm or destroy the crop which is causing pollution in respect of which an appropriate order passed under clause (e) of sub-section (1) of section 11 of the Act has not been complied with.
- Authorize/recognize laboratories to carry out analysis of soil, water, farmed animals/other farmed aquatic life for the purpose of detection of banned antibiotics, chemicals, and other pharmacologically active compounds.

Effluent Treatment System (ETS)

Effluent Treatment System (ETS) is mandatory for farms above 5 ha. The pond area earmarked for the ETS may be used for secondary aquaculture, particularly for culture of mussels, oysters, seaweed, other fin fishes, etc. Such integrated culture projects would help improving the waste water quality, reducing the organic and nutrient loads and producing an additional cash crop.

Environment Impact Assessment (EIA)

- An Environment Impact Assessment (EIA) should be made even at the planning stage by all the aquaculture units above 40 ha size.
- For 10 ha and above a statement will be required to be given in the detailed plans.
- The District/ State Level Committees set up by the Coastal Aquaculture Authority should ensure that such an EIA has been carried out by the aquaculture units before their proposal is recommended to the Coastal Aquaculture Authority for approval.

Environment Monitoring Plan and Environment Management Plan (EMMP)

The shrimp culture units with a net water area of 40 ha or more shall incorporate an Environment Monitoring Plan and Environment Management Plan (EMMP) covering the areas mentioned below:

- Impact on the water courses in the vicinity;
- Impact on ground water quality;
- Impact on drinking water sources;
- Impact on agricultural activity;
- Impact on soil and soil salinisation;
- Waste water treatment;
- Green belt development (as per specifications of the local authorities)
- The standards prescribed in the Table given below are for the wastewaters discharged from the aquaculture systems, hatcheries, feed mills and processing plants.

S No	Parameters	Final Discharge Point	
		Coastal Marine Waters	Creek or estuarine courses when the same inland water courses are used as water source & disposal point
1	pH	6.0 – 8.5	6.0 – 8.5
2	Suspended solids ppm	100	100
3	Dissolved oxygen ppm	Not less than 3	Not less than 3
4	Free Ammonia (as NH3-N) ppm	1.0	0.5
5	Biochemical Oxygen Demand-BOD^5 ppm	50	20
6	Chemical Oxygen Demand-COD ppm	100	75
7	Dissolved Phosphate (as P) ppm	0.4	0.2
8	Total Nitrogen (as N) ppm	2.0	2.0

The following Institutions or Laboratories are recognized and approved for testing of samples and analysis, namely;-

(a) Government of India laboratories;

(b) Indian Council of Agriculture Research laboratories;

(c) Council of Scientific and Industrial Research laboratories;

(d) Marine Products Exports Development Authority laboratories;

(e) Export Inspection Agency laboratories;

(f) State Government National Accredited Board for testing andcalibration laboratories; and

(g) Private National Accredited Board for testing and Calibration laboratories accredited laboratories.

(1) The officer authorized by the Authority shall serve the occupier of the coastal aquaculture farm or his agent or the person in charge of the farm, a notice in Form I given in Schedule II of his intention to have the sample analyzed.

(2) The officer authorized by the Authority to take samples shall collect the sample in sufficient quantity to be divided into two uniform parts seal and mark the same and the officer shall permit the person from whom the sample is taken to add his own seal or mark to all or any of the portions so sealed and marked.

(3) In case, the samples is made up in containers or small volumes and is likely to deteriorate or be otherwise damaged if exposed, the officer shall take two of the said samples without opening the containers, seal and mark the same in the same manner.

(4) The officer taking samples shall-

(a) Hand over one portion of the sample to the person from whom the sample is taken under acknowledgement which if so desired and be sent for analysis by him to any of the approved laboratories.

(b) Send the other portion of the sample forthwith to the designated laboratory for analysis by registered post or through special messenger along with Form II as given in Schedule II.

(c) Send a copy of the said form II with specimen impression of seals of the farm or mark, if any of the person from whom the sample is taken separately in a sealed cover by registered post or through special messenger to a designated laboratory.

(5) The findings of the analysis shall be recorded in Form III as given in Schedule II in triplicate and signed by the analyst and sent to the officer from whom the sample was received for analysis.

(6) On receipt of the report of the analyst, the officer shall forthwith send one copy of the report to the person from whom the sample was taken, a copy shall be retained by him to be produced in the court, if necessary and one copy shall be sent to the Authority.

Where the report of analysis by the Institution or Laboratory, reveals contravention of any of the provisions in the Act, rules, regulations or conditions of registration, the Authority may without prejudice to any other action that may be taken, cancel the registration of the farm.

Guidelines for regulating seed production of SPF *L. vannamei*

1. Criteria for application to breed SPF *L. vannamei*

(1) Hatcheries engaged or intending to be engaged in shrimp seed production having the required bio-security facilities as prescribed by Coastal Aquaculture Authority would be eligible to apply for registration under the Coastal Aquaculture Authority Act, 2005 and the Rules framed there under and for permission to import SPF *L. vannamei* broodstock and to produce and sell post larvae of SPF *L. vannamei*.

(2) Approval of the hatchery for rearing *L. vannamei* will be given by CAA after due inspection of the hatchery facilities by a team constituted by Coastal Aquaculture Authority for this purpose.

(3) The hatchery facilities should have strict biosecurity control through physical separation or isolation of the different production facilities which is a feature of good hatchery design. In existing hatcheries with no physical separation, effective isolation may also be achieved through the construction of barriers and implementation of process and product flow controls.

(4) The hatchery facility should have a wall or fence around the periphery of the premises, with adequate height to prevent the entry of animals and unauthorized persons. This will help to reduce the risk of pathogen introduction by this route, as well as improve overall security.

2. Sanitary requirement

(1) Entrance to the hatchery should be restricted to the personnel assigned to work exclusively in this area and a record of personnel entering the facility should be maintained by the security personnel.

(2) Hatchery staff should enter through a shower or dressing room, where they remove their street clothes and take a shower before entering another dressing room to put on working clothes and boots. At the end of the working shift, the sequence should be reversed.

(3) There should be means provided for disinfection of vehicle tyres (tyre baths at the gate), feet (footbaths containing hypochlorite solution at >50 ppm active ingredient), and hands {bottles containing iodine-PVP (20 ppm and/or 70% alcohol)} to be used upon entering and exiting the unit.

3. Water intake

(1) Each functional unit of the hatchery should have independent water treatment facility and it should be isolated from all other water supply systems. Separate recirculation systems may be used for each functional unit of hatchery to reduce water usage and improve biosecurity, especially in high-risk areas.

(2) Water for the hatchery should be filtered and treated to prevent the entry of vectors and pathogens that may be present in the source water. This may be achieved by initial filtering through sub-sand well points, sand filters (gravity or pressure), or mesh bag filters into the first reservoir or settling tank. Following primary disinfection by chlorination, and after settlement, the water should be filtered again with a finer filter and then disinfected using ultraviolet light (UV) and/or ozone.

(3) The water supply system may include use of activated carbon filters, the addition of ethylene diamine tetra acetic acid (EDTA) and temperature and salinity regulation.

4. Water treatment and discharge of waste water

(1) The discharged water from the hatchery should be held temporarily and treated with hypochlorite solution (>20 ppm active chlorine for not less than 60 min) or other effective disinfectant prior to discharge. This is particularly crucial where the water is to be discharged to the same location as the abstraction point.

(2) The seawater to be used in the facility must be delivered into a storage tank where it will be treated with hypochlorite solution (20 ppm active ingredient for not less than 30 minutes) followed by sodium thiosulphate (1 ppm for every ppm of residual chlorine) and strong aeration.

(3) No waste water shall be released out of the hatchery without chlorination and dechlorination, especially to prevent the escape of the larvae into the natural waters. Effluent Treatment System (ETS) should be designed to include this provision.

5. Disinfection of implements

(1) Used containers and hoses must be washed and disinfected with hypochlorite solution (20 ppm) before further use.

(2) Each brood stock holding tank should have a separate set of implements which must be clearly marked and placed near the tanks. Facilities for disinfection of all the implements at the end of each day's use should be available.

6. Brood stock in hatchery

(1) Only SPF brood stock cleared through the quarantine should be used in the hatchery for seed production.

(2) Use of pond-reared brood stock is strictly prohibited.

(3) Hatcheries involved in SPF *L. vannamei* seed production should not use any other species within the hatchery premises.

Guidelines for regulating farm for culture of SPF *L. vannamei*

1. Eligibility criteria for farms

(1) Aquaculture farmers who are registered with CAA will be required to submit a separate application for permission for farming SPF *L. vannamei*. In case of so far unregistered farms, the application for registration must clearly spell out the intention to culture *L. vannamei*. Decision on such applications will be taken in accordance with these guidelines.

(2) Inspection team authorized by CAA shall inspect the farm and based on its recommendation regarding the suitability of the facility for farming of SPF*L. vannamei*, applications shall be processed by the Member Secretary for consideration of the CAA for issuing permission to farms for farming of SPF*L. vannamei*.

(3) Farms must establish adequate biosecurity measures including fencing, reservoirs, bird-scare, separate implements for each of the ponds etc. The farms should be managed by the personnel who are trained and/or experienced in management of bio-security measures.

(4) Farms irrespective of their size should have an Effluent Treatment System (ETS). Since loading of the environment with suspended solids is very high during the harvest, the ETS should be able to handle the waste water let off during harvest. Harvesting should be sequential depending on the size of the ETS. The quality of the waste water should conform to the Standards prescribed under the Guidelines issued by CAA.

2. Water discharge protocols

(1) In case of any outbreak of disease, distress harvesting is permitted through netting only and the water should be chlorinated and de-chlorinated before release into drainage system.

(2) Waste water should be retained in the ETS for a minimum period of two days.

(3) Farms which follow Zero Water Exchange system of farming will also be encouraged to take up SPF *L. vannamei* farming.

3. Biosecurity considerations

(1) It is advisable not to culture SPF *L. vannamei* if the neighboring farms are culturing native species, which are non-SPF, since SPF *L. vannamei* is susceptible for all the viral pathogens reported in *Penaeus monodon* in India.

(2) Farms approved for SPF *L. vannamei* culture would not be permitted for farming of any other crustacean species.

4. Norms for culture of *L. vannamei*

(1) Tested and certified seed should be procured only from hatcheries authorized for import of the SPF *L. vannamei* brood stock and production of SPF *L. vannamei* seed.

(2) Stocking densities should not exceed 60 nos/m^2.

(3) Strict compliance for the waste water standards is a mandatory requirement and inspection team authorized by CAA in each case shall monitor the quality of waste water as per the procedures laid down in the Regulations under Coastal Aquaculture Authority Act, 2005.

Conclusion

Coastal aquaculture, which is now confined mainly to shrimp farming, is one among the several activities in the coastal area involving the coastal communities. Much of the social conflicts in coastal areas are due to the larger demands on the limited resources, resulting in competition amongst the various stakeholders. Secondly, diversification is an urgent need and it is the high time that promotion of a variety of species with export potential as well as domestic demand is required to be regulated in the same manner as in the case of SPF *L. vannamei* along with increasing aqua production of our country. In this regard CAA is putting constant efforts in bringing out suitable guidelines and code of practices for the culture of different species for coastal aquaculture.

Bioremediation: Eco Technology of Cultured Water Using Efficient Microbes (ECO Microbes)

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The emerging role of bacteria in the field of bioremediation eco- technology with countless new genes and biochemical pathways using antagonistic compounds and other useful molecules has generated new interest in them. After testing all the physical, chemical and biological means of bioremediation it has been found that for management of contaminated waters the best option is microbiological treatment which is more efficient economically and consumes less energy. "*In situ*" bioremediation is the cleanup approach where the dissolved and absorbed contaminants are in contact with microorganisms. The microorganisms act well only when the waste material helps them to generate energy and nutrients to build up more cells. Lack of biodegradation capacity of native microorganisms can be overcome by addition of selective substrates during. Insitu bio remediation or manipulate the native microorganisms for efficient and speedy biodegradation.

Advantages of *in situ* bioremediations are minimum exposure to site personnel, minimal site disruption, simultaneous treatment of soil and ground water and low costs. Disadvantages are seasonal variations of microbial activity due to direct exposure to environmental factors and also lack of control of these factors. Time consuming processing when compared to other bioremediation processes and probiotic application of treatment additives, nutrients, surfactants, oxygen etc. Several species of microorganisms are reported by Colwell and Walker (1977), Maeda and Liao (1992), Moriarty (1998) which have diverse metabolism and ability to degrade the recalcitrant organic compounds.This article highlights application of specific "EM" flora developed for the treatment of aquaculture pond water, like bacillus, photosynthetic bacteria, actinomycetes a yeast which can maintain neutral pH in pond water resulting in the occurrence of pathogenic vibrio's in pond. Water quality and control of disease are independent and linked to microbial activities in ponds. Only 17% feed is utilized. Microbial food webs are an integral part of all aquaculture ponds and have direct impact on productivity. If we can quantify productivity of bacteria we can make informed judgments of the three functional roles of bacteria and thus improve pond management to optimize productivity are as follows:

- Oxygen content of water is governed by bacterial activity. Respiration is often predominantly due to microbial processes affect water quality factors such as O_2, NH_3.
- In all extensive, semi-intensive and in some intensive aquaculture system bacteria also contributes significantly to the food web. They may be eaten directly by tilapia or mullet (adult producer) or by small animals. E.g.

Larvae and juveniles of penaeid prawn. Feeding may be impaired by formation of aggregates or by saline products.

- Through the activity of heterotrophic decomposers nitrogen and phosphorous are recycled to stimulate primary production.

Recent advances in microbial ecology now enable us to study community composition and activities of the bacterial members of aquatic systems. The results are now being applied to intensive aquaculture. This is an application of bioremediation eco technology which is essential for management of grow out ponds if harvests are to be sustainable, seasonal, quantitative, estimation and qualitative distribution pattern was studied for 2 years in the project FEM/ MB/1.

Heterotrophic bacteria consume oxygen and release CO_2 and ammonia while oxidizing organic matter.

In contrast the autotrophic, nitrifying and sulphur bacteria consume O_2 an CO_2 while oxidizing ammonium, nitrite or sulphide. The end products are nitrate and sulphate.

Feed contains high protein content. Ammonium release by the heterotrophic bacteria and cultured animals is inevitable. It must be taken up by algae or oxidized again by nitrifying bacteria rapidly to prevent toxicity to the cultured animal in the aquaculture pond. If nitrate concentrations become too high it will create problem at the end of the grow-out. In pond bottom detritus layer: oxygen diffusion is limited and thus oxygen is rapidly depleted due to consumption by bacteria and other microbes and animals. In the absence of O_2, nitrate present is used in place of O_2 for respiration producing nitrite, ammonia and nitrogen gas.

Fermenting bacteria also become active releasing acids like lactic acid, acetic acid, butyric acid, pyruvic acid, alcohols, CO_2 and H_2 which are then used by aerobic sulphate reducing bacteria. An oxygen debt is built up which may not be balanced during grow out stage, leading to an increase in reduced sediment on pond bottom. The ammonia and sulphide may not be present in toxic oxygen concentrations do not fall below 4pp in the water column.

Where the rate of feeding is very high as in the case in later stages of grow out excess of leached material in sediment surface leads to increased heterotrophic bacterial growth. Which inevitably causes anoxic conditions close to the sediment surface where bacterial oxygen requirement exceed the oxygen diffusion rate into the sediments? Thus the cultured animal will be exposed to sub-lethal concentrations of toxic compounds that is sulphate, nitrite and ammonia. Disease resistance is known to decrease in fish under such circumstances when pH is acidic and redox potential and this pathogens can invade. It is important therefore, to ensure that organic detritus and slime do not build up on the pond bottom as sludge. All faeces, excess feed and dead algae must be rapidly decomposed preferably in the water column itself. Regulation of bacterial growth;

Species composition:

In natural ecosystem, bacterial growth rates and biomass are controlled – by the slow rate at which large compounds or polymers such as proteins, starch or cellulose or fats are broken into smaller units. These particles are present as dead algae, uneaten food, faeces of animals.

Bacteria– efficient in hydrolyzing polymers would have a selective advantage and dominate– provided other conditions like O_2, pH, nutrients like phosphate are not limiting.

Bacillus:

Gram – positive bacteria bacillus group produce a wide range of exoenzymes efficicent at breaking down polymers so they are very useful in ponds. Normally, they are not present in high proportions in the water column. Their natural habitat is the sediment. Where there exoenzymes are held close to the cells by the sediment matrix and provide direct benefit to the cell and colony that secretes them. When certain bacillus strains are added to water sufficiently frequently and at high enough diversity – they do make an impact on the available organic matter. The bacterial strains must be adapted to the particular conditions in a pond. Eg. Strains that produce exoenzymes can degrade the particular bio chemicals in the organic detritus.The added bacteria then compete with the bacterial flora naturally present for the available organic matter such as leached or excess feed components and faeces. The results are that there is less accumulation of slime, slime cannot be completely eliminated. Lower numbers of potentially pathogenic bacteria and less accumulation of organic matter on the pond bottom. Thus there is better penetration of O_2 into sediment making a better environment into which cultured animals can burrow.

Competitive exclusion:

It is an ecological process that can be manipulated to modify the species composition of a soil or water body or other microbial environment. Small changes in factors that affect growth or mortality rates will lead to changes in species dominance. We are still a long way from knowing all the factors that control bacterial species, growth rate, and even the complete species composition in natural environments best enough is known that it is possible to change species composition by making use of competitive exclusion principles.

Species composition

Partly determined by chance; Partly determined by physiological factor, that allow a species to grow and divide more rapidly than others. Thus dominate numerically. Dilution, adsorption, aggregation, sedimentation etc contributes to the decrease in pathogenic bacterial contents. Chance follows: Those organisms that happen to be in the right place at the right time to respond to a sudden increase in nutrients. Eg: from the lysis of algal cells or decomposition of feed pellets that fall around them. So the farmer can manipulate the species composition by seeding large numbers of desirable strains of bacteria or algae. In other words : by giving chance a helping hand.

Bio- remediation:

The practice of bioremediation or bio augmentation is applied in many areas, but seems varies greatly depending on the nature of the products used and the technical information available to the end user. Selection of suitable ones doing specific functions that are amenable to bioremediation and added in a high enough heterotrophic bacillus density and under the right environmental conditions will enhance the productivity. Bio augmentation by DMS and the use of probiotics are significant management tools. But efficacy depends on understanding the nature of competition between species or strains of bacteria. They rely on the same concepts as used successfully for soil bio- remediation and probiotic usage in the animal industry. Criticism of this practice – bacterial products did not work as claimed. Products did not contain a large number of the right strains of bacteria to be effective or the bacteria were not viable. Suppliers of bacterial products must be aware of the physiological and ecological requirements of their bacteria. For eg: some contain purple sulphur bacteria that will remove sulphide only when conditions are anaerobic and light is present. Such conditions would be lethal to the cultured organism and would obviously not be present in a well-managed productive pond. The efficacy of the products containing nitrifying bacteria that were supposed to control ammonium concentration was also examined. Ammonium and nitrite oxidation is however a different process from control of pathogens and organic matter concentration by bacillus.

Nitrobacter and Nitrosomonas, Autotrophs

The nitrifiers are autotrophic. They need CO_2 for their carbon source. They use energy from oxidation of inorganic compounds such as ammonia. They are very difficult to maintain in a storage condition. Shipment and transport as commercial prepration cannot be done in nitrifiying bacteria. Thus the bacteria may not be viable or the number of bacteria added could have been too low to be effective.

Factors affecting effective usage of 'DMS'

Slow growing organisms require oxygen; Built up of nitrite and ammonia in pond which will inhibit their activity. Autothonus nitrifiers are best maintained by pond management practices. For eg: ensuring that there is a continual supply inorganic nutrients together with O_2 allowing natural populations of Nitrosomonas and Nitrobacter to grow to keep in balance with ammonium supply.

When to add bacterial products:

Sometimes – conditions develop that leads to a decrease in the density of nitrifiers with corresponding increase in nitrite or ammonium concentration. A rapid response is necessary. Increasing the aeration only would be insufficient because nitrifiers have long generation time. In such a case rapid response could involve adding a large inoculum of the nitrifiers together with an increase in aeration and mixing.

Criticism of bioaugmentation with "DMS"

For example in agriculture rhizobium inoculation for leguminous plants and more general inoculation of plant root zones with growth promoting bacteria such as bacillus species is widely practiced with high beneficial results. Shrimp farms in Indonesia that use the DMS range of bacillus do not have problems from disease caused by luminescent vibrio species. The number of luminous vibrio was inversely correlated to the addition of particular strains of bacillus. In intensive aquaculture however time is important. A good way to achieve rapid response and to reduce lag time and to low floral density is to add sufficient numbers of desired bacillus bacteria. The application of bioremedial technology is feasible and necessary. Instead of asking how bacterial abundance is controlled by nutrient availability or grazing we are asking what is the best way to change bacterial density of a particular bacterial species at a given time. The research field of microbial ecology will advance with the demand that the aquaculture industry is placing on it. In aquaculture the concept of microbial food chain can be adapted. The addition of low concentration of organic matter promotes the growth of fish. Certain species of bacteria like spore forming bacillus may be added with live feed like algae, artemia or rotifers which can enhance survival rate of fish significantly as they are excellent bioconverters.

Bioconvertors and bioprobiotics

Bioconvertors is a new technology that allows to keep aquaculture ponds clean to improve zooplznkton growth. All the 5 types of gases methane, ammonia, nitrate and H2S gases that are harmful to aquaculture producing acidic waters reducing the immune potential of the animals. In the bioconverter technology the degraders converts these gases water and carbon di oxide and free nitrogen and release the same into atmosphere air. Thus bioconverters reduces pond pollution and improve zooplankton and increase their immune potential.

Pond water is classified as neutral if the pH is 6.5 to 7.5.

6.5 – 6 is designated as slightly acidic.

6 – 5 is moderately acidic

5 – 4 is strongly acidic

< 4 is extremely acidic

Whereas pH 7.5 – 8 is slightly alkaline

8 – 9 is moderately alkaline

9 – 10 is strongly alkaline

>10 as extremely alkaline

Ingredients for EM solutions

A mixture of bacterial microbes was used as EM by Takashi Kyan and Terno Higa (1996). The first creation is known as EM – 1 containing yeast photosynthetic bacteria and lactic acid bacteria. EM technology is PRO EM is a liquid probiotic supplement that suppots healthy digestive and immune system, supports weight loss, improves absorption of food nutrients and aids in controlling yeast infections. Dr. Higa's brilliant discovery has been introduced in 120 countries worldwide. Teraganic is exclusive distributor of EM technology products. Carotenoid pigments including hydrocarbons such as â- carotenoid or xanthophylls such as lutein and zeaxanthine are widely distributed in nature where they play an important role in protecting cells and organisms against the harmful effects of light, air and sensitizer pigments. This process has been demonstrated in bacteria algae, plants, animals and even humans in the light sensitive diseases, erythropoetic protoporphy. The primary mechanism of action of this phenomenon appears to be the ability of carotenoids to quench excited sensitizer molecules. Caroteinoids can also sense as antioxidants under conditions other than photosensitzation. Antioxidant action can be documented in both enzymic and non- enzymic systems, and has been reported as subcellular, cellular and animal studies. Their anticarcinogenic properties may be related to their ability to interact with and quench various radical species that can be generated within cells.

Concluding remarks

Contamination of cultured water will have economic impact and the bioremediation of cultured water is acheviable only with microbial metabolism. Autocthonous microorganisms alone cannot do the bioremediation if the load of wastes is too heavy for them and remediation percentage after supplement application (microbes or nutrients) were generally higher than control. It was evident that nutrients (organic and inorganic) could also promote bioremediation. A successful implementation of a remediation regime required a consideration of the indigenous biota, nutrient availability as well as environmental factors necessary to achieve optimal results. A combination of technologies regulated with stringent conditions and allowed enough time will prove definitely successful bioremediation culture water. Interdisciplinary approach is required for bio remediation with a combination of biotechnology, microbiology, biochemistry, genetic engineering as bio remediation tools. Ecological risk analysis has to be done. EIA is a prerequisite before commercial application of EM. Probiotic use require responsible care for sustainability an option to uplift the livelihood of fish farmers.

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Mariculture and Biodiversity

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Introduction

Aquaculture experienced a drastic increase throughout the world with a range species from giant clam, mussels, oysters, carps, salmon, grouper, milkfish, catfish, pompano, and tuna cultured in diverse environments. Diversity observed from filter feeders, herbivore to highly carnivorous groups. Fish culture habitats also showed the diversity from estuary, lakes, mangroves, coastline, inshore to offshore areas. Two major subsectors emerged in the aquaculture sector are the family and co-operative farms mainly follow the extensive and semi-intensive practices, whereas the commercial farms follow the intensive and semi-intensive practices to produce high valued products for the global market. The aquaculture production can reduce the pressure on the capture production and can lower the investment in the fishing fleets and effort. Major farmed fish are common carp, tilapia, milkfish, cod, haddock and pollock. Mariculture is the cultivation of marine organisms in their natural habitats, usually for commercial purposes. It is the culture of organisms, both plants and animals in both the sea and inland brackish water areas. Mariculture worldwide is growing and according toFAO statistics, it showed an increase from 9 million tonnes in 1990 to more than 24.7 million tonnes in 2012. Some of the species shown potential for future growth but may be sensitive aquaculture efforts are *Acipencer* spp., *Anguilla* spp., *Epinephelus* spp., *Lates* spp., *Lutjanus* spp., *Oreochromis* spp., *Thunnus* spp., and *Ulva* spp. (CBD, 2004).

Mariculture is dominated by seaweed (Japanese Kelp) and molluscs (Pacific cupped oyster) and high valued finfish salmon. Also, there are small scale cultures of Sea horse, giant clam, microalgae, rotifers and brine shrimp. The species like milkfish, etrpolus, and mullets are cultured in brackish water. At the same time the pressure on the aquatic resources and wild fish stock is showing an increasing trend as the human population grows. The Global marine catch was about 14 million tonnes (1950), which increased to65 MMT in 2012 (FAO, 2014). It is also noted that the total catch was more or less stable around 70-65 MMT overt the last 25 years and gives the indication that there may not be further increase from the capture section. Mariculture offers good quality food and relatively more efficient thanseveral other food production systems. It is recognized that all forms of mariculture disturb the biodiversity at species, genetic and ecosystem level and will result in adverse impact. The main effects include habitat degradation, decline of wild populations, introduction of non-indigenous species, biological pollution, genetic impacts of target species and social effects like human health issues, loss of employment income of traditional fishermen. There are severalopenapproaches for circumventing the adverse effects of mariculture on biodiversity. They include the effective site selection, proper environmental assessment, proper feeding protocol, better effluent and waste control measures, better genetic resource management, setting up of hatcheries for seed collection, reducing the collection of wild seed and enhancing positive effect of mariculture to reduce the pressure on capture fisheries.

Effect of Mariculture on marine and coastal biodiversity

All forms of mariculture affect biodiversity at genetic, species and ecosystem levels, which results in the supply of ecosystem goods and services. Mariculture can change, destroyhabitat, disrupt trophic structures, spread diseases and reduce the genetic capability. The by-products of the mariculture systems like particulate organic matter, nitrogen, phosphorus, remains of antibiotics, pesticides, and hormones move into the water column. The genetic effects of mariculture are wide-ranging and highly important for biodiversity. The major effects of mariculture on marine and coastal biodiversity are summarized below.

I. Ecological effects of Mariculture

1. Effluent discharge

Mariculture activities release untreated nutrients, chemicals, feed materials, antibiotics and pharmaceuticals into marine ecosystem. This will lead to degenerated water quality in the shallow water bodies and high concentrated production areas. Nutrient loading from the culture systems will affect the biogeochemistry of the habitatsmaking it toxic to the fish and shellfish. The farmed Salmon discharged an average of 48.2 kg of nutrient nitrogen into the surrounding environment per ton of production, whereas 72.3 kg N per ton of farmed cod and 86.9 kg of N per ton of farmed turbot (Ervik *et al.*, 1997). Davies and Slaski (2003) has shown that effluent from Halibut rose in marine environments tend to have high impact as the sea cages need to be wide, shallow and in sheltered areas for optimal growth. It is estimated that waste production from farmed Halibut indicate and average loss of 66 kg N per ton of fish output.

2. Habitat modification

Large areas of mangrove and coastal areas have been converted to shrimp and fish ponds. This conversion results in the loss of ecosystem services provided by the mangroves such as nursery habitat, coastal protection, flood control, sediment trapping and water treatment (Naylor *et al.*, 2000). The loss of mangrove will affect the catch of the mangrove dependent fish species. As mangroves are closely related to the Coral reefs and sea grass beds, the change in the mangrove area will havea deleterious effect on the coral and sea grass ecosystem (Ogden, 1988).Culturing of milkfish and shrimp often involves changing mangroves and salt swamps, the ecosystem that offers many key services such as erosion control, flood control, trapping of sediments and dispensation of wastes. As the culturing intensifies natural habitats will be destroyed and can in turn result in biodiversity imbalance.

3. Use of wild seed to stock mariculture

The use of wild collected seeds for the mariculture operations in extensive, pond and cage culture activities will have consequences in the wild fisheries. Wild collected seeds are used in the milkfish culture in the Philippines and Indonesia, tuna in South Australia, shrimp in Asia and Latin America, eels in Europe and Japan (Naylor *et al.*, 2000). The fry collection results in the loss of other frys collected along with the target group and it may be some times a higher magnitude than the targeted group. The fry removed from the wild will ultimately have an impact on the wild production of the species.

4. Increased predation on wild fish and other organisms

Aquaculture in general can have incidental predation effects on other non-target organisms. A variety of piscivorous birds like terns, cormorants, pelicans, gulls, egrets, heron, and kingfisherare commonly aggregate around the culture areas.

5. Biological Pollution

The mariculture affects the wild and farmed fish through biological pollution. Escape or the accidental release of fishes into the wild from aquaculture farms,has an adverse impact on native species and ecosystem, it paves wayto a major environmental apprehension. Introduction of exotic species and the escape of genetically modified fish samples which are used for aquaculture purposes or laboratory testing result in competition and predation of wild fish varieties. Hilborn *et al.* (2003) reviewed that the introduction of exotic species as a form of biological pollution which affecting the native fish species mainly of coastal ecosystem. As a result of the introduction many indigenous varieties of fishes have been replaced by exotic varieties, and with increasing demand and world trade the frequency of exotic introduction is said to increase exponentially (Cohen *et al.,* 1998; Carlton *et al.*, 1996). The Atlantic salmon the dominant Salmon species farmed, frequently escape from farms. It was reported that about 40% of the Atlantic Salmon caught by fishermen in areas of the North Atlantic are of farmed origin (Hansen *et al.,* 1993). Farm escaped fishes may hybridize with wild and alter the genetic make-up of the wild populations which results in the decline of many locally endangered species.

II. Genetic Impacts of Mariculture

1. Genetically Modified Organisms (GMO's)

The concept of Genetically Modified Organisms is a controversial topic when it is associated with food products. The basis for developing GMO's is essential to increase the productivity, yield, resistance to parasites and diseases, enhanced nutritional quality and flavor. When compared with other higher animals, fish transgenics offers certain advantages such as large no. of eggs are laid and at the same time fertilization and embryonic development takes place outside the mother (in most species), which make them less susceptible to human pathogens and the fact that aquaculture is rapidly expanding adds on to the cause. First transgenic fish was developed in 1984, since that time more than 30 species of fishes have been genetically modified (NRC, 2002).

In general, there are two opposing views about the GMOs.

a. Precautionary: Transgenic technologies arehavingunidentifiedhazards that need to be cautiouslywatched and controlled to guarantee the protection of both the environment and human well-being.

b. Genetic engineering is a little challenging from other technologies involving genetic upgrading or domestication, and GMOs as extremely domesticated and therefore doubtful to survive in the wild if they escape, the procedure therefore needs little extra testing or oversight.

2. Transgenic Fish

Transgenic fish are those that carry or transmit copies of the recombinant DNA sequence produced *in vitro* using rDNA technology. The recombinant DNA Sequence which is introduced into the fish mainly consists of three regions; promoters or signaling region, coding region or the code for the target protein and the terminator region or stop codon. The construct is introduced into the fish at its early embryonic stage or into fertilized egg using microinjection techniques. The chance for successful incorporation of the microinjected rDNA into the fish genome is 1 out of 100. The incorporated rDNA sequence will be subsequently passed onto its progeny. The growth hormone gene has been the most extensively used target gene for transgenesis, because of its high productivity in short time with less spending on feed cost. More than 14 species of fish have been genetically engineered for enhanced growth (Van Eenennamet *al.*, 2006). These fishes are said to have higher food conversion efficiency, which results in less feed wastage and minimize effluent discharge from fish farms (Cook *et al.,* 2000).

Many varieties of fishes which are involved in the ornamental fish trade are developed into transgenic forms, which emits a glowing aura that the native breeds do not have. Zebra fish (*Danio rerio*) was the first fish species to be genetically modified with fluorescent abilities later Black tetra (*Gymnocorym busternetzi*) and Tiger barb (*Puntius tetrazona*) varieties were also modified. Another type of GMO involved in the aquarium trade is the Genetically Improved Farmed Tilapia (GIFT, *Oreochromis niloticus*), which has been labeled as the 'Frankenstein fish'. This GMO has been engineered to survive in a wider range of environmental conditions and temperatures that non-GMO individuals would be incapable of surviving in. Although none of the GMO's were approved to be used for food purpose globally, until a company named Aqua bounty got approval from FDA recently for its Aqua bounty Atlantic Salmon. Different types of transgenes used in the aquaculture are summarized in the Table 1.

Table 1.Details of transgenes and targeted phenotypes in different species of fishes.

Phenotype targeted	Fishes	Transgene
Growth	Atlantic salmon Tilapia Rainbow trout Coho salmon Chinook salmon RohuLoach	Growth hormone
Freeze tolerance	Atlantic salmon	Antifreeze protein
Disease resistance	CatfishCarpMedaka	CercopinLactoferrinCecropin
Carbohydrate metabolism	Rainbow troutRainbow trout	Glucose transporterHexokinase
Reproduction	Rainbow trout	Antisense GnRH
Lipid metabolism	Zebrafish	D6- desaturase
Phosphorus metabolism	Zebrafish	Phytase
Vitamin C metabolism	Rainbow trout	L-gulono-gamma-lacotne-oxidase

Source: Devlin R. H., Sundstrom L F. Muir W M. 2006. Interface of biotechnology and ecology for environmental risk assessment of transgenic fish. p. 89-97.

In general the genetic engineering is a complex technology executed on complex biological systems; results will produce complications. Over and over again manipulated and accidental consequences that fuel the excitements of anxiety and public expose and defend precautionary approaches to transgenic (Helfman, 2007).

3. Risk factors of Transgenic Fish and environmental impact

The main risk associated with transgenic fish is its release or escape. Concern range from interbreeding with native fish population to effects on biodiversity of ecosystem resulting from increased competition for food and prey (Muir and Howard, 2002). Another assumed risk is by 'Trojan gene hypotheses' as per the hypotheses, the transgenic fish carrying sex chromosomes will possess enhanced mating success, but the offspring's produced will be having reduced juvenile viability. This may result in demographic destabilization and ultimately the extinction of wild species (Muir and Howard,1999; Hedrick *et al.,* 2001). Apart from the interbreeding, if we consider the potential impact of the environmental factors on the survival of transgenic and non-transgenic populations, it may or may not possess a threat to other species. In a study involving native salmon and transgenic salmon it was proved that, both the fishes coexisted and were not competing for food when food availability was high, but when the availability was reduced to 0.75% of total fish biomass, it was found that transgenic fishes were dominating the native as they were bigger in size and at the same time they were displaying strong cannibalistic behavior over their counterparts (Devlin *et al.,* 2004).

Considering these risks, the containment of transgenic fish should be the major component of any commercialization plan and at the same time a bottleneck in using transgenic fishes in Aquaculture, as fishes possess an innate ability to escape from confinement. If transgenic fishes are effectively contained, it will possess only a little risk tothe environment and wild fish stock (NRC, 2004). Bioconfinement methods or physical containment with a failsafe mechanism should be employed in transgenic fish aquaculture on approval.

III. Parasites and diseases associated with Mariculture

Asian countries contribute more than 90% of the world aquaculture production. As any other farming system, aquaculture is also affected with different parasites and diseases. This is mainly due to commercialized, intensified and unhygienic farming practices intended for making high profit. As the aquaculture industry intensifies and expands, it became susceptible to different diseases and problems caused by viruses, bacteria, fungi, parasites and other unidentified and emerging pathogens. Translocation of aquatic animals also results in introduction of parasites. Typical examples for parasite translocations with the host are as follows. In a study (Lumanlan *et al.,* 1992); it was found that imported fishes entering Philippines were infected with pathogenic parasites of protozoan genera such as *Trichodina*, *Ichtyophthirius, Cryptobia, Ichtyobodo* and *Trypanosoma; Dactylogyrus* and *Gyrodactylus; Ascocotyle* (digenean)*;* the *Bothriocephalus* (Cestode)and the *Lernaea* and *Argulus* (Crustacean). The most commonly reported monogenean parasite of grouper (*Epinephelus spp.*) and other marine fishes *Neobenedenia girellae* was introduced to Japan along with amberjack fry (*Seriola dumerili*) from Hainan and Hong Kong, China. They cause heavy infection among flounders cultured in floating net cages in 1991. In Japan, a total of fifteen cultured marine fishes were affected by *N. girellae* (Ogawa *et al.,* 1995). On introduction of the Pacific oyster (*Crassostrea gigas*) to the West coast of United States from Japan, it carried the parasite *Haplosporidium sp.* The stocks which were moved from west coast to the east of U.S was then heavily infected with the parasite and caused mortalities among eastern oysters along the eastern coast (Buresson *et al.,* 2000). Another classical example for range and distance parasites can travel along with the host is demonstrated by the WSSV affecting shrimps. The WSSV was first detected in the 1990's in Asia later on it spread to Americas by 1999 and was most recently reported in Brazil in 2005. A second important Shrimp disease Taura Syndrome (TS) caused by TSV was previously reported only in the Western hemisphere, but now it is widespread in Asia (Bondad-Reantaso *et al.,* 2005).

The Office International des Epizooties (OIE) presentlylists about 35 pathogens / diseases of finfish, molluscs and crustaceans. Of the 35 listed pathogens/diseases, 16 are diseases of finfish, 11 are affecting molluscs (other than one all are parasites) and 8 are diseases affecting crustaceans (none are of parasitic origin) (NACA/ FAO,2005). The impact of the diseases has been estimated in socio economic terms such as lose in production, income, employment, market access or market share, investment and consumer confidence, food shortages industrial failure etc. Economic impacts of aquatic animal diseases are not much analyzed and so there is not much data available, even though due to the frequency of occurrence, magnitude and spread many countries are providing some estimates of diseases in shrimp, molluscan and finfish aquaculture (Bondad -Reantaso *et al.,* 2005).

IV. Probiotics in Aquaculture

The widely accepted definition for Probiotics is the one from Fuller (1989) he defined Probiotics as a cultured product or live microbial feed complement, which usefully affects the host by improving its intestinal equilibrium. Probiotics must not be harmful to host and at the same time it should tolerate an extreme conditions such as salinity, temperature, acidity etc. The application of Probiotics can be via feed or injections as suitable (Salminen *et al.,* 1999). The Probiotics studied for use in aquaculture ranges from Bacteria (both Gram negative and positive), bacteriophages, algae (unicellular) and yeasts (Irianto and Austin, 2002). Mode of action of Probiotics contains; stimulation of humoral/cell mediate immune response, change of microbial metabolism by the increasing or decreasing of relevant enzyme levels and competitive inhibition of potential pathogens by production of inhibitory compounds or by competition for space, nutrient, oxygen etc (Fuller, 1989). However the precise mechanism of action of Probiotics is unknown, so a great deal of care should be taken in the choice of Probiotics. At the same time it should be ensured that the organism is apt for the host and free from side effects (Irianto and Austin, 2002).

V. Socioeconomic effects

Increased production of farmed fish in coastal and open ocean ecosystems has important implications on human health, employment, income and use of the marine environment.

1. Health effects

The benefits of eating fish have been fully documented and well known. The health hazards of eating farmed fish are just beginning and yet to be quantified. Farmed Salmon being a carnivorous fish that feed on the food web, and they will accumulate organic contaminants like PCBs and dioxins. The combined effects of several contaminants in a single product may pose significant threats to human health. The health benefits of consuming omega-3 polyunsaturated fatty acids will be also reduced due to the consumption of more vegetarian diet by the farmed fish (Rembold *et al.,* 2004). Salmon from Chile was found to have traces of chemicals used for the storage and preservation along with presence of malachite green, fungicide and antibiotic residue.

2. Employment and Income Effects

The net employment increases from growth in mariculture are also controversial. The Governments have often promoted mariculture for the purpose of employment and income generation, particularly in cases where wild fish stock has been declining due to overexploitation and overcapacity of vessels. Several countries started the aquaculture as an alternative avocation to the fishermen community and projected more employment and growth in the sector. Canada, Norway and Scotland initiated Salmon farming industry, but there was a mismatch in the employment and income loss from capture fisheries, which was larger than the employment and income generated in the aquaculture industry. There is no guarantee that the fishermen who lost their employment and income due to decline in the catch may get the aquaculture jobs. The Intensive aquaculture and multinational companies entering into the business usually do not benefit to the fishermen community (Naylor *et al*., 2003; Forster, 1999).

VI. Convention on Biodiversity (CBD) and Mariculture

1. Avoiding the adverse effects of mariculture on marine and coastal biodiversity

Convention on biodiversity (CBD) provided an elaborated programme of work on mariculture in relation to marine and coastal biological diversity. CBD presented the following guidelines to minimize the negative impacts of mariculture on marine and coastal biodiversity and to augment any positive effects of mariculture using native species (CBD, 2004; 2015).

1. The environmental impact assessment and monitoring procedures for mariculture developments as well as carrying capacities of the ecosystem. Need to address the likely immediate, intermediate and long term impacts on all levels of biodiversity.
2. Development of effective site selection methods, in the framework of integrated marine and coastal area management, considering the special needs and problems encountered by the stakeholders. The proper site selection for the location of cages, pens, rafts, should ensure that proper water circulation and the disbursing of nutrients and wastes.
3. Management of appropriate feeding protocol to reduce waste and environmental degradation. The workers feeding finfish and crustaceans should have proper knowledge and training to avoid work against biodiversity.
4. Development of effective methods for effluent and waste control. The organic matter accumulation may result in the eutrophication and biodiversity loss in the system. By using proper site selection and efficient mitigation process the effect on the benthos can be addressed.
5. Development of appropriate genetic resource management tactics at the hatchery level and in the breeding areas as well as cryo-preservation techniques, intended at biodiversity conservation.
6. Development of controlled low cost hatchery and genetically sound reproductive methods and these methods should be made available for widespread use, in order to avoid seed collection from nature. In case where seed collection from nature cannot be avoided, environmentally sound practices for spat collecting operation should be employed.
7. Use of selective fishing gear in order to avoid or minimize by-catch, in cases where seed is collected from the nature.
8. Use of native species and subspecies in mariculture can improve the ecosystem and marine polyculture using bivalves, seaweeds and marine finfish can reduce the waste produced in the system.
9. Implementation of effective measures to prevent the inadvertent release of mariculture species and productivepolyploidscomprising the framework of the Cartagena Protocol on Biosafety, living modified organisms (LMOS).
10. Use of proper methods of breeding and proper places of releasing in order to protect genetic diversity.
11. Minimize the use of antibiotics through better husbandry techniques. Vaccination for major diseases like furunculosis, vibriosisand yersisniosis of salmon displayed a decrease in the use of antibiotics.
12. Make sure that fish stocks used for fish meal and fish oil are managed in such a way as to be sustainable and to conserve the trophic web.
13. Use selective methods in industrial fisheries to avoid or minimize by-catch.
14. In view of Indigenous Traditional Knowledge (ITK) where applicable as a source to develop sustainable mariculture techniques.

15. Enhance the positive effects of mariculture on marine biodiversity and coastal productivity. Best site selection could actually promote the total productivity in the oligotrophic and mesotrophic system.

16. Principles, standards and certification of mariculture and mariculture products in relation to biodiversity should be developed in accordance with international standards for environmental protection.

17. Implementation of Article 9 of the code of conduct for responsible fisheries and other provision of the code dealing with aquaculture by developing necessary guidelines and legislative policy framework at the regional, national and international levels.

18. Certain precautions to elude the bad effects of GMOs are to limit transgenic to land based closed circulation setups; limit the production of sterile individuals; monosex culture and sterile culture; avoid manipulation of temperature and salinity tolerance tests to avoid the escape of species which have substantial invasive potential (Helfman, 2007).

Sustainable Mariculture

For aneffectivemariculture industry, major objectives recommended are the expansion of farming of lower trophic level fishes, reduction of fish meal and fish oil inputs in feed, development of integrated farming systems, promotion of environmentally sound mariculture practices for resource management and succeeding sustainability in conservation of biodiversity (Naylor *et al.,* 2000).It is well known that many of the capture fisheries resources are declining and mariculture seem to be the only substitute to increase the fish production from the sea. Mariculture with finest scientific and technological backup with public and private sector business approach, based on an ecosystem based management principles is the need of the hour.

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Cage Mooring Systems

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Introduction

Moorings are required to keep the cages in a fixed position and to reduce the transfer of excessive forces generated by wind, currents and waves to cages. In well protected bays and seawater sites and freshwater sites, the forces of exerted by environmental factors are reduced, small mooring system can used. Open sea cages where cages are exposed to greater environmental forces require more effective mooring systems. Mooring depends on the type of cage, how exposed the sites are exposed to weather, and the requirement for positional precision. Mooring failures were common place in the early days of coastal farming, but a better understanding of the problems, and more sophisticated analysis has largely reduced these risks. Cage and mooring design is "site specific", and careful and combined choice of cage type, nets and most specifically moorings, has a considerable bearing on the ability of fish stocks to survive in major storms, on exposed sites.

The mooring system for a fish farm consists primarily of ropes, floats and anchors. In addition, several smaller components like shackles, connection plates, chains, rings etc. The moorings influence the stress acting on cage structural members and the behavior of the cages in rough weather, and can affect production, profitability and staff safety. They are therefore an important – indeed -, integral part of the cage system and should be carefully designed. Thus the collar, net and mooring components of a cage system should be designed together, although in practice the cages are usually chosen or built first with the mooring system being designed as an afterthought.

Mooring requirements should be determined by the design and type of the cages and the characteristics of the site. It would first be necessary to quantify the incident forces that are likely to act on the cage under the worst possible weather conditions, and then to evaluate the proportion of energy transferred to the mooring lines and anchors. Two types of analysis can be used: quasi static and dynamic response. The loadings transferred to mooring lines vary enormously depending on current and wave conditions, cage design and number of lines employed.

Mooring design for a specific cage system and site

Wind and current forces are proportional to the square of the velocity. Thus an increase in current from 1 knot to 2 knots will generate 4 times the drag on a rigid submerged body. Effect of wave force is more difficult to compute, because the dynamic response of a system depends on so many factors. A change in the mooring system will change the internal loads on the cage system. In general a mooring system should be designed not only for specific cages, but also for the expected site conditions of water depth, wind, waves and current.

Mooring components :

For a proper mooring system for any type of cage, a number of elements need to be assembled together, correctly specified and installed, physically and operationally compatible with each other, and effective in use and maintenance. Important components include the anchor or mooring unit on the seabed, the rising line, which connects the anchor to the surface system, and the surface or subsurface mooring grid. The major elements comprise several smaller sub-units – particularly links, shackles, droppers, safety lines, buoys, etc., which in effect are integral in the complete system.

Anchor specifications

A range of different types is available, commonly from the shipping/fishing industry. Major options are usually between gravity or dead weight devices – mooring blocks or mass anchors, which rely primarily on their weight, and those which rely on their ability to wedge into the seabed substrate. The holding coefficient of the anchor (k) is defined as (R) the horizontal force divided by the mass of the anchor. The holding coefficient(k) depends upon the angle between the anchor and the cage and thus the ratio between water depth and line length and the nature of the substrate. The simplest and cheapest type of marine anchor is the dead weight or block anchor, which typically consists of a bag of sand or stones or a block of concrete or scrap metal. To prevent block anchors being displaced on the bottom, good friction between anchor and the bottom is necessary; this depends on the bottom condition and is given friction coefficient. Block anchors have low holding power per unit-installed weight. Block anchors are not recommended for use in rocky ground. Concrete block anchors may be simply fabricated using wooden shuttering, tyres or any other convenient object as mould. Steel rods for strengthening and eyebolt for a mooring attachment are usually incorporated. Once fabricated, the blocks can be transported to the waters edge at low tide and floats attached, so that they can be floated to the required location at high tide. Once installed, they are difficult to recover. There are numerous types of embedding anchor. The holding power of an embedding anchor is related to its frictional resistance in soil, and so is dependant on fluke area, soil penetration and the mechanical properties of the soil rather than simply the mass of the anchor. They designed to be dragged down into the ground like a plough and become fixed. The holding capacity of drag anchor has been reported to be upto 25 times the weight with good bottom conditions. Embedding anchors are very efficient, i.e. they have a high holding power to mass ratio. Under optimum conditions, they are 10-500 times as efficient as block anchors. They are more expensive than block anchors in terms of cost per unit holding power and have to be bedded in properly. The use of two anchors connected together gives greater holding power than the sum of independently moored anchors. There are numerous other type of anchor, combining the properties of block and embedding types, while others are designed for particular types of substrate. Prior to choosing or installing anchors it is advisable to survey the sea bed. Anchors should be positioned first. The position of the anchors can be accurately established using a global positioning system or by taking bearings with respect to local. Easily visible land marks. Rising line components A range of materials and configurations may be used, the most common of which involves a chain section at the lower end of the line, a synthetic rope in the main upper length, and various elements of buoyancy or weighting to adjust the profile of the line, and its response geometry when subject to varying load. A range of different types and specifications may be available for chain and rope. Key issues concern weight and tensile strength, elasticity (length change with applied tension), stretching, dimensional wear, degradation. Float units need to be specified according to volume and shape, and to their resistance to deformation when submerged Mooring lines must perform two functions: they must withstand and transmit forces. The loads imposed on a cage mooring system are principally dynamic. It is important that mooring lines have a high breaking strength and can absorb much of the kinetic energy of rapidly changing force s, otherwise theses forces will be transmitted directly to the anchors. Natural fibre rope is not suitable as it is easily abraded and prone to rotting. Steel cable, although immensely strong, is expensive and heavy. Chain is extremely strong but again is heavy and is usually used in conjunction with synthetic fiber rope. Synthetic ropes of same diameter nylon and PES are considerably heavier than PP or PES. However, nylon is much stronger on a per unit weight or equivalent diameter basis than ropes fabricated from the other materials. Braided ropes are lighter than laid ropes and are generally weak. They also cost more and have few advantages other than they are easier and more pleasant to handle and do not kink. Although it can cost twice as much as PE or PP rope of equivalent strength, nylon has high extensibility and thus energy absorbing properties, an important factor in designing cage moorings. Ropes should not be attached directly to either shore or sea anchors, but instead should be connected via a section of chain. The chain serves to increase the effectiveness of the mooring system, which directly act as an efficient type of anchor and improves the holding power of existing anchor by both reducing the angle between the mooring line and anchor and by increasing energy absorbing properties of the mooring line. Moreover, a section of chain is necessary at the anchor since it is much resistant than synthetic fibre rope to the prevailing high abrasion forces. There are several types of chains are available. Wrought iron is very variable in quality; the best has excellent corrosion resistance while the poorer grades are inferior in all respects. Mild steel chain, with low carbon and manganese contents has been widely recommended for cage anchorages. A fairly heavy grade of chain is recommended. The total length of the mooring line should be at least three times the maximum depth of water at the site and where the rope joins the chain, a galvanized heavy duty thimble should be spliced into the rope and a galvanized shackle of the appropriate size should be used to connect the chain and tot eh rope. An alternative mooring line composed mainly of chain is occasionally employed. Typically 12- 25 mm chain, two or three times the maximum depth of water in length is connected from the anchor to a float positioned 10m or so from the cage and a section of rope –PES or nylon- used to link the floats to the cages. The buoy minimizes the vertical loading on the cages and must be sufficiently large to support the mass of the chain in the water and to resist the vertical forces imposed by the cages on the mooring system. Under shock loads, the chain/buoy acts as a spring absorbing much of the energy that would otherwise be transmitted to the anchor. Two types of mooring systems be used: multiple and single point. The former is more common and involves securing the cages in one particular orientation while with the latter the cage are moored from one point only, allowing them to move in complete circle. Single point moorings tend to be used with rigid collar designs in sheltered sites. They use less chain and cable than multiple point moorings and because they adopt a position of least resistance to the prevailing wind, wave and current forces, both inter cage forces and torsional forces at linkages are reduced. Single point mooring systems also reduce the enormous net deformation seen in conventional mooring systems and have been used with successes to moor large offshore cages. Cages moored from a single point also distributes wastes over considerably larger areas than those secured by a multiple point system. The orientation of cages with multiple moorings depends upon the nature of the site and upon the type and group configuration of the cages. If particularly exposed or if currents are strong, then it may be best to secure cages in the position of least resistance to the prevailing wind and current forces. Where a site is sheltered and water circulation is poor, it may be better to moor cages so that water exchange is maximized. However, there may be restrictions on mooring orientation imposed by the site size or by suitability of mooring grounds. The number of mooring lines used determines the distribution of forces to the anchors. Most methods of mooring involve the use of ropes and chain to link the cage or cage group to anchors or pegs secured to the sea bed. The mooring line is often termed as a 'riser'. Although this is most common system there are alternatives. Some cages may use a submerged rope or cable based mooring grid, to which cages may be attached temporarily using near horizontal lines. One further alternative is to drive long posts into substrate and to attach cage directly either with ropes or with metal hoops or tyres that permit some vertical tidal and wave induced movement. In theory the number and dimensions of posts required and the to depth to which they must be buried could be computed from the estimates of the forces acting on the cage system and data on the soil characteristics, but in practices it is determined by experience. Although sometimes employed in sheltered and shallow inland and coastal sites with suitable substrates, this method of mooring is not widely used.

Installation methods:

The installation of mooring systems is an important aspect of the overall development of a cage site, and requires to be planned with care.

i. Working base: a suitable and secure area for storing and laying out the mooring components needs to be identified – ideally a level, surfaced area.

ii. Workboat or mooring vessel: capable of moving and positioning the mooring components and operating in the expected site conditions

iii. Cranes: dockside and on mooring vessels – capable of lifting and moving the mooring elements safely at the required horizontal reach.

iv. Access: – for materials to be taken to the assembly areas, for mooring components to be taken safely to the intended cage site.

v. Marking out: key locations in the mooring site can be marked out on a hydrographic chart, checked on site with GPS or conventional optical surveys; local transect markers can be identified, and temporary positions marked with light lines and floats.

vi. Making up moorings: the mooring lines and grids need to be adjusted to length and assembled to form the appropriate sub-components, which would then be finally linked together on site once the anchors are laid. Primary work can most easily be done on shore, using temporary measure lines or markers to help lay off the line lengths. Further adjustments can be done at sea, and all components and connections given a final check before installation.

vii. Laying anchors and risers: if blocks are used, these can be set at the intended site, using positioning co-ordinates to define the location. For embedding anchors, these should be dropped a suitable distance outwards (i.e., opposite the direction of tension) from the place of intended location, and tensioned inwards to their final position. Laying of moorings and lines should be done carefully, taking particular care not to foul anchors with riser line, to tangle or snag the line, or to endanger staff.

viii. Tensioning the rising lines: these need to be finally adjusted to ensure that the cage and/ or mooring assembly is correctly and evenly tensioned around its axes.

ix. Diver swim of rising lines: finally, it is very important to check the whole system visually – to ensure that blocks or anchors are cleanly placed and/or embedded, that lines are lying properly and are not kinked or tangled, and that connections are sound.

Mooring maintenance

Cage moorings are a dynamic system, which must respond to motion, under load, every minute of the years it is installed. Maintenance is critical, to ensure that components are physically sound and that linkages are secure. Critical dimensions of items subject to wear – chain links, brackets, shackles, splicing eyes, need to be checked periodically, bolts and shackle pins need to be tightened, and riser lines may need to be adjusted. With a rigorous and effective system of maintenance of both cages and moorings, with clearly defined parameters for replacement or repair, a well designed and installed system should be capable of reliable and secure operation. Mooring systems must be checked at regular intervals and fouling removed from buoys and mooring lines. it is essential that any mooring inspection assesses component strength to see if it deviates significantly from design strength and that it should also assess likely deterioration in the interval to the next inspection.

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Aqaurium Making and Maintenance

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An aquarium is a miniature form of an ecosystem which adds to the beauty of our home. This natural "living jewels" makes our living room more attractive and reduce the tensions experienced by the family members or the visitors. The major advantage of aquarium keeping is the low expenditure incurred when compared to other pets.

History of keeping aquarium fishes as pets

The idea of aquarium fish keeping is as old as recorded in history. The Sumerians, Assarians and Egyptians have all kept fish in ponds. By the end of the 17th century gold fish was introduced in several countries and became popular in England and Scotland. The opening of the fish house in London Regent Park during the spring of 1853 is the world's first aquarium.

Fabrication of aquarium tank and accessories

Considering the safety and reliability of aquarium tank you should remember the following factors.

1. Aesthetic beauty
2. Size and shape of the tank
3. The volume of water

Table 1: Size of the tank and required thickness of the glass

Tank size in feet	Thickness in mm
LxBxH	
2x1x2	4
3x1x2	6
4x1x2	8
3x2x2	10
4x2x2	10
5x2x2	12
6x2x2	12
7x2x2	12

Additional care- There is no additional cross belt in the upper portion of the tank up to a size of 3x1x2. The tanks above 3x1x2 size and up to 4x2x2' size requires additional cross belt on the upper side. Above 4x2x2' size needs beading and cross link with a size of two inch. Recently, imported modular tanks of various sizes are available in the market.

Fabrication of the tank

Fabrication of aquarium tank is an art which we can learn within two to three days of practical experience. The good quality glass, gum, glass cutter and silicone sealant can be purchased from glass merchants. When taking measurement for cutting the glass or giving order you should take care about the side glass (width wise glass). Regarding the width; deduct two times thickness of selected glass from the width of base glass.

Place the base glass on a leveled floor after pasting sealant near to the edges for fixing the other side glass. Then paste sealant along two sides of lengthy glass and fix above the base glass. Later paste sealant on one edge of side glasses and fix it in the corner of lengthy glass. Finally attach the lengthy glass to the previous one. After finishing the mould, firmly tie a sting covering four sides of the tank for avoid sliding the glass while pasting sealant in the corners.

Height of the tank- The aquarium tank should always be kept at height of 2.5 feet for viewing from standing and sitting positions in a living room.

Hood and lighting- The tank is covered with beautiful roofs made up of plywood or any other wood. The roof is provided with feeding facility and the facility to attach suitable lighting. The tank must be placed not far away from the window,(but not close to the window) which helps to allow some natural light into the aquarium and to promote the growth of plants inside the tank. Keeping the tank near to the window invite excess algal growth, which will destroy the beauty of the tank. For easy operation and safety providing electrical plug points near to the tank is ideal.

Accessories for tank setting

Items	Units
1. Aquarium tank	1
2. Aquarium hood	1
3. Aerator	1
4. Air tube	2 meter
5. Air regulator	2
6. Air stone	2
7. T-joint and I-joint	2
8. Florescent light with fittings	2.
9. Thermocool sheet (suitable size)	1
10. River sand (3 to 4mm) enough quantity	
11. Rocks and drift woodenough quantity	
12. Aquarium plant"	
13. Thermo meter	1

14. Heater with thermostat	1
15. Power filter	1
16. Hand net	1
17. Filter bed	1
18. Magnetic cleaner	1

Advance preparation for tank setting- Necessary drift wood, river sand and rocks should be thoroughly washed under running water till water turns clear. Some quantity of gravel and river sand(raw) mixed with vermicompost is better for growth of the plants. This mixture should be spread just below the washed river sand. Landscaping is to be decided well in advance,we can use silicone sealant for making desired shape in wood or in rock.

Setting of aquarium- Place the aquarium tank on an even surface(use water level hose or spirit level gadget) preferably on one inch thickness Thermocol sheet. After placing tank carefully insert under water gravel filter plate into the tank along with air lift pump. Then spread one to two cm manured mixture above the filter, above the mixture spread through washed river sand slopping towards front side. Modulated rocks and drift woods are firmly fixed in the land scape position. Air stones can be placed behind rocks for good visual effect. Decorate with aquarium plants depending upon your imagination. Fast growing plant and tall plants like vallisneria, cobomba, sagittaria are ideal for background planting. Bushy plants should be used to fill the corners and plants like ludwigia,amazon sword, small mint, water fern can be used in front portion.

While planting the long rooted species, assure that the roots are not damaged. Bushy plants should be tied with a stone to fix them in position. Before planting, the plants must be thoroughly washed in running water to remove any unwanted snail ,eggs and larvae attached with this plants. Dip the washed plants in 0.1% $KMno_4$ (Potassium permanganate)solution one to five minute and again wash in running water. Once the planting is over, the aquarium tank is filled with water without tilting the plants and other settings. Then cover the tank with the lighted hood.

Tank conditioning- Air pump and other electrical fittings (power head, filter, heater etc) are switched on and allow to run continuously for three to five days. During this time water will be cleared and the plants roots will take their position. Flow rate should be adjusted to 18 to 20 times per day for proper functioning of biofilter and the consequent removal of ammonia with the help of nitrifies.

Introducing the fishes- When purchasing fishes it is essential to make sure that they come from reliable source and are free from disease. Keep the bags containing fishes in the aquarium tank for an hour to acclimatize. After half an hour gradually acclimatize the fish by adding tank water into the fish bag for better survival of fish in the tanks. Stocking density can be adjusted as) 75 cm^2 space for a 2.5 cm fish. As a thump rule-Total surface area (Length x Breadth) of the tank divided by (3x2+6x+3)/2, where 'x' is size of the fish.

Water quality parameters

The key to a successful, healthy aquarium is in maintaining good water quality for the creatures in your care. Most fish health problems are caused by poor water quality and many factors can cause this including type and frequency of the maintenance you carry out, inadequate filtration, stocking levels, overfeeding, and so on. The most important water quality parameters for a tropical community aquarium, or goldfish aquarium are as follows:

Ammonia - excreted by fish into the water; ammonia is poisonous and must be removed. If the filter is working properly, there should be no ammonia in the water. It is recommended to test for ammonia every week.

Nitrite - bacteria in the filter turn ammonia into nitrite, which is also poisonous. If the filter is working properly, this is also removed, and there should be no nitrite in the water. It is recommended to test for nitrite every week.

Nitrate - bacteria in the filter turn nitrite into nitrate, which is harmless to most fish. It is however an algae nutrient, and should be controlled if it gets very high. It is worth testing the nitrate level if you have a problem with algae in the aquarium or pond. Very low nitrate levels are only important for sensitive freshwater fish and marine aquariums.

pH - a measure of the water's acidity. Fish do not respond well to rapidly changing pH levels, and therefore a stable value is important. Pond fish, goldfish, and hardy tropical fish require a stable pH between 6.5 – 8.5. Sensitive tropical fish and marine fish have more particular pH requirements.

Oxygen - like all animals, fish require a plentiful supply of oxygen. Because water contains much less oxygen that air, it is important to provide some form of aeration in an aquarium.. Extra aeration can also be provided with aerators, air-pumps,.

Ideal water quality conditions are as follows

	Freshwater	**Marine**
Ammonia	0	0
Nitrite	0	0
Nitrate	0	0
pH	6.8 - 7.2	8.1 - 8.4
Carbonate Hardness	40 - 60	120 - 180
General Hardness	60 - 150	N / A
Phosphate	<0.5	<0.5
Calcium	N / A	N / A
Salinity	N / A	1.002 - 1.024 (30 - 35g/l)

Aquarium foods

Properly feeding your fish helps them to stay healthy and is helpful in maintaining your aquarium. It is important to know the types of foods your fish need and how much food they need, which differs from species to species. In most cases, fish only need to be fed once a day, and you only need to feed a small amount. Small, regular feedings provide fish with the nutrients they need and keep your tank cleaner than large or more frequent feedings. Over feeding can also contribute to algae growth, which can be unsightly, remove vital oxygen from the water, and increase your tank maintenance routine.

There are a number of food options available for your aquarium fish, and a combination of foods is necessary to provide your fish with the nutrients they need. All of these foods fall into two broad categorizations of fish food: live and processed.

(a) live feeds - Tubifex worms, Blood worms, earth worm, Daphnia, Copepods, Rotifer, Artemia and infusoria.

(b) Processed feeds: Pellet and flakes.

Filters

Selecting the correct filtration system for aquarium is an important factor that will impact not only the type and quantity of fish that you wish to keep, but also the amount of maintenance that the system will require. The filtration system is responsible for keeping the water clear and free of particulate matter and toxic compounds that are dangerous to the inhabitants.

There are three types of filtration that are necessary for the health of any aquarium:

- Mechanical : Mechanical filtration is the process in which particulate matter is removed from the water.
- Chemical : Chemical filtration removes toxic or unwanted chemicals as the water passes through a chemical media or resin.
- Biological: n biological filtration, different types of bacteria convert the toxic chemical byproducts produced by the aquarium inhabitants into less toxic nutrients. This breakdown process by the bacteria is called the Nitrogen Cycle.

Types of Fileters:

-a) Biofilter (b) Foam filter (c) Powerfilter

Biofilter :-harmful substance like ammonia and nitrites are gradually accumulated in the tank due to bio degradation of food remains and fecal matters. The accumulated ammonia and nitrates can be removed by the action of nitrifying bacteria attached to the biofilter. The other parts of filter mechanically prevent the turbidity of the aquarium water.

Parts of Biofilter:- Oyster shell or zeolite, charcoal, blue metal, river sand and water lifting system.

Function of bacteria:- The bacteria synthesize ammonia into nitrate leaving H+ ions into the water. This H+ ions reduced the PH of water (lethargic condition of the fish).The oyster shell present in the biofilter neutralize the H + ion. Charcoal act as a deodorant in the water

The steps involved in aerobic nitrification can be summarized as follows

$$NH3^{+} + 1.5\ O_2 \rightarrow NO_2^{-} + H_2O + 2H^{+}$$

$$G = -65\ Kcal\ mol^{-1}N$$

$$NO_2^{-} + 0.5O_2 \rightarrow NO_3^{-}$$

$$G = -18\ Kcal\ mol^{-1}N$$

The overall reaction is $NH_4^{+} + 2O_2 \rightarrow NO_3^{-} + 2H + H_2O$

This $2H^{+}$ions react with OH group of calcium hydroxide and neutralize the PH of the water.

Use of scavanchers as tank cleaners:-Scavanchers are creatures which takes undesirable matter out off aquarium water. Snails, Armored catfishes, Shrimps and Mussel are the common scavanchers used in the aquarium.

General disease and treatment:-

Disease	Symptom	Treatment
Constipation	Feces of the fish are long and stringy and remain attached to the fish went.	Keep the fish on fast
Branchitis (Inflammation of the gills)	The gill become inflamed and swollen	Potassium Permanganate 3 ppt for 10 minutes or 1ppm salt solution
Fin rot and tail rot	Fins and tails become frayed	3ppm oxytetracyclin for half to one hour
hite spot	Irritating tendency	4 to 5 drops of formalin in 10ml of water or Methylene Blue 2mg per 10 liter water, Keep the fish for one weak

Regular maintenance

1. The fishes are fed one or two times a day ad-libitum
2. At the time of feeding air pumps and power filters switched off
3. Daily switch off aerator, heater, power filter etc. for half an hour to avoid overheating.
4. Monitor the tank regularly during winter season especially the heater.
5. Do not spray insecticide near the tank
6. Assure sufficient light
7. Check air connectivity to the tank
8. Remove dead animals from the tank immediately
9. Use magnetic cleaner
10. Use chlorine free water always.

Cost-benefit Analysis and Input Requirements for Mariculture of Finfishes in India

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Global aquaculture production stood at 66.6 million tonnes in 2012. Two third of the total aquaculture production is contributed by finfish species from inland sector (44.2 million t) and mariculture (5.6million t). Even though finfish from mariculture contributed 12.6% of the total finfish production, it represented 26.9% of total farmed finfish owing to better value realization compared to inland species. More than 600 aquatic species are cultured worldwide in freshwater, marine and brackish water. Cage culture of fishes was originated in South East Asia and later spread to other countries. Cage farming of marine fishes was initiated in India by CMFRI in 2007 in Vizakhapatanam. Cage culture experiments were carried out at 14 different locations along the west and east coast of the country from Veraval in Gujarat to Balasore in Orissa. Initially 15 m diameter cages were used which were subsequently replaced with 6 meter diameter HDPE and then with low cost GI cages in 2009.

The economic and financial feasibility indicators are crucial in the successful adoption of any new technology. The gross income obtained from an enterprise can be maximized either by reducing the costs of inputs or by increasing the revenue.The initial investment cost on cage structure, operating cost components such as feed, seed, labour as well as consistent production and prices decides the economic viability of cage farming. The initial investment on a 15 meter diameter cage was Rs. 8 lakhs and that of 6m diameter was Rs. 4 lakh during the experimental trials. With further research interventions and participatory methods, the size and cost of the cages were further reduced to suit various locations as wellas brackish water areas in the country. Different economic and financial feasibility indicators used for assessing the economic viability and feasibility of investment are discussed below.

Different economic and financial indicators

Net operating income = Gross revenue- operating costs

Net profit = Gross revenue minus all costs including the costs of depreciation and imputed interest. The NCF or net profit can be seen as the reward for entrepreneurship and expresses the absolute income of the entrepreneur

Operating ratio = Operating costs / Gross revenue

Net –benefit-Earnings ratio=Net Profit/Gross revenue

Net Cash Flow (NCF)/Total earnings (TE) ratio expresses the NCF or net benefit as a percentage of TE. A ratio of more than 10 % can be considered as good (Pradoand Tietze, 1999, Tietze and Lasch, 2001).

The financial performance is usually measured by NCF/investment ratio or rate of return on investment (ROI), IRR, and BCR.

ROI = Annual net profit/Initial investment expressed as a percentage

A level of 10 % is generally considered as a good indicator. The NCF or net profit expressed as a percentage of the invested capital indicates the profitability of the investment in relation to other alternative investments.

BCR is the ratio of present discounted benefits to the discounted cost.

$$BCR = \{\Sigma_i Bi/ (1+r)^i\} / \{\Sigma_i Ci/1+r)^i\}$$

Where Bi is the total revenue earned at year i, Ci is the total costs at year i, i is the average number of years of operation of fishing units and r is the discount rate.

IRR of an investment is the discount rate at which the net present value of costs (negative cash flows) of the investment equals the net present value of the benefits (positive cash flows) of the investment.

$$NPV = \Sigma_i Bi/ (1+r)^i - \Sigma_i Ci/1+r)^i = 0$$

Where NPV is the net present value and r is the internal rate of return. An investment is considered acceptable if its internal rate of return is greater than an established minimum acceptable rate of return or cost of capital.

The economic performanceof cage culture demonstrations done in various parts of the country are presented below. The analysis shows that the feed cost varied widely in different demonstrations and with type of fish cultured. The capital productivity was almost same in different demonstrations and return on investment was high for low cost GI cages with reduction in initial investment cost. (Table 1).

Table1.Comparative economics of cage culture demonstrations in various locations

Particulars	**HDPE cage in Balasore (Orissa) with seabass**	**Low cost GI cage in Karwar with cobia**	**Etroplus in Kerala using HDPE cage**
Initial investment	300000	100000	200000
Annual fixed cost	54000	16000	40000
Annual variable cost	231750	314820	215750
Annual Total cost	285750	330820	279750
Feed cost	175000	120000	30000
% Feed cost to total operating cost	0.76	0.38	0.13
Yield	3T	2T	1T
Gross revenue	575760	600000	400000
Net profit	290010	269000	120250
Operating ratio	0.5	0.52	0.54
Return on investment	96.67%	269%	60%

The economic and financial feasibility analysis is presented using a model lowcost cage farming project for a period of 5 years for brackish water areas. The analysis shows that cage farming is a viable enterprise with BCR more than one and internal rate of return well above the prevailing bank ratesunder the assumptions of constant input and output prices.

Table 2. Economics of cage farming of (cobia) in brackish water using GI cages (5m X 2m X 2.5m)

Sl. No	Cost components	Rate (Rs.)	Cost (Rs.)
	Initial investment		110000
	Operational costs		
1.	Fish seed @ Rs.20/- for Stocking density @ 750 per cage unit	20	15000
2.	Fish feed 900 kg per cage unit	35	31500
3.	Labour charges	42000	42000
4.	Fuel / boat hiring &other expenses	10000	10000
	Sub total		**98500**
	Yield (at 80% survival and average weight of fish 800 gm)		480 kg
	Expected farm gate price (Rs.)		400
	Gross income (Rs.)		192000
	Annual Fixed cost (with 20% depreciation & 12% interest on investment)		24640
	Total production cost per crop (Rs.)		123140
	Gross revenue (Rs.)		192000
	Net profit		68860
	Operating ratio		0.51
	Return on investment		62.6%

Table 3. Cash flow analysis

Year	Investment	Annual cash outflow	Total cash outflow	Annual Cash inflow	Net cash flow
0	110000	0	110000	0	-110000
1		98500	98500	192000	93500
2		98500	98500	192000	93500
3		98500	98500	192000	93500
4		98500	98500	192000	93500
5		98500	98500	192000	93500
				NPV	203427
				BCR	1.46
				IRR	81%

Seed and feed requirement for cage farming in India

The finfish varieties which are preferred for seacage farming in India are seabass, cobia, pompano, groupers, Thilapia,snappers and Etroplus.At an average seed cost of Rs.15-20/ piece, the projected seed requirement for the production of at least 1lakh tonne of finfishes through cage farming is 290 million numbers consisting of seabass, cobia, pompano, etroplus, groupers and snappers.

Pelleted feed and chopped fish are used for feeding the finfishes in cage farming. The feed cost constitutes 30-60% of the total cost of production in cage farming of various finfishes.The lower FCR values indicated better economic viability with lower feed cost. The FCR values of cobia in the culture demonstrations in India ranged from 1.5-2.2 and that of seabass was 0.8-1 (S Mojjada, Philippose, 2014, Liao *et al.*, 2004, Benetti *et a*l., 2010). At FCR value of 2 at least two lakh tonnes of fish feed is required for the production of 1lakh tonne of finfish. At the rate of Rs.25000/tonne of trash fish,the feed cost required for the production of 1tonne of fish is Rs. 50,000.

Table 4. Projected seed requirements for the production of 1lakh tonne of finfishes through cage farming

Name of fish	No. of cages	Av stocking density/cage	Survival %	Projected production (t)
Cobia	30000	1500	80%	36000
seabass	30000	1500	80%	25200
Pompano	30000	2500	80%	12000
GIFT Thilapia	10000	2500	70%	5250
Etroplus	10000	5000	70%	10500
Others	10000	5000	70%	14000

The major challenges for the popularization of cage farming in India are high feed cost and non-availability of quality seeds. Heavy dependence on fish based feeds or trash fish is a threat to the stagnating capturefishery resources. Eventhough finfish produced through cage farming command better price and provide quality fish for consumption, finfish farmingwith heavy dependence on fish based feeds or low value fishesneed to be promoted with caution. It is essential to develop low cost alternate feeds which suit the dietary requirements of fishes throughparticipatory methods. The wide variability in FCR values in various culture demonstrations and participatory trials suggest the need for developing optimal feeding schedules to improve the economic viabilityof cage farming. In addition, non-availability of sufficient seeds in time is another important constraint in cage farming. Currently CMFRI and Rajiv Gandhi Centre for Aquaculture (RGCA) of MPEDA are the chief sources for finfish seeds for cage farming in India. NFDB provides subsidy assistance upto 20% for commercial shrimp hatcheries for production of finfish seed. Production of quality seeds and development of alternate feedsat low costthrough participatory methodsthroughpublic funded programmesare essential for the widespread adoption of technology.